Shell Canada Limited

application for the approval of

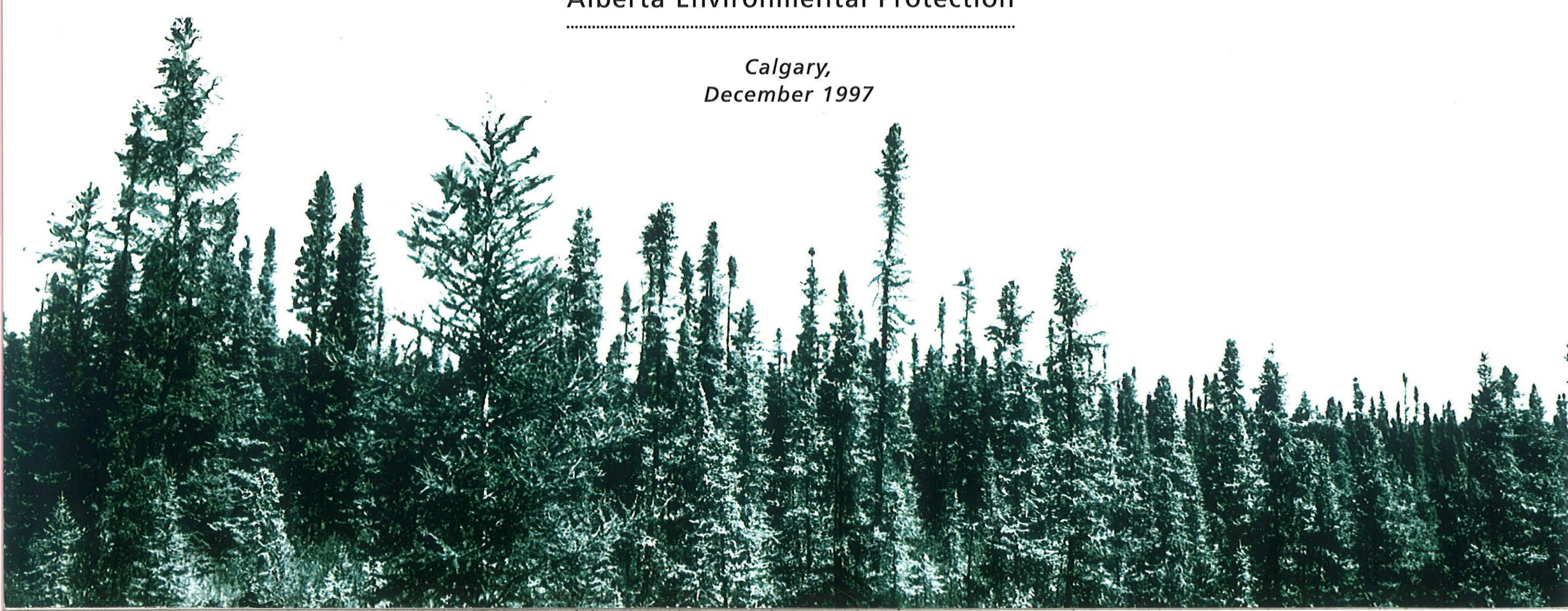
MUSKEG RIVER MINE PROJECT

Volume 3 • Environmental Impact Assessment

Biophysical and Historical Resources Part 1: Impact Assessment

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

Calgary,
December 1997



E ENVIRONMENTAL IMPACT ASSESSMENT

This section of the EIA contains information describing the potential incremental effect of the Muskeg River Mine Project on the baseline conditions described in Section D (Volume 2 of the Application) and its relationship to the Muskeg River Mine Project EIA terms of reference. Included are predictions about how the Project could affect environmental resources and resource uses in the Local and Regional study areas. Section E is followed by the Cumulative Effects Assessment Section F (Section F, Volume 4 of the Application), which describes the potential effect of the Muskeg River Mine Project in combination with existing, approved and planned regional developments within the Local and Regional study areas.

Socio-economic considerations for the Project are discussed in Volume 5 of the Application.

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
µg/L	microgram per litre
µg/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

Section Title	Description	Cross-Reference	
		Volume	Section
Introduction	**Introduction**		
	identify for Shell and the public, information required by government agencies for EIA report	Terms of Reference	
Purpose	relevant impacts, mitigation options and residual impacts will be addressed	2 3	A E1
	impact predictions in terms of magnitude, frequency, duration, seasonal timing, reversibility, geographic extent.	2	A
	identify residual and cumulative impact and significance	1 2	10 A
	discuss mitigation measures, protection plans, monitoring or research programs, environmental performance objectives, anticipated regulatory requirements	1 2	10 A
Public Participation	EIA will be part of application to EUB	1	1
	Residents from:	1	12
	Fort McMurray		
	Fort McKay		
	Fort Chipewyan		
	communities of Wood Buffalo and		
	industrial, recreational, and environmental groups		
	public given opportunity to participate and express concerns		
	public notification of EIA given		
	Project Overview		
Proponent and Lease 13 History	provide proponent name and name of legal entity	1 2	1 A
	description of history of proposed development, resource characterization, environmental studies	1 2	1 A, B
Project Area and EIA Study Areas	includes all disturbed areas	2	D
	description of rationale and assumptions of Regional and Local Study Area boundaries including those related to cumulative effects	2	D1
	maps of study areas to include township and range lines	2	D1
	provide maps with lease boundaries, land tenure, facility locations	1	4
	include lakes, streams and other geographic information	1	4
Project Components and Development Schedule	overview of project components, mining operations, process facilities, buildings, transportation infrastructure, utilities, pipeline to Scotford and Scotford upgrader project	1 2	1,4,5,7,13 B
	development schedule including:	1 3	4,16 E16
	pre-construction		
	construction		
	operation		
	reclamation and		
	decommissioning		
	key factors controlling schedule	1	1,15
	describe major components to be applied for and constructed within 10 years	1	1,16
Project Need and Alternatives	analysis of need of project, including a no development scenario	1	1.1
	discuss an alternative means of doing project	1	1.1
	identify potential cooperative development opportunities	1	1.1
	summary of reasons for selecting project and major components	1	1

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Section Title	Description	Cross-Reference	
		Volume	Section
Regulatory Approval	identify regulatory approvals and legislation.	1	1
	consider municipal, provincial and federal governments	1	1
	identify government policies, resource management, planning or study initiatives pertinent to the Project and discuss implications	1	1
	Project Description		
General Information	describe mining, extraction and waste management components	1	4,5,6,7,8,9,16
	provide map of buildings, road access, pipeline routes, water pipelines, utility corridors, sand and waste disposal sites	1	1,4,8
	identify criteria and assumptions for locating facilities	1	4,8
	provide description and schedule of land clearing	1	4
	provide schedule for location and relocation of pit storage	1	4
	follow Oil Sands Subregional Integrated Resource Plan (IRP) setbacks for Athabasca, Muskeg and other tributaries	1 3	1 E16
Process Description	describe preparation and extraction processes	1	5
	provide material and energy balances	1	9
	basic flow diagrams	1	7,8,9
	describe technologies used and describe effects on water use, waste generation, chemical use, tailings, air emissions and bitumen recovery	1	6,7,8,16
	discuss alternative technologies considered	1	1,4,5,6
	hydrocarbon and sulphur balance and energy efficiency information	1	9
Mining Description	describe mining method	1	4
	discuss alternatives considered and environmental implications	1	3,4
	describe minimum ore grade selected and effect on tailings and fine tailings volumes, water requirements and long term reclamation	1	3,4
Utilities and Description	maps of utilities	1	7
	discuss amount of energy needed and source	1	7
	discuss options considered for thermal and electric power and environmental implications	1	7
	describe road access and needs for upgrading and new roads	1	7
	discuss the need for access management	5	
	provide results of consultation with local road authority	5	
	describe methodology and projected frequency for traffic on Highway 63 and Ft. Chipewyan winter road	5	
	discuss mitigation	5	
	discuss cooperation with other oil sand and industry operators	5	
	describe access through Lease 13	1	7
	describe location, volume and source for road construction material	1	7
	describe utility and pipeline stream and river crossings	1	7
Air Emissions Management	indicate type, rate and source of air emissions, include construction and vehicle pool	1 3	16 E2.2
	identify emission and fugitive emission points on site plan	3	E2.2.3 E2.2.5 E2.2.6
	describe monitoring and control systems	3	E2
	describe Shell's existing monitoring and involvement in RAQCC and CASA	1 3	12 E2
	estimate greenhouse gases	2 3	D2.7 E2.2.7 E2.7.1
	describe greenhouse gas management plan and place emission estimates in context with total emissions provincially and nationally	2 3	D2.7 E2.7.1

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Section Title	Description	Cross-Reference	
		Volume	Section
Water Supply and Management	describe process water and chemical requirements	1	8,16
	discuss water efficiency designs considered for all aspects of the project including, emergency operation designs	1 3	8 E4
	describe source of water and options considered	1	8
	discuss seasonal variability of water use, diversion and impacts	1	8
	describe nature, location, volume, quality and fluctuations of effluents	1	8
	show locations of water intakes and associated facilities treatment plants	1	8
	provide a water management plan and water balance, address site run-off and containment, groundwater protection and depressurization	1 3	8 E3
	describe wastewater treatment and disposal	1	8
	include water balance for life of project	1	8
	describe alternatives to minimize wastewater	1	8
	describe alternatives to minimize change in Muskeg River and tributary flows	1 3	8 E4
Waste Management	describe management plan for tailings, overburden, other mining wastes and camp.	1	4,6
	include plans to minimize fine tailings production	1	4,6
	identify all on-site disposal areas on site plan	1	4,6
	indicate strategy for disposal areas, their location and timing	1	4,6
	include plans to minimize above ground storage of overburden and tailings	1	4,6
	describe waste management strategy on-site industrial landfills, estimate quantity and composition of routine landfill wastes	1	16
	describe waste minimization and recycling plans	1	16
	describe waste management strategy for hazardous wastes, provide quantity and composition of hazardous wastes	1	16
	describe storage and handling methods proposed	1	16
	Environmental Impact Assessment Methodology		
Assessment Requirements	provide information on the environmental resources and resource uses that could be affected by the project	2	D
	provide sufficient information to predict positive and negative impacts	2,3,4	all sections
	extent impacts can be mitigated by planning, project design, construction techniques, operational practices, and reclamation techniques	3 2	all sections A
	quantify impacts in terms of spatial, temporal and cumulative effects	3	all sections
	sources of information will be reviewed and discussed	2,3,4	all sections
	limitations will be discussed	3	all sections
	information sources will include: • EIA studies	2,3,4	all sections
	• operating experience from current oil sands operations		
	• industry study groups		
	• traditional knowledge		
	• government sources		
	undertake studies where additional information is needed	Baseline Reports 2	all sections
	broad-based examination of ecosystem components, including previous environmental assessment work	2 3,4	D E,F,G
	describe and rationalize the selection of key components and indicators examined:	2 3	D E
	• For each environmental parameter	2	D
	• describe existing locations and comment if available data are	2	D

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Section Title	Description	Cross-Reference	
		Volume	Section
	sufficient to assess impacts and mitigative measures	3	E
	• identify environmental disturbance from previous activities that have become part of baseline conditions	2	D
	• describe the nature and significance of environmental effects and impacts associated with development activities	3,4	E,F,G
	• present an environmental protection plan (EPP) to mitigate negative impacts, discuss key elements	2 3,4	A E,F,G
	• identify residual impacts and significance	3,4	E,F,G
	• present a plan to identify possible effect and impacts, monitor environmental impacts and manage environmental changes to demonstrate the project is operating in a environmentally sound manner	2 3 4	A E F,G
	• present recommendations for environmental protection or mitigation which may require joint government, industry and community resolution	2 3 4	A E F,G
Cumulative Environmental Effects Assessment	assess cumulative environmental effects for the project	4	F,G
	• define study and time boundaries, give rationale and assumptions	4	FG
	• consider environmental effects of other existing and proposed projects (public disclosure stage) or reasonably foreseeable activities in the region	3,4	E,F,G
	• demonstrate that any information of data from previous oil sands and other development projects is appropriate, supplement where required and consider all relevant environmental components	3,4	E,F,G
	• explain the approach and methods used to identify and assess cumulative impacts	3,4	E,F,G
	provide a record of all assumptions, confidence in data and analysis to support conclusions	2 3,4	D E,F
Climate, Air Quality and Noise	discuss baseline air quality and climate of area	2	D2.4,2.5 D4
	identify components of project and effect on local and regional air quality	3	E2
	document appropriate air quality parameters including NO_x, VOCs, ground level ozone, TRS, total hydrocarbons, acidifying emissions, and particulates	2 3	D2.2 D2.5 E2
	model ground-level ozone as part of joint industry cumulative effects assessment	3 4	E2.6 F2
	estimate ground levels of appropriate air quality parameters	3	E2.3, E2.4
	discuss changes to ambient particulate levels or acidic depositional patterns	2 3	D2.6, E2.5
	justify and identify limitations of models used	Appendix II	
	identify potential for decreased air quality	3	E2
	discuss implications on environmental protection and public health	3	E9,E11 E12
	discuss interactive effects of co-exposure of receptors to emissions and discuss limitation in present understanding of this subject	3	E12.7 E12.11
	discuss how impacts will be mitigated	3	E2
	identify a program to monitor air quality	3	E2
	identify project components that will increase noise, discuss mitigation	3	E12.11
	assess cumulative effects of air quality in the study area	4	F2, F12,G2, G12
Geology, Terrain and Soils	describe and map bedrock and surficial geology, topography and drainage patterns in study area	1 2	2 D4

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Section Title	Description	Cross-Reference	
		Volume	Section
	relate bedrock and surficial geology to regional areas (e.g., Susan Lake Moraine)	1	2
	assess and map changes due to projects construction, operation and reclamation	3 4	E8 F8
	describe and map soil types and distribution	2	D8
	provide an assessment and map of pre and post-disturbance land capability	2 3	D8 E8,E16
	develop soils reclamation management plan	3	E16
	describe availability and suitability of soils for reclamation	3	E8,E16
	outline criteria for salvaging soils	1 3	16 E16
	identify areas for soil salvage and stockpiling and estimate volumes	3	E16
	identify soil constraints and limitations on reclamation.	1 3	16 E8
	identify activities that may potentially contaminate soils	3	E8
	collect baseline information to enable ecological land classification (ELCs)	2	D7
	describe impacts on ELCs	3	E7
Vegetation and Forest Resources	describe and map vegetation communities	2 Baseline Reports	D9
	identify rare, threatened or endangered species	2 3	D9.6 E9.7
	identify amount of land and types of vegetation communities to be disturbed	3	E9.7.4 E10.8.3
	describe mitigative measures	3	E9.9
	evaluate forest and peatlands/wetlands outlined in Alberta Vegetation Standards (AVI) Manual Version 2.2	2	D9,D10
	describe impact on commercial forestry	3	E14, E16
	assess development and mitigation affect on peatlands/wetlands cumulatively	3 4	E10 F10,G10
	identify and evaluate potential impacts, including cumulative impacts (in context of Draft Wetlands Policy for Alberta)	3 4	E10 F10,G10
	illustrate, on a conceptual end land use map, type and distribution of proposed reclaimed vegetation	1 3	16 E16
Wildlife	describe wildlife habitat types and use	2	D11
	identify rare and endangered species, habitat requirements and seasonal habitat use in significant areas	2	D11
	describe and map significant local habitat, seasonal habitat use, winter and summer range, and movement corridors for moose and other key indicator species	Golder 1998b 3	Golder 1998b E11.6.3
	comment on the sensitivity of key species and habitat to impacts	3	E11.6
	discuss regional and temporal effect and potential return to pre-disturbance conditions	3 3 4	E11.12 E11.15 F11,G11
	provide a mitigation plan	3	E11
	identify and discuss monitoring programs to assess impacts of project and mitigation plans	3	E11
	assess cumulative effects on wildlife (and wildlife health)	3 4	E11 F11,G11
Surface Hydrology	describe pre and post project surface hydrology	2 3	D4 E4
	identify potential impacts on local and regional hydrology	3 4	E4 F4

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Section Title	Description	Cross-Reference	
		Volume	Section
	include impacts on thermal regime of surface water of Muskeg River and associated tributaries	3	E5.7
	describe alterations to timing, volume, and duration of peak flows including the western portion of Lease 13 and future development on Lease 13 east, as appropriate	3	E4.4
	describe design and plans to protect Muskeg and tributaries, include location and dimensions of buffers	3	E4.3 E4.6 E4
	describe monitoring program to assess water management	3	E4,E5
	describe the design parameters for all water management plans and facilities required within duration of Water Resources Act (WRA) approval	1 3	16 E4.3
	describe and discuss with respect to other projects including cumulative effects	3 4	E5 F5,G5
	identify wastewater effluents, mine depressurized water and runoff in terms of source, volume, and seasonal timing	3	E3,E4.4
	describe management plans, mitigation measures and monitoring programs	3	E4
	discuss probable maximum flood and precipitation and influence on project design and contingency plans	3	E4.3 E4.9
Groundwater	discuss the groundwater regime	2 3 4	D3 E3 F3,G3
	summarize existing databases including flow patterns, groundwater quality, and regional interactions	2	D3
	describe effects on existing groundwater including water quality, quantity and thermal regime.	3 4	E3.6,E3.7 F3,G3
	discuss effects on basal aquifer	3 Appendix	E3.5, E3.6 E3.7
	discuss relationship between groundwater and surface water	3 4	E3.5,E3.6 E3.7,E4 F3
	describe monitoring programs and mitigative measures	3 4	E3 F3
	describe surficial and upper bedrock groundwater regimes	2	D3
Water Quality	describe baseline conditions	2	D5
	identify activities influencing water quality (before, during, after)	3	E5
	describe potential impacts with respect to location, magnitude, duration and extent, and significance	3	E5
	describe mitigation measures during construction, operation and reclamation	3	E5
	discuss seasonal variation and effects	3	E5.5 E5.6 E5.7
	describe monitoring program to assess water management system for collection, handling, treatment and discharge	3	E5.5.4 E5.6.4
	assess cumulative effects	4	F5,G5
	predict water quality conditions in Muskeg, Athabasca and other water bodies down stream of project	3	E5.5 E5.6
	compare predicted and existing water quality to Alberta Ambient Surface Water Quality Interim Guidelines, relevant US EPA guidelines, and Canadian Water Quality Guidelines	2 3	D5 E5
	consider the recommended procedure for using existing guidelines described in "Alberta Environmental Protection Protocol for	3	E5

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Section Title	Description	Cross-Reference	
		Volume	Section
	Determining Water Quality Guideline Use"		
	discuss implications for short and long term water quality, resource use and aquatic resources	3 4	E5,E14 F5,F14
Aquatic Resources	describe fish resources including species composition, distribution, relative abundance, movements and life history parameters	2 Appendix VI Golder 1997d	D6
	describe and map appropriate fish habitat of Athabasca, Muskeg and tributaries affected by project	2 Golder 1997d, Golder 1998a	D6
	describe impacts to fish and fish habitat because of changes in water quality, water quantity, substrate and hydrology	3	E6.5 E6.6 E6.8
	discuss nature, extent, duration, magnitude and significance of impacts	3	E6.5.3, E6.6.3, E6.7.3, E6.8.3
	describe relevance to existing or potential domestic, recreational or commercial fishery	3	E14.12
	identify critical or sensitive habitats such as spawning, rearing and overwintering areas	2 Golder 1997d	D6
	describe existing information base, any deficiencies in information and studies proposed to evaluate the status of fish and aquatic resources	3	E6.5.4 E6.6.4 E6.7.4 E6.8.4
	identify, provide rationale and selection criteria for key indicator species	2 3	D1 E6.3
	identify impacts on fish and fish habitat from project construction and operation	3	E6.5 E6.6 E6.8
	assess cumulative effects in the on fish and fish habitats	4	F6,G6
	discuss cooperative mitigation strategies	4	F6,G6
	discuss design, construction and operation factors to protect fish resources	3	E6.5.2
	identify proposed mitigation and compensation plans for each impact and specific site identified	3	E6.5 E6.6 E6.7 E6.8
	identify residual impacts on fish and fish habitat, discuss significance to local and regional fisheries	3	E6.5.3 E6.6.3 E6.7.3 E6.8.3, E14.12
	discuss how development and mitigation will address "no net loss"	3	E6.5.2
	identify monitoring programs to address impacts and mitigation	3	E6.10
	discuss potential for fish tainting, survival of eggs and fry, chronic and acute health effects, and stress on populations from contaminants, sedimentation, and habitat changes	3	E6.5 E6.6 E6.7 E6.8
	Reclamation/Mine Closure		
	provide a reclamation plan describing anticipated land capability and end land use, land stability, erosion control, revegetation, development	1 3	16 E16

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Volume 4 - Cumulative Effects Assessment (F and G)
Volume 5 - Socio-Economic Baseline, Impact Assessment and Cumulative Effects Assessment

Section Title	Description	Cross-Reference	
		Volume	Section
	phasing, pit backfill sequencing, and time frames		
	describe how the final landform is incorporated into mine planning	3	E16
	describe implications to water quality and other ecosystem components of the technology selected for managing fine tailings and alternative technologies	3	E16.6
	describe management and disposal of water and processing wastes	3	E16.4
	describe how reclamation plan addressed IRP and other government policies	3	E16
	describe impacts on biodiversity	3	E9, E10, E16.6
	compare pre-disturbed and anticipated species list	3	E9, E11
	describe differences in type, size, variety or distribution of terrestrial and aquatic landscape units on wildlife habitat, traditional uses, aesthetics, recreation, or forestry	3	E16.5
	describe physical and biological parameters to be monitored and evaluated	3	E16.8
	outline key milestones and progress measures	1 3	16 E16.4
	describe plans to demonstrate success	3	E16.2
	review reclamation research and experience	3	E16.8
	describe future research initiatives to further reclamation technology	3	E16.8
	Land Use		
	identify aboriginal traditional land uses	3	E15
	identify existing land uses	2	D14, D15
	identify potential impacts on all land uses and possible mitigation	3	E14, E15
	identify area that are potential sites for special status	2	D13, D14
	Public Health and Safety Issues		
	describe aspects that may have pubic health implications	3	E12
	describe measures to minimize adverse health effects	3	E12
	describe monitoring	3	E12
	describe plans to participate in Alberta Oil Sands Community Exposure Health Effects Assessment Program	3	E12.7
	provide outline of emergency response plan	3	E12.10
	describe mitigation plans to ensure worker and public safety	3	E12.10
	include prevention and safety for wildfires, chemical releases and water and fluid holding structure failures	3	E12.10
	Public Consultation		
Public Consultation	document public consultation program	1 2	12 C
	describe method for dissemination of information to public	1	12
	describe type of information disseminated	1	12
	describe level and nature of response	1	12
	describe consultative process	1	12
	show how public input was obtained and addressed	1	12
	describe and document concerns expressed by public	1	12
	describe actions to address issues and concerns	1	12
	describe how resolutions of issues and concerns were incorporated into Project development, mitigation and monitoring	1	12
	describe plans to maintain the process after EIA review	1	12
	ensure proper public forum for expressing views during ongoing development, operation and reclamation	1	12
	Socio-Economic		
Socio-Economic Assessment	describe existing socio-economic conditions	5	4, Appendix

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Section Title	Description	Cross-Reference	
		Volume	Section
	define mitigation measures	5	5.1
	impacts of region with respect to: • local employment and training • opportunities and procurement • local services and infrastructure • timing and size of workforce • population changes	5	5.1
	Shell policy re. local hire, purchase	5	5.1
	Outline plans to work with local residents and business re employment and contracting opportunities	5	5.1.6
	evaluate cumulative impacts on local services and infrastructure	5	6
	Historical Resources		
	consult Alberta Community Development and Aboriginal communities, specifically Fort McKay, to establish process to assess historical, archaeological and palaeontological significance	2 3	D13, D15 E13, E15.4
	complete a field investigation which meets requirements of Alberta Community Development	3	E13
	develop appropriate mitigation plans	3	E13

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E1 IMPACT ASSESSMENT METHODOLOGY

E1.1 Introduction

This section of the Muskeg River Mine Project (the Project) EIA provides information as required by the Project Terms of Reference (TofR) issued on November 7, 1997 (AEP 1997a). Specifically, Section E of the EIA addresses the following requirements as detailed in the TofR:

- provide information on the environmental resources and resource uses that could be affected by the project;
- provide sufficient information to predicted positive and negative impacts;
- detail the extent to which impacts can be mitigated by planning, project design, construction techniques, operational practices, and reclamation techniques;
- quantify impacts in terms of spatial, temporal and cumulative effects;
- review and discuss sources, and the limitations of information;
- include the following information sources:
  - EIA studies,
  - operating experience from current oil sands operations,
  - industry study groups,
  - traditional knowledge, and
  - government sources;
- undertaking studies where additional information is needed;
- broad-based examination of ecosystem components, including previous environmental assessment work; and
- describe and rationalize the selection of key components and indicators examined.

For each environmental parameter:

- describe existing locations and comment if available data are sufficient to assess impacts and mitigative measures;
- identify environmental disturbance from previous activities that have become part of baseline conditions;
- describe the nature and significance of environmental effects and impacts associated with development activities;
- present an environmental protection plan (EPP) to mitigate negative impacts, discuss key elements;
- identify residual impacts and significance;
- present a plan to identify possible effect and impacts, monitor environmental impacts and manage environmental changes to demonstrate the project is operating in a environmentally sound manner; and

- present recommendations for environmental protection or mitigation which may require joint government, industry and community resolution.

E1.2 Framework

This environmental impact assessment (EIA) is structured to provide focused, understandable and relevant information and analysis about the type and extent of environmental effects related to the Muskeg River Mine Project (the Project). The EIA is designed to be:

- issue driven - seeks out concerns of the community, regulators and technical experts and directs EIA investigations so that answers to those concerns can be provided;
- balanced - includes input from community, regulators and technical experts is integrated;
- transparent - clearly explains the assumptions and factors used to assess environmental effects;
- quantitative - uses quantitative analysis methods where possible; and
- cumulative/regional - considers the Project's contribution to regional effects associated with existing developments (i.e., the Impact Assessment as described in Volume 3 - Section E) and with planned projects (i.e., the regional cumulative effects assessment as described in Volume 4 - Section F).

One of the goals of this EIA is to balance and consider equally, community, regulatory and scientific/technical issues. To some extent, the issues and concerns of the community, regulators and technical groups may be shared, but each group may also have independent perspectives. The greatest impacts, both positive and negative, of a project are on the neighbouring communities. It is essential to incorporate the views of regional communities views into the design of the Project. Regulators are charged with a responsibility to ensure public interests are considered, through the application of public policy and legislation. The EIA must provide sufficient information about the project and potential impacts to allow regulators to fulfill their responsibilities.

The EIA must be explicit in identifying the issues which are addressed, and how the relationships between the Project and the environmental effects have been examined. This allows reviewers to understand the rationale and assumptions being used to come to conclusions.

The purpose of an EIA is to examine the relationships between a proposed project and its potential impacts on the social and natural environment. It is this relationship that is the focus of the EIA, and is revealed in the impact analysis, particularly in terms of definable assessment and measurement end points. The impact analysis is based on an examination of the ways the proposed project will result in changes to the environment, and then assessing if those environmental changes will result in an impact to an issue of importance to the communities who could be affected.

Finally, the impact analysis cannot assess the effect of the Muskeg River Mine Project in isolation, but rather in terms of the incremental impact of the Project on the existing baseline, which includes both oil sands and other development activities. This part of the Muskeg River Mine Project EIA is presented in Volume 3, Section E of the Application. In addition, the impact of the cumulative effects of the Muskeg River Mine Project together with existing and approved projects and future planned projects (i.e., the regional development) is assessed. The cumulative effects assessment for the Project, and the Regional Development scenario is presented in Sections F and G of Volume 4 of the Application.

E1.3 Approach

The approach to the impact assessment involves the following steps:

1. Identifying issues of concern to the regional communities, regulators and the other project stakeholders.
2. Formulating key questions to address the issues.
3. Preparing linkage diagrams that describe the linkages between project activities and environmental changes for each key question.
4. Defining the spatial and temporal boundaries of the assessment.
5. Selecting key indicator resources (KIRs) to focus the analyses.
6. Collecting and analyzing data in support of impact analyses, including:
   - identifying project activities;
   - collecting and analyzing baseline information; and
   - conducting predictive modelling.
7. Completion of the impact analyses. Quantitative methods for the analyses are used where possible. This includes an analysis of:
   - potential linkages; and
   - key questions.
8. Classification of impacts for valid linkages according to standard, qualitative criteria.
9. Identifying the degree of concern for classified impacts and rating the certainty of the assessment.
10. Identifying monitoring activities to be implemented to verify: predicted impacts; effectiveness of mitigative actions; and to aid in identification of further mitigative opportunities.

E1.3.1 Issues

A key component of the impact assessment process is to identify and focus on the issues that are of the greatest concern to the community and regulators. This process was initiated through evaluation of the issues and responses in recent oils sands EIAs as well as through community consultation. The primary information sources from the recent oil sands EIAs, as well as for the Project EIA draft terms of reference, are shown in Table E1-1. Detailed information on the types of consultation and the inputs for the program are provided in Section 12, Volume 1 of the Application.

Table E1-1 Information Sources for Issue Focusing

EIA	Documents
Aurora Mine EIA	Supplemental information questions and responses.
	Hearing notification submissions.
	Alberta Energy and Utilities Board Approval for Project.
Steepbank Mine EIA	Comments on EIA from Department of Fisheries and Oceans, Environment Canada, Pembina Institute.
	AXYS review of Steepbank EIA.
	Steepbank Mine and Fixed Plant Application Approvals.
	Alberta Environmental Protection (AEP) Environmental Operating Approval for Steepbank Mine.
Muskeg River Mine Project EIA	AEP comments on draft EIA terms of reference.
	Canadian Environmental Assessment Agency comments on draft EIA terms of reference.
	Fort McKay (SMART) comments on draft EIA terms of reference.

In addition to the information sources described in Table E1-1, issues relevant to the Muskeg River Mine Project EIA were clarified during community and regulatory consultation (as detailed in Section 12 of Volume 1 of the Application).

E1.3.2 Key Questions and Linkage Diagrams

An important step in the EIA is to outline how project activities could potentially affect aspects of the environment. Key questions were identified for each EIA component to address the specific issues identified as important by the communities, regulators or technical experts. A list of the key questions for the impact assessment is provided in Table E1-2. Questions for the regional development cumulative effects assessment are reviewed in Volume 4, Section F1 of the Application.

Table E1-2 Summary of Key Questions for the Muskeg River Mine Project

Question Number	Key Question
Air Quality	
AQ-1	Will the Muskeg River Mine Project emissions result in exceedances of ambient of air quality guidelines?
AQ-2	Will the Muskeg River Mine Project emissions result in human health effects?
AQ-3	Will the Muskeg River Mine Project emissions result in the deposition of acid forming compounds that exceed target loadings?
AQ-4	Will the Muskeg River Mine Project precursor emissions result in the formation of ozone (O_3) that exceed air quality guidelines?
AQ-5	Will the Muskeg River Mine Project produce enhanced greenhouse gas emissions?
Hydrogeology - Groundwater	
GW-1	Will the Muskeg River Mine Project change groundwater levels and groundwater flow patterns?
GW-2	Will the groundwater systems re-establish after mining and closure?
GW-3	Will the Muskeg River Mine Project change groundwater quality?
Surface Water Hydrology	
SW-1	Will the Muskeg River Mine Project affect flows and water levels in receiving streams, lakes, ponds, and wetlands?
SW-2	Will the Muskeg River Mine Project affect the water balance of nearby lakes, ponds, wetlands and streams?
SW-3	Will the Muskeg River Mine Project affect basin sediment yields and sediment concentrations in receiving streams?
SW-4	Will the Muskeg River Mine Project affect channel regimes of receiving streams?
SW-5	Will the Muskeg River Mine Project change the open-water areas including lakes and streams?
SW-6	Will the Muskeg River Mine Project affect landscape and drainage system sustainability after closure?
Surface Water Quality	
WQ-1	Will Operational and Reclamation Water Releases from the Project Result in Water Quality Guideline Exceedances in the Athabasca and Muskeg Rivers and Isadore's Lake?
WQ-2	Will Operational and Reclamation Water Releases from the Project Result in Toxicity Guideline Exceedances in the Athabasca and Muskeg Rivers?
WQ-3	Will Operational and Reclamation Water Releases from the Project Alter the Temperature Regime of the Muskeg River?
WQ-4	Will Muskeg Dewatering Activities Associated with the Project Reduce Dissolved Oxygen Concentrations to Unacceptable Levels in the Muskeg River?
WQ-5	Will PAHs in Operational and Reclamation Waters Released From the Project Accumulate in Sediments and Be Transported Downstream?
WQ-6	Will End Pit Lake Water Be Toxic prior to Discharge to the Muskeg River?
WQ-7	Will Accidental Water Releases Occur that could Affect Water Quality in the Athabasca and Muskeg Rivers?
WQ-8	Will Changes in Water Quality Result from Acidifying Emissions?

(Continued)

Table E1-2 Summary of Key Questions for the Muskeg River Mine Project (Continued)

Aquatic Resources	
AR-1	Will the Muskeg River Mine Project change fish habitat?
AR-2	Will the Muskeg River Mine Project change aquatic ecosystem health?
AR-3	Will the Muskeg River Mine Project change fish tissue quality?
AR-4	Will the Muskeg River Mine Project change fish abundance?
AR-5	Will the Muskeg River Mine Project end pit lake support a viable ecosystem?
ELC	
ELC-1	Will Muskeg River Mine Project activities result in a loss or alteration of ELC units?
ELC-2	Will the activities from the Muskeg River Mine Project change biodiversity?
Terrain and Soils	
TS-1	Will the activities from the Muskeg River Mine Project result in loss or alteration of terrain and soils?
TS-2	Will reclamation for the Muskeg River Mine Project change distribution of terrain and soils?
TS-3	Will the reclamation of the landscape for the Project change soil productivity?
Terrestrial Vegetation	
VE-1	Will the activities from the Muskeg River Mine Project result in a loss or alteration of vegetation communities?
VE-2	Will air emissions or water releases from the Muskeg River Mine Project alter vegetation health?
VE-3	Will the Muskeg River Mine Project change plant diversity?
VE-4	Will the reclamation of the landscape for the Muskeg River Mine Project result in replacement of plant communities?
Wetlands	
WL-1	Will the Muskeg River Mine Project activities result in a loss or alteration of wetlands?
WL-2	Will landscape reclamation and of closure of the Muskeg River Mine Project result in a replacement of wetlands?
WL-3	Will the Muskeg River Mine Project change wetlands diversity?
Wildlife	
W-1	Will activities from the Muskeg River Mine Project change wildlife habitat?
W-2	Will water releases from the Muskeg River Mine Project change wildlife health?
W-3	Will consumption of plants from the Muskeg River Mine Project change wildlife health?
W-4	Will consumption of plants and water releases from the Muskeg River Mine Project change wildlife health?
W-5	Will the Muskeg River Mine Project change wildlife abundance and diversity?
W-6	Will the reclaimed landscape from the Muskeg River Mine Project change wildlife habitat?
W-7	Will the reclaimed landscape from the Muskeg River Mine Project change wildlife health?
W-8	Will the reclaimed landscape from the Muskeg River Mine Project change wildlife abundance and diversity?

(Continued)

Table E1-2 Summary of Key Questions for the Muskeg River Mine Project (Continued)

Human Health	
HH-1	Will water releases from the Muskeg River Mine Project change human health?
HH-2	Will air emissions from the Muskeg River Mine Project change human health?
HH-3	Will consumption of local plants and game animals affected by the Muskeg River Mine Project change human health?
HH-4	Will the combined exposure to water, air, plants and game animals change human health?
HH-5	Are sufficient procedures in place to assure worker health and safety during construction and operation of the Muskeg River Mine Project?
HH-6	Will the release of chemicals from the reclaimed landscape change human health?
HH-7	Will noise from Muskeg River Mine Project activities during the construction and operation of the Project unduly affect people who reside in the local area?
Historical Resources	
HR-1	Will the Muskeg River Mine Project expose additional sites?
HR-2	Will the mitigation program for the Muskeg River Mine Project offset project affects?
Resource Use	
RU-1	Will there be a change in surface and mineral materials?
RU-2	Will there be a change in environmentally significant areas?
RU-3	Will there be a change in agriculture?
RU-4	Will there be a change in forestry?
RU-5	Will there be a change in berry picking?
RU-6	Will there be a change in non-consumptive recreational use?
RU-7	Will there be a change in hunting?
RU-8	Will there be a change in trapping?
RU-9	Will there be a change in fishing?
Traditional Land Use	
TLU- 1	Will the Muskeg River Mine Project change food gathering and medicinal or spiritual plant use?

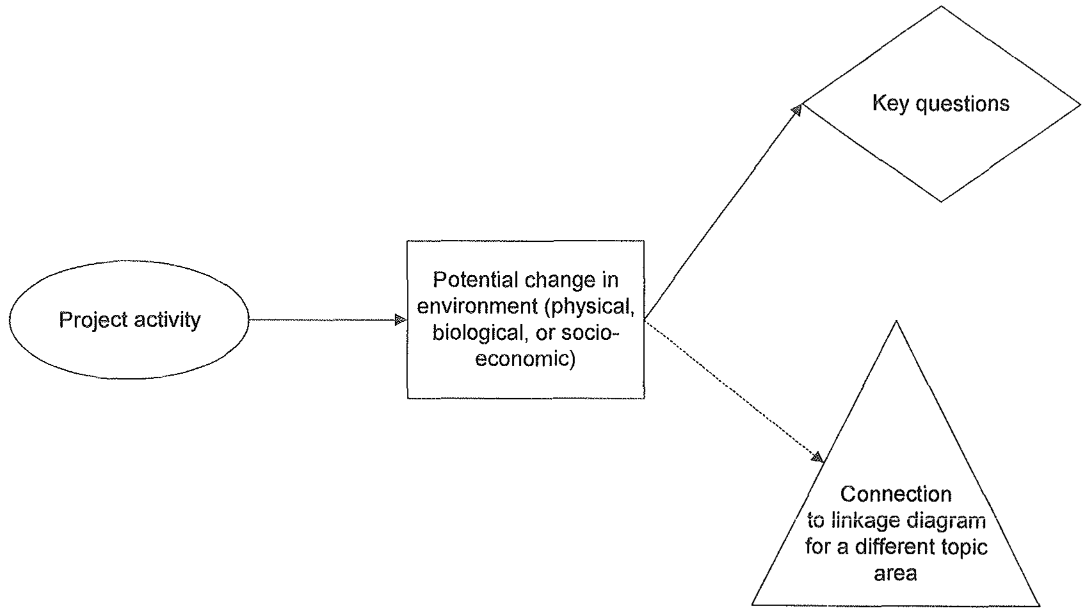
E1.3.3 Linkage Diagrams

Linkage diagrams are used to clearly describe in a transparent manner how project activities could potentially lead to environmental changes, which in turn can affect specific components of the environment. Figure E1-1 illustrates the general format of the linkage diagrams. Symbols on the linkage diagrams include:

- ovals (project activities);
- rectangles (potential changes in the environment);
- diamonds (key questions); and
- triangles (connection to or from a different component area).

These diagrams are used as tools to guide the impact analysis, which addresses each link on the linkage diagram. They also show how the different environmental and social components are inter-related.

Figure E1-1 Key to Using Linkage Diagrams



E1.3.4 Spatial and Temporal Boundaries

Spatial Boundaries

The descriptions of the Local Study Areas (LSA) and the Regional Study Area (RSA) for the Muskeg River Mine Project are provided in Section D1.

Temporal Boundaries

The temporal boundaries of the EIA are based on the Project description and include unique conditions that may affect environmental components differently. Table E1-3 summarizes the main project and reclamation activities of the Muskeg River Mine Project from construction to closure.

Impact analysis for each environmental or social component examines the main phases of the project (construction, operation and closure). For most components, two main phases were examined. Construction and operations were considered together, while closure was considered separately. The time snapshots examined in different components vary to accommodate component specific issues.

Table E1-3 The Activity Phases of the Muskeg River Mine Project

Phase / Year	Activity
Baseline Conditions	
• 1997 / 1998	• pre-development conditions
Construction Phase	
• 1999	• main access road enhancement • initial diversion ditch construction and muskeg drainage • haul road and tailings settling pond area prestrip • haul road construction • starter dyke construction for tailings settling pond
• 2000	• clearing for mine area, overburden waste dump, tailings settling pond and oil sands stockpile area • drainage ditch construction • muskeg removal • starter dyke construction
• 2001	• clearing for mine area • drainage ditch construction • muskeg drainage • groundwater depressurization • in-pit haul road construction • muskeg removal
• 2002	• clearing of mine pit • muskeg drainage • groundwater depressurization • in-pit haul road construction • plant commissioning • first oil sands ore to plant
Operation Phase	
• 2003	• first full-production year without recycle
• 2005	• production with recycle without CT manufacture
• 2010	• production of CT at 75% capacity
• 2020	• production of CT at 95% capacity
• 2025	• mining completed in 2022; closure activities underway
Closure Phase	
• 2030	• first year of closure
• Far Future	• equilibrium closure conditions

Baseline Conditions

The impact analyses consider the potential effects of the Muskeg River Mine Project on both a local and a regional baseline. Baseline conditions for the Project are defined as the existing (1997) environmental conditions and developments in both the LSA and RSA. These study areas are described in Section D1.

The existing (baseline) conditions are characterized in terms of the baseline data collected as part of this EIA, data collected as part of other regional environmental programs, and knowledge of the processes and environmental impacts of other developments that may impact the local and regional study areas. The developments included in the baseline for the incremental impact assessment of the Muskeg River Mine Project are shown in Table E1-4. The locations of these developments are shown in Figure E1-2.

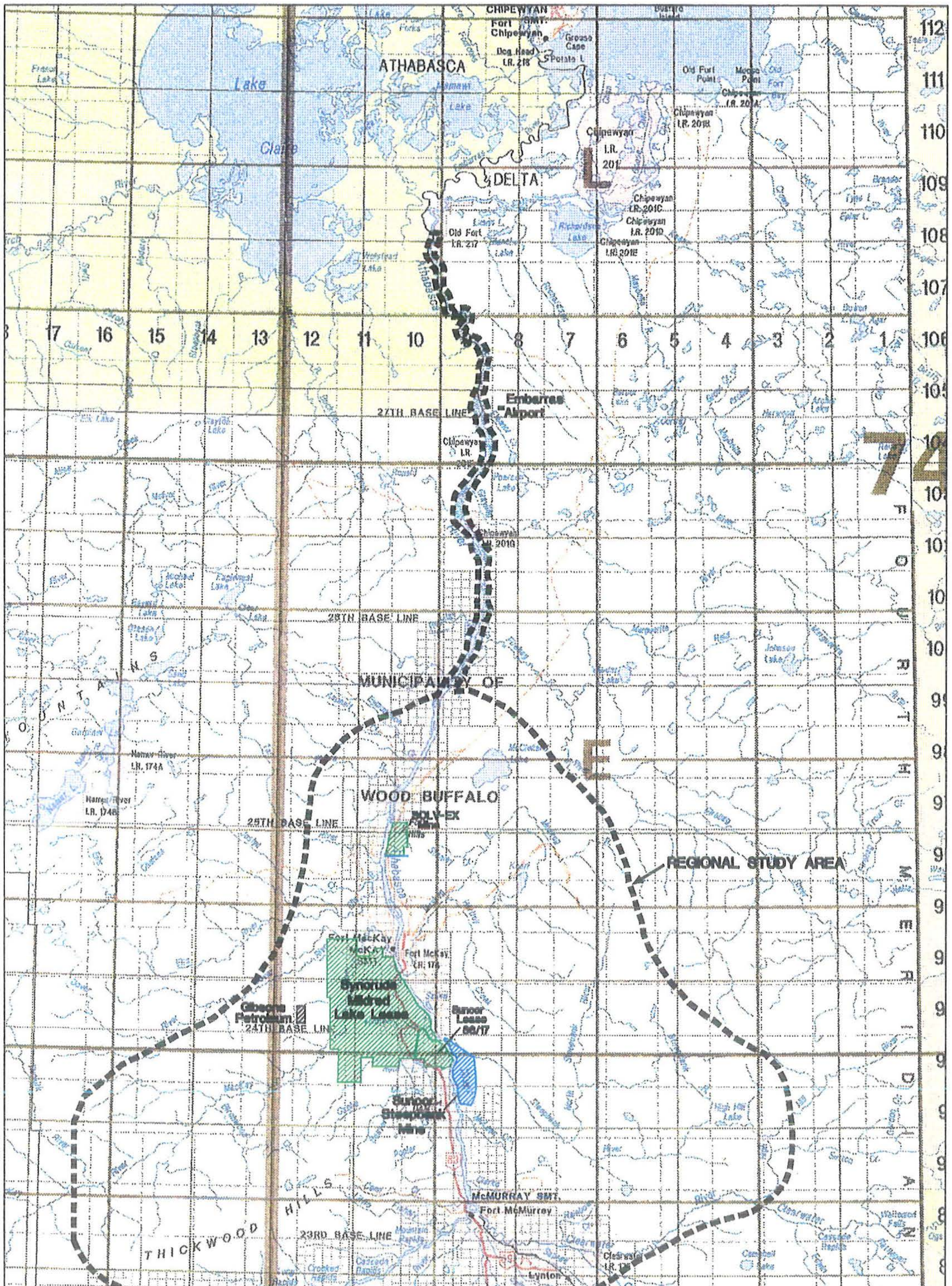
Description of Activities in the Baseline

Baseline activities in the RSA include both existing surface mine and in-situ oil sands operations as well as non-oil and gas operations such as roadways and transmission lines, municipalities and forestry developments. Oil sands related activities include:

- The Suncor Lease 86/17 development, including oil sands mining, bitumen extraction, upgrading facilities and reclamation activities. Current production volume is 85,000 bpd of upgraded product.
- The Suncor Steepbank Mine Project, which received both EUB and AEP approval in 1997, have just begun, with activities limited to completion of construction of the Steepbank Bridge as well as some site clearing. No mining activities have been initiated to date.
- The Syncrude Mildred Lake development, includes oil sands mining, extraction, upgrading facilities and reclamation activities. Current production volume is 205,000 bpd of upgraded product.
- The SOLV-EX Project has included development of a mine and processing facilities, but actual bitumen production to date has been very limited and is currently suspended.
- Gibsons Petroleum is operating a steam assisted gravity drainage project (formerly the AOSTRA Underground Test Facility) to the west of the Syncrude Mildred Lake development. Production from this facility is approximately 2,000 barrels per day of bitumen.

Table E1-4 Existing Developments in the RSA

Development	Air Quality	Hydro-geology	Surface Water Hydrology	Aquatics and Water Quality	Terrestrial	Human Health	Resource Use	Historical/ Traditional Land Use
Suncor Lease 86/17 Oil Sands Mining Bitumen Extraction Upgrading	YES	YES	YES	YES	YES	YES	YES	YES
Suncor Steepbank Bridge Construction Site Clearing				YES	YES			
Syncrude Mildred Lake Oil Sands Mining Bitumen Extraction Upgrading	YES	YES	YES	YES	YES	YES	YES	YES
SOLV-EX (Koch) Surface Disturbance and Plant site					YES			
Gibsons Petroleum UTF In-Situ Bitumen Production	YES				YES		YES	
Pipelines Simmons Gas Pipeline Albersun Gas Pipeline Spur to Gibsons Alberta Energy Oil Pipeline Suncor Oil Pipeline					YES		YES	
Roadways Highways south of Fort McMurray Highway 63 to the Lougheed Bridge Highway 963 north of Lougheed Bridge Road to Gibsons UTF Winter Road to Fort Chipewyan					YES		YES	
Others Power Lines outside Road Rights of Way					YES		YES	
Municipalities Fort McMurray Fort McKay Upstream Municipalities				Background	YES YES	Background Background	YES YES	
Forestry Pre-1997 Permitted Cutblocks Previously Cut Areas					YES		YES	
Pulp Mills Upstream Mills				Background		Background		
Other Areas					YES		YES	



REFERENCE

SCANNED IMAGE OF ALBERTA ENVIRONMENTAL PROTECTION PROVINCIAL BASE MAP 1997, ORIGINAL SCALE 1:1,000,000

SHELL CANADA LIMITED

Golder Associates

EXISTING DEVELOPMENT IN THE REGIONAL STUDY AREA

07 DEC 97	Figure E1–2	DRAWN BY: TM

Linear disturbances included in the analyses are pipelines, roadways and power lines:

- Existing pipelines servicing the oil sands development area include the Albersun gas pipeline to Suncor and the Simmons gas pipeline to Syncrude, a spur gas pipeline to the Gibsons facility, the Alberta Energy oil pipeline from Syncrude Mildred Lake and the Suncor oil pipeline from the Lease 86/17 facility. The Simmons pipeline and the Alberta Energy oil pipeline share a common right of way. An additional gas pipeline, which services the Fort McMurray area, is located to at the very south of the RSA and has not been considered as a separate facility for the purpose of this analysis.

- Major roadways considered for the analyses were Highway 63 from the point it enters the RSA to the south of Fort McMurray, to its northern point. Additionally, Highway 963 north of the Lougheed Bridge and the winter road to Fort Chipewyan (as far as it runs in the RSA) were included. The other major road is the gravel road from Highway 63 to the Gibsons Petroleum operation.

- There is currently one major power line right of way which services the oil sands development area.

The urban areas have been assessed through remote imaging. Water quality issues related to urban areas and upstream pulp mills are accounted through consideration of river water quality upstream of oil sands developments.

Baseline forestry conditions have been evaluated through consideration of existing cutblocks by remote sensing imaging for Alberta Pacific Forest Industries Inc. (Al-Pac) and Northlands Forest Products.

Existing development areas not included in the analyses are linear disturbances below a width of 10 m, such as seismic lines.

E1.3.5 Key Indicator Resources (KIRs)

Environmental systems include an infinite number of complex, interconnected elements, with each element contributing to the functioning of the whole. To focus the environmental assessments for the terrestrial, wildlife and aquatic components of the EIA, a variety of environmental components were identified as Key Indicator Resources (KIRs). Additionally, to allow comparison among the Muskeg River Mine Project EIA, the Suncor Steepbank EIA (Suncor 1996a) and the Syncrude Aurora Mine EIA (BOVAR 1996a), attempts were made to employ the same KIRs.

Selection of KIRs is based on a process defined in detail by BOVAR Environmental (1996a) for the Aurora Mine project. In summary, the KIRs were selected based on ecological importance and vulnerability, resource use value, monitoring value and/or political importance. Selection criteria details for KIRs are provided for aquatic resources in Table E1-5, terrestrial vegetation and wetlands in Table E1-6, and wildlife in Table E1-7.

Input during the consultation program for the Project EIA resulted in requests to add some additional KIRS to those used for the Steepbank and Aurora Mine EIAs. The final list of KIRs for the Muskeg River Mine Project EIA and the rational for selection are summarized in Table E1-8.

Discussions on the KIRs selected for the Project are provided in the Aquatic Resources (Section E6), ELC (Section E7) and Wildlife (Section E11) sections of the EIA.

E1.3.6 Collection and Analyses of Data

The activities associated with the Project are defined in Volume 1 of the Application and summarized in Volume 2, Section B of the Application. These activities formed the basis upon which impacts are predicted and measured.

The baseline for EIA components have been presented in detail in Volume 2, Section D of the Application.

Analyses of data and completion of predictive modelling provides component-specific information to feed into the impact analyses.

E1.3.7 Impact Analyses

Impact analysis were performed within each EIA component, separately for each key question. The analyses address each link on the component linkage diagram. The impact analysis consists of three main steps:

- identification of Project activities which could contribute to environmental change;
- analysis of potential linkages; and
- identification and description of mitigation measures.

Table E1-5 Criteria Used to Select Aquatic Resources Key Indicator Resources

Criteria for Selecting Fish KIRs	Description
Abundance	Ranked based on residence and relative abundance: • Common • Moderately abundance • Uncommon
Status Classification	Ranked based on provincial importance (or status, measure of the relative abundance and degree of management concern or aesthetic value): • Species abundant, no concern (green-listed) • Species rare, but not threatened or special status (yellow-listed) • Threatened or vulnerable species (blue-listed) • Endangered species (red-listed)
Commercial Economic Importance	Ranked based on importance of fish to guides, outfitters and fisheries: • No importance • Low importance • Moderate importance • High importance
Subsistence Economic Importance	Ranked based on fish species importance for subsistence: • Not fished for food • Low • Moderate • High
Recreational Importance	Ranked based on fish species importance for recreational fishing: • Non-game species • Low • Moderate • High
Habitat Niche/Sediment Exposure	Ranked based on habitat niche/sediment exposure: • Yes • No
Spawning in Study Area	Ranked based on spawning in study area: • Yes • No
Benthic Food Preference	Ranked based on benthic food preference: • Yes • No
Importance of Prey	Ranked based on importance as prey: • Yes • No
Fecundity	Ranked based on fecundity: • Low fecundity • Moderate fecundity • High fecundity
Growth Rate	Ranked based on growth rate: • Low growth rate • High growth rate
Age of Maturity	Ranked based on age to maturity: • Long age to maturity • Moderate age to maturity • Short age to maturity
Feasibility of Studying	Ranked based on feasibility of studying: • None • Limited • Moderate • Abundant
Availability of Information	Ranked based on the amount of information available for each species or species: • None • Limited • Moderate • Abundant

From BOVAR (1996a)

Table E1-6 Criteria Used to Select Terrestrial Vegetation and Wetlands

Criteria for Selecting Terrestrial Vegetation and Wetlands KIRs	Description
Abundance	Ranked based on relative abundance in the LSA: • Common • Moderately abundance • Uncommon
Status Classification	Ranked based on national, provincial or regional classification of rare or uncommon species: • Designated rare species, group or community • Species, group or community at extreme end of range • Species, group or community uncommon, but not threatened • Species abundant and no concern
Diversity	Ranked based on number or extent of species in a community and their distribution within the community: • Diverse • Moderately diverse • Simple
Sensitivity to Physical Disturbance	Ranked based on species' or communities' ability to recover following disturbance: • Unable to survive minor changes in habitat • Able to recover rapidly after minor changes in habitat • Very hardy species or communities, able to recover from a high level of disturbance
Economic Importance (Consumptive Use)	Ranked based on forestry and food gathering: • High productivity • Moderate productivity • Low productivity
Recreational Importance	Ranked based on aesthetic value and recreational importance: • High • Moderate • Low

From BOVAR (1996a)

Table E1-7 Criteria Used to Select Wildlife Key Indicator Resources

Criteria for Selecting Wildlife KIRs	Description
COSEWIC Status	Ranked based on wildlife species of concern at the federal level (Committee on Status of Endangered Wildlife in Canada 1996)[a]: • Not listed • Vulnerable species • Threatened species • Endangered species
Provincial Status	Ranked based on wildlife species of concern at the provincial level[b]: • Green - listed, or not listed • Yellow - listed species • Blue - listed species • Red - listed species
Commercial Economic Importance	Ranked based on importance of species to trappers, guides and outfitters: • No importance • Low importance • Moderate importance • High importance
Subsistence Economic Importance	Ranked based on importance of species as food for people: • No importance • Low importance • Moderate importance • High importance
Consumptive Recreational Importance	Ranked based on importance to recreational hunters: • No importance • Low importance • Moderate importance • High importance
Non-Consumptive Recreational Importance	Ranked based on species attractiveness to viewers: • Low interest • Moderate interest • High interest
Ecological Importance	Ranked based on importance of a species as a predator or as a prey item in the ecosystem, or as an ecosystem modifier such as beaver: • No importance • Low importance • Moderate importance • High importance
Habitat Specificity	Ranked based on the ability of a species to use a variety of habitats and altered habitats: • Habitat generalist • Habitat moderate • Habitat specialist • Nil
Inherent Land Capability	Ranked based on the capability of the land to support a species: • Low • Moderate • High

From BOVAR (1996a)

[a] COSEWIC (1997) classifications: **vulnerable** - a species of special concern because of characteristics that make it particularly sensitive to human activities or natural events; **threatened** - a species likely to become endangered if limiting factors are not reversed; and **endangered** - a species facing imminent extirpation or extinction.
[b] Alberta status evaluation system (Alberta Forestry, Lands and Wildlife 1996b):

Red: These species are in serious trouble. Their populations are nonviable or at immediate risk of declining to nonviable levels in Alberta. They have been or will be considered for designation as endangered species in Alberta;

Blue: These species are also at risk, but the threats they face are less immediate. They are particularly vulnerable to noncyclical declines in population or habitat, or to reductions in provincial distribution. Species that are generally suspected of being vulnerable, but for which information is too limited to clearly define their status, have also been placed in this category;

Yellow: These are sensitive species that are not at risk. They may require special management to address concerns related to low natural populations, limited provincial distribution, or particular biological features (e.g., colonial nesting, narrow habitat requirements);

Green: These species are not at risk. Their populations are healthy and often widespread, and their key habitats are generally secure. This category also includes non-resident migrants and species whose occurrence in Alberta is accidental or at the periphery of their normal distribution.

Table E1-8 Summary of Muskeg River Mine Project Key Indicator Resources and Rationale for Selection

Resource	KIR	Rationale for KIR selection
Aquatic	walleye (Athabasca River)	economical and recreational importance, abundance, top predator
	goldeye (Athabasca River)	economic importance, abundance
	lake whitefish (Athabasca River)[a]	economic importance, stage and migrate through study area
	longnose sucker (Athabasca and Muskeg River system)	importance in food chain, abundance, spawns in Muskeg River
	Arctic grayling (Muskeg River system)	recreational importance, spawns in study area
	northern pike (Muskeg River system, Isadore's Lake)	recreational importance, spawns in study area, top predator
	forage fish guild (Muskeg River system, Isadore's Lake)	abundance in Muskeg River, spawns in study area, importance in food chain
Terrestrial	aspen - white spruce communities	economic importance, multiple use
	riparian shrub complexes	diversity, multiple use, disturbance sensitivity, wild life corridor
	patterned fens	diversity, disturbance sensitivity, runs wetland type
	old growth forests	rare plant community, wildlife habitat
	rare plant species	biodiversity
	traditional use plants	subsistence and medicinal/spiritual importance
Wildlife	moose	economic importance, early successional species
	red-backed vole	importance in food chain
	snowshoe hare	importance in food chain
	black bear	economic importance, carnivore
	beaver	economic importance, semi-aquatic habits
	fisher	use of late seral stages, economic importance, carnivore
	dabbling ducks	importance in food chain, economic and recreational importance
	ruffed grouse	economic and recreational importance
	Cape May warbler	use of white spruce forests, neotropical migrant
	western tanager[a]	use of open forest mixed wood, neotropical migrant
	pileated woodpecker[a]	use of late seral stages, large-diameter trees and snags
	great gray owl	raptor, use of wetlands

[a] KIRs added specifically for the Muskeg River Mine Project EIA.

Analysis of Potential Linkages

The potential linkages between project activities and environmental change were evaluated for each EIA component. Where the changes in an environmental component are impacted by changes in another environmental component, the linkages are represented as triangles. Sub-headings are provided for each link on the linkage diagram. Within each of the sub-headings the potential for the Project activity to result in an environmental change is determined and the link is classified as valid or invalid.

Validation of the link includes consideration of the mitigation measures. Mitigation, within the context of this EIA, is defined as follows: "the application of design, construction or scheduling principles to minimize or eliminate potential adverse impacts and, where possible, enhance environmental quality" (Sadar 1994). For certain activities, ongoing mitigation can minimize or eliminate physical or chemical stresses, thereby rendering invalid the link between Project activity and environmental changes.

Analysis of Key Questions

If a link between a Project activity and an environmental change is considered valid, the key question under consideration is examined. For components with KIRs, impacts on each KIR are evaluated separately.

Quantitative Methods

Quantitative methods of assessment are used where possible. Predictive modelling is used as a tool in the air, hydrogeology, surface water hydrology, surface water quality, aquatic resources and wildlife assessments. Risk assessment techniques are used to assess effects on human, wildlife and aquatic health. Ecological land classification and geographic information systems were used to assess impacts on terrestrial resources. The assessment techniques are described in the individual component sub-sections.

E1.3.8 Impact Description

Impact Description Criteria

The residual impact was classified using quantification criteria and degree of concern. Each impact is described in terms the following criteria: direction, magnitude, geographic extent, duration, reversibility and frequency.

Direction of an impact may be positive, neutral, or negative with respect to the key question (e.g., gain habitat for a KIR would be classed as positive, whereas a loss in habitat would be considered negative).

Magnitude is a measure of the degree of change in a measurement or analysis endpoint, and is classified as negligible, low, moderate or high, (e.g., no change from background, near existing background, above background but less than guideline, exceeds guidelines).

Geographic extent refers to the area affected by the impact and is classified as local, regional or beyond regional.

Duration refers to the length of time over which an environmental impact occurs. It considers the actual length of the period during which the impact occurs and whether it is reversible once its source is removed.

Reversibility is an indicator of whether the ecological or socioeconomic endpoint might recover from the impact within a time period of one human generation (35 years). In some cases, reversibility is closely tied to duration (e.g., in the case of a temporary loss of habitat). In other cases, the effect may extend well beyond the end of the period of the original impact (e.g., a spill of chemicals might result in longer-term effects on fish health)

Frequency describes how often the effect occurs within a given time period and is classified as low, medium or high in occurrence.

Table E1-9 details the Impact Description Criteria for each of the Muskeg River Mine Project EIA components.

Criteria for direction, reversibility and frequency are the same for all environmental components. Magnitude, geographic extent and duration vary depending on the component.

E1.3.9 Degree of Concern

Degree of concern is an overall property associated with an impact and is a function of direction, magnitude, duration and geographic extent. For example, an impact scoring moderate to high on all criteria would generally be of high concern. However an impact of negligible magnitude is considered to be of negligible concern regardless of higher scores for other criteria.

The quantification methodology applied for identifying the degree of concern is shown in Table E1-10. Degree of concern is defined in terms of the following four categories:

- Negligible: impacts that are negligible in magnitude.
- Low: impacts that are low in magnitude, restricted to the local study area, and of short to medium duration.
- Moderate: impacts that are intermediate between low and high.
- High: moderate or high magnitude impacts that are of long-term duration and/or which extend beyond the regional study area.

Table E1-9 Impact Description Criteria for the Muskeg River Mine Project [(a)]

RESOURCE	DIRECTION[(b)]	MAGNITUDE[(c)]	GEOGRAPHIC EXTENT[(d)]	DURATION[(e)]	REVERSIBILITY[(f)]	FREQUENCY[(g)]
Air Quality	**Positive:** a decrease in emissions and/or ambient concentrations **Negative:** an increase in emissions and/or ambient concentrations	**Negligible:** non-detectable **Low:** near existing ambient conditions **Moderate:** > existing ambient conditions, but < ambient guidelines **High:** above ambient guidelines	**Local:** effect restricted to LSA **Regional:** effect restricted to within 60 km of development site **Beyond Regional:** effect beyond 60 km of development site	**Short-term:** acute (1 hour to 1 day) **Mid-term:** chronic (annual) **Plant-life:** during operation/reclamation period of Project (30 years) **Long-term:** >30 years	**Reversible** or **Irreversible**	**Low:** occurs once **Medium:** occurs intermittently **High:** occurs continuously
Hydrogeology - Groundwater	**Positive, Negative** or **Neutral** for the measurement endpoints	**Negligible:** no change from pre-development condition **Low:** <1% change **Moderate:** 1 to 10% change **High:** >10% change	**Local:** effect restricted to LSA **Regional:** effect extends beyond the LSA into the RSA **Beyond Regional:** effect extends beyond the RSA	**Short-term:** <2 years **Medium-term:** 2 to 30 years **Long-term:** >30 years	**Reversible** or **Irreversible**	**Low:** occurs once **Medium:** occurs intermittently **High:** occurs continuously
Surface Water Hydrology	**Positive, Negative** or **Neutral** for the measurement endpoints	**Negligible:** <1% **Low:** 1 to 5% **Moderate:** 5 to 15% **High:** >15%	**Local:** effect restricted to LSA **Regional:** effect extends beyond the LSA into the RSA **Beyond Regional:** effect extends beyond the RSA	**Short-term:** <1 years **Medium-term:** 1 to 30 years **Long-term:** >30 years	**Reversible** or **Irreversible**	**Low:** occurs once **Medium:** occurs intermittently (1 to 10 times per year) **High:** occurs frequently (> 10 times per year)
Surface Water Quality	**Positive, Negative** or **Neutral** for the measurement endpoints	**Negligible:** releases do not cause exceedance of guidelines **Low:** releases contribute to existing background exceedances **Moderate:** releases cause marginal exceedance of guidelines **High:** releases cause substantial exceedance of guidelines	**Local:** effect restricted to LSA **Regional:** effect extends beyond the LSA into the RSA **Beyond Regional:** effect extends beyond the RSA	**Short-term:** <2 years **Medium-term:** 2 to 30 years **Long-term:** >30 years	**Reversible** or **Irreversible**	**Low:** occurs once **Medium:** occurs intermittently **High:** occurs continuously

(a) Seasonally is assessed as relevant for each specific component as Spring, Summer, Fall or Year-Round.
(b) Direction: positive or negative effect for measurement endpoints, as defined for the specific component.
(c) Magnitude: degree of change to analysis endpoint
(d) Geographic Extent: area affected by the impact
(e) Duration: length of time over which the environmental effect occurs
(f) Reversibility: effect on the resource can or cannot be reversed in one human generation (approximately 35 years)
(g) Frequency: how often the environmental effect occurs
(h) Criteria can include acute and chronic aquatic life as well as no observed effects concentration (NOEC)
(i) ER: exposure ratio, the predicted exposure divided by the exposure limit

RESOURCE	DIRECTION[b]	MAGNITUDE[c]	GEOGRAPHIC EXTENT[d]	DURATION[e]	REVERSIBILITY[f]	FREQUENCY[g]
Aquatic Resources	**Positive, Negative** or **Neutral** for the measurement endpoints	**Negligible:** no measurable change **Low:** <10% change in measurement endpoint **Moderate:** 10 to 20% change measurement endpoint **High:** >20% change in measurement endpoint **Where guidelines or criteria [h] exist:** **Negligible:** releases do not cause exceedance of guidelines **Low:** releases contribute to existing background exceedances **Moderate:** releases cause marginal exceedance of guidelines **High:** releases cause substantial exceedance of guidelines	**Local:** effect restricted to LSA **Regional:** effect extends beyond the LSA into the RSA **Beyond Regional:** effect extends beyond the RSA	**Short-term:** <2 years **Medium-term:** 2 to 30 years **Long-term:** >30 years	**Reversible** or **Irreversible**	**Low:** occurs once **Medium:** occurs intermittently **High:** occurs continuously
Terrain and Soils	**Positive, Negative** or **Neutral** for the measurement endpoints	**Negligible:** No measurable effect **Low:** <10% change in terrestrial resource **Moderate:** 10 to 20% change in terrestrial resource **High:** >20% change in measurement endpoint	**Local:** effect restricted to LSA **Regional:** effect extends beyond the LSA into the RSA **Beyond Regional:** effect extends beyond the RSA	**Short-term:** <2 years **Medium Term:** 2 to 30 years **Long-term:** >30 years	**Reversible** or **Irreversible**	**Low:** occurs once **Medium:** occurs intermittently **High:** occurs continuously

(a) Seasonally is assessed as relevant for each specific component as Spring, Summer, Fall or Year-Round.
(b) Direction: positive or negative effect for measurement endpoints, as defined for the specific component.
(c) Magnitude: degree of change to analysis endpoint
(d) Geographic Extent: area affected by the impact
(e) Duration: length of time over which the environmental effect occurs
(f) Reversibility: effect on the resource can or cannot be reversed in one human generation (approximately 35 years)
(g) Frequency: how often the environmental effect occurs
(h) Criteria can include acute and chronic aquatic life as well as no observed effects concentration (NOEC)
(i) ER: exposure ratio, the predicted exposure divided by the exposure limit

RESOURCE	DIRECTION[b]	MAGNITUDE[c]	GEOGRAPHIC EXTENT[d]	DURATION[e]	REVERSIBILITY[f]	FREQUENCY[g]
ELCs/Terrestrial Vegetation/Wetlands/ Biodiversity	**Positive, Negative** or **Neutral** for the terrestrial resources under review	**Negligible:** No measurable effect **Low:** < 10% change in terrestrial resource **Moderate:** 10 to 20% change in terrestrial resource **High:** >20% change in measurement endpoint	**Local:** effect restricted to LSA **Regional:** effect extends beyond the LSA into the RSA **Beyond Regional:** effect extends beyond the RSA	**Short-term:** <2 years **Medium-term:** 2 to 30 years **Long-term:** >30 years	**Reversible** or **Irreversible**	**Low:** occurs once **Medium:** occurs intermittently **High:** occurs continuously
Wildlife	**Positive, Negative** or **Neutral** for the wildlife species under consideration	**Negligible:** No measurable effect **Low:** < 10% change in terrestrial resource **Moderate:** 10 to 20% change in terrestrial resource **High:** >20% change in terrestrial resource	**Local:** effect restricted to LSA **Regional:** effect extends beyond the LSA into the RSA **Beyond Regional:** effect extends beyond the RSA	**Short-term:** <2 years **Medium-term:** 2 to 30 years **Long-term:** >30 years	**Reversible** or **Irreversible**	**Low:** occurs once **Medium:** occurs intermittently **High:** occurs continuously
Wildlife Health	**Positive, Negative** or **Neutral** for the measurement endpoints	**Negligible:** ER<1 or, ER marginally greater than 1 due to naturally elevated background exposures and/or conservative exposures **Low:** no ER due to lack of data; anecdotal data suggests low hazard, but additional information necessary to characterize potential impact) **Moderate:** ER >1 with mitigating factors **High:** ER >1 without mitigating factors	**On-site:** impacts confined to the development area **Off-site:** impacts extend beyond the development area	**Short-term:** <1 years **Medium-term:** 1 to 30 years **Long-term:** >30 years	**Reversible** or **Irreversible**	**Low:** occurs once **Medium:** occurs intermittently **High:** occurs continuously

(a) Seasonally is assessed as relevant for each specific component as Spring, Summer, Fall or Year-Round.
(b) Direction: positive or negative effect for measurement endpoints, as defined for the specific component..
(c) Magnitude: degree of change to analysis endpoint
(d) Geographic Extent: area affected by the impact
(e) Duration: length of time over which the environmental effect occurs
(f) Reversibility: effect on the resource can or cannot be reversed in one human generation (approximately 35 years)
(g) Frequency: how often the environmental effect occurs
(h) Criteria can include acute and chronic aquatic life as well as no observed effects concentration (NOEC)
(i) ER: exposure ratio, the predicted exposure divided by the exposure limit

RESOURCE	DIRECTION[(b)]	MAGNITUDE[(c)]	GEOGRAPHIC EXTENT[(d)]	DURATION[(e)]	REVERSIBILITY[(f)]	FREQUENCY[(g)]
Historical Resources	**Positive, Negative** or **Neutral** for the historical resource under consideration	**High:** resources of high scientific or interpretive value are affected **Medium:** if sites similar to other in the region are found affected **Low:** areas of minimal physical impact or when few or low value resources are affected **Negligible:** no physical impact takes place or no sites	**Local:** sites in development area are affected **Regional:** sites in RSA indirectly affected (e.g., increase use or demand for other facilities) **Beyond Regional:** effect extends beyond the RSA	**Immediate:** immediate direct impacts **Long-term:** an indirect impact which occurs over the life of the project	**Reversible** or **Irreversible**	**Not Applicable**
Socio-Economics	**Increase** or **Decrease** in parameter being reviewed	**Negligible:** No measurable effect **Low:** < 10% change in measurement endpoint **Moderate:** 10 to 20% change in measurement endpoint **High:** >20% change in measurement endpoint	**Local:** affects Fort McKay and Fort McMurray **Regional:** affects the Regional Municipality of Wood Buffalo **Provincial/National:** affects Alberta or Canada	**Short-term:** <1 year **Medium-term:** 1 to 5 years **Long-term:** 5 years or more	**Reversible** or **Irreversible**	**Low:** occurs once **Medium:** occurs intermittently **High:** occurs continuously
Human Health	**Positive, Negative** or **Neutral** for the measurement endpoints	**Negligible:** ER<1 or, ER marginally greater than 1 due to naturally elevated background exposures and/or conservative exposures **Low:** no ER due to lack of data; anecdotal data suggests low hazard, but additional information necessary to characterize potential impact) **Moderate:** ER>1 with mitigating factors **High:** ER >1 without mitigating factors	**On-site:** impacts confined to the development area **Off-site:** impacts extend beyond the development area	**Short-term:** <1 years **Medium-term:** 1 to 30 years **Long-term:** >30 years	**Reversible** or **Irreversible**	**Low:** occurs once **Medium:** occurs intermittently **High:** occurs continuously

(a) Seasonally is assessed as relevant for each specific component as Spring, Summer, Fall or Year-Round.
(b) Direction: positive or negative effect for measurement endpoints, as defined for the specific component.
(c) Magnitude: degree of change to analysis endpoint
(d) Geographic Extent: area affected by the impact
(e) Duration: length of time over which the environmental effect occurs
(f) Reversibility: effect on the resource can or cannot be reversed in one human generation (approximately 35 years)
(g) Frequency: how often the environmental effect occurs
(h) Criteria can include acute and chronic aquatic life as well as no observed effects concentration (NOEC)
(i) ER: exposure ratio, the predicted exposure divided by the exposure limit

RESOURCE	DIRECTION[b]	MAGNITUDE[c]	GEOGRAPHIC EXTENT[d]	DURATION[e]	REVERSIBILITY[f]	FREQUENCY[g]
Resource Use and Traditional Land Use	**Positive, Negative** or **Neutral** for the measurement endpoints	**Negligible:** No measurable effect **Low:** < 10% change in measurement endpoint **Moderate:** 10 to 20% change in measurement endpoint **High:** >20% change in measurement endpoint	**Local:** effect restricted to the development area and area immediately adjacent **Regional:** effect extends beyond the development area into the regional area **Beyond Regional:** effect extends beyond the RSA	**Short-term:** <2 years **Medium-term:** 2 to 30 years **Long-term:** >30 years	**Reversible** or **Irreversible**	**Low:** occurs once **Medium:** occurs intermittently **High:** occurs continuously

(a) Seasonally is assessed as relevant for each specific component as Spring, Summer, Fall or Year-Round.
(b) Direction: positive or negative effect for measurement endpoints, as defined for the specific component.
(c) Magnitude: degree of change to analysis endpoint
(d) Geographic Extent: area affected by the impact
(e) Duration: length of time over which the environmental effect occurs
(f) Reversibility: effect on the resource can or cannot be reversed in one human generation (approximately 35 years)
(g) Frequency: how often the environmental effect occurs
(h) Criteria can include acute and chronic aquatic life as well as no observed effects concentration (NOEC)
(i) ER: exposure ratio, the predicted exposure divided by the exposure limit

Table E1-10 Degree of Concern

Direction	Magnitude	Duration	Geographic Extent	Degree of Concern
Negative or Positive	Negligible	Short-term	Local	Negligible
			Regional	Negligible
			Beyond Regional	Negligible
		Medium-term	Local	Negligible
			Regional	Negligible
			Beyond Regional	Negligible
		Long-term	Local	Negligible
			Regional	Negligible
			Beyond Regional	Negligible
	Low	Short-term	Local	Low
			Regional	Low
			Beyond Regional	Low
		Medium-term	Local	Low
			Regional	Moderate
			Beyond Regional	Moderate
		Long-term	Local	Low
			Regional	Moderate
			Beyond Regional	Moderate
	Moderate	Short-term	Local	Moderate
			Regional	Moderate
			Beyond Regional	High
		Medium-term	Local	Moderate
			Regional	High
			Beyond Regional	High
		Long-term	Local	Moderate
			Regional	High
			Beyond Regional	High
	High	Short-term	Local	Moderate
			Regional	High
			Beyond Regional	High
		Medium-term	Local	Moderate
			Regional	High
			Beyond Regional	High
		Long-term	Local	High
			Regional	High
			Beyond Regional	High

E1.3.10 Monitoring

Monitoring proposals are presented where impacts have been predicted, and where mitigative activities are suggested.

E2 AIR QUALITY

E2.1 Introduction

This section of the Muskeg River Mine Project (the Project) EIA provides information as required by the Project Terms of Reference (TofR) issued on November 7, 1997 (AEP 1997). Specifically, the following are addressed in this section:

- indication of the type, rate and source of air emissions from the Project including construction and vehicle emissions;
- indication of the emissions points on the site plan and the potential sources of fugitive emissions
- description of the monitoring and control systems to be employed;
- description of any existing monitoring that Shell is undertaking, and any involvement in activities of the Regional Air Quality Coordinating Committee and Clean Air Strategic Alliance which have relevance to the proposed development;
- estimation of the greenhouse gas emissions from the project (TofR, Section 3.5);
- identification of components of the Project that will affect air quality from a local and regional perspective (Regional in Section F2 and G2);
- estimation of ground level concentrations of appropriate air quality parameters, including discussion on expected changes to particulate deposition or acidic deposition patterns;
- justification for selection of models used (Appendix II);
- identification of the potential for decreased air quality resulting from the Project and discussion of the expected air quality for environmental protection and public health;
- description of how air quality impacts resulting from the Project will be mitigated; and
- identification of a program to monitor air quality during construction and operation of the Project.

The potential cumulative effects on air quality associated with the Project will be addressed in Section F2. Section D2 provides details on the air quality baseline for the Project.

The emissions from the Muskeg River Mine Project (the Project) activities fall broadly into two categories:

- **Combustion sources** result from burning fossil fuel (e.g., natural gas, diesel fuel). The end products from the complete combustion of these fuels are water (H_2O) and carbon dioxide (CO_2). Since combusion is never complete, the products also include trace amounts of oxides of nitrogen (NO_x), carbon monoxide (CO), total hydrocarbon compounds (THC) and particulate matter (PM).

- **Fugitive sources** are defined for the purposes of this assessment as non-combustion sources. The sources include volatilization of THC and total reduced sulphur (TRS) compounds from tailings settling ponds, mine areas and plant process areas. Fugitive PM sources can result from mining activities as well as from weathering of disturbed and exposed surfaces (e.g., mine area, tailings dykes).

Air quality changes due to these emissions will combine with emissions from existing sources in the Regional Study Area (RSA) and with imported (background) ambient concentrations associated with air flow into the RSA. Air quality related issues associated with these emissions can be summarized as a series of key questions whose linkages are identified in Figure E2-1. The key questions are as follows:

AQ-1 Will Muskeg River Mine Project Emissions Result in Exceedances of Ambient Air Quality Guidelines?

The linkage pathway for this key question is depicted by the dark blue line in Figure E2-1.

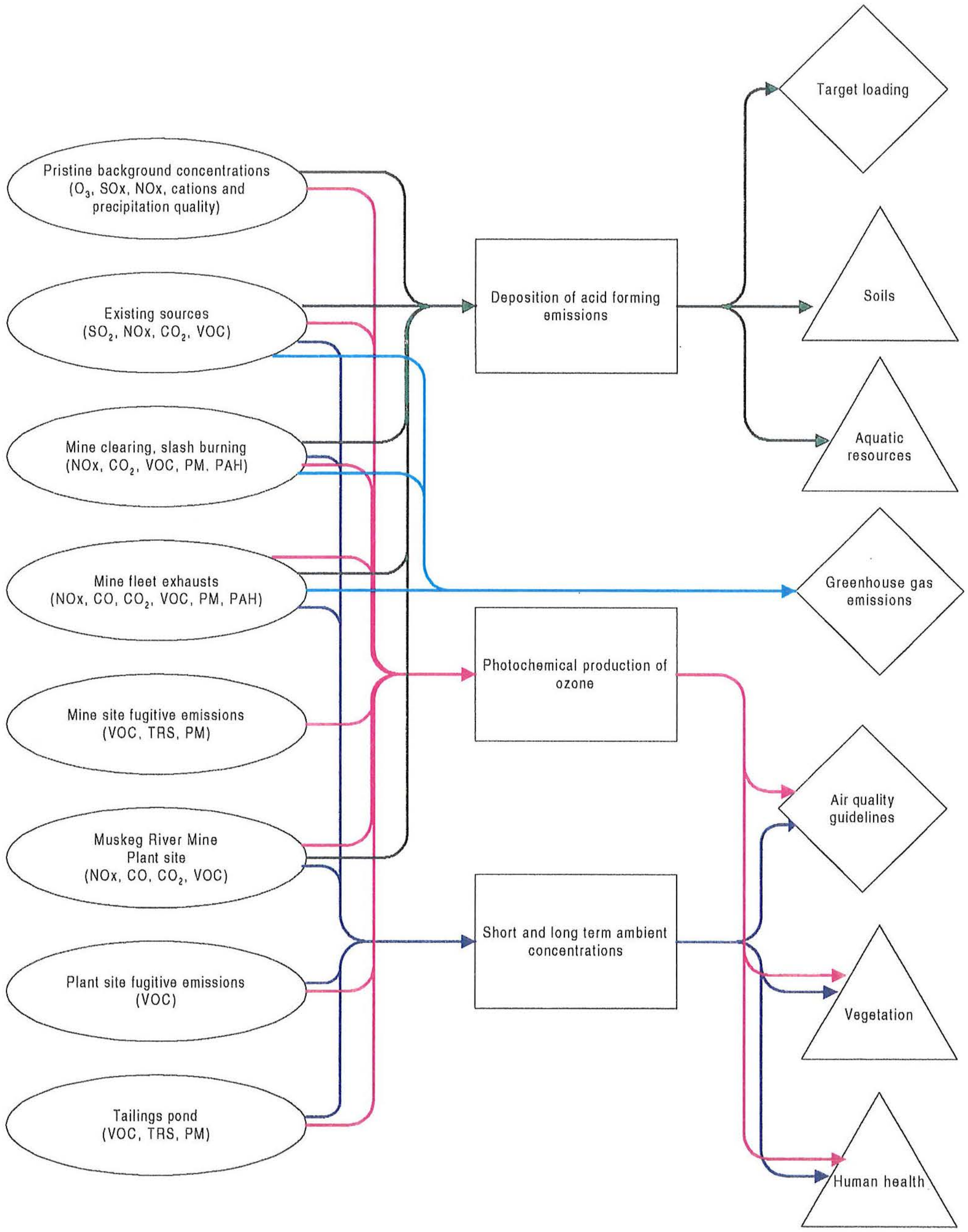
Ambient concentrations due to emissions vented directly into the atmosphere are expected to be greatest in the local study area (LSA) that was defined in Section D1. The maximum ambient values after the development of the Muskeg River Mine Project can be compared to the Alberta ambient air quality guidelines and the Canadian federal air quality objectives for sulphur dioxide (SO_2), NO_2, CO and PM. In addition, the maximum values can be compared to threshold concentration guidelines associated with vegetation effects.

AQ-2 Will Muskeg River Mine Project Emissions Result in Human Health Effects?

The linkage pathway for this key question is also depicted by the dark blue line in Figure E2-1.

Maximum ambient concentrations of emissions that could potentially have adverse effects in the mine, plant area and in the communities of Fort McKay, Fort McMurray and Fort Chipewyan are estimated.

Figure E2-1 **Linkage Diagram for the Air Quality for Construction, Operation and Closure Phases of Muskeg River Mine Project**



r:\1997\2200\972-2237\9600\linkm! vsd

The implications of these concentrations on human health are discussed in Section E12.

AQ-3 Will Muskeg River Mine Project Emissions Result in the Deposition of Acid Forming Compounds That Exceed Target Loadings?

The linkage pathway for the key question is depicted by the green line in Figure E2-1.

NO_x emissions are potential acid forming compounds and the combined effects of the Muskeg River Mine Project NO_x emissions with existing sources of SO_2 and NO_x and with those associated with the air flow into the Regional Study Area are additive. The predicted NO_x deposition and associated Potential Acid Input (PAI) can be compared to the target loading criteria. The implications of the predicted PAI on aquatic resources and soils are discussed in Sections E6 and E9, respectively.

AQ-4 Will Muskeg River Mine Project Precursor Emissions Result in The Formation of Ozone (O_3) That Exceed Air Quality Guidelines?

The linkage pathway for this key question is depicted by the red line in Figure E2-1.

NO_x and volatile organic compounds (VOC) are precursors to the photochemical formation of ozone (O_3). Regional ozone concentrations will depend on other sources of precursor emissions and natural O_3 levels. Maximum O_3 production is expected to occur at considerable distances downwind from the precursor emission source area on days favourable to the photochemical formation of O_3.

AQ-5 What are the Muskeg River Mine Project Greenhouse Gas Emissions and how do They Compare to Those Associated with Conventional Production?

The linkage pathway for this key question is depicted by the light blue line in Figure E2-1.

The production, transportation and consumption of petroleum products that result in greenhouse gas emissions include CO_2 and methane (CH_4). The efficient use of resources and energy can reduce these emissions on a per unit production basis. The efficiency of the Project in terms of CO_2 emissions can be evaluated by comparing the CO_2 emissions associated with conventional oil production.

Assessment Organization

This air quality assessment is organised as follows:

- Section E2.2 Muskeg River Mine Project Emission Sources are Defined And Quantified for Various Project Activities.
- Section E2.3 Key Question AQ-1. Will Muskeg River Mine Project Emissions Result in Exceedances of Ambient Air Quality Guidelines?
- Section E2.4 Key Question AQ-2. Will Muskeg River Mine Project Emissions Result in Human Health Effects?
- Section E2.5 Key Question AQ-3. Will Muskeg River Mine Project Emissions Result in the Deposition of Acid Forming Compounds That Exceed Target Loadings?
- Section E2.6 Key Question AQ-4. Will Muskeg River Mine Project Precursor Emissions Result in the Formation of Ozone (O_3) That Exceed Air Quality Guidelines?
- Section E2.7 Key Question AQ-5. What are the Muskeg River Mine Project Greenhouse Gas Emissions and how do They Compare With Those Associated With Conventional Oil Production?

The primary focus of the air quality impact assessment is to determine the potential effect of air emissions on air quality for the Local Study Area (LSA). The implications of these changes are discussed in the respective discipline sections (e.g., human health, aquatic resources, vegetation and soils). Selected air quality hypotheses are further discussed under the Cumulative Effects (Section F2) to include issues that are more regional in nature.

E2.2 Muskeg River Mine Project Emissions

The operation of the proposed Muskeg River Mine Project will result in gaseous and particulate emissions to the atmosphere. The following summarizes the emissions associated specifically with the proposed mining operations:

- **Mine clearing/slash burning**. The combustion products will be similar to those that result from forest fires and include NO_x, CO, CO_2, THC, PM and polycyclic aromatic hydrocarbons (PAH). Slash burning will be intermittent and of short duration, will be primarily undertaken at the beginning of the project and will occur periodically during the project (at a reduced level) as additional land is cleared (Section E2.2.1).

- **Mine fleet exhausts.** The truck and shovel operation will be diesel fuelled. Products of combustion include NO_x, CO, CO_2, THC, PM and PAH. The truck and shovel operation will be a continuous mining operation (a nominal 24 hours per day, 7 days a week) (Section E2.2.2).

- **Mine fugitive sources.** THC/TRS emissions are associated with exposed mine surfaces and are expected to be the greatest during warm summer periods. PM emissions will also result from the tire/haul road surface abrasion and entrainment of dust into the atmosphere. These PM emissions will depend on the type of road surface, level of mining activity and meteorological parameters such as rainfall, snow cover and wind speed (Section E2.2.3).

Sources associated with **extraction operations** include:

- **Stationary combustion sources** are primarily comprised of natural gas-fired process heaters and boilers. The amount of energy required is dependent on production rate and season. Products of combustion include NO_x, CO, CO_2, THC and PM (Section E2.2.4).

- **Potential plant site fugitive emissions** include those from all process equipment, maintenance activities, extraction plant vents and storage tank vents. Storage tank vents release THC trapped in the head space as part of the diurnal "breathing" of the tank or when it is displaced during filling (Section E2.2.5). Activity in the plant area can also produce fugitive PM emission

Sources associated with the **management of tailings** include:

- **Tailings settling pond surfaces.** Volatilization of VOC/TRS from diluent in the tailings discharged to the pond can occur. These emissions will depend on the temperature of the pond surface, the nature of the VOC and the exposed surface area. Wind blown PM can also occur from the unreclaimed portions of the pond, the top of the pond dykes and the beach areas of the pond. PM emissions will be associated with dry, high wind speed conditions (Section E2.2.6).

- **Consolidated tailings surfaces.** Initially the consolidated tailings (CT) will be capped with water and any VOC/TRS in the capping layer can potentially volatilize from the water surface. The CT will then form a solid surface and residual VOC/TRS can potentially volatilize from the exposed surface (Section E2.2.6).

Table E2-1 provides a summary source/emission matrix for the proposed Muskeg River Mine project operations. All combustion sources result in NO_x, CO, CO_2, PM and THC emissions. PM emissions associated with mine activities and the tailings settling pond are crustal in origin and will reflect the composition of the parent surface material. Although not identified in the table, trace amounts of sulphur in the diesel fuel can result in SO_2 emissions from the fleet exhausts.

Table E2-1 Summary Source/Emission Matrix for the Muskeg River Mine Project Operations

Source	Emission				
	NO_x	CO	CO_2	PM	THC/TRS
Mining					
Clearing/slash burning	✓	✓	✓	✓	✓
Fleet exhausts	✓	✓	✓	✓	✓
Fugitive Mine Sources	×	×	×	✓	✓
Extraction					
Stationary sources	✓	✓	✓	✓	✓
Fugitive plant sources	×	×	×	✓	✓
Tailings Management					
Tailings settling pond	×	×	×	✓	✓
Consolidated Tailings	×	×	×	✓	✓

E2.2.1 Mine Clearing / Slash Burning Emissions

During the construction and operation of the Muskeg River Mine Project, various surface disturbance activities will produce particulate matter (PM) emissions. Specific activities include the following:

Vegetation Clearing. Commercial timber will be salvaged when vegetation is removed for the mine, plant site and tailings settling pond areas. The waste material (slash) will be disposed of by burning, which will release combustion products (including PM) to the atmosphere.

In the extreme, emissions from the burning of waste materials can result in a well-defined visible plume that can extend tens of kilometres. These plumes will be most visible during early morning hours that are characterized by stable, low wind speed conditions. This type of plume condition will likely be dissipated within a few hours after sunrise due to mixing caused by solar heating. Under these types of conditions, the plumes are likely to be dark brown in colour. In addition, the persistence of burning can also result in a regional haze similar to that associated with forest fires. The haze would be white in colour.

Mitigation measures which will be implemented to reduce visible emissions (smoke) include:

- Minimize the amount of fuel to be burned through salvage logging.
- Burn when large fuel material (i.e., material 7 to 23 cm in diameter) has a high moisture content and fine fuel material has a low moisture content.
- Minimize the smouldering phase by keeping burn piles clean (i.e., free of dirt) and by actively repiling burning material.
- Clean up burn piles immediately following burn to limit the smouldering of residual material.

Most of the clearing activities will take place in a single year and the fuel material will be allowed to dry through a summer season prior to burning. Burning will take place in late winter, early spring while there is snow cover.

The burning of slash is regulated by Alberta Forestry. The Project will work with Alberta Forestry to meet burning requirements and obtain the associated permits to conduct this activity. Shell will participate with other industries in the region to examine means to dispose of slash other than by burning.

Overburden Removal. After the vegetation has been cleared, the overburden will be removed from the mine area and stockpiled. As the overburden is inherently moist, fugitive dust emissions associated with the removal are expected to be minimal. However, under dry, windy conditions, the exposed surface of the overburden stockpiles would dry out, thereby increasing the potential for windborne particulate matter. The establishment of a vegetation cover through seeding to stabilize surfaces on the overburden stockpiles will reduce the duration and frequency of these fugitive windborne particulate emissions.

The initial mining locations at the Muskeg River Mine Project are characterized by shallow overburden. This will result in reduced out-of-pit haulage and hence reduce particulate emissions resulting from the haul trucks.

Road and Plant Site Construction. The mine pit operations require the construction of haul roads along pit walls, on-ramps and access routes to all mine benches and to overburden disposal sites. Other roads include: major arteries between the pit operations and the plant site, and perimeter roads around the tailings settling pond. The construction and use of these roads and the preparation of the plant site under dry conditions will produce fugitive particulate emissions. Mitigation measures to reduce fugitive dust emissions include the watering of roadways when appropriate.

Emission Estimates. The magnitude of the PM emissions from these activities was not estimated as these activities tend to occur during the first few years of activity and the emission levels are expected to be controlled with the mitigation measures in place.

E2.2.2 Mine Fleet Exhaust Emissions

The exhaust emissions associated with ideal combustion of diesel fuel would be limited to CO_2, NO_x and H_2O. Under normal conditions, however, PM, SO_2, VOC and PAHs are also emitted.

Emission Factors. Mine fleet exhaust emissions can be estimated by the application of emission factors that are based on the amount of fuel consumed. The emission factors applied to the Muskeg River Mine Project are based on a composite of emission factors obtained from a number of different sources. These include those provided by Environment Canada (1991) for a mix of mining equipment, the U.S. EPA (1985) for off-road haul trucks, the U.S. EPA (1995) for large stationary diesel engines and those provided by Westerholm et al. (1991). The two latter sources provide a more comprehensive list and quantification for trace organic (THC) and PAHs.

The U.S. EPA stationary source factors indicate about 85% of the total particulates emissions are in the PM_{10} size fraction and about 72% are in the $PM_{2.5}$ size fraction. This compares to Bagley et al. (1996) who reported that most of the PM in a diesel exhaust is in the sub-micron range (less than 1 μm in diameter). For this assessment, the 85% and 72% factors are applied to estimate PM_{10} and $PM_{2.5}$ emissions, respectively.

Table E2-2 provides the emission factors based on the amount of fuel consumed that were applied to the Project mine fleet exhausts. The largest emission factors are associated with greenhouse gases (e.g., CO_2) and criteria contaminants (e.g., NO_x and CO). For hydrocarbons, the largest factors are associated with alkanes, alkenes and aldehydes. The smallest factors are associated with PAHs.

Emission Guidelines. The emission factors are based on off-road vehicles built and operated before the 1990's. As such, the factors will not reflect emission control technologies that may be available for these types of vehicles by the year 2000. There is an indication that the U.S. EPA will require reduced emissions from these types of vehicles. This may result in fleet vehicles with an improved emissions control technology for the units servicing the Muskeg River Mine Project. Table E2-3 compares current and proposed emission standards (kg/10^3 L) for off-road diesel engines. The proposed CO standards (both U.S. EPA and Economic Commission for Europe (ECE) www.dieselnet.com/standards/) and HC standard (ECE) are similar to the emission factor values in Table E2-2. The proposed standards would reduce NO_x emissions by about 40% and PM emissions by about 60% from the average values in Table E2-2. To be conservative, however, the emission factor values in the Table E2-2 were used for this air quality assessment.

Mine Fuel Use. Expected fuel consumption will vary over the Project lifetime:

- Less than 50,000 L/d (1999 to 2001)
- Between 100,000 and 150,000 L/d (2002 to 2005)
- Between 150,000 and 200,000 L/d (2006 to 2014)
- More than 200,000 L/d (2015 to 2022)

The highest fuel use of 227,000 L/d is forecast for 2020. For this assessment, the emissions based on this maximum fuel rate are used to be conservative.

About 80% of the diesel fuel consumption is expected to take place in the mine pits, therefore 80% of the emissions will also be released in the pits. The dispersion of these emissions from the mine will depend on the physical dimensions of the pit in addition to meteorology. Table E2-4 provides the mine dimensions for selected time periods. For the purpose of the assessment, all the fuel was assumed to be consumed and associated emissions be released from within the mine pit.

Emission Rate. The corresponding mine fleet emissions are given in Table E2-2 and are based on the year with the greatest fuel consumption. The emissions represent an average daily rate and assume the fuel consumption is uniform over 354 operating days a year. This accounts for downtime due to holidays and weather conditions (11 days/a). Table E2-5 summarizes emissions associated with the mine fleet exhausts.

E2.2.3 Fugitive Mine Emissions

Sources: Mine surfaces are comprised of freshly exposed oil sands faces, wind rows, bench tops and pit floors. Given the hydrocarbon (i.e., bitumen) nature of the mine and various levels of disturbances and exposures, fugitive particulate matter (PM), total hydrocarbon (THC) and reduced sulphur (TRS) emissions can occur. Emissions from the mine area will vary with ambient temperature and wind speed but generally will be the highest during hot days and the lowest during cold days.

PM Emissions. Mining activities have the potential for producing fugitive dust (PM) emissions.

- **Loading/Unloading:** Shovels will be used to load the oil sands into the trucks. The trucks will dump the oil sands into a crusher. These operations will take place in the mine pit area and the moisture and hydrocarbon content of the oil sands are such that fugitive dust is not expected to be significant.

- **Hauling:** The trucks will be hauling overburden to the disposal areas and oil sands to the crusher site. Most of the hauling will be associated with the latter, which will take place in the pit.

- **Wind erosion**: Wind erosion of exposed mine surfaces can potentially occur under high wind speed, dry conditions. However, given the nature of the oil sands surface, wind erosion is not expected to be significant.

Table E2-2 Diesel Emission Factors Estimates and Associated Emissions from the Muskeg River Mine Project

Compound	Average ($kg/10^3$ L)	2020 (kg/d)	Group Subtotals (kg/d)
Criteria Compounds			
CO	14.8	3360	
NO_x	44.0	9994	
SO_2	2.78	643	
CO_2	2711	615,724	
PM_{10}	2.10	476	
$PM_{2.5}$	1.33	303	-
Alkanes			
Methane	0.285	64.7	
Ethane	0.163	37.1	
Propane	0.115	26.2	
Butane	0.170	38.6	
Pentane	0.111	25.1	
Hexane	0.211	48.0	
Heptane	0.142	32.3	
Octane	0.056	12.6	
Nonane	0.037	8.4	
Decane	0.173	39.3	
Undecane	0.176	40.0	
Dodecane	0.108	24.6	397
Alkenes			
Ethylene	0.817	186	
Propylene	0.141	32.0	
Butene	0.030	6.9	
Pentene	0.005	1.2	226
Aromatics			
Benzene	0.021	4.7	
Ethylbenzene	0.021	4.8	
Toluene	0.004	0.8	
Xylene	0.006	1.3	12
Aldehydes			
Formaldehyde	0.692	157	
Acetaldehyde	0.221	50	
n-Butanal	0.013	3.0	
3-Methylbutanal	0.002	0.4	
Methacrolein	0.0106	2.4	
Acrolein	0.0318	7.2	221

Table E2-2 Diesel Emission Factors Estimates and Associated Emissions from the Muskeg River Mine Project (Concluded)

Compound	Average ($kg/10^3$ L)	2020 (kg/d)	Group Subtotals (kg/d)
Ketones			
Acetone	0.0576	13.1	
Methyl Ethyl Ketone	0.0123	2.8	
3-Buten-2-one	0.0231	5.2	21.1
Alcohols			
2-Propanol	0.0046	1.0	1.0
PAHs			
Napthalene	2.14E-03	4.9E-01	
Acenapthylene	1.52E-04	3.4E-02	
Acenaphthene	7.68E-05	1.7E-02	
Fluorene	2.10E-04	4.8E-02	
Phenanthrene	6.18E-04	1.4E-01	
Anthracene	2.29E-05	5.2E-03	
Fluoranthene	5.48E-05	1.2E-02	
Pyrene	4.32E-05	9.8E-03	
Benz(a)anthracene	5.55E-06	1.3E-03	
Chrysene	1.53E-05	3.5E-03	
Benzo(b)fluoranthene	1.82E-05	4.1E-03	
Benzo(k)fluoranthene	2.07E-06	4.7E-04	
Benzo(a)pyrene	2.17E-06	4.9E-04	
Indeno(1,2,3-W)pyrene	3.45E-06	7.8E-04	
Dibenz(a,h)anthracene	5.69E-06	1.3E-03	
Benzo(g,h,l)perylene	4.70E-06	1.1E-03	
3-Methylphenanthrene	2.40E-04	5.5E-02	
2-Methylanthracene	2.75E-04	6.2E-02	
4-+9-Methylphenanthrene	2.96E-04	6.7E-02	
1-Methylphenanthrene	2.46E-04	5.6E-02	
Benzo[a]fluorene	4.96E-06	1.1E-03	
2-Methylpyrene	4.09E-06	9.3E-04	
Benzo[ghi]fluoranthene	2.88E-06	6.5E-04	
Cyclopenta[cd]pyrene	3.46E-07	7.9E-05	
Benzo[e]pyrene	3.07E-07	7.0E-05	
Perylene	3.84E-08	8.7E-06	
Indwno[1,2,3-cd]fluoranthene	1.92E-07	4.4E-05	
Picene	3.84E-08	8.7E-06	
2-Methylfluorene	4.61E-07	1.0E-04	
Benzo[ghi]perylene	2.69E-07	6.1E-05	
Coronene	3.84E-08	8.7E-06	
1-Nitropyrene	3.07E-06	7.0E-04	
Dibenzothiophene	3.27E-07	7.4E-05	
4-Methyldibenzothiophene	5.38E-07	1.2E-04	
3-Methyldibenzothiophene	8.45E-07	1.9E-04	1.0
Total hydrocarbon and PAH			879.0

Table E2-3 Proposed Emission Standards (kg/10^3 L) of Off-Road Diesel Engines

Agency:	U.S. EPA	U.S. EPA	ECE (Europe)
Status:	Current	Proposed	Proposed
Year	1994	2000	2002
Engine Size	> 560 kW	> 560 kW	130 to 560 kW
CO	43.9	13.5	13.5
NO_x	35.7	24.7[a]	27.0
PM	2.07	0.77	0.77
HC	5.17	-	3.86

[a] Includes NO_x and HC.

Table E2-4 Muskeg River Mine Project Pit Dimensions for 2006, 2011, 2016 and 2021

Year	Pit Area (km^2)	Pit Volume (10^8 m^3)	Equivalent Pit Depth (m)
2006	4.2	2.47	59
2011	4.5	2.84	63
2016	6.3	2.61	42
2021	5.6	0.48	9

Table E2-5 Summary of the Muskeg River Mine Project Mine Fleet Exhaust Emissions (2020)

	Emission (t/d)
NO_x	10.0
CO	3.4
CO_2	616
PM_{10}	0.5
$PM_{2.5}$	0.3
THC	0.9
CH_4	0.06
VOC	0.8
PAH	0.001

PM_{10} and $PM_{2.5}$ emission factors are available for Western U.S. surface coal mines and for unpaved roads. These factors depend on parameters such as vehicle weight, vehicle speed, surface wetness and silt loadings. The identified factors are not applicable to an oil sands mine given the influence of the bitumen surface in reducing dust emissions. For this reason these factors were not applied and fugitive PM emissions for the Muskeg River Mine Project were not estimated. Experience at the Syncrude and Suncor mines does not indicate significant PM emissions due to mine activities.

Given the coarse nature of oil sands (bitumen and sand combination), the identified mining activities are not expected to produce PM emissions that are typically associated with other types of mining operations (e.g., coal mining). Additionally, due to the high quality of ore to be mined at the Muskeg River Mine Project, the resulting waste to ore ratio will be low, thereby reducing PM emissions from mining equipment on a production basis.

The control of fugitive particulate emissions will be undertaken at the Project for safety (e.g., the control of wind dust reduces potential for traffic related incidents), reclamation (e.g., sand blown into reclaimed areas can reduce the effectiveness of the reclamation process), economic (e.g., increased dust causes wear on vehicles and other machinery) and worker health concerns, in addition to environmental concerns. The application of water to mining haul roads has been shown to reduce PM emissions by about 75%.

THC and TRS Emission Factors. In 1987, a surface flux monitoring study identified and characterized THC and TRS emissions from several mine surfaces at the Syncrude north mine (Concord Environmental 1988). The average surface emission flux estimates from these measurements are provided in Table E2-6.

THC and TRS Emission Rates. For the purposes of predicting emissions, the area of the mine is required. The expected mine areas and the corresponding THC and TRS emissions are provided in Table E2-7. The detailed emission rate speciation for the 2016 mine development, which is associated with the greatest surface area, is given in Table E2-6. THC emissions are dominated by C_1 to C_3 compounds and THC emissions are in excess of TRS emissions by two orders of magnitude. These emissions represent ambient conditions for the late summer, early fall period. As the emissions are related to ambient temperature, higher emission rates can occur during the hotter summer period with lower rates during the cooler winter period.

E2.2.4 Stationary Plant Sources

Plant Site Sources. Various sources at the Muskeg River Mine Project extraction plant will result in combustion products being vented into the atmosphere.

- **The Water System Heaters.** Six natural gas fired heaters will be used to heat water for the extraction process. The emissions will be greater during the winter due to increased heating demands. For the purpose of assessment, each heater is assumed to be serviced by an individual stack.

- **The Utilities Plant Boilers.** Two natural gas fired boilers will be used to produce process steam. Again, the heating demands during the winter are greater than those during the summer. Each boiler is assumed to be serviced by an individual stack.

- **Building Heaters.** Natural gas fired heaters will be used for space heating. These heaters will be used primarily during the colder winter period.

- **The Flare.** The flare system will be used for emergency and maintenance purposes. The flare will be serviced by a continuously burning pilot.

Table E2-6 Mine Surface VOC and TRS Emission Factors and Estimated Emissions for the Muskeg River Mine Project

THC	Emission Flux (kg/km^2-d) Average	Emission 2016 (kg/d)
C_1 to C_3	149.9	942.9
i-butane	3.5	21.7
n-butane	6.0	38.0
i-pentane	2.6	16.3
Unknown	2.6	16.3
Cyclopentane	5.2	32.6
3-Methyl-Pentane	1.7	10.9
Methylcyclopentane	1.7	10.9
Unknown	2.6	16.3
Cyclohexane	1.7	10.9
2,3-Dimethylpentane	1.7	10.9
3-Methylhexane	4.3	27.2
n-Heptane	0.9	5.4
Methylcyclohexane	3.5	21.7
Unknown	2.6	16.3
Toluene	2.2	13.6
Unknown	1.7	10.9
3-Methylheptane	5.6	35.3
2,3,4-Trimethylhexane	1.3	8.2
n-Octane	4.8	29.9
Branched Nonane	4.3	27.2
Ethylbenzene	1.7	10.9
m,p-Xylene	0.9	5.4
Unknown	4.3	27.2
o-Xylene	4.3	27.2
Unknown	5.2	32.6
n-Nonane	6.5	40.8
Cumene (i-propylbenzene)	4.3	27.2
Unknown	9.5	59.8
Unknown	3.0	19.0
Unknown	20.3	127.7
n-Decane	6.9	43.5
C_1-C_{10}	**257.0**	**1616.8**
C_5-C_{10}	**97.2**	**611.4**
TRS	**Emission Flux (kg/km^2-d) Average**	**Emission 2016 (kg/d)**
H_2S	0.29	1.8
COS	0.83	5.2
CS_2	0.71	4.4
Unknown	0.72	4.6
TRS	**2.11**	**13.3**

Table E2-7 Summary of Areas Hydrocarbon Emission Rates and TRS Emission Rates for the Muskeg River Mine Project

	2006	2011	2016	2021
Area (km^2)	4.2	4.5	6.3	5.6
C_1 to C_{10} (t/d)	1.1	1.2	1.6	1.4
C_5 to C_{10} (t/d)	0.4	0.4	0.6	0.5
TRS (t/d)	0.009	0.010	0.013	0.012

Emission Factors. Factors for estimating emissions from the combustion of natural gas are provided in Table E2-8. The emission factors are dependent on the firing rate of the units.

Table E2-8 Emission Factors (ng/J) Used to Determine Emissions Due to Natural Gas Consumption

	Unit Size (GJ/h)		
	> 105	10.5 to 105	< 10.5
NO_2 [a]	40	26	-
CO [b]	17	15	9
THC [c]	0.73	2.4	3.4
VOC [c]	0.60	1.1	2.2
PM_{10} [d]	5.3	5.8	5.1

(a) From Environment Canada (1997a), Table E1-8.
(b) From U.S. EPA (1995), Table 1.4-2.
(c) From U.S. EPA (1995), Table 1.4-3.
(d) From U.S. EPA (1995), Table 1.4-1.

Emission Rates. The source and emission characterization associated with these sources are summarized in Table E2-9 for winter conditions. Table E2-10 compares winter and summer emissions (t/d). On average, the summer emissions are about 70% of the winter values due to reduced heating demands. Most of the emissions are associated with the water system heaters (82% for the winter emissions).

The flare system will be serviced with a continuously burning pilot and will be used to protect the froth treatment plant and diluent recovery units from over pressure during process upsets. The flare will also be used to dispose of diluent vapours during plant shutdown and maintenance periods. During these periods, larger quantities of gas will be flared. These scenarios have not been identified or quantified as they are intermittent and of limited duration.

Table E2-9 Source and Emission Parameters Associated with the Muskeg River Mine Project Stationary Sources for Winter Conditions

Source	Fired Heaters						Boilers		Space Heating	Flare Pilot	Total
	1	2	3	4	5	6	1	2			
Energy input (GJ/h)	283	283	283	283	283	283	93	93	196	2	2084
Fuel consumption (m^3/s)	2.24	2.24	2.24	2.24	2.24	2.24	0.73	0.73	1.55	0.01	16.49
Stack height (m)	25	25	25	25	25	25	25	25	-	-	-
Stack diameter (m)	1.986	1.986	1.986	1.986	1.986	1.986	1.136	1.136	-	-	-
Total flow (m^3/s)	29.79	29.79	29.79	29.79	29.79	29.79	9.76	9.76	20.59	0.18	-
Velocity (m/s)	15.2	15.2	15.2	15.2	15.2	15.2	15.2	15.2	-	-	-
Temperature (°C)	182	182	182	182	182	182	182	182	-	-	-
NO_2											
Emission factor (ng/J)	40	40	40	40	40	40	26	26	26	26	-
Concentration (ppmv)	54	54	54	54	54	54	35	35	35	35	-
Emissions (g/s)	3.15	3.15	3.15	3.15	3.15	3.15	0.67	0.67	1.42	0.01	-
Emissions (t/d)	0.272	0.272	0.272	0.272	0.272	0.272	0.058	0.058	0.122	0.001	1.87
CO											
Emission factor (ng/J)	17	17	17	17	17	17	15	15	15	9	
Concentration (ppmv)	38	38	38	38	38	38	34	34	34	20	-
Emissions (g/s)	1.34	1.34	1.34	1.34	1.34	1.34	0.39	0.39	0.82	0.00	-
Emissions (t/d)	0.116	0.116	0.116	0.116	0.116	0.116	0.033	0.033	0.071	0.00	0.83
CO_2											
Emissions (t/d)	415	415	415	415	415	415	136	136	287	3	3049
THC											
Emission factor (ng/J)	0.73	0.73	0.73	0.73	0.73	0.73	2.4	2.4	2.4	3.4	-
Concentration (ppmv)	2.9	2.9	2.9	2.9	2.9	2.9	9.4	9.4	9.4	13.3	-
Emissions (g/s)	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.13	0.00	-
Emissions (t/d)	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.011	0.0001	0.05
VOC											
Emission factor (ng/J)	0.6	0.6	0.6	0.6	0.6	0.6	1.1	1.1	1.1	2.2	-
Concentration (ppmv)	2.3	2.3	2.3	2.3	2.3	2.3	4.3	4.3	4.3	8.6	-
Emissions (g/s)	0.05	0.05	0.05	0.05	0.05	0.05	0.03	0.03	0.06	0.00	-
Emissions (t/d)	0.004	0.004	0.004	0.004	0.004	0.004	0.002	0.002	0.005	0.0001	0.03
PM_{10}											
Emission factor (ng/J)	5.3	5.3	5.3	5.3	5.3	5.3	5.8	5.8	5.8	5.1	-
Emissions (g/s)	0.42	0.42	0.42	0.42	0.42	0.42	0.15	0.15	0.32	0.002	-
Emissions (t/d)	0.036	0.036	0.036	0.036	0.036	0.036	0.013	0.013	0.027	0.0002	0.27

Table E2-10 Comparison of Winter and Summer Emissions (t/d) for the Muskeg River Mine Project Plant Site

	Winter	Summer
NO_2	1.87	1.37
CO	0.83	0.59
CO_2	3049	2151
PM_{10}	0.27	0.19
$PM_{2.5}$ [(a)]	0.27	0.19
THC	0.05	0.03
VOC	0.03	0.02

[(a)] All PM was conservatively assumed to be in the $PM_{2.5}$ size fraction.

SO_2 Emissions. The Muskeg River Mine Project will not have an on-site upgrader. All the bitumen product and the associated sulphur content will be shipped via pipeline to markets outside of the RSA for upgrading, therefore no SO_2 emissions are expected from the plant site.

E2.2.5 Fugitive Plant Sources

Potential fugitive sources and emissions of THC at the extraction plant include vents, building exfiltration and storage tank losses. These emissions, however, will be minimized through the following:

- While steam vents may contain trace amounts of bitumen during upset conditions, they are not expected to produce gaseous VOC since diluent has not been added to the steam.
- The extraction process will be undertaken at a reduced temperature (50°C) instead of 70°C used for other extraction operations in the region. This lower process temperature will reduce volatilization of lighter hydrocarbons.
- Diluent is handled in the froth treatment plant; the separation processes will be blanketed with nitrogen and any captured vapours will be directed to the flare.
- The diluent storage tank will be blanketed with nitrogen and a vapour recovery unit (VRU) will be used to control tankage emissions.
- The product tanks are provided with floating roofs incorporating double seals to control vapour losses.

In summary, the extraction plant is not expected to be a significant source of fugitive THC and TRS emissions and as such, these emissions were not quantified.

E2.2.6 Tailings Management

Tailings Settling Pond Emissions

The proposed tailings settling pond, will receive effluent from the primary bitumen extraction and from the froth treatment processes. Table E2-11 provides the proposed composition of the effluent received by the tailings systems from the proposed extraction operations. The amount of diluent losses to the tailings settling pond are similar to those associated with other oil sands operations.

Once in the pond, hydrocarbon emissions from the surface can occur. Due to the nature of the tailings discharge (e.g., diluent, bitumen and fines), and the chemistry of the pond, the composition profile of emissions from the surface can differ from that associated with the discharge to the pond.

Table E2-11 Summary of Muskeg River Mine Project Tailings Composition

	Flow Rate (t/d)	Composition (wt %)
Solids (sand)	200,368	54.99
Water	160,377	44.02
Bitumen	2441	0.67
Asphaltene	1027	0.28
Diluent	154	0.04
Total	364,367	100.00

Emission Factors: The Syncrude tailings settling pond (referred to as the Mildred Lake Settling Basin or MLSB) receives tailings from the extraction (Plant 5) and from the froth treatment (Plant 6) plants. Plant 5 tailings is comprised of water, sand and trace amounts of bitumen, while the Plant 6 tailings is comprised of fines, water and residual amounts of diluent and bitumen. The Plant 5 discharge points vary along the perimeter of the settling basin while the Plant 6 discharge is near the south end of the settling basin.

Surface flux chamber measurements were obtained at seven different MLSB locations during the summer of 1992 (Concord Environmental 1992b). On average, THC and TRS emissions at the north end of the MLSB are lower than those at the south end of the pond. This indicates that most of the fugitive THC and TRS emissions are from the Plant 6 froth treatment discharge and may be due to the residual diluent in the tailings. The surface flux emission estimates provided in Table E2-12 represent an average emission flux for the whole settling basin.

The Syncrude emission factors were obtained in the spring during daytime hours. Lower emission rates may occur during the night and the cooler winter season. Similarly, higher emission rates may occur in the warmer summer season. In the absence of process specific data, these factors provide a first order indication of both type and magnitude of emissions that could occur from the Muskeg River Mine Project tailings settling pond.

Diluent Analysis. The hydrocarbon emissions from the tailings settling pond will depend to some degree on the composition of the diluent lost to the ponds. The diluent proposed for the Muskeg River Mine Project operations is comprised primarily of pentane (C_5) and hexane (C_6) hydrocarbons in contrast to the diluent used by Syncrude that is comprised primarily of octane (C_8), nonane (C_9) and decane (C_{10}) hydrocarbons. The hydrocarbon emission factors given in Table E2-12 may therefore underestimate C_5 and C_6 emissions and overestimate C_8 to C_{10} emissions. However, since other biological/chemical processes in the pond likely contribute to the VOC emission profile, no attempt at effecting a correction for estimating Muskeg River Mine emissions was undertaken.

THC and TRS Emissions: The estimation of the VOC and TRS emissions associated with the tailings settling pond will depend on the exposed water surface that will vary during the project life. The exposed water surface area of the Muskeg River Mine Project tailings settling pond is expected to vary from a maximum of 6.77 km^2 in 2004 to 5.67 km^2 in 2022. For this assessment, the emissions based on the maximum area are estimated and are presented in Table E2-12. Table E2-13 summarizes the expected emissions from the pond.

and C_6 and less C_8 to C_{10}. The emission estimates in Table E2-12 are based on measurements taken at the end of May when the temperatures varied from 10 to 20°C.

PM Emissions. The exterior slopes and the crests of the tailing settling ponds as well as the interior beach areas will be comprised of sand. Under high wind speed conditions, wind blown sand can result. Mitigation measures include the timely reclamation and revegetation of the exterior surfaces to reduce exposed surface areas. Blowing sand from beach areas can be reduced by stabilizing the surface by mixing the sand with other materials such as mature fine tailings or peat. Since these mitigation measures will be undertaken, low emission PM levels are expected.

Table E2-12 Tailings Settling Pond Surface THC, VOC and TRS Emission Factors and Associated Emissions. Emissions are Based on a Maximum Tailings Settling Pond Area of 6.77 km^2, Which is Expected to Occur in 2004

Compound	(kg/km^2/d)	(kg/d)
THC Emissions		
C_1 to C_3	60.07	406.6
i-butane	1.11	7.5
i-pentane	0.28	1.9
n-Pentane	0.41	2.8
Cyclopentane	0.07	0.5
2,3-Dimethylbutane	2.35	15.9
n-Hexane	1.94	13.1
2,4-Dimethylpentane	3.87	26.2
Cyclohexane	7.05	47.7
Unknown	8.99	60.8
2,3-Dimethylpentane	0.90	6.1
3-Methylhexane	2.90	19.7
Unknown	2.70	18.2
2,2,4-Trimethylpentane	6.50	44.0
n-Heptane	3.59	24.3
Unknown	21.84	147.9
Unknown	0.14	0.9
Toluene	5.94	40.2
Unknown	0.55	3.7
3-Methylheptane	2.35	15.9
2,2,5-Trimethylhexane	6.98	47.3
n-Octane	6.84	46.3
Unknown	9.26	62.7
Unknown	2.42	16.4
Unknown	2.14	14.5
Ethylbenzene	16.31	110.4
(p+m)-Xylene	16.31	110.4
n-Nonane	3.73	25.3
o-Xylene	5.11	34.6
Cumene (i-propylbenzene)	2.63	17.8
Unknown	1.11	7.5
1,3,5-Trimethylbenzene	0.76	5.1
1,2,4-TMB+n-Decane	3.87	26.2
1,2,3-TMB+p-Cymene	5.53	37.4
Total C_1-C_{10}	216.35	**1465.0**
Total C_5-C_{10}	155.11	**1050.0**
TRS Emissions		
Hydrogen Sulphide	0.178	1.20
Carbonyl Sulphide	0.045	0.30
Methyl Mercaptan	0.006	0.04
Ethyl Mercaptan	0.000	0.00
Carbon Disulphide	0.025	0.17
Thiophene	0.058	0.39
2-Methyl Thiophene	0.458	3.10
3-Methyl Thiophene	0.228	1.54
Isobutyl Mercaptan	0.022	0.15
Diethyl Sulphide	0.022	0.15
n-Butyl Mercaptan	0.000	0.00
n-Amyl Mercaptan	0.150	1.02
Unknown-4	0.461	3.12
Diallyl Sulphide	0.163	1.10
2-Ethylthiophene	0.217	1.47
2,5-Dimethyl Thiophene	0.660	4.47
di-n-Butyl Sulphide	1.810	12.25
Unknown-5	0.410	2.77
TOTAL	4.911	**33.25**

As per the diluent analysis, the VOC component may have to be more C_5

Consolidated Tailings Management

Mature fine tailings (MFT) from the tailings settling pond will be combined with tailings sand and gypsum to produce consolidated tailings (CT). The CT will be disposed of in mined out areas as part of the reclamation process. Initially, the CT will be capped by a water layer, but over time will become a solid surface which will be capped by overburden or tailings sand during reclamation. Two potential air quality issues associated with the CT process are:

- The transfer of the MFT to the mixing tank and the transfer of the CT mixture to the mine cells may result in the release of THC and TRS compounds contained in the MFT. A closed mixing tank with vapour recovery unit may be required to reduce potential THC and TRS emissions when CT is produced. Additionally, discharging the CT below the water surface in the capping layer of the mine cells would limit the direct volatilization of THC and TRS. Shell is initiating a pilot program to identify an approach for CT discharge and placement.

- The further volatilization of THC and TRS compounds from the surface of the capping layer of water. The emission flux from the CT pond surfaces are not expected to be greater than those associated with the tailings settling pond. As dry land reclamation proceeds, the fugitive emissions are expected to be reduced due to ageing.

At this stage, no data are available as to the magnitude and speciation of potential emissions associated with the CT process. For this reason, emission estimates have not been provided for this component.

Table E2-13 Summary of Muskeg River Mine Project Tailings Settling Pond THC, VOC and TRS Emissions

	Emission Rate (t/d)
THC (C_1 to C_{10})	1.5
VOC (C_5 to C_{10})	1.1
TRS	0.03

E2.2.7 Summary of Muskeg River Mine Project Emissions

Muskeg River Mine Project Emissions

Table E2-14 summarizes the emissions expected from the Muskeg River Mine Project. Based on these data, the following comments can be made:

- Primary sources of combustion products (NO_x, CO, and CO_2) are the mine fleet with a secondary contribution from the natural gas fired heaters and boilers at the plant site (stationary sources).

- The mine fleet exhausts additionally produce PM and PAH emissions.

- PM emissions can also result from the mine traffic and exposed surfaces. The emissions associated with haul roads can be reduced by a factor of four through dust suppression practices. Windblown PM from exposed surfaces can be controlled over the long-term through progressive reclamation techniques.

- Fugitive THC and TRS emissions result primarily from the mine surfaces and tailings settling pond. These emissions result from a combined surface area of up to 12 km^2. Smaller amounts result from mine fleet exhausts.

Detailed speciation of emissions from vehicle exhausts, fugitive mine sources and fugitive tailings settling pond surfaces have been provided.

Comparison to Existing Sources

Table E2-15 compares the emissions due to Muskeg River Mine Project activities with those due to the existing sources. Based on these data, the Muskeg River Mine Project is expected to result in:

- Less than 1% of the regional SO_2 and TRS emissions.
- About 3% of the regional CO emissions.
- About 7% of the regional PM and THC emissions.
- About 10% of the regional CO_2 emissions.
- About 13% of the regional NO_x emissions.

Table E2-15 includes an estimate for on-site SO_2 emissions, which has not been emphasized in the previous emission estimation discussion. Trace amounts of sulphur compounds are contained in diesel fuel and natural gas. The Muskeg River Mine Project value provided in the table is based on the estimate provided in Table E2-2.

Table E2-14 Summary of Emissions from the Muskeg River Mine Project

Source	Emission (t/d)							
	NO_x	CO	CO_2	PM_{10}	$PM_{2.5}$	THC	VOC	TRS
Mining								
Clearing/Slash burning	nq[(a)]	nq	nq	nq	nq	nq	nq	nq
Fleet exhausts	10.0	3.4	616	0.5	0.3	0.9	0.8	nq
Fugitive Mine Sources	0.0	0.0	0.0	nq	nq	1.6	0.6[(b)]	0.013
Extraction								
Stationary plant sources[(c)]	1.9	0.8	3049	0.3	0.3	0.05	0.03	nq
Fugitive plant site sources	0.0	0.0	0.0	nq	nq	nq	nq	nq
Tailings Management								
Tailings settling pond	0.0	0.0	0.0	nq	nq	1.5	1.1[(b)]	0.03
Consolidated tailings	0.0	0.0	0.0	nq	nq	nq	nq	nq
TOTAL	11.9	4.2	3665	0.8	0.6	4.0	2.5	0.01

(a) nq = not quantified.
(b) C_5 to C_{10}
(c) Worst-case winter conditions.

Table E2-15 Comparison of Muskeg River Mine Project Emissions (t/d) With Other Sources in the Region

	Muskeg River Mine	Suncor Lease 86/17	Syncrude Mildred Lake	Other Sources[(c)]	Total (t/d)
SO_2	0.6	72.5[(a)]	199.5	0.3	272.9
NO_x	11.9	39.3	36.7	1.8	89.7
CO_2[(b)]	3,665	9,440	20,833	1,311	35,249
CO	4.2	21.4	58.6	40.6	124.8
PM_{10}[(b)]	0.8	1.8	9.6	nq[d]	12.2
THC	4.0	23.0	15.5	5.4	47.9
TRS	0.01	0.7	0.8	nq	1.5

(a) Assumes 95% FGD uptime.
(b) Only assumes combustion emissions.
(c) Other includes the facility listed in Table D2-1.
(d) Not quantified.

E2.3 Key Question AQ-1: Will Muskeg River Mine Project Emissions Result in Exceedances of Ambient Air Quality Guidelines?

Table D1-4 identifies Alberta ambient air quality guidelines and federal government air quality objectives for SO_2, NO_2, CO, O_3 and TSP. As there are no Alberta and Federal Government criteria for PM_{10} or $PM_{2.5}$, the table also indicates criteria for PM_{10} and $PM_{2.5}$ from other regulatory jurisdictions.

This section provides estimates of maximum ground-level concentrations for all but O_3 and TSP. Ambient O_3 exposures, which is a secondary product, is further discussed in Section E2.5. PM_{10} and $PM_{2.5}$ estimates are provided in lieu of TSP since they are important from a health perspective.

E2.3.1 SO_2 Exposures

SO_2 emissions typically result from the combustion of fuels containing sulphur compounds. Trace amounts of sulphur compounds are present in the diesel fuel used by the mine fleet. SO_2 emissions are expected to be about 0.6 t/d, this is much less than the SO_2 emissions from the current sources (e.g., 272.3 t/d, assuming the Suncor FGD is operational). As such, air quality changes associated with incremental SO_2 concentrations due to the Muskeg River Mine Project will be negligible compared to those measured in the region (Table D2-6, Figure D2-7). As such, no measurable changes in ambient SO_2 concentrations due to the Muskeg River Mine Project are expected.

E2.3.2 NO_2 Exposures

NO_x emissions will arise from the mine fleet exhausts (combustion of diesel fuel) and the stationary plant sources (combustion of natural gas). These sources are expected to produce 10.0 and 1.9 t/d, respectively of NO_x emissions. The NO_x emissions occur primarily as NO and are converted to NO_2 through reactions with ambient ozone. Immediately adjacent and downwind of these sources, ambient ozone will be depleted below background levels due to these NO emissions.

Dispersion modelling was used to predict the maximum NO_2 concentrations that could result from Muskeg River Mine Project. The model predictions are summarized in Table E2-16 and concentration contours are shown in the following figures:

- Figure E2-2 shows the maximum hourly average NO_2 concentrations of 207 $\mu g/m^3$ due to the mine fleet (Guideline = 400 $\mu g/m^3$). The maximum concentrations are predicted to occur near the downwind edge of the mine and then decrease with increasing distance from the mine. The values of 80 to 100 $\mu g/m^3$ that occur along the Athabasca River are due to the limited crosswind plume spread associated with receptors located in the Athabasca River Valley. This portion of the model is applicable to river valley sources.

- Figure E2-3 shows the maximum hourly average NO_2 concentrations due to stationary plant sources. The maximum hourly concentration of 66 $\mu g/m^3$ is predicted to occur 3 to 6 km downwind of the plant area and within Lease 13. The maximum NO_2 concentrations associated with the plant are significantly less than those associated with the mine fleet emissions.

- Figure E2-4 shows the maximum hourly average NO_2 concentrations due to the combined mine fleet and stationary plant sources. The local NO_2 concentration pattern is clearly dominated by the emissions from the mine fleet with the corresponding maximum of 207 $\mu g/m^3$ located close to the mine pit. These are within the 400 $\mu g/m^3$ guideline.

- Figure E2-5 shows the maximum hourly average NO_x concentrations due to the combined operation of Muskeg River Mine Project, and current Suncor and Syncrude sources. Predicted concentrations are within the NO_2 guidelines. While the effects of the Muskeg River Mine Project are clearly shown in the vicinity of the mine, the contribution from current sources is shown in the southwest portion of the LSA.

The maximum predicted values are associated with low wind speed (1.0 m/s or 3.6 km/h) night-time (PG Classes E or F) conditions. While the additional Suncor and Syncrude NO_x emissions change the concentration pattern, the maximum predicted values in the vicinity of the Muskeg River Mine Project are not significantly influenced by these other sources.

Table E2-16 also shows the maximum daily and annual average NO_2 concentrations due to the four emission scenarios evaluated. The maximum daily (117 $\mu g/m^3$) and annual (65 $\mu g/m^3$) average NO_2 concentrations are predicted to be less than the corresponding air quality guidelines (i.e., 200 $\mu g/m^3$ and 100 $\mu g/m^3$, respectively).

E2.3.3 CO Exposures

CO emissions will also result from combustion sources. The mine fleet and the stationary plant sources are expected to produce 3.3 and 0.8 t/d, respectively. The CO emissions are about one-third to one-half the expected NO_x emissions. As ambient exposure levels are directly proportional to emission rates, the expected CO exposures would also be about one-third to one-half those associated with NO_x emissions.

Based on the predicted NO_x values presented in Table E2-16, the maximum hourly NO_x concentrations are about 1,580 $\mu g/m^3$. Therefore the maximum predicted CO concentrations would be about one-third these values, that is about 530 $\mu g/m^3$. This value is significantly less than the air quality guideline of 13,000 $\mu g/m^3$ for CO.

Table E2-16 Maximum Predicted NO_x and NO_2 Concentrations Associated with the Muskeg River Mine Project

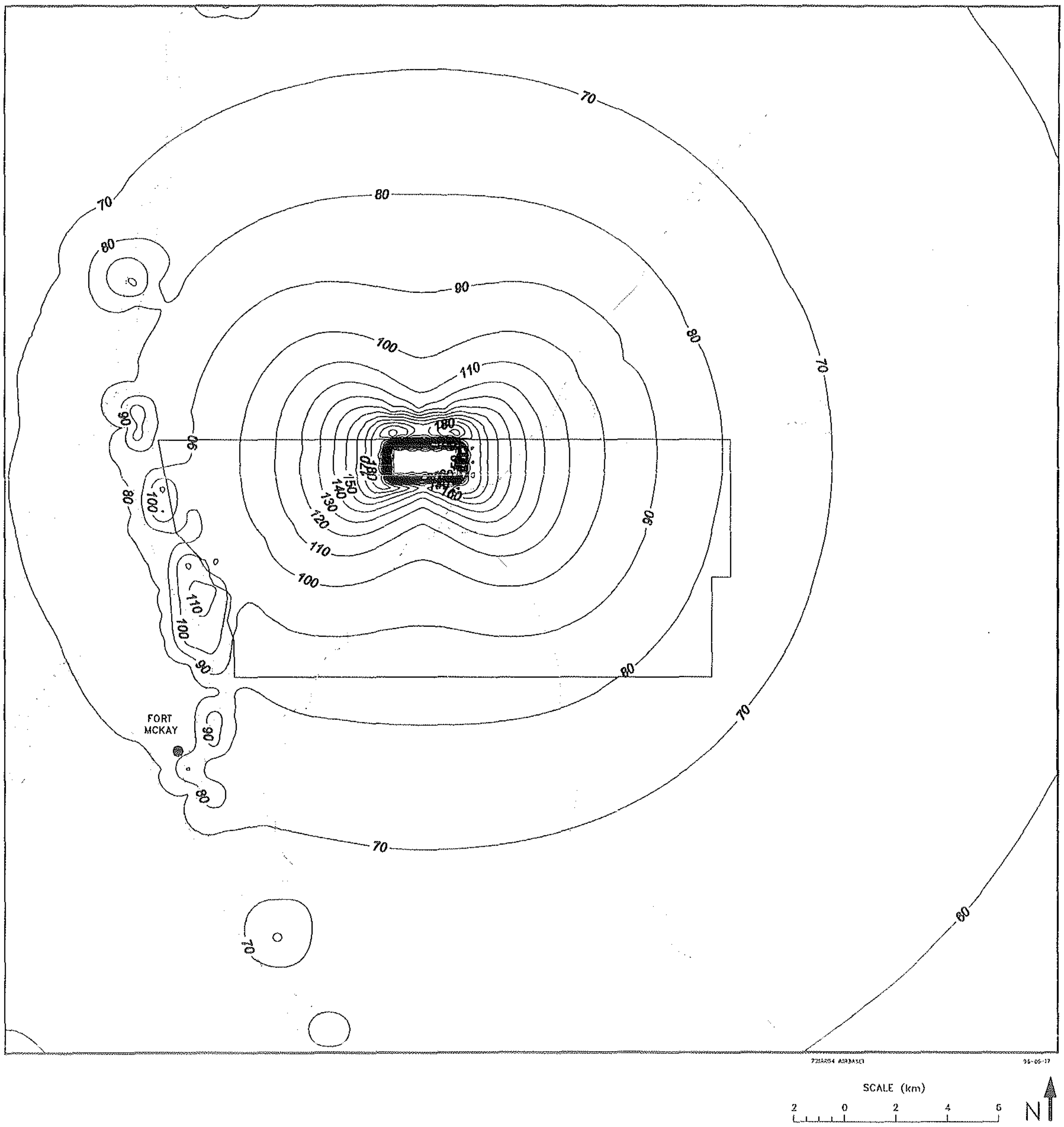
Source	Hourly	Daily	Annual
Muskeg River Mine Project Mine Fleet			
NO_x ($\mu g/m^3$)	1580	672	155
NO_2 ($\mu g/m^3$)	207	117	76
PG Class	F	-	-
Wind Speed (m/s)	1.0	-	-
Location with respect to centre of Mine	1.5 km NW	1.5 km NW	1 km N
Muskeg River Mine Project Plant Site			
NO_x ($\mu g/m^3$)	130	31	2.3
NO_2 ($\mu g/m^3$)	66	31	2.3
PG Class	E	-	-
Wind Speed (m/s)	1.0	-	-
Location with respect to Plant	6 km WSW	3 km SW	4 km WSW
Muskeg River Mine Project Combined			
NO_x ($\mu g/m^3$)	1580	672	156
NO_2 ($\mu g/m^3$)	207	117	65
PG Class	F	-	-
Wind Speed (m/s)	1.0	-	-
Location from plant site	5 km NNW	5 km NNW	4.5 km NNW
Muskeg River Mine, Suncor and Syncrude			
NO_x ($\mu g/m^3$)	1580	675	159
NO_2 ($\mu g/m^3$)	207	117	65
PG Class	F	-	-
Wind Speed (m/s)	1.0	-	-
Location from plant site	1.5 km NW	5 km NNW	4.5 km NNW
NO_2 Guideline ($\mu g/m^3$)	400	200	100

E2.3.4 $PM_{10}/PM_{2.5}$ Exposures

Ambient PM_{10} and $PM_{2.5}$ concentrations associated with combustion sources (i.e., mine fleet exhausts and plant stacks) were estimated. For the purposes of evaluation, all PM emissions from the plant stacks were assumed to be in the $PM_{2.5}$ size fraction. The maximum predicted values (as 24-hour averages) are as follows:

- Mine fleet (PM_{10}) - 32 $\mu g/m^3$
- Mine fleet ($PM_{2.5}$) - 20 $\mu g/m^3$
- Plant stacks ($PM_{2.5}$) - 4.5 $\mu g/m^3$

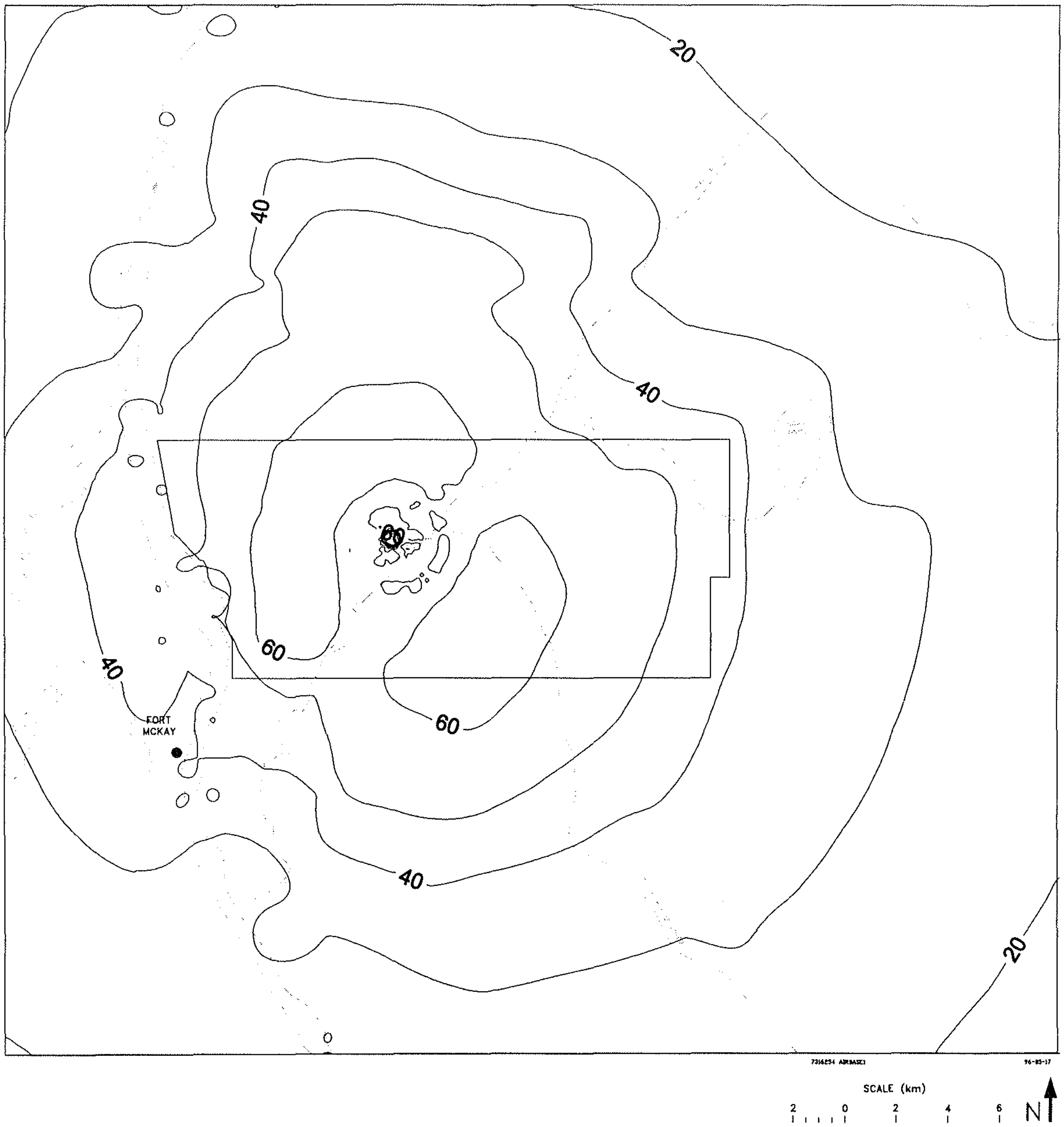
Figure E2-2 Maximum Hourly Average NO_2 Concentrations (µg/m^3) Due to Muskeg River Mine Project Fleet Exhaust Emissions



FIGE2-6.PRE 30NOV97 PSt

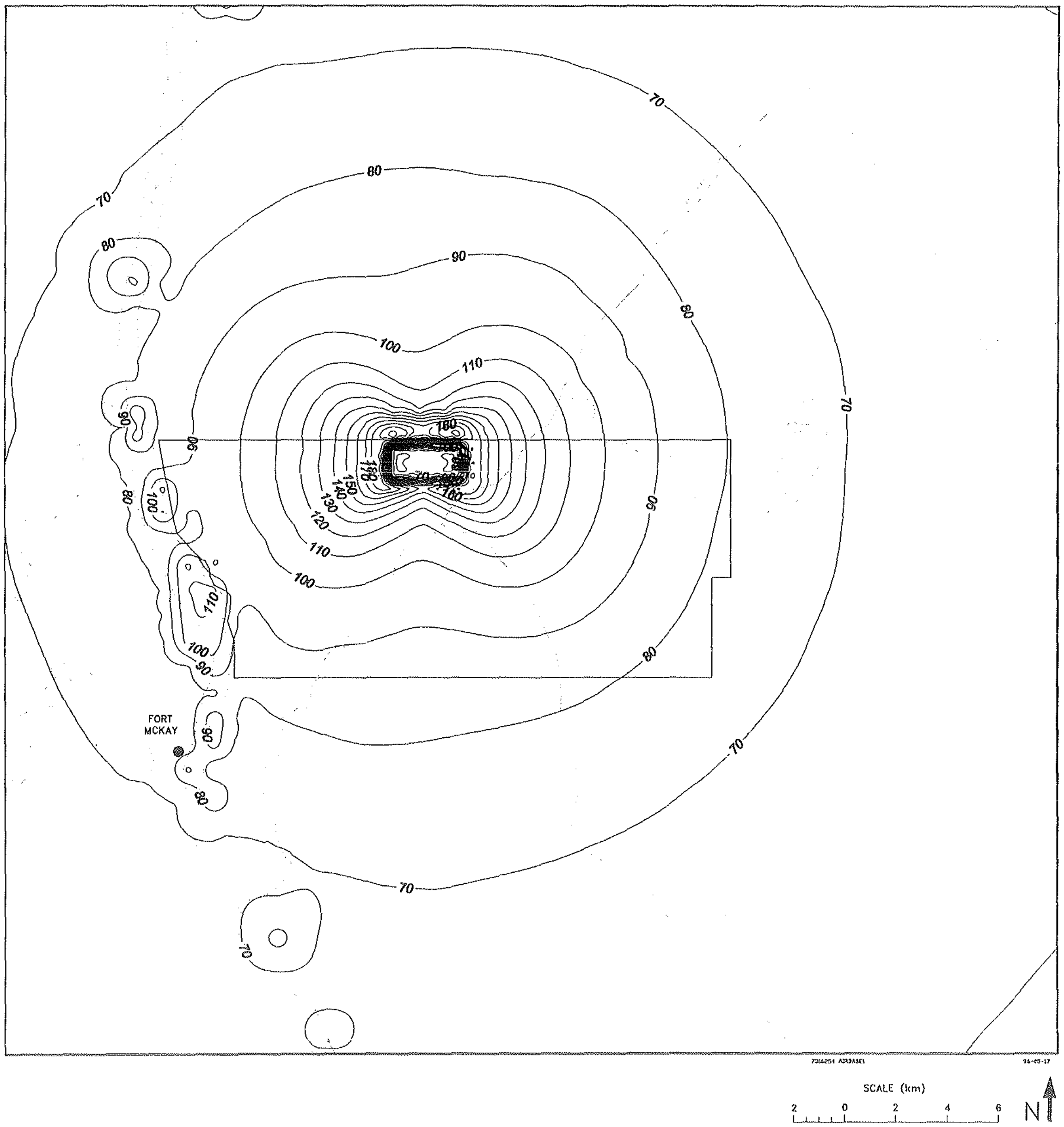
Model:	ISC3BE
Meteorology:	OSLO
Sources:	Muskeg River Mine Project NO_x = 10.0 t/d
NO_2 Guideline:	400 µg/m^3

Figure E2-3 Maximum Hourly Average NO_2 Concentrations (µg/m³) Due to Muskeg River Mine Project Stationary Plant Emissions



Model:	ISC3BE
Meteorology:	OSLO
Sources:	Muskeg River Mine Project NO_x = 1.9 t/d
NO_2 Guideline:	400 µg/m³

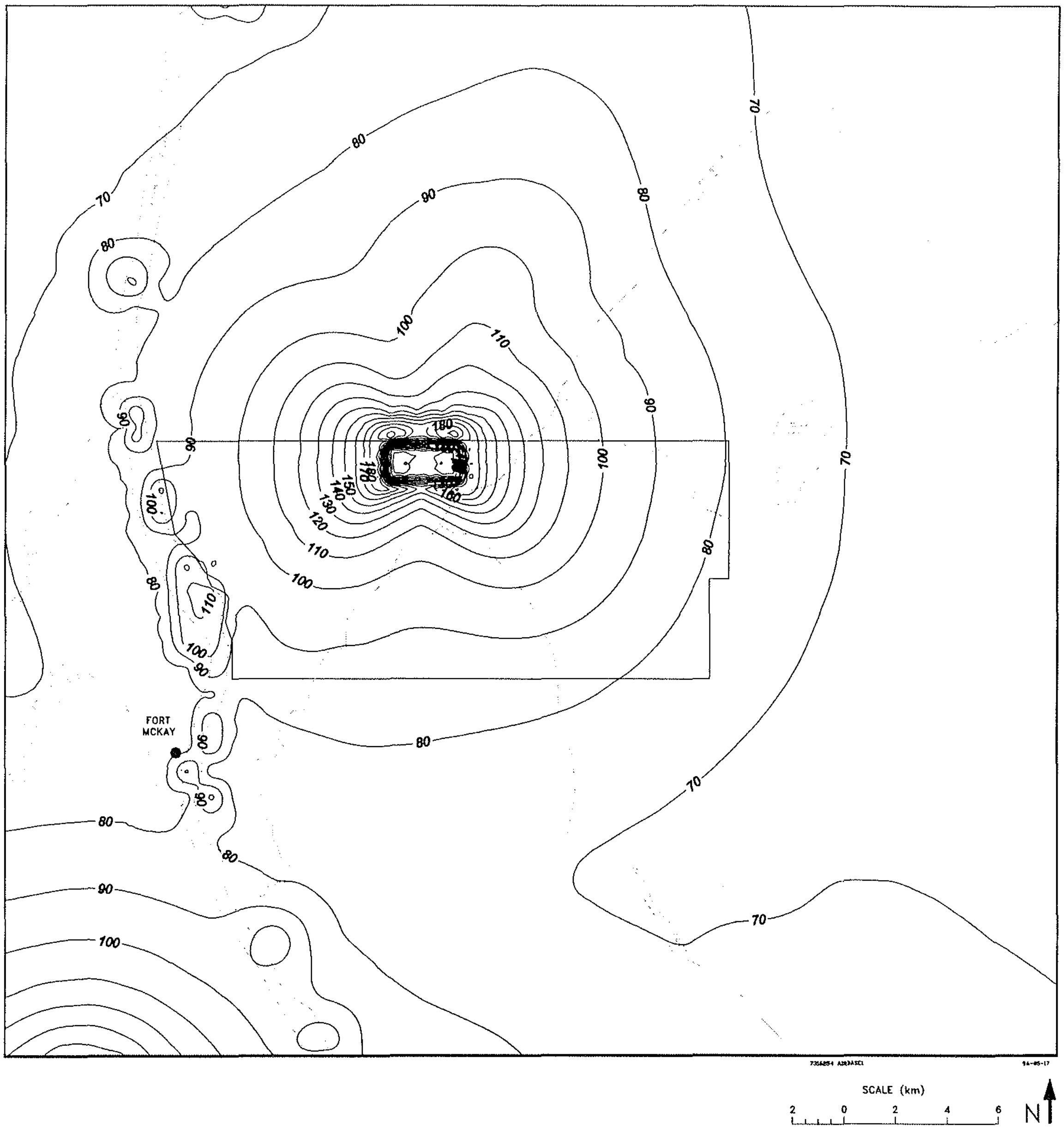
Figure E2-4 Maximum Hourly Average NO_2 Concentrations (µg/m^3) Due to Combined Muskeg River Mine Project Emissions



FIGE2-8.PRE 29NOV97 PSt

Model:	ISC3BE
Meteorology:	OSLO
Sources:	Muskeg River Mine Project NO_x = 11.9 t/d
NO_2 Guideline:	400 µg/m^3

Figure E2-5 Maximum Hourly Average NO_2 Concentrations (µg/m³) Due to Combined Muskeg River Mine Project, Suncor and Syncrude Emissions



FIGE2-9.PRE 29NOV97 PSt

Model:	ISC3BE	
Meteorology:	OSLO	
Sources:	Muskeg River Mine Project	NO_x = 11.9 t/d
	Suncor	NO_x = 39.1 t/d
	Syncrude	NO_x = 36.7 t/d
NO_2 Guideline:	400 µg/m³	

The maximum concentrations due to the mine fleet are predicted to occur adjacent to the mine while those due to the plant stacks are predicted to occur 3 km to the Southeast of the plant site and within Lease 13. The predicted concentrations decrease with further increases in distance from the sources.

These predicted PM_{10} values (32 $\mu g/m^3$) compare to the BC and U.S. EPA PM_{10} guideline values of 50 and 150 $\mu g/m^3$, respectively. The predicted $PM_{2.5}$ values (20 and 4.5 $\mu g/m^3$) compare to the U.S. EPA guideline of 65 $\mu g/m^3$.

These maximum values do not include contributions due to non-combustion sources (i.e., fugitive dust emissions that are crustal in origin) nor natural background sources. As such, PM_{10} (and $PM_{2.5}$) values can be greater than those indicated. However, mitigation of crustal fugitive emissions with dust suppression methods can reduce these contributions significantly.

E2.3.5 Residual Impact Classification

Table E2-17 classifies the air quality impacts associated with Key Question AQ-1. Air quality changes associated with SO_2, NO_x, CO and $PM_{10}/PM_{2.5}$ were quantified. The overall degree of concern for each compound is classified as follows:

- SO_2 emissions - Negligible
- NO_2 emissions - Low to Moderate
- CO emissions - Negligible
- PM_{10} emissions - Low to Moderate

The degree of concern was based on the classification approach outlined in Table E1-10.

E2.3.6 Monitoring

Source. A source monitoring program comprised of periodic stack sampling will confirm NO_x emissions are within expected guidelines. Annual NO_x emissions estimates based on fuel use will be undertaken.

Ambient. An ambient air quality monitoring program adjacent to the mine will measure ambient NO_2, PM_{10} and $PM_{2.5}$ concentrations. This corresponds to the location where the maximum values are predicted to occur. If warranted, additional sampling and analysis will determine the relative importance of combustion sources, the fugitive mine sources and background sources.

Table E2-17 Impact Classification Associated with Key Question AQ-1 (Ambient Guidelines)

	SO_2	NO_2	CO	PM_{10}
Direction	Negative: an increase of 0.6 t/d.	Negative: An increase of 11.9 t/d.	Negative: An increase of 4.2 t/d.	Negative; an increase of 0.8 t/d due to combustion sources.
Magnitude	Negligible: Non-measurable changes in ambient concentrations.	Low to Moderate: Maximum NO_2 concentrations are about 50% of the hourly guideline.	Negligible: Maximum CO concentrations are about 5% of the hourly guideline.	Low to Moderate: Maximum PM_{10} concentrations are about 65% of the BC 24 hour guideline.
Geographic Extent	Local area: Adjacent to mine pit and plant site.	Local area: Maximum concentrations adjacent to mine pit.	Local area: Maximum concentration adjacent to mine pit.	Local area: Maximum concentrations adjacent to mine pit.
Duration	Plant life: Emissions occur over the life of the plant. Short-term: Maximum concentrations tend to be of short-term duration due to meteorological variability.	Plant life: Emissions occur over the life of the plant. Short-term: Maximum concentrations tend to be of short-term duration due to meteorological variability.	Plant life: Emissions occur over the life of the plant. Short-term: Maximum concentrations tend to be of short-term duration due to meteorological variability.	Plant life: Emissions occur over the life of the plant. Short-term: Maximum concentrations tend to be of short-term duration due to meteorological variability.
Reversibility	Reversible.	Reversible.	Reversible.	Reversible.
Frequency	Intermittent.	Intermittent.	Intermittent.	Intermittent.
Season	All seasons.	All seasons.	All seasons.	All seasons.

E2.4 Key Question AQ-2: Will Muskeg River Mine Project Emissions Result in Human Health Effects?

Ambient exposures to air emissions may have potential adverse health effects. For this reason, ambient concentrations of criteria and non-criteria emissions due to the Muskeg River Mine Project were predicted at the following locations:

- The location where the overall maximum value is predicted to occur to obtain a "worst-case" scenario.
- Fort McKay can be regarded as a local community being located 5 km to the Southwest of the proposed tailings settling pond and 12 km to the Southwest from the Project area.
- Fort McMurray can be regarded as a regional community being located about 61 km to the south of the Project area.
- Fort Chipewyan can also be regarded as a regional community being located about 166 km to the north of the Project area.

Hourly, daily and annual average concentrations of identified compounds were predicted for these locations. Each of the sources (i.e., mine fleet exhaust, mine surface and tailings settling pond) were considered individually.

The model predictions for Fort McKay and Fort McMurray are expected to be representative since the ISC3BE model was "tuned" using these source-receptor distances. There will be greater uncertainty for the predictions at Fort Chipewyan because of the significantly greater plume travel distances. For receptors at the same elevation as the river, the model does not account for plume meander associated with long travel distances. As such, the Fort Chipewyan values may be overestimated.

E2.4.1 Model Predictions

The maximum concentrations are presented in a series of tables as follows:

- Table E2-18 provides maximum predicted concentrations due to mine fleet exhaust emissions. The predictions are based on the emission profile given in Table E2-2 that represents average daily emissions. The maximum predicted values in Fort McKay, Fort McMurray and Fort Chipewyan are about 14, 21 and 104 times lower than the overall maximum values that are predicted to occur on-site.

Table E2-18 Maximum Hourly, Daily and Annual Average Concentrations (µg/m³) in Local and Regional Communities Due to Muskeg River Mine Project Mine Fleet Exhaust Emissions

Community	Muskeg River Mine Project			Fort McKay			Fort McMurray			Fort Chipewyan		
Distance (km)				12			61			166		
Averaging Period	Hour	Day	Annual	Hour	Day	Annual	Hour	Day	Annual	Hour	Day	Annual
Criteria Compounds												
CO	531	226	52	149	16	1	63	11	0.28	39	2.2	0.09
NO_x	1580	672	156	442	47	3	187	33	0.83	115	6.5	0.28
SO_2	100	42	10	28	3	0	12	2.1	0.053	7	0.4	0.02
CO_2	97338	41400	9611	27217	2874	172	11525	2026	51	7115	399	17
PM_{10}	75	32	7	21	2	0	8.9	1.6	0.040	5.5	0.31	0.013
$PM_{2.5}$	48	20	5	13	1	0	5.7	1.0	0.025	3.5	0.20	0.008
Alkanes												
Methane	10.2	4.35	1.01	2.86	0.30	0.018	1.21	0.21	0.0054	0.75	0.042	0.0018
Ethane	5.9	2.49	0.58	1.64	0.17	0.010	0.69	0.12	0.0031	0.43	0.024	0.0010
Propane	4.1	1.76	0.41	1.16	0.12	0.007	0.49	0.09	0.0022	0.30	0.017	0.0007
Butane	6.1	2.60	0.60	1.71	0.18	0.011	0.72	0.13	0.0032	0.45	0.025	0.0011
Pentane	4.0	1.69	0.39	1.11	0.12	0.007	0.47	0.083	0.0021	0.29	0.016	0.0007
Hexane	7.6	3.23	0.75	2.12	0.22	0.013	0.90	0.16	0.0040	0.55	0.031	0.0013
Heptane	5.1	2.17	0.50	1.43	0.15	0.009	0.60	0.11	0.0027	0.37	0.021	0.0009
Octane	2.0	0.85	0.20	0.56	0.06	0.004	0.24	0.042	0.0011	0.146	0.008	0.0004
Nonane	1.3	0.56	0.13	0.37	0.04	0.002	0.16	0.028	0.0007	0.097	0.005	0.0002
Decane	6.2	2.64	0.61	1.74	0.18	0.011	0.74	0.129	0.0033	0.45	0.025	0.0011
Undecane	6.3	2.69	0.62	1.77	0.19	0.011	0.75	0.131	0.0033	0.46	0.026	0.0011
Dodecane	3.9	1.65	0.38	1.09	0.11	0.007	0.46	0.081	0.0021	0.28	0.016	0.0007
Alkenes												
Ethylene	29.3	12.5	2.9	8.2	0.9	0.1	3.5	0.6	0.015	2.144	0.120	5.2E-03
Propylene	5.1	2.2	0.5	1.4	0.1	0.0	0.6	0.1	0.00267	0.370	0.021	9.0E-04
Butene	1.1	0.5	0.1	0.3	0.0	0.0	0.1	0.0	0.00058	0.080	0.0045	1.9E-04
Pentene	0.19	0.08	0.02	0.05	0.01	0.00	0.0224	0.0039	0.00010	0.014	0.001	3.4E-05

Table E2-18 Maximum Hourly, Daily And Annual Average Concentrations (µG/M³) In Local and Regional Communities due to Muskeg River Mine Project Mine Fleet Exhaust Emissions (Continued)

Community	Muskeg River Mine Project			Fort McKay			Fort McMurray			Fort Chipewyan		
Distance (km)				12			61			167		
Averaging Period	Hour	Day	Annual	Hour	Day	Annual	Hour	Day	Annual	Hour	Day	Annual
Aromatics												
Benzene	0.75	0.32	0.074	0.21	0.022	0.00132	0.088	0.016	0.00039	0.055	0.0031	1.3E-04
Ethylbenzene	0.76	0.32	0.075	0.21	0.022	0.00134	0.090	0.016	0.00040	0.055	0.0031	1.3E-04
Toluene	0.13	0.05	0.013	0.04	0.004	0.00023	0.015	0.003	0.00007	0.009	0.0005	2.3E-05
Xylene	0.21	0.09	0.020	0.06	0.006	0.00036	0.024	0.004	0.00011	0.015	0.0008	3.6E-05
Aldehydes												
Formaldehyde	24.9	10.6	2.5	7.0	0.7	0.044	2.94	0.52	0.013	1.82	0.102	4.4E-03
Acetaldehyde	7.9	3.4	0.8	2.2	0.2	0.0140	0.94	0.16	0.0042	0.58	0.032	1.4E-03
n-Butanal	0.48	0.20	0.05	0.13	0.01	0.0008	0.0564	0.0099	0.0003	0.035	0.0020	8.4E-05
3-Methylbutanal	0.07	0.03	0.01	0.02	0.00	0.0001	0.0078	0.0014	0.0000	0.0048	0.0003	1.2E-05
Methacrolein	0.38	0.16	0.04	0.11	0.01	0.0007	0.0449	0.0079	0.0002	0.028	0.0016	6.7E-05
Acrolein	1.14	0.49	0.11	0.32	0.03	0.0020	0.135	0.024	0.0006	0.083	0.0047	2.0E-04
Ketones												
Acetone	2.07	0.88	0.20	0.58	0.061	0.004	0.25	0.043	0.0011	0.15	0.0085	3.67E-04
Methyl Ethyl Ketone	0.44	0.19	0.044	0.12	0.013	0.001	0.05	0.009	0.0002	0.032	0.0018	7.82E-05
3-Buten-2-one	0.83	0.35	0.082	0.23	0.024	0.001	0.10	0.017	0.0004	0.061	0.0034	1.47E-04
Alcohols												
2-Propanol	1.7E-01	7.0E-02	1.6E-02	4.6E-02	4.9E-03	2.9E-04	2.0E-02	3.4E-03	8.7E-05	1.2E-02	6.8E-04	2.9E-05
PAH												
Napthalene	7.7E-02	3.3E-02	7.6E-03	2.1E-02	2.3E-03	1.4E-04	9.1E-03	1.6E-03	4.1E-05	5.6E-03	3.1E-04	1.4E-05
Acenapthylene	5.4E-03	2.3E-03	5.4E-04	1.5E-03	1.6E-04	9.6E-06	6.4E-04	1.1E-04	2.9E-06	4.0E-04	2.2E-05	9.6E-07
Acenaphthene	2.8E-03	1.2E-03	2.7E-04	7.7E-04	8.1E-05	4.9E-06	3.3E-04	5.7E-05	1.5E-06	2.0E-04	1.1E-05	4.9E-07
Fluorene	7.5E-03	3.2E-03	7.5E-04	2.1E-03	2.2E-04	1.3E-05	8.9E-04	1.6E-04	4.0E-06	5.5E-04	3.1E-05	1.3E-06
Phenanthrene	2.2E-02	9.4E-03	2.2E-03	6.2E-03	6.5E-04	3.9E-05	2.6E-03	4.6E-04	1.2E-05	1.6E-03	9.1E-05	3.9E-06
Anthracene	8.2E-04	3.5E-04	8.1E-05	2.3E-04	2.4E-05	1.5E-06	9.7E-05	1.7E-05	4.3E-07	6.0E-05	3.4E-06	1.5E-07
Fluoranthene	2.0E-03	8.4E-04	1.9E-04	5.5E-04	5.8E-05	3.5E-06	2.3E-04	4.1E-05	1.0E-06	1.4E-04	8.1E-06	3.5E-07
Pyrene	1.5E-03	6.6E-04	1.5E-04	4.3E-04	4.6E-05	2.7E-06	1.8E-04	3.2E-05	8.2E-07	1.1E-04	6.4E-06	2.7E-07
Benz(a)anthracene	2.0E-04	8.5E-05	2.0E-05	5.6E-05	5.9E-06	3.5E-07	2.4E-05	4.1E-06	1.1E-07	1.5E-05	8.2E-07	3.5E-08
Chrysene	5.5E-04	2.3E-04	5.4E-05	1.5E-04	1.6E-05	9.7E-07	6.5E-05	1.1E-05	2.9E-07	4.0E-05	2.2E-06	9.7E-08
Benzo(b)fluoranthene	6.5E-04	2.8E-04	6.5E-05	1.8E-04	1.9E-05	1.2E-06	7.7E-05	1.4E-05	3.5E-07	4.8E-05	2.7E-06	1.2E-07

Table E2-18 Maximum Hourly, Daily and Annual Average Concentrations (μg/m^3) in Local and Regional Communities Due to Muskeg River Mine Project Mine Fleet Exhaust Emissions (Concluded)

Community	Muskeg River Mine			Fort McKay			Fort McMurray			Fort Chipewyan		
Distance (km)				12			61			167		
Averaging Period	Hour	Day	Annual	Hour	Day	Annual	Hour	Day	Annual	Hour	Day	Annual
PAH (concluded)												
Benzo(k)fluoranthene	7.4E-05	3.2E-05	7.3E-06	2.1E-05	2.2E-06	1.3E-07	8.8E-06	1.5E-06	3.9E-08	5.4E-06	3.0E-07	1.3E-08
Benzo(a)pyrene	7.8E-05	3.3E-05	7.7E-06	2.2E-05	2.3E-06	1.4E-07	9.2E-06	1.6E-06	4.1E-08	5.7E-06	3.2E-07	1.4E-08
Indeno(1,2,3-W)pyrene	1.2E-04	5.3E-05	1.2E-05	3.5E-05	3.7E-06	2.2E-07	1.5E-05	2.6E-06	6.5E-08	9.1E-06	5.1E-07	2.2E-08
Dibenz(a,h)anthracene	2.0E-04	8.7E-05	2.0E-05	5.7E-05	6.0E-06	3.6E-07	2.4E-05	4.3E-06	1.1E-07	1.5E-05	8.4E-07	3.6E-08
Benzo(g,h,l)perylene	1.7E-04	7.2E-05	1.7E-05	4.7E-05	5.0E-06	3.0E-07	2.0E-05	3.5E-06	8.9E-08	1.2E-05	6.9E-07	3.0E-08
3-Methylphenanthrene	8.6E-03	3.7E-03	8.5E-04	2.4E-03	2.5E-04	1.5E-05	1.0E-03	1.8E-04	4.6E-06	6.3E-04	3.5E-05	1.5E-06
2-Methylanthracene	9.9E-03	4.2E-03	9.7E-04	2.8E-03	2.9E-04	1.7E-05	1.2E-03	2.1E-04	5.2E-06	7.2E-04	4.0E-05	1.7E-06
4-+9-Methylphenanthrene	1.1E-02	4.5E-03	1.0E-03	3.0E-03	3.1E-04	1.9E-05	1.3E-03	2.2E-04	5.6E-06	7.8E-04	4.4E-05	1.9E-06
1-Methylphenanthrene	8.8E-03	3.8E-03	8.7E-04	2.5E-03	2.6E-04	1.6E-05	1.0E-03	1.8E-04	4.7E-06	6.5E-04	3.6E-05	1.6E-06
Benzo[a]fluorene	1.8E-04	7.6E-05	1.8E-05	5.0E-05	5.3E-06	3.2E-07	2.1E-05	3.7E-06	9.4E-08	1.3E-05	7.3E-07	3.2E-08
2-Methylpyrene	1.5E-04	6.2E-05	1.5E-05	4.1E-05	4.3E-06	2.6E-07	1.7E-05	3.1E-06	7.8E-08	1.1E-05	6.0E-07	2.6E-08
Benzo[ghi]fluoranthene	1.0E-04	4.4E-05	1.0E-05	2.9E-05	3.1E-06	1.8E-07	1.2E-05	2.2E-06	5.5E-08	7.6E-06	4.2E-07	1.8E-08
Cyclopenta[cd]pyrene	1.2E-05	5.3E-06	1.2E-06	3.5E-06	3.7E-07	2.2E-08	1.5E-06	2.6E-07	6.6E-09	9.1E-07	5.1E-08	2.2E-09
Benzo[e]pyrene	1.1E-05	4.7E-06	1.1E-06	3.1E-06	3.3E-07	2.0E-08	1.3E-06	2.3E-07	5.8E-09	8.1E-07	4.5E-08	2.0E-09
Perylene	1.4E-06	5.9E-07	1.4E-07	3.9E-07	4.1E-08	2.4E-09	1.6E-07	2.9E-08	7.3E-10	1.0E-07	5.7E-09	2.4E-10
Indwno[1,2,3-cd]fluoranthene	6.9E-06	2.9E-06	6.8E-07	1.9E-06	2.0E-07	1.2E-08	8.2E-07	1.4E-07	3.6E-09	5.0E-07	2.8E-08	1.2E-09
Picene	1.4E-06	5.9E-07	1.4E-07	3.9E-07	4.1E-08	2.4E-09	1.6E-07	2.9E-08	7.3E-10	1.0E-07	5.7E-09	2.4E-10
2-Methylfluorene	1.7E-05	7.0E-06	1.6E-06	4.6E-06	4.9E-07	2.9E-08	2.0E-06	3.4E-07	8.7E-09	1.2E-06	6.8E-08	2.9E-09
Benzo[ghi]perylene	9.7E-06	4.1E-06	9.5E-07	2.7E-06	2.9E-07	1.7E-08	1.1E-06	2.0E-07	5.1E-09	7.1E-07	4.0E-08	1.7E-09
Coronene	1.4E-06	5.9E-07	1.4E-07	3.9E-07	4.1E-08	2.4E-09	1.6E-07	2.9E-08	7.3E-10	1.0E-07	5.7E-09	2.4E-10
1-Nitropyrene	1.1E-04	4.7E-05	1.1E-05	3.1E-05	3.3E-06	2.0E-07	1.3E-05	2.3E-06	5.8E-08	8.1E-06	4.5E-07	2.0E-08
Dibenzothiophene	1.2E-05	5.0E-06	1.2E-06	3.3E-06	3.5E-07	2.1E-08	1.4E-06	2.4E-07	6.2E-09	8.6E-07	4.8E-08	2.1E-09
4-Methyldibenzothiophene	1.9E-05	8.2E-06	1.9E-06	5.4E-06	5.7E-07	3.4E-08	2.3E-06	4.0E-07	1.0E-08	1.4E-06	7.9E-08	3.4E-09
3-Methyldibenzothiophene	3.0E-05	1.3E-05	3.0E-06	8.5E-06	9.0E-07	5.4E-08	3.6E-06	6.3E-07	1.6E-08	2.2E-06	1.2E-07	5.4E-09

- Table E2-19 provides maximum predicted concentrations due to mine surface emissions. The predictions are based on the emission profile given in Table E2-6 that represents late summer, early fall emissions. The maximum predicted values in Fort McKay, Fort McMurray and Fort Chipewyan are about 15, 21 and 105 times lower than the overall maximum values that are predicted to occur on-site.

- Table E2-20 provides maximum predicted concentrations due to tailings settling pond emissions. The predictions are based on the emission profile given in Table E2-12 that represents late spring emissions. The maximum predicted values in Fort McKay, Fort McMurray and Fort Chipewyan are about 25, 64 and 428 times lower than the overall maximum values that are predicted to occur on-site.

- Table E2-21 provides maximum predicted concentrations due to stationary source emissions. The maximum predicted values in Fort McKay, Fort McMurray and Fort Chipewyan are about 6, 8 and 45 times lower than the overall maximum values.

The implication of these predicted incremental changes in air quality on human health is discussed further in the human health section (SectionE12).

E2.4.2 Residual Impact Classification

The changes in ambient air quality associated with potential human health effects are summarized in Table E2-22. The complete impact classification with respect to human health is undertaken in Section E12.

E2.4.3 Monitoring

Source. The greatest uncertainty is associated with the estimation of fugitive emissions from the surface of the tailings settling pond. A surface flux monitoring program will be undertaken to quantify these emissions. This monitoring will take place during the summer when volatilization rates are expected to be the greatest.

Ambient. An initial ambient monitoring program to determine particulate (e.g., PAH) and VOC speciation for the identified sources may be implemented if warranted.

Table E2-19 Maximum Hourly, Daily and Annual Average Concentrations (µg/m³) in Local and Regional Communities Due to Muskeg River Project Mine Project Surface Emissions

Community	Muskeg River Mine Project			Fort McKay			Fort McMurray			Fort Chipewyan		
Distance (km)				12			61			167		
Averaging Period	Hour	Day	Annual	Hour	Day	Annual	Hour	Day	Annual	Hour	Day	Annual
THC Emission												
C_1 to C_3	271.36	115.12	26.243	75.52	7.93	0.477	31.90	5.60	0.141	19.71	1.096	0.0461
i-butane	6.26	2.65	0.605	1.74	0.18	0.011	0.74	0.13	0.003	0.45	0.025	0.0011
n-butane	10.95	4.64	1.059	3.05	0.32	0.019	1.29	0.23	0.006	0.80	0.044	0.0019
i-pentane	4.69	1.99	0.454	1.31	0.14	0.008	0.55	0.10	0.002	0.34	0.019	0.0008
Cyclopentane	9.38	3.98	0.908	2.61	0.27	0.016	1.10	0.19	0.005	0.68	0.038	0.0016
3-Methyl-Pentane	3.13	1.33	0.303	0.87	0.09	0.005	0.37	0.06	0.002	0.23	0.013	0.0005
Methylcyclopentane	3.13	1.33	0.303	0.87	0.09	0.005	0.37	0.06	0.002	0.23	0.013	0.0005
Cyclohexane	3.13	1.33	0.303	0.87	0.09	0.005	0.37	0.06	0.002	0.23	0.013	0.0005
2,3-Dimethylpentane	3.13	1.33	0.303	0.87	0.09	0.005	0.37	0.06	0.002	0.23	0.013	0.0005
3-Methylhexane	7.82	3.32	0.756	2.18	0.23	0.014	0.92	0.16	0.004	0.57	0.032	0.0013
N-Heptane	1.56	0.66	0.151	0.44	0.05	0.003	0.18	0.03	0.001	0.11	0.006	0.0003
Me-Cyclohexane	6.26	2.65	0.605	1.74	0.18	0.011	0.74	0.13	0.003	0.45	0.025	0.0011
Toluene	3.91	1.66	0.378	1.09	0.11	0.007	0.46	0.08	0.002	0.28	0.016	0.0007
3-Methylheptane	10.17	4.31	0.983	2.83	0.30	0.018	1.20	0.21	0.005	0.74	0.041	0.0017
2,3,4-Trimethylhexane	2.35	1.00	0.227	0.65	0.07	0.004	0.28	0.05	0.001	0.17	0.009	0.0004
n-Octane	8.60	3.65	0.832	2.39	0.25	0.015	1.01	0.18	0.004	0.62	0.035	0.0015
Branched Nonane	7.82	3.32	0.756	2.18	0.23	0.014	0.92	0.16	0.004	0.57	0.032	0.0013
Et-Benzene	3.13	1.33	0.303	0.87	0.09	0.005	0.37	0.06	0.002	0.23	0.013	0.0005
THC Emission												
m,p-Xylene	1.56	0.66	0.151	0.44	0.05	0.003	0.18	0.03	0.001	0.11	0.006	0.0003
O-Xylene	7.82	3.32	0.756	2.18	0.23	0.014	0.92	0.16	0.004	0.57	0.032	0.0013
n-Nonane	11.73	4.98	1.134	3.26	0.34	0.021	1.38	0.24	0.006	0.85	0.047	0.0020
Cumene	7.82	3.32	0.756	2.18	0.23	0.014	0.92	0.16	0.004	0.57	0.032	0.0013
n-Decane	12.51	5.31	1.210	3.48	0.37	0.022	1.47	0.26	0.007	0.91	0.051	0.0021
C_1-C_{10}	465.3	197.4	45.0	129.5	13.6	0.818	54.7	9.61	0.243	33.8	1.88	0.079
C_5-C_{10}	175.95	74.65	17.017	48.97	5.14	0.309	20.68	3.63	0.092	12.78	0.711	0.0299
TRS												
H_2S	0.53	0.22	0.051	0.15	0.02	0.001	0.06	0.01	0.000	0.04	0.0021	0.00009
COS	1.50	0.64	0.145	0.42	0.04	0.003	0.18	0.03	0.001	0.11	0.0061	0.00025
CS_2	1.28	0.54	0.124	0.36	0.04	0.002	0.15	0.03	0.001	0.09	0.0052	0.00022
TRS	3.83	1.62	0.370	1.07	0.11	0.007	0.45	0.08	0.002	0.28	0.0155	0.00065

Table E2-20 Maximum Hourly, Daily and Annual Average Concentrations (µg/m^3) in Local and Regional Communities Due to Muskeg River Mine Project Tailings Settling Pond Surface Emissions

Community	Muskeg River Mine Project			Fort McKay			Fort McMurray			Fort Chipewyan		
Distance (km)				12			61			167		
Averaging Period	Hour	Day	Annual	Hour	Day	Annual	Hour	Day	Annual	Hour	Day	Annual
THC Emissions												
C_1 to C_3	335.7	187.5	70.39	49.4	7.5	8.9E-01	16.1	2.9	7.6E-02	8.9	0.44	1.9E-02
Isobutane	6.2	3.5	1.30	0.9	0.1	1.6E-02	0.3	0.1	1.4E-03	0.2	0.01	3.4E-04
Isopentane	1.5	0.9	0.32	0.2	0.0	4.1E-03	0.1	0.0	3.5E-04	0.0	0.00	8.5E-05
n-Pentane	2.3	1.3	0.49	0.3	0.1	6.2E-03	0.1	0.0	5.2E-04	0.1	0.00	1.3E-04
Cyclopentane	0.4	0.2	0.08	0.1	0.0	1.0E-03	0.0	0.0	8.7E-05	0.0	0.00	2.1E-05
2,3-Dimethylbutane	13.1	7.3	2.75	1.9	0.3	3.5E-02	0.6	0.1	3.0E-03	0.3	0.02	7.3E-04
n-Hexane	10.8	6.0	2.27	1.6	0.2	2.9E-02	0.5	0.1	2.4E-03	0.3	0.01	6.0E-04
2,4-Dimethylpentane	21.6	12.1	4.54	3.2	0.5	5.8E-02	1.0	0.2	4.9E-03	0.6	0.03	1.2E-03
Cyclohexane	39.4	22.0	8.26	5.8	0.9	1.0E-01	1.9	0.3	8.9E-03	1.0	0.05	2.2E-03
2,3-Dimethylpentane	5.0	2.8	1.05	0.7	0.1	1.3E-02	0.2	0.0	1.1E-03	0.1	0.01	2.8E-04
3-Methylhexane	16.2	9.1	3.40	2.4	0.4	4.3E-02	0.8	0.1	3.7E-03	0.4	0.02	9.0E-04
2,2,4-Trimethylpentane	36.3	20.3	7.61	5.3	0.8	9.7E-02	1.7	0.3	8.2E-03	1.0	0.05	2.0E-03
n-Heptane	20.1	11.2	4.21	3.0	0.5	5.3E-02	1.0	0.2	4.5E-03	0.5	0.03	1.1E-03
Toluene	33.2	18.6	6.97	4.9	0.7	8.8E-02	1.6	0.3	7.5E-03	0.9	0.04	1.8E-03
3-Methylheptane	13.1	7.3	2.75	1.9	0.3	3.5E-02	0.6	0.1	3.0E-03	0.3	0.02	7.3E-04
2,2,5-Trimethylhexane	39.0	21.8	8.18	5.7	0.9	1.0E-01	1.9	0.3	8.8E-03	1.0	0.05	2.2E-03
n-Octane	38.2	21.4	8.02	5.6	0.9	1.0E-01	1.8	0.3	8.7E-03	1.0	0.05	2.1E-03
Ethylbenzene	91.2	50.9	19.12	13.4	2.0	2.4E-01	4.4	0.8	2.1E-02	2.4	0.12	5.0E-03
(p+m)-Xylene	91.2	50.9	19.12	13.4	2.0	2.4E-01	4.4	0.8	2.1E-02	2.4	0.12	5.0E-03
n-Nonane	20.9	11.7	4.37	3.1	0.5	5.6E-02	1.0	0.2	4.7E-03	0.6	0.03	1.2E-03
o-Xylene	28.6	16.0	5.99	4.2	0.6	7.6E-02	1.4	0.2	6.5E-03	0.8	0.04	1.6E-03
Cumene	14.7	8.2	3.08	2.2	0.3	3.9E-02	0.7	0.1	3.3E-03	0.4	0.02	8.1E-04
1,3,5-Trimethylbenzene	4.2	2.4	0.89	0.6	0.1	1.1E-02	0.2	0.0	9.6E-04	0.1	0.01	2.4E-04
1,2,4-TMB+n-Decane	21.6	12.1	4.54	3.2	0.5	5.8E-02	1.0	0.2	4.9E-03	0.6	0.03	1.2E-03
1,2,3-TMB+p-Cymene	30.9	17.3	6.48	4.5	0.7	8.2E-02	1.5	0.3	7.0E-03	0.8	0.04	1.7E-03
Total C_5-C_{10}	866.9	484.2	181.77	127.5	19.5	2.3E+00	41.5	7.6	2.0E-01	23.0	1.13	4.8E-02
Total C_1-C_{10}	1209.4	675.6	253.6	177.9	27.14	3.22	57.88	10.57	0.274	32.1	1.58	0.067

Table E2-20 Maximum Hourly, Daily and Annual Average Concentrations (µg/m³) in Local and Regional Communities Due to Muskeg River Mine Project Tailings Settling Pond Surface Emissions (Concluded)

Community	Muskeg River Mine Project			Fort McKay			Fort McMurray			Fort Chipewyan		
Distance (km)				12			61			167		
Averaging Period	Hour	Day	Annual	Hour	Day	Annual	Hour	Day	Annual	Hour	Day	Annual
TRS Emissions												
Hydrogen Sulphide	9.9E-01	5.6E-01	2.1E-01	1.5E-01	2.2E-02	2.6E-03	4.8E-02	8.7E-03	2.3E-04	2.6E-02	1.3E-03	5.5E-05
Carbonyl Sulphide	2.5E-01	1.4E-01	5.2E-02	3.7E-02	5.6E-03	6.6E-04	1.2E-02	2.2E-03	5.7E-05	6.6E-03	3.3E-04	1.4E-05
Methyl Mercaptan	3.3E-02	1.9E-02	7.0E-03	4.9E-03	7.5E-04	8.8E-05	1.6E-03	2.9E-04	7.5E-06	8.8E-04	4.3E-05	1.8E-06
Carbon Disulphide	1.4E-01	7.7E-02	2.9E-02	2.0E-02	3.1E-03	3.7E-04	6.6E-03	1.2E-03	3.1E-05	3.7E-03	1.8E-04	7.7E-06
Thiophene	3.3E-01	1.8E-01	6.8E-02	4.8E-02	7.3E-03	8.7E-04	1.6E-02	2.8E-03	7.4E-05	8.7E-03	4.3E-04	1.8E-05
2-Methyl Thiophene	2.6E+00	1.4E+00	5.4E-01	3.8E-01	5.7E-02	6.8E-03	1.2E-01	2.2E-02	5.8E-04	6.8E-02	3.3E-03	1.4E-04
3-Methyl Thiophene	1.3E+00	7.1E-01	2.7E-01	1.9E-01	2.9E-02	3.4E-03	6.1E-02	1.1E-02	2.9E-04	3.4E-02	1.7E-03	7.0E-05
Isobutyl Mercaptan	1.2E-01	6.9E-02	2.6E-02	1.8E-02	2.8E-03	3.3E-04	5.9E-03	1.1E-03	2.8E-05	3.3E-03	1.6E-04	6.8E-06
Diethyl Sulphide	1.2E-01	6.8E-02	2.5E-02	1.8E-02	2.7E-03	3.2E-04	5.8E-03	1.1E-03	2.7E-05	3.2E-03	1.6E-04	6.7E-06
n-Amyl Mercaptan	8.4E-01	4.7E-01	1.8E-01	1.2E-01	1.9E-02	2.2E-03	4.0E-02	7.3E-03	1.9E-04	2.2E-02	1.1E-03	4.6E-05
Diallyl Sulphide	9.1E-01	5.1E-01	1.9E-01	1.3E-01	2.0E-02	2.4E-03	4.4E-02	8.0E-03	2.1E-04	2.4E-02	1.2E-03	5.0E-05
2-Ethylthiophene	1.2E+00	6.8E-01	2.5E-01	1.8E-01	2.7E-02	3.2E-03	5.8E-02	1.1E-02	2.7E-04	3.2E-02	1.6E-03	6.7E-05
2,5-Dimethyl Thiophene	3.7E+00	2.1E+00	7.7E-01	5.4E-01	8.3E-02	9.8E-03	1.8E-01	3.2E-02	8.3E-04	9.8E-02	4.8E-03	2.0E-04
di-n-Butyl Sulphide	1.0E+01	5.7E+00	2.1E+00	1.5E+00	2.3E-01	2.7E-02	4.8E-01	8.8E-02	2.3E-03	2.7E-01	1.3E-02	5.6E-04
TOTAL	27.4	15.3	5.8	4.0	0.62	0.073	1.314	0.240	0.006	0.729	0.036	0.002

Table E2-21 Maximum Hourly, Daily and Annual Average Concentrations (µg/m^3) in Local and Regional Communities Due to Muskeg River Mine Project Stationary Plant Emissions

Community	Muskeg River Mine Project			Fort McKay			Fort McMurray			Fort Chipewyan		
Distance (km)				12			61			167		
Averaging Period	Hour	Day	Annual	Hour	Day	Annual	Hour	Day	Annual	Hour	Day	Annual
Stationary Sources												
NO_x	130	31	2.3	43.2	5.36	0.232	15.36	3.79	0.1439	9.0	0.69	0.034
NO_2	66.0	31.0	2.3	43.2	5.4	0.23	15.4	3.8	0.144	9.0	0.69	0.034
CO	57.8	13.8	1.0	19.2	2.4	0.10	6.8	1.7	0.064	4.0	0.31	0.015
PM	18.7	4.5	0.3	6.2	0.8	0.03	2.2	0.5	0.021	1.3	0.10	0.0049
THC	3.6	0.9	0.1	1.2	0.1	0.01	0.4	0.1	0.004	0.2	0.02	0.0009
VOC	2.4	0.57	0.043	0.800	0.099	0.004	0.28	0.07	0.003	0.2	0.01	0.0006

Table E2-22 Impact Classification Associated with Key Question AQ-2 (Human Health)

Direction	Negative.
Magnitude	See Human Health section.
Geographic Extent	Local (on-site, Fort McKay), regional (Fort McMurray), beyond regional (Fort Chipewyan).
Duration	Plant life (duration of emissions) and short-term (poor dispersion conditions).
Reversibility	Reversible.
Frequency	Intermittent.
Season	All seasons for diesel exhaust emissions and bias to summer season for fugitive mine and tailings settling pond VOC/TRS emissions.

E2.5 Question AQ-3: Will Muskeg River Mine Project Emissions Result in the Deposition of Acid Forming Compounds That Exceed Target Loadings?

E2.5.1 Model Predictions

Local and regional SO_2 and NO_x emissions are associated with the deposition of acidifying compounds through wet and dry deposition processes. The depositions associated with these emissions are in addition to those associated with air flow into the RSA. The combined deposition can be compared to critical loading criteria.

The proposed Muskeg River Mine Project will result in an additional 11.9 t/d of NO_x emissions in the region. Predictions associated with these emissions are expressed as a deposition (wet and dry) flux in terms of nitrate equivalent deposition (by NO_3^-/ha/a) and potential acid input (PAI: kg/ha/a). Background nitrate and PAI values associated with airflow into the LSA and RSA are 2.2 kg NO_3^-/ha/a and 0.083 kg/ha/a, respectively.

The maximum deposition values due to the Muskeg River Mine Project emissions are predicted to area adjacent to the mine. Table E2-23 provides a summary of the current and the Project source contributions at this location. The results indicate the Project is the largest contributor at this location.

The spatial deposition (both nitrate and PAI) are summarized in the following figures:

- Figure E2-6 shows the annual nitrate deposition (wet plus dry) due to the Muskeg River Mine Project NO_x emissions. The maximum nitrate deposition value of about 24 keq NO_3^-/ha/a is predicted to occur in the vicinity of the mine. This value is associated with the dry deposition of NO_x.

- Figure E2-7 expresses the nitrate deposition from the Muskeg River Mine Project in keq/ha/a. The maximum nitrate deposition of about 0.45 keq/ha/a includes the regional background value of 0.08 kg/ha/a.

- Figure E2-8 shows the annual nitrate deposition (wet plus dry) due to the combined Muskeg River Mine Project, Syncrude and Suncor NO_x emissions. The maximum predicted deposition value of about 26 kg NO_3^-/ha/a is predicted to occur adjacent to the Muskeg River Mine Project area.

- Figure E2-9 shows the PAI (keq/ha/a) due to the combined operation of the Muskeg River Mine Project, Syncrude and Suncor NO_x (and SO_2) emissions. The maximum PAI of about 0.58 keq/ha/a is predicted to occur adjacent to the Muskeg River Mine Project. The PAI values shown in the figure include a background value.

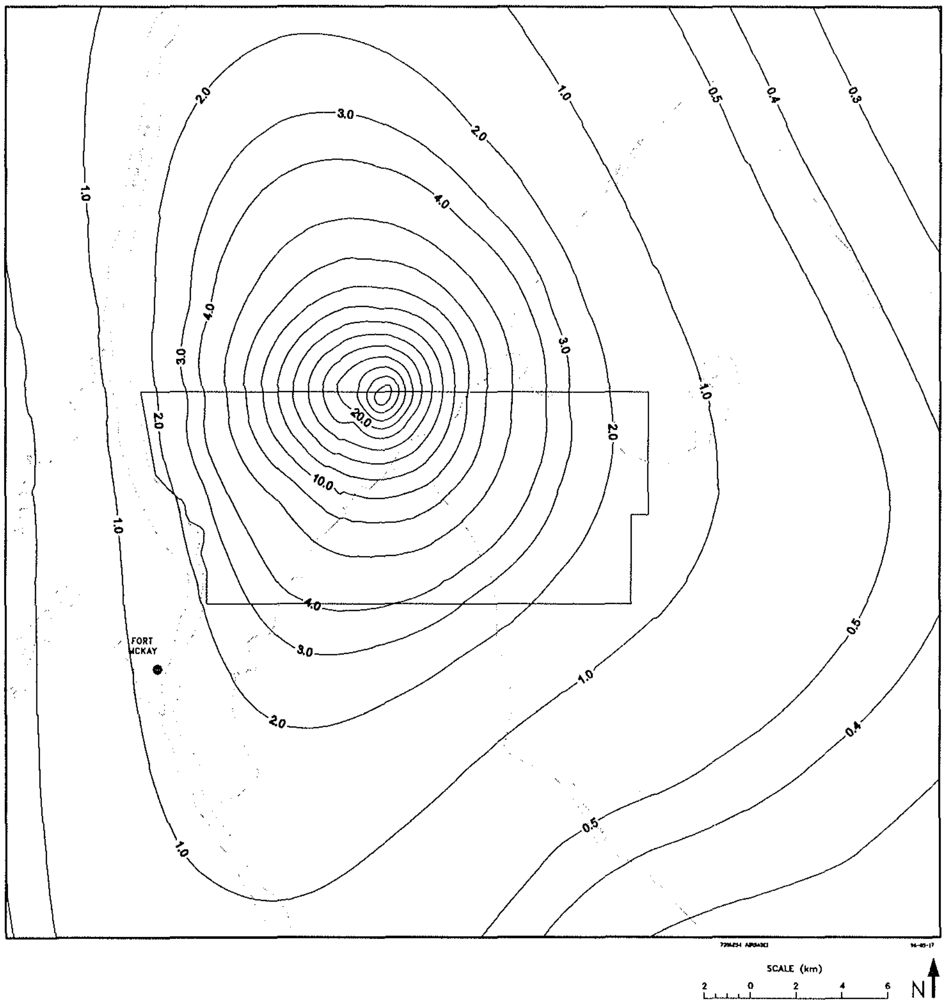
The maximum nitrate deposition values result almost entirely from the dry deposition of NO_x which is directly related to ambient NO_x concentrations. As such, the high deposition is predicted to occur adjacent to the mine where high NO_x values are predicted. These values are expected to be conservative as a uniform canopy resistance corresponsing to summertime conditions was assumed. During the non-summer months, the canopy resistance is expected to increase and the removal efficiency will decrease accordingly.

Further regional study area modelling (Section F2) indicate the Muskeg River Mine Project emissions increases the area where the 0.25 keq/ha/a value is exceeded from 1,200 to 1,530 km^2. Similarly the area where the 0.50 keq/ha/a value is exceeded increases from 130 to 150 km^2. Based on a 1° latitude by a 1° longitude block (110 km x 60 km = 6,600 km^2), the area where the 0.25 value is exceeded increases from 18 to 23%; similarly the area where the 0.50 value is exceeded increases from 2.0 to 2.3%.

Table E2-23 Summary of Maximum NO_x and PAI Deposition in the Vicinity of the Muskeg River Mine Project

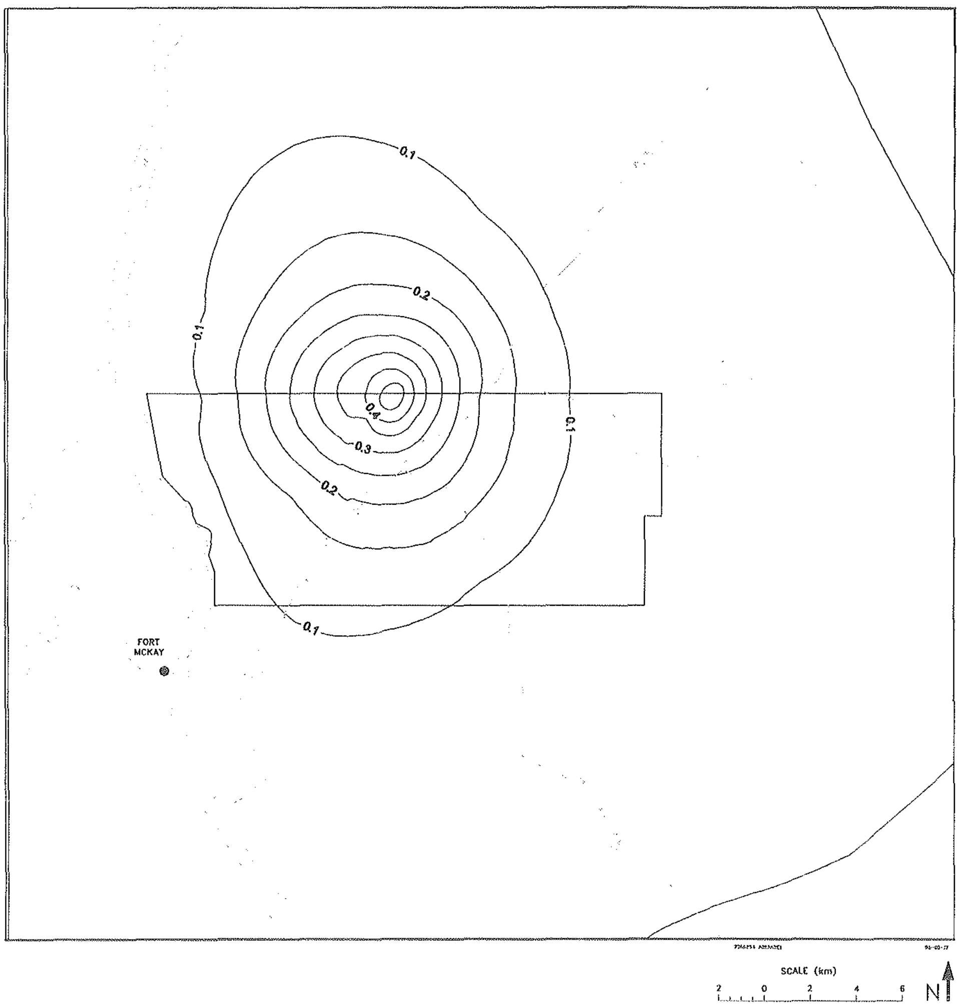
Source	NO_x Deposition (kg NO_3^-/ha/a)	PAI (keq/ha/a)	PAI (keq/ha/a)
Suncor and Syncrude	2	0.12	0.20
Muskeg River Mine Project	24	0.38	0.45
Muskeg Rive Mine Project, Suncor and Syncrude	26	0.50	0.58
Regional Background	2.2	0.083	(included above)

Figure E2-6 Annual NO_3^- (kg NO_3^-/ha/a) Deposition Due to Muskeg River Mine Project NO_x Emissions (No Background)



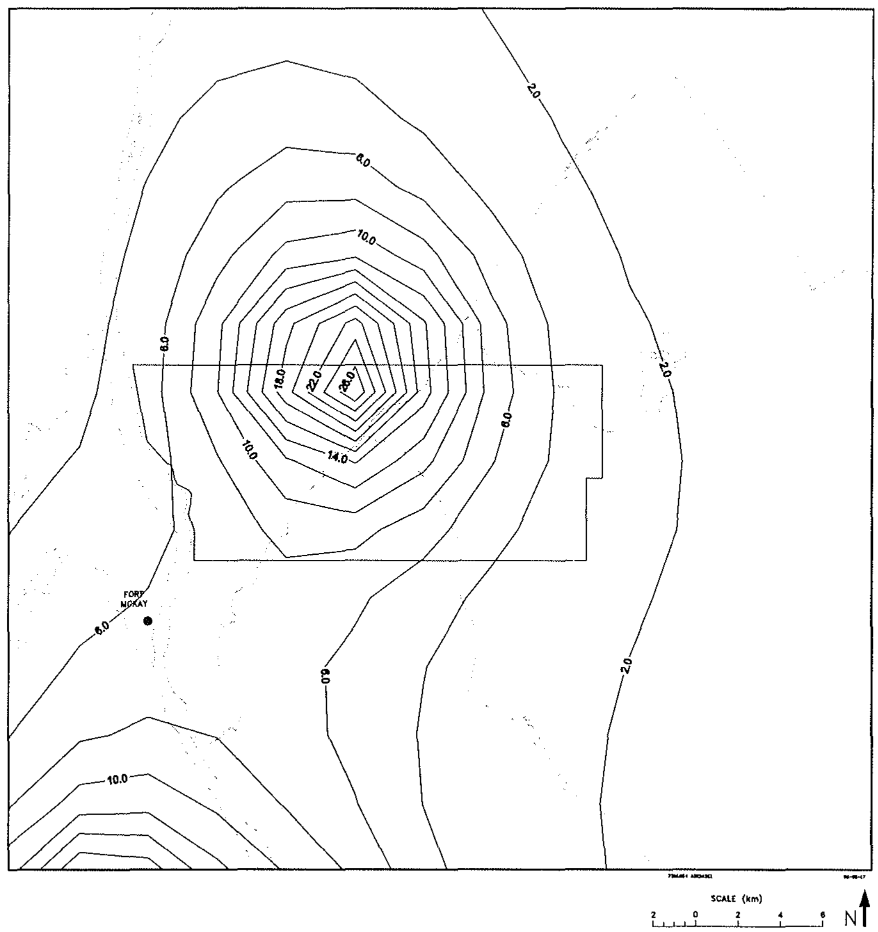
Model:	CALPUFF
Meteorology:	Mannix
Sources:	Muskeg River Mine Project NO_x = 11.9 t/d

Figure E2-7 Annual NO_3^- Deposition Due to the Muskeg River Mine Project Expressed in Terms of keq/ha/a (With Background of 0.083 keq/ha/a)



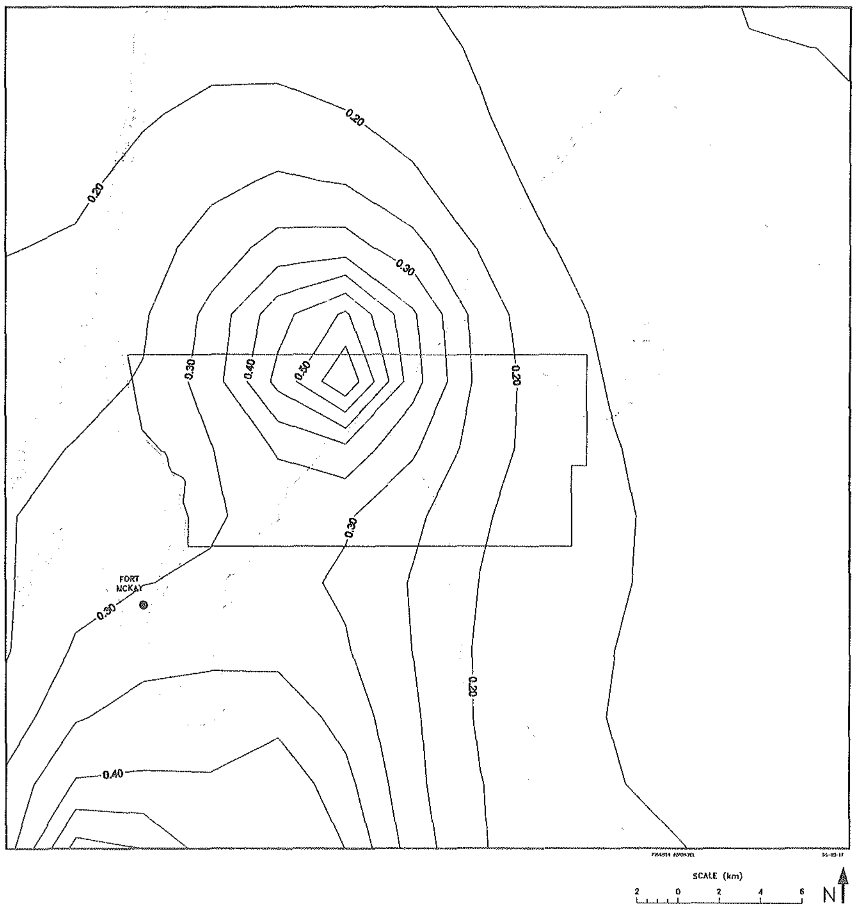
Model:	CALPUFF	
Meteorology:	Mannix	
Sources:	Muskeg River Mine	NO_x = 11.9 t/d

Figure E2-8 Annual NO_3^- (kg NO_3/ha/a) Deposition Due to Muskeg River Mine Project, Suncor and Syncrude NO_x Emissions



Model:	CALPUFF	
Meteorology:	Mannix	
Sources:	Muskeg River Mine	NO_x = 11.9 t/d
	Suncor	NO_x = 39 t/d
	Syncrude	NO_x = 37 t/d

Figure E2-9 Annual Potential Acid Input (PAI) (keq/ha/a) Due to Muskeg River Mine Project, Suncor, Syncrude NO_x and SO_2 Emissions (With Background of 0.083 keq/ha/a)



Model:	CALPUFF
Meteorology:	OSLO
Sources:	Muskeg River Mine Project NO_x = 11.9 t/d
	Suncor SO_2 = 57 t/d
	Suncor NO_x = 39 t/d
	Syncrude NO_x = 37 t/d
	Syncrude SO_2 = 197 t/d

E2.5.2 Residual Impact Classification

Table E2-24 classifies the air quality impact associated with Key Question AQ-3. The maximum PAI (of about 0.58 keq/ha/a) associated with current and Project sources is predicted to exceed the critical loading of 0.25 keq/ha/a for sensitive ecosystems and the critical loading of 0.50 keq/ha/a for less sensitive systems. The effect of the Muskeg River Mine Project emissions is to increase the maximum PAI in the vicinity of the mine from about 0.20 to 0.58 keq/ha/a. The overall degree of concern is rated as moderate to high.

E2.5.3 Monitoring

Shell will participate in the Southern Wood Buffalo Air Quality zone monitoring program to obtain and confirm background concentration estimates of SO_x, NO_x and base cations as well as changes due to LSA and RSA emission sources.

Table E2-24 Classification of Air Quality Impacts Associated with Key Question AQ-3 (Acidification)

Direction	Negative due to an increase in NO_x emissions of 11.9 t/d.
Magnitude	Moderate to High in the local area since target loading criteria are exceeded.
Geographic Extent	Local.
Duration	Plant life (duration of emissions).
Reversibility	Non-reversible.
Frequency	Continuous.
Season	All seasons.

E2.6 Key Question AQ-4: Will Muskeg River Mine Project Precursor Emissions Result in the Formation of Ozone (O_3) That Exceed Air Quality Guidelines?

There are no direct O_3 emissions released to the atmosphere from the Muskeg River Mine Project activities. Ozone occurs naturally and NO emissions will decrease natural O_3 levels near the emission sources. Ozone, however, may be photochemically produced due to NO_x and VOC emissions. The region of maximum O_3 production generally occurs several tens of kilometres downwind of the source region when photochemical conditions are favourable. The production of ozone requires simultaneous NO_x emissions, VOC emissions and sufficient solar intensity to initiate the reaction mechanisms.

E2.6.1 Meteorological Requirements

The photochemical production of ozone is associated with meteorological conditions such as high solar intensity, high ambient temperature and stagnation wind systems. These associated conditions are reviewed with respect to the LSA.

Solar Intensity

Solar intensity is related to latitude, season and cloud cover. In spite of the LSA's northerly latitude (57°N), the integrated light intensity during the summer has almost the same potential to form ozone as that in Los Angeles (34°N) (Nieboer 1976). During the spring and summer, the ozone forming potential at 57°N is about one-half that of Los Angeles. During the winter, photochemical ozone production in the LSA is negligible due to lower solar elevations and short days. In conclusion, there is sufficient solar intensity for the photochemical production of ozone in the LSA during the summer months.

Ambient Temperature

The photochemical production of ozone has been related to ambient temperatures (Walcek and Yuan 1995, Olszyna et al. 1997). Elevated temperatures have the direct effect of increasing reaction rates, increasing hydrocarbon emissions from natural sources or be indirectly related by being associated with increased solar intensity and stagnation air mass conditions. Specifically, Olszyna et al. (1997) found that higher temperatures increased ozone production near the emission sources. This letter study was based on data from a rural site in south Tennessee where ambient temperatures range from 22 to 33°C.

While the ozone summer temperatures in the RSA tend to be in the 15 to 19°C range (BOVAR 1996b), temperatures in excess of 20°C can occur during the period May to September. Similarly, temperatures in excess of 30°C can occur during the period May to August. Longley (1972) indicates that the maximum temperature in the RSA can exceed 26°C 10 to 15 days a year. In conclusion, the temperatures in the LSA area are sufficient during the summer to result in the photochemical production of ozone.

Stagnation Conditions

Stagnation air flow is associated with synoptic high pressure weather systems. This condition is characterized by low wind speeds, recirculating air flows and large scale subsidence. As indicated in Section D2.4, wind speeds in the LSA are relatively low when compared to other areas in Alberta. During the summer, the prairies are characterized by frequent and intermittent thunderstorm activity which are not associated with high pressure systems. Notwithstanding this characterization, stagnation conditions occur in northern Alberta during the summer months.

Comments

The meteorological requirements for the formation of ozone are available during the summer months in the LSA. Given these conditions, associated precursor emissions can lead to the photochemical production of ozone. Historically, hourly O_3 values in excess of the 160 $\mu g/m^3$ guideline have occurred in the region most frequently during April and May. This reduces the potential for overlap between the high naturally occurring values in the spring time and the conditions favourable for the photochemical production during the summer.

E2.6.2 Hydrocarbon Reactivity

Each individual hydrocarbon species will have a differing capability to form photochemical ozone. Three major sources of hydrocarbon emissions have been identified with the Muskeg River Mine Project:

- The exhausts of the mine fleet. Table E2-2 indicates the primary hydrocarbon emissions and alkanes, aromatics and aldehydes.
- The volatilization from the mine surface. Table E2-6 indicates the primary hydrocarbon emissions are alkanes and aromatics. The analyses available from existing information indicated several unidentified hydrocarbon species.
- The volatilization from the tailings settling pond. Table E2-12 indicates the primary hydrocarbon emissions are also alkanes and aromatics. Again, the analyses indicated several unidentified hydrocarbon species.

To assist in determining the importance of specific VOC emissions on the production of O_3, the concept of a "Photochemical Ozone Creation Potential (or POCP)" has been used (e.g., Derwent et al. 1996). POCP or similar values have been determined for specific VOC compounds and used to evaluate the effect VOC control strategies have on ozone production. POCP values are determined through the application of photochemical models to a region.

The POCP for a mixture of compounds will depend upon the overall VOC/NO_x mixture, meteorology and the transport time. Similar to the POCP concept, reactivity factors such as "Maximum Incremental Reactivity (or MIR)" have been developed for U.S. urban centres (Carter 1994) and have been applied to Edmonton (Cheng et al. 1997). The MIR values provided by Carter can be normalized and also expressed as a POCP.

Based on the HC speciation provided in Tables E2-2 (diesel exhaust), E2-6 (mine surface) and E2-12 (tailings settling pond), POCP values were calculated for each of these source based on:

- One set is based on values derived from the emissions inventory and photochemical modelling undertaken for the U.K. and N.W. Europe (Derwent et al. 1996). The selected values were based on maximum predicted ozone levels on the first day of the trajectory.

- The other set is based on values derived from photochemical box modelling that has been confirmed with chemical reaction chambers and input from 39 U.S. urban areas (Carter 1994). The POCP values were obtained from the relative Maximum Incremental Reactivity (MIR).

In the calculation of the POCP, unidentified compounds were assigned a value similar to a known value for comparison with a similar structure. As such, there is some subjectivity to the application of the POCP approach. The results presented in Table E2-25 are consistent in that the largest contribution is estimated to be due to the diesel exhausts even though the diesel emissions are the lowest.

Table E2-25 Source Weighted POCP Indicators of Ozone Generation Potential for the Muskeg River Mine Project VOC Emissions

	THC Emission (t/d)	POCP[a] (UK)	POCP[b] (US)
Diesel Exhaust	0.88	350	508
Mine Surface	1.62	230	139
Tailings settling pond	1.47	320	362

(a) Based on U.K. derived POCP values, weighted according to mass emissions.
(b) Based on U.S. derived POCP values, weighted according to mass emissions.

E2.6.3 Estimate of Ozone Formation

The effect of the Muskeg River Mine project is to increase the regional NO_x emissions from 77.8 to 89.7 t/d and the regional TCH emissions from 43.9 to 47.9 t/d. The photochemical model SMOG has been applied for a hypothetical meteorological condition (i.e., northerly summertime air flow) to evaluate the potential for ozone production downwind of the oil sands area. The model was applied to NOx emission scenarios that ranged from 59 to 114 t/d and for anthropogenic VOC emission scenarios that ranged from 28 to 63 t/d (Concord Environmental Corporation 1993, BOVAR 199b). The SMOG model predicted ozone concentrations that were about 10 ppb larger for the higher emission scenarios than those for the lower emission scenarios. Over the last four years, the maximum ozone concentration in Fort McMurray has averaged 67 ppb. Given the concurrent occurrence of this maxima (67 ppb) and the incremental photochemically produced value of 10 ppb, the resulting maximum would be near the 82 ppb guideline.

E2.6.4 Residual Impact Classification

Table E2-26 classifies the air quality component associated with Key Question AQ-4. This issue is further discussed in the cumulative impact assessment (Section F2). Given the previous modelting results, and the ozone baseline, the overall magnitude is rated tentatively as moderate.

Table E2-26 Classification of Air Quality Impacts Associated With Key Question AQ-4 (Ozone)

Direction	Negative; an increase of 11.9 t/d of NO_x precursors and 2.5 t/d of VOC precursors (4.0 t/d of THC).
Magnitude	Unknown: Without explicit modelling, the magnitude is rated as unknown. However, based on previous modelling, the magnitude is tentatively set at moderate to emphasize the need to further evaluate this issue on a regional basis.
Geographic Extent	Regional
Duration	Short-term.
Reversibility	Reversible.
Frequency	Intermittent.
Season	Summer.

E2.6.5 Monitoring

Source: Confirmation of the VOC emissions from the mine fleet, mine surface and tailings handling will be undertaken.

Ambient: Participation in the Southern Wood Buffalo air quality program will provide observations of background and downwind ozone concentrations in the regional study area.

E2.7 Key Question AQ-5: What are the Muskeg River Mine Project Greenhouse Gas Emissions and how do They Compare to Those Associated With Conventional Oil Production?

E2.7.1 Emissions

The estimated greenhouse gas emissions due to the Muskeg River Mine Project total 5,602 t/d and come from:

- CO_2 emissions 3,571 t/d
- CH_4 emissions 34 t/d
- Electrical requirement 1,998 t/d

For the purposes of comparison, the combustion CO_2 emissions associated with the Muskeg River Project (3,571 t/d) can be compared with these for Suncor (9,440 t/d) and Syncrude (20,833 t/d) (Table D2-1). These values are based on combustion estimates on a per unit (i.e., furnace, boiler basis) and may differ from those projected by the individual companies since their calculations are based on a carbon balance approach.

The methane (CH_4) contribution is expressed as CO_2 equivalent and assume all fugitive C_1 to C_3 emissions occur as methane. The electrical contribution is based on the 1,025 g CO_2/kwh emission factor recommended by CAPP (1994).

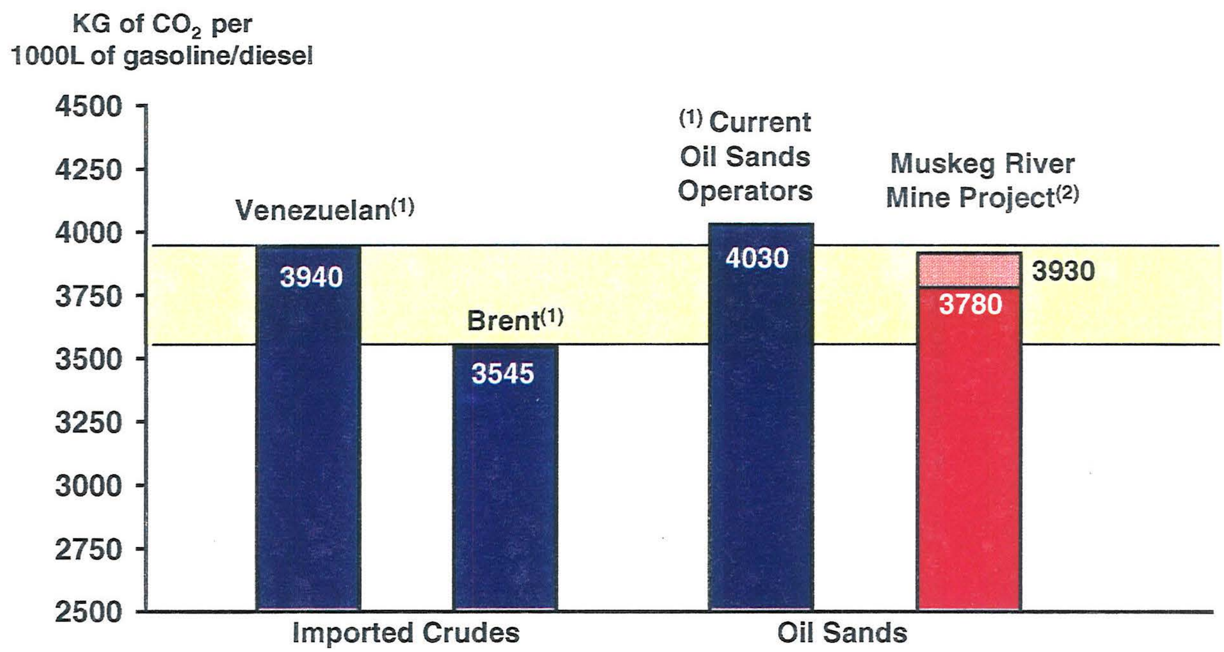
The respective Alberta and Canada 1995 estimates of greenhouse gas emissions are 518,000 t/d and 1,700,000 t/d respectively. The Muskeg River Mine Project greenhouse emission estimate are therefore 1.1 and 0.03% of the respective totals for Alberta and Canada.

E2.7.2 Assessment

The CO_2 emissions from the Muskeg River Mine Project are estimated to be lower than those associated with conventional synthetic crude oil presently produced in the Athabasca Oil sands area and those associated with conventional imported crude from Venezuela (Figure E2-10). There is room for further reduction in CO_2 emissions through process and utility enhancements as well as synergy with nearby industries. This will allow the Muskeg River Mine Project oil sands development to be competitive with imported crude oils for CO_2 emissions on a full cycle basis.

The CO_2 emissions from the Project can be compared to today's conventional synthetic crude operations as follows:

Figure E2-10 A "Full Cycle" Comparison of CO_2 Emissions Associated with Imported Crude Oil, Current Oil Sands Production and the Muskeg River Mine Project



Source (1) T.J. McCann & Associates - 1995
(2) Shell Canada - 1997f

- CO_2 from the Project truck and shovel mining operations will beroughly equivalent to that of the other oil sands operators.

- CO_2 emissions from the Project extraction process will be slightly higher than for existing operations due to the caustic free process, but the Project has potential for reduction of CO_2 through the addition of process or utility enhancements such as Cogeneration or lower temperature extraction. Diluent recovery process will require more energy than conventional production and will therefore create slightly more CO_2 emissions for extraction than conventional oil sands operators.

- CO_2 emissions for the Upgrading component of the bitumen produced by the Project will be greatly reduced. This is due to the combined hydroconversion and hydrotreating processes as well as the integration with the Scotford Refinery hydrocracking capacity. CO_2 emissions are estimated to be 25 to 30 % less than conventional upgrading.

- CO_2 emissions related to refining will be equivalent to that of conventional synthetic crude operations.

The overall CO_2 emissions associated with the Muskeg River Mine Project are less than conventional synthetic crude oil producers and can compete with imported crude oils on a "Wells to Wheels Basis".Shell Canada participates in the Voluntary Climate Challenge and Registry Program. Since 1990, Shell has improved the energy efficiencies of their refineries and has decreased the energy per unit of upstream production. All new Shell projects consider greenhouse gas emissions and Shell is pursuing programs to incorporate energy efficiency and emission minimization feature in their design and operation (Shell Canada 1997f).

E2.7.3 Residual Impact Classification

Table E2-27 classifies the impact associated with Key Question AQ-5. An overall degree of concern has not been assigned due to the nature of the greenhouse gas issue.

E2.7.4 Monitoring

An emission inventory program will document greenhouse gas emissions. Ongoing review of energy efficiencies will allow improvements to be made on an ongoing basis.

Table E2-27 Classification of Air Quality Impacts Associated With Key Question AQ-5 (Greenhouse Gas Emissions)

Direction	Negative, in that the Project will result in greenhouse gas emissions. Neutral, in that the Project greenhouse gas emissions are comparable to those associated with the conventional production of crude oil.
Magnitude	The magnitude is not assigned due to the nature of the greenhouse gas issue.
Geographic Extent	Global due to the nature of the greenhouse gas issue.
Duration	Long-term.
Reversibility	Non-reversible.
Frequency	Continuous.
Season	All seasons.

E2.8 Air Quality Impact Assessment Summary

The air quality impact assessment focused on the potential effects of the Project on:

- Oxides of nitrogen (NO_x) emissions from the mine fleet and extraction plant combustion sources. These emissions can result in ambient air quality changes, deposition of acidic precursors and the photochemical production of ozone.
- Hydrocarbon emissions (including volatile organic compounds or VOCs) from the mine fleet exhaust, mine pit area and tailings settling pond area. These emissions can result in ambient air quality changes, and, in conjunction with NO_x emissions, can result in the photochemical production of ozone.
- Fugitive total reduced sulphur (TRS) emissions from the mine pit and tailings settling pond area. These emissions have the potential to cause odours.
- Particulate matter (PM) emissions from site clearing, mining activities and combustion sources. PM and associated polycyclic aromatic hydrocarbons (PAHs) can have adverse effects on human health.
- Greenhouse gas emissions, principally carbon dioxide (CO_2) from emission sources.

The impact assessment for air quality considered the potential effects from the Project on: exceedance of ambient concentration guidelines; human health effects due to air emissions; acidification potential; photochemical production of ozone; and greenhouse gases.

Mitigation strategies to reduce NO_x emissions include the selection of low NOx burners for the plant site and mine fleet vehicles equipped with emission control technology. The Tailings Solvent Recovery Unit will reduce VOC and TRS losses to the tailings settling pond. A vapour control system will reduce VOC and TRS emissions from the solvent and product storage tanks.

PM emissions during site clearing will be reduced by controlled burning procedures and fugitive PM emissions will be controlled through road maintenance (e.g., watering) and progressive reclamation activities. An optimized mine plan to minimize material handling and travel distances coupled with a warm water extraction process will help manage CO_2 emissions.

It is concluded that the maximum ambient NO_x and PM_{10} emissions from combustion sources will be less than the ambient air quality guidelines. The primary deposition of acid forming precursors is predicted to result from the dry deposition of NO_2 from the mine fleet. Values in excess of the 0.25 keg/ha/a target loading for sensitive ecosystems are predicted in the vicinity of the Project from existing sources.

For limited periods during the summer, there is the potential for the photochemical production of ozone from the Project and existing sources. Greenhouse gas emissions associated with the production of synthetic crude are estimated to be similar to that associated with the conventional production of crude oil.

Source monitoring recommended for the Project includes the ongoing estimation of NO_x and CO_2 emissions as well as a periodic monitoring to assess fugitive PM and VOC emissions. Ambient monitoring recommended for the Project includes a single trailer to measure NO_2 and PM_{10} in the vicinity of the mine. Participation in the Southern Wood Buffalo Zone airshed monitoring program will address regular monitoring needs.

E3 HYDROGEOLOGY IMPACT ANALYSIS

E3.1 Introduction

This section of the Muskeg River Mine Project (the Project) provides information as required by the Project Terms of Reference (TofR) issued on November 7, 1997 (AEP 1997a). Specifically, the following are addressed in this section:

- description of the effects of the Project on the existing groundwater resources of the Study Area, including water quality, quantity and thermal regime;
- discussion on the effects of the Project on the Basal Aquifer;
- description of the groundwater monitoring program and mitigation measures to address impacts on the groundwater (TofR, Section 4.7); and
- description of the sources of water to be used in the development and the options for water sourcing considered (TofR, Section 3.6).

Discussions on the potential cumulative effects on groundwater associated with the Project are addressed in Section F3. Section D3 provides details on the groundwater environmental baseline for the Project.

The types of potential hydrogeologic impacts from the Muskeg River Mine Project (the Project) include impacts on groundwater resources, and changes in groundwater regimes that interact with surface water both in terms of quantity of surface flows, and effects on groundwater quality that are subsequently transmitted to receiving surface waters.

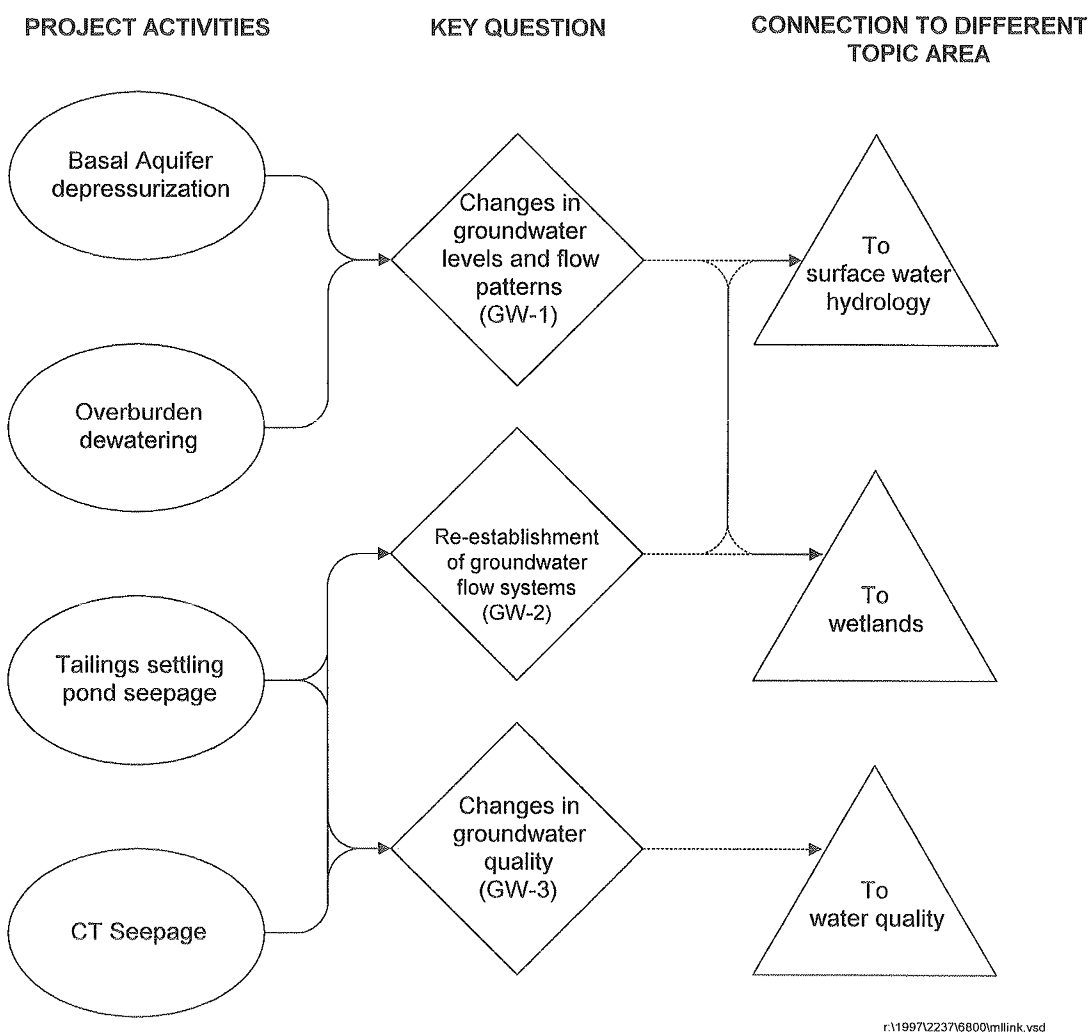
E3.2 Potential Linkages and Key Questions

Potential issues related to hydrogeology can be summerized in three key questions, whose linkages are shown in Figure E3-1.

GW-1: Will the Muskeg River Mine Project Change Groundwater Levels and Groundwater Flow Patterns?

Surficial aquifers in the Project area will be dewatered before mining, and the Basal Aquifer beneath the oil sands will have to be depressurized to ensure stable pit floor conditions during mining. Both of these operations will lower groundwater levels in the vicinity of the mine pit, creating a

Figure E3-1 Linkage Diagram for Hydrogeology for Construction, Operation, and Closure Phases of the Muskeg River Mine Project



"drawdown cone" in the groundwater surfaces around the mine. The groundwater collected from the muskeg dewatering and overburden dewatering system will be released to surface streams; that collected from the Basal Aquifer depressurization wells will be used as process water. Since groundwater is one component of a hydrologic regime that includes the interaction between groundwater and surface water, the changes in groundwater levels or in groundwater flow patterns due to dewatering/depressurization activities may have an impact on surface water flows or quality.

The linkages associated with this key question are as follows:

Linkage GW-1.1: Will Overburden Dewatering Affect Groundwater Levels in Surficial Aquifers?

Linkage GW-1.2: Will Basal Aquifer Depressurization Reduce Groundwater Levels in the Basal Aquifer?

GW-2: Will Groundwater Systems Re-Establish After Mining and Reclamation?

The post-development landscape will be substantially different from pre-mining conditions, in terms of such key features as topography, surface drainage and geology. For example, within the mine development area itself, surficial materials and oil sands will be removed by mining, and replaced by materials (e.g., consolidated tailings (CT), mined overburden, reject materials) in the reclaimed landscape. Any groundwater flow systems that re-establish in this landscape will interact with surface water drainage systems both within and beyond the limit of mining. This may result in a change in surface flows associated with changes in groundwater base flows in the post-development landscape.

The linkage associated with this key question is as follows:

Linkage GW-2.1: Will Groundwater Levels Recover and Groundwater Flow Systems Re-establish in the Post-Development Landscape?

GW-3: Will the Muskeg River Mine Project Change Groundwater Quality?

The Project will include an external tailings facility as well as CT disposal in mine pits, along with other features of the development and reclamation process. Any seepage from these facilities into groundwater in adjacent areas is likely to affect the quality of the groundwater, to the extent that seepage water quality is different from natural groundwater quality. This groundwater of altered quality will flow to discharge areas that may include streams within the Project area. The discharge of groundwater of altered quality to streams will cause a change in surface water quality.

The linkages associated with this key question are as follows:

Linkage GW-3.1: Will There Be Seepage of Consolidated Tailings Porewater From In-Pit Mine Disposal Areas Into the Basal Aquifer?

Linkage GW-3.2: Will There Be Seepage of Consolidated Tailings Porewater From In-Pit Disposal Areas Into Groundwater Beyond the Mine Pits?

Linkage GW-3.3: Will There be Seepage of Tailings Sand Porewater From the External Tailings Facility Into Groundwater?

E3.3 Study Area Boundaries

The hydrogeological local study area (LSA) and regional study area (RSA) were described in Sections D1 and D3.

E3.4 Methods Used in Groundwater Assessment

E3.4.1 Overburden Dewatering Calculations

Surficial overburden is expected to be dewatered by means of a series of ditches, collecting groundwater for discharge to the surface water management system. Considering that much of the dewatered overburden is ultimately mined, the groundwater to be collected by the dewatering system represents a finite volume, consisting of the volume of groundwater that can be released from storage in the overburden, plus any natural recharge that may occur from precipitation during the dewatering 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 (Driscoll 1987). These approaches are discussed in detail in Appendix IV.

Both methods of calculation depend on the thickness of sand in the overburden. The thickness of sand in the overburden is quite variable, but generally ranges from 2 to 6 m thick, with an estimated average thickness of 4 m. Other variables also affect the dewatering discharge calculations. The water balance discharge calculations are influenced by the natural groundwater recharge rate, and two values of recharge (low recharge of 50 mm/a, and high recharge of 69 mm/a, Alsands Energy Ltd. 1981) are used to calculate a range of discharge that reflects variation in this parameter. Similarly, the analytical calculation is affected by the hydraulic conductivity (K) of the overburden, so discharge values are calculated reflecting high K ($1x10^{-3}$ m/s) and low K ($5x10^{-4}$ m/s) overburden materials (Figure E3-2).

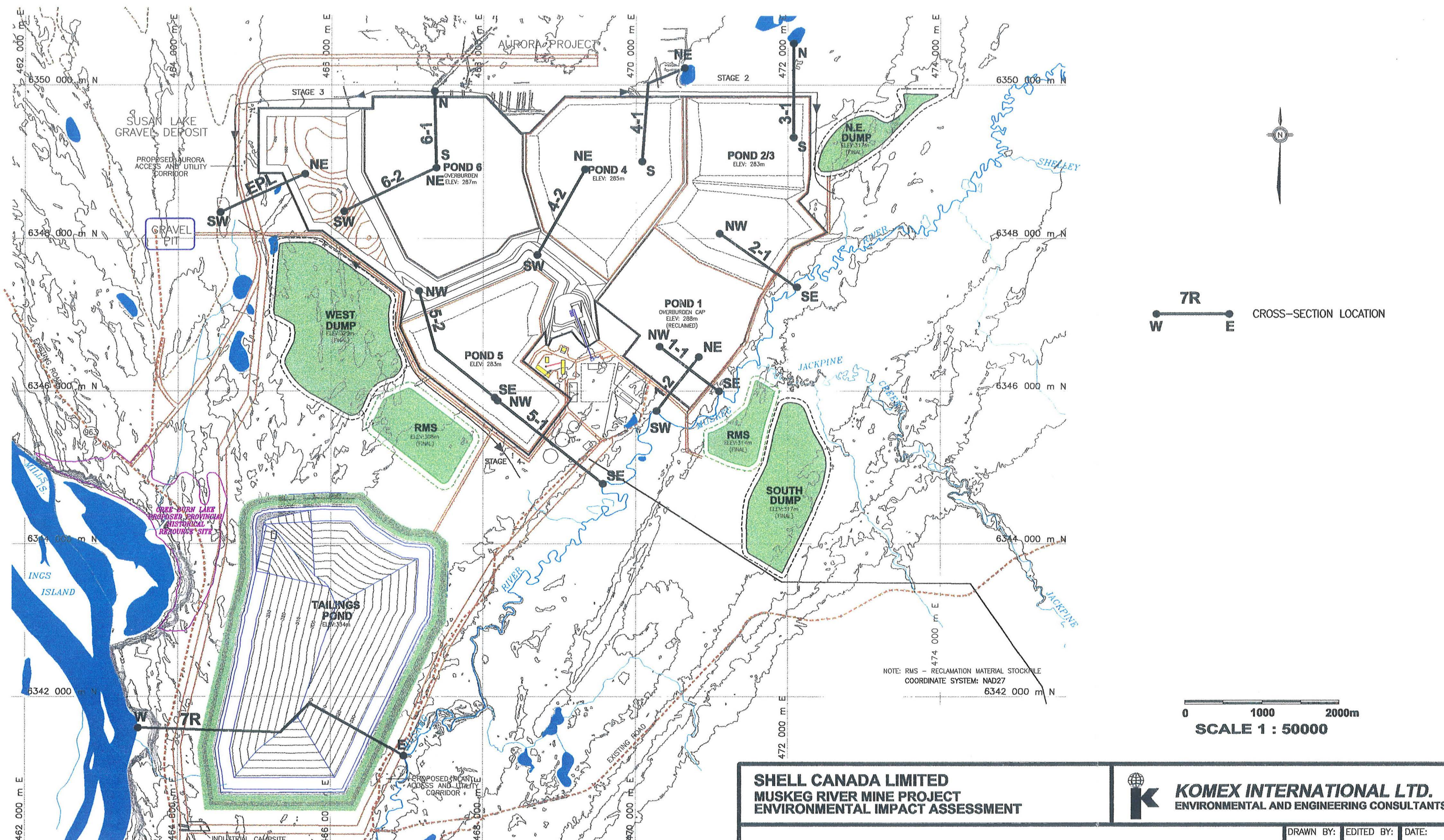
E3.4.2 Basal Aquifer Depressurization Calculations

The natural groundwater level in the Basal Aquifer in the area of the Project is 270 to 280 masl, which is substantially above the elevation of the base of the mine pit, at 200 to 230 masl. To have a stable pit floor, the Basal Aquifer must be depressurized before development. Depressurization of the Basal Aquifer involves pumping of the aquifer to lower the groundwater surface to below the base of the mine pit. Discussion of the detailed calculations is included in Appendix IV.

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 the individual mine pits will act as very large-diameter wells, the diameter of which will be proportional to the area of each pit.

Given the thickness and hydraulic conductivity 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). 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 was applied to each 5-year mine block. 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.

Variation in several major parameters was included in the calculations for each 5-year mine block. Minimum, maximum and average thicknesses of the Basal Aquifer were estimated from the isopach map for this unit (Appendix IV). The minimum, maximum and average drawdown required were estimated by subtracting range in-pit floor elevations of the Norwest mine plan from the Basal Aquifer groundwater surface elevations, established in the Baseline Hydrogeology study (Komex 1997). Several pumping tests have been conducted in the Basal Aquifer, and a geometric mean hydraulic conductivity of $5x10^{-5}$ m/s, derived from these tests (Komex 1997) was used in all depressurization analyses.



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SHELL CANADA LIMITED
MUSKEG RIVER MINE PROJECT
ENVIRONMENTAL IMPACT ASSESSMENT

KOMEX INTERNATIONAL LTD.
ENVIRONMENTAL AND ENGINEERING CONSULTANTS

LOCATION OF MINE PITS AND MODEL CROSS-SECTIONS

DRAWN BY:	EDITED BY:	DATE:
J.P.	J.P.	DEC.03/97
APPROVED:		FIGURE: E3-2

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E3.4.3 Seepage From Backfilled Mine Pits

Five of the six mine pits will be backfilled with mined materials; four with CT, and one with mined overburden. Calculations of seepage from the backfilled mine pits were done for nine snapshot times ranging from 2002 to a far-future equilibrium condition. The calculations focused on settings where seepage from the mine could potentially reach a receiving stream.

The seepage calculations were done using a two-dimensional 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, one or two vertical cross-sections were selected to calculate seepage that would represent a unit length of the pit perimeter. The locations of the model cross-sections are shown in Figure E3-2. The cross-sections generally extend from near the centre of a pit, across the mine highwall, to a potential point of 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.

For each of the snapshot times 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 times. 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.

E3.4.4 Tailings Settling Pond Seepage

Seepage from the tailings settling pond was calculated in a similar manner as seepage from the backfilled mine pits. That is, a two-dimensional, finite element groundwater flow model was developed for a vertical cross-section extending from the Athabasca River on the west, to the Muskeg River on the east, transecting the tailings settling pond toward its southern end, where the tailings settling pond is nearest to both rivers, as shown in Figure E3-1. SEEP/W modelling software was also used for these calculations.

A finite element model was constructed for each of the nine snapshot times. Each model reflects the approximate tailings settling pond configuration and tailing/water elevations expected for that time. The tailings settling pond models include perimeter ditches 5 m deep on both east and west sides of the tailings settling pond. In the model, the perimeter ditches extend 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 to both the Athabasca

River and Muskeg River for each snapshot time. For each snapshot time, the model, which is run as a steady-state flow simulation, assumes that equilibrium or near equilibrium conditions have been attained.

E3.5 Key Question GW-1: Will the Muskeg River Mine Project Change Groundwater Levels And Groundwater Flow Patterns?

E3.5.1 Analysis of Potential Linkages

Linkage GW-1.1: Between Overburden Dewatering and Groundwater Levels in Surficial Aquifers.

The calculated discharge rates of groundwater that will be collected by the overburden dewatering ditches are given in Table E3-1. Considering a 4 m thickness of overburden to be the most representative case, the water balance results show overburden discharge rates at the start of dewatering to be 38 to 40 m^3/h, reaching a maximum of 109 to 114 m^3/h 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 E3-3. 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 5×10^{-4} m/s (i.e., a low K case) and for high and low groundwater recharge conditions (5.7 and 7.9 $m^3/h/km^2$, respectively, Alsands Energy Ltd. 1981), as calculated using the SEEP/W model for a generic ditch. Figure E3-3 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.

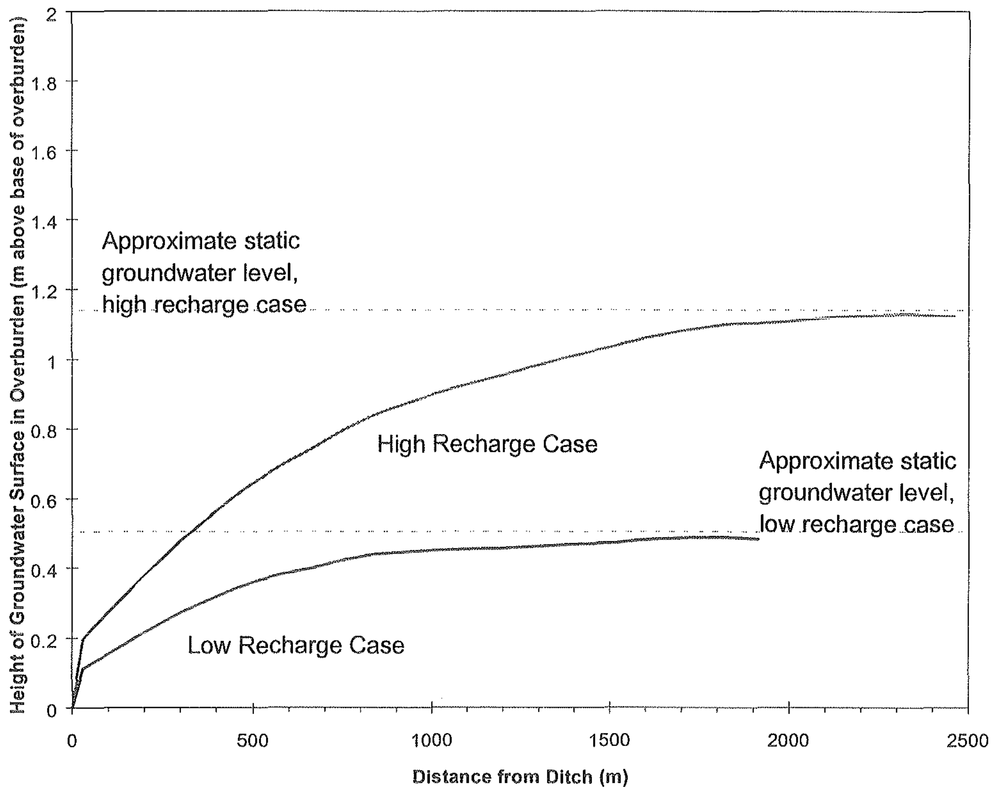
Consequently, this analysis leads to the conclusion that overburden dewatering will lower groundwater levels in surficial aquifers within 1 to 2 km of the Project area, and therefore linkage GW-1.1 is valid.

Linkage GW-1.2 Between Basal Aquifer Depressurization and Lowered Groundwater Levels in the Basal Aquifer.

Table E3-1 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
2000 - 2022	**44**	**48**	**78**	**82**	**112**	**116**	**21**	**42**	**83**	**166**	**187**	**374**

Figure E3-3 Groundwater Surface Adjacent to One Overburden Dewatering Ditch



Basal Aquifer depressurization is designed to reduce the groundwater level in the Basal Aquifer to an elevation below the base of the mine pit. In the Project area, this requires a drawdown of between 39 and 80 m, with an average drawdown of 48 m. To achieve this drawdown requires pumping groundwater from the Basal Aquifer at an average rate of 218 m^3/h, or approximately 5,200 m^3/d. Table E3-2 summarizes the groundwater discharge rate for Basal Aquifer depressurization for average transmissivity and drawdown conditions, and also for minimum and maximum transmissivity and drawdown conditions. The mean discharge rate over the 23-year period ranges from 90 to 459 m^3/h. Over the dewatering period, the discharge rate peaks in 2012, with an average of 459 $^{m3}/h$, and a range from 194 to 1,018 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 kilometres of the mine pit. Figure E3-4 shows the distance drawdown relationship for the Basal Aquifer, for long-term steady-state pumping at the discharge rate required to produce the average required drawdown (48 m) 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. These calculations lead to the conclusion that groundwater levels in the Basal Aquifer will be lowered within 30 to 40 km of the mine, and therefore linkage GW-1.2 is valid.

E3.5.2 Analysis of Key Question

Overburden dewatering for the Project will reduce groundwater levels within 1 to 2 km of the mine pit, and will remove surficial aquifers by mining within the mine pit itself. In the natural setting, shallow groundwater discharges to streams and wetlands, and recharges deeper groundwater systems. The lowering of groundwater levels will affect groundwater flow patterns by directing groundwater from surficial aquifers into the dewatering system, and not toward natural discharge areas. The shallow groundwater collected by the overburden dewatering system will, however, be released to the surface water drainage system, which will help mitigate the interception of natural baseflow.

Basal Aquifer depressurization will lower groundwater levels in the Basal Aquifer up to 40 km from the mine, however, over most of the RSA this aquifer is overlain by a substantial thickness of low-permeability oil sands or lean oil sands. These low-permeability materials will inhibit the transmission of the reduced hydraulic head to shallower groundwater systems or to surface waterbodies.

A potential concern from the lowering of groundwater levels in the Basal Aquifer is the possibility that this may induce seepage from important surface waterbodies such as Kearl Lake. Under natural conditions, Kearl Lake, which is assumed to have an elevation of 334 masl, is separated from the Basal Aquifer by approximately 80 m of low-permeability oil sands, fine-textured Cretaceous sediments and Quaternary deposits. Consequently, under natural conditions, the groundwater level in the Basal Aquifer, at approximately 315 masl, is 19 m lower than the lake level, therefore there is a downward-directed vertical hydraulic gradient of 0.24, with downward seepage from the lake at a rate of 15 mm/a, assuming a hydraulic conductivity of $2x10^{-9}$ m/s for the intervening oil sands.

Table E3-2 Basal Aquifer Discharge

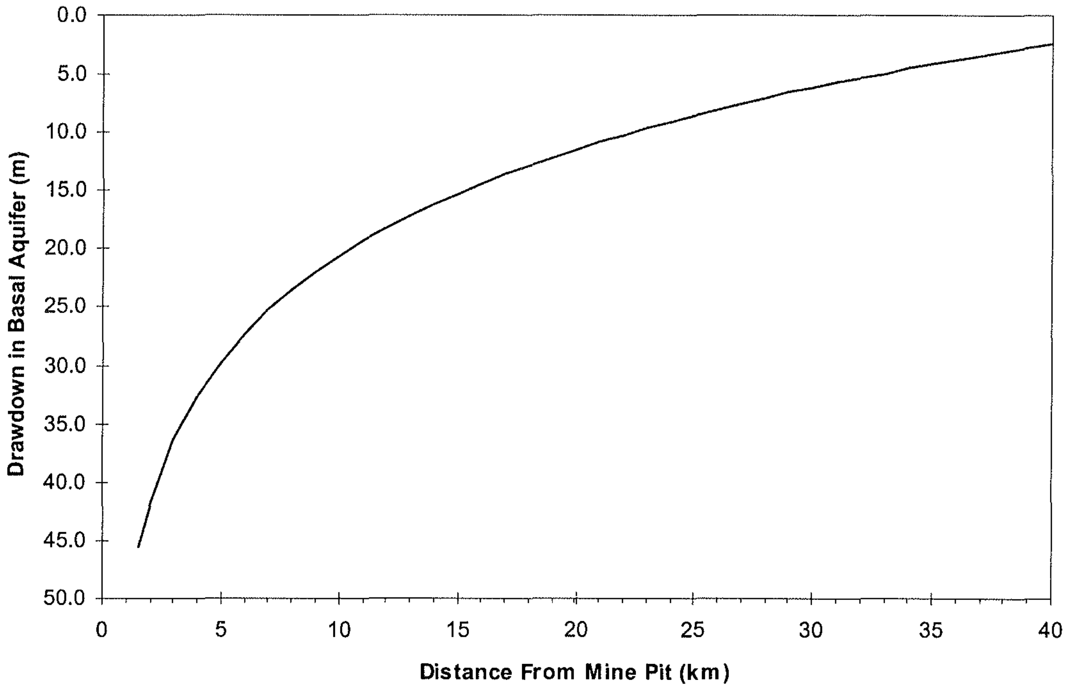
	Basal Aquifer Discharge (m^3/hr)		
Year	**Mean[(a)]**	**Minimum[(b)]**	**Maximum[(c)]**
2002	326	87	707
2003	250	59	562
2004	216	49	493
2005	216	49	493
2006	216	49	493
2007	233	82	752
2008	176	55	596
2009	151	46	523
2010	151	46	523
2011	151	46	523
2012	459	194	1018
2013	359	141	827
2014	313	120	734
2015	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.

Kearl Lake is situated approximately 12 km from the proposed mine pit. From Figure E3-4, at a distance of 12 km the drawdown in the Basal Aquifer is approximately 18 m. Drawdown of this magnitude will increase the vertical hydraulic gradient beneath Kearl Lake to 0.46, which corresponds to a downward seepage rate of 29 mm/a, an increase of 14 mm/a. This value represents 3% of average annual precipitation received by the lake.

A similar concern regarding induced seepage losses has been expressed for McClelland Lake. McClelland Lake is located approximately 18 km north-east of the Muskeg River Mine Project development area. The southern shore of the lake is beyond the subcrop of the Basal Aquifer according to the published bedrock geology map for the area, by the Alberta Research

Figure E3-4 Steady State Drawdown in Basal Aquifer With Distance From the Mine Pit



Council (Green and Mellon 1962, Carrigy and Green 1965). Since there is no hydraulic connection through the low-permeability Devonian strata beneath the lake, it is not expected that the Project development will have any impact on water levels in McClelland Lake.

The potential to drawdown the water level in Isadore's Lake was investigated. Under natural conditions, Isadore's Lake appears to be in hydraulic equilibrium with the Basal Aquifer. The elevation of the lake is estimated to be 233 masl, and the hydraulic head in the Basal Aquifer approximately 1 km east of the Lake, at site MW97-42, is about 231 masl (Golder 1997a). Assuming the head in the Basal Aquifer will decrease to the west, as indicted by the regional hydraulic gradient (Komex 1997), then the head in the Basal Aquifer beneath Isadore's Lake is estimated to be approximately 230 masl, giving a head difference of 3 m between the lake and the Basal Aquifer. Beneath the Athabasca River, the hydraulic head in the Basal Aquifer should be very similar to the level of the river, since they are hydraulically connected. Estimating the total thickness of sediments between the lake bottom and the Basal Aquifer to be about 25 m, and assuming that one-half this thickness is low-permeability lean oil sands, then the natural vertical hydraulic gradient beneath the lake is estimated to be about 0.24 (downward). Assuming the lean oil sands has a vertical hydraulic conductivity of $1x10^{-8}$ m/s, then the seepage from Isadore's Lake to the Basal Aquifer is 95 m^3/d, under natural conditions. Note that this analysis is a simplification since it does not consider seasonal variations in water levels.

Basal Aquifer depressurization will lower the head in the Basal Aquifer beneath the mine by about 46 to 60 m, at distances ranging from 4,400 to 8,000 m from Isadore's Lake. This corresponds to a horizontal hydraulic gradient of 0.006 to 0.01. Drawdown of the Basal Aquifer immediately beneath Isadore's Lake is expected to be insignificant, since the Athabasca River will act as a recharge boundary for the Basal Aquifer. Consequently, drawdown in the Basal Aquifer beneath the river is expected to be negligible, and Isadore's Lake is immediately adjacent to the Athabasca River. Therefore, only lateral seepage losses from Isadore's Lake may be expected. If lateral seepage occurs around the eastern perimeter of the lake (approximately 1,500 m) through a vertical cross-section of alluvial sediments 5 m thick, and assuming a hydraulic conductivity of the sediments to be $1x10^{-5}$ m/s, then this lateral groundwater seepage from Isadore's Lake could be up to 68 m^3/d in addition to the natural seepage. This seepage estimate reflects worst-case conditions, since there is not a continuous horizon of high hydraulic conductivity material from the lake to the mine pit, but in fact a substantial thickness of low-permeability oil sands is expected to be present between the lake and the mine pit.

When dewatering ceases on completion of the Project, groundwater levels in the Basal Aquifer will recover to near pre-mining levels, with recovery occurring at a rate similar to drawdown. Consequently, the effects of Basal Aquifer depressurization on groundwater levels in the Basal Aquifer are largely reversible in the long term.

Impacts expected due to changes in groundwater levels associated with the Project are as follows:

- Overburden dewatering for the Muskeg River Mine Project will reduce groundwater levels within 1 or 2 km of the mine pit, and will remove surficial aquifers within the limits of mining.

- Basal Aquifer depressurization may cause the downward seepage out of Kearl Lake to increase from the natural rate of 15 mm/a to a rate of 29 mm/a when aquifer drawdown is at its maximum.

- Basal Aquifer depressurization is not expected to have any impact on water levels in McClelland Lake, since this lake is beyond the outcrop of the Basal Aquifer.

- Basal Aquifer depressurization may cause groundwater seepage out of Isadore's Lake to increase by up to 68 m^3/d under worst-case conditions, compared with seepage losses of 95 m^3/d under natural conditions.

E3.5.3 Residual Impact Classification and Degree of Concern

The dewatering of overburden and depressurization of the Basal Aquifer will lower groundwater levels from their natural state. The direction of residual impact is considered to be negative, relative to the natural condition and the magnitude of impact low to moderate. The impact is expected to be limited to the Project LSA, so the geographic extent is considered to be local. The groundwater levels will recover within about 2 to 30 years after mining, the duration of the impact is medium to long-term. The reduced groundwater levels represent a temporary change, although the reduction will persist year-round so the frequency is high. Overall, the degree of concern related to lowering of groundwater levels due to dewatering/depressurization, is considered to be low.

E3.5.4 Monitoring

Groundwater monitoring wells will be installed in surficial aquifers and the Basal Aquifer in selected locations around the perimeter of the mine pit. Groundwater levels in these wells will be monitored periodically, to assess the performance of the overburden dewatering and Basal Aquifer depressurization systems, and to monitor the magnitude of drawdown in the adjacent unmined overburden and Basal Aquifer.

E3.6 Key Question GW-2: Will Groundwater Systems Re-Establish After Mining And Reclamation?

The linkage associated with this key question is as follows:

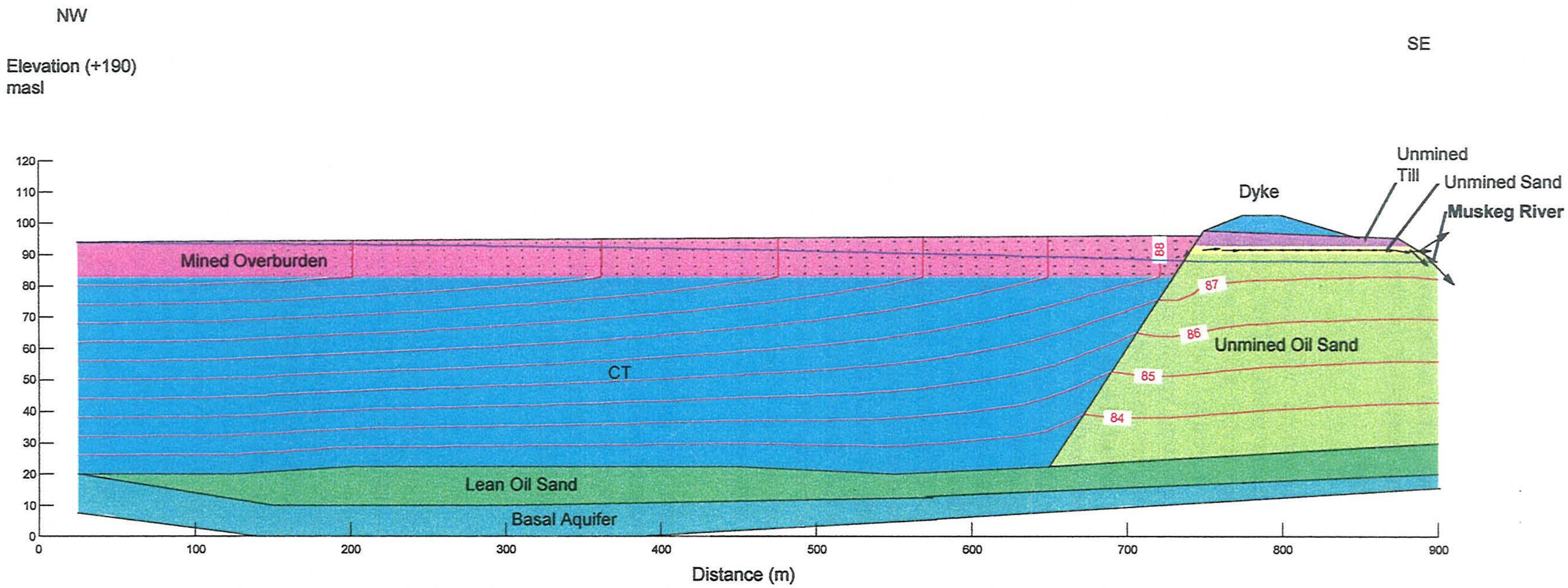
Linkage GW-2.1	Between mining/reclamation and recovery of groundwater levels and groundwater flow systems re-establishment in the post-development landscape.

The reclaimed landscape will be characterized by differences in topography and drainage relative to the natural landscape. In addition, subsurface materials within the mine pits will be different than the overburden and oil sands that are in place in the natural landscape. The natural hydrogeologic regime reflects, in part, relatively flat topography superimposed on a geologic sequence that can be characterized as a relatively thin, relatively permeable veneer of surficial sediments and muskeg, over a great thickness of low-permeability oil sands, all of which is underdrained by the permeable Basal Aquifer. In relative terms, the reclaimed landscape will have many similarities to the natural landscape. The veneer of surficial sediments will be replaced by a cap of relatively permeable mined overburden or tailings sand; this will overlie a relatively great thickness of low-permeability consolidated tailings. Although the hydraulic conductivity of the replaced materials will not be the same as the natural materials, a substantial permeability contrast is still expected to exist. This condition is expected to play a significant role in re-establishment of groundwater flow systems in the reclaimed landscape that are expected to be similar in nature to the natural flow systems.

The type of groundwater flow systems likely to re-establish in the reclaimed landscape are illustrated in Figure E3-5, which shows the results from a two-dimensional, finite element groundwater flow model for one of the vertical cross-sections. The model results indicate that groundwater levels will re-establish in the reclaimed landscape, and the following general pattern of groundwater flow will develop. Horizontal flow, directed outward from the mine, will dominate in the relatively permeable overburden or tailings sand capping materials. In the underlying CT, downward-directed vertical flow will dominate, with vertical seepage into the underlying lean oil sands and/or Basal Aquifer. This pattern is similar to the natural groundwater flow systems, in which horizontal flow dominates in the surficial sand aquifers, with vertical, downward-directed flow through the oil sands, into the Basal Aquifer.

The magnitude of groundwater recharge likely to occur in the reclaimed landscape is difficult to predict, however, the modelling results suggest that groundwater recharge rates in the reclaimed landscape will be lower than under natural conditions, reflecting the generally lower permeability of the reclaimed materials. The recharge rates in simulations that produce reasonable post-development groundwater surface elevations, range from 5 to 16 mm/a in overburden-capped CT pits, and from 16 to 31 mm/a in sand-capped CT pits. The recharge rates assume a hydraulic conductivity for CT of $1x10^{-9}$ m/s, for overburden cap material of $1x10^{-7}$ m/s, and for tailings sand cap of $1x10^{-6}$ m/s. Groundwater recharge rates under natural conditions were estimated to range from 50 to 69 mm/a (Alsands Project Ltd. 1981).

With reduced groundwater recharge rates and somewhat lower permeability materials than the natural setting, groundwater from the perimeter of the mined areas should be readily drained away from the reclaimed land by natural groundwater flow systems in the relatively permeably surficial sand (K = 1x10-4 m/s). As shown in Figure E3-5, in most cases the groundwater



NOTES

Contours are hydraulic head, (+190 m) asl

Groundwater surface

Location of Cross Section 1-1 shown in Figure E3-1

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 E3-5	

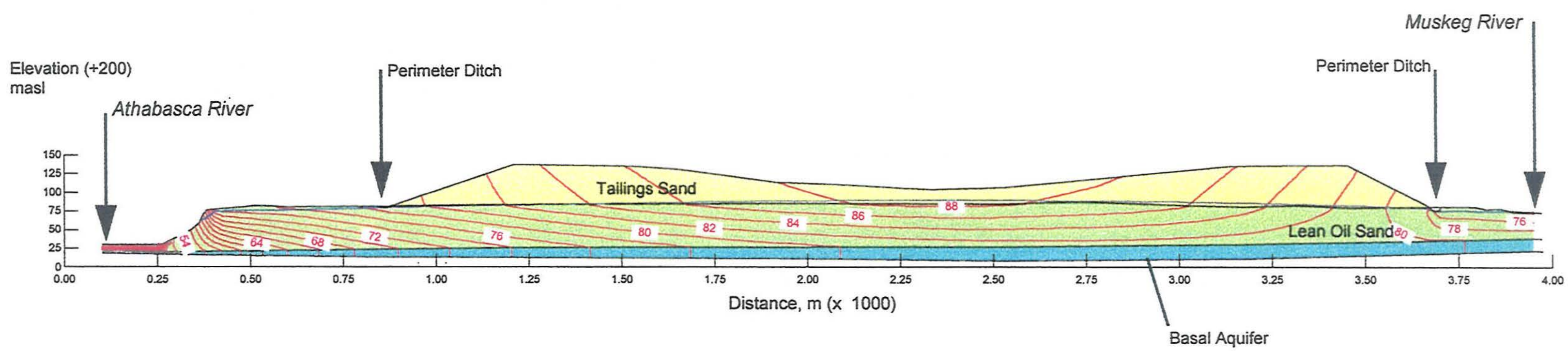
surface elevation in the reclaimed lands may be very shallow (less than 1 or 2 m below ground surface) in the centre of a reclaimed pit. Near the perimeter of the Project the groundwater surface is likely to be deeper than under natural conditions. This is because the relatively low rate of lateral seepage from the mine perimeter is very readily drained by the high-permeability surficial sand.

A groundwater flow system will also become established under the reclaimed tailings settling pond. The simulation results in Figure E3-6 show the groundwater levels and groundwater flow patterns that may develop within and beneath the tailings structure after mining and reclamation. The simulation results suggest that the groundwater surface within the tailings structure will be approximately 5 m above the natural ground surface, and about 14 m below the reclaimed ground surface. Groundwater will flow downward and outward from the tailings structure. The seepage exiting the tailings sand will encounter unmined surficial overburden, and groundwater flow will be dominantly horizontal in this unit, discharging primarily to the perimeter ditch system. The simulation results indicate that there will also be a vertical component of seepage from the tailings structure. This vertical seepage will pass into the lean oil sands beneath the surficial overburden. Groundwater flow within the lean oil sands will have both vertical and horizontal components, with vertical seepage exiting into the Basal Aquifer. Horizontal groundwater flow will partially bypass the perimeter ditch system, and will discharge into the Muskeg River on the east side of the structure, and into the Athabasca River or Isadore's Lake, on the west side of the structure.

The results of this analysis indicate that groundwater flow systems will re-establish in the reclaimed landscape. These groundwater flow systems will be similar in many ways to the natural groundwater systems, however, the post mining groundwater regime will be different than the natural regime. Consequently, linkage GW-2.1 is valid.

E3.6.1 Analysis of Key Question

The re-establishment of groundwater flow systems during the operations phase and in the reclamation and closure phase, was evaluated at the nine snapshot times for each of the vertical cross-sections (where applicable) shown in Figure E3-2. The simulations show a general pattern of seepage into the mine pits from undeveloped areas during operations and into closure, with outward seepage from the mine perimeter in the closure period and beyond. The results of the seepage calculations are given in Table E3-3 (at the end of Section E3). Along the eastern side of the mine, ultimate seepage rates from reclaimed areas in pits 1, 2 and 5 into the Muskeg River total 106.1 m^3/d. The west side of the mine is almost entirely bounded by the end pit lake. The simulation results indicate that there will not be any seepage of porewater from CT disposal or overburden-backfilled pits westward (laterally) from the Project area to the Athabasca



NOTES

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

— Groundwater surface

Location of Cross Section 7B shown in Figure E3-1

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** E3-6	

River. As shown in Table E3-3, the end pit lake is expected to lose water to the groundwater system, with lateral seepage from the end pit lake discharging ultimately to Isadore's Lake at a rate of 26.6 m^3/d, plus seepage losses to the Basal Aquifer of 103 m^3/d. The seepage simulations conducted for the end pit lake include 12.5 m of mature fine tails (MFT) in the bottom of the lake. The lateral seepage to Isadore's Lake will be fresh water from the water cap of the lake. Any seepage through the MFT moves vertically downward into the Basal Aquifer and becomes seepage to the Basal Aquifer.

From the CT disposal pits into the Basal Aquifer is estimated to total 255 m^3/d, from pits 1, 2, 3, 4 and 5 (Table E3-3). To put these seepage rates in perspective, total groundwater horizontal discharge through the Basal Aquifer under the mine can be estimated for natural conditions from the hydraulic conductivity ($5x10^{-5}$ m/s) and horizontal hydraulic gradient (0.002) reported by Komex (1997) together with the average thickness of the Basal Aquifer, estimated to be approximately 7 m and the length of the mine perpendicular to groundwater flow direction in the Basal Aquifer (approximately 5,000 m). From Darcy's Law (Q=KiA, where K-hydraulic conductivity, i = hydraulic gradient, and A = cross-sectional area of flow) the daily total discharge (Q) through the Basal Aquifer is estimated to be 300 m^3/d. Consequently, the estimated seepage from CT pits corresponds to 85% of this discharge, which clearly represents a significant proportion of the total flow through the Basal Aquifer beneath the mine.

Deep groundwater seepage from the tailings settling pond and reclaimed tailings structure will discharge to the Muskeg River, Athabasca River and Isadore's Lake, as indicated by the seepage discharges given in Table E3-3. In the Far Future, calculated discharge rates are on the order of 200 to 300 m^3/d, for each of the discharge nodes. During the operational period of the tailings settling pond, seepage discharge to Muskeg River is higher than in the far future, due to the high hydraulic head that is present in the liquid-filled tailings settling pond. During the operational period, the perimeter ditches on the west side of the tailings settling pond intercept a greater proportion of the seepage than in the far future case, and seepage discharge from the tailings settling pond to the Athabasca River and Isadore's Lake are lower than in the far future case.

Impacts of the Project on the re-establishment of groundwater systems are summarized as follows:

- After mining, horizontal groundwater flow, directed outward from the reclaimed mine, will dominate in the relatively permeable overburden or tailings sand capping materials. In the underlying CT, downward-directed vertical flow will dominate, with vertical seepage into the underlying lean oil sands and/or Basal Aquifer.

- There will be no seepage of porewater from CT disposal or overburden-backfilled pits westward (laterally) from the Project area to the Athabasca River.

- Along the eastern side of the Project area, lateral seepage from reclaimed areas in pits 1, 2 and 5 will discharge into the Muskeg River.

- The end pit lake is expected to lose water to the groundwater system, with lateral seepage from the water cap of the end pit lake discharging ultimately to Isadore's Lake and vertical seepage losses to the Basal Aquifer.

- Vertical seepage from the CT disposal pits 1, 2, 3, 4 and 5 into the Basal Aquifer will comprise a substantial proportion of post-development groundwater flow through the Basal Aquifer beneath the mine.

- Deep groundwater seepage from the tailings settling pond and reclaimed tailings structure will discharge to the Muskeg River, Athabasca River and Isadore's Lake.

E3.6.2 Residual Impact Classification and Degree of Concern

The groundwater flow systems and groundwater levels that re-establish after mining will be altered from their natural state. However, the groundwater flow patterns will be similar to the natural state, so the direction of residual impact is considered to be neutral, and the magnitude of impact low to moderate. The impact is expected to be limited to the Project LSA, so the geographic extent is considered to be local. The post-development groundwater flow systems will exist far into the future, so the duration of the impact is long-term. The altered groundwater flow systems represent a continuous or ongoing change so the frequency is high, and the changes will persist year-round. Overall, the degree of concern related to re-establishment of groundwater flow systems, in terms of groundwater quantity, is considered to be low.

E3.6.3 Monitoring

Monitoring of recovery of groundwater levels, and re-establishment of post-development groundwater flow systems will be accomplished by installation of monitoring wells at selected sites within and adjacent to reclaimed mine pits and the reclaimed Tailings Structure. It will be possible to monitor groundwater levels in the wells periodically over time to establish recovery trends and provide a basis for projecting equilibrium levels.

E3.7 Key Question GW-3: Will the Muskeg River Mine Project Change Groundwater Quality?

The potential for impact on groundwater quality is associated with seepage of porewater from consolidated tailings or tailings sand into the natural hydrogeologic regime. The water quality characteristics of CT seepage and tailings sand seepage are summarized in Table E3-4, which gives the upper range of parameter concentrations, as provided by Golder Associates.

The linkages associated with this key question are as follows:

Linkage GW-3.1 Between Seepage of Consolidated Tailings Porewater From In-Pit Disposal Areas and Groundwater Quality in the Basal Aquifer.

As discussed in Section E3.6, the rate of vertical seepage from CT disposal pits into the Basal Aquifer is estimated to total 255 m^3/d under far future conditions, representing 85% of the estimated natural discharge of groundwater through the Basal Aquifer beneath the Project area. Natural groundwater quality in the Basal Aquifer is discussed in detail by Komex (1997), and in the vicinity of the mine, can be characterized as $Na\text{-}Cl\text{-}HCO_3$ or $Na\text{-}HCO_3\text{-}Cl$ type water, with total dissolved solids (TDS) concentrations ranging from 2,000 to 7,400 mg/L, although generally TDS concentrations are between 3,000 and 4,000 mg/L. Chloride concentrations are commonly between 500 and 2,000 mg/L, and sulphate concentrations are typically less than 60 mg/L. Consequently, the quality of groundwater in the Basal Aquifer is not considered to be potable.

Consolidated tailings porewater seepage is a $Na\text{-}SO_4$ type water, with TDS of up to 1,780 mg/L. Chloride concentration is less than 70 mg/L, and sulphate concentration is up to 1,270 mg/L. In addition, CT seepage exceeds maximum acceptable concentrations of benzo(a)pyrene, cadmium, lead, mercury, and uranium for drinking water, as established by Health Canada (1996).

The water quality of CT seepage is substantially different than the natural groundwater in the Basal Aquifer, therefore seepage of CT porewater from in-pit disposal areas will alter the groundwater quality in the Basal Aquifer. Consequently, linkage GW-3.1 is valid.

Linkage GW-3.2 Between Seepage of Consolidated Tailings Porewater From In-pit Disposal Areas and Groundwater Beyond the Mine Pits.

The groundwater flow patterns that re-establish in reclaimed CT disposal pits, as discussed in Section E3.6 and illustrated in Figure E3-5, indicate that the great majority of porewater seepage from CT will migrate downward into the Basal Aquifer. Conversely, the great majority of lateral seepage, outward from the reclaimed pits, will take place through the recast overburden or tailings sand that caps the CT. Consequently, as a general rule, the lateral seepage from the mine pits will be overburden or tailings sand porewater. A significant exception to this general rule is the penetration of upward seepage of porewater from the CT during the consolidation period of the CT. Presumably, this upward seepage will mix with and displace pre-existing overburden or tailings sand porewater, and may be subsequently transported beyond the Project perimeter with seepage from overburden or tailings sand cap material. Although this CT porewater will be diluted by both overburden/sand cap porewater plus any groundwater recharge, it is prudent to consider the possibility that a pulse of full-concentration CT porewater could migrate laterally out of the capping materials.

Assuming that one pore volume of recast overburden will be filled with CT porewater (any additional CT porewater being collected as seepage in the surface drainage system), then it is possible to estimate the time required to flush one pore volume from the overburden cap due to recharge from precipitation. The recharge rate in overburden-capped CT was estimated in Section 3.6, and ranges from 5 to 16 mm/a. Assuming that the overburden cap has a porosity of 0.33, and assuming plug displacement without mixing, then the recharge from one year will displace porewater in 5 mm/0.33 = 15 mm to 16 mm/0.33 = 48 mm of overburden cap material. The thickness of overburden cap is about 13 m in Pit 1, 7 m in Pit 2 and 15 m in Pit 3. Therefore, to displace one pore volume of water from the full thickness of overburden cap, at the above rates, would take 270 to 860 years (Pit 1), 140 to 460 years (Pit 2), and 310 to 990 years (Pit 3). Consequently, one pore volume of CT porewater within the overburden cap materials represents a relatively long-term source of degraded groundwater quality.

The seepage calculations in Section E3.6 indicate that the total lateral discharge from the Project area to the Muskeg River would be 106 m^3/d. This seepage from in-pit CT disposal areas will flow into either unmined oil sands adjacent to the mine, or into Quaternary sediments beyond the mine. Groundwater in the oil sands in the mine area is of Na-, Na-Ca-, or Na-Ca-Mg-HCO_3 hydrochemical type, with TDS ranging from 840 to 2,150 mg/L (Komex 1997). Chloride and sulphate concentrations are less than 70 mg/L. Groundwater in Quaternary sediments in the mine area is commonly of Ca-Mg- or Na-Ca-Mg-HCO_3 hydrochemical type, with TDS concentration between 300 and 750 mg/L (Komex 1997). Chloride concentrations are less than 25 mg/L, and sulphate concentrations are less than 50 mg/L. The water quality of CT seepage, as summarized above, is of comparable TDS, but much higher in sulphate than groundwater in the oil sands. CT seepage water quality is very different from natural groundwater in Quaternary sediments, exceeding the natural concentrations of all indicator parameters.

It is evident that seepage of CT porewater from CT disposal pits will alter groundwater quality in either unmined oil sands or Quaternary surficial sediments in unmined areas adjacent to the Project area, where such seepage is expected to occur. The calculations of lateral seepage from reclaimed mine pits, presented in Section 3.6, indicate that no seepage from CT disposal pits will discharge laterally to the Athabasca River or Isadore's Lake, because there is no continuous horizontal flowpath. All seepage to the west of the mine, from CT pits, moves vertically into the Basal Aquifer, which is assumed to ultimately discharge into the Athabasca River.

The calculations in this section indicate that porewater from CT disposal pits may migrate laterally from the mine pits through groundwater in adjacent unmined areas, to the Muskeg River. Consequently, linkage GW-3.2 is valid.

Linkage GW-3.3 Seepage of Tailings Sand Porewater From the External Tailings Facility Into Groundwater.

The groundwater flow patterns that re-establish around the tailings settling pond during operations, and in the reclaimed tailings structure in the closure landscape, as discussed in Section E3.6, indicate that seepage of tailings porewater into groundwater adjacent to the tailings settling pond will occur both during operations and on closure. The perimeter ditch system around the tailings settling pond will intercept any groundwater flow through the surficial sediments, so any seepage from the tailings settling pond that bypasses the ditch will have to flow through the lean oil sands that underlies the surficial sediments.

The groundwater quality in the McMurray Formation oil sands (or lean oil sands) in the vicinity of the tailings settling pond is quite variable, but is generally Ca-Mg or Ca-Mg-Na-HCO_3 type water, with TDS ranging from 270 to 1,460 mg/L (Komex 1997). Tailings sand seepage water is expected to be Na-HCO_3 type water, with TDS of approximately 1,300 mg/L, which is generally similar to the upper range of natural groundwater quality. None of the water quality parameters for tailings sand seepage in Table E3-4 exceed maximum acceptable concentrations for drinking water, as established by Health Canada (1996), although iron, manganese, sodium and total dissolved solids exceed aesthetic objectives for drinking water. However, in view of the dominance of sodium as the main cation, and elevated TDS relative to the least saline groundwater from the oil sands, seepage of tailings sand porewater may alter the groundwater quality beneath and adjacent to the tailings settling pond, therefore this linkage is valid.

Table E3-4 Summary of Water Quality in CT and Tailings Sand Porewater

Type of Drainage		CT Porewater Seepage	Tailings Sand Porewater Seepage	Drinking Water Quality Guidelines (mg/L) [a]
Parameter	units	Max.	Max.	
Aluminum -Total	mg/L	1.92	0.01	-
Ammonia -Total	mg/L	6.31	10.76	-
Antimony - Total	mg/L	0.0018	0.0005	-
Arsenic - Total	mg/L	0.007	0.000073	0.025 (IMAC)
Barium - Total	mg/L	0.16	0.064	1
Benzo(a)anthracene	mg/L	0.0016		
Benzo(a) Pyrene	mg/L	0.0005		0.00001
Beryllium - Total	mg/L	0.006		
Boron - Total	mg/L	3.74		5 (IMAC)
Cadmium - Total	mg/L	0.0066	0.005	.005(IMAC)
Calcium	mg/L	157	25	-
Chloride	mg/L	67	19	≤250 (AO)
Chromium - Total	mg/L	0.023	0.005	0.05
Conductivity	mg/L	2402		-
Copper - Total	mg/L	0.022	0.072	≤ 1.00 (AO)
Ethylbenzene	mg/L	0.015		≤ .0024 (AO)
Fluorene	mg/L	0.0003		-
Iron - Total	mg/L	1.01	1.52	≤ 0.3 (AO)
Lead - Total	mg/L	0.02	0.009	0.01
Lithium - Total	mg/L	0.201		-
Magnesium	mg/L	28.1	11	-
Manganese - Total	mg/L	0.065	0.187	≤ 0.05(AO)
Mercury - Total	mg/L	0.05	5E -08	0.001
Molybdenum - Total	mg/L	1.42	0.031	-
naphthalene	mg/L	0.00005		-
Naphthenic Acids	mg/L	100		-
Nickel - Total	mg/L	0.0295	0.024	-
Nitrate	mg/L	0.05	0.4	45.0
Phenolics - Total	mg/L	0.000015	0.03	-
Phosphorus - Total	mg/L	0.073	0.423	-
Pyrene	mg/L	0.00004		-
Selenium - Total	mg/L	0.00036	0.0049	0.01
Silver - Total	mg/L	0.01		-
Sodium	mg/L	510	337	≤ 200(AO)
Sulphate	mg/L	1270	98.8	≤ 500(AO)
Total Dissolved Solids	mg/L	1.78E +03	1330	≤ 500(AO)
Total PAH's	mg/L	0.03176		
TSS	mg/L	17	153	
Uranium - Total	mg/L	0.5		0.1
Vanadium - Total	mg/L	0.17	0.016	
Zinc - Total	mg/L	0.08	0.113	≤ 5.0(AO)

Notes: [a] Health Canada, 1996
MAC, IMAC: Maximum Acceptable Concentration (I=Interim)
AO: Aesthetic Objective Concentration
Concentration >MAC or IMAC
Concentration>Aesthetic Objective

E3.7.1 Analysis of Key Question

In terms of groundwater resources, groundwater in the Basal Aquifer is not of potable quality, and any seepage of CT or tailings sand porewater into this unit will not change this state. Groundwater within the oil sands may or not be of potable quality, however the hydraulic conductivity of this unit is too low to support exploitation of its groundwater as a resource, and therefore, any change in groundwater quality in this unit, due to tailings sand or CT porewater seepage, will not affect the lack of groundwater resource potential of this unit. Surficial aquifers in Quaternary sediments adjacent to the Project area have sufficient permeability and water quality to be potentially exploited for groundwater use. However, these aquifers in the Project area have not been exploited in the past, and with the exception of buried valley-type surficial aquifers, which will not be impacted by the Project, the setting of the shallow surficial aquifers (in a remote area, immediately adjacent to a mine site) makes any future exploitation of this groundwater resource unlikely.

Seepage of CT porewater is expected to impact groundwater quality in the Basal Aquifer beneath the CT-disposal pits. Once mixed with groundwater in the Basal Aquifer, the seepage from the CT disposal pits will migrate toward the discharge area, presumably in the Athabasca River. Assuming that the equilibrium post-development hydraulic head distribution in the Basal Aquifer is similar to natural conditions, the advective transport of the diluted CT porewater in the Basal Aquifer will occur at the average linear porewater velocity in the Basal Aquifer. This velocity can be estimated using values reported by Komex (1997), and applying Darcy's Law (i.e., $v=Ki/n$, where v is the average linear porewater velocity, K is the hydraulic conductivity ($5x10^{-5}$ m/s), i is the horizontal hydraulic gradient (0.025 in the steep-gradient zone west of the mine), and n is the effective porosity, assumed to be 0.2 (intergranular porosity). This gives an estimated groundwater velocity of 197 m/a. Assuming the Athabasca River to be 3 km from the western edge of the mine pit, the travel time for this diluted porewater to reach the Athabasca River by advection only, is estimated to be 15 years after groundwater levels in the Basal Aquifer have returned to an equilibrium state in the far future setting.

Lateral seepage of CT-derived porewater is expected to impact groundwater quality to the east of the Project area. The advective travel time for CT porewater to flow through the undeveloped oil sands and reach the Muskeg River can be estimated from the groundwater velocities calculated in the numerical simulations for each cross-section. Using Cross-section 1-1 (Figure E3-2, Figure E3-5) as an example, approximating worst-case conditions since it is located where Pit 1 is closest to the Muskeg River (160 m), and assuming an effective water-filled porosity of 0.01 in the undeveloped oil sands, the average linear porewater velocity through the oil sands is 0.16 m/a. The time to travel 160 m by advection only is therefore 1,000 years. A supplementary analysis can also be conducted assuming that groundwater flow occurs along the base of the surficial sand unit, which is only partially saturated, as shown in Figure E3-5. In this case, with groundwater flow through the surficial sand, and assuming an effective porosity of 0.2 (intergranular), v = 11.4 m/a, the corresponding travel time is 14 years.

The perimeter ditch around the tailings settling pond will cut through the surficial sediments, and extend into underlying lean oil sands. Lateral seepage that bypasses the perimeter ditch from the tailings settling pond must therefore flow through lean oil sands on its flowpath to discharge points in either the Muskeg or Athabasca rivers. The simulation results indicate nearly the entire groundwater flow path from the tailings settling pond to the Muskeg or Athabasca rivers is through lean oil sands. On the east side of the tailings settling pond, the groundwater velocity in the oil sands through the operation and closure periods, assuming a water-filled effective porosity of 0.05, ranges from 0.06 to 1.9 m/a, with a time-weighted average velocity of 0.95 m/a. The advective travel time for groundwater to flow a distance of 270 m to the Muskeg River, at the average velocity, is therefore 284 years. In the worst case, groundwater could possibly bypass the perimeter ditch flowing through only 30 to 50 m of lean oil sands before re-entering the surficial sediments downgradient of the ditch. In this case, groundwater might, for example, flow through 30 m of lean oil sands, and 240 m of surficial sand. From the simulation results, groundwater velocity in the surficial sand to the west of the tailings settling pond averages 95 m/a, assuming an effective porosity of 0.2. In this case the travel time for tailings sand seepage to reach the Muskeg River would consist of 32 years to flow through 30 m of lean oil sands, and 2.5 years to flow through 240 m of surficial sand, for a total travel time of 34.5 years to the Muskeg River. It should be noted, however, that the simulation results indicate that this flow path is not likely, and tailings sand seepage is expected to move only through the lean oil sands on its way to the Muskeg River.

On the west side of the tailings settling pond, groundwater velocity in the lean oil sands is very similar to that on the east side. The groundwater flow path to the Athabasca River or Isadore's Lake is approximately 900 m on the west side of the tailings settling pond, and therefore travel time for tailings sand seepage to reach the Athabasca River or Isadore's Lake is on the order of 1,000 years. On the west side of the tailings settling pond, surficial sediments are not continuous to the Athabasca River, due to the presence of the steep valley wall. Consequently, tailings sand seepage must pass through a substantial thickness of lean oil sands before it can reach the Athabasca River or Isadore's Lake.

Vertical seepage of tailings sand porewater into the Basal Aquifer will mix with the natural groundwater in the Basal Aquifer. Total groundwater discharge through the Basal Aquifer can be estimated based on the hydraulic conductivity, horizontal hydraulic gradient, and cross-section area of flow using Darcy's Law, as previously discussed. The geometric mean hydraulic conductivity of the Basal Aquifer is $5x10^{-5}$ m/s, and the tailings settling pond is located in the steep gradient zone where i = 0.025 (Komex 1997). The cross-sectional area of groundwater flow beneath the tailings settling pond, assuming an average thickness of 15 m and the length of the tailings settling pond to be about 5,000 m perpendicular to the direction of groundwater flow, is 75,000 m^2. Therefore, the total groundwater discharge through the Basal Aquifer beneath the tailings settling pond, under natural groundwater conditions, is 8,100 m^3/d. Total vertical seepage from the tailings settling pond into the Basal Aquifer ranges from 1,540 to 2,480 m^3/d (Table E3-3), which represents between 19 and 31% of the natural groundwater discharge. This tailings sand seepage will mix with the natural groundwater flow on its way to the point of discharge in the Athabasca River.

Groundwater recharge through the reclaimed tailings settling pond will eventually flush out the tailings sand porewater, and replace it with fresh water. The time required for one pore volume of tailings sand water to be displaced by fresh recharge, assuming plug flow, can be estimated in the following manner. The groundwater recharge rate for the reclaimed tailings settling pond, from the numerical simulations is 159 mm/a. Assuming the porosity of the tailings sand to be 0.33, then one year's recharge will displace porewater from 159/0.33 = 482 mm of tailings sand. The thickness of tailings sand is assumed to range from about 19 m in the centre of the structure, to about 55 m at the edge. Therefore at this rate of porewater displacement, between 40 and 117 years will be required to flush one pore volume of tailings sand water from the reclaimed tailings settling pond, assuming plug flow.

Impacts of the Project on groundwater quality are summarized as follows:

- Seepage of CT porewater is expected to impact groundwater quality in the Basal Aquifer beneath the CT disposal pits, however, natural groundwater in the Basal Aquifer is not of potable quality.

- CT porewater in reclaimed overburden or sand cap materials represents a long-term source of degraded groundwater quality.

- Lateral seepage of CT-derived porewater is expected to impact groundwater quality to the east of the Project, however, the travel time for CT porewater to reach the Muskeg River is on the order of 1,000 years.

- Lateral seepage from the tailings settling pond, which bypasses the perimeter ditch, will discharge into either the Muskeg River, Athabasca River or Isadore's Lake. However, the travel time to reach the Muskeg

River is on the order of 300 years; travel time to reach the Athabasca River or Isadore's Lake is on the order of 1,000 years.

- Several decades or more will be required to flush one pore volume of tailings sand water from the reclaimed tailings settling pond.

E3.7.2 Residual Impact Classification and Degree of Concern

Groundwater quality in the Basal Aquifer beneath the mine and the tailings settling pond will be altered from the natural state. Groundwater quality in oil sands/lean oil sands, and possibly surficial sediments, to the east of CT disposal pits, and on both sides of the tailings settling pond, will also be altered from its natural condition. The direction of impact is negative, and the magnitude of impact is considered to be moderate to high. The extent of impact is expected to be limited to the Project LSA, so the geographic extent is considered to be local. The post-development change in groundwater quality will exist far into the future, so the duration of the impact is long-term. The time for flushing of CT or tailings sand porewater is sufficiently long (on the order of 100s of years) to be considered irreversible. The altered groundwater quality represent a continuous or ongoing change, therefore the frequency is high, and the changes will persist year-round. Overall, the degree of concern related to re-establishment of groundwater flow systems, in terms of groundwater quality, is considered to be low in the Basal Aquifer, and moderate to high in unmined oil sands or surficial aquifers.

E3.7.3 Monitoring

Monitoring of groundwater quality during operations and far future will be accomplished by installation of monitoring wells at selected sites within and adjacent to reclaimed mine pits and the reclaimed tailings structure. Groundwater quality in the wells will be monitored through periodic sampling over time to establish any changes or trends in groundwater quality, and provide a basis for projecting future groundwater quality.

Mitigation of seepage impacts might only be required if seepage was found to be flowing through surficial aquifers to the Muskeg River. In this event, interceptor ditches between the river and the tailings settling pond could be used to collect tailings seepage before it reaches the Muskeg River.

E3.8 Hydrogeology Impact Assessment Summary

The hydrogeology impact assessment focused on the potential effects of the Project on:

- local and regional groundwater systems;

- groundwater quality; and
- re-establishment of groundwater systems following closure of the Project.

The groundwater impact assessment considered the potential influence of the Project on water levels in area lakes, including Kearl Lake, McClelland Lake and Isadore's Lake, as well as on the Muskeg and Athabasca rivers.

Mitigation strategies applied in order to minimize potential impacts on groundwater resources include construction of a perimeter ditch surrounding the tailings settling pond. Further mitigation through the installation of interceptor ditches would only be necessary based on identification of groundwater quality changes in monitoring wells.

Groundwater levels and flow patterns will be altered from their natural state only in the LSA. The impact is considered low and the effect is reversible after mining is completed. Groundwater quality in the Basal Aquifer beneath the mine and tailings settling pond, in the oil sands/lean oil sands, possibly surficial sediments to the east of the pond and on both sides of the tailings settling pond will be altered in varying degrees from their natural state. Overall the degree of concern related to re-establishment of groundwater flow systems, in terms of groundwater quality, is considered low in the Basal Aquifer, and moderate to high in unmined oil sands or surficial aquifers.

Monitoring wells will be located by the mine pits and reclaimed tailings structure to evaluate any changes or trends in groundwater quality. Wells will also be installed to monitor the performance of the overburden dewatering and Basal Aquifer and to monitor the magnitude of drawdown in the adjacent unmined overburden and Basal Aquifer.

Table E3-3 Seepage Discharge From Mine Pits and Tailings Ponds

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	1	1-1	NA	NA	NA	S16	NA
Pre-construction Drainage	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	1	1-1	-68.8	Muskeg River	Mined Overburden	S16	0
Pre pit opening	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

Table E3-3 Seepage Discharge From Mine Pits and Tailings Ponds

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

Table E3-3 Seepage Discharge From Mine Pits and Tailings Ponds

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	1	1-1	-67.2	Muskeg River	Mined Overburden	S16	59
75% of capacity	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	1	1-1	-63.7	Muskeg River	Mined Overburden	S16	71
Processing complete	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

Table E3-3 Seepage Discharge From Mine Pits and Tailings Ponds

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	Mined Overburden/Tailings Sand	S32	NA
	6	6-1	NA	NA	Mined Overburden	S16	186
	6	6-2	22.1	End-pit Lake	Mined Overburden/Tailings Sand	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

Table E3-3 Seepage Discharge From Mine Pits and Tailings Ponds

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	Mined Overburden/Tailings Sand	S32	NA
	6	6-1	NA	NA	Mined Overburden	S16	1285
	6	6-2	6.3	End-pit Lake	Mined Overburden/Tailings Sand	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

E4 SURFACE WATER HYDROLOGY

E4.1 Introduction

This section of the Muskeg River Mine Project (the Project) EIA provides information as required by the Project Terms of Reference (TofR) issued on November 7, 1997 (AEP 1997a). Specifically, the following are addressed in this section:

- description of the sources of water to be used in the development and the options for water sourcing considered and discussion on the water management plan;
- description of alternatives considered to minimize changes to water flows in the Muskeg River and associated tributaries (TofR, Section 3.6);
- identification of the mining and development activities that may impact surface water hydrology and assess the potential impacts on local and regional hydrology;
- description of any alteration in timing, volume and duration of peak flows from the Project Area as a result of mining operations;
- description of the design parameters and plans to protect the Muskeg River and its tributaries, including the location and dimensions of buffers;
- description of the surface water monitoring program to assess the design and performance of the water management structures for handling, collection, treatment, containment and discharge;
- identification of wastewater effluents, mine depressurization waters and runoff from the Project area in terms of source, volume and seasonal timing during the life of the Project;
- description of the surface water management plans, mitigation measures and monitoring programs; and
- discussion of probable maximum flood or probable maximum precipitation events and indication on how these events influence Project design and development of contingency plans (TofR, Section 4.6).

Discussions on the potential cumulative effects on surface water hydrology associated with the Project are addressed in Section F4. Section D4 provided details on the surface water hydrology baseline for the Project.

Muskeg River Mine Project will cause some disturbance to the surface water hydrologic systems in the Local Study Area (LSA) during various phases of the Project including construction, operation and closure. For example, muskeg and overburden dewatering during construction will increase the Muskeg River flows; water withdrawal from the Athabasca river and closed-circuit water management during operational phase will reduce flows in the Muskeg and Athabasca rivers; and reclaimed surfaces on closure will have different runoff characteristics than the natural basin.

The effects of the Project on the surface water hydrology are related to the following key issues:

1. Change in flows and water levels in receiving streams, lakes, ponds and wetlands.

2. Change in water balance of nearby lakes, ponds, wetlands and streams.

3. Change in basin sediment yields and sediment concentrations in receiving streams, lakes, ponds and wetlands.

4. Change in the regime or geomorphic conditions of receiving streams.

5. Change in open-water areas including lakes and streams.

6. Sustainability of reclaimed landscape and reclamation drainage systems.

These key issues are addressed by quantifying the incremental impacts of the Project on the surface water hydrologic conditions in the LSA by the following methodology:

- identify the linkage of various Project activities with the potential changes in quantifiable hydrologic parameters;
- formulate key questions corresponding to the key issues;
- develop water management and reclamation drainage plans and design water handling facilities to minimize residual effects on the environment;
- conduct hydrologic and hydraulic analyses to quantify the residual impacts on the surface water hydrology; and
- classify the residual impacts and define the degrees of concern of these impacts.

Residual impacts on the surface water hydrology are classified based on measured physical parameters such as flow rate, erosion rate and area. The quantifiable changes in these parameters are compared with the criteria in Table E1-6 to form a basis for the impact classification. The Project impacts on the hydrology conditions in streams and lakes are evaluated based on the changes during average and extreme flood conditions. The seasonal changes and the changes during low-flow conditions are also quantified. These changes are used as input for evaluation of the Project impacts on water quality and aquatic resources in receiving waterbodies. The impacts on the surface water hydrology are not inherently or implicitly linked to the impacts on the receptors to be evaluated for aquatic resources.

E4.1.1 Potential Linkages and Key Questions

The effects of the Project on the surface water hydrologic conditions in the LSA vary in time and space. The linkages between Project activities and the key issues during construction and operation and after closure are identified and shown in Figures E4-1 to E4-3. The linkage of the Project activities to each key issue is described in Table E4-1. The quantified changes in surface water hydrology are used as input for assessment of impacts on water quality, wetlands and aquatic resources.

Table E4-1 Linkage of Project Activities to Key Issues

Key Issues		Project Phase	Project Activities Linked to Each Key Issue
No.	Description		
1	Change in flows and levels in receiving waterbodies	Construction	Infrastructure development, muskeg and overburden dewatering, site clearing, and diversion and disruption of natural drainage
		Operation	Infrastructure development, muskeg and overburden dewatering, site clearing, diversion and disruption of natural drainage, Basal Aquifer depressurization, open-pit mining, muskeg and overburden storage, tailings settling pond, plant site, closed-circuit operation and water withdrawal from the Athabasca River
		Closure	Reclaimed landscape, closure drainage systems and the end pit lake
2	Change in water balance of nearby waterbodies	Construction	mine pits and Basal Aquifer depressurization
		Operation	mine pits and Basal Aquifer depressurization
		Closure	end pit lake
3	Change in basin sediment yields and sediment concentrations in receiving streams	Construction	Infrastructure development, muskeg and overburden dewatering and site clearing
		Operation	Infrastructure development, muskeg and overburden dewatering, and site clearing
		Closure	Reclaimed landscape, closure drainage systems and the end pit lake
4	Change in channel regimes of receiving streams	Construction	Increased flows in receiving streams because of muskeg drainage and overburden dewatering
		Operation	Increased flows in receiving streams because of muskeg drainage and overburden dewatering
		Closure	Increased flows in the receiving streams because of runoff from the reclaimed surfaces
5	Change in open-water areas	Construction	Infrastructure development, muskeg drainage, overburden dewatering and site clearing
		Operation	Infrastructure development, muskeg and overburden dewatering, site clearing, open-pit mining, muskeg and overburden storage, and tailings settling pond.
		Closure	Reclaimed surfaces, closure drainage system and the end pit lake
6	Sustainability of closure landscape and drainage systems	Closure	Reclaimed landscape, closure drainage systems and the end pit lake

Figure E4-1 Surface Water Linkage Diagram, Phase: Construction

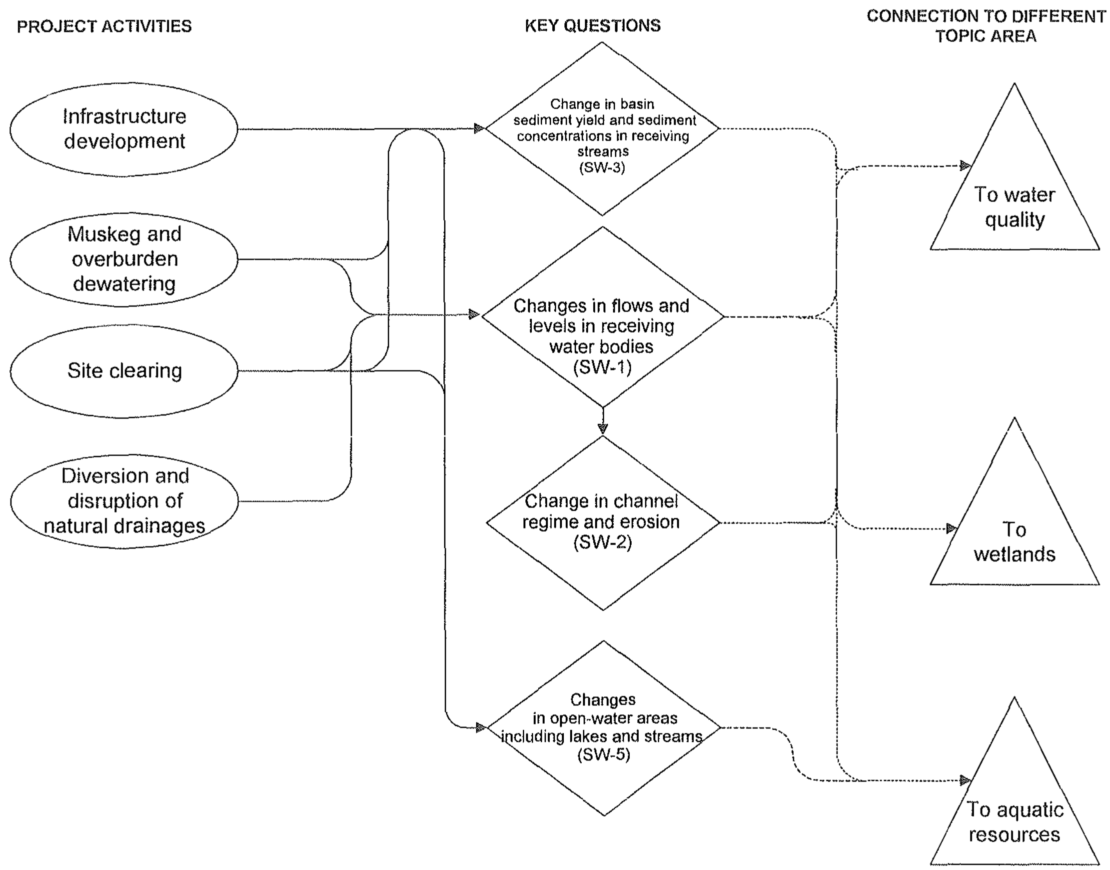


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Figure E4-2 Surface Water Linkage Diagram, Phase: Operation

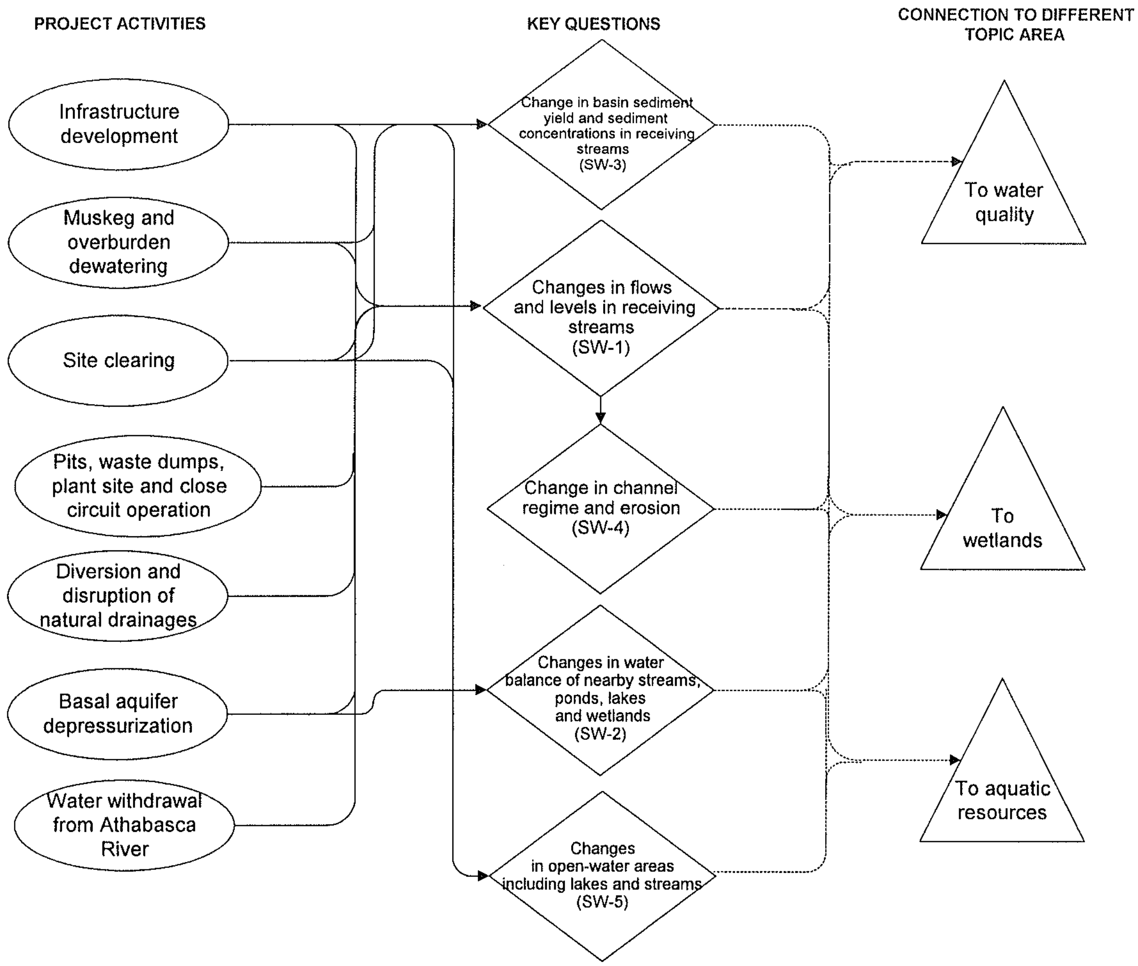

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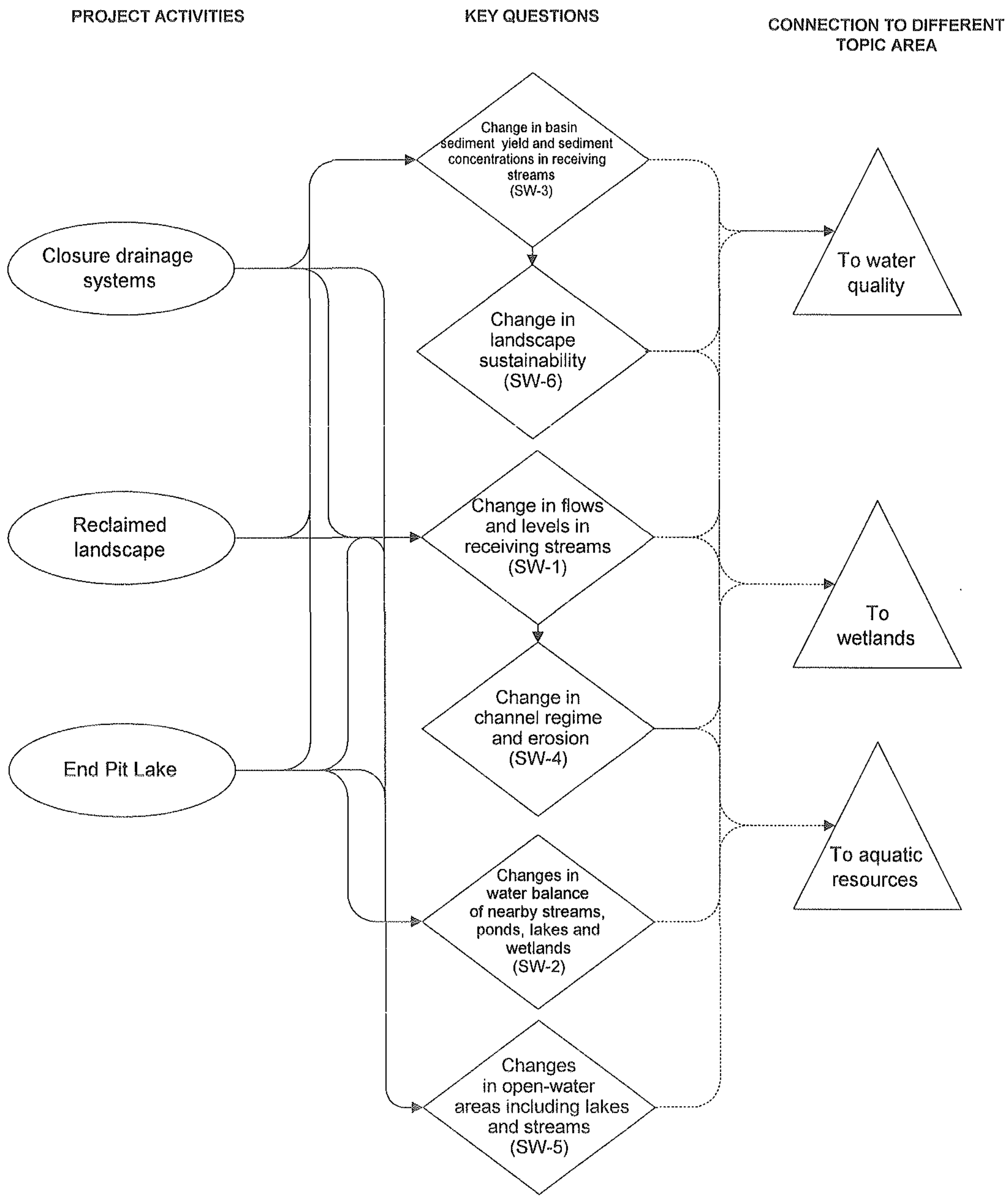
Figure E4-3 Surface Water Linkage Diagram, Phase: Closure



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The key questions which need to be addressed for assessing the Muskeg River Mine Project impacts on the surface water hydrologic conditions are itemized below. These key questions provide a framework for systematically addressing the key issues, presenting the results of the impact analysis, and assessing the residual impacts.

SW-1: Will the Muskeg River Mine Project Affect Flows and Water Levels in Receiving Streams, Lakes, Ponds and Wetlands?

SW-2: Will the Muskeg River Mine Project Affect the Water Balance of Nearby Lakes, Ponds, Wetlands and Streams?

SW-3: Will the Muskeg River Mine Project Affect Basin Sediment Yields and Sediment Concentrations in Receiving Streams?

SW-4: Will the Muskeg River Mine Project Affect Channel Regimes of Receiving Streams?

SW-5: Will the Muskeg River Mine Project Change the Open-Water Areas Including Lakes and Streams?

SW-6: Will the Muskeg River Mine Project Affect Landscape and Drainage System Sustainability After Closure?

Water Management Plan, Reclamation Drainage Plan and Mitigation Measures

A conceptual water management plan covering the operational water handling facilities and reclamation drainage systems for the Muskeg River Mine Project has been developed to enable economic development without excessive risk to operations and with minimum residual impacts on the surface water hydrologic conditions and the environment. The plans include conceptual layouts and feasibility designs of the drainage systems and the Project water handling facilities. The water management plan is presented in a supplemental technical report entitled Water Management Plan for the Muskeg River Mine Project (Golder 1997j). The design of the reclamation drainage system is represented in another supplemental technical report entitled Feasibility Design of the Reclamation Drainage Systems for the Muskeg River Mine Project (Golder 1997i).

Figure E4-4 shows the LSA, Project area and locations of the reference nodes for the surface water hydrology impact analysis. The staged diversion, drainage and dewatering systems at various time snapshots during Project construction and operation are shown in Figures E4-5 to E4-12. The water management plan for construction and operational phases of the Project includes various mitigation measures and best management practices to achieve the following environmental objectives:

- Minimize raw water withdrawal from the Athabasca River by maximizing use of tailings and consolidated tailings porewater release, Basal Aquifer water and site runoff.

- Minimize impacts on the flows and water levels in the Muskeg River and Mills Creek by distributing muskeg drainage operations evenly through the mine life to avoid a large increase in flows in the receiving streams.

- Minimize incremental sediment loads to the Muskeg River by routing muskeg drainage, overburden dewatering, and runoff from site clearing and overburden stripping operations to settling and polishing ponds before releasing to the receiving streams.

- Minimize impacts of closed-circuit operations on the flows and water levels in Muskeg River and Mills Creek by maximizing diversion of natural runoff from undisturbed areas (no contact with oil sands) around the mining area to the receiving streams.

The planned reclamation landscape and drainage systems for Project closure are shown in Figure E4-13. They are designed to achieve the following environmental objectives:

- Minimize impacts on the flows and water levels in the Muskeg River and Mills Creek by developing a drainage layout to minimize the changes in the natural drainage areas of the receiving streams and by distributing muskeg drainage operations evenly through the Project life to avoid a large increase in flows in the receiving streams.

- Minimize sediment yields from reclaimed surfaces by developing a final topography and soil moisture conditions to sustain a biologically productive and landscape with vegetation providing a dense root mass.

- Minimize gully and channel erosion by developing robust and sustainable reclamation drainage systems with built-in self-healing capability like natural drainage systems.

- Create new areas of lakes, wetlands and streams during reclamation for no net loss of aquatic habitat at the Project area and for bio-remediation of the consolidated tailings (CT) porewater release and seepage from the reclaimed tailings settling pond area.

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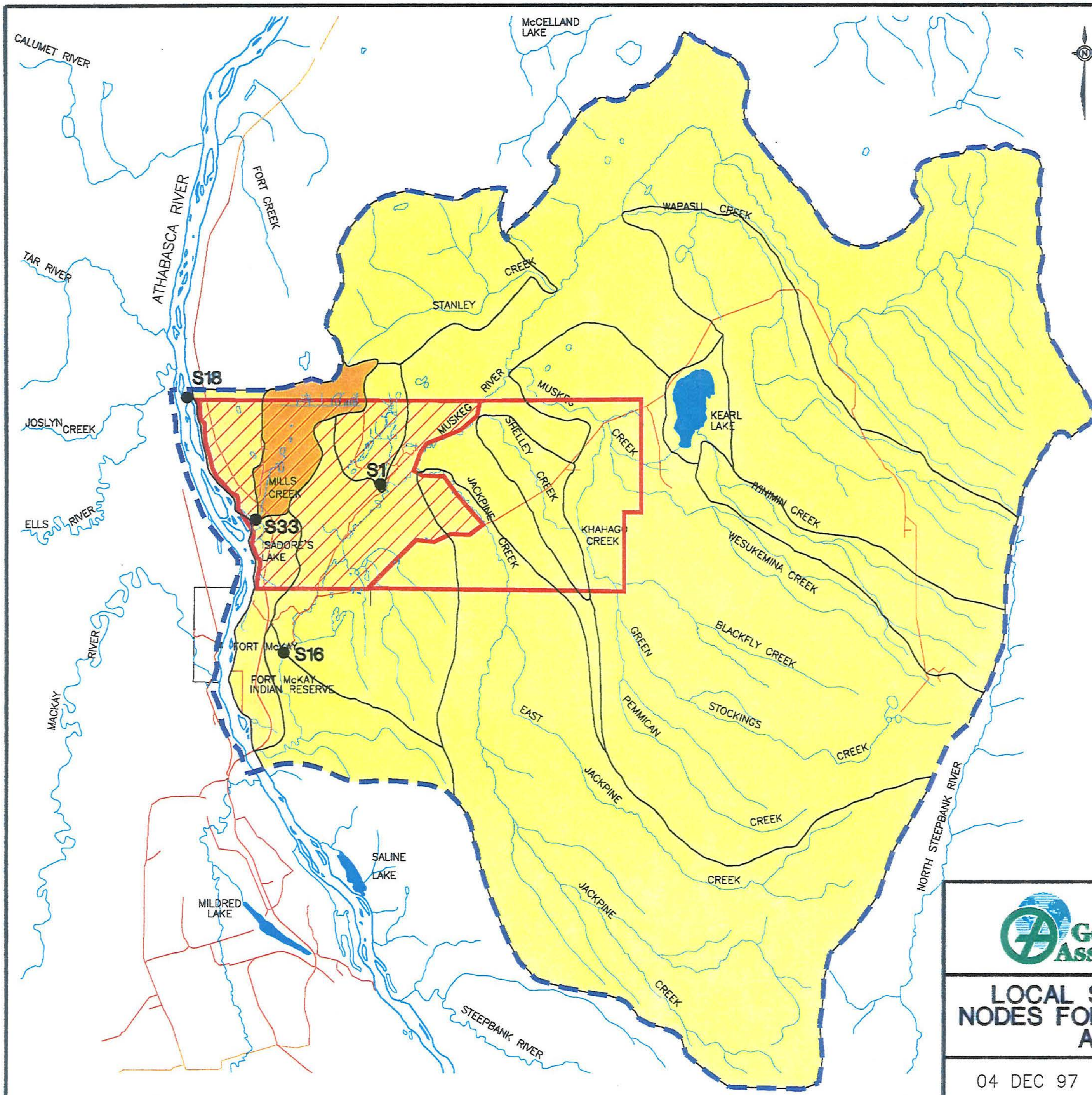

LEGEND

- LOCAL STUDY AREA FOR HYDROLOGY, WATER QUALITY AND AQUATICS
- MUSKEG RIVER MINE PROJECT
- LEASE 13
- S16 ● REFERENCE NODES FOR IMPACT ASSESSMENT

REFERENCE

DIGITAL DATA SETS 74D, 74E, 74I 84A AND 84H FROM RESOURCE DATA DIVISION ALBERTA ENVIRONMENTAL PROTECTION, 1997.

0 5 10 15km

SCALE 1:300,000

Golder Associates

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LOCAL STUDY AREA AND REFERENCE NODES FOR HYDROLOGY, WATER QUALITY AND AQUATIC ANALYSIS

04 DEC 97	Figure E4-4	DRAWN BY: RFM

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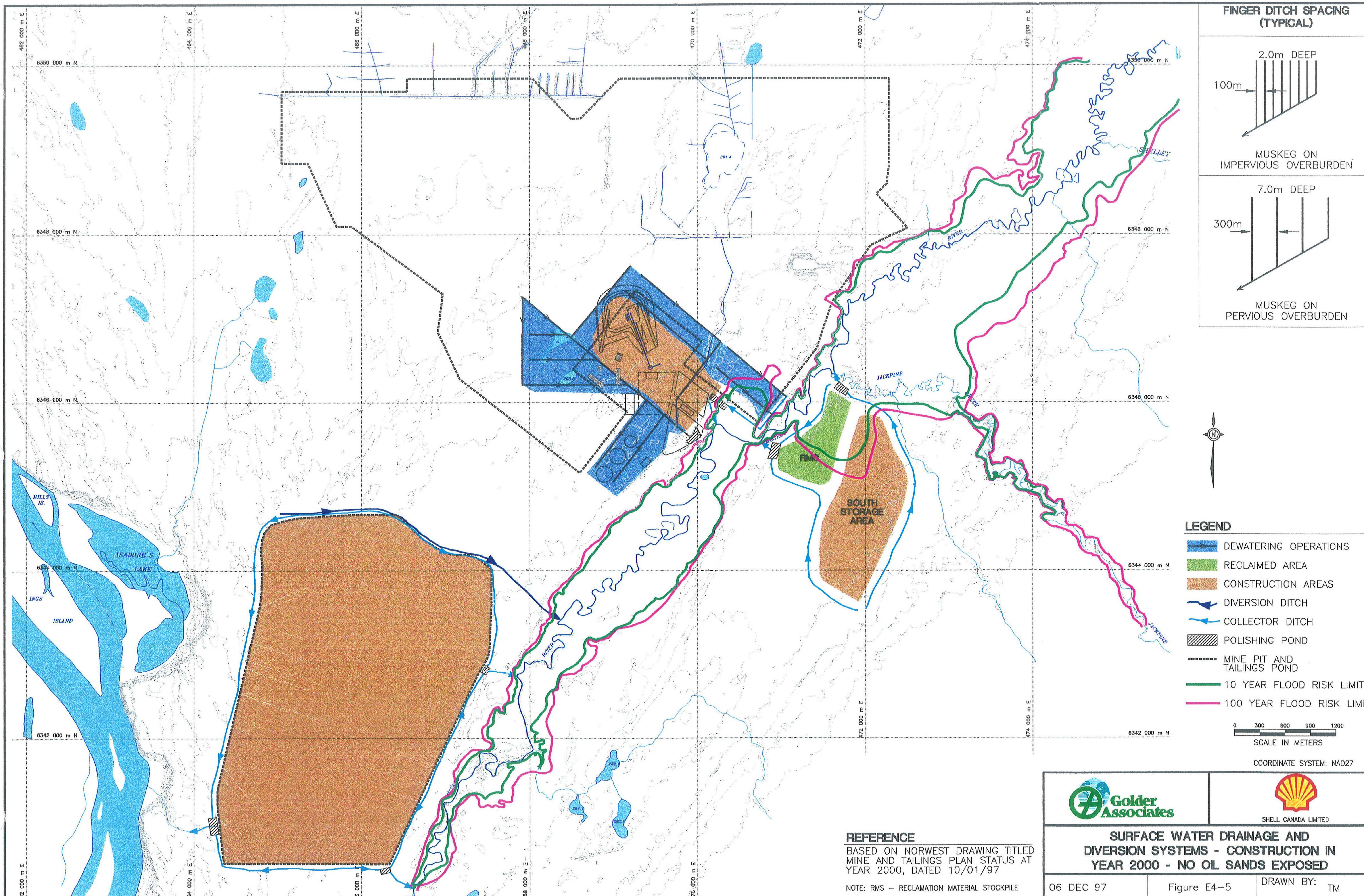
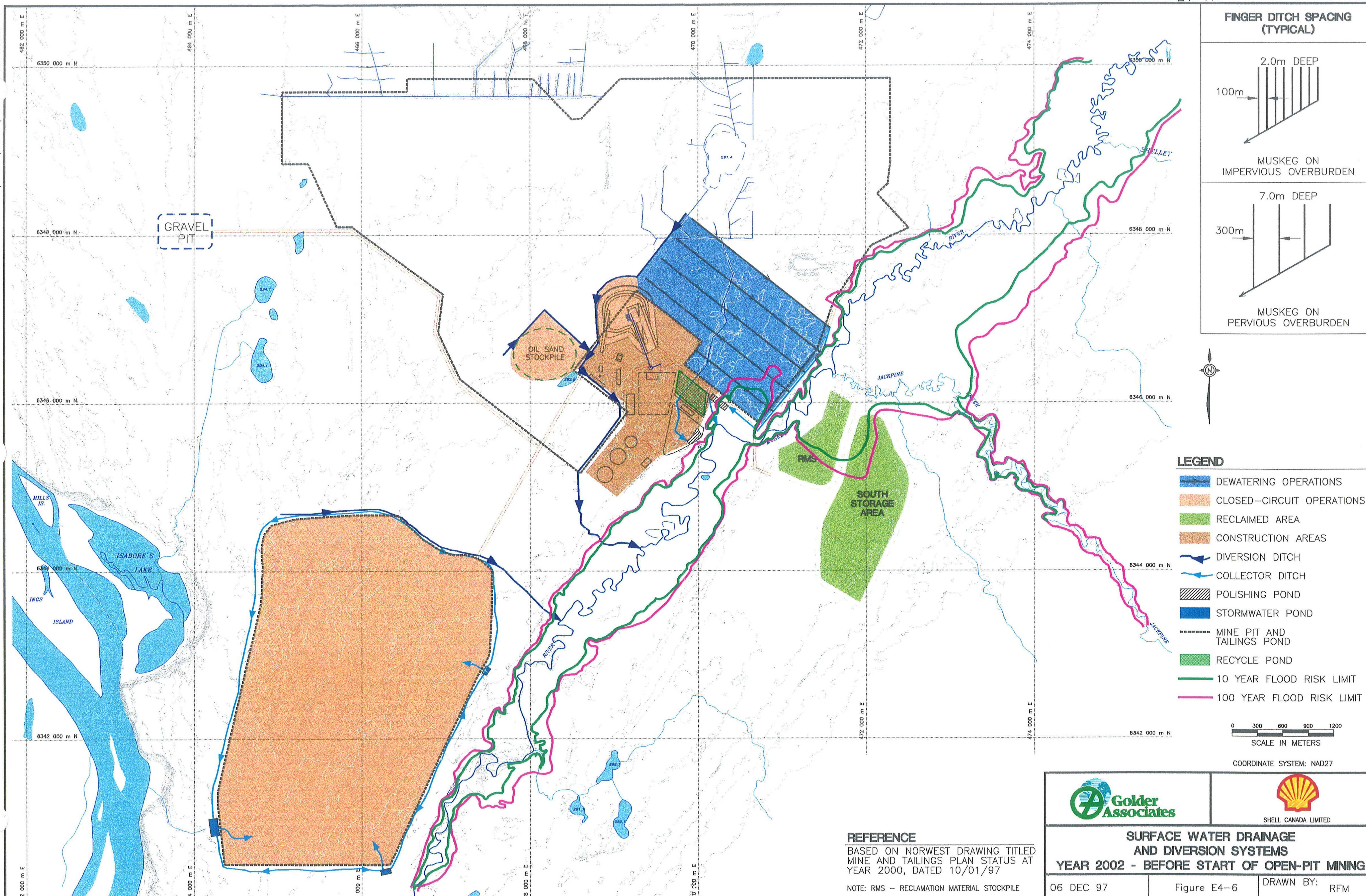


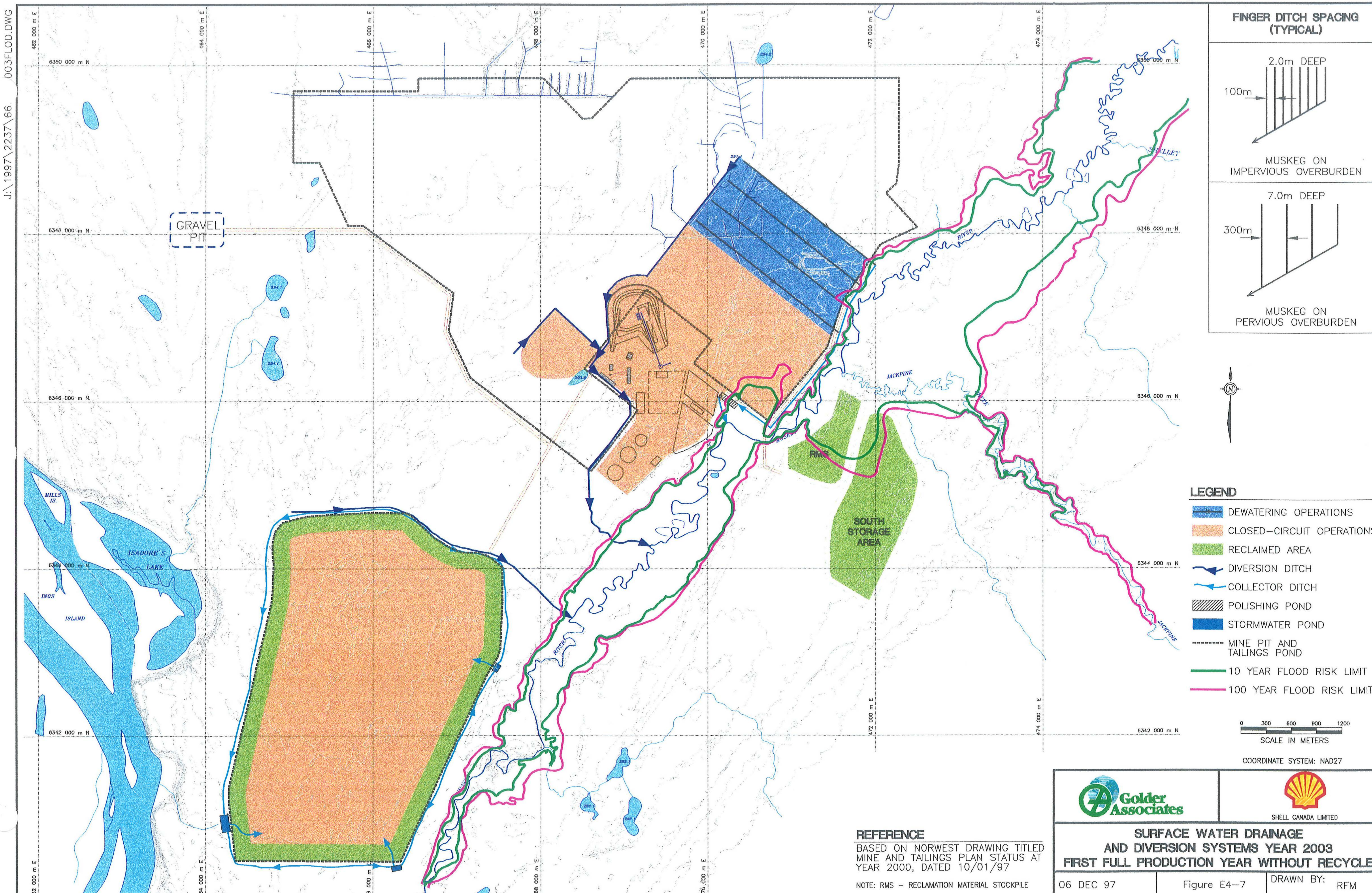
SURFACE WATER DRAINAGE AND DIVERSION SYSTEMS - CONSTRUCTION IN YEAR 2000 - NO OIL SANDS EXPOSED

Figure E4–5



SURFACE WATER DRAINAGE AND DIVERSION SYSTEMS YEAR 2002 - BEFORE START OF OPEN-PIT MINING

Figure E4–6


J:\1997\2237\66 003FLOD.DWG
FINGER DITCH SPACING (TYPICAL)
2.0m DEEP
100m
MUSKEG ON IMPERVIOUS OVERBURDEN
7.0m DEEP
300m
MUSKEG ON PERVIOUS OVERBURDEN
GRAVEL PIT
RMS
SOUTH STORAGE AREA
JACKPINE
ISADORE'S LAKE
MILLS IS.
INGS ISLAND
LEGEND
DEWATERING OPERATIONS
CLOSED-CIRCUIT OPERATIONS
RECLAIMED AREA
DIVERSION DITCH
COLLECTOR DITCH
POLISHING POND
STORMWATER POND
MINE PIT AND TAILINGS POND
10 YEAR FLOOD RISK LIMIT
100 YEAR FLOOD RISK LIMIT
0 300 600 900 1200
SCALE IN METERS
COORDINATE SYSTEM: NAD27
REFERENCE
BASED ON NORWEST DRAWING TITLED MINE AND TAILINGS PLAN STATUS AT YEAR 2000, DATED 10/01/97
NOTE: RMS – RECLAMATION MATERIAL STOCKPILE
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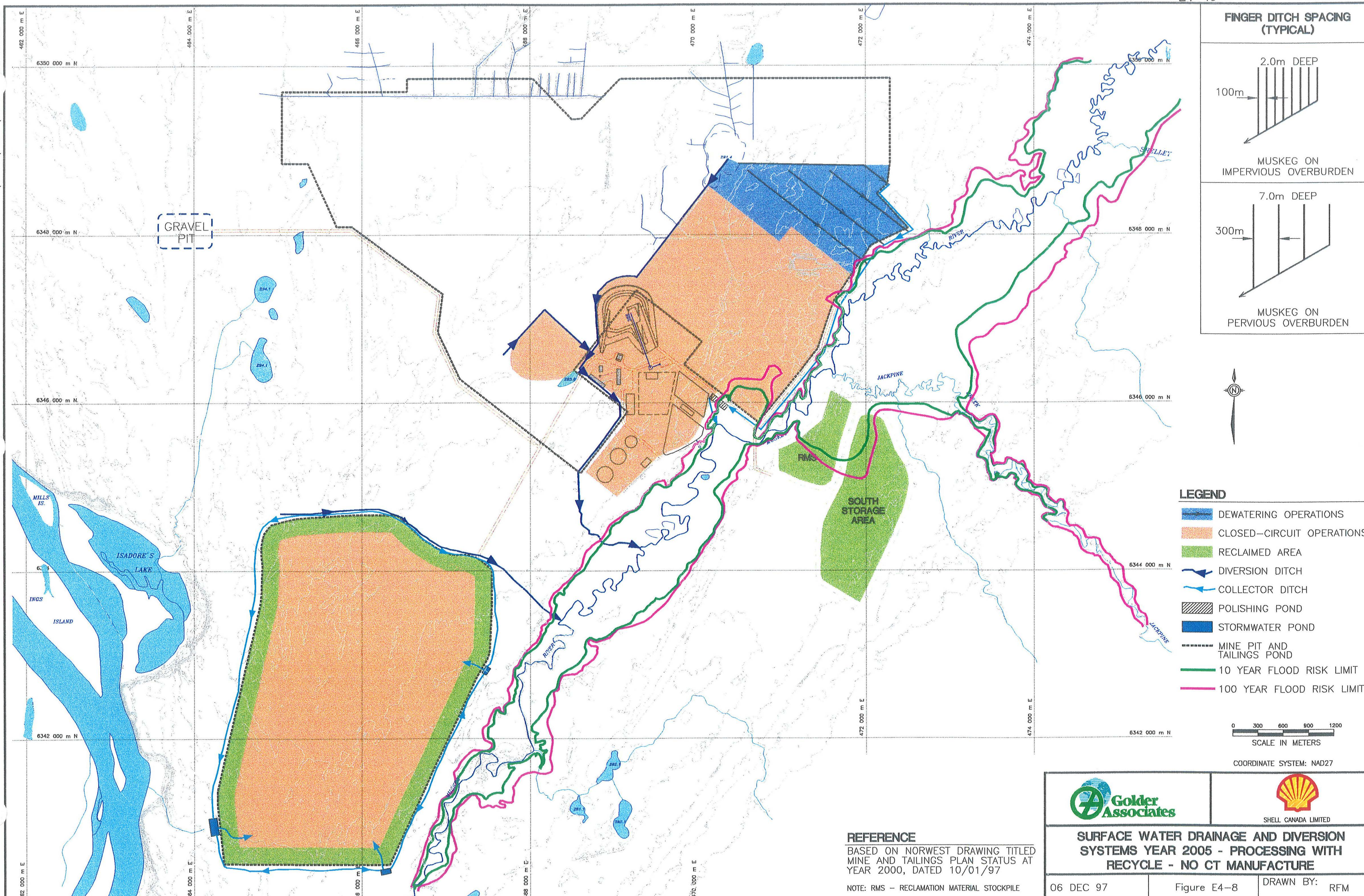
SURFACE WATER DRAINAGE AND DIVERSION SYSTEMS YEAR 2003 FIRST FULL PRODUCTION YEAR WITHOUT RECYCLE
06 DEC 97
Figure E4-7
DRAWN BY: RFM


FINGER DITCH SPACING (TYPICAL)
2.0m DEEP
100m
MUSKEG ON IMPERVIOUS OVERBURDEN
7.0m DEEP
300m
MUSKEG ON PERVIOUS OVERBURDEN
GRAVEL PIT
MILLS IS.
ISADORE'S LAKE
ISLAND
JACKPINE
RMS
SOUTH STORAGE AREA
LEGEND
DEWATERING OPERATIONS
CLOSED–CIRCUIT OPERATIONS
RECLAIMED AREA
DIVERSION DITCH
COLLECTOR DITCH
POLISHING POND
STORMWATER POND
MINE PIT AND TAILINGS POND
10 YEAR FLOOD RISK LIMIT
100 YEAR FLOOD RISK LIMIT
0 300 600 900 1200
SCALE IN METERS
COORDINATE SYSTEM: NAD27
REFERENCE
BASED ON NORWEST DRAWING TITLED MINE AND TAILINGS PLAN STATUS AT YEAR 2000, DATED 10/01/97
NOTE: RMS – RECLAMATION MATERIAL STOCKPILE
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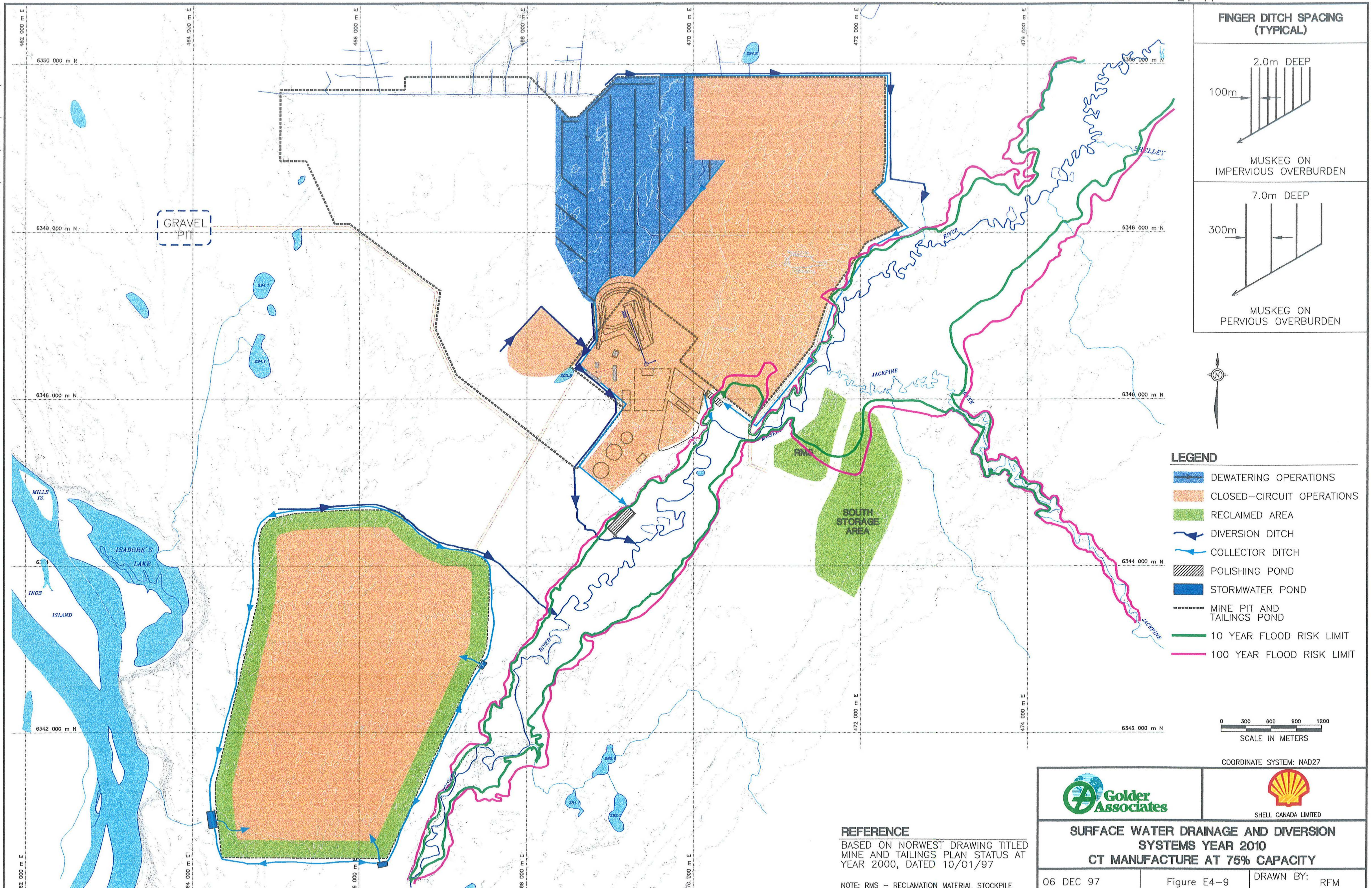
SURFACE WATER DRAINAGE AND DIVERSION SYSTEMS YEAR 2005 - PROCESSING WITH RECYCLE - NO CT MANUFACTURE
06 DEC 97
Figure E4–8
DRAWN BY: RFM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FINGER DITCH SPACING (TYPICAL)
2.0m DEEP
100m
MUSKEG ON IMPERVIOUS OVERBURDEN
7.0m DEEP
300m
MUSKEG ON PERVIOUS OVERBURDEN
GRAVEL PIT
MILLS IS.
ISADORE'S LAKE
INGS ISLAND
SHELLEY
RIVER
JACKPINE
CREEK
RMS
SOUTH STORAGE AREA
LEGEND
DEWATERING OPERATIONS
CLOSED-CIRCUIT OPERATIONS
RECLAIMED AREA
DIVERSION DITCH
COLLECTOR DITCH
POLISHING POND
STORMWATER POND
MINE PIT AND TAILINGS POND
10 YEAR FLOOD RISK LIMIT
100 YEAR FLOOD RISK LIMIT
462 000 m E
464 000 m E
466 000 m E
468 000 m E
470 000 m E
472 000 m E
474 000 m E
6350 000 m N
6348 000 m N
6346 000 m N
6344 000 m N
6342 000 m N
0 300 600 900 1200
SCALE IN METERS
COORDINATE SYSTEM: NAD27
REFERENCE
BASED ON NORWEST DRAWING TITLED MINE AND TAILINGS PLAN STATUS AT YEAR 2000, DATED 10/01/97
NOTE: RMS – RECLAMATION MATERIAL STOCKPILE
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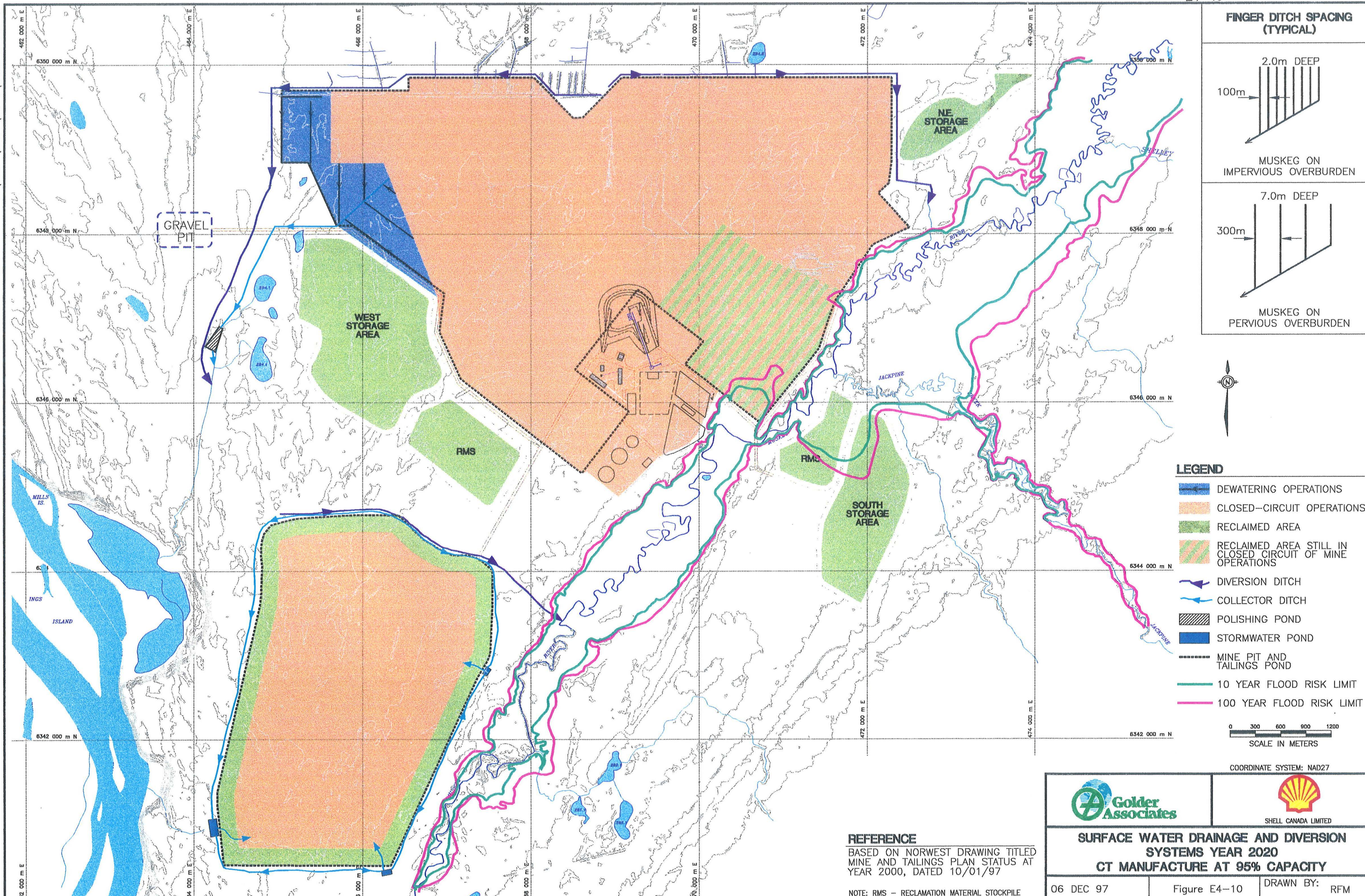
SURFACE WATER DRAINAGE AND DIVERSION SYSTEMS YEAR 2010
CT MANUFACTURE AT 75% CAPACITY
06 DEC 97
Figure E4-9
DRAWN BY: RFM



REFERENCE
BASED ON NORWEST DRAWING TITLED MINE AND TAILINGS PLAN STATUS AT YEAR 2000, DATED 10/01/97

NOTE: RMS – RECLAMATION MATERIAL STOCKPILE

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SURFACE WATER DRAINAGE AND DIVERSION SYSTEMS YEAR 2020 CT MANUFACTURE AT 95% CAPACITY

06 DEC 97	Figure E4-10	DRAWN BY: RFM

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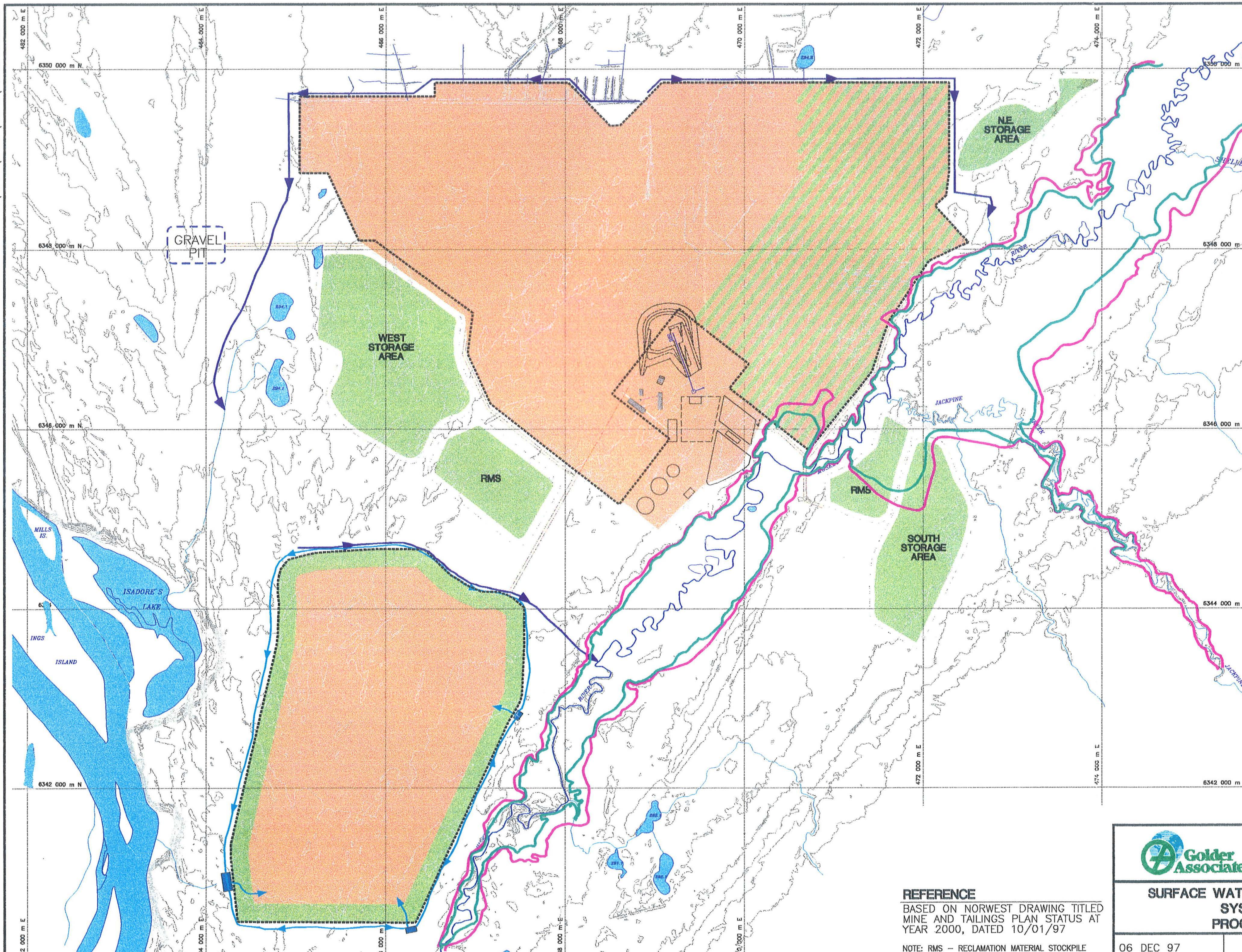

LEGEND

- CLOSED–CIRCUIT OPERATIONS
- RECLAIMED AREA
- RECLAIMED AREA STILL IN CLOSED CIRCUIT OF MINE OPERATIONS
- DIVERSION DITCH
- COLLECTOR DITCH
- STORMWATER POND
- MINE PIT AND TAILINGS POND
- 10 YEAR FLOOD RISK LIMIT
- 100 YEAR FLOOD RISK LIMIT

REFERENCE

BASED ON NORWEST DRAWING TITLED MINE AND TAILINGS PLAN STATUS AT YEAR 2000, DATED 10/01/97

NOTE: RMS – RECLAMATION MATERIAL STOCKPILE

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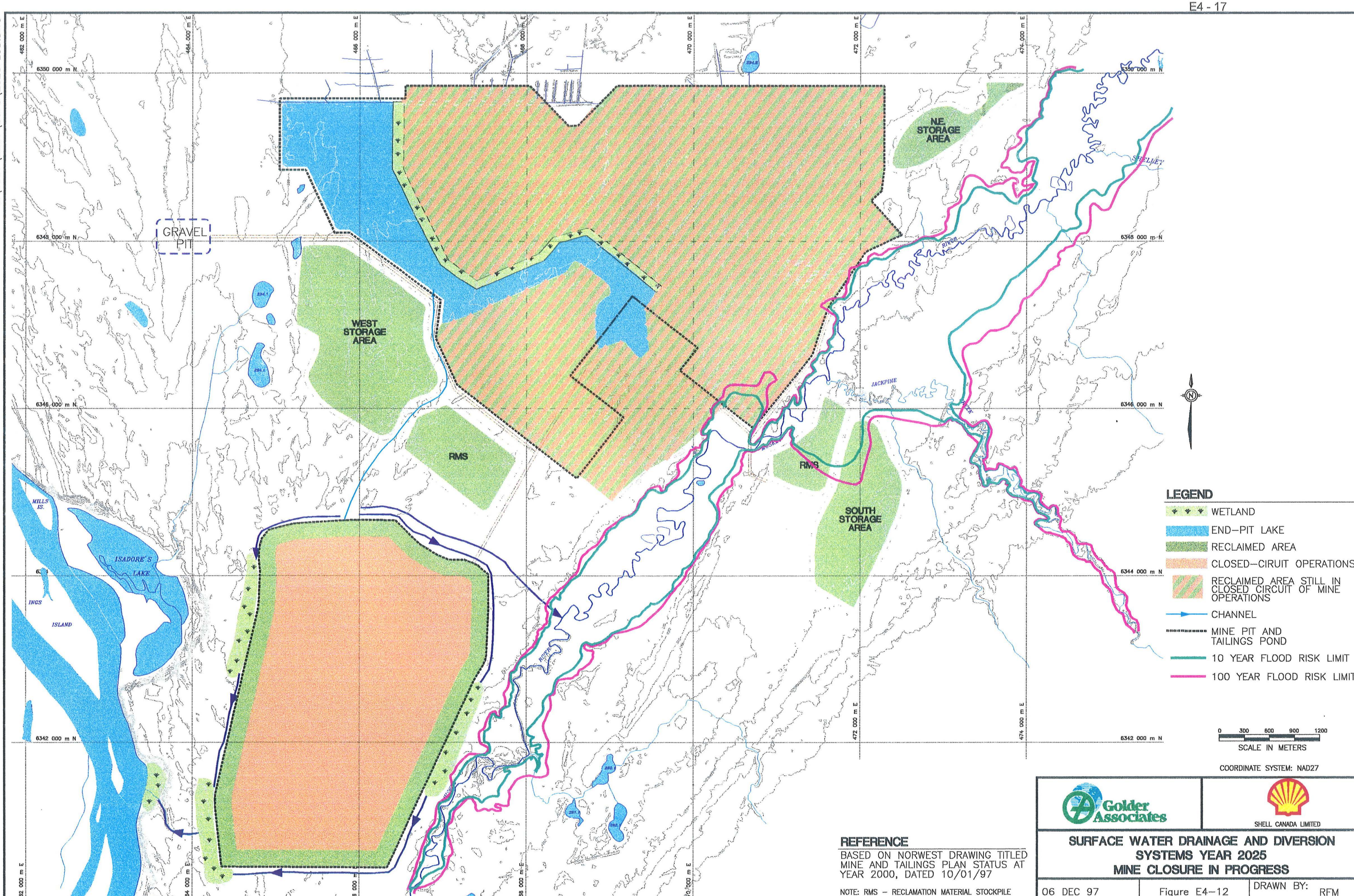
SURFACE WATER DRAINAGE AND DIVERSION SYSTEMS YEAR 2022 PROCESSING COMPLETE

06 DEC 97	Figure E4–11	DRAWN BY: RFM



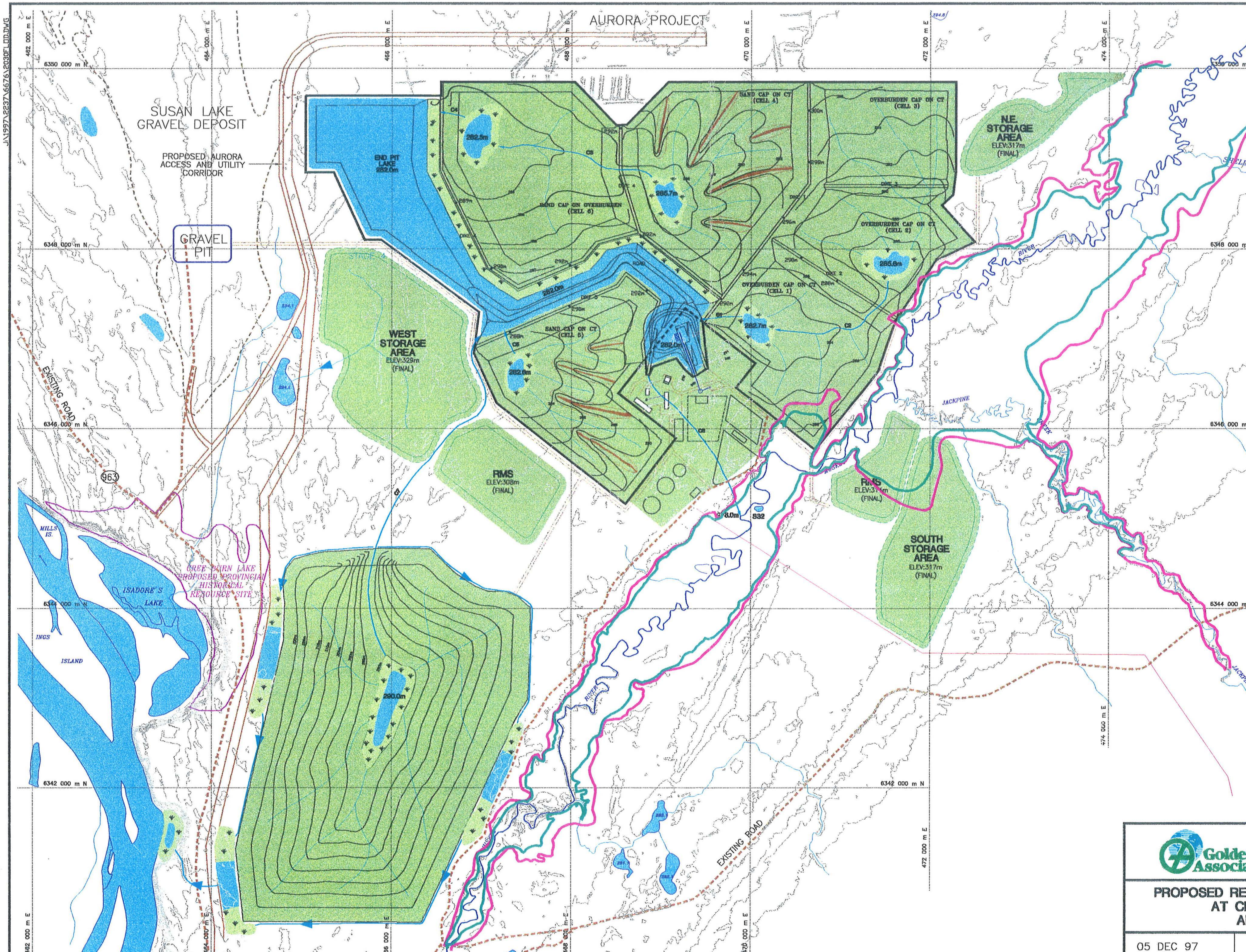
REFERENCE

BASED ON NORWEST DRAWING TITLED MINE AND TAILINGS PLAN STATUS AT YEAR 2000, DATED 10/01/97

NOTE: RMS – RECLAMATION MATERIAL STOCKPILE

SURFACE WATER DRAINAGE AND DIVERSION SYSTEMS YEAR 2025 MINE CLOSURE IN PROGRESS

06 DEC 97	Figure E4–12	DRAWN BY: RFM



LEGEND

- WETLAND
- LAKE
- RECLAIMED AREA
- MAIN CHANNEL
- SECONDARY CHANNEL
- EXISTING ROAD
- SAND RIDGES
- COLLECTOR DITCHES
- 10 YEAR NATURAL FLOOD RISK LIMIT
- 100 YEAR NATURAL FLOOD RISK LIMIT
- C1 MAIN CHANNEL NUMBER

NOTE

ALL ELEVATIONS IN METRES

REFERENCE

BASE PROVIDED BY NORWEST, DATED 09/09/97 TITLED MINE AND TAILINGS PLAN STATUS AT END OF YEAR 2023. 150000bbls/day SCENARIO

NOTE: RMS – RECLAMATION MATERIAL STOCKPILE

0 400 800 1200 1600 2000m

SCALE

Golder Associates

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PROPOSED RECLAMATION DRAINAGE SYSTEM AT CLOSURE IN YEAR 2030 AND IN FAR FUTURE

05 DEC 97	Figure E4–13	DRAWN BY: RFM

E4.2 Key Question SW-1: Will the Muskeg River Mine Project Affect Flows and Water Levels in Receiving Streams, Lakes, Ponds and Wetlands?

E4.2.1 Analysis of Potential Linkages

Affected Waterbodies and Nodes for Impact Analysis

The Muskeg River and Isadore's Lake are the two main waterbodies receiving natural runoff from the Project area. Inflows to these waterbodies will be affected to various degrees during the life of the Project. Changes in inflows will cause changes in water levels of theses waterbodies. Most of the existing runoff from the Project area is collected by the man-made Alsands Drain channel. Therefore, changes in flows in this channel are included in this assessment.

The Muskeg River and Isadore's Lake discharge to Athabasca River. Changes in flows from these two waterbodies will affect the Athabasca River flows. However, the effect will be small because the Project area is a very small percentage of the total drainage of the Athabasca River in the LSA.

Impacts of the Project on the flows and water levels of Muskeg River, Isadore's Lake and Athabasca River were evaluated. Four nodes (reference locations for assessing the impacts) were selected as shown in Figure E4-4. A description of these reference nodes is presented in Table E4-2.

Table E4-2 List of Reference Nodes for Incremental Impact Analysis

Node	Description
S1	Alsands Drain outlet; settling pond outlet to Muskeg River during construction and operation; and end pit lake outlet to Muskeg River after closure
S16	Muskeg River downstream of the Muskeg River Mine Project area
S33	Total inflow to Isadore's Lake
S18	Athabasca River at northwest corner of the LSA

Detailed Linkages during Construction

The following activities will affect inflows to the receiving waterbodies during the construction phase of the Project (May 1999 to June 2002).

- Muskeg drainage, overburden dewatering and runoff from the cleared plant site and tailings dyke area, which will be routed through the polishing ponds, will temporarily increase the inflows to receiving waterbodies.

- Runoff from the crusher excavation and tailings settling pond areas will be conveyed to and stored in the recycle pond and tailings settling pond and will not be released to the environment. This closed-circuit operation will reduce drainage areas and inflows to the receiving waterbodies.

The loss of drainage areas and inflows to receiving waterbodies caused by closed-circuit operations will be partially compensated by an increase of inflows from muskeg drainage and overburden dewatering, which will result in higher flows in receiving waterbodies.

The linkage between the Project activities discussed above and changes in flows and water levels of receiving waterbodies is valid.

Detailed Linkages During Operation

The operational phase of the Muskeg River Mine Project (July 2002 to 2030) includes the mining period (2002 to 2022), and the reclamation and end pit lake management period (2023 to 2030). The following Project activities will affect the flows and water levels in the receiving waterbodies during the operational phase of the Project.

- Muskeg drainage and overburden dewatering will continue through the mining period from 2002 to about 2020. The resulting discharges and the runoff from cleared areas before overburden removal, which will be routed through the polishing ponds, will temporarily increase the inflows to the receiving waterbodies.

- Water withdrawal from the Athabasca River is required during the mining period to make up the water lost to evaporation, tailings porewater and water inventory and to supply clean water for utilities and boiler feed. This withdrawal will temporarily reduce the Athabasca River flows.

- Flows from Basal Aquifer depressurization, in-pit CT upward flux, and runoff from the plant site, mine pits and the tailings settling pond area will be conveyed to and stored in pits, the recycle pond and the tailings settling pond. This closed-circuit operation will reduce the drainage areas and flows to the receiving waterbodies.

- Several diversions will be required to divert natural runoff around the Project area and thereby minimize impacts on the flows to the receiving streams.

- Mine pit development will drawdown the water table of the surficial aquifers at the perimeters of the mine pits and thereby reduce surface runoff of these areas to the receiving streams.

- By the end of the end pit lake management period, transfer of the mature fine tailings (MFT) to the lake will increase discharges from the lake to the Muskeg River.

The linkage between the Project activities discussed above and changes in flows and water levels of receiving waterbodies is valid.

Detailed Linkages After Closure

The closure reclamation landscape drainage systems will have some temporary and long-term effects on flows and water levels of receiving waterbodies as described below.

- The relatively large end pit lake outflow near the end of the end pit lake management period will temporarily increase Muskeg River flows.

- The runoff characteristics of reclaimed in-pit CT, sand and overburden storage areas, the reclaimed tailing settling pond area, and the external overburden storage areas will be different from the natural conditions.

- The drainage pattern of the reclamation drainage systems will be different from the natural drainage pattern.

- The reclaimed drainage conveyance systems consist of secondary and main drainage channels, wetlands and a large end pit lake. These facilities, particularly the end pit lake, have a marked effect on the runoff characteristics and discharges to the Muskeg River.

The linkage between the Project activities discussed above and changes in flows and water levels of receiving waterbodies is valid.

E4.2.2 Methods of Impact Analysis

Hydrologic Parameters for Characterizing Impacts

The following hydrologic parameters are used to characterize the changes of flows and water levels of the receiving streams, particularly the Muskeg River:

- mean annual discharge and flow depth;
- mean open-water season (mid-April to mid-November) discharge and flow depth;

- mean ice-cover season (mid-November to mid-April) discharge and flow depth;
- open-water season 7Q10, which denotes the 7-day duration low-flow with 10-year return period and flow depth;
- ice-cover season 7Q10 and flow depth; and
- 10-year return period flood peak discharge and flow depth.

The following hydrologic parameters are used to characterize the changes of the levels of Isadore's Lake:

- mean water level and depth during the open-water and ice-cover seasons; and
- daily water level and depth exceedance statistics including 10, 50 and 90 percentiles.

In addition, the daily lake water levels for both the natural and future (developed) conditions were simulated using the hydrologic model described below and analyzed to derive the daily water level exceedance curves for a detailed comparison of the water level fluctuation.

Simulating Changes in Flows and Water Levels

The HSPF model, which is a continuous (dynamic) hydrologic simulation model from the United States Environmental Protection Agency (U.S. EPA), was calibrated based on measured flows and then used to derive simulated daily flows to characterize the existing baseline (natural) conditions and to predict the future conditions at various time snapshots. The simulated future and natural daily flows were analyzed to determine the hydrologic parameters at each reference node. The parameters for the baseline and future conditions were compared to quantify the changes in flows.

Figure E4-14 shows an example of the comparison between the simulated baseline and far future daily flow series of Muskeg River (S16). The simulations were conducted based on the available climatic data for the period of record from 1954 to 1996. Figure E4-15 shows the corresponding daily flow exceedance curves. The relevant flow parameters are shown on the same figure.

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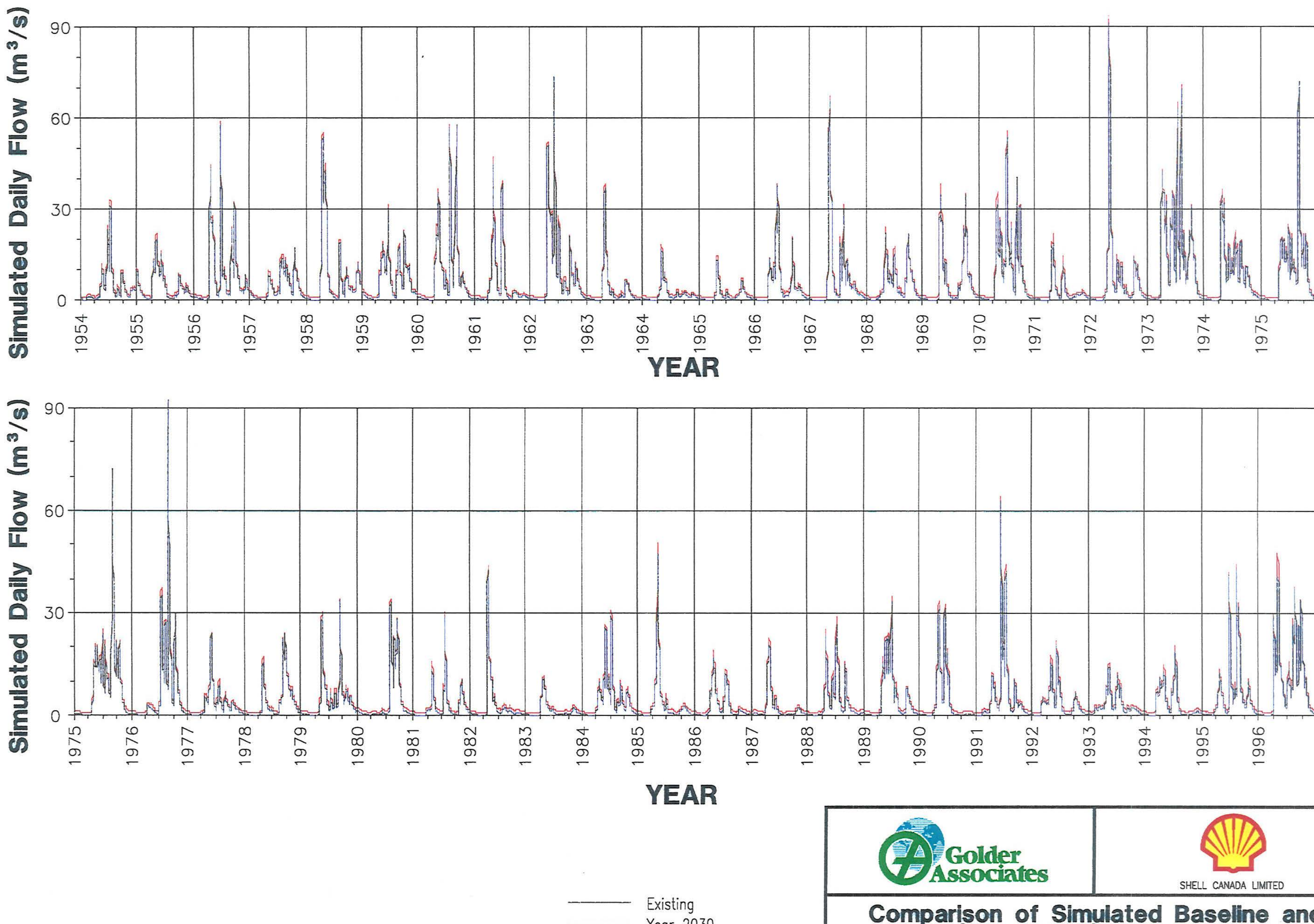

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Comparison of Simulated Baseline and Future (Year 2030) Daily Flow Series on the Muskeg River (S16)

05 DEC 97	Figure E4-14	DRAWN BY: RFM

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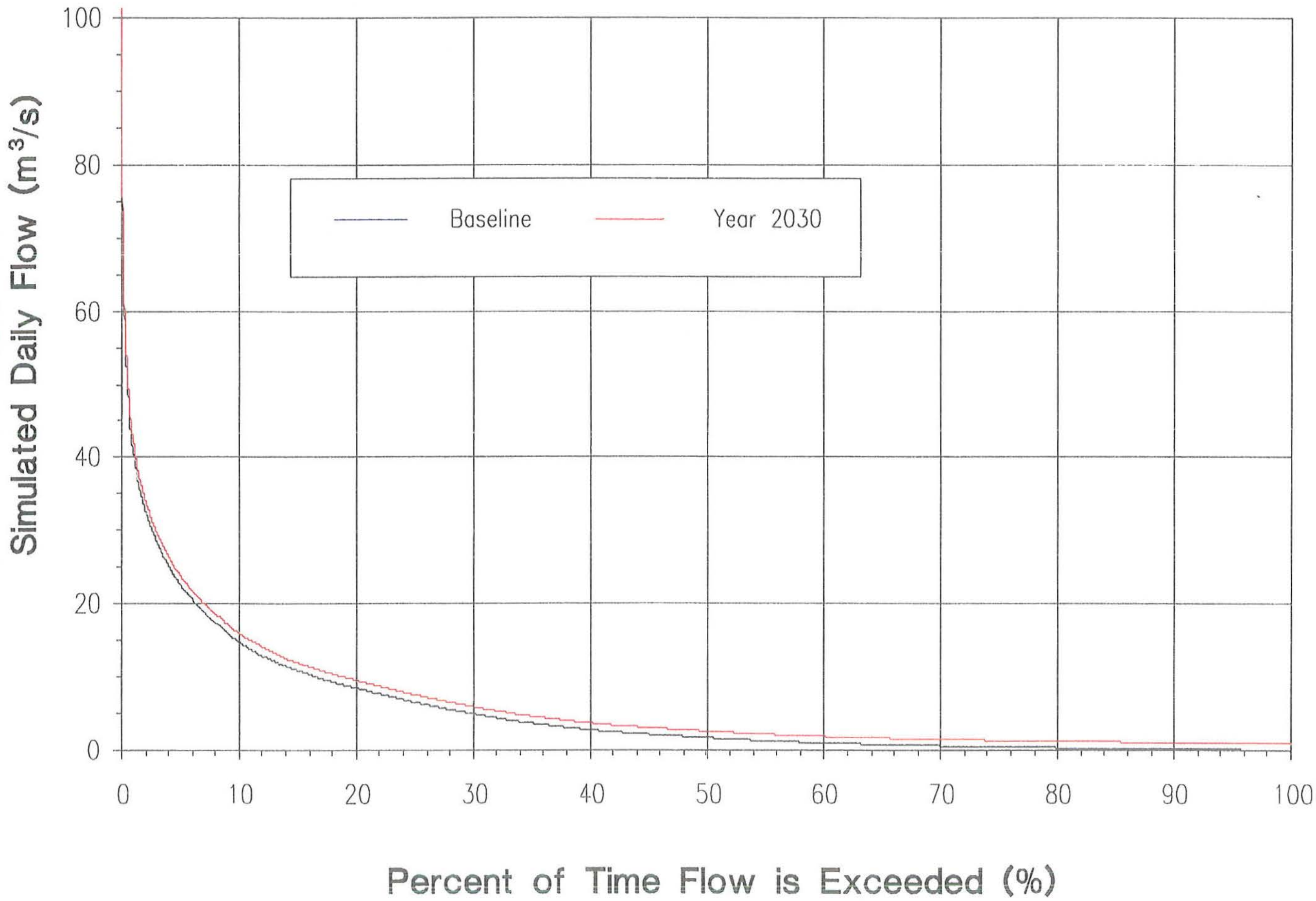

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Comparison of Simulated Baseline and Future (Year 2030) Daily Flow Exceedance Curves of Muskeg River Flows at S16

04 DEC 97	Figure E4-15	DRAWN BY: RFM

The rating curve of average flow depths against discharges on Muskeg River (S16) was developed based on available hydrometric data including measured flows and water levels by WSC. The discharge rating curve for the Muskeg River at node 16 is shown in Figure E4-16. Changes in flow depth parameters were determined based on changes in the flow parameters.

The simulated daily lake inflows including basin runoff and net precipitation (gross precipitation minus lake evaporation) were routed through Isadore's Lake using the HSPF model. A lake storage-elevation curve was developed based on the existing bathymetric survey and available topographic information. The lake outlet elevation-discharge rating curve was estimated based on available field data for lower Mills Creek. Simulated daily water levels were analyzed to derive the daily flow exceedance curves and relevant water level parameters for the baseline and future conditions. These were compared to characterize the changes caused by the Project.

Figure E4-17 shows an example comparison between the simulated baseline and future daily water level series of Isadore's Lake for Year 2020 when there will be mine dewatering discharge into the lake. The simulations were conducted based on the available climatic data for the period of record from 1954 to 1996. The corresponding daily water level exceedance curves and relevant hydraulic parameters are shown in Figure E4-18.

E4.2.3 Impact Analysis

Impacts on Flows and Water Levels During Construction

Muskeg Drainage and Overburden Dewatering Discharges

The Muskeg River Mine Project area is mantled with a layer of peat of variable thickness. Most of the area is subject to high water table conditions and therefore the peat is typically saturated. A portion of the water storage in the peat will be released by surface water drainage ditching to facilitate subsequent muskeg stripping operations. Another portion will be released during stripping operations, and the remainder will remain as porewater in the muskeg stockpiles. A large portion of the Project development area is underlain by a surface aquifer in the overburden sand and gravel (beneath the peat layer). This aquifer will need to be dewatered before muskeg and overburden excavation.

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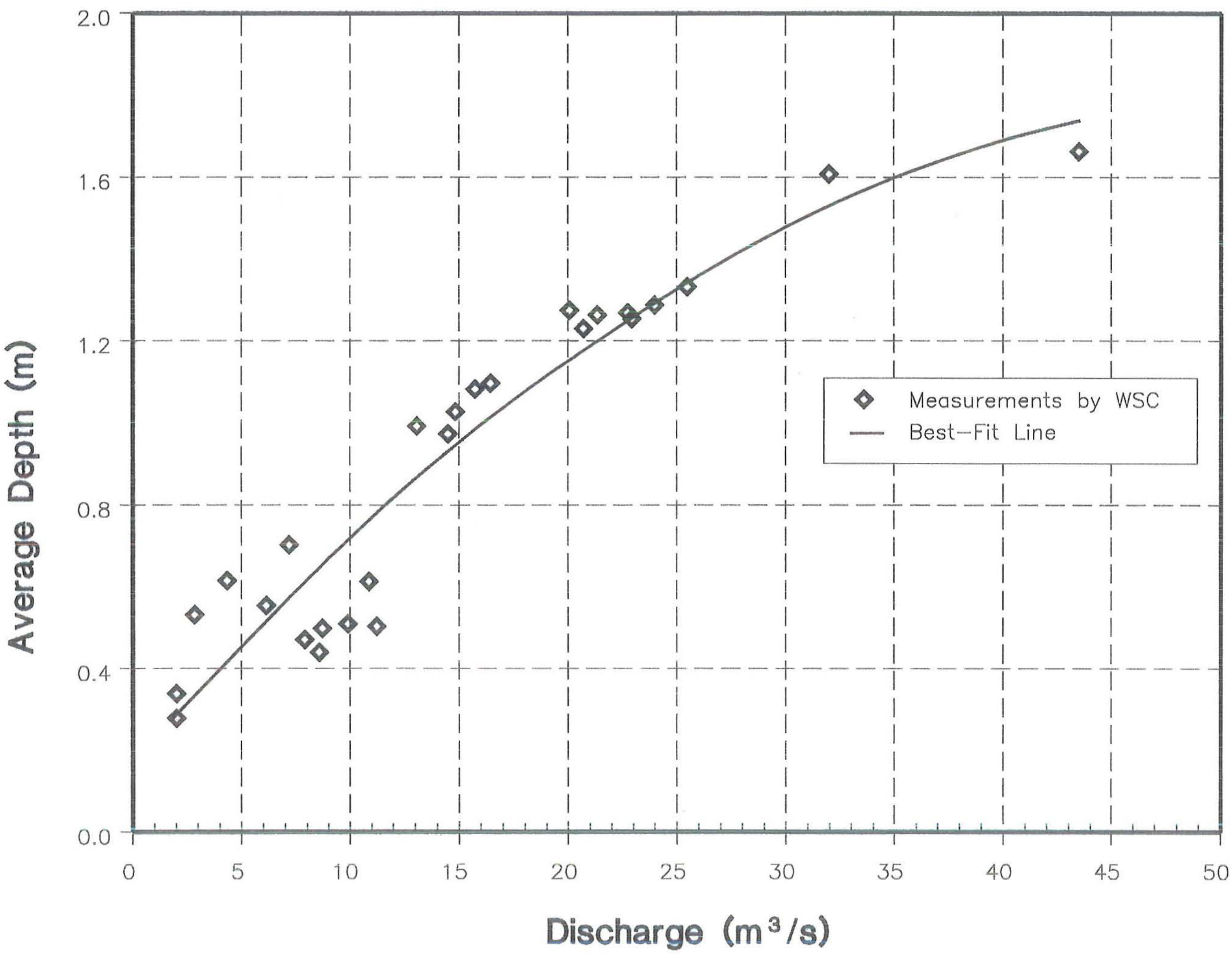

Golder Associates		SHELL CANADA LIMITED
AVERAGE DEPTH DISCHARGE RATING CURVE OF MUSKEG RIVER AT NODE S16		
05 DEC 97	Figure E4-16	DRAWN BY: RFM

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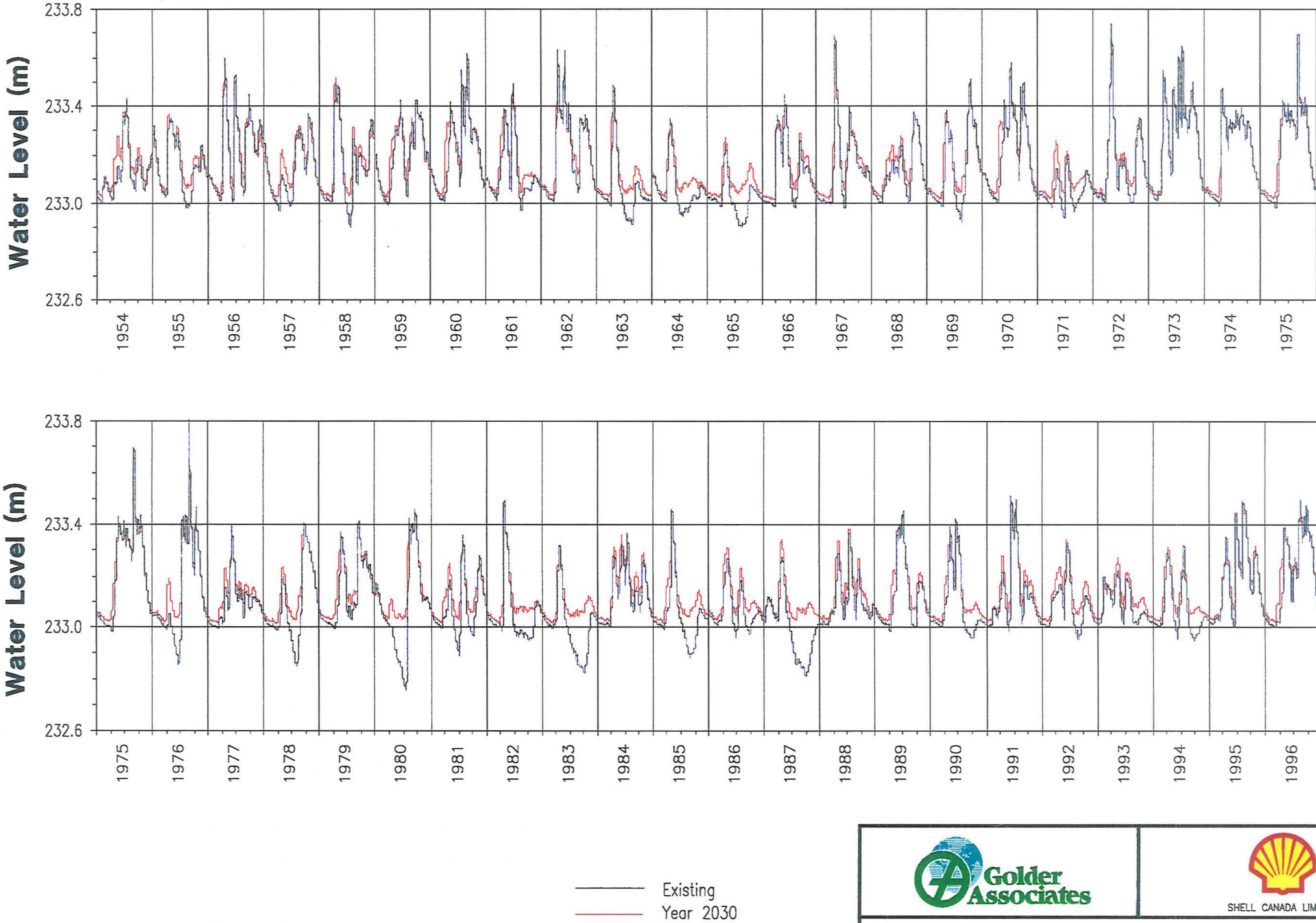

Golder Associates

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Comparison of Simulated Baseline and Future (Year 2020) Water Levels at Isadore's Lake

05 DEC 97	Figure E4-17	DRAWN BY: RFM

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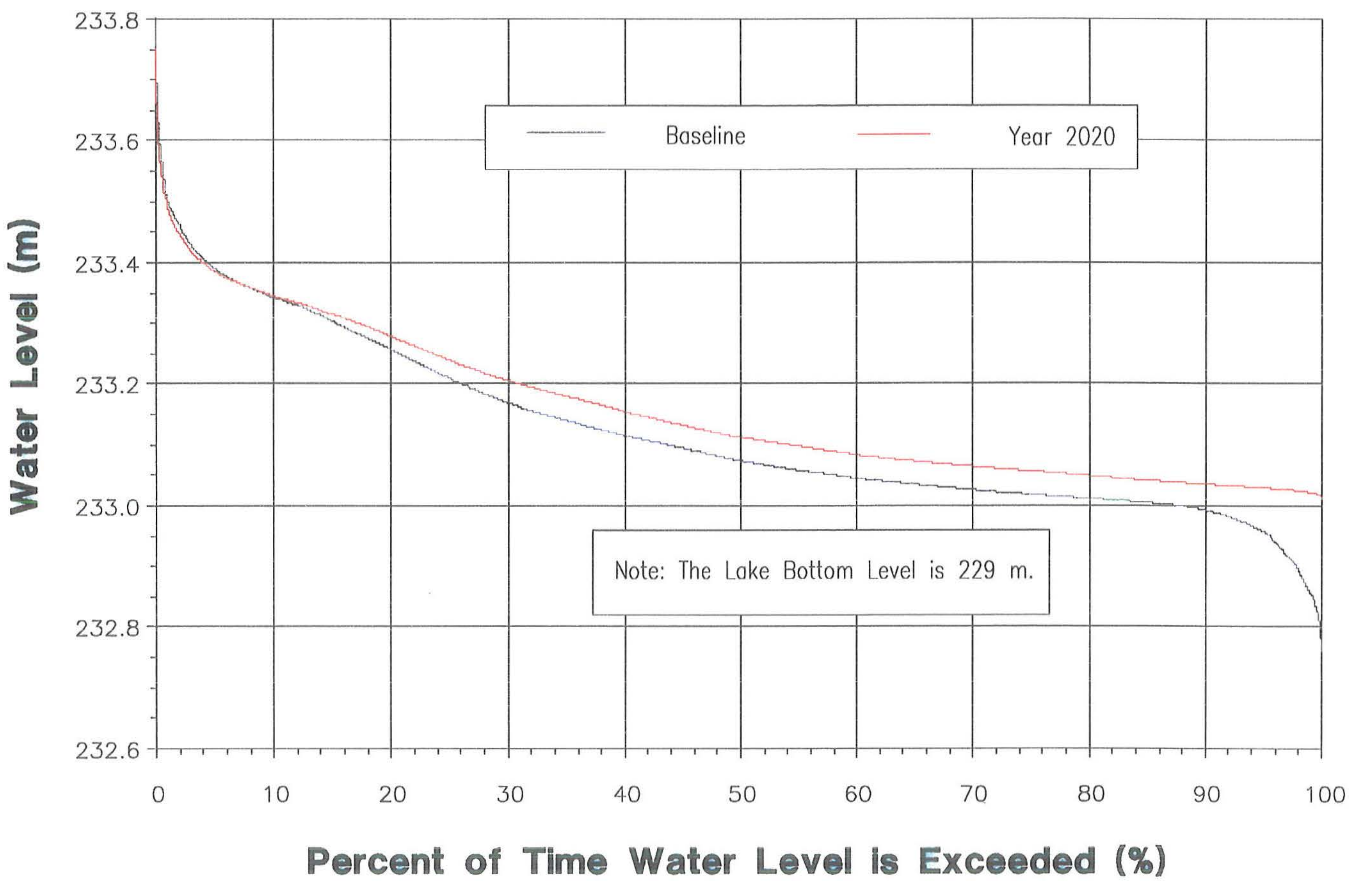

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Comparison of Simulated Baseline and Future (Year 2020) Exceedence Curves of Water Levels at Isadore's Lake

04 DEC 97	Figure E4-18	DRAWN BY: RFM

The muskeg drainage and overburden dewatering rates during construction and operation were estimated and presented in the Water Management Plan report (Golder 1997j). Muskeg drainage water yield per unit area was estimated based on the following assumptions:

- the average depth of muskeg in the Project area is 1.5 m;
- the muskeg water storage that can be drained by gravity is 0.9 m;
- 0.36 m of the muskeg water storage plus 0.17 m water yield from precipitation during the six-month open-water season will be released for each of the first two years of drainage by ditching; and
- the remaining 0.18 m of the muskeg water storage will be released in the third year when placed in a stockpile.

These discharge rates during two time snapshots of construction are summarized in Tables E4-3 and E4-4. The discharge is expressed as the mean annual value. However, the muskeg drainage and overburden dewatering water will only contribute to the surface runoff during the open-water season, because frost penetration during winter will immobilize the free water and stop the seepage outflow.

Table E4-3 Muskeg Drainage Discharges During Construction

Year	Receiving Node	Dewatered Area (km^2)	Mean Annual Discharge (m^3/s)
2000	S1 - Alsands Drain	1.43	0.02
	S16 - Muskeg River	2.2	0.03
	S33 - Isadore's Lake Inflow	0	0
2002	S1 - Alsands Drain	0	0
	S16 - Muskeg River	1.8	0.03
	S33 - Isadore's Lake Inflow	0	0

Table E4-4 Overburden Dewatering Discharges During Construction

Year	Receiving Node	Dewatered Area (km^2)	Mean Annual Discharge (m^3/s)
2000	S1 - Alsands Drain	0	0
	S16 - Muskeg River	0.9	0.02
	S33 - Isadore's Lake Inflow	0	0
2002	S1 - Alsands Drain	0	0
	S16 - Muskeg River	1.8	0.02
	S33 - Isadore's Lake Inflow	0	0

The maximum muskeg drainage and overburden dewatering rate will occur around 2000 during pre-construction drainage when the area being drained will be larger than any other time during the life of the Project. The mean annual dewatering rate is about 0.052 m^3/s, equivalent to 0.10 m^3/s released in the open-water season. This will increase the open-water season 7Q10 low-flow on the Muskeg River from natural conditions of 0.28 m^3/s to 0.39 m^3/s in 2000, which is equivalent to a 36% increase.

Runoff from Stripped Areas

Stripping of muskeg will usually be undertaken during winter, when surface water runoff will be minimal. Overburden removal follows soon after muskeg clearing. Therefore, any potential increase in surface runoff to the receiving streams from the stripped areas will be minimal and were neglected in the overall water balance analysis.

Closed-Circuit Operations

The operational water management system is based on the assumption that all water from areas disturbed by overburden removal and in contact with the oil sands will be contained within the Project area. During construction, the crusher excavation area is subject to contact with oil sands and is therefore treated as a closed-circuit area. The tailings settling pond containment area is also treated as closed-circuit area because it drains to the ponded area. These closed-circuit areas are summarized in Table E4-5.

Table E4-5 Closed-Circuit Areas During Construction

Year	Receiving Node	Closed-Circuit Areas (km^2)
2000	S1 - Alsands Drain	0
	S16 - Muskeg River	0
	S33 - Isadore's Lake Inflow	0
2002	S1 - Alsands Drain	0.8
	S16 - Muskeg River	7.1
	S33 - Isadore's Lake Inflow	1.3

Results of Impact Analysis

The results of impact analysis for the construction phase of the Project are presented in the following tables:

- Changes in flows in receiving streams are presented in Table E4-6.
- Changes in average flow depths of the Muskeg River at node S16 are presented in Table E4-7.
- Changes in Isadore's Lake average water levels and depths and changes in daily water level and depth exceedance statistics are presented in Table E4-8.

Table E4 - 6 Effects on Flows in Receiving Streams During Construction of Muskeg River Mine Project

Year	Location	Node	Existing Undisturbed Area (km²)	Future Area (km²): Undisturbed Area	Future Area (km²): Reclaimed Area[d]	Future Area (km²): Closed Circuit Area	Future Area (km²): Area Contributing Runoff[e]	Water Withdrawal/ Flow Loss[a] (m³/s)	Runoff Loss at Pit Perimeter[a] (m³/s)	Mean Annual Seepage and Dewatering Discharges (m³/s): Muskeg Drainage[b]	Overburden Dewatering[b]	Perimeter CT Seepage[b]	Upward CT Flux[b]	Sand Storage Seepage[b]
2000	Alsands Drain	S1	15.8	1.3	0.0	0.0	1.3	0	0	0.021	0.000	0	0	0
Pre-Construction	Muskeg River	S16	1393	1383	2.9(6)	0.0	1393	0	0	0.032	0.020	0	0	0
Drainage	Inflow to Isadore's Lake	S33	27.3	26.0	1.3(6)	0.0	27.3	0	0	0	0	0	0	0
	Athabasca River	S18	144000	143999	2.9	0.0	144000	0	0	0.053	0.020	0	0	0
2002	Alsands Drain	S1	15.8	1.2	0.0	0.8	1.2	0	0	0	0	0	0	0
Before	Muskeg River	S16	1393	1383	2.9	7.1	1386	0	0	0.030	0.022	0	0	0
Commencement of	Inflow to Isadore's Lake	S33	27.3	26.0	0.0	1.3	26.0	0	0	0	0	0	0	0
Open-Pit Mining	Athabasca River	S18	144000	143986	2.9	11.1	143989	0	0	0.030	0.022	0	0	0

Year	Location	Node	Streamflow Discharge (m³/s): Annual Mean Discharge: Existing	Future	Difference	Mean Open-Water Discharge[c]: Existing	Future	Difference	Mean Ice-Cover Discharge[c]: Existing	Future	Difference	Open-Water 7Q10 Discharge[c]: Existing	Future	Difference	Ice-Cover 7Q10 Discharge[c]: Existing	Future	Difference	10 Year Flood Peak Discharge: Existing	Future	Difference
2000	Alsands Drain	S1	0.046	0.021	-54%	0.070	0.040	-43%	0.012	0.001	-92%	0.003	0.034	1033%	0.001	0.000	-100%	0.7	0.1	-81%
Pre-Construction	Muskeg River	S16	5.28	5.33	1%	8.21	8.30	1%	1.11	1.11	0%	0.281	0.373	33%	0.052	0.052	0%	68.7	68.8	0%
Drainage	Inflow to Isadore's Lake	S33	0.079	0.079	0%	0.118	0.118	0%	0.023	0.023	0%	0.006	0.006	0%	0.001	0.001	0%	1.38	1.39	1%
	Athabasca River	S18	693	693	0%	1106	1106	0%	279	279	0%	331	331	0%	120	120	0%	4220	4220	0%
2002	Alsands Drain	S1	0.046	0.004	-91%	0.070	0.006	-91%	0.012	0.001	-92%	0.003	0.000	-100%	0.001	0.000	-100%	0.7	0.1	-86%
Before	Muskeg River	S16	5.28	5.31	1%	8.21	8.28	1%	1.11	1.11	0%	0.281	0.335	19%	0.052	0.052	0%	68.7	67.8	-1%
Commencement of	Inflow to Isadore's Lake	S33	0.079	0.075	-4%	0.118	0.112	-5%	0.023	0.022	-5%	0.006	0.005	-5%	0.001	0.001	0%	1.38	1.31	-5%
Open-Pit Mining	Athabasca River	S18	693	693	0%	1106	1106	0%	279	279	0%	331	331	0%	120	120	0%	4220	4220	0%

(a): Water withdrawal refers to raw water intake from the Athabasca River. The baseflow loss refers to the seepage inflow from the Muskeg River to the mine pits. The flow is negative if there is a baseflow gain from seepage inflow from the mine area to the Muskeg River excluding the CT and sand seepage.
(b): Muskeg drainage, overburden dewatering, and CT upward flux will occur in the open-water season, while perimeter seepage and sand seepage will occur throughout the year. Mine seepage rate is assumed to be constant in all seasons. This is a conservative assumption for the winter low flow conditions, because frost penetration may reduce the seepage inflows to receiving streams, particularly during the 7Q10 low flow conditions.
(c): The "open-water" season is defined as the period from mid-April to mid-November inclusive. The "ice-cover" season is defined as the period from mid-November to mid-April.
(d): Reclaimed area includes end-pit lakes and wetlands.
(e): Sum of the undisturbed and reclaimed areas that contribute runoff to the node. This does not include the area diverted to other basins.
(f): These areas will not been reclaimed in year 2000, but runoff will be routed through polishing ponds before release to the receiving streams.

Table E4-7 Effects on the Flow Depths of the Muskeg River During Construction of the Muskeg River Mine Project

Year	2000			2002		
	Existing	**Future**	**Difference**	**Existing**	**Future**	**Difference**
Annual Mean Flow Depth (m)	0.47	0.48	1%	0.47	0.47	negligible
Mean Open-Water Flow Depth (m)	0.63	0.63	1%	0.63	0.63	1%
Mean Ice-Cover Flow Depth (m)	0.23	0.23	negligible	0.23		negligible
Open-Water 7Q10 Flow Depth (m)	0.18	0.19	4%	0.18	0.19	2%
Ice-Cover 7Q10 Flow Depth (m)	0.17	0.17	negligible	0.17	0.17	negligible
10 Year Flood Peak Flow Depth (m)	1.52	1.52	negligible	1.52	1.54	1%

A detailed analysis of these changes at each node and at Isadore's Lake is provided below.

Flows at Alsands Drain (S1): During construction, a significant portion of the drainage area will be diverted around this man-made drainage course. The drainage area will be reduced from 15.8 km^2 in natural conditions to 1.2 to 1.3 km^2 during construction, a reduction of over 90%. This will reduce the surface runoff contributing flow to this node. The muskeg drainage and overburden dewatering to this node in 2000 will partially compensate for the loss of the drainage area, but the total impact will be present in 2002 when the dewatering will not be discharged to the node.

Muskeg River (S16) Flows and Levels: The areas requiring clearing and dewatering during construction are relatively small (10 km^2) in comparison with the total drainage area at Node S16 (1,393 km^2). Therefore, the changes of the flows in the Muskeg River will generally be negligible except for the open-water season low-flow. The dewatering discharge will have a small effect on the open-water season mean flow conditions (up to 1% increase), but will increase the open-water season 7Q10 low-flow (up to 33%). Accordingly, the average flow depth at 7Q10 will increase by 0.08 m or 4% from 0.184 m (natural conditions) to 0.192 m (Year 2002).

The south corner of mine pit #1 footprint, a portion of the east muskeg storage area, and a portion of the south overburden storage area will be situated in the 100 year floodplain of the Muskeg River and Jackpine Creek, as shown in Figures E4-5 to E4-13. These floodplain encroachments will have negligible effects on the river flood levels, because they are situated in the backwater areas, instead of the active flood flow conveyance areas. Flood protection measures will be provided in the potentially flooded areas to prevent flooding and erosion of Project facilities during floods.

Table E4 - 8 Effects on Isadore's Lake Levels and Depths During Construction of the Muskeg River Mine Project

Year	Parameter	Mean Open - Water Conditions				Mean Ice - Cover Conditions				10 % Exceedance				Median				90 % Exceedance			
		Existing	Future	Difference		Existing	Future	Difference		Existing	Future	Difference		Existing	Future	Difference		Existing	Future	Difference	
				(m)	(%)			(m)	(%)			(m)	(%)			(m)	(%)			(m)	(%)
2000	Water Level (m)	233.157	233.157	0.000		233.069	233.069	0.000		232.993	232.993	0.000		233.074	233.074	0.000		233.342	233.342	0.000	
Pre-Construction	Maximum Depth (m)	4.157	4.157	0.000	0.0	4.069	4.069	0.000	0.0	3.993	3.993	0.000	0.0	4.074	4.074	0.000	0.0	4.342	4.342	0.000	0.0
Drainage	Average Depth (m)	1.550	1.550	0.000	0.0	1.585	1.585	0.000	0.0	1.486	1.486	0.000	0.0	1.577	1.577	0.000	0.0	1.621	1.621	0.000	0.0
2002	Water Level (m)	233.157	233.150	-0.008		233.069	233.064	-0.005		232.993	232.987	-0.006		233.074	233.069	-0.005		233.342	233.337	-0.005	
Before Commencement	Maximum Depth (m)	4.157	4.150	-0.008	-0.2	4.069	4.064	-0.005	-0.1	3.993	3.987	-0.006	-0.2	4.074	4.069	-0.005	-0.1	4.342	4.337	-0.005	-0.1
of Open-Pit Mining	Average Depth (m)	1.550	1.551	0.002	0.1	1.585	1.588	0.002	0.1	1.486	1.486	0.001	0.0	1.577	1.581	0.003	0.2	1.621	1.622	0.001	0.0

Note: The "open-water" season is defined as the period from mid-April to mid-November inclusive. The "ice-cover" season is defined as the period from mid-November to mid-April.

Inflows to Isadore's Lake (S33) and Lake Levels: The drainage area of the Isadore's Lake will not be affected in Year 2000. Its drainage area will be reduced to 26 km^2 (about 5% reduction from the natural drainage area) because of construction of the tailings settling pond. The reduction in inflows (mean, low and high flows) will be about 5% of the natural flows. As shown in Table E4-8, the lake water level will only be reduced by 5 to 8 mm in Year 2002. These will represent a negligible 0.1 to 0.2% reduction in the maximum water depth in the lake.

Athabasca River (S18) Flows and Levels: The Muskeg River Mine Project will not reduce the drainage area of the Athabasca River in 2000. The closed-circuit area in 2002 only represent 0.008% of the total drainage area of the river at Node 17. There will be no water withdrawal requirement during mine construction. Therefore, the Project will have negligible effect on both the river flows and levels.

Impacts on Flows and Water Levels During Operation

Muskeg Drainage and Overburden Dewatering Discharges

The muskeg drainage and overburden dewatering rates during operation were estimated and presented in the water management plan report (Golder 1997j). These discharge rates are summarized for five operation snapshots in Tables E4-9 and E4-10. The discharges are expressed as the mean annual value, although the muskeg drainage and overburden dewatering water will only contribute to the surface runoff during the open-water season.

There will be no drainage and dewatering discharge to Alsands Drain (Node S1) during Project operation. Both muskeg and overburden dewatering discharges to the Muskeg River (Node S16) will reach the maximum rate (0.068 m^3/s) in about Year 2010. This peak dewatering rate is about 24% of the open-water season 7Q10 low-flow (0.28 m^3/s) on the Muskeg River. Muskeg and overburden dewatering will end around Year 2020.

Closed-Circuit Operations

The closed-circuit areas during the operational phase of the Project are summarized in Table E4-11. Water yield from Basal Aquifer dewatering will be discharged to the closed-circuit water management system to form a component of raw water supply for processing and to reduce the water withdrawal requirement from the Athabasca River.

Table E4-9 Muskeg Drainage Discharges During Operation

Year	Receiving Node	Dewatered Area (km^2)	Mean Annual Muskeg Drainage Discharge (m^3/s)
2003	S1 - Alsands Drain	0	0
	S16 - Muskeg River	1.8	0.03
	S33 - Isadore's Lake Inflow	0	0
2005	S1 - Alsands Drain	0	0
	S16 - Muskeg River	1.8	0.03
	S33 - Isadore's Lake Inflow	0	0
2010	S1 - Alsands Drain	0	0
	S16 - Muskeg River	2.2	0.04
	S33 - Isadore's Lake Inflow	0	0
2020	S1 - Alsands Drain	0	0
	S16 - Muskeg River	0	0
	S33 - Isadore's Lake Inflow	1.4	0.03
2022	S1 - Alsands Drain	0	0
	S16 - Muskeg River	0	0
	S33 - Isadore's Lake Inflow	0	0
2025	S1 - Alsands Drain	0	0
	S16 - Muskeg River	0	0
	S33 - Isadore's Lake Inflow	0	0

Table E4-10 Overburden Dewatering Discharges during Operation

Year	Receiving Node	Dewatered Area (km^2)	Mean Annual Overburden Dewatering Discharge (m^3/s)
2003	S1 - Alsands Drain	0	0
	S16 - Muskeg River	1.8	0.02
	S33 - Isadore's Lake Inflow	0	0
2005	S1 - Alsands Drain	0	0
	S16 - Muskeg River	1.8	0.02
	S33 - Isadore's Lake Inflow	0	0
2010	S1 - Alsands Drain	0	0
	S16 - Muskeg River	2.2	0.03
	S33 - Isadore's Lake Inflow	0	0
2020	S1 - Alsands Drain	0	0
	S16 - Muskeg River	0	0
	S33 - Isadore's Lake Inflow	1.4	0.01
2022	S1 - Alsands Drain	0	0
	S16 - Muskeg River	0	0
	S33 - Isadore's Lake Inflow	0	0
2025	S1 - Alsands Drain	0	0
	S16 - Muskeg River	0	0
	S33 - Isadore's Lake Inflow	0	0

Table E4-11 Closed-Circuit Areas During Operation

Year	Receiving Node	Closed-Circuit Areas (km^2)
2003	S1 - Alsands Drain	3.1
	S16 - Muskeg River	11.5
	S33 - Isadore's Lake Inflow	1.3
2005	S1 - Alsands Drain	3.6
	S16 - Muskeg River	12.8
	S33 - Isadore's Lake Inflow	1.3
2010	S1 - Alsands Drain	5.3
	S16 - Muskeg River	17.2
	S33 - Isadore's Lake Inflow	1.3
2020	S1 - Alsands Drain	11.6
	S16 - Muskeg River	26.8
	S33 - Isadore's Lake Inflow	3.2
2022	S1 - Alsands Drain	11.6
	S16 - Muskeg River	26.8
	S33 - Isadore's Lake Inflow	4.7
2025	S1 - Alsands Drain	11.6
	S16 - Muskeg River	26.8
	S33 - Isadore's Lake Inflow	1.3

Consolidation of CT material will cause upward flux of CT porewater to the surface at the in-pit CT disposal sites. The in-pit CT porewater will not seep into the receiving streams because the surfaces of the CT material will be much lower than the ground levels. Upward flux of CT porewater will be contained on-site as part of the closed-circuit water system. However, there will be some water seepage from the external tailings settling pond to the receiving streams as discussed in the groundwater component of this EIA.

Closed-circuit area will reach maximum around Year 2022 and will remain the same until Year 2027 when the runoff from the reclaimed in-pit and external storage areas will begin to be discharged to the Muskeg River. Progressive reclamation of the in-pit storage areas will begin around 2016, but the surface runoff will be collected in the closed-circuit system until 2027 to minimize impacts to receiving streams.

Water Withdrawal from the Athabasca River

The maximum instantaneous withdrawal rate from the Athabasca River will be approximately 2.5 m^3/s. This maximum would only occur during periods when recycle water would not be available, namely the first two years of processing (i.e., 2002 and 2003). In normal hydrologic conditions, the maximum annual withdrawal rate during this period of no recycle operation is only 1.65 m^3/s, because of discontinuous operation of the extraction plant and variations in water demand for utilities. The mean annual withdrawal rate would gradually reduce to about 0.19 m^3/s in Years 2015 to 2022, which is about 11% of the maximum annual withdrawal rate. Table E4-12 lists the mean annual withdrawal rates for various time snapshots during operation.

Table E4-12 Mean Annual Water Withdrawal Rate from the Athabasca River

Year	Mean Annual Withdrawal Rate (m^3/s)
2003	1.65
2005	0.70
2010	0.40
2020	0.19
2022	0.19
2025	0.00

Mine Pit Development

Mine pit development will cause some drainage of the surficial aquifer at the perimeter of the pits. This water table drawdown at the mine pit perimeter will result in water losses from the surface muskeg by percolation to the surface aquifer with overburden. Water in the surface aquifer in the overburden will drain into the mine pits. The area of influence of the mine pits is estimated to be 1 to 2 km from the edges of the mine pits as discussed in Section E3.

Most of the excess surface water in the drawdown area of influence will be lost to the aquifer in the overburden because of the flat topography, the large water storage capacity of the surficial peat soils and the high permeability of the peat soils and underlying overburden materials. This will result in a reduction in surface water runoff of about 40 to 61 mm per year over the area affected by the drawdown of the surface aquifer. The 40 to 60 mm of surface water represents the moisture which normally represents surface runoff to receiving streams. The resulting reduction in surface runoff to receiving streams are indicated in Table E4-13 based on the areas affected by drawdown of the water table (average length = 1.5 km from the mine pit edges).

The drawdown area at the perimeter of the pits will reach a maximum around Year 2022 when the mine pit area will reach the maximum. The maximum loss of surface runoff because of this drawdown will represent about 0.1% of the mean annual flow on the Muskeg River at Node S16. This is considered to be negligible. The maximum loss of surface runoff caused by this drawdown of the water table in the Mills Creek basin will represent about 11% of the mean annual flow. This is considered to be moderate.

Table E4-13 Water Losses Caused by Drawdown of Surface Aquifer in Vicinity of Mine Pits

Year	Receiving Node	Area Subject to Drawdown of Surface Aquifer (km^2)	Mean Annual Water Losses[a] (m^3/s)
2003	S1 - Alsands Drain	0.0	0.0
	S16 - Muskeg River	1.4	0.003
	S33 - Isadore's Lake Inflow	0.0	0.0
2005	S1 - Alsands Drain	0.0	0.004
	S16 - Muskeg River	1.8	0.004
	S33 - Isadore's Lake Inflow	0.0	0.0
2010	S1 - Alsands Drain	0.0	0.0
	S16 - Muskeg River	3.3	0.01
	S33 - Isadore's Lake Inflow	0.0	0.0
2020	S1 - Alsands Drain	0.0	0.0
	S16 - Muskeg River	3.6	0.01
	S33 - Isadore's Lake Inflow	2.5	0.005
2022	S1 - Alsands Drain	0.0	0.0
	S16 - Muskeg River	3.6	0.01
	S33 - Isadore's Lake Inflow	4.6	0.01
2025	S1 - Alsands Drain	0.0	0.0
	S16 - Muskeg River	3.6	0.01
	S33 - Isadore's Lake Inflow	4.6	0.01

[a] Mean annual water loss is conservatively estimated based on 61 mm per year.

The presence of a mine pit during operation will also cause some loss of flow in the Muskeg River because of seepage from the river into the mine pit. This will not cause a significant impact on normal river flows but would represent a small impact on river baseflows. Derivation of these seepage inflows has been discussed in Section E3. Table E4-14 lists the estimated reduction of flows in the Muskeg River at Node S16 caused by the drawdown of the surface aquifer in the vicinity of mine pits.

Table E4-14 Muskeg River (Node S16) Flow Reduction Caused by Drawdown of Surface Aquifer in Vicinity of Mine Pits

Year	Mean Annual Reduction in Flow (m^3/s)
2003	0.0020
2005	0.0027
2010	0.0034
2020	0.0032
2022	0.0032
2025	0.0032

The peak reduction in flows will occur in about Year 2010. The reduction rate of 0.0034 m^3/s is about 0.3% of the mean ice-cover season discharge (1.1 m^3/s) of the Muskeg River. The reduction rate is about 1% of the open-water season 7Q10 low-flow. These reductions are very small. The reduction rate is about 6% of the annual 7Q10 low-flow (occurs in ice-cover season).

Basal Aquifer depressurization will cause small increases in groundwater outflow from Isadore's Lake as discussed in Section E3. This factor was considered in evaluating the potential Project effects on the Isadore's Lake water balance including lake levels and outflows.

Other Activities

Other activities in the LSA that will cause some changes to surface water flows are listed below:

- Construction of access roads, causing redirection and ponding of surface flows.
- Ditching along roads causing drainage of adjacent terrain.
- Channelization of flows in the vicinity of Project development and along utility corridors redirecting and concentrating surface runoff.

These changes are expected to be minor and much less significant than the changes discussed earlier.

Reclamation and End Pit Lake Management Period Before Project Closure

This period will span over eight years from early 2023 to 2030. Reclamation activities will include the following:

- Reclaim the remaining in-pit storage areas (Pits 4 to 6), and construct drainage channels and wetlands.
- Construct a 20% littoral zone along the east shore of the end pit lake.
- Drain tailings settling pond water and CT porewater into the end pit lake.
- Transfer consolidated MFT in the tailings settling pond to the bottom of the end pit lake.
- Reclaim the reclaimed tailings settling pond area, and construct drainage channels and wetlands.

Filling of the end pit lake will begin in Year 2023. This will involve transfer of CT porewater and runoff from reclaimed mine-pit areas, and transfer of tailings porewater and MFT from the tailings settling pond at a controlled rate to ensure a non-acutely and non-chronically toxic discharge of the end pit lake water to the Muskeg River.

Starting in about Year 2027, MFT in the tailings settling pond will be transferred to the end pit lake over a four year period after the thin fine tailings (TofR) has consolidated to about 30% solid content. The transfer will be made using a submerged pipe outlet to minimize mixing and to settle on the lake bottom. The 19 m deep, clear, non-toxic layer of water will cover the MFT.

The end pit lake will begin discharging to the Muskeg River in about Year 2028. The transfer will be conducted only during the open-water season to minimize impacts on the Muskeg River low-flows in winter. The initial rate of discharge from the lake will be relatively high with a mean value of about 1 m^3/s. This is about 19% of the mean annual flow of the Muskeg River. However, the mean annual outflow from the end pit lake will decrease in Year 2030 and it will be about 0.6 m^3/s.

Results of Impact Analysis

A summary of the results of impact analysis for the operation phase of the Project are presented in the following tables:

- Changes in flows of receiving streams are presented in Table E4-15.
- Changes in average flow depths of the Muskeg River at node S16 are presented in Table E4-16.
- Changes in Isadore's Lake average water levels and depths, and changes in daily water level and depth exceedance statistics are presented in Table E4-17.

Table E4 - 15 Effects on Flows in Receiving Streams During Operation of Muskeg River Mine Project

Year	Location	Node	Existing Undisturbed Area (km^2)	Future Area (km^2)				Water Withdrawal / Flow Loss[a] (m^3/s)	Runoff Loss at Pit Perimeter[f] (m^3/s)	Mean Annual Seepage and Dewatering Discharges (m^3/s)					Streamflow Discharge (m^3/s)																	
				Undisturbed Area	Reclaimed Area[d]	Closed Circuit Area	Area Contributing to Runoff[e]			Muskeg Drainage[b]	Overburden Dewatering[b]	Perimeter CT Seepage[b]	Upward CT Flux[b]	Sand Storage Seepage[b]	Annual Mean Discharge			Mean Open-Water Discharge[c]			Mean Ice-Cover Discharge[c]			Open-Water 7Q10 Discharge[c]			Ice-Cover 7Q10 Discharge[c]			10 Year Flood Peak Discharge		
															Existing	Future	Difference	Existing	Future	Difference	Existing	Future	Difference	Existing	Future	Difference	Existing	Future	Difference	Existing	Future	Difference
2003	Alsands Drain	S1	15.8	0.1	0.0	3.1	0.1	0	0	0	0	0	0	0	0.046	0.000	-100%	0.070	0.000	-100%	0.012	0.000	-100%	0.003	0.000	-99%	0.001	0.000	-99%	0.7	0.0	-99%
First-Full	Muskeg River	S16	1393	1379.0	2.9	11.5	1382	0.0020	0.0027	0.030	0.022	0	0	0.0043	5.28	5.30	0%	8.21	8.26	1%	1.11	1.10	-1%	0.281	0.375	33%	0.052	0.054	4%	68.7	68.2	-1%
Production Year	Inflow to Isadore's Lake	S33	27.3	26.0	0.0	1.3	26.0	0	0	0	0	0	0	0.0008	0.079	0.076	-3%	0.118	0.113	-4%	0.023	0.023	-1%	0.006	0.006	10%	0.001	0.002	75%	1.38	1.32	-5%
Without Recycle	Athabasca River	S18	144000	143982	2.9	15.5	143985	1.65	0.0027	0.030	0.022	0	0	0.0060	693	691	0%	1106	1104	0%	279	277	-1%	331	329	0%	120	118	-1%	4220	4218	0%
2005	Alsands Drain	S1	15.8	0.1	0.0	3.6	0.1	0	0	0	0	0	0	0	0.046	0.000	-100%	0.070	0.000	-100%	0.012	0.000	-100%	0.003	0.000	-99%	0.001	0.000	-99%	0.7	0.0	-99%
Production with	Muskeg River	S16	1393	1377	2.9	12.8	1380	0.0027	0.0035	0.031	0.023	0	0	0.0058	5.28	5.29	0%	8.21	8.25	1%	1.11	1.10	-1%	0.281	0.379	35%	0.052	0.055	5%	68.7	68.1	-1%
Recycle - without	Inflow to Isadore's Lake	S33	27.3	26	0.0	1.3	26.0	0	0	0	0	0	0	0.0009	0.079	0.076	-3%	0.118	0.113	-4%	0.023	0.023	0%	0.006	0.006	12%	0.001	0.002	85%	1.38	1.32	-5%
CT Manufacture	Athabasca River	S18	144000	143980	2.9	16.8	143983	0.70	0.0035	0.031	0.023	0	0	0.0076	693	692	0%	1106	1105	0%	279	278	0%	331	330	0%	120	119	-1%	4220	4219	0%
2010	Alsands Drain	S1	15.8	0.1	0.0	5.3	0.1	0	0	0	0	0	0	0	0.046	0.000	-100%	0.070	0.000	-100%	0.012	0.000	-100%	0.003	0.000	-99%	0.001	0.000	-99%	0.7	0.0	-99%
Production of	Muskeg River	S16	1393	1373	2.9	17.2	1376	0.0034	0.0064	0.037	0.031	0	0	0.008	5.28	5.29	0%	8.21	8.26	6896%	1.11	1.10	0%	0.281	0.406	45%	0.052	0.056	8%	68.7	68.0	-1%
CT at 75%	Inflow to Isadore's Lake	S33	27.3	26	0.0	1.3	26.0	0	0	0	0	0	0	0.001	0.079	0.076	-3%	0.118	0.113	-4%	0.023	0.023	0%	0.006	0.006	13%	0.001	0.002	95%	1.38	1.32	-5%
Capacity	Athabasca River	S18	144000	143976	2.9	21.2	143979	0.40	0.0064	0.037	0.031	0	0	0.010	693	693	0%	1106	1106	0%	279	279	0%	331	331	0%	120	120	0%	4220	4219	0%
2020	Alsands Drain	S1	15.8	0.1	1.1	11.6	0.1	0	0	0	0	0	0	0	0.046	0.000	-100%	0.070	0.000	-100%	0.012	0.000	-100%	0.003	0.000	-99%	0.001	0.000	-99%	0.7	0.0	-99%
Production of	Muskeg River	S16	1393	1361	8.3	26.8	1366	0.0032	0.0069	0	0	0	0	0.013	5.28	5.22	-1%	8.21	8.02	-2%	1.11	1.10	-1%	0.281	0.277	-1%	0.052	0.061	17%	68.7	67.4	-2%
CT at 95%	Inflow to Isadore's Lake	S33	27.3	22	2.6	3.2	24.1	0	0.0048	0.026	0.008	0	0	0.001	0.079	0.102	30%	0.118	0.169	44%	0.023	0.021	-9%	0.006	0.074	1243%	0.001	0.002	88%	1.38	1.28	-7%
Capacity[g]	Athabasca River	S18	144000	143959	10.9	30.0	143962	0.19	0.0117	0.026	0.008	0	0	0.015	693	693	0%	1106	1106	0%	279	279	0%	331	331	0%	120	120	0%	4220	4219	0%
2022	Alsands Drain	S1	15.8	0.1	2.3	11.6	0.1	0	0	0	0	0	0	0	0.046	0.000	-100%	0.070	0.000	-100%	0.012	0.000	-100%	0.003	0.000	-99%	0.001	0.000	-99%	0.7	0.0	-99%
Processing	Muskeg River	S16	1393	1361	12.4	26.8	1366	0.0032	0.0069	0	0	0	0	0.013	5.28	5.20	-1%	8.21	8.10	-1%	1.11	1.10	-1%	0.281	0.285	2%	0.052	0.061	17%	68.7	67.4	-2%
Complete	Inflow to Isadore's Lake	S33	27.3	20	2.6	4.7	22.6	0	0.0089	0	0	0	0	0.001	0.079	0.060	-23%	0.118	0.086	-27%	0.023	0.020	-13%	0.006	0.006	1%	0.001	0.002	83%	1.38	1.13	-18%
	Athabasca River	S18	144000	143958	15.0	31.5	143961	0.19	0.0158	0	0	0	0	0.015	693	693	0%	1106	1106	0%	279	279	0%	331	331	0%	120	120	0%	4220	4219	0%
2025	Alsands Drain	S1	15.8	0.1	6.3	11.6	0.1	0	0	0	0	0	0	0	0.046	0.000	-100%	0.070	0.000	-100%	0.012	0.000	-100%	0.003	0.000	-99%	0.001	0.000	-99%	0.7	0.0	-99%
Mine Closure	Muskeg River	S16	1393	1361	18.5	26.8	1366	0.0032	0.0069	0	0	0	0	0.003	5.28	5.19	-2%	8.21	8.09	-2%	1.11	1.09	-2%	0.281	0.275	-2%	0.052	0.051	-2%	68.7	67.4	-2%
in Progress	Inflow to Isadore's Lake	S33	27.3	20.1	5.9	1.3	22.7	0	0.0089	0	0	0	0	0.0024	0.079	0.062	-22%	0.118	0.088	-26%	0.023	0.021	-7%	0.006	0.007	27%	0.001	0.003	223%	1.38	1.13	-18%
	Athabasca River	S18	144000	143958	24.4	28.1	143961	0	0.0158	0	0	0	0	0.0078	693	693	0%	1106	1106	0%	279	279	0%	331	331	0%	120	120	0%	4220	4219	0%

(a): Water withdrawal refers to raw water intake from the Athabasca River. The baseflow loss refers to the seepage inflow from the Muskeg River to the mine pits.
The flow is negative if there is a baseflow gain from seepage inflow from the mine area to the Muskeg River excluding the CT and sand seepage.

(b): Muskeg drainage, overburden dewatering, and CT upward flux will occur in the open-water season, while perimeter seepage and sand seepage will occur throughout the year.
Mine seepage rate is assumed to be constant in all seasons. This is a conservative assumption for the winter low flow conditions, because frost penetration may reduce the seepage inflows to receiving streams, particularly during the 7Q10 low flow conditions.

(c): The "open-water" season is defined as the period from mid-April to mid-November inclusive. The "ice-cover" season is defined as the period from mid-November to mid-April.

(d): Reclaimed area includes end-pit lakes and wetlands.

(e): Sum of the undisturbed and reclaimed areas that contribute runoff to the node. This does not include the area diverted to other basins.

(f): This runoff reduction is resulting from groundwater table drawdown at the mine pit perimeter.

(g): Muskeg drainage and overburden dewatering discharge will end in year 2019. This drainage and dewatering discharge is included year 2020 to capture the effect of the discharge on the inflows to Isadore's Lake.

Table E4-16 Effects on the Flow Depths of the Muskeg River During Operation of the Muskeg River Mine Project

Year	2003			2005		
	Existing	Future	Difference	Existing	Future	Difference
Annual Mean Flow Depth (m)	0.47	0.47	negligible	0.47	0.47	negligible
Mean Open-Water Flow Depth (m)	0.63	0.63	negligible	0.63	0.63	negligible
Mean Ice-Cover Flow Depth (m)	0.23	0.23	negligible	0.23	0.23	negligible
Open-Water 7Q10 Flow Depth (m)	0.18	0.19	3%	0.18	0.19	3%
Ice-Cover 7Q10 Flow Depth (m)	0.17	0.17	negligible	0.17	0.17	negligible
10 Year Flood Peak Flow Depth (m)	1.52	1.53	1%	1.52	1.53	1%
Year	**2010**			**2020**		
	Existing	**Future**	**Difference**	**Existing**	**Future**	**Difference**
Annual Mean Flow Depth (m)	0.47	0.47	negligible	0.47	0.47	-1%
Mean Open-Water Flow Depth (m)	0.63	0.63	negligible	0.63	0.62	-1%
Mean Ice-Cover Flow Depth (m)	0.23	0.23	negligible	0.23	0.23	negligible
Open-Water 7Q10 Flow Depth (m)	0.18	0.19	4%	0.18	0.18	negligible
Ice-Cover 7Q10 Flow Depth (m)	0.17	0.17	negligible	0.17	0.17	negligible
10 Year Flood Peak Flow Depth (m)	1.52	1.53	1%	1.52	1.55	2%
Year	**2022**			**2025**		
	Existing	**Future**	**Difference**	**Existing**	**Future**	**Difference**
Annual Mean Flow Depth (m)	0.47	0.47	-1%	0.47	0.47	-1%
Mean Open-Water Flow Depth (m)	0.63	0.62	-1%	0.63	0.62	-1%
Mean Ice-Cover Flow Depth (m)	0.23	0.23	negligible	0.23	0.23	negligible
Open-Water 7Q10 Flow Depth (m)	0.18	0.18	negligible	0.18	0.18	negligible
Ice-Cover 7Q10 Flow Depth (m)	0.17	0.17	negligible	0.17	0.17	negligible
10 Year Flood Peak Flow Depth (m)	1.52	1.55	2%	1.52	1.58	2%

A detailed analysis of these changes at each node and at Isadore's Lake is provided below.

Flows at Alsands Drain (S1): The drainage area of Alsands Drain will be reduced from 15.8 km^2 for existing conditions to only 0.1 km^2 during Project operation. This will temporarily terminate flows in this man-made channel during operation. The Alsands Drain will be used as an outlet for the end pit lake after 2027.

Muskeg River (S16) Flows and Levels: The maximum closed-circuit area (23.8 km^2) causing reduced surface runoff to the Muskeg River will occur in Year 2020. Year 2025 will represent a maximum reduction of the Muskeg River flow during Project operation, because the sand seepage to the river will reach the minimum (0.003 m^3/s), muskeg and overburden dewatering discharge to the river will be zero, closed-circuit area will reach a maximum (26.8 km^2), and the area of water table drawdown will also reach a maximum (3.6 km^2). These combined factors will reduce the Muskeg River flows (high, mean and low flows) by about 2% and average flow depth by about 1%. This level of impact is considered to be low.

Muskeg and overburden dewatering during the open-water season will have negligible effects on increasing the Muskeg River mean and flood flows. However, the dewatering discharges during the open-water season will

Table E4 - 17 **Effects on Isadore's Lake Levels and Depths During Operation of the Muskeg River Mine Project**

Year	Parameter	Mean Open - Water Conditions				Mean Ice - Cover Conditions				10 % Exceedance				Median				90 % Exceedance			
		Existing	Future	Difference		Existing	Future	Difference		Existing	Future	Difference		Existing	Future	Difference		Existing	Future	Difference	
				(m)	(%)			(m)	(%)			(m)	(%)			(m)	(%)			(m)	(%)
2003	Water Level (m)	233.157	233.152	-0.005		233.069	233.067	-0.002		232.993	232.992	-0.001		233.074	233.071	-0.003		233.342	233.338	-0.004	
First - Full Production	Maximum Depth (m)	4.157	4.152	-0.005	-0.1	4.069	4.067	-0.002	-0.1	3.993	3.992	-0.001	0.0	4.074	4.071	-0.003	-0.1	4.342	4.338	-0.004	-0.1
Year Without Recycle	Average Depth (m)	1.550	1.551	0.001	0.1	1.585	1.586	0.001	0.1	1.486	1.486	0.001	0.0	1.577	1.579	0.002	0.1	1.621	1.621	0.000	0.0
2005	Water Level (m)	233.157	233.153	-0.004		233.069	233.068	-0.002		232.993	232.993	0.000		233.074	233.072	-0.003		233.342	233.338	-0.004	
Production with Recycle	Maximum Depth (m)	4.157	4.153	-0.004	-0.1	4.069	4.068	-0.002	0.0	3.993	3.993	0.000	0.0	4.074	4.072	-0.003	-0.1	4.342	4.338	-0.004	-0.1
Without CT Manufacture	Average Depth (m)	1.550	1.551	0.001	0.1	1.585	1.586	0.001	0.0	1.486	1.486	0.001	0.0	1.577	1.579	0.002	0.1	1.621	1.621	0.000	0.0
2010	Water Level (m)	233.157	233.154	-0.004		233.069	233.069	-0.001		232.993	232.994	0.001		233.074	233.072	-0.002		233.342	233.338	-0.004	
Production of	Maximum Depth (m)	4.157	4.154	-0.003	-0.1	4.069	4.069	-0.001	0.0	3.993	3.994	0.001	0.0	4.074	4.072	-0.002	0.0	4.342	4.338	-0.004	-0.1
CT at 75% Capacity	Average Depth (m)	1.550	1.551	0.001	0.1	1.585	1.586	0.000	0.0	1.486	1.486	0.000	0.0	1.577	1.579	0.001	0.1	1.621	1.621	0.000	0.0
2020	Water Level (m)	233.157	233.209	0.052		233.069	233.084	0.015		232.993	233.035	0.043		233.074	233.113	0.039		233.342	233.345	0.003	
Production of	Maximum Depth (m)	4.157	4.209	0.052	1.2	4.069	4.084	0.015	0.4	3.993	4.035	0.043	1.1	4.074	4.113	0.039	1.0	4.342	4.345	0.003	0.1
CT at 95% Capacity	Average Depth (m)	1.550	1.530	-0.020	-1.3	1.585	1.576	-0.009	-0.6	1.486	1.485	0.000	0.0	1.577	1.557	-0.021	-1.3	1.621	1.601	-0.020	-1.2
2022	Water Level (m)	233.157	233.136	-0.021		233.069	233.054	-0.016		232.993	232.987	-0.006		233.074	233.059	-0.015		233.342	233.312	-0.030	
Processing	Maximum Depth (m)	4.157	4.136	-0.021	-0.5	4.069	4.054	-0.016	-0.4	3.993	3.987	-0.006	-0.2	4.074	4.059	-0.015	-0.4	4.342	4.312	-0.030	-0.7
Complete	Average Depth (m)	1.550	1.555	0.005	0.3	1.585	1.593	0.007	0.5	1.486	1.491	0.005	0.3	1.577	1.586	0.009	0.6	1.621	1.621	0.000	0.0
2025	Water Level (m)	233.157	233.142	-0.015		233.069	233.059	-0.010		232.993	232.997	0.004		233.074	233.064	-0.010		233.342	233.314	-0.028	
Mine Closure	Maximum Depth (m)	4.157	4.142	-0.015	-0.4	4.069	4.059	-0.010	-0.3	3.993	3.997	0.004	0.1	4.074	4.064	-0.010	-0.2	4.342	4.314	-0.028	-0.6
in Progress	Average Depth (m)	1.550	1.554	0.004	0.3	1.585	1.590	0.005	0.3	1.486	1.490	0.005	0.3	1.577	1.583	0.006	0.4	1.621	1.620	-0.001	-0.1

Note: The "open-water" season is defined as the period from mid-April to mid-November inclusive. The "ice-cover" season is defined as the period from mid-November to mid-April.

affect the river low-flow conditions and will increase the 7Q10 low-flow by up to 45% and increase the average flow depth by 4% in Year 2010.

During Project operation, no additional facilities will be built within the 100 year floodplain of the Muskeg River and Jackpine Creek. Therefore, the impacts of the Project operations will have negligible impacts on the river flood levels, similar to the impacts during construction.

Inflows to Isadore's Lake (S33) and Lake Levels: The tailings settling pond will reduce the surface area contributing runoff to Isadore's Lake during the early years of Project operation, but the impacts will be small. During the period of discharge to Mills Creek from muskeg drainage and overburden dewatering, inflows to Isadore's Lake will increase. This represents a relatively large increase in flows. During the later period of Project operation, the drainage area of Mills Creek will be reduced, and the reduction in mean annual inflow to the lake will be about 23%. This impact is considered to be moderate because flow reduction is less important than flow increase in terms of its consequent effects on the stream geomorphic conditions.

The ratio of natural drainage basin area to surface area of Isadore's Lake is about 58. This is a very large ratio so that the expected changes in drainage area during operation will only cause small reduction on the lake water levels, less than 30 mm or 1% of maximum water depth as shown in Table E3-17. The muskeg drainage and overburden dewatering discharge to the lake will cause a small increase in the lake water levels of about 51 mm or 1% of maximum water depth.

Athabasca River (S18) Flows and Levels: The closed-circuit area, which will causing a reduction in surface runoff to the Athabasca River, will reach a maximum value of 31.5 km^2 at the end of mining. This only represents 0.02% of the total drainage area of the river at Node 17. In Year 2003 when the mean annual water withdrawal rate from the Athabasca River will reach a maximum of 1.65 m^3/s among the selected time snapshots, the withdrawal will have negligible effects on the mean and high river flows. Even during the 7Q10 low-flow conditions, the maximum withdrawal rate will represent only about 1% of the river flow. This impact is considered to be negligible. The maximum instantaneous withdrawal rate of 2.5 m^3/s will represent about 0.4% of the mean river flow and about 2% of the 7Q10 low-flow. Consequently, the Project activities during operations will have a negligible impact on the river levels.

Impacts on Flows and Water Levels After Closure

Runoff from Reclaimed Surfaces

Reclaimed Tailing Settling Pond Area: This area will be composed largely of free draining subsoils, which will be covered by topsoil composed of a mixture of organic and mineral soils. The underlying sand material will limit the moisture storage in the surficial soils because any increase in soil moisture above field capacity will be lost to percolation through the free draining subsoils. Without a relatively impervious subsoil, the reclaimed tailings settling pond area will have less moisture available for evapotranspiration (ET) and surface runoff. The reduced ET will report to increased deep percolation losses. Deep percolation losses will report mainly to seepage discharge in perimeter ditches of the reclaimed tailings settling pond area but some will bypass the seepage interceptor system and seep into the receiving waterbodies such as Muskeg River, Isadore's Lake and the Athabasca River.

Flood runoff from the reclaimed tailings settling pond area will be much smaller than natural lowland surface in summer because of the relatively dry conditions and pervious soils. However, flood runoff during snowmelt will be higher because the relatively steep slopes will convey flow more quickly down reclaimed surfaces which will be nearly impervious when frozen.

Overburden Storage Areas: The overburden storage areas will be reclaimed with a thick layer of topsoil. The top surfaces will be crowned to encourage drainage to the edges of the storage areas. The surface will be landscaped with grassed waterways and drainage swales to minimize erosion. These areas are expected to have hydrologic characteristics similar to the natural upland conditions. However, water yield and flood peak discharges of the overburden storage areas are expected to be greater than the natural upland areas because of steeper slopes and reduced soil storage capacity.

In-Pit CT Storage Areas (Pits 1 to 5): The final elevations of the CT surfaces in Pits 1 to 5 will be below original ground. Consequently, there will be no seepage of the CT porewater to the receiving waterbodies. Instead, there will be a net inflow of seepage into the CT area from the perimeter area. The in-pit CT disposal areas will be capped with overburden in Pits 1 to 3 and tailings sand in Pits 4 and 5 to raise the final reclaimed surface levels to near original ground level. This infill is required to provide positive drainage of reclaimed CT areas.

The reclaimed sand cap on CT (Pits 4 and 5) will be characterized by wet conditions, similar to the existing muskeg terrain. Wet soil moisture conditions and standing water are expected to characterize the lowland areas of these disposal sites, particularly the channel draining each pit. Any periphery areas which are situated below the existing ground level will also be subject to particularly wet conditions. The areas located above original ground level at the periphery of the Project pit will be relatively dry and are expected to support typical upland vegetation.

The wet areas of the sand cap on CT in Pits 4 and 5 will be subject to relatively high evapotranspiration losses because of the greater available soil moisture. Consequently, the annual water yield and flood discharge characteristics of these areas will be more like the existing muskeg terrain.

Annual water yield may be slightly greater at CT areas than at natural muskeg areas because of the smaller soil moisture storage capacity of reclamation topsoil and the presence of sand ridges which will result in lower evaporation than natural lowland areas. Surface runoff from drier portions of the sand-capped CT areas will be relatively small except during snowmelt when melting governs water yield.

Portions of the overburden-capped CT areas (Pits 1 to 3) will have similar basin and runoff characteristics as the reclaimed overburden storage areas. However, the channel areas will be capped by sand to enable release of upward flux of CT porewater. These areas will be very wet with similar runoff characteristics as the natural lowland muskeg terrain. The periphery areas will be subject to wet conditions, like the original muskeg terrain, because of seepage into the CT areas from the higher ground surface of perimeter areas.

In-Pit Sand Cap on Overburden Area (Pit 6): This area will consist of overburden material below original ground and tailings sand infill on top of overburden material to raise the surface level to near the original ground level. The sand subsoil will be overlaid by reclamation topsoil. The final topography will have an overland slope of 0.5%, similar to the natural muskeg terrain.

The in-pit sand cap on overburden in Pit 6 is expected to have similar runoff characteristics as the reclaimed sand storage area. However, the channel areas are expected to be wet due to seepage and runoff collection in these areas. The perimeter areas situated below original ground levels will also be subject to wet conditions as a result of seepage from the adjacent undisturbed terrain. These areas are expected to result in higher water yield because of the high water table and relatively small soil moisture storage.

Shallow Lakes and Wetlands: Shallow lakes and wetlands will be built into the reclaimed landscape at in-pit CT storage areas and the reclaimed tailing settling pond area. The lakes/wetlands will attenuate flood peak discharges and provide for residence time which will improve drainage water quality through biological treatment. The lake/wetlands areas are sized to represent about 5% of the contributing catchment area.

End Pit Lake: A productive end pit lake will be a part of the closure landscape to provide for remediation of CT porewater seepage, sand porewater seepage and MFT porewater release during consolidation of MFT at the bottom of the end pit lake. It will also contribute to the balance of dry and wet landscape in the reclaimed Project area. A large littoral zone occupying 20% of the end pit lake area will be provided along the east shore. The littoral zone is needed to enable biological productivity of the lake.

The presence of the end pit lake in the reclaimed landscape will reduce flood flows by providing lake storage for flow attenuation. However, the lake will reduce the net annual water yield because annual lake evaporation exceeds annual precipitation.

Estimates of Annual Runoff from Reclaimed Surfaces: The estimated annual water yields for various types of reclaimed surfaces are presented in Table E4-18. The water yields from natural upland and low land areas are included in the table for comparative purposes.

Table E4-18 Estimated Annual Runoff from Natural and Reclaimed Surfaces

Area Type	Parameter	Annual Water Yield (mm)				
		100 Year Dry	10 Year Dry	Mean	10 Year Wet	100 Year Wet
All	Precipitation	269	319	423	545	712
Natural Lowland	Evapotranspiration	269	302	357	427	522
	Percolation	0	0	5	5	5
	Runoff	0	17	61	113	185
Natural Upland	Evapotranspiration	235	264	319	389	484
	Percolation	0	0	5	5	5
	Runoff	34	55	99	151	223
Reclaimed Sand Cap on CT	Evapotranspiration	237	267	322	383	464
	Percolation	0	0	8	20	39
	Runoff	32	52	93	142	209
Reclaimed Overburden Cap on CT	Evapotranspiration	256	266	304	339	383
	Percolation	0	0	4	6	12
	Runoff	8	43	115	200	317
Reclaimed Sand Cap on Overburden	Evapotranspiration	185	208	231	254	277
	Percolation	79	102	174	202	393
	Runoff	7	12	21	33	48
Reclaimed Overburden Storage	Evapotranspiration	256	266	293	322	350
	Percolation	5	10	15	23	45
	Runoff	8	43	115	200	317
Reclaimed Tailing Settling Pond Area	Evapotranspiration	185	208	231	254	277
	Percolation	79	102	174	202	393
	Runoff	7	12	21	33	48
Wetlands	Evaporation	677	640	588	534	495
	Percolation	32	32	32	32	32
	Runoff	-440	-353	-197	-21	185
End pit lake	Evaporation	677	640	588	534	495
	Percolation	11	11	11	11	11
	Runoff	-419	-332	-176	0	206

Note: These estimates were made based on the available records of measured flow data at the regional WSC gauging stations and an understanding of the differences in runoff characteristics between natural and reclaimed surfaces.

Discharge of Mine Seepage Water

There will be some seepage of tailings porewater from the reclaimed areas to the receiving streams over the long term as described below:

- The total seepage from the reclaimed in-pit storage areas to the Muskeg River is estimated to be 0.001 m^3/s.

- Majority of the seepage water from the external sand storage area will be collected by the perimeter ditch system and diverted through shallow lakes and wetlands before discharging to the Athabasca River. The estimated rate of seepage water, which will bypass the collector system, is estimated as described in Section E3. The seepage rates are summarized as follows:

- seepage to Muskeg River (S16) is estimated to be 0.0035 m^3/s, which is about 1% of the open-water season 7Q10 low-flow;
- seepage to Isadore's Lake (S33) is estimated to be 0.0024 m^3/s, which is about 4% of its open-water season 7Q10 low-flow; and
- the total seepage discharge to the Athabasca River is estimated to be 0.027 m^3/s, which is negligible in comparison with the river discharge.

Upward flux of CT porewater drained to the end pit lake is estimated to be 0.04 m^3/s in Year 2030. This will reduce to zero in the far future.

Drainage Systems and the End Pit Lake

The closure drainage systems will include well-defined drainage courses which will alter the natural drainage pattern in the Project area. The reclaimed topography will have similar overland slope as the natural conditions. The provision of wetlands and the end pit lake will help attenuate flood flows in addition to providing bioremediation of runoff and seepage from the reclaimed areas.

The end pit lakes will attenuate flows through the lake so that flood flows will be reduced and low flows will be increased. This is illustrated at Alsands Drain (S1) where the ultimate drainage area will increase without increasing flood discharges. Although the drainage area will increase from 15.8 km^2 (natural conditions) to 29.3 km^2 (far future conditions), which is an increase of 85%, the 10 year flood peak discharges are about the same. Mean ice-cover season flow will increase by 425%, relative to the natural conditions. This illustrates the benefit of flow attenuation by the large end pit lake.

The occurrence of the permanent end pit lake will cause some drainage of adjacent surficial aquifers in the overburden, because the end pit lake will be depressed below the original ground by about 10 m. The average length of influence of the drawdown of overburden aquifer is expected to be about 1.5 km.

Drawdown of the surface aquifer in the overburden will create a soil profile with free draining subsoils. Consequently, all excess water in the surface peat soils above field capacity will percolate to the groundwater table in the overburden. This will result in some drying of the muskeg and reduced surface runoff. Most of the water which would normally report to surface runoff will be lost to the groundwater which will seep to the end pit lake.

If all excess water in the area of influence of overburden dewatering is lost to groundwater, surface runoff will be reduced by about 0.016 m^3/s. This is calculated by applying the natural mean annual surface water yield of 61 mm over the drawdown area of influence after closure. This change in surface water yield will be reflected in an equal (or slightly larger) change in seepage to the end pit lake. The more important impact is that the reduced moisture content in the muskeg could change the type of vegetation which can grow in this area. Reduced moisture in surface soils will probably create conditions more favorable for forest timber production.

Results of Impact Analysis

Two time snapshots are selected to represent the closure conditions. Year 2030 represents the conditions towards the end of MFT transfer from the tailings settling pond to the end pit lake and the residual upward flux inflow of CT porewater to the end pit lake. This is used to represent the temporary, large release of water from the reclaimed areas to the Muskeg River. The far future time snapshot represent the dynamic equilibrium conditions at closure. The results of impact analysis for the closure phase of the Project are presented in the following tables:

- Changes in flows in receiving streams are presented in Table E4-19.
- Changes in flow depths of the Muskeg River at node S16 are presented in Table E4-20.
- Changes in Isadore's Lake average water levels and depths and changes in daily water level and depth exceedance statistics are presented in Table E4-21.

Table E4 - 19 Effects on Flows in Receiving Streams After Closure of Muskeg River Mine Project

			Existing	Future Area (km²)				Water	Runoff	Mean Annual Seepage and Dewatering Discharges (m³/s)				
Year	Location	Node	Undisturbed Area (km²)	Undisturbed Area	Reclaimed Area[d]	Closed Circuit Area	Area Contributing Runoff[e]	Withdrawal/ Flow Loss[a] (m³/s)	Loss at Pit Perimeter[g] (m³/s)	Muskeg Drainage[b]	Overburden Dewatering[b]	Perimeter CT Seepage[b]	Upward CT Flux[b]	Sand Storage Seepage[b]
2030	Alsands Drain	S1	15.8	0.0	29.3	0.0	29.3	0	0	0	0	0	0.040	0.00026
Second Year	Muskeg River	S16	1393	1366	32.3	0.0	1398	0.00007	-0.006	0	0	0	0.040	0.0033
after Closure[f]	Inflow to Isadore's Lake	S33	27.3	18.8	3.0	0.0	21.8	0	0.006	0	0	0	0	0.0024
	Athabasca River	S18	144000	143965	35.3	0.0	144000	0	0	0	0	0	0.040	0.027
Far Future	Alsands Drain	S1	15.8	0.0	29.3	0.0	29.3	0	0	0	0	0	0	0.00007
Equilibrium	Muskeg River	S16	1393	1366	32.3	0.0	1398	-0.0009	-0.006	0	0	0	0	0.0035
Post-Closure	Inflow to Isadore's Lake	S33	27.3	18.8	3.0	0.0	21.8	0	0.006	0	0	0	0	0.0024
Conditions	Athabasca River	S18	144000	143965	35.3	0.0	144000	0	0	0	0	0	0	0.027

			Streamflow Discharge (m³/s)																	
			Annual Mean Discharge			Mean Open-Water Discharge[c]			Mean Ice-Cover Discharge[c]			Open-Water 7Q10 Discharge[c]			Ice-Cover 7Q10 Discharge[c]			10 Year Flood Peak Discharge		
Year	Location	Node	Existing	Future	Difference	Existing	Future	Difference	Existing	Future	Difference	Existing	Future	Difference	Existing	Future	Difference	Existing	Future	Difference
2030	Alsands Drain	S1	0.046	0.760	1560%	0.070	1.437	1953%	0.012	0.075	527%	0.003	1.316	43775%	0.001	0.001	0%	0.7	2.0	188%
Second Year	Muskeg River	S16	5.28	6.10	16%	8.21	9.77	19%	1.11	1.15	4%	0.281	1.603	471%	0.052	0.099	91%	68.7	69.5	1%
after Closure[f]	Inflow to Isadore's Lake	S33	0.079	0.063	-19%	0.118	0.091	-23%	0.023	0.019	-16%	0.006	0.007	20%	0.001	0.003	240%	1.38	1.16	-16%
	Athabasca River	S18	693	694	0%	1106	1107	0%	279	279	0%	331	332	0%	120	120	0%	4220	4221	0%
Far Future	Alsands Drain	S1	0.046	0.102	123%	0.070	0.121	73%	0.012	0.075	526%	0.003	0.000	-98%	0.001	0.000	-93%	0.7	0.7	0%
Equilibrium	Muskeg River	S16	5.28	5.44	3%	8.21	8.46	3%	1.11	1.15	4%	0.281	0.288	3%	0.052	0.100	93%	68.7	68.2	-1%
Post-Closure	Inflow to Isadore's Lake	S33	0.079	0.063	-19%	0.118	0.091	-23%	0.023	0.019	-16%	0.006	0.007	20%	0.001	0.003	240%	1.38	1.16	-16%
Conditions	Athabasca River	S18	693	693	0%	1106	1106	0%	279	279	0%	331	331	0%	120	120	0%	4220	4220	0%

(a): Water withdrawal refers to raw water intake from the Athabasca River. The baseflow loss refers to the seepage inflow from the Muskeg River to the mine pits. The flow is negative if there is a baseflow gain from seepage inflow from the mine area to the Muskeg River excluding the CT and sand seepage.

(b): Muskeg drainage, overburden dewatering, and CT upward flux will occur in the open-water season, while perimeter seepage and sand seepage will occur throughout the year. Mine seepage rate is assumed to be constant in all seasons. This is a conservative assumption for the winter low flow conditions, because frost penetration may reduce the seepage inflows to receiving streams, particularly during the 7Q10 low flow conditions.

(c): The "open-water" season is defined as the period from mid-April to mid-November inclusive. The "ice-cover" season is defined as the period from mid-November to mid-April.

(d): Reclaimed area includes end-pit lakes and wetlands.

(e): Sum of the undisturbed and reclaimed areas that contribute runoff to the node. This does not include the area diverted to other basins.

(f): Mean annual mature fine tailings (MFT) transfer rate of 0.618 m3/s was added to each future surface runoff discharge component at Node S1, S16 and S18 for the open-water season only.

(g): This runoff reduction is resulting from groundwater table drawdown at the mine pit perimeter.

Table E4-20 Effects on the Flow Depths of the Muskeg River After Closure of the Muskeg River Mine Project

Year	2030			Far Future		
	Existing	Future	Difference	Existing	Future	Difference
Annual Mean Flow Depth (m)	0.472	0.515	9%	0.472	0.480	2%
Mean Open-Water Flow Depth (m)	0.627	0.705	12%	0.627	0.638	2%
Mean Ice-Cover Flow Depth (m)	0.234	0.237	1%	0.234	0.237	1%
Open-Water 7Q10 Flow Depth (m)	0.184	0.263	43%	0.184	0.185	negligible
Ice-Cover 7Q10 Flow Depth (m)	0.170	0.173	negligible	0.170	0.173	negligible
10 Year Flood Peak Flow Depth (m)	1.519	1.525	negligible	1.519	1.515	negligible

A detailed analysis of the changes at each node and at Isadore's Lake is provided below.

Flows at Alsands Drain (S1): At the end of the end pit lake management period in Year 2030, flows at the Alsands Drain will increase because of temporary displacement of the end pit lake water by MFT transferred from the tailings settling pond. The mean annual flow will be increased by about 16 times and the 10 year flood peak discharge will be doubled.

In far future, the drainage area of the Alsands Drain will be increased by about 80%. This will increase the mean open-water flow by about 123%, but the increase in the ice-cover flow will be much higher at 526%. This illustrates the effect of the end pit lake storage, which distributes the outflow more evenly through the year. Although the mean flow at Alsands Drain will be increased, the 10 year flood peak discharge will be about the same as the natural conditions, as a result of the flood attenuation effect of the end pit lake.

Muskeg River Flows and Levels (S16): At the end of the end pit lake management period in Year 2030, the temporary, large outflows at the lake outlet will increase the mean annual discharge of the Muskeg River by 16% and the average flow depth by 9%. The outflows will increase the mean open-water flow by 19% and average open-water flow depth by 12%. This temporary, large outflow will have negligible effects on the 10 year flood peak discharge and level.

After closure, the drainage area of the Muskeg River at Node S16 will be slightly increased by 0.4% because a portion of the Isadore's Lake drainage basin will be diverted to the Muskeg River. In the far future, Muskeg River flows will be moderately increased by about 3% because of seepage inflows from the reclaimed areas. The large end pit lake will help reduce the 10 year flood peak discharge on the Muskeg River by about 1%. The reclaimed areas will have negligible impacts on the Muskeg River flood levels.

Table E4 - 21 Effects on Isadore's Lake Levels and Depths After Closure of the Muskeg River Mine Project

Year	Parameter	Mean Open - Water Conditions				Mean Ice - Cover Conditions				10 % Exceedance				Median				90 % Exceedance			
		Existing	Future	Difference		Existing	Future	Difference		Existing	Future	Difference		Existing	Future	Difference		Existing	Future	Difference	
				(m)	(%)			(m)	(%)			(m)	(%)			(m)	(%)			(m)	(%)
2030	Water Level (m)	233.157	233.143	-0.014		233.069	233.060	-0.010		232.993	232.999	0.006		233.074	233.065	-0.009		233.342	233.315	-0.028	
Second Year	Maximum Depth (m)	4.157	4.143	-0.014	-0.3	4.069	4.060	-0.010	-0.2	3.993	3.999	0.006	0.2	4.074	4.065	-0.009	-0.2	4.342	4.315	-0.028	-0.6
after Closure	Average Depth (m)	1.550	1.554	0.004	0.3	1.585	1.590	0.004	0.3	1.486	1.490	0.004	0.3	1.577	1.583	0.005	0.3	1.621	1.620	-0.002	-0.1
Far Future	Water Level (m)	233.157	233.143	-0.014		233.069	233.060	-0.010		232.993	232.999	0.006		233.074	233.065	-0.009		233.342	233.315	-0.028	
Equilibrium	Maximum Depth (m)	4.157	4.143	-0.014	-0.3	4.069	4.060	-0.010	-0.2	3.993	3.999	0.006	0.2	4.074	4.065	-0.009	-0.2	4.342	4.315	-0.028	-0.6
Post-Closure Conditions	Average Depth (m)	1.550	1.554	0.004	0.3	1.585	1.590	0.004	0.3	1.486	1.490	0.004	0.3	1.577	1.583	0.005	0.3	1.621	1.620	-0.002	-0.1

Note: The "open-water" season is defined as the period from mid-April to mid-November inclusive. The "ice-cover" season is defined as the period from mid-November to mid-April.

Inflows to Isadore's Lake (S33) and Lake Levels: On closure, the mean annual flows in Mills Creek will reduce by about 19% because of a reduction in its drainage area. However, the annual 7Q10 low-flow will be raised by about 2.4 times because of seepage inflows from the reclaimed tailings settling pond area. The 10 year flood peak discharge to Isadore's Lake will be reduced by about 16%. These levels of flow reduction are considered to be moderate.

The reduced inflows to Isadore's Lake will reduce the mean lake level by only 14 mm or 0.3% of the maximum water depth. The overall change in the lake water levels including 10%, 50% and 90% exceedance statistics will be less than 1%. This is considered to be negligible.

Athabasca River Flows and Levels: On closure, the temporary, large surface water releases from the end pit lake will increase the annual 7Q10 low-flow of the Athabasca River by less than 1%. In the far future, the impact of the Muskeg River Mine Project on the Athabasca River flows will be negligible, because equilibrium conditions will have been established at the end pit lake and because runoff from reclaimed areas will be released back to the river. Consequently, the Project will have negligible effects on the Athabasca River levels.

E4.2.4 Residual Impact Classification and Degree of Concern

The residual impacts of the Muskeg River Mine Project on the flows and water levels in the receiving waterbodies are classified and rated as shown in Table E4-22 for various phases of the Project including construction, operation and closure.

The degree of concern of most of the impacts on the flows and water levels in the receiving waterbodies are rated nil to low. The impacts on the Alsands Drain during construction and operation are rated moderate based on the flow changes. However, this drain is a man-made system and the degree of concern of the impacts is rated nil because it is mainly used for conveying mine drainage and dewatering discharges. During the end pit lake management period (2027 to 2030), the degree of concern of the impacts on the Muskeg River flows and water levels are rated as moderate, because the end pit lake surface discharges will cause a relative large increase in the Muskeg River flows. The degree of concern of the residual impacts on flows in Mills Creek or inflows to Isadore's Lake is rated moderate during operation (increased flows) and after closure (reduced flows), but the degree of concern of its impacts on the lake water level is rated as nil.

Surface Water Flow and Water Level Monitoring

The existing streamflow monitoring stations in the LSA include the WSC gauging station on the Muskeg River (S16) at the downstream reach of the

Table E4-22 Classification and Degree of Concern of the Residual Impacts on Flows and Water Levels in the Receiving Waterbodies

Project Phase	Receiving Waterbodies	Impact Classification						*Degree of Concern*
		Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	
Construction	Alsands Drain	negative	high	local	medium term	reversible	continuous	*Nil* [(a)]
	Muskeg River	negative	low	local	medium term	reversible	intermittent	*Low*
	Mills Creek	negative	low	local	medium term	reversible	continuous	*Low*
	Isadore's Lake	negative	negligible	local	medium term	reversible	continuous	*Nil*
	Athabasca River	neutral	negligible	local	medium term	reversible	continuous	*Nil*
Operation	Alsands Drain	negative	high	local	medium term	reversible	continuous	*Nil* [(a)]
	Muskeg River	negative	low	local	medium term	reversible	continuous	*Low*
	Mills Creek	negative	low to high	local	medium term	reversible	continuous	*Moderate*
	Isadore's Lake	negative	negligible	local	medium term	reversible	continuous	*Nil*
	Athabasca River	neutral	negligible	local	medium term	reversible	continuous	*Nil*
End Pit Lake Management During Reclamation	Alsands Drain	negative	high	local	medium term	reversible	continuous	*Nil* [(a)]
	Muskeg River	negative	low to high	local	medium term	reversible	continuous	*Moderate*
	Mills Creek	negative	high	local	medium term	reversible	continuous	*Moderate*
	Isadore's Lake	negative	negligible	local	medium term	reversible	continuous	*Nil*
	Athabasca River	neutral	negligible	local	medium term	reversible	continuous	*Nil*
After Closure	Alsands Drain	neutral	low to high	local	long-term	irreversible	continuous	*Nil* [(a)]
	Muskeg River	negative	low	local	long-term	irreversible	continuous	*Low*
	Mills Creek	negative	moderate	local	long-term	irreversible	continuous	*Moderate*
	Isadore's Lake	negative	negligible	local	long-term	irreversible	continuous	*Nil*
	Athabasca River	neutral	negligible	local	long-term	irreversible	continuous	*Nil*

[(a)] The Alsands Drain is a man-made channel, which does not represent a natural system. Therefore, the degree of concern of the impacts on this man-made system is rated nil, although there are temporary changes to its flows and levels during construction and operation.

Muskeg River, and the streamflow and water level monitoring stations operated by Shell Canada Limited and Syncrude Canada Ltd. (Figure D4-12). The stations include:

- S1 Alsands Drain
- S2 Jackpine Creek
- S3 Iyinimin Creek
- S4 Blackfly Creek
- S5 Muskeg Creek
- S6 Mills Creek

Based on the results of the impact analysis, a lake water level monitoring station will be established near the outlet of the Isadore's Lake to monitor the lake levels and outflows. The flow and water level monitoring stations in the LSA will be continued through the life of the Project including the reclamation management period. Hydrologic data from these stations are needed to provide:

- a basis for future updating of the hydrologic analyses of flows from natural and disturbed areas for design of operational water management and future mine closure;
- ongoing monitoring and verification of the Project impacts on the surface water flows and levels;
- a basis for interpreting water quality measurements and monitoring water quality impacts; and
- a basis for regulating future water releases from the Project area.

This flow monitoring program will be continued in conjunction with a climate monitoring program to monitor the areal variation of precipitation in the LSA. This is necessary to correlate with and interpret the hydrologic monitoring results and to provide a sound basis for design of water management facilities for operation and closure.

Future Studies

Future investigations pertaining to surface water flows and water levels that could be incorporated in the RAMP or CONRAD regional programs include the following:

- Update hydrology analysis of natural undisturbed areas after four or five years of stream flow and concurrent climate monitoring in the LSA.

- Update the hydrology analysis of reclaimed areas after the sand, CT and overburden areas have been successfully reclaimed at the existing Mildred Lake and Suncor Projects. Data from other oil sands operators can be obtained through a data-sharing agreement among the operators in the region.

- Reference the existing bathymetric data of the Isadore's Lake to geodetic datum to derive an accurate definition of the lake storage elevation curve and conduct a detailed survey of the Isadore's Lake outlet channel for an accurate definition of the lake outlet discharge rating curve. This will allow a future update of the lake water balance analysis for verification of the hydrologic impacts on the Isadore's Lake.

E4.3 Key Question SW-2: Will the Muskeg River Mine Project Affect Water Balance of Nearby Lakes, Ponds, Wetlands and Streams?

E4.3.1 Analysis of Potential Linkages

Nearby waterbodies are those waterbodies which do not directly receive surface runoff from the Muskeg River Mine Project area in natural conditions. These nearby waterbodies are treated separately because they will be affected indirectly by the Project. The impacts of the Project on the water balance of the receiving waterbodies are analyzed in Section E4.4.

Mine pit development during operation and on closure will cause drawdown of the surficial aquifer at the perimeter areas of the mine pits and the end pit lake as well as a reduction in base flows of adjacent streams. These effects are discussed in Section E4.4. The mining facilities during operation will cause Basal Aquifer depressurization, which will potentially increase the deep percolation loss of the nearby ponded water to the Basal Aquifer. Kearl Lake which is located about 12 km east of the Project area, will be affected by Basal Aquifer depressurization during mining. However, after closure and filling of the end pit lake, the end pit lake water level will be about 10 m higher than the natural piezometric head of the Basal Aquifer in the Project area. Therefore, the nearby lake water balance will not be negatively affected after closure of the Muskeg River Mine Project.

As discussed in Section E3, McClelland Lake is located beyond the subcrop of the Basal Aquifer. The Muskeg River Mine Project is therefore not expected to have any impact on the McClelland lake water levels.

The linkage between Basal Aquifer depressurization and changes in Kearl Lake water balance is valid.

Methods for Quantifying Changes in Lake Water Balance

The calibrated, continuous HSPF hydrologic model was used to simulate daily inflows through Kearl Lake. The simulation included basin runoff, net lake precipitation (gross precipitation minus lake evaporation) and deep percolation losses to the Basal Aquifer. The resulting simulated daily inflows were routed through the lake based on the lake storage-elevation curve and the lake outlet discharge rating curve. The historic period of record used for the simulation is from 1954 to 1996.

The simulated daily Kearl Lake water levels during both the natural and future conditions were analyzed to derive daily water level exceedance curves and the following water level and depth parameters. These were compared to quantify changes in lake levels.

- mean lake water levels and depths during the open-water and ice-cover seasons; and
- daily mean water level and depth exceedance statistics including 10, 50 and 90 percentiles.

E4.3.2 Results of Impact Analysis

Kearl Lake has a drainage area of 68.8 km^2, which compares with the lake area of 4.8 km^2. The ratio of drainage area to lake area is about 14, which is larger than the other regional lakes such as McClelland Lake.

The deep percolation loss from the lake to the Basal Aquifer was estimated to be 15 mm per year (72,000 m^3 per year) during natural conditions as discussed in Section E3. Basal Aquifer depressurization during operation at the Muskeg River Mine Project area will increase deep percolation losses by up to 17 mm per year equivalent to 81,600 m^3 per year. This compares with the mean annual inflow of 10.4 million m^3 to Kearl Lake. The increased losses to the Basal Aquifer represents only 0.8% of the total lake inflow. This is very small and can be considered to be negligible.

After Project closure, depressurization of the Basal Aquifer will be discontinued. Instead, the end pit lake level will be about 10 m higher than the natural piezometric level of the Basal Aquifer. Derivation of the deep percolation rates at Kearl Lake is discussed in Section E3.

Table E4-23 lists the types of drainage areas in the Kearl Lake basin. Figure E4-19 shows a comparison of the exceedance curves of simulated daily lake water levels of natural conditions and disturbed conditions during mine operation. The summary of the changes in Kearl Lake levels are given in Tables E4-24 and E4-25.

Table E4-23 Types of Areas in the Kearl Lake Basin

Type of Area	Area (km^2)
Upland	49.0
Lowland	19.8
Lake	4.8
Total	73.6

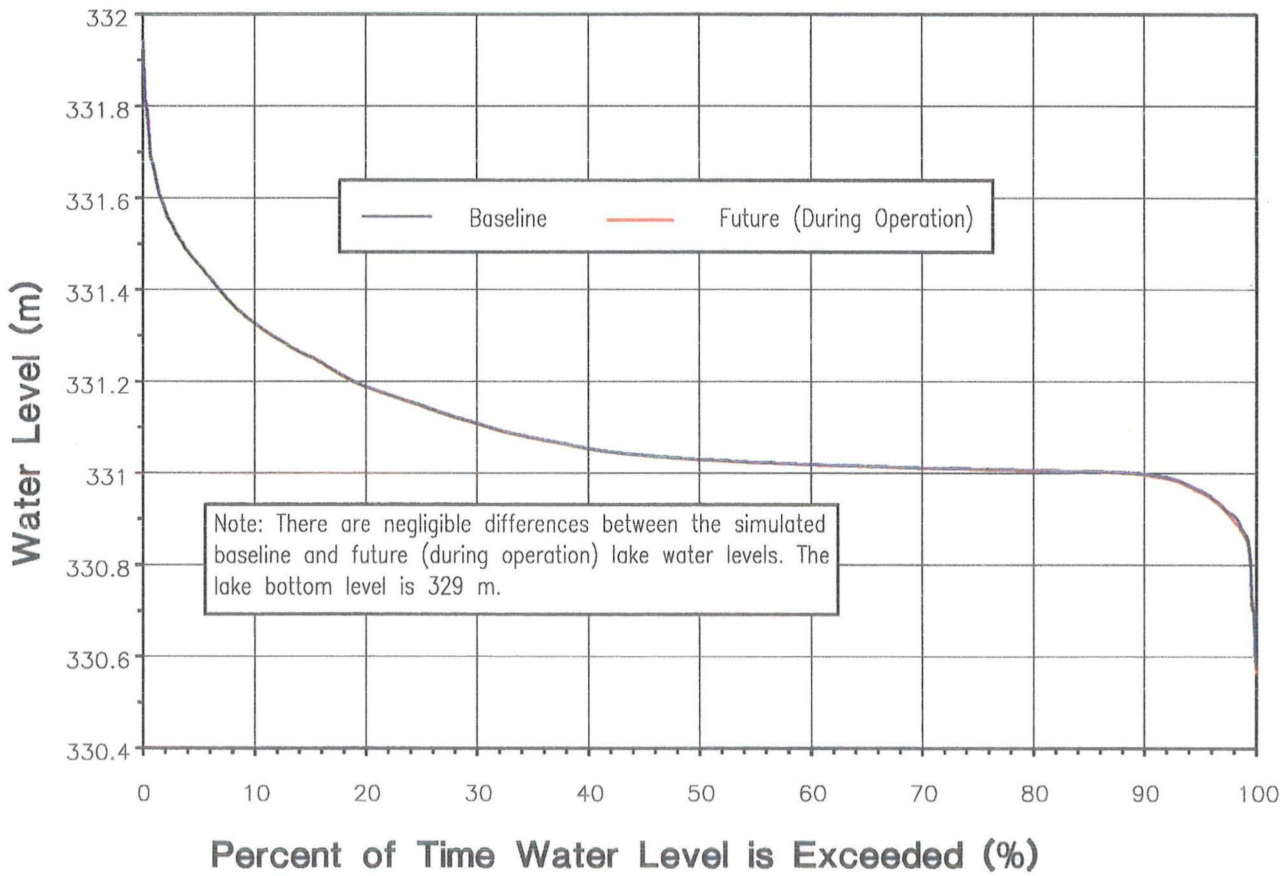
Table E4-24 Changes in Mean Lake Levels During Open-Water and Ice-Cover Seasons (Period of Simulation: 1954 to 1996)

Parameter		Water Level (m)	Max. Depth (m)	Average Depth (m)
Open-Water Season	Existing	331.15	2.15	0.87
	During Operation	331.15	2.15	0.87
	Difference (m) Different (%)	-0.001	-0.001 -0.07%	negligible
Ice-Cover Season	Existing	331.03	2.03	0.80
	During Operation	331.03	2.03	0.80
	Difference (m) Different (%)	-0.001	-0.001 -0.05%	negligible

Table E4-25 Changes in Lake Level Exceedance Statistics (Period of Simulation: 1954 to 1996)

Parameter		Water Level (m)	Max. Depth (m)	Average Depth (m)
10% Exceedance	Existing	330.99	1.99	0.77
	During Operation	330.99	1.99	0.77
	Difference (m) Different (%)	-0.003	-0.003 -0.01%	negligible
Median	Existing	331.030	2.03	0.81
	During Operation	331.03	2.03	0.80
	Difference (m) Different (%)	-0.001	-0.001 -0.03%	-0.001 -0.07%
90% Exceedance	Existing	331.33	2.33	0.98
	During Operation	331.33	2.33	0.98
	Difference (m) Different (%)	-0.002	-0.002 -0.07%	-0.001 -0.08%

The statistics in Table E4-24 show that the mean lake levels in both the open-water and ice-cover seasons will only be drawdown by 1 mm during the operation of the Project. This represents a 0.07% reduction in the mean lake depths, which is negligible.



Golder Associates

SHELL CANADA LIMITED

Comparison of Simulated Baseline and Future Exceedence Curves of Water Levels at Kearl Lake

04 DEC 97	Figure E4-19	DRAWN BY: RFM

A comparison of the lake level exceedance statistics presented in Table E4-25 shows that the open-pit development during the Project operation will have negligible effect on the daily, monthly and season variation of the lake water levels, because the daily lake level exceedance statistics between the existing and operational conditions are negligible.

E4.3.3 Residual Impact Classification and Degree of Concern

Depressurization of the Basal Aquifer during operation of the Muskeg River Mine Project will cause an increase in deep percolation loss (an increase of 17 mm per year) at Kearl Lake This increase will represent about 1 mm reduction in the lake water levels, which is negligible. The classification and degree of concern of this residual impact are presented in Table E4-26. The degree of concern of this impact is nil.

Table E4-26 Classification and Degree of Concern of the Residual Impact on the Kearl Lake Water Balance

Direction	**Negative**
Magnitude	Negligible
Geographic Extent	Local
Duration	Medium term
Reversibility	Reversible
Frequency	Continuous
Degree of Concern	***Nil***

Lake Water Level Monitoring

A hydrologic monitoring station at McClelland Lake was installed by Syncrude in 1997 to monitor the potential impact of the Aurora North Project on the lake water balance. The monitoring program included continuous lake water level measurements and monthly manual flow measurements at the lake outlet. A similar lake water level and flow monitoring station will be installed at Kearl Lake as part of RAMP for monitoring the potential impact from the Muskeg River Mine Project. These hydrologic data are needed to provide:

- a basis for better definition of the discharge rating curve at the lake outlet and for future updating of the hydrologic analysis; and
- monitoring data for assessment of any potential impact on the lake water balance.

E4.4 Key Question SW-3: Will the Muskeg River Mine Project Affect Basin Sediment Yields and Sediment Concentrations in Receiving Streams?

E4.4.1 Analysis of Potential Linkages

Affected Streams

Various Project activities will increase the basin sediment yields and potentially increase the sediment loads in the receiving streams. An increase in flow in a receiving stream can cause increased channel erosion and sediment loads in the stream. For example, muskeg drainage and overburden dewatering during construction and operation may increase the sediment loads to the Muskeg River and Mills Creek. This drainage and dewatering discharge will increase the flows in the Muskeg River. This can cause an increase in its channel erosion and sediment loading. Reclaimed surfaces after closure will be subject to higher sediment yield than the natural muskeg terrain in the Project area. The increased sediment yield could cause increased sedimentation in the Muskeg River which is the major receiving stream of the reclaimed areas. Excessive sedimentation could affect the sustainability of the aquatic habitat in the Muskeg River.

Muskeg River and Mills Creek are the two main receiving streams of the runoff from the Project area. Impacts of the Project on the sediment loads in the receiving streams were evaluated for the Muskeg River at Node S16 and the Mills Creek at Node S33. The descriptions of these nodes are provided in Table E4-1. As discussed in Section E4.4, the Project will have negligible impact on the Athabasca River flows. Therefore, there will be no risk of increased sediment loading to the river and increased channel erosion to be resulted from the Muskeg River Mine Project.

Detailed Linkage Analysis for Construction and Operation

The following activities of the Muskeg River Mine Project during construction and operation will affect the basin sediment yields and may affect the sediment concentrations in the receiving streams:

- Muskeg drainage and overburden dewatering discharge and runoff from cleared and construction areas will carry flows with higher sediment concentration than the receiving streams.
- Construction of the access corridors, pipeline crossings at Upper Jackpine Creek and Muskeg River, and a Muskeg River road crossing will potentially introduce sediments to the receiving streams.

- Increased flows in the receiving streams because of dewatering discharge will increase the channel erosion potential of the receiving streams.

The operational water management plan calls for provision of sedimentation and polishing ponds and for routing any discharges with increased sediment loads through the ponds before releasing the flows to the receiving streams. These polishing ponds will be designed based on the criteria of no negative effects on the water quality and aquatic habitat of the receiving streams. Therefore, releases from the polishing ponds will have little residual risk of increasing the sediment loads in the receiving streams. During operation, closed-circuit water management of the runoff from the mining areas will prevent the release of any site runoff in contact with oil sands to the receiving streams.

Relevant regulatory guidelines and standards of best management practices will be following during construction of pipeline crossings at Upper Jackpine Creek and Muskeg River to minimize stream sediment loading. The relevant regulatory guidelines by AEP, Fisheries Management Division and Lands and Forest Services for the protection of aquatic resources during timber harvest will be followed to minimize erosion and sediment loading during site clearing. Tree clearing will likely be performed during winter when equipment is unlikely to cause disruption to the surface soil because of frozen ground conditions.

All Project facilities will be located at least 100 m away from the channels of Muskeg River and Jackpine Creek as shown in Figures E4-5 to E4-13. This ensures that most of the facilities will be outside of the 100-year flood risk limits. Only the road embankments along the boundaries of Pits 1 and 2, the south muskeg storage and the south overburden dump will be located within the 100-year flood risk limits. Erosion protection measures will be provided to minimize erosion of the embankments and the storage facilities during floods.

Best management practices and regulatory guidelines (e.g., Alberta Transportation and Utilities and Alberta Forestry, Lands and Wildlife 1992) will be followed during construction of access roads and the Muskeg River crossing to minimize sediment loadings to the receiving streams and impacts to aquatic resources. These will include the following measures:

- Construct road ditches to collect and route surface runoff from disturbed areas to polishing ponds before release to the receiving streams.

- Cover road surfaces with asphalt or packed silty sands and gravels to minimize exposure of more erodible silty/clay soils.

- Supply drop structures to prevent channel erosion down steep slopes.

- Revegetate areas disturbed during construction by mulching and seeding.

- Provide erosion protection measures such as riprap at river crossing embankments.

The mitigation measures discussed above will minimize the risk of increased sediment loadings to receiving streams. However, increased flows in receiving streams caused by muskeg drainage and overburden dewatering may affect sediment concentrations in receiving streams. This impact will be analyzed in the next section.

Detailed Linkage Analysis for Closure

Reclamation landscape and drainage systems after closure will result in higher basin sediment yield and may affect the sediment loads in the receiving streams as described below:

- Reclaimed surfaces may be unsustainable and may result in excessive sediment yields because of hill slope and gully erosion. The external sand and overburden storage areas will be particularly vulnerable to erosion and gullying as a result of the highly erodible sandy soils and relatively steep side slopes of these storage facilities.

- Man-made reclamation drainage channels may not be "in regime" and future evolution of these channels to develop a characteristic regime may result in excessive channel erosion and sediment loading to receiving streams.

- Reclaimed landscape will have unique runoff characteristics that are different from natural conditions. This may result in an increase in flows in receiving streams and an increase in erosion rates at the stream channels.

The linkage between the Project activities discussed above and changes in sediment concentrations in receiving streams is valid.

E4.4.2 Impact Analysis

Impact on Stream Sediment Concentration During Construction

During construction, muskeg drainage and overburden dewatering will cause small increases in the Muskeg River mean flows and negligible increases in flood peak discharges as discussed in Section E4.4. Therefore, drainage and dewatering will have negligible effects on the erosion of the Muskeg River channel.

Development and operation of the closed-circuit tailings settling pond will reduce the drainage area of the Mills Creek and will moderately reduce the flows in the creek as discussed in Section E4.4. Therefore, there will be little risk of increased channel erosion because the flows will not be increased.

Impact on Stream Sediment Concentration During Operation

As discussed in Section E4.4, closed-circuit areas during mining operation will not increase the flows on the Muskeg River, but will result in a small reduction of mean flows and flood peak discharges in Muskeg River. Therefore, mining operation is not expected to increase the natural erosion rates of the Muskeg River.

The flows of Mills Creek will be reduced most of time during mining operation. However, muskeg drainage and overburden dewatering from Year 2016 to Year 2020 will cause an increase of the mean flow by about 30%.

The sediment data collected to date for the small sub-basins is the LSA suggest that sediment concentrations in small streams are about 16 times higher than that measured on the Muskeg River for the same discharge. This indicates that the small and steeper stream channels such as Mills Creek have higher erosion rates than the larger, milder river channels such as the Muskeg River. Therefore, the sediment concentrations as a function of discharges developed for the Muskeg River shown in Figure D4-20 were adjusted upward by a ratio of 16 to account for the basin size, because the available sediment data for the small streams in the LSA are insufficient for developing a similar relationship.

The average change in sediment concentration in Mills Creek caused by mine drainage and dewatering discharge is estimated to be 0.3 mg/L increased from 70.1 mg/L in natural conditions to 70.4 mg/L during the dewatering period. This level of increase is considered to be negligible.

Impact on Sediment Concentration After Closure

Sediment Yields from Reclaimed Landscape and Sediment Runoff to Receiving Streams

The reclaimed landscape and reclamation drainage systems have been designed to minimize surface erosion by creating a final topography and soil moisture condition to sustain a biologically productive landscape, and to minimize gully and channel erosion. The latter will be accomplished by developing a robust and sustainable reclamation drainage system patterned after natural analogues and with built-in, self-healing capability like natural systems.

Available studies and data on sediment yields from reclaimed surfaces in the RSA included the full-scale rainfall simulation studies conducted for Suncor and Syncrude (AGRA 1996b) and an extensive literature review of sediment yields from various types of disturbed and reclaimed surfaces, which was conducted for Syncrude (Golder 1996c). These studies provided a basis for estimating the sediment yields from various types of reclaimed surfaces in the Project area as listed in Table E4-27.

Table E4-27 Estimates of Sediment Yields from Various Natural and Reclaimed Surfaces

Types of Surfaces	Estimated Mean Annual Sediment Yield (mm)
Natural lowland	0.002
Natural upland	0.02
Reclaimed muskeg storage	0.01
Reclaimed overburden	0.1
Reclaimed tailings settling pond	0.4
Reclaimed overburden cap on CT	0.05
Reclaimed sand cap on CT	0.3
Reclaimed sand cap on overburden	0.2
End pit lake, and shallow lakes/wetlands	0.0

The mean annual sediment yields for the lowland and upland areas were estimated based on the available sediment measurements in the Muskeg River and Beaver River. Sediment yield for the reclaimed muskeg storage area is estimated to be 0.01 mm per year, a value that is between the values for the natural lowland and natural upland areas. A reclaimed overburden area is expected to yield more sediment than the natural upland area, so the mean annual sediment yield (0.1 mm) from this type of surface is estimated to be about four times the natural upland area (0.024 mm).

The reclaimed sand cap on overburden has a mild overland slope, and its mean annual sediment yield (0.2 mm) is estimated to be twice the reclaimed overburden storage areas (0.1 mm). The reclaimed tailings settling pond area has a steeper slope than the sand cap on overburden, and its mean annual sediment yield (0.4 mm) is estimated to be twice the sand cap on overburden (0.2 mm). The reclaimed sand cap on CT has sand ridges and its sediment yield (0.3 mm) is expected to lie between the steeper sand storage area (0.4 mm) and flatter sand cap on overburden area (0.2 mm). The reclaimed overburden cap on CT area (0.05 mm) has a milder slope than the external overburden storage areas and it is expected to yield less sediment than the external steeper overburden areas (0.1 mm).

Based on these sediment yield estimates, the mean annual sediment yield from reclaimed areas to the shallow lakes/wetlands and end pit lake is estimated to be 6,175 m^3 as shown in Table E4-28. At this rate, it will take about 11,000 years to fill these wetlands and lakes, which have a water storage of about 65 million m^3 in Year 2030. The relatively large end pit lake will settle virtually all inflow sediments. Therefore, outflow sediment concentration will be much lower than the natural Muskeg River sediment concentration.

Table E4-28 Estimated Annual Sediment Volumes Generated from Reclaimed Surfaces

Receiving Waterbodies	Type of Surface	Area (km^2)	Annual Sediment Volumes (m^3)
End pit lake	Reclaimed tailings setting pond area	7.6	3040
	Reclaimed overburden cap on CT	6.7	335
	Reclaimed sand cap on CT	6.8	2040
	Reclaimed sand cap on overburden	3.8	760
	Shallow lakes/wetlands	0.12	0
	End pit lake	3.4	0
	Sub-Total	25.0	6175
Muskeg River	Reclaimed overburden storage	2.5	250
	Reclaimed muskeg storage	1.9	19
	Sub-Total	4.4	269
Mills Creek	Reclaimed overburden storage	2.9	290

Reclaimed overburden and muskeg storage areas alongside Muskeg River will reach a maximum outer area of 4.4 km^2 and will yield about 0.3% of the total drainage area of the river (1,398 km^2). Sediment yield from the majority of these areas will be routed through the lowland areas where natural filtering will trap most of the sediment release to the receiving streams. Therefore, the residual impact of increased sediment yields from these reclaimed surfaces on the Muskeg River will be negligible.

The reclaimed overburden area of 2.9 km^2, which directly contributes runoff to Mills Creek, will be about 13% of its total drainage area (21.8 km^2). The sediment runoff from this area will be routed through a shallow lakes/wetlands before release to Mills Creek. Therefore, the residual impact of the increased sediment yields from these reclaimed surfaces on Mills Creek will be negligible.

Potential Increase in Channel Erosion Rates

During the reclamation period and the last few years of the end pit lake management period from 2027 to 2030, the end pit lake will discharge a large quantity of water to Muskeg River. This is caused mainly by transfer of the MFT from the tailings settling pond to the lake. This will increase the mean river flows by about 16% but will have negligible effects on the river flood peak discharge. Based on the relationship presented in Figure D3-20, this will only result in an estimated increase of the average total suspended sediment concentration in Muskeg River from 9.5 mg/L in natural conditions to 10.3 mg/L from Year 2027 to Year 2030. This level of increase in sediment concentration is considered to be small.

In the far future, the mean flow on the Muskeg River at Node S16 will increase moderately by about 3%. However, the river flood peak discharge will reduce slightly. This will result in a small increase in sediment concentration of about 2%, from 9.5 mg/L in natural conditions to 9.7 mg/L in the far future. This is well within the natural range of variation.

In the far future, flows in Mills Creek will be reduced because of a reduction of drainage area. Therefore, there will be little risk of increased channel erosion associated with this change in flows.

E4.4.3 Classification and Degree of Concern of Residual Impacts

The residual impacts of the Muskeg River Mine Project on increased sediment concentrations in the receiving streams are classified and rated in Table E4-29 for various phases of the Project.

Table E4-29 Classification and Degree of Concern of Residual Impacts on Sediment Concentrations in Receiving Streams

Project Phase	During Construction	During Operation	After Closure
Direction	Negative	Negative	Negative
Magnitude	Negligible	Negligible to Low	Low
Geographic Extent	Local	Local	Local
Duration	Medium term	Medium term	Long-Term
Reversibility	Reversible	Reversible	Irreversible
Frequency	Continuous	Continuous	Continuous
Degree of Concern	***Nil***	***Low***	***Low***

The degree of concern of increased sediment concentrations in the receiving streams during construction, operation and closure are summarized below:

- During construction, muskeg drainage and overburden dewatering will be routed through polishing ponds before release to the receiving streams. The small increase in the stream flows caused by this drainage and dewatering will cause negligible increases in the sediment concentrations in the receiving streams. The degree of concern of these impacts is nil.

- During operation, the increase of flows in the Muskeg River and Mills Creek will cause increased channel erosion and a small increase in the streamflow sediment concentrations. The degree of concern of the impacts is low.

- After closure, the small increase in the Muskeg River flows will cause a small increase in the sediment concentration in the river. The degree of concern of this impact is low.

Stream Sediment Monitoring

The existing sediment sampling program at the hydrologic monitoring stations (S1 to S6) in the LSA (Figure D4-12) will be continued as part of RAMP through the life of the Project. These sediment data are needed to provide:

- a basis for an improved definition of the sediment yield characteristics of the small undisturbed areas;
- monitoring data for assessment of the Project impacts on the sediment concentrations in the receiving streams; and
- a basis for interpreting water quality measurements and monitoring water quality and aquatic impacts.

E4.5 Key Question SW-4: Will the Muskeg River Mine Project Affect Channel Regimes of Receiving Streams?

E4.5.1 Analysis of Potential Linkages

Channel regime defines the natural equilibrium geomorphic conditions of a stream channel, in which the evolution of channel dimension, shape, gradient, meander pattern, and erosion/sedimentation has stabilized under the long-term influence of the stream hydrologic and geologic conditions. A prolonged, large increase in flows in the receiving stream can cause a change in its channel regime, as the channel attempts to adjust its regime or geomorphic conditions to suit the new flow conditions.

Muskeg River and Mills Creek are the natural streams receiving runoff from the Project area and changes in inflows to these receiving streams, caused by the Project, may affect the channel regimes of these streams to various degrees. Two of the four reference nodes (S16 and S33), which were used for the analysis of the impacts on the surface water flows and levels, were also selected for the assessment of the impacts on the channel regimes of these two receiving streams. The locations of these nodes are shown in Figure E4-4. A description of these nodes is given in Table E4-1.

The analysis in Section E4.4 shows that the Project will cause negligible changes in the Athabasca River streamflows and water levels. Therefore, the channel regime of the Athabasca River will not be affected by the Muskeg River Mine Project.

The linkage between the changes in flows of the Muskeg River and Mills Creek, and the changes in their channel regimes is valid.

E4.5.2 Impact Analysis

Muskeg River Channel Regime

Table E4-30 summarizes the percentage changes in the mean annual flows of the Muskeg River at Node S16 at various points in time during the life of the mine. The table shows that changes in the Muskeg River mean flow condition during construction and operation will be small to negligible. Therefore, construction and operation of the Project is expected to have a negligible impact on the Muskeg River channel regime.

Table E4-30 Summary of Percentage Changes in Mean Annual Flows of the Muskeg River (Node S16)

Project Phase	Time Snapshot	Percent Change in Mean Annual Flow
Construction	2000	1%
	2002	1%
Operation	2003	negligible
	2005	negligible
	2010	negligible
	2020	-1%
	2022	-1%
	2025	-2%
Closure	2030	16%
	Far Future	3%

Note: Positive = flow increase; negative = flow decrease.

In the last few years of reclamation from 2027 to 2030, transfer of the MFT from the tailings settling pond to the end pit lake will increase the mean flow in the Muskeg River by 16%. The time snapshot in Year 2030 presented in Table E4-19, which will be the end of the end pit lake management period and also the beginning of the closure period, represents the tail end of this water release and its effect on the mean flow conditions on the Muskeg River.

As discussed in Section E4-6, the average increase in sediment concentration in the Muskeg River will be about 0.8 mg/L during the end pit lake management period. This corresponds to an increased rate of about 0.005 kg/s in channel erosion, or 631,000 kg or 238 m^3 over a four year period along a river reach of about 30 km long, 20 m wide and 1 m deep. The equivalent erosion depth around the perimeter of the river channel will be about 0.04 mm of the channel wetted perimeter area. This level of erosion is negligible. Therefore, increased flows in the Muskeg River caused by the end pit lake release will have a negligible effect on the Muskeg River regime.

In the far future, the average Muskeg River flow will increase by 3%. This corresponding increase in average sediment concentration in the river will be well within the natural range of variation in the basin sediment yield and channel erosion rate. Therefore, this small increase in the Muskeg River flow will cause negligible change in the river channel erosion rate and its regime conditions in the far future.

Mills Creek Channel Regime

Table E4-31 summarizes the expected changes in the mean annual flows in the Mills Creek at Node S33 at various time snapshots. The table shows that the flows on Mills Creek will be reduced most of the time, except during snapshot 2020 when the mean flow in the creek will increase by 30% because of muskeg drainage and overburden dewatering discharge to the creek.

Table E4-31 Summary of Percentage Changes in Mean Annual Flows in Mills Creek (Node S33)

Project Phase	Time Snapshot	Percent Change in Mean Annual Flow
Construction	2000	no change
	2002	-4%
Operation	2003	-3%
	2005	-3%
	2010	-3%
	2020	30%
	2022	-23%
	2025	-22%
Closure	2030	-23%
	Far future	-23%

Note: Positive = flow increase; negative = flow decrease

The duration of Project drainage and dewatering discharge to Mills Creek will be about 5 years. As discussed in Section E4-6, the average increase in sediment concentration in the stream will be about 0.3 mg/L. This will correspond to an increased rate of 30 mg/s in channel erosion, or 4,730 kg or 2.0 m^3 over the 5 year period. The equivalent erosion depth around the wetted perimeter of the stream channel will be about 0.01 mm along a channel reach of 4.5 km long and 5 m wide. This level of erosion is negligible. Therefore, the increase in flows in Mills Creek caused by mine drainage and dewatering will have a negligible effect on its channel regime.

E4.5.3 Classification and Degree of Concern of Residual Impacts

Based on the detailed impact analysis presented above, the residual impacts of the Muskeg River Mine Project on the channel regimes of the receiving streams are classified and rated in Tables E4-32 and E4-33 for various stages of Project development.

Table E4-32 Classification and Degree of Concern of Residual Impacts on Muskeg River Channel Regime

Project Phase	During Construction and Operation	After Closure
Direction	Neutral	Negative
Magnitude	Negligible	Negligible
Geographic Extent	Local	Local
Duration	Medium term	Long-Term
Reversibility	Reversible	Irreversible
Frequency	Continuous	Continuous
Degree of Concern	***Nil***	***Nil***

Table E4-33 Classification and Degree of Concern of Residual Impacts on Mills Creek Channel Regime

Project Phase	During Construction and Operation	After Closure
Direction	Neutral	Neutral
Magnitude	Negligible	Negligible
Geographic Extent	Local	Local
Duration	Medium term	Long-Term
Reversibility	Reversible	Irreversible
Frequency	Continuous	Continuous
Degree of Concern	***Nil***	***Nil***

A relatively large increase in Muskeg River flows during the end pit lake management period will cause a negligible increase in the river channel erosion. The degree of concern of this impact on the Muskeg River channel regime is rated as nil. The increase in flows in Mills Creek during the period of mine drainage and dewatering discharge to the creek will have a negligible effect on the creek channel regime. The degree of concern of this impact is rated as nil. The degree of concern of the impacts on the channel regimes of Muskeg River and Mills Creek after mine closure is rated as nil.

E4.6 Key Question SW-5: Will the Muskeg River Mine Project Change the Open-Water Areas Including Lakes and Streams?

E4.6.1 Analysis of Potential Linkages

During Construction and Operation

There are a small number of shallow lakes or ponds, and small streams located within the Project footprint of the Muskeg River Mine Project. During construction and operation, these natural lakes/ponds and streams will be lost because of site clearing, infrastructure development, mine pit development, storage of stripped muskeg and overburden materials, and development of the tailings settling pond. Mine pits will cause subsurface water table drawdown, and lowering of the water levels of shallow ponds at the mine pit perimeters.

The linkage between the Project activities discussed above and the changes in the open-water areas is valid.

After Closure

Reclamation of the Muskeg River Mine Project will create new drainage systems consisting of secondary drainage ditches, main drainage channels, shallow lakes/wetlands, and the end pit lake. This will cause an increase in the areas of lakes/wetlands and streams in the Project area. The locations of these new lakes, wetlands and streams are shown in Figure E4-12. The reclaimed landscape with these built-in drainage features will replace the natural landscape of poorly drained lowland area with a small number of identifiable streams and shallow lakes/ponds.

The linkage between the Project activities discussed above and the changes in the open-water areas is valid.

E4.6.2 Impact Analysis

During Construction and Operation

The maximum loss in areas of streams and shallow lakes/ponds during construction and operation is represented in Table E4-34 based on the maximum development footprint reached in Year 2022. The areas of the existing waterbodies in the LSA were estimated based on the available topographic maps supplied by the Canadian Department of Energy, Mines and Resources and the satellite imagery produced by Radarsat International in 1996. The waterbodies lost during construction and operation will include those in the mining footprint area plus the mine pit perimeter area which is subject to water table drawdown caused by the development. These areas were estimated by assuming a 1.5 km length of influence at the perimeter of the mine pits.

Table E4-34 Maximum Change in Areas of Streams and Lakes and Ponds During Construction and Operation

Type of Area	Streams and Man-Made Channels		Areas of Lakes and Ponds (ha)	Total Surface Area (ha)
	Length (km)	Area (ha)		
Existing Conditions in the LSA	868	852	819	1671
Loss during Construction and Operation	13.6	3.4	26	29
Percent Reduction	**1.6%**	**1.4%**	**3.2%**	**1.7%**

Figure D6-1 shows the locations of the man-made Alsands Drain channel system and the shallow lakes and ponds within the mining footprint area, which will be lost during construction and operation. The lost channels at the Project area are not natural streams. The lost lakes and ponds are shallow waterbodies located south of the Alsands Drain and west of the Muskeg River.

The loss of stream area in the Project area will be less than 1% of those in the LSA. This is considered to be negligible. The total surface area of shallow lakes or ponds lost during construction and operation in the Project area is 26 ha, which is about 3% of the total surface area of all lakes and ponds in the LSA. This reduction is considered to be moderate. The total surface area of lakes, ponds and streams lost during construction and operation will represent less than 2% of that in the LSA. This level of reduction is rated as low.

After Closure

The areas of streams, wetlands and lakes created during reclamation are presented in Table E4-35. The areas were estimate based on the designs of the reclaimed landscape and drainage systems.

Table E4-35 Areas of Streams, Wetlands and Lakes Created During Reclamation

Type of Area	Length (km)	Area (ha)
Streams	39	10
Wetlands and Shallow Lakes	n/a	218
End pit lake	n/a	442
Total	**39**	**670**

n/a = not applicable

The 27 ha of shallow lakes, ponds and streams lost during construction and operation will be replaced by 670 ha of streams, wetlands, shallow lakes and the end pit lake after closure. This represents an increase in area of about 25 times at the Project area. This represents an increase of about 38% in area of lakes, ponds, wetlands and streams in the LSA.

E4.6.3 Residual Impact Classification and Degree of Concern

The residual impacts of the Muskeg River Mine Project on the changes in the areas of lakes, ponds, wetlands and streams in the LSA are classified and rated as shown in Table E4-36 based on the detailed impact analysis presented above.

During construction and operation, the Muskeg River Mine Project will displace a small number of shallow lakes/ponds and streams located within the footprint of mine development and at some areas at the perimeter of the mine pits which are affected by drainage of the surface aquifer. The degree of concern of this impact is low. After closure, the reclaimed landscape and drainage systems will provide larger areas of streams, wetlands and lakes in the Project area, thus replacing those areas lost during Project development and operation. The degree of concern for this impact is rated as nil.

Table E4-36 Classification and Degree of Concern of Residual Impacts on Changes in Areas of Lakes, Ponds, Wetlands and Streams

Project Phase	Construction and Operation	Closure
Direction	Negative	Neutral to Positive
Magnitude	Low	High
Geographic Extent	Local	Local
Duration	Medium Term	Long-Term
Reversibility	Reversible	Irreversible
Frequency	Continuous	Continuous
Degree of Concern	*Low*	*Nil*

E4.7 Key Question SW-6: Will the Muskeg River Mine Project Affect Landscape and Drainage System Sustainability After Closure?

E4.7.1 Analyses of Potential Linkages and Impacts

Excessive surface erosion from the reclaimed surfaces, gully erosion resulting from a reclaimed landscape with immature drainage density, and channel evolution to its regime conditions could cause rapid deterioration of the closure landscape and the reclamation drainage systems. Such landscape and drainage conditions could change the aquatic habitats in the receiving streams or lakes, wildlife habitat and end land use of the reclaimed areas.

Sustainable reclamation landscape and drainage systems, which are capable of accommodating evolutionary, dynamic equilibrium changes without accelerated surface gullying and channel erosion are planned for the Project. Such dynamic systems have robust drainage facilities with several lines of defense and self-healing capability to ensure that the reclaimed landscape and the drainage systems will be stable, safe, robust and sustainable over the geological time frames. Instead of uniform slopes and a beach profile, the CT storage areas will be configured with undulating topography including drainage swales and grassed waterways.

In addition, the closure landscape and reclamation drainage systems are designed to provide a biologically productive and well-vegetated landscape with wetlands, lakes and floodplains. These features will minimize surface erosion and enhance not only the physical longevity and sustainability of the systems by attenuating flood peak discharges, but also the biological sustainability of the closure landscape by bioremediation of the surface runoff originating from the reclaimed surfaces.

Sustainable landscape and drainage systems are designed by replicating natural analogues and by building dynamic elements capable of adjusting to changes. This is unlike the conventional engineering approach for drainage system design which requires regular maintenance and uses rigid facilities and structures composed of man-made materials. The design of the sustainable landscape and drainage systems for the Muskeg River Mine Project has included the following measures:

- All the reclaimed surfaces will be covered with topsoils consisting of organic and mineral soils to support vegetation. Sand ridges will be provided on the sand-capped CT surfaces to provide drained soil conditions to support upland vegetation growth. These measures will minimize surface erosion from the reclaimed landscape.

- All the reclaimed surfaces will be designed and built with mature drainage networks with suitable drainage densities characteristic of the various types of the reclaimed surfaces. The drainage density is defined as the channel length per unit drainage area. The characteristic drainage density of a landform is an important parameter that depicts its geomorphic character and is indicative of the erosion potential. Provision of drainage densities based on natural systems will ensure minimum gully erosion, which is usually the main source of basin sediment yield from an immature landscape.

- All main drainage channels will be built "in regime" by replicating geomorphic relationship exhibited by natural streams, which express cross-sectional shapes, and channel depth, slope and meander pattern in terms of discharge, bed material and valley gradient. Floodplains will be provided to accommodate extreme flood events including the 100 year and even the Probable Maximum Flood (PMF) without excessive channel erosion and sediment yield.

- Shallow lakes, wetlands and the end pit lake will help attenuate flood peak discharges to the downstream channels and minimize flow velocities and channel erosion. Rock breakwaters will be provided to protect the 20% littoral zone to ensure biological productivity and to minimize wave erosion. The large end pit lake will settle sediment runoff from the reclaimed surfaces and minimize risks of increased sediment loading to the Muskeg River.

By providing these mitigation measures to minimize surface, gully and channel erosion, the risk of an unsustainable reclamation landscape and drainage systems is minimized. However, there will still be residual risk of higher sediment yields from the reclaimed landscape and the drainage systems, as discussed in Section E4-6. Further studies are needed to reduce the degree of uncertainty associated with the actual performance of the proposed systems.

The linkage between the changed basin sediment yield characteristics and closure landscape sustainability is valid.

E4.7.2 Residual Impact Classification and Degree of Concern

A reclamation drainage plan has been designed for the Project to develop a long-term sustainable reclamation landscape and drainage systems after closure. The residual impact of the Muskeg River Mine Project on the closure landscape and drainage system sustainability is classified and rated in Table E4-37. The degree of concern of the residual impact is rated low.

Table E4-37 Classification and Degree of Concern of the Residual Impact on the Sustainability of Closure Landscape and Drainage Systems

Direction	Negative
Magnitude	Low
Geographic Extent	Local
Duration	Long-Term
Reversibility	Irreversible
Frequency	Continuous
Degree of Concern	***Low***

E4.7.3 Future Studies

To ensure development of a long-term sustainable landscape and drainage systems after closure, future studies will be conducted to provide detailed design criteria for final design of the reclamation systems and to allow accurate prediction of the performance of the systems. These studies will include the following:

- Study the erodibility of the sand and overburden materials in which reclamation drainage channels will be built. This will provide field data to define the design criteria and to help refine drainage design concepts.

- Investigate reclamation landscape options to identify the landforms that minimize the long-term risk of erosion resulting from incompatible surface drainage.

E5 SURFACE WATER QUALITY IMPACT ANALYSIS

E5.1 Introduction

This section of the Muskeg River Mine Project (the Project) EIA provides information as required by the Project Terms of Reference (TofR) issued on November 7, 1997 (AEP 1997a). Specifically, the following are addressed in this section:

- prediction of water quality conditions in the Muskeg River and Athabasca River downstream from the Project and any other waterbodies potentially affected by the Project;
- description of the potential impacts of the Project on surface water quality within the Study Area with respect to location, magnitude, duration, extent and significance;
- discussion of seasonal variation in impacts;
- discussion of potential alteration of the thermal regime of rivers in the Project area; and
- description of the surface water quality monitoring program to assess the design and performance of the water management system for collection, handling, treatment and discharge.

Discussions of the potential cumulative effects on surface water quality associated with the Project are addressed in this section and in Section F5. Section D5 summarizes existing water quality in the study area.

This impact assessment predicts whether Project-related releases, in combination with releases from existing developments, affect surface water quality in the Local Study Area (LSA). Figure E1-3 shows the existing developments being considered. The Cumulative Effects Assessment (CEA) in Section F5 reviews the effects of newly approved (but not yet operating) and planned projects on surface water quality in the Regional Study Area (RSA).

Water quality predictions are based on baseline water quality data discussed in Section D5 and in Golder (1997d). Chemistry of oil sands-related waters is discussed in Golder (1996f). Hydrogeological and hydrological input data were derived from Section E4. Predictions of the effects of acidic deposition on surface water quality were based on air quality modelling discussed in Section E2.

The water quality predictions in this section are used to assess impacts on aquatic biota (Section E6), wildlife (Section E11) and human health (Section E12).

E5.2 Approach

The overall approach for assessing potential impacts of the Project on water quality consisted of the following steps:

1. Identify issues of concern to stakeholders and regulators.

2. Formulate key questions that address these issues.

3. Identify Project activities and associated water releases that may affect water quality.

4. Review the scale and timing of these activities and water releases.

5. Conservatively predict the changes in water quality that might occur.

6. Evaluate those changes relative to regulatory water quality guidelines.

E5.2.1 Overview of Activities and Water Releases That May Affect Surface Water Quality

Several aspects of the Project associated with construction, operation and closure phases could potentially affect water quality, including:

- construction activities;
- muskeg and overburden dewatering;
- accidental releases;
- tailings settling pond seepage;
- sand seepage;
- consolidated tailings (CT) seepage;
- releases of acid-forming substances; and
- end pit lake (EPL) outflow.

Table E5-1 provides a short description of each of these activities and release waters.

Table E5-1 Activities and Water Releases That May Affect Surface Water Quality

Activity/Release	Description
Muskeg and overburden dewatering	• an operational water (Appendix V) • the quality of these waters is presented in Table V-1 • highest flows during first two years of operation • may affect temperature regime of Muskeg River • potential issues related to dissolved oxygen levels in Muskeg River
Accidental releases	potential issues during construction and/or operations related to: • spills, pipeline ruptures or vehicle accidents • flooding • failure of retention structures
Tailings settling pond seepage	• a reclamation water (Appendix V) • the quality of these waters is presented in Table V-1 • tailings settling pond seepage • seepage reaching the Muskeg River would take several hundred years (Key Question GW-3.3)
Sand seepage	• a reclamation water (Appendix V) • tailings sand dyke porewater (includes small amounts of tailings water) is collected in a perimeter ditch during operation and recycled back into the tailings settling pond • at closure, seepage is directed to long retention (approximately one year) wetlands and discharged to the Athabasca River • small amounts of seepage may escape the perimeter ditch • perimeter ditches intercept seepages and slow down residual seepages that move toward the Muskeg River over several hundred years • sand placed on top of CT deposits during reclamation will result in flows through wetlands to the EPL
CT seepage	• a reclamation water (Appendix V) • the quality of these waters is presented in Table V-1 • only source of CT seepage is from CT deposits placed in the mined-out pit • majority of flow to EPL for limited period • extremely small volume of seepage water directly to the Muskeg River
Releases of acid-forming substances	• NOx and other acid-forming emissions from plant utilities, vehicle fleet and other developments
End pit lake	• contain seepages and flux from CT deposits, tailings settling pond water, sand seepage and overburden drainage plus surface runoff from undisturbed areas • release of EPL water may influence the temperature regime of Muskeg River

E5.2.2 Overview of Water Management for the Project

The Water Management Plan for the Muskeg River Mine Project (Golder 1997j) describes drainage, water supply, storage, process water balance and reclamation drainage for the Project. This section briefly outlines the water management plan.

During construction of the mine and in preparation for mining, muskeg and overburden must be dewatered before being removed to expose the oil sands deposits. Water released during this activity is the only operational water released during the life of the Project. This water will be directed to sedimentation ponds before release to the Muskeg River. Questions have been raised regarding how this water might affect water chemistry, oxygen levels and temperature regime of the Muskeg River.

Reclamation water releases, such as sand seepage from the tailings settling pond will be collected in a perimeter ditch and pumped back into the tailings settling pond during operation. At mine closure, these releases will be directed through a series of wetlands with long retention times for bioremediation and ultimate discharge to the Athabasca River at closure. Small amounts of seepages may flow through the low-permeability lean oil sands layer beneath the perimeter ditch and, over hundreds of years, travel to the Muskeg River.

CT flux from the reclaimed pits (CT waters expressed upward during consolidation) will be channelled through wetlands before flowing into the EPL. Once in the EPL, water will be further diluted and bioremediated before release to the Muskeg River. CT seepages to the Muskeg River (CT water that seeps laterally out of the pit area during consolidation) from these reclaimed pits will be small to non-existent, because the upper surface of the CT deposit will be at or below the adjacent ground level. These seepages would also take hundreds of years to reach the Muskeg River.

E5.2.3 Control and Mitigation Measures

In making predictions about the quality of water resulting from the Project, a number of mitigation controls were assumed to be in place. Mitigation features relevant to water quality protection are reviewed in Table E5-2.

E5.3 Potential Linkages and Key Questions

Figure E5-1 shows the linkages between Project activities and potential changes in water quality. Each key question shown on the linkage diagram is examined in detail in the sections that follow. Key questions were as follows:

WQ-1 Will Operational and Reclamation Water Releases From the Project Result in Water Quality Guideline Exceedances in the Athabasca and Muskeg Rivers and Isadore's Lake?

The potential for effects on surface water quality has been raised as a concern associated with oil sands developments. To address this issue, predicted surface water chemistry at various phases of the Project was compared with water quality guidelines for the protection of aquatic life and human health.

Figure E5-1 Linkage Diagram for Surface Water Quality for Construction, Operation and Closure Phases of the Muskeg River Mine Project

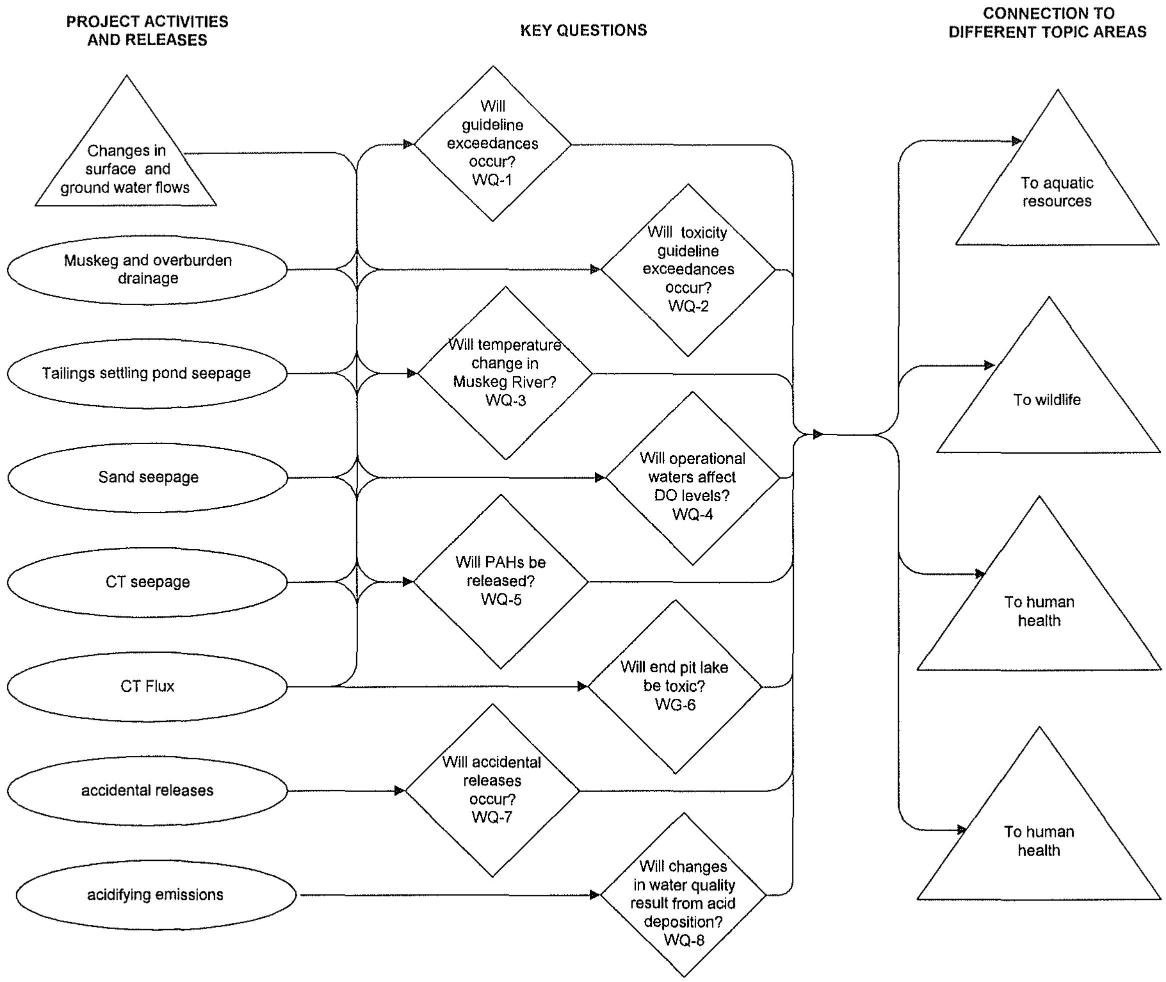


Table E5-2 Key Mitigation Features

Key Mitigation Feature	Description
Construction activities mitigation	• follow comprehensive guidelines • implement best management practices • timing of construction activities near streams to minimize disturbance to sensitive life stages of fish
Perimeter ditch around tailings settling pond	• seepages will be collected in perimeter ditch around tailings settling pond and pumped back into the pond during operation • ditch will penetrate to the underlying low-permeability oil sands layer and effectively prevent any seepages from progressing beyond this point (Section 6.4 of Application)
CT deposited below grade	• virtually eliminates seepages that might otherwise occur from CT deposits at a higher elevation than the surrounding land
CT water recycled into closed circuit system during operation	• water formed from CT and deposited into mined-out pits will be recycled into the closed circuit system during operation • after operation, CT flux will be directed to the EPL
Sand seepages from reclaimed tailings settling pond directed through wetlands into the Athabasca River at closure	• at closure the perimeter ditch will be connected to drain to wetlands and eventually to the Athabasca River • perimeter ditch will be deepened to the top of the impervious oil sands layer, hence will effectively prevent any seepages from moving beyond the ditch
Wetlands on CT deposits and reclaimed tailings settling pond	• wetlands are maintained as a reclaimed landscape feature that collect and treat upward fluxes of CT porewater and deposited sand seepages • these waters are directed to the EPL
End pit lake	• EPL will receive seepages and flux from CT deposits, sand seepage, surface runoff, precipitation and eventually aged, non-toxic tailings water and mature fine tails (MFT) • lake will serve a remediation function through its utility in promoting natural degradation of organic material related to oil sands • filling of the EPL will be controlled at such a rate that lake discharges will be non-toxic

WQ-2 Will Operational and Reclamation Water Releases From the Project Result in Toxicity Guideline Exceedances in the Athabasca and Muskeg Rivers?

This question is related to WQ-1, and addresses the issue of potential toxicity in surface waters caused by water releases from oil sands developments. To evaluate this question, predicted toxicity levels in surface waters were compared against guidelines for acute and chronic whole effluent toxicity (WET).

WQ-3 Will Operational and Reclamation Water Releases From the Project Alter the Temperature Regime of the Muskeg River?

This question addresses the issue of potential changes in the thermal regime of the Muskeg River in the reach adjacent to the Project. Predicted temperature changes were compared with the applicable water guideline and the potential to impair sensitive life stages of fish was assessed in Section E6.

WQ-4 Will Muskeg Dewatering Activities Associated with the Project Reduce Dissolved Oxygen Concentrations to Unacceptable Levels in the Muskeg River?

The issue of potential declines in dissolved oxygen levels in streams has been raised in connection with releases of muskeg drainage water during the construction phase of the Project. Muskeg drainage waters contain levels of organic carbon that may result in oxygen depletion. Declines in dissolved oxygen levels may have adverse effects on aquatic biota.

WQ-5 Will PAHs in Operational and Reclamation Waters Released From the Project Accumulate in Sediments and be Transported Downstream?

This question addresses the issue of potential accumulation of polycyclic aromatic hydrocarbons (PAHs) in sediments of waterbodies receiving oil sands-related water releases. PAHs are a group of organic compounds that are toxic to aquatic biota at elevated levels and may also affect human health.

WQ-6 Will End Pit Lake Water Be Toxic Before Discharge to the Muskeg River?

The EPL will be constructed before closure. It will treat reclamation waters derived from the reclaimed landscape. The lake will receive drainage from all mine-disturbed areas and surrounding lands that drain into mine-disturbed areas. It is critical that EPL water be non-toxic, to allow development of a productive, self-sustaining aquatic ecosystem.

WQ-7 Will Accidental Water Releases Occur that Could Affect Water Quality in the Athabasca and Muskeg Rivers?

Accidental releases could occur from spills, vehicle accidents, pipeline ruptures, flooding or failure of retention structures. This question addresses the potential for accidental releases and mitigation and contingency plans that will be put in place to minimize the risk of such releases.

WQ-8 Will Changes in Water Quality Result From Acidifying Emissions?

NO_x and SO_2 emissions result in the deposition of acid-forming compounds on land and water in the area surrounding sources of such emissions. This question addresses whether the combined effects of NO_x emissions from the Project and NO_x and SO_2 emissions from existing developments in the region could result in acidification of waterbodies.

E5.4 Methods

This section describes the methods used to address the key questions. First, the general approaches followed to predict changes in different aspects of surface water quality are described; then, the physical, chemical and temporal aspects of the models are outlined and the computer models used to predict changes in water quality are described. Lastly, model assumptions and screening criteria used to evaluate potential changes in water quality are presented.

E5.4.1 Predicting Changes in Water Quality

Changes in water quality were assessed by predicting changes in substance concentrations and stream temperature regimes, and determining the acidifying potential of emissions on waterbodies. A number of different modelling approaches were employed, each specific to the issue or question addressed. General descriptions of each model and boundary conditions are provided below.

Water Quality Modelling - Athabasca and Muskeg Rivers

The approach used to predict water quality changes in the Athabasca and Muskeg rivers consisted of the following steps:

1. Mean open-water and annual 7Q10 flow statistics were generated for the Athabasca and Muskeg rivers (Table D4-13).

2. Background water quality data representing mean open-water and annual 7Q10 flow were compiled for each river (Section D5). These data reflect impacts from upstream municipalities and pulp mills.

3. Water chemistry data were compiled for existing oil sands release waters (Table V-1 and V-2).

4. Regulatory water quality guidelines developed for the protection of aquatic life were assembled (Table V-3) according to the recommended sequence contained in AEP's Protocol to Develop Alberta Water

Quality Guidelines for Protection of Freshwater Aquatic Life (AEP 1996c). Guidelines for protection of human health were also compiled as recommended in AEP's Water Quality Based Effluent Limits Procedures Manual (AEP 1995b).

5. Time snapshots representing each stage of the Project were identified, to account for different operational conditions and associated combinations of release waters.

6. Nodes were identified for modelling based on locations of water release points to surface waters. Nodes represent specific locations where water quality is predicted.

7. Computer models were used to predict substance concentrations for the time snapshots and conditions specified for modelling, consistent with AEP's Water Quality Based Effluent Limits Procedures Manual (AEP 1995b).

8. Predicted substance concentrations were compared with regulatory guidelines for the protection of aquatic life and human health.

9. If exceedances of guidelines were projected, the possible reasons for the exceedances were explored.

Toxicity Modelling - Athabasca and Muskeg Rivers

The water quality models described above were also used to predict acute and chronic toxicity in receiving waters for comparison with water quality guidelines for WET (AEP 1995b).

Since reclamation waters will not be produced by the Project until the beginning of mine reclamation, it was necessary to assume that the toxicity of reclamation waters produced by the Project will be similar to those of existing oil sands reclamation waters. Toxicity of sand seepage water was assumed to be the same as that shown for Tar Island Dyke (TID) water during testing for Suncor (HydroQual 1996a). Toxicity of CT water was assumed to be the same as that of CT water produced by addition of gypsum to Suncor's fine tailings during recent CT trials.

Concentrations of Suncor's reclamation waters representing the LC50 (median lethal concentration) and the IC25 (concentration causing 25% inhibition of reproduction or growth) to the most sensitive test organisms in laboratory tests were used to assign acute and chronic Toxic Units (TUa and TUc, respectively) to CT water and sand seepage water. Toxic Units were calculated as 100 divided by the LC50 (to arrive at TUa) or IC25 (to arrive at TUc). The resulting TU values were as follows:

Reclamation Water	TUa	TUc
Sand seepage water	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 rationale for the above approach and details of the procedure used are provided in Appendix VII.

Thermal Regime Modelling - Muskeg River

The approach to predict river temperature consisted of the following steps:

1. Characterize existing baseline temperature regime in the Muskeg River on a monthly basis, using available data.

2. Estimate the temperature of muskeg drainage water, overburden drainage water and EPL water. These waters represent the majority of mine-related water discharges.

3. Select time snapshots corresponding to periods of highest water discharges during each phase of mine development.

4. Obtain monthly discharge estimates for the Muskeg River, muskeg drainage water, overburden drainage water and EPL water for each snapshot.

5. Predict the river water temperature on a monthly basis for each snapshot year, using thermal balance equations.

6. Compare predicted temperatures with the applicable temperature guideline.

E5.4.2 Water Releases and Flows Modelled

Sections E3 and E4 describe the methods used to calculate groundwater and surface water flows. A chemical profile was assigned to each type operational and reclamation water (Table V-1), based on water chemistry of operational and reclamation waters produced by existing oil sands operations. Then, flows of each water type, obtained from Sections E3 and

E4 (Table E4-15), were assigned to each node (Figure E5-2). Figures V-1 to V-10 in Appendix V illustrate the specific waters associated with each node. Models were used to simulate water quality at these nodes for the various snapshots identified for the Project.

Simulations were run for the Athabasca and Muskeg rivers at annual 7Q10 and mean open-water flows to examine seasonal impacts. Annual 7Q10 flow was used to predict the worst-case concentrations of substances, due to availability of the lowest dilution capacity under this flow condition. Screening at mean open-water flows was done for two reasons: (1) to assess the potential water quality differences associated with the higher natural sediment loading during that period; and (2) to arrive at predictions regarding potential exceedances of human health water quality guidelines.

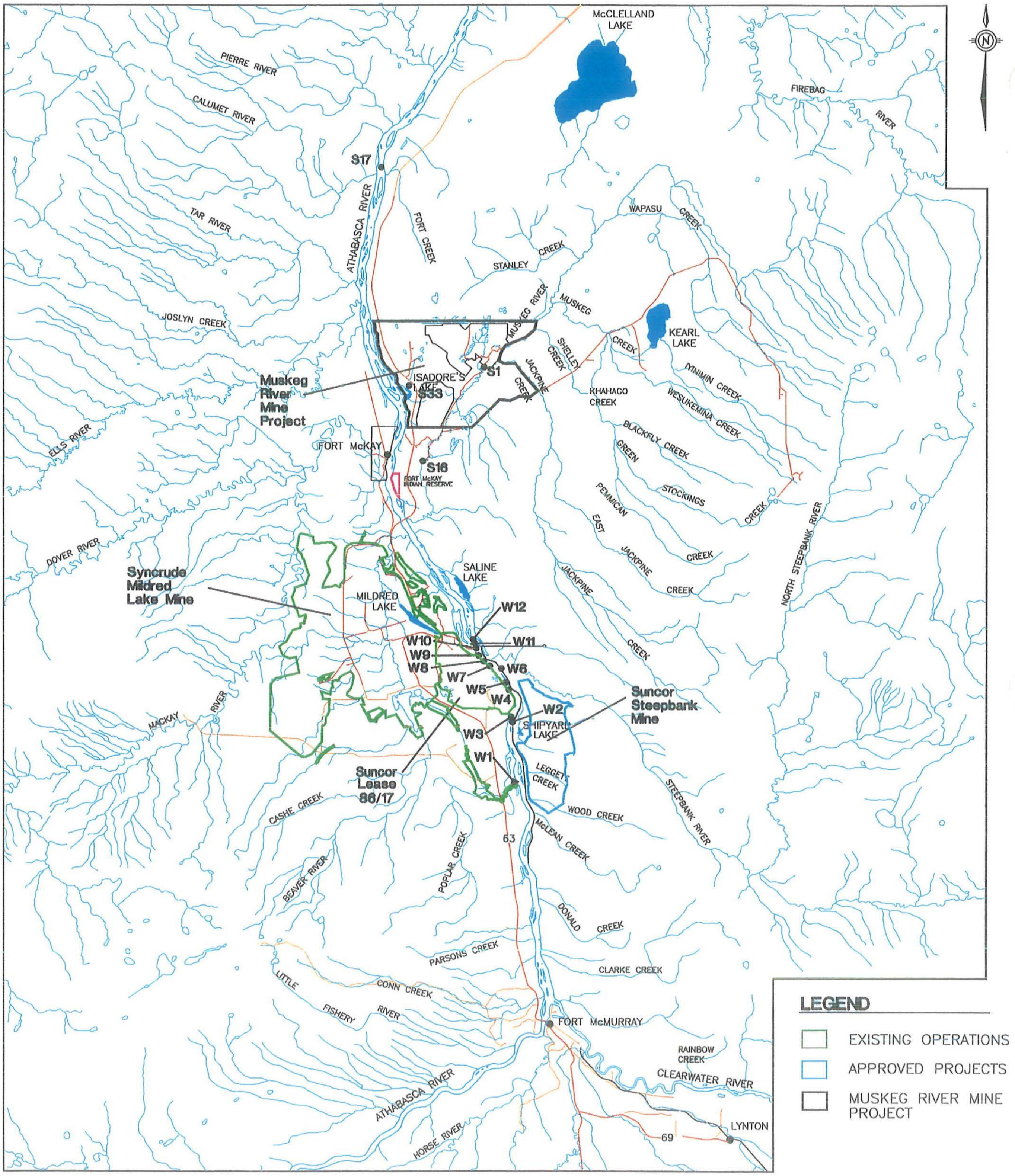
E5.4.3 Time Snapshots Modelled

Water Quality Modelling

Impacts on water quality were examined for each major phase of the Project: construction, operation, closure and far future. The waters associated with each phase generally overlap. For example, because reclamation will proceed concurrently with operation, water quality changes associated with releases of reclamation waters can occur during all phases. However, each Project phase will have a distinct combination of flows and associated water quality. The sequence of mine activities and descriptions of how different Project phases and activities are expected to affect water flows are described in Table E1-3.

To capture all combinations of water releases and, by extension, all possible water quality conditions, the following time snapshots were selected for water quality modelling:

- Year 2000
- Year 2002
- Year 2003
- Year 2005
- Year 2010
- Year 2020
- Year 2022
- Year 2025
- Year 2030
- Far Future



REFERENCE

DIGITAL DATA SETS 74D, 74E, 74I
84A AND 84H FROM RESOURCE DATA DIVISION
ALBERTA ENVIRONMENTAL PROTECTION, 1997.

Golder Associates

SHELL CANADA LIMITED

REGIONAL WATER QUALITY MODELLING NODES

06 DEC 97	Figure E5–2	DRAWN BY: CG/VS

Thermal Regime Modelling

Temperature predictions for the Muskeg River were made for the following three time snapshots:

- Year 2005, approximately corresponding to the highest releases of operational waters during mine construction;
- Year 2010, corresponding to the highest releases of operational waters during mine operation; and
- Year 2030, representing maximum EPL discharge rate.

E5.4.4 Models Employed

Four different computer models were used to predict water quality changes:

- Small Streams Model
- Athabasca River Model
- End Pit Lake Model
- Thermal Regime Model

Small Streams Model

A steady state, dilution model was used to predict water quality in the Muskeg River. Operational and reclamation waters discharged from the Project Site were assigned chemistry based on existing oil sands information (Table V-1), and assumed to completely mix within the receiving waterbody. Chemical concentrations within the receiving waterbodies were calculated as a function of total incoming mass divided by total water volume. Given the short residency time of water in the Muskeg River, no decay of organic substances was modelled before discharge to the Athabasca River.

The following is an example of the equation used to predict water chemistry in streams:

$$(C_1Q_1 + C_2Q_2 + C_3Q_3 + \ldots\ldots C_nQ_n) / (Q_1 + Q_2 + Q_3 + \ldots\ldots + Q_n)$$

where:

n = number of water flows mixing together
C_1 = concentration of a substance in water flow 1
Q_1 = flow rate of water flow 1
C_2 = concentration of a substance in water flow 2
Q_2 = flow rate of water flow 2
C_3 = concentration of a substance in water flow 3
Q_3 = flow rate of water flow 3

C_n = concentration of a substance in water flow n
Q_n = flow rate of water flow n

Athabasca River Model

A two-dimensional, steady state model was used to predict water quality and mixing in the Athabasca River. The model was based on analytical solutions to river dispersion equations. It has the capability of handling both point-source discharges (e.g., surface runoff or mine effluents) and non-point source discharges (e.g., groundwater seepage). A detailed description of the model is provided by Golder (1996f).

Reclamation waters from the Project will be released to the Athabasca River at several points. These include discharges and seepages traveling via the Muskeg River and EPL, and directly from wetlands draining the tailings settling pond perimeter ditch. In addition there are numerous mine water sources that discharge into the Athabasca River, both upstream and downstream of the Project (e.g., Suncor Lease 86/17 and Syncrude Mildred Lake Mine; other approved and planned projects are included in the cumulative effects modelling).

To accommodate these multiple sources, the model was set up to allow simulation of each discharge separately and the total river concentration downstream of the sources was obtained by an additive approach. This was accomplished by applying a grid to the study reach with more than 2,800 nodes. For each discharge, downstream concentrations were calculated at each node. Total concentrations at each node were then determined by summing all individual, discharge-specific concentrations attributed to that node. Using this summation procedure, all discharges to the Athabasca River were accounted for, and their combined effects was assessed.

End Pit Lake Model

A dynamic model was used to predict water quality in the EPL. The lake was considered to be a completely mixed waterbody, with a maximum volume of 130 Mm^3. Inflows included surface runoff, precipitation, CT water (seepages and flux) and sand seepages collected in the reclamation areas, tailings settling pond water and MFT. Water loss through evaporation and seepage were also accounted for, and lake outflow volumes were proportional to total inflows minus within-lake water losses. Influent, evaporation and seepage volumes were taken from Golder (1997j) and Section E4. Each water flow was assigned chemistry based on available data from existing oil sands operations (Table V-1).

Given the projected two to 10 years retention time of the EPL, the model incorporated the decay of organic compounds and their associated acute and chronic toxicity. The model was also configured to account for the continuous consolidation of MFT placed into the bottom of the EPL. Chemical concentrations within the lake were calculated as a mass balance of incoming flows mixing with existing lake volumes minus lake outflows.

Thermal Regime Model

To calculate the mean monthly water temperature in the Muskeg River after the addition of operational and reclamation waters, a simple, mass-balance equation was used. This equation incorporated the discharge and temperature of each component of the system. The equation is as follows:

$$Tp = (TR*QR+TM*QM+TD*QD+TL*QL+TG*QG) / (QR+QM+QD+QL+QG)$$

Where:

Tp = Predicted monthly mean water temperature (°C)
TR, QR = Muskeg River temperature (°C) and discharge (m^3/s), respectively
TM, QM = Muskeg drainage water temperature (°C) and discharge (m^3/s), respectively
TD, QD = Overburden drainage water temperature (°C) and discharge (m^3/s), respectively
TL, QL = EPL drainage temperature (°C) and discharge (m^3/s), respectively
TG, QG = Groundwater seepage temperature (°C) and discharge (m^3/s), respectively

E5.4.5 Screening Criteria

Oil sands parameters used to screen against water quality guidelines were discussed in Golder (1996f) and were used in the two recent environmental impact assessments (EIAs) for oil sands developments (BOVAR 1996a, Golder 1996f). Parameters included in the water quality modelling included those that were both detectable in one or more release waters and for which an established guideline exists (Table V-3).

The following water quality screening criteria (Table E5-3) were used for assessing predicted substance concentrations against regulatory water quality guidelines (Table V-3). This approach is consistent with AEP (1995b, 1996c) recommendations and previous EIAs.

Table E5-3 Water Quality Screening Conditions

Water Quality Guideline	Stream Flow Modelled	Receiving Waterbody	Mixing Zone Boundary Condition
Protection of aquatic life	annual 7Q10	Muskeg River	full mixing
Protection of aquatic life	mean open-water	Muskeg River	full mixing
Protection of aquatic life	annual 7Q10	Athabasca River	10% of river width
Protection of aquatic life	mean open-water	Athabasca River	10% of river width
Human health non-carcinogen	mean open-water	Muskeg River	full mixing
Human health carcinogen	mean open-water	Muskeg River	full mixing
Human health non-carcinogen	mean open-water	Athabasca River	full mixing
Human health carcinogen	mean open-water	Athabasca River	full mixing
Protection of aquatic life (temperature)	monthly means	Muskeg River	full mixing

The guidelines for toxicity in the receiving environment were ≤0.3 for TUa and ≤1 for TUc as specified by AEP (AEP 1995b). These guidelines were developed by the U.S. EPA, based on a large set of effluent toxicity data. The guideline values correspond to the approximate value of the No Observed Effects Concentration (NOEC). The NOEC is the highest concentration of a substance or an effluent at which no adverse effects are found during a toxicity test. Hence, TU values below the guidelines indicate the absence of toxicity.

Water quality screening assumptions for operational and reclamation waters associated with the Project are described in Appendix V.

E5.5 Key Question WQ-1: Will Operational and Reclamation Water Releases From the Project Result in Water Quality Guideline Exceedances in the Athabasca and Muskeg Rivers and Isadore's Lake?

E5.5.1 Analysis of Potential Linkages

Linkage Between Operational and Reclamation Water Releases and Exceedances of Water Quality Guidelines in the Athabasca and Muskeg Rivers

Operational and reclamation water releases can reach the Athabasca and Muskeg rivers through discharge from the EPL, via seepage or through wetlands associated with the tailings settling pond perimeter ditch. Since these waters may have substance levels in excess of water quality guidelines, it is concluded that these waters have the potential to cause exceedances of water quality guidelines in the Athabasca and Muskeg rivers. Therefore this linkage is valid.

Linkage Between Operational and Reclamation Water Releases and Exceedances of Water Quality Guidelines in Isadore's Lake

Exceedances of water quality guidelines are not expected to occur in Isadore's Lake as a result of operational or reclamation discharges. During the construction and operation phases, releases of muskeg and overburden drainage waters will be controlled, so that relevant water quality guidelines will be met.

During closure, there will be no direct seepage from the CT disposal pits to Isadore's Lake because there is no continuous horizontal flow-path. Sand seepages will not reach Isadore's Lake since groundwater modelling calculations indicate that it would take on the order of 1,000 years for any process-related seepages to reach the area (Section E3). Degradation and dilution of those seepages would eventually cause these waters to be indistinguishable from background groundwater.

Therefore, the linkage between operational and reclamation waters and exceedances of water quality guidelines in Isadore's Lake is invalid.

E5.5.2 Analysis of Key Question

Results are presented in Appendix V for each substance modelled during each snapshot and flow condition in the Athabasca and Muskeg rivers. The summary tables below provide results for exceedances of water quality guidelines, the majority of which are due to background levels of the substances in question. The values shown in the summary tables represent the highest concentrations predicted for all snapshot years simulated. The reasons for the results are subsequently discussed under "Significance of Water Quality Guideline Exceedances."

Summary tables for the Athabasca River provide the following information for substances that were predicted to exceed guidelines:

- the existing concentration upstream of Fort McMurray, as measured during baseline studies or monitoring;
- predicted concentration at the LSA mixing zone boundary, resulting from upstream sources and existing oil sands developments. Modelled, rather than measured values are shown, since the available data are limited for the reach of the river immediately upstream from the Muskeg River; and
- the effects of the Project in the form of existing concentration at the LSA mixing zone boundary (from Step 2) plus the increase caused by the Project.

Summary tables for the Muskeg River provide the following information for substances that were predicted to exceed guidelines:

- the existing concentration upstream of Node 16 (Figure E5-2) on the Muskeg River, as measured during baseline studies; and
- the effects of the Project, in the form of existing concentration upstream of Node 16 (from Step 2) plus the increase caused by the Project.

Mean Open-Water Flow in Athabasca River

Model results indicate that during mean open-water flow, compliance with most water quality guidelines is achieved during all time snapshots (Tables V-5 and V-6). Table E5-4 includes the concentrations of substances that were predicted to exceed water quality guidelines.

Table E5-4 Predicted Substance Concentrations Compared with Water Quality Guidelines at Mean Open-Water Flow in the Athabasca River

Substance	Existing		Project[c] (existing plus incremental)	Guideline[d]	Comment
	Upstream Fort McMurray[a]	Predicted at LSA[b]			
aluminum (mg/L)	0.68 (<0.005 - 11.4)	0.68	0.68	0.1 C	exceedance of chronic guideline is a result of existing river conditions; concentration constant throughout all Project phases; most of the aluminum is associated with particulate material and is not bioavailable (Table D5-11)
arsenic (mg/L)	0.001 (0.0003 - 0.0125)	0.001	0.001	0.01 C 0.000018 HC	exceedance of HC guideline is a result of existing river conditions; Project contribution of arsenic minimal relative to background levels
iron (mg/L)	3.0 (0.25 - 10.7)	3.0	3.0	0.3 C, HNC	exceedance of C and HNC guidelines are a result of existing river conditions; Project contribution of iron minimal relative to background levels
manganese (mg/L)	0.4	0.4	0.4	0.05 C, HNC	exceedance of C and HNC guidelines are a result of existing river conditions; Project contribution of manganese minimal relative to background levels
mercury (mg/L)	0.0001 (<0.00004 - 0.0001)	0.0001	0.0001	0.000012 C 0.00014 HNC	exceedance of C and HNC guidelines are a result of existing river conditions; Project contribution of mercury minimal relative to background levels

NOTES:
(a) Upstream concentrations taken from Golder (1997d).
(b) Concentrations at the 10% mixing zone boundary without the Muskeg River Mine Project.
(c) Concentrations at the 10% mixing zone boundary with the Muskeg River Mine Project included.
(d) C = Chronic, HC = Human Health Carcinogen, HNC = Human Health Non-Carcinogen.

Annual 7Q10 Flow in Athabasca River

Tables V-7 and V-8 provide predictions of substance concentrations at annual 7Q10 flow on the Athabasca River. Table E5-5 shows the one exceedance; for manganese and mercury at annual 7Q10 flow in the Athabasca River.

Table E5-5 Predicted Substances Concentrations Compared with Water Quality Guidelines at Annual 7Q10 Flow in the Athabasca River

Substance	Existing		Project[c] (existing plus incremental)	Guideline[d]	Comment
	Upstream Fort McMurray[a]	Predicted at LSA[b]			
manganese (mg/L)	0.1	0.1	0.1	0.05 C	exceedance of C guideline is a result of existing river conditions; Project contribution of manganese minimal relative to background levels
mercury (mg/L)	0.0001 (<0.00004 - 0.0001)	0.0001	0.0001	0.000012 C	exceedance of C guideline is a result of existing river conditions; Project contribution of mercury minimal relative to background levels

NOTES:
[a] Upstream concentrations taken from Golder (1997d).
[b] Concentrations at the 10% mixing zone boundary without the Muskeg River Mine Project.
[c] Concentrations at the 10% mixing zone boundary with the Muskeg River Mine Project included.
[d] C = Chronic.

Mean Open-water Flow in Muskeg River

Tables V-9 and V-10 provide predictions of substance concentrations at mean open-water flow on the Muskeg River. Table E5-6 includes the concentrations of substances that were predicted to exceed water quality guidelines.

Annual 7Q10 Flow in Muskeg River

Tables V-11 and V-12 provide predictions of substance concentrations at annual 7Q10 flow on the Muskeg River. Table E5-7 summarizes exceedances of water quality guidelines.

Significance of Water Quality Guideline Exceedances

The following substances were predicted exceed water quality guidelines in the Athabasca and Muskeg rivers:

Athabasca River:
- aluminum
- iron
- mercury
- arsenic
- manganese

Muskeg River:
- aluminum
- iron
- manganese
- mercury
- benzo(a)anthracene group
- benzo(a)pyrene group
- arsenic

Table E5-6 Predicted Substance Concentrations Compared With Water Quality Guidelines at Mean Open-Water Flow in the Muskeg River

Substance	Existing[a]	Project[b] (existing plus incremental)	Guideline[c]	Comment
aluminum (mg/L)	0.05 (<0.01 - 0.42)	0.22	0.1 C	highest concentrations are predicted for 2030 as a result of EPL discharge; concentrations of aluminum are not likely to be toxic; most of the aluminum is thought to be associated with particulate material and not bioavailable, mirroring current river conditions (Table D5-11)
arsenic (mg/L)	0.0029 (<0.0004 - 0.001)	0.0032	0.01 C 0.000018 HC	exceedance of HC guideline is a result of existing river conditions; highest instream concentrations are predicted for 2030 when the EPL discharges to the river; Project contribution of arsenic small relative to background levels
benzo(a)anthra-cene group (mg/L)	-	0.000017	0.0000028 HC	exceedance of HNC guideline projected for 2030 when the EPL discharges to the river; exceedance is probably not realistic, because substance would likely precipitate out in the EPL; result is further evaluated in human health, Section E12
benzo(a)pyrene group (mg/L)	-	0.0000037	0.0000028 HC	exceedance of HNC guideline projected for 2030 when the EPL discharges to the river; exceedance is probably not realistic, because substance would likely precipitate out in the EPL; result is further evaluated in human health, Section E12
iron (mg/L)	0.79	0.97	0.3 C, HNC	exceedance of C and HNC guidelines are a result of existing river conditions; highest instream concentrations are predicted for 2030 when the EPL discharges to the river; Project contribution of iron small relative to background levels
manganese (mg/L)	0.04	0.07	0.05 C, HNC	highest concentrations are predicted for 2030 as a result of EPL discharge
mercury (mg/L)	0.0001 (<0.0001 - 0.0004)	0.0001	0.000012 C 0.00014 HNC	exceedance of C and HNC guidelines are a result of existing river conditions

NOTES:
[a] Background concentrations from Golder (1997d).
[b] Instream concentrations when accounting for the Muskeg River Mine Project.
[c] C = Chronic, HC = Human Health Carcinogen, HNC = Human Health Non-Carcinogen.

Of the substances identified in Tables E5-4 to E5-7, aluminum, arsenic, iron, manganese and mercury are projected to exceed water quality guidelines under natural background conditions. Naturally elevated levels of metals are usually not considered to be of concern, because most of the metals are associated with suspended particulates (Section D5.1.4) and are thus not in a bioavailable form. For example, as Table D5-11 illustrates, for samples analyzed from the Muskeg River in the fall of 1997 (Golder 1997d), only 7 to 14% of aluminum and variable percentages of iron and manganese were found to be in the dissolved form. Dissolved fractions were typically lower in the Athabasca River, which usually carries a greater suspended sediment load. The dissolved fraction may be considered an approximation of the bioavailable portion of total metals.

Table E5-7 Predicted Substance Concentrations Compared with Water Quality Guidelines at Annual 7Q10 Flow in the Muskeg River

Substance	Existing[a]	Project[b] (existing plus incremental)	Guideline[c]	Comment
aluminum (mg/L)	0.04 (<0.01-0.58)	0.14	0.1 C	exceedance of C guideline projected for 2010, 2020 and 2022 due to increased surficial aquifer flows; most of the aluminum is thought to be associated with particulate material and not bioavailable, mirroring current river conditions (Table D5-11)
iron (mg/L)	2.42 (1.9 - 2.9)	3.21	0.3 C	exceedance of C guideline projected for 2020 and 2022 due to increased surficial aquifer flows; most of the iron is thought to be associated with particulate material and not bioavailable, mirroring current river conditions (Table D5-11)
manganese (mg/L)	0.55 (0.43 - 0.66)	0.60	0.05 C	exceedance of C guideline projected for 2020 and 2022 due to increased surficial aquifer flows
mercury (mg/L)	0.0001 (<0.0001 - 0.0005)	0.0001	0.000012 C	exceedance of C guideline is a result of existing river conditions

NOTES:
[a] Background concentrations from Golder (1997d).
[b] Instream concentrations when accounting for the Muskeg River Mine Project.
[c] C = Chronic.

The predicted concentrations are conservative, since no reduction in these particulate-bound metals was assumed during modelling, even though most of the particulates would settle in sedimentation ponds, in EPLs and wetlands, or would be trapped as seepage waters travelling through the ground.

Benzo(a)anthracene and benzo(a)pyrene groups were predicted to exceed the human health water quality guidelines. However, it is anticipated that these PAHs would also be tightly bound to particulates and would settle out in the EPL, or be trapped by soil particles as seepages move through the ground (this aspect is discussed further under Key Question WQ-5). The predicted guideline exceedances by benzo(a)anthracene and benzo(a)pyrene groups were brought forward for further screening under the human health section (Section E12). Their analysis indicated that the risks were acceptable for human health and wildlife during this period.

It is concluded that operational and reclamation water releases from the Project have limited potential to cause exceedances of water quality guidelines in the Athabasca and Muskeg rivers.

E5.5.3 Residual Impact Classification and Degree of Concern

The predicted impacts of operational and reclamation water releases, as defined by their contribution to exceedances of water quality guidelines, are classified in Table E5-8. Metals are not considered to be of concern due to their naturally elevated levels in the Project area.

Table E5-8 Residual Impact Classification and Degree of Concern for Water Quality Guideline Exceedances

Impact	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
Exceedances of guidelines at mean open-water flow in the Athabasca River	Negative	Negligible	not applicable	not applicable	not applicable	not applicable	Negligible
Exceedances of guidelines at annual 7Q10 flow in the Athabasca River	Negative	Negligible	not applicable	not applicable	not applicable	not applicable	Negligible
Exceedances of guidelines at mean open-water flow in the Muskeg River	Negative	Low	Local	Medium-term	Reversible	Medium	Low
Exceedances of guidelines at annual 7Q10 flow in the Muskeg River	Negative	Negligible	not applicable	not applicable	not applicable	not applicable	Negligible

E5.5.4 Monitoring

The proposed monitoring plan for the Athabasca and Muskeg rivers will be finalized on AEP review and acceptance of the joint industry Regional Aquatic Monitoring Program (RAMP).

E5.5.5 Mitigation

Because seepage flows are projected to occur at such a low rate, the groundwater monitoring programs implemented to monitor seepages will enable mitigation solutions to be applied where necessary. For example, if degradation rates are slower than the rates assumed, or if seepage flows are higher than projected, elongated wetlands or ponds could be created between the perimeter ditch and the Muskeg River to intercept flow and promote aerobic degradation of any remaining organic toxicity. A similar approach could be taken for the CT deposit areas, although the risk that CT seepages will be higher than assumed for the Project is considered to be exceptionally low.

E5.6 Key Question WQ-2: Will Operational and Reclamation Water Releases From the Project Result in Toxicity Guideline Exceedances in the Athabasca and Muskeg Rivers?

E5.6.1 Analysis of Potential Linkages

Linkage Between Operational Water Releases and Exceedances of Toxicity Guidelines

Operational water releases consist of muskeg and overburden drainage waters. These waters are essentially shallow groundwater, which constantly seeps into waterbodies under natural conditions and accounts for a large proportion of the flow of streams in the study area during the winter (baseflow). For example, Schwartz (1980) estimated that 60% of the flow of the Muskeg River during the open-water season is made up of muskeg drainage water. Therefore, it was assumed that muskeg and overburden drainage waters are not toxic to aquatic organisms. Based on this information, this linkage is invalid.

Linkage Between Reclamation Water Releases and Exceedances of Toxicity Guidelines

Reclamation waters include CT water, which may reach streams via seepage and direct discharge from the EPL after closure, sand seepage and tailings settling pond seepage. Seepage from the tailings settling pond will be captured in a perimeter ditch and will be pumped back to the tailings settling pond.

Toxicity tests of Suncor's reclamation waters have shown that they have the potential to cause acute (i.e., short-term, usually lethal) and chronic (i.e., long-term, sublethal or lethal) effects on aquatic organisms. Therefore, this linkage is valid.

Detailed description of the rationale for using aquatic toxicity tests as the basis for predicting acute and chronic effects on aquatic organisms and toxicity profiles of reclamation waters used for the assessment are provided in Appendix VII.

E5.6.2 Analysis of Key Question

Mean Open-Water Flow in Athabasca River

Model results indicate that during mean open-water flow, compliance with WET guidelines is achieved. The values shown in Table E5-9 represent the highest numbers predicted for acute and chronic toxicity for all snapshot years simulated. Dispersion model contour plots of TU values are presented for the Year 2030 in Figures V-11 (acute) and V-12 (chronic) and for the far future in Figures V-13 (acute) and V-14 (chronic).

Table E5-9 Predicted TU Values Compared With WET Guidelines at Mean Open-Water Flow in the Athabasca River

Parameter	Existing		Project[c] (existing plus incremental)	Guideline[d]	Comment
	Upstream Fort McMurray[a]	Predicted at LSA[b]			
acute toxicity (TUa)	0	0.0006	0.003	0.3 A	no guideline exceedance
chronic toxicity (TUc)	0	0.004	0.005	1.0 C	no guideline exceedance

NOTES:
[a] River assumed to be non-toxic upstream of oil sands operations.
[b] Concentrations at the 10% mixing zone boundary without the Muskeg River Mine Project.
[c] Concentrations at the 10% mixing zone boundary with the Muskeg River Mine Project included.
[d] A = Acute, C = Chronic.

Annual 7Q10 Flow in Athabasca River

Model results indicate that during annual 7Q10 flow, compliance with WET guidelines is achieved. The values shown in Table E5-10 represent the highest numbers predicted for all snapshot years simulated. Dispersion model contour plots are presented for the far future in Figures V-15 (acute) and V-16 (chronic).

Mean Open-Water Flow in Muskeg River

Model results indicate that during mean open-water flow, compliance with WET guidelines is achieved. The values shown in Table E5-11 represent the highest numbers predicted for all snapshot years simulated.

Table E5-10 Predicted TU Values Compared With WET Guidelines at Annual 7Q10 Flow in the Athabasca River

Parameter	Existing		Project[c] (existing plus incremental)	Guideline[d]	Comment
	Upstream Fort McMurray[a]	Predicted at LSA[b]			
acute toxicity (TUa)	0	0.0008	0.002	0.3 A	no guideline exceedance
chronic toxicity (TUc)	0	0.002	0.003	1.0 C	no guideline exceedance

NOTES:
[a] River assumed to be non-toxic upstream of oil sands operations.
[b] Concentrations at the 10% mixing zone boundary without the Muskeg River Mine Project.
[c] Concentrations at the 10% mixing zone boundary with the Muskeg River Mine Project included.
[d] A = Acute, C = Chronic.

Table E5-11 Predicted TU Values Compared With WET Guidelines at Mean Open-Water Flow in the Muskeg River

Parameter	Existing[a]	Project[b] (existing plus incremental)	Guideline[c]	Comment
acute toxicity (TUa)	0	0.01	0.3 A	no guideline exceedance
chronic toxicity (TUc)	0	0.02	1.0 C	no guideline exceedance

NOTES:
[a] River assumed to be non-toxic upstream of oil sands operations.
[b] Instream concentrations when accounting for the Muskeg River Mine Project.
[c] A = Acute, C = Chronic.

Annual 7Q10 Flow in Muskeg River

Model results indicate that during annual 7Q10 flow, compliance with WET guidelines is achieved. The values shown in Table E5-12 represent the highest numbers predicted for all snapshot years simulated.

E5.6.3 Residual Impact Classification and Degree of Concern

The predicted impacts of operational and reclamation water releases on toxicity in receiving waters are classified in Table E5-13.

Table E5-12 Predicted TU Values Compared With Water Quality Guidelines at Annual 7Q10 Flow in the Muskeg River

Parameter	Existing[a]	Project[b] (existing plus incremental)	Guideline[c]	Comment
acute toxicity (TUa)	0	0.03	0.3 A	no guideline exceedance
chronic toxicity (TUc)	0	0.03	1.0 C	no guideline exceedance

NOTES:
(a) River assumed to be non-toxic upstream of oil sands operations.
(b) Instream concentrations when accounting for the Muskeg River Mine Project.
(c) A = Acute, C = Chronic.

Table E5-13 Residual Impact Classification and Degree of Concern for WET Guideline Exceedances

Impact	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
Exceedances of WET guidelines at mean open-water flow in the Athabasca River	Negative	Negligible	not applicable	not applicable	not applicable	not applicable	Negligible
Exceedances of WET guidelines at annual 7Q10 flow in the Athabasca River	Negative	Negligible	not applicable	not applicable	not applicable	not applicable	Negligible
Exceedances of WET guidelines at mean open-water flow in the Muskeg River	Negative	Negligible	not applicable	not applicable	not applicable	not applicable	Negligible
Exceedances of WET guidelines at annual 7Q10 flow in the Muskeg River	Negative	Negligible	not applicable	not applicable	not applicable	not applicable	Negligible

E5.6.4 Monitoring

Although toxicity predictions indicate no cause for concern, monitoring of toxicity will continue to be part of the proposed monitoring plan for the Athabasca and Muskeg rivers as outlined in the RAMP. Details on the location and frequency of toxicity monitoring will be finalized on AEP review and acceptance of the monitoring plan.

E5.6.5 Mitigation

Mitigation measures identified under Key Question WQ-1 are applicable.

E5.7 Key Question WQ-3: Will Operational and Reclamation Water Releases From the Project Alter the Temperature Regime of the Muskeg River?

E5.7.1 Analysis of Potential Linkages

Linkage Between Operational and Reclamation Water Releases and Temperature Regime of the Muskeg River

Due to changes in surface and groundwater flows during the life of the Project, the linkage between these waters and a change in temperatures in the Muskeg River is classified as valid.

E5.7.2 Analysis of Key Question

Construction and Operation Phases

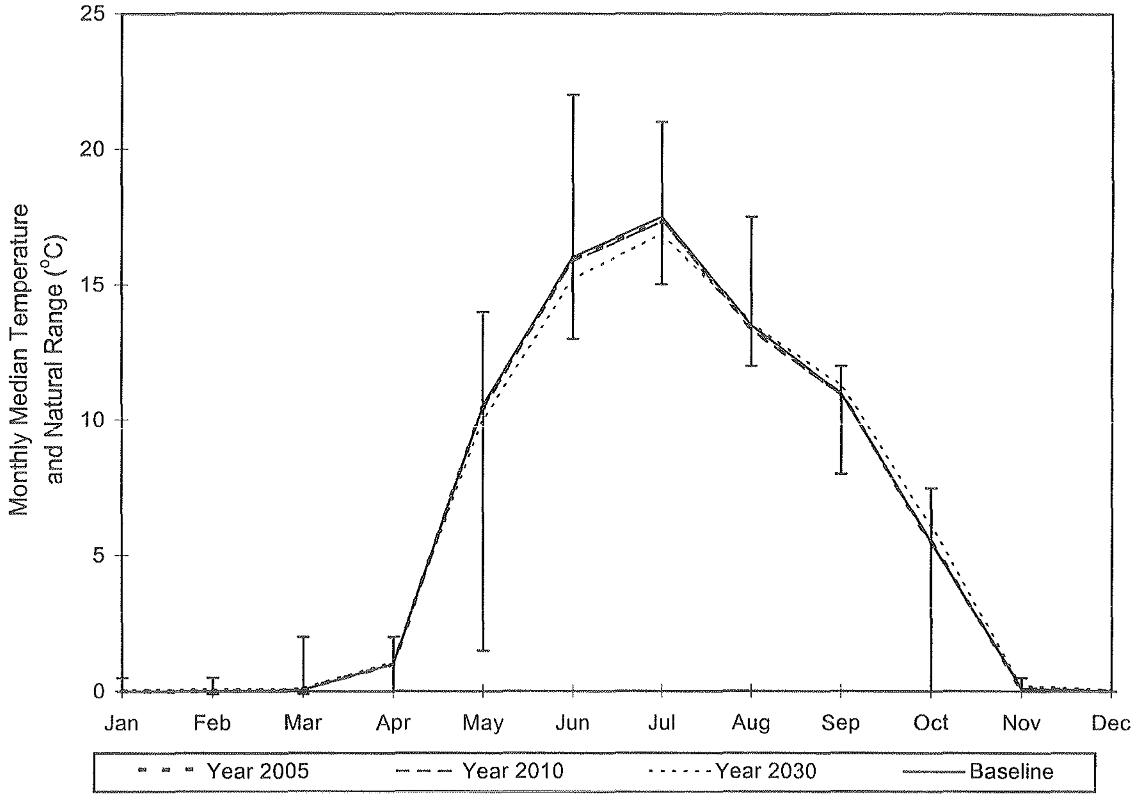
Results of temperature modelling suggest that even the highest rates of muskeg and overburden drainage water releases during mine construction (2005) and operation (2010) will have very little potential to alter water temperature in the Muskeg River (Figure E5-3). End pit lake water is not a factor at this stage, since its discharge to the Muskeg River will only begin in 2028.

The lack of a predicted effect on river water temperature in 2005 and 2010 is not unexpected, considering that muskeg and overburden drainage waters were predicted to reach the Muskeg River during the open-water season, when discharge of the river is considerably greater than those of mine-related water releases. The maximum percentage of muskeg and overburden drainage waters in the lower Muskeg River was estimated as <2% during the open-water season in 2005 and 2010. In light of such high dilution of incoming waters, river water temperature during these periods is unlikely to be affected, regardless of the magnitude of the temperature differential.

Reclamation Phase

End pit lake water inputs are more likely to alter the temperature regime of the Muskeg River than releases of muskeg and overburden drainage waters, due to higher volumes. The year 2030 represents a period when MFT will be added to the EPL during the open-water season. This, combined with surface runoff and CT flux, is expected to result in maximum EPL water release to the Muskeg River, at the approximate mean rate of 1.4 m^3/s in the open-water season.

Figure E5-3 Predicted Monthly Median Water Temperatures in the Muskeg River Below the End Pit Lake (at Node S16) Compared with the Baseline Temperature Regime of the Lower Muskeg River



Since MFT transfer and the associated EPL discharge will not occur in winter, no effects were predicted in this season. During the open-water season, 10 to 20% of the Muskeg River's water flow was predicted to originate from the EPL. Because of the relatively large temperature differential between EPL water and river water after ice breakup (estimated as up to 5°C), inputs from the EPL were predicted to cause slower warming of river water in the spring, a general cooling effect during the open-water season and slower cooling in the fall in 2030 (Figure E5-3). The magnitudes of the predicted temperature changes are very slight, with a maximum of <1°C, which is well below the currently available water quality temperature guideline of <3°C change. Hence, the predicted cooling of river water in the open-water season is classified as negligible.

The available data are insufficient to conduct a detailed analysis of impacts on rates of seasonal warming and cooling of river water. Although the expected changes are minor, they can be mitigated using the following simple approach: if it is found during temperature monitoring (see below), that the delay in seasonal warming or cooling is a potential problem for aquatic life, timing of MFT transfer can be adjusted to prevent impacts. Therefore, this impact is expected to be negligible.

Daily (diurnal) temperature variation of river water may also be affected downstream of the EPL. Since the temperature of EPL water would fluctuate less within a day than river water temperature, a general reduction in the amplitude of daily temperature fluctuation may also be expected downstream of the EPL. The available baseline data are insufficient to assess the magnitude of this potential effect. However, based on the length of the EPL discharge channel (>2 km), some diurnal fluctuation may develop, which may offset any potential effects.

E5.7.3 Residual Impact Classification and Degree of Concern

The predicted impacts of mine activities on the temperature regime of the Muskeg River were classified as shown in Table E5-14.

Table E5-14 Residual Impact Classification and Degree of Concern for Change in Thermal Regime of the Muskeg River

Impact	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
Cooling in open-water season	Neutral	Negligible	not applicable	not applicable	not applicable	not applicable	Negligible
Slower seasonal warming and cooling	Neutral	Negligible	not applicable	not applicable	not applicable	not applicable	Negligible
Reduced diurnal fluctuation	Neutral	Undetermined	Local	Medium-term	Reversible	Low	Undetermined

E5.7.4 Certainty

This analysis was based on a number of conservative assumptions. In particular, it was assumed that the temperature of mine-related waters will not change during travel from the source (i.e., EPL or area being dewatered) to the river. Since the distance from the EPL to the Muskeg River is >2 km, some warming or cooling and diurnal fluctuation may be expected during travel. This may be sufficient to arrive at a temperature regime that is near the natural regime of the river at the point of inflow.

The analysis was also conducted using a relatively coarse resolution (i.e., monthly mean temperatures were predicted). Although results suggest that the absolute changes in river water temperature will be minor, the presence, absence and severity of slower seasonal warming and cooling of river water and reduced diurnal temperature fluctuation are difficult to assess using the available data.

E5.7.5 Monitoring

Temperature regime of the Muskeg River will be monitored in selected years representing greatest inputs of mine-related waters, to verify impact predictions.

E5.7.6 Mitigation

If monitoring indicates unacceptable temperature changes during EPL water discharge, mitigation will be applied in the form of adjusting the scheduling of MFT transfer to the EPL to avoid impacts on aquatic life.

E5.8 Key Question WQ-4: Will Muskeg Dewatering Activities Associated with the Project Reduce Dissolved Oxygen Concentrations to Unacceptable Levels in the Muskeg River?

E5.8.1 Analysis of Potential Linkages

Linkage Between Muskeg Dewatering Activities and Dissolved Oxygen Concentrations

Recent muskeg drainage water data generated by Syncrude (Table V-1) were used for the small streams model predictions. As determined in Key Question WQ-1, these waters do not result in exceedances of water quality guidelines in receiving waters. However, these waters do have elevated organic matter concentrations and hence, the potential for lowered dissolved oxygen levels in the Muskeg River theoretically exists. Therefore this linkage is classified as valid.

E5.8.2 Analysis of Key Question

The following factors were considered in evaluating the potential for these waters to affect dissolved oxygen levels:

- Based on biochemical oxygen demand (BOD) levels of 0.05 to 8.0 mg/L (n=4; muskeg drainage water data submitted to AEP by Syncrude in September 1997), muskeg waters contain lower BOD levels than that permitted for municipal discharges into small streams. Therefore, it is unlikely that oxygen demanding materials in these waters would be sufficient to significantly lower dissolved oxygen levels in the Muskeg River.

- Discharge of muskeg and overburden drainage waters will be very low or will cease in the winter due to freezing of both the walls of, and water in, the channels in dewatering areas. However, it is possible that reduced flows of this water will occur in areas where the thickness of the muskeg and overburden are sufficient to be below the depth of winter freezing. During the winter period, natural flows are at their minimum and ice cover would limit re-aeration of the natural stream flow.

- The maximum percentage of muskeg and overburden drainage waters in the lower Muskeg River was estimated as <2% during the winter in 2005, which represents the year with the highest operational flows.

- Levels of organic material could be controlled in muskeg drainage waters by aeration of drainage system sedimentation ponds during Muskeg River low-flow periods, if monitoring of dissolved oxygen levels in the sedimentation ponds or downstream of the discharge from the ponds shows a potential problem.

E5.8.3 Residual Impact Classification and Degree of Concern

The predicted impact of dewatering activities on dissolved oxygen levels of the Muskeg River are classified as shown in Table E5-15. It is not expected that dewatering activities will result in an unacceptable lowering of dissolved oxygen levels in the Muskeg River. In any case, mitigation measures are available to address potential problems.

Table E5-15 Residual Impact Classification and Degree of Concern for Change in Dissolved Oxygen Concentrations

Impact	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
Lowered dissolved oxygen levels	Negative	Negligible	not applicable	not applicable	not applicable	not applicable	Negligible

E5.8.4 Certainty

Although recent muskeg drainage data were used in this analysis, questions remain regarding the representativeness of the data.

E5.8.5 Monitoring

The surface water monitoring program will include dissolved oxygen monitoring to verify impact predictions.

E5.8.6 Mitigation

If monitoring of dissolved oxygen levels indicates a potential problem, oxygen levels could be controlled in muskeg drainage waters entering the Muskeg River by aeration of sedimentation ponds during Muskeg River low-flow periods.

E5.9 Key Question WQ-5: Will PAHs in Operational and Reclamation Waters Released From the Project Accumulate in Sediments and Be Transported Downstream?

Reclamation waters produced by oil sands operations contain polycyclic aromatic hydrocarbons (PAHs) at low concentrations (Table V-2) and hence may contribute PAHs to receiving waters. Oil sands mining and processing does not result in the production of PAHs; rather PAHs that occur naturally in oil sand deposits are mobilized and released into the environment. The PAHs of concern include the larger compounds (four rings or more), which are largely insoluble in water and thus tend to adsorb to sediments. These compounds are bioaccumulative and toxic to aquatic organisms at elevated concentrations. Once released, sediment-bound PAHs may be transported for long distances and may affect aquatic organisms at considerable distances from the point of discharge. To allow assessment of the effects of sediment-associated PAHs, Environment Canada has recently developed interim sediment quality guidelines for a number of PAHs with known biological effects (Smith, S.L. et al. 1996).

E5.9.1 Analysis of Potential Linkages

Linkage Between PAHs in Operational and Reclamation Waters and PAH Accumulation and Transport in Sediments

In key question WQ-1, levels of PAHs are predicted to exceed water quality guidelines for human health. However, the pathways for their release into the environment are thought to be limited.

The validity of the linkage between operational and reclamation waters and PAH levels in sediments is uncertain due to lack of relevant data. Therefore, the linkage is classified as uncertain. It is unlikely that PAHs would be released by oil sands operations at levels that would cause biological effects; however, our understanding of this issue is limited.

E5.9.2 Analysis of Key Question

The effects of oil sands developments on sediment quality and toxicity have not been evaluated in detail. As a result, the available data regarding this issue are very limited. Most sediment PAH surveys sampled two to three sites in the lower Athabasca River (Brownlee 1990, Brownlee et al. 1993, 1997, Crosley 1996, Golder 1996b) and four samples were collected at two sites in the Steepbank River in 1995 (Golder 1996b). There are no data regarding PAHs in sediments in the Muskeg River basin. The following are the major findings of the above studies:

- Sediment data collected by NRBS suggest that although there is an increase in PAHs in bottom sediments of the Athabasca River within the oil sands area, there are no additional increases below existing oil sands operations. An increase in sediment PAHs was reported near the upstream limit of the oil sands area (upstream Fort McMurray), followed by a slight decline below existing oil sands operations (at Fort McKay; Crosley 1996). Brownlee et al. (1997) also found no spatial trend in PAHs in bottom sediments in the lower Athabasca River, with the exception of a slight increase in chrysene level.

- Typical levels of total PAHs in bottom sediments are higher in the Peace and Wapiti rivers than in the lower Athabasca River (Crosley 1996). Natural sources were suggested as the sources of PAHs.

- Brownlee (1990) found slight increases in levels of individual PAHs in suspended sediments in the Athabasca River below the oil sands area. These increases were not attributed to specific sources.

- One sample collected from the mouth of the Steepbank River in 1995 had considerably higher levels of PAHs than all other samples collected in the oil sands area however, (this sample likely consisted mostly of oil sands, Golder 1996b).

- Few or no exceedances of the threshold effect level (TEL) occurred in the Athabasca rivers during the NRBS studies from 1988 to 1995 (detailed data are not given, there were a number of exceedances in the Peace River). In samples collected from the Athabasca River in 1995 by Golder (1996b), PAH levels were also below the guidelines. In one Steepbank River sample, levels of most PAHs with available guidelines were higher than the TEL, but only benzo(a)anthracene/chrysene exceeded the probable effect level (PEL) (Golder 1996b).

Although the available information is scarce, some general conclusions can be made regarding the release of PAHs by oil sands operations and resulting deleterious effects on aquatic organisms. These are described below:

- Since the PAHs of greatest concern readily partition to the sediments in surface waters, there are no obvious pathways for them to leave the Project development area. The water management plan for the Project was designed to incorporate considerable attenuation of discharge waters before release to the environment. This will be achieved by the fact that release waters will be held naturally in wetlands or lakes for at least one year. This holding period is expected to result in biological degradation of a large fraction of organic constituents and the removal of suspended sediments, which are the most likely reservoir of PAHs.

- Before closure, the only untreated process-affected waters that can reach the Muskeg or Athabasca rivers are seepages from CT and sand deposits and tailings settling pond perimeter ditches, that are expected to be released to surface waters at very low rates. Since these waters will move underground for long periods, any larger PAH molecules present will likely adsorb to soil particles and will not reach surface waters.

- The heavier PAHs associated with tailings water remaining at closure and pumped to the EPL will be bound to particulates, some of which will likely settle out in the EPL. Biodegradation in the EPL would also reduce the amount of PAHs that may reach other surface waters.

- Biological effects of any PAHs mobilized by oil sands operations have not been demonstrated in the Athabasca River. However, because this river experiences a considerable natural loading of hydrocarbons, it has not been possible to separate indicators of oil sands industry-related exposure, if any, from those of natural exposure (e.g., MFO induction in fish). As well, ecological characteristics of the Athabasca River do not reflect any deleterious effects that could be attributed to oil sands operations.

- Baseline studies conducted for Suncor's Steepbank Mine reported PAHs in fish and invertebrate tissues at levels near the analytical detection limits (0.02 to 0.04 μg/g) in the Athabasca River, and no PAH metabolites were detected in fish bile (Golder 1996b). Spatial trends in tissue concentrations of PAHs in benthic invertebrates were not consistent with PAH inputs from oil sands operations. PAHs were largely non-detectable in the Athabasca River (which receives wastewater from Suncor and seepage from Tar Island Dyke), but individual PAHs were slightly elevated in samples from the Steepbank and Muskeg rivers. Therefore, some bioaccumulation of naturally occurring PAHs is occurring in the oil sands area, but any contributions of PAHs by oil sands operations have not been demonstrated to cause bioaccumulation in aquatic organisms.

- The available data provide little evidence that levels of PAHs have changed in sediments of the Athabasca River as the result of oil sands operations. In fact, other northern rivers, (Peace and Wapiti rivers) which are not influenced by such developments, contain sediments with higher PAH levels than the oil sands reach of the Athabasca River (Crosley 1996).

Based on the weight of evidence described above, it is unlikely that PAHs released from the Project will result in substantial accumulation in sediments.

E5.9.3 Residual Impact Classification and Degree of Concern

The predicted impacts of PAH releases resulting from the Project on sediment levels are classified in Table E5-16.

Table E5-16 Residual Impact Classification and Degree of Concern for PAH Accumulation in Sediments

Impact	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
PAH accumulation in sediments	Negative	Negligible to Low	Local	Medium-term	Reversible	Moderate	Negligible to Low

E5.9.4 Monitoring

The Project is participating in regional aquatic monitoring efforts (RAMP) aimed at determining the chemical and biological effects of oil sands operations and is committed to develop specific monitoring programs to address issues of concern to regulators and stakeholders.

E5.10 Key Question WQ-6: Will End Pit Lake Water Be Toxic Before Discharge to the Muskeg River?

E5.10.1 Analysis of Potential Linkages

Linkage Between End Pit Lake Water Quality and Toxicity to Aquatic Life

The EPL will be become a receiving waterbody for drainage from mine-disturbed areas. The intended end use for the lake is a self-sustaining, biologically productive waterbody. Because EPL water may be toxic initially, this linkage is valid.

E5.10.2 Analysis of Key Question

Water quality of the EPL will be a function of several variables, including:

- rates and relative amounts of reclamation and natural waters flowing into the lake;
- depth and physical layout of the lake, as this affects mixing conditions;
- watershed design criteria, such as number and placement of wetlands, as this will affect water quality of the influent streams; and
- rate of filling and relative contribution of types of water used to fill the lake.

These design criteria can be optimized to ensure that water quality conditions in the lake will be suitable for end-use purposes. The concept of a water-capped, fine tails bottom lake has been evaluated and approved as a reclamation feature for Syncrude's Mildred Lake facility (Base Mine Lake). The EPL for the Project is similar to that lake with the following major differences:

- The Project extraction process is caustic-free and is expected to result in lower naphthenic acid levels and hence lower toxicity levels than those observed to date (Mikula and Kasperski 1997). Therefore, initial water quality of the EPL is expected to be better than those in other planned EPLs.

- The water is much deeper (20 m) than proposed for Base Mine Lake (5 m). This eliminates the possibility of mixing of MFT into surface waters, but creates the potential for a concentration of chemicals below a thermocline.

- It will consist of aged MFT, 30% water by volume, so consolidation rates will be very low, thus input from MFT consolidation to chemical loads will be very low.

These are positive design differences that should result in an EPL that is sustainable and safe for users. Even so, there are a number of potential issues that need resolution and further evaluation:

- stratification potential;
- nutrient status;
- H_2S generation;
- possibility of incomplete mixing of releases; and
- time frame over which lake water quality will improve so that it would be acceptable for discharge.

The substance concentrations relative to guidelines shown in Table E5-17 are the same as those modelled in Syncrude's Aurora EPL (BOVAR 1996a). Discharges from the EPL will not begin until the Year 2028.

Table E5-17 Predicted Substance Concentrations in the End Pit Lake Compared With Water Quality Guidelines

Substance	Guideline	Highest Concentration Before Discharge	2030	Far Future
benzo(a)pyrene group (µg/L)	0.0028[a]	0.32	0.03	<0.0001
benzo(a)anthracene group (µg/L)	0.0028[a]	1.1	0.13	<0.0001
naphthenic acids (mg/L)	NG[b]	73	2.1	0.3
chronic toxicity (TUc)	1.0	5.4	0.15	0.02
total dissolved solids (mg/L)	NG	1400	1207	221

NOTES: (a) human health water quality guideline
(b) NG=no guideline

The results of the modelling indicate that organic substances that may cause toxicity to aquatic organisms (naphthenic acids) will decay quickly, after an initial increase in concentration during the first few years after filling.

The values for the benzo(a)pyrene and benzo(a)anthracene groups are compared with U.S. EPA water quality guideline values for human health, which are based on a 70-year exposure period and a one-in-one million risk factor. Given the shorter time required to reach the guideline value for the benzo(a)anthracene group (2044), and the fact that most of the concentration represented would actually be tied up in particulate matter that would likely settle out of the water column in the EPL, it is unlikely that any risk would be posed to humans either from the EPL or from discharges from the EPL. This group of compounds is discussed further in Section E-12.

There is no naphthenic acids regulatory guideline for aquatic biota. However, data collected by AEP and Golder (1996b) indicate that naturally occurring levels of naphthenic acids reach 1 mg/L in streams within the RSA, e.g., Steepbank and Clearwater rivers (M. MacKinnon, Syncrude Research pers. comm.). Within seven years after filling, naphthenic acids levels are expected to drop below 2.0 mg/L, then to 0.1 mg/L within a few years after that.

Total dissolved solids in the EPL are expected to vary from 150 mg/L to over 1000 mg/L. Total dissolved salt concentration at the high end of this range is elevated relative to natural lakes in the region of the Project, but is well below the level that tends to suppress algal growth (Bierhuizen and Prepas 1985) and thus should not affect lake productivity. This range is also well below the concentration (2,000 mg/L) that would reduce the diversity of aquatic macrophytes (Pip 1979, Hammer et al. 1975). Therefore salt concentration is not expected to limit the productivity of the EPL at any time after filling and during discharge to the Muskeg River.

E5.10.3 Residual Impact Classification and Degree of Concern

The predicted impacts of EPL water quality were classified as shown in Table E5-18.

Table E5-18 Residual Impact Classification and Degree of Concern for End Pit Lake Water Quality

Impact	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
Toxic EPL water	Negative	Negligible	not applicable	not applicable	not applicable	not applicable	Negligible

E5.10.4 Monitoring

As previously mentioned, there are a number of potential issues that need resolution and further evaluation:

- stratification potential;
- nutrient status;
- H_2S generation;
- MFT timing and transfer rate to EPL;
- possibility of incomplete mixing of releases; and
- time frame over which lake water quality will improve so that it would be acceptable for discharge.

The Project is committed to participate in research efforts to ensure that the EPL meets regulatory and stakeholder end land use goals. Since this is an issue facing all oil sands operators, it is best addressed through a coordinated effort.

E5.10.5 Mitigation

There are a number of options available for achieving compliance with regulatory water quality guidelines in the EPL and the fundamental goal of a non-toxic discharge into the Muskeg River. Some of these are:

- limit the timing and/or rate of MFT and MFT porewater inflow to the EPL, especially during the winter when Muskeg River flows are at a minimum;
- direct the MFT porewater flow through the reclaimed mine wetlands before its discharge into the EPL to gain additional remediation and solids settling;
- decrease the depth of the capping layer of water to promote the continuous mixing of chemicals of concern and avoid any sudden release of chemicals if the thermocline breaks down;
- introduce Athabasca River water into the EPL at a rate necessary to supplement substance reductions achieved by natural decay processes operating within the lake;
- biologically or physio-chemically treat the MFT porewater before discharge into the EPL, if necessary; and
- add nutrients to the EPL to elevate its level of production and hence its biological treatment capability.

E5.11 Key Question WQ-7: Will Accidental Water Releases Occur That Could Affect Water Quality in the Athabasca and Muskeg Rivers?

E5.11.1 Analysis of Potential Linkages

Linkage Between Accidental Water Releases and Water Quality

Three types of accidental releases are considered with respect to potential changes in surface water quality:

- failure of retention structures;
- spills associated with bitumen product pipeline transport, or accidents with vehicles on crossings or roads adjacent to waterbodies; and
- flooding of storage ponds.

Although the probability of accidental releases is low and can be effectively managed, accidental releases can occur, and therefore, the link is valid.

E5.11.2 Analysis of Key Question

Failures of Engineered Structures

The Project includes an out-of-pit tailings settling pond for storage and consolidation of fine tails until the MFT are transferred for production of CT. This structure will be designed and operated to accepted Canadian standards for fluid retention structures. The design and safe operating conditions will be supported by an extensive monitoring program and reviewed by independent review boards and regulatory agencies. An emergency response plan will be developed in case of the exceedingly unlikely event of a major instability problem, to provide warning to those who may be affected, as well as to provide timely, efficient response by trained personnel to help minimize any environmental impact of a failure.

Spills

Trucks will be used to transport construction material, sewage during the initial stages of construction, chemicals and other materials to and from the site. Plant facilities will have storage areas for fuel, gas and oil. Chemicals such as aluminum sulphate, chlorine and polymers will be used on-site.

The potential for spills into surface water from traffic accidents on crossings near water courses is low. The potential for accidents will be minimized through coordinating the nature and timing of heavy traffic volumes. In addition, most materials transported by truck are not hazardous.

A number of pipelines within the LSA transport bitumen, diluent and natural gas across the Muskeg River. In the event of spills from pipeline breaks, traffic accidents on crossings, or on roads near surface waterbodies, the Project will follow spill containment procedures developed to deal with such events as part of the emergency spill response manual to be developed under EPEA requirements. These procedures will be based on current Shell/BHP spill response plans and will meet or exceed the standard procedures used by the Alberta petroleum industry.

Flooding

All Project facilities are located above or contained within bermed areas relative to the one-in-one-hundred-year flood level, and therefore the potential for flooding of the plant site facilities and contamination of surface water is minimal.

In summary, the potential for releases of spilled materials to the Athabasca River or the Muskeg River is extremely low given the features discussed above.

E5.11.3 Residual Impact Classification and Degree of Concern

The predicted impact of accidental releases is classified in Table E5-19. Because the effect of accidental releases on water quality cannot be evaluated in certain terms, the impact is classified in terms of the probability of those releases occurring. The risk of accidents will be minimized by corporate policies, spill prevention plans, best management practices and spill response training. Any effects of accidents and malfunctions will be assessed as part of established procedures.

Table E5-19 Residual Impact Classification And Degree Of Concern for Accidental Releases

Impact	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
Accidental releases to Athabasca and Muskeg rivers	Negative	Negligible	not applicable	not applicable	not applicable	not applicable	Negligible

E5.12 Key Question WQ-8: Will Changes in Water Quality Result From Acidifying Emissions?

E5.12.1 Analysis of Potential Linkages

Linkage Between Acidifying Emissions and Changes in Water Quality

Deposition of acid-forming substances can affect surface water quality and functioning of sensitive aquatic ecosystems. The sensitivity of Alberta surface waterbodies to acidic deposition has been described in numerous AEP reports. The most recent report has been updated to include data collected in 1995 (Saffran and Trew 1996). Lakes sensitive to acidic deposition are those with low buffering capacity, i.e., total alkalinity <10 mg/L.

Sources of acidifying emissions associated with the Project include NO_x from extraction, boilers and from vehicles. Very limited SO_2 emissions are associated with the Project. Modelled values for annual potential acid input (PAI) exceed the interim Critical Load of 0.25 keq/ha/a in an area 7 to 8 km diameter, just north of the confluence of the Muskeg River and Jackpine Creek (Section E2). A moderate increase in NO_x deposition accounts for the exceedance of the interim Critical Load. Based on this predicted exceedance, this linkage is valid.

E5.12.2 Analysis of Key Question

The Fort McMurray oil sands area is subject to a higher than background rate of sulphate deposition, which has not been attributed to specific sources (Schindler 1996). However, despite the higher sulphate deposition rate, there is no evidence of anthropogenic acidification of lakes in this area, or in the province of Alberta (Schindler 1996).

Based on total alkalinity measurements, there are a number of lakes just east of the Muskeg River basin that are sensitive to acidic deposition (Schindler 1996). However, there are no acid-sensitive lakes within and downstream of the area where modelling predicted an exceedance of the interim Critical Load. The few ponds and streams present in this area do not represent fish habitat and will be eliminated during oil sands mining. Therefore, the modelled exceedance is not expected to influence lakes or small streams in the LSA.

The Athabasca and Muskeg rivers will ultimately receive runoff containing acidifying substances released by the Project. Based on its water chemistry and its large dilution capacity, the Athabasca River is not sensitive to acidification.

The sensitivity of the Muskeg River to acidification cannot be assessed with certainty based on the available data. Schindler (1996) designated the Firebag, Steepbank and Muskeg rivers as acid-sensitive and reported moderate pH depressions in the Firebag and Steepbank rivers during the spring snowmelt period in 1989 and 1990. The magnitude of the pH depressions documented in these rivers (from between 7 and 8.5 to <6) were sufficient to be of concern to aquatic life. The depressions lasted for a "few days" and were followed by a recovery period of up to a month, depending on the river. During the same period, the pH of the Muskeg River did not change, despite a greater increase in flow than in the other two rivers.

Since water quality in general and the ranges of total alkalinity measurements are similar in the Muskeg and Steepbank rivers (Golder 1996b), there is no explanation at this time for the observed differences in spring pH levels between these rivers. However, there is no reason to expect major differences between the sensitivities of these rivers to acidification in the spring, which implies that the Muskeg River is potentially sensitive, as suggested by Schindler (1996).

In absolute terms, the Project's input of acidifying emissions to the study area will be relatively small, which, coupled with the lack of past records of spring pH depression in the Muskeg River, suggests that an occurrence of spring pH depression is unlikely. However, the available information is insufficient to conclusively evaluate the potential for spring pH depression in the Muskeg River as the result of acidifying emissions from the Project.

During other seasons, it is very unlikely that acidification would occur in the Athabasca or Muskeg rivers. Total alkalinity typically ranges from 60 to several hundred mg $CaCO_3$/L in these rivers, which indicates that they are not sensitive to acidification. As well, pulses of acid-forming substances are not expected to occur in any season other than the spring. Therefore, year-round acidification is not predicted to occur in the Athabasca or Muskeg rivers during the life of the Project.

E5.12.3 Residual Impact Classification and Degree of Concern

The predicted impacts of acidifying emissions on surface waters are classified as shown in Table E5-20.

Table E5-20 Residual Impact Classification and Degree of Concern for Changes in Surface Water Quality Caused by Acidifying Emissions

Impact	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
Acidification of lakes and small streams	Negative	Negligible	not applicable	not applicable	not applicable	not applicable	Negligible
Year-round acidification of the Athabasca and Muskeg rivers	Negative	Negligible	not applicable	not applicable	not applicable	not applicable	Negligible
Spring pH depression in the Muskeg River	Negative	Undetermined	Local	Medium-Term	Reversible	Medium	Undetermined

E5.12.4 Monitoring

To evaluate the Muskeg River's sensitivity to spring acid pulses, monitoring studies during the critical snowmelt period will be undertaken as part of the RAMP or RAQCC program. These studies will also evaluate the existing level of metals and organic compounds released to the river during snowmelt, for which baseline data are not available at present. Details of the monitoring program will be finalized on AEP's review.

E5.13 Summary of Impact Predictions

Table E5-21 provides a summary of surface water quality impact predictions.

Although background levels of several metals exceed water quality guidelines in the Muskeg and Athabasca rivers, it is concluded that the Project, in combination with existing developments in the local or regional study areas, will not cause exceedances of water quality or toxicity guidelines for aquatic life.

Exceedances of human health water quality guidelines for two PAH compounds were predicted to occur during initial high end pit lake discharges. These exceedances will be mitigated through various means as previously discussed. Followup risk analysis in Section E11 and Section E12 rejected these compounds as being of concern to wildlife and human health.

Temperature fluctuations in the Muskeg River, as a result of changing flow regimes, would remain within acceptable ranges.

Dissolved oxygen impacts from muskeg drainage waters are not anticipated to occur.

Table E5-21 Summary of Predicted Surface Water Quality Impacts

Impact	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
WQ-1 Will Operational and Reclamation Water Releases From the Project Result in Water Quality Guideline Exceedances in the Athabasca and Muskeg Rivers and Isadore's Lake?							
Mean open-water flow in the Athabasca River	Negative	Negligible	not applicable	not applicable	not applicable	not applicable	Negligible
Annual 7Q10 flow in the Athabasca River	Negative	Negligible	not applicable	not applicable	not applicable	not applicable	Negligible
Mean open-water flow in the Muskeg River	Negative	Low	Local	Medium-term	Reversible	Medium	Low
Annual 7Q10 flow in the Muskeg River	Negative	Negligible	not applicable	not applicable	not applicable	not applicable	Negligible
WQ-2 Will Operational and Reclamation Water Releases From the Project Result in Toxicity Guideline Exceedances in the Athabasca and Muskeg Rivers?							
Mean open-water flow in the Athabasca River	Negative	Negligible	not applicable	not applicable	not applicable	not applicable	Negligible
Annual 7Q10 flow in the Athabasca River	Negative	Negligible	not applicable	not applicable	not applicable	not applicable	Negligible
Mean open-water flow in the Muskeg River	Negative	Negligible	not applicable	not applicable	not applicable	not applicable	Negligible
Annual 7Q10 flow in the Muskeg River	Negative	Negligible	not applicable	not applicable	not applicable	not applicable	Negligible
WQ-3 Will Operational and Reclamation Water Releases From the Project Alter the Temperature Regime of the Muskeg River?							
Cooling in open-water season	Neutral	Negligible	not applicable	not applicable	not applicable	not applicable	Negligible
Slower seasonal warming and cooling	Neutral	Negligible	not applicable	not applicable	not applicable	not applicable	Negligible
Reduced diurnal fluctuation	Neutral	Undetermined	Local	Medium-term	Reversible	Low	Undetermined
WQ-4 Will Muskeg Dewatering Activities Associated with the Project Reduce Dissolved Oxygen Concentrations to Unacceptable Levels in the Muskeg River?							
Lowered dissolved oxygen levels	Negative	Negligible	not applicable	not applicable	not applicable	not applicable	Negligible
WQ-5 Will PAHs in Operational and Reclamation Waters Released From the Project Accumulate in Sediments and be Transported Downstream?							
PAH accumulation in sediments	Negative	Negligible to Low	not applicable	not applicable	not applicable	not applicable	Negligible to Low
WQ-6 Will End Pit Lake Water be Toxic Before Discharge to the Muskeg River?							
Toxic EPL water	Negative	Negligible	not applicable	not applicable	not applicable	not applicable	Negligible

E6 AQUATIC RESOURCES IMPACT ANALYSIS

E6.1 Introduction

This section of the Muskeg River Mine Project (the Project) EIA provides information as required by the Project Terms of Reference (TofR) issued on November 7, 1997 (AEP 1997a). Specifically, the following are addressed in this section:

- identification of key indicator species (KIRs) and the rationale and criteria for their selection;
- discussion of the design, construction and operational factors to be incorporated into the Project that will protect fish resources;
- discussion of how the proposed development and mitigation plans will achieve "No Net Loss" of fish habitat;
- description of how stream alterations and changes to substrate conditions, water quality and water quantity may affect fish and fish habitat in the study area;
- discussion of the potential effects of the Project on fish tainting, survival of eggs and fry, chronic or acute health effects and increased stress on fish populations from possible releases of chemicals, increased sedimentation and general habitat changes;
- identification of impacts on fish and fish habitat that are likely to result from Project construction, operation or reclamation;
- identification of proposed mitigation for each impact identified;
- identification of proposed plans to offset any loss in productivity of fish habitats;
- identification of residual impacts on fish and fish habitat and discussion of their significance in the context of local and regional fisheries;
- discussion of the nature, extent, duration, magnitude and significance of anticipated impacts; and
- identification of any monitoring programs that will be initiated by the Project or in cooperation with other oil sands operators to monitor the status of the fish resources and to measure the effectiveness of proposed mitigation strategies (TofR, Section 4.9).

Discussions of the potential cumulative effects on aquatic resources associated with the Project are addressed in Section F6. Section D6 provides details on the aquatic resources baseline for the Project.

The approach to impact analysis and classification is presented in Section E1. The aquatic resources impact analysis is based on issues identified by the study team and Project stakeholders. These issues can be combined in the following broad categories:

- effects on aquatic habitat;
- effects on aquatic biota; and
- effects on fish tissue quality.

This section includes:

- presentation of potential linkages between activities from the Project and aquatic resources;
- a list of key questions regarding effects on aquatic resources;
- rationale for KIR selection;
- aquatic impact analysis methods;
- impact analysis including:
  - analysis of potential linkages,
  - analysis of key question,
  - residual impact classification and degree of concern,
  - certainty of the assessment; and
- a monitoring program for aquatic resources.

E6.2 Potential Linkages and Key Questions

Potential linkages between Project activities and aquatic resources are illustrated in Figures E6-1 and E6-2. Key questions and the main issues associated with them are described below.

AR-1 Will Muskeg River Mine Project Activities Change Fish Habitat?

Concerns raised about aspects of fish habitat were addressed as part of this key question and include:

- changes in flows in watercourses;
- changes in the thermal regime;
- direct loss of habitats;
- possibility of effects on spawning habitat;
- possibility of increased bank erosion and instability (channel regime);
- changes in dissolved oxygen levels; and
- increases in suspended solids.

Figure E6-1 Aquatic Resources Linkage Diagram for Construction and Operation Phase of the Muskeg River Mine Project

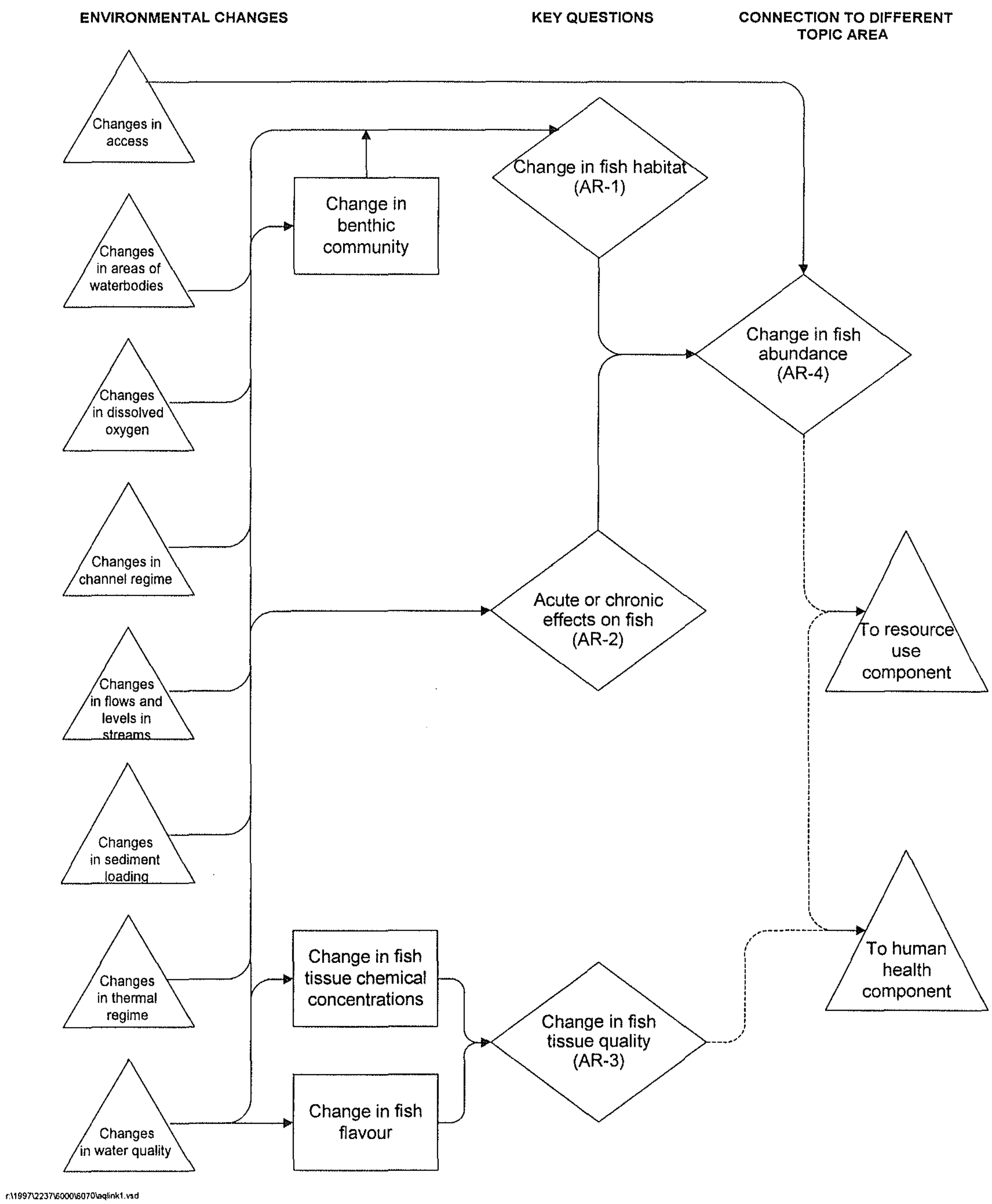
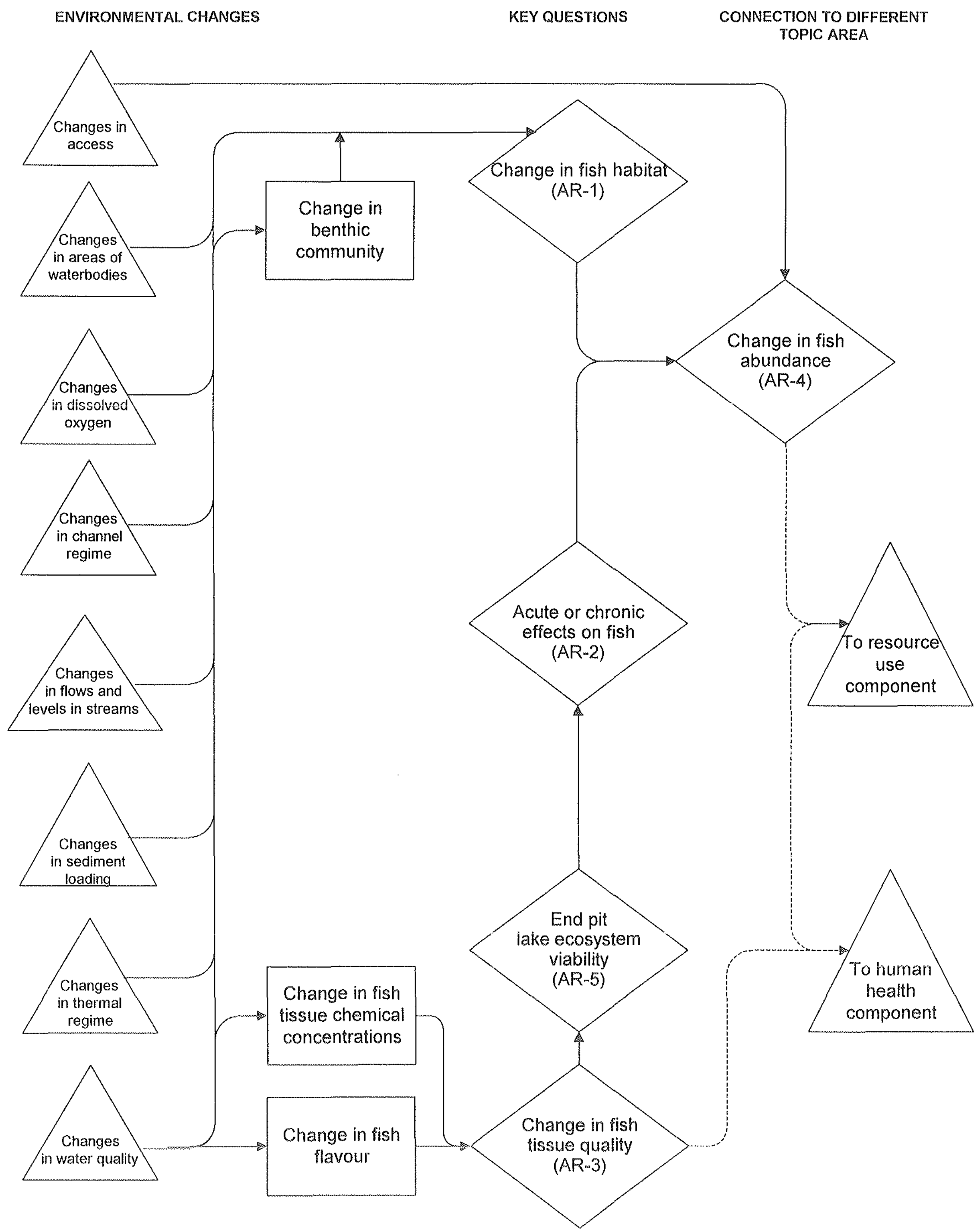


Figure E6-2 Aquatic Resources Linkage Diagram for Closure Phase of the Muskeg River Mine Project



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AR-2 Will Muskeg River Mine Project Activities Result in Acute or Chronic Effects on Fish?

The potential for water releases from the Project (particularly consolidated tailings (CT) and sand seepage water) to cause acute or chronic effects on fish was assessed.

AR-3 Will Muskeg River Mine Project Activities Change Fish Tissue Quality?

The potential for tainting (flavour impairment) of fish flesh and bioaccumulation of chemicals in fish tissue because of exposure to CT and sand seepage water was examined.

AR-4 Will Muskeg River Mine Project Activities Change Fish Abundance?

Fish abundance can be affected by changes in habitat, acute or chronic effects on fish and changes in fishing pressure. Each of these linkages are assessed within this key question.

AR-5 Will the Muskeg River Mine Project End Pit Lake Support a Viable Ecosystem?

The potential for the end pit lake to support a viable ecosystem has been raised as a concern by fisheries regulators. Concerns related to the end pit lake include viability of an aquatic ecosystem, potential for establishment of a fishery and fish tissue quality.

E6.3 Key Indicator Resources

Two sets of KIRs were selected for the aquatic resources impact assessment based on differences in fish species compositions. The Athabasca River KIRs are:

- lake whitefish
- walleye
- goldeye
- longnose sucker

The KIRs for the Muskeg River and Isadore's Lake watersheds are:

- longnose sucker
- forage fish guild

- Arctic grayling
- northern pike

These KIRs were selected according to the matrix which was developed and used for the Steepbank and Aurora EIAs (Golder 1996b, BOVAR 1996a). The system involves ranking each potential species according to the criteria shown in Table E6-1. The criteria were adapted from those designed for environmental effects monitoring investigations (Environment Canada and Department of Fisheries and Oceans 1993) and from a receptor screening process suggested for ecological risk assessments (Suter 1993). A weighting factor of two is applied to criteria considered to be of primary importance (e.g., residence/abundance, recreational importance).

Each candidate indicator species was rated according to the criteria in Table E6-1. The results of candidate species rating in both the Muskeg River and the Athabasca River are shown in Tables E6-2 and E6-3. The species with the highest scores (and thus the highest suitability as KIRs) in the Muskeg River were longnose sucker, forage fish guild, Arctic grayling and northern pike. The forage fish guild consists of common forage fish species in the LSA and includes fathead minnow, brook stickleback, pearl dace, lake chub and slimy sculpin.

The species with the highest scores in the Athabasca River were walleye, goldeye and longnose sucker. White sucker had a similar score to longnose sucker in the Muskeg River; however, longnose sucker was chosen so there was a common KIR species in the two rivers. Habitat requirements for each of the KIRs are described in Appendix V1.

The species chosen for the Athabasca River were consistent with the KIRs used for the Aurora and Steepbank Mine EIAs with the exception of lake whitefish. This species was included for the Project because it scored high on the KIR matrix and because of input from regional communities and regulators. The Fort Chipewyan community has expressed concern about the potential for effects on lake whitefish. As well, regulators at a Water Workshop held on October 7, 1997 indicated that lake whitefish should be considered as a KIR due to their high socio-economic importance and abundance in the LSA during their spawning season in the fall.

The species chosen for the Muskeg River were similar to the Aurora EIA with the exception of northern pike. Northern pike were added as a KIR because this species rated high on the KIR matrix. It was also added because of concerns expressed by federal and provincial fisheries officials as well as advice from fish habitat specialists on the EIA team. The reason for the inclusion of northern pike is the abundant northern pike habitat in the Muskeg River and concerns about effects on this species via effects on habitat. The inclusion of northern pike as a KIR also adds a top predator species for the Muskeg River watershed.

Table E6-1 Scoring Criteria for Fish KIRs

1. residence and relative abundance: 1 = uncommon 2 = moderately abundant 3 = common
2. provincial importance: (or status, measure of the relative abundance and degree of management concern or aesthetic value) 0 = species abundant, no concern (green-listed) 1 = species rare, but not threatened or special status (yellow-listed) 2 = threatened or vulnerable species (blue-listed) 3 = endangered species (or red-listed)
3. commercial economic importance (importance to guides, outfitters, fisheries) 0 = no importance 1 = low importance 2 = moderate importance 3 = high importance
4. subsistence economic importance: (fish species important for subsistence) 0 = not fished for food 1 = low 2 = moderate 3 = high
5. recreational importance: (fish species important for recreational fishing) 0 = non-game species 1 = low 2 = moderate 3 = high
6. habitat niche/sediment exposure yes/no
7. spawning in study area yes/no
8. benthic food preference: yes/no
9. important as prey: yes/no
10. high fecundity: 1 = low fecundity 2 = moderate fecundity 3 = high fecundity
11. high growth rate: 1 = low growth rate 2 = high growth rate
12. age to maturity: 1 = long age to maturity 2 = moderate age to maturity 3 = short age to maturity
13. feasibility of studying 0 = none 1 = limited 2 = moderate 3 = abundant
14. availability of information: (the amount of information available for each species or species group) 0 = none 1 = limited 2 = moderate 3 = abundant

Table E6-2 Weighted Potential Muskeg River Fish KIRs for the Muskeg River Mine Project

Species	Residence / Abundance	Political Importance	Commercial Importance	Subsistence Importance	Recreational Importance	Sediment Exposure	Spawning in Study Area	Benthic Food Preference	Important as Prey	High Fecundity	High Growth Rate	Age to Maturity	Feasibility to Study	Information Availability	Total
Weighting Factor	2	2	2	2	2	1	1	1	1	1	1	1	2	2	
Longnose Sucker	4	0	0	0	0	Yes	Yes	Yes	Yes	2	2	2	6	4	20
Northern Pike	4	0	0	0	4	No	Yes	No	No	3	2	3	2	4	22
Walleye	2	0	2	0	0	No	No	No	No	3	2	2	4	4	19
Lake Whitefish	2	0	2	0	0	No	No	Yes	Yes	2	2	2	4	4	18
White Sucker	4	0	0	0	0	Yes	Yes	Yes	Yes	2	2	3	4	4	19
Mountain Whitefish	2	0	0	0	0	No	No	Yes	Yes	2	2	2	0	4	12
Burbot	2	0	0	0	0	Yes	No	No	No	2	2	2	0	2	10
Arctic Grayling	4	2	0	0	6	No	Yes	Yes	No	2	2	2	0	4	22
Forage Guild[a]	4	0	0	0	0	Yes	Yes	Yes	Yes	1	1	3	4	4	23

No = 0

Yes = 1

? = 0

[a] The forage guild consists of fathead minnow, brook stickleback, pearl dace, lake chub and slimy sculpin

Table E6-3 Weighted Potential Athabasca River Fish KIRs for the Muskeg River Mine Project

Species	Residence/ Abundance	Political Importance	Commercial Importance	Subsistence Importance	Recreational Importance	Sediment Exposure	Spawning in Study Area	Benthic Food Preference	Important as Prey	High Fecundity	High Growth Rate	Age to Maturity	Feasibility To Study	Information Availability	Total
Weighting Factor	2	2	2	2	2	1	1	1	1	1	1	1	2	2	
Goldeye	6	0	2	6	2	No	No	Yes	Yes	3	2	2	0	2	27
Longnose Sucker	4	0	0	1	0	Yes	Yes	Yes	Yes	2	2	2	6	4	25
Northern Pike	2	0	0	2	4	No	No	No	No	3	2	3	2	4	22
Walleye	6	0	4	4	6	No	Yes	No	No	3	2	2	4	4	36
Lake Whitefish	4	0	6	6	2	No	?	Yes	Yes	2	2	2	4	4	34
White Sucker	2	0	0	0	0	Yes	Yes	Yes	Yes	2	2	3	4	4	21
Flathead Chub	4	0	0	0	0	No	Yes	Yes	Yes	1	2	3	4	4	21
Emerald Shiner	4	0	0	0	0	No	Yes	Yes	Yes	1	?	3	4	4	19
Trout - Perch	6	0	0	0	0	Yes	Yes	Yes	Yes	1	1	3	6	2	23
Lake Chub	4	0	0	0	0	No	?	Yes	Yes	?	?	3	2	2	13
Mountain Whitefish	2	0	0	0	0	No	No	Yes	Yes	2	2	2	0	4	14
Burbot	2	0	0	0	0	Yes	Yes	No	No	2	2	2	0	2	12
Arctic Grayling	4	2	0	0	6	No	No	Yes	No	2	2	2	0	4	23
Bull Trout	2	4	0	0	0	Yes	?	No	No	2	3	2	0	2	16

No = 0
Yes = 1
? = 0

E6.4 Aquatic Impact Evaluation Methods

E6.4.1 Approach

The impact analysis was done by evaluating linkages between Project activities and key questions based on expected modes of action and information generated from modelling. Invalid linkages were eliminated by using screening arguments derived from modelling results, or based on Project design features that will remove the mode of action or pathway.

If a link between Project activities and KIRs was deemed valid (i.e., if there actually is a plausible mode of action or pathway), then impacts were quantified and compared with quantitative effects guidelines such as water quality or toxicity guidelines (if possible). The impacts were then classified according to the criteria outlined in Table E1-9. For changes in measurement endpoints such as habitat area, the criteria are: negligible (no measurable change), low (<10% change), moderate (10 to 20% change) and high (> 20% change). For parameters where guidelines exist, the criteria are the same as for water quality: negligible (releases do not cause exceedance of guideline), low (releases contribute to existing background exceedances), moderate (releases cause marginal exceedance of guideline) and high (releases cause substantial exceedance of guideline).

Following classification, certainty of the assessment, and monitoring were described. Certainty of the assessment is described at the end of each key question analysis. The aquatic resources monitoring program is presented in Section E6-10.

Monitoring programs are routine environmental programs that generate data for key indicators in the aquatic environment. These data are gathered at regular intervals. The data are compared with baseline data and are also examined for trends over time. Monitoring data provide feedback on the effectiveness of mitigation measures.

E6.4.2 Effects on Fish Habitat

There is potential for both direct and indirect effects on fish habitat (Figure E6-1). Direct effects are caused by physical factors such as changes in water levels and flows (discharge, velocity), channel regime, dissolved oxygen, thermal regime, sediment loading and loss of habitat area. Indirect effects occur via changes in the quality or quantity of their food (e.g., benthic invertebrates) which, in turn, might be affected by physical and chemical factors.

Changes in physical habitat variables have been analyzed in the Surface Water Hydrology (E4) and Surface Water Quality (E5) sections. The Surface Water Hydrology section contains quantification of changes in flow, channel regime, sediment levels and areas of waterbodies (i.e., direct loss). Water quality and thermal regime changes are described in the Surface Water Quality section.

Physical Changes and Direct Effects on Habitat

Fish habitats assessed within the LSA include the Athabasca River, Muskeg River, Jackpine Creek, Mills Creek, Isadore's Lake, Alsands Drain and unnamed ponds and lakes (Figure D6-1). Each of these waterbodies was examined separately, since they differ in habitat characteristics and types of potential Project effects.

Physical changes, including those to flows and temperature in the Muskeg River, flows in Mills Creek and levels of Isadore's Lake, were compared with habitat suitability indices (HSI) for longnose sucker, Arctic grayling and northern pike that were developed by the U.S. Fish and Wildlife Service (U.S. FWS 1981) (Edwards 1983, Inskip 1982, Hubert et al. 1985). The habitat suitabilities reported in the U.S. FWS blue books have been reviewed by the study team and are considered adequate for this level of assessment.

The HSI models consist of a graph for each variable which shows the relationship between the variable and habitat suitability. Habitat suitability is based on a scale of 0 to 1, where 0 is unsuitable and 1 is ideal habitat. Changes in physical habitat variables (e.g., velocity) were compared against individual graphs to quantify habitat change. Overall habitat suitabilities were not calculated.

No HSI information was available for the forage fish guild. For this KIR, information from the literature on habitat requirements was compared with predicted changes in habitat. Descriptions of habitat requirements for each of the KIRs are in Appendix VI.

Indirect Effects on Habitat

Benthic invertebrates may be affected by physical factors such as changes in sediment loading, stream flows and substratum characteristics. Changes in water quality may also affect benthic invertebrates in the form of toxicity.

To assess the potential effects of physical changes associated with the Project, the data summarized for the assessment of effects on fish habitat were examined. Predicted changes in physical habitat variables applicable to invertebrate habitat (i.e., suspended sediment concentration, current velocity) were compared with baseline ranges to assess impacts. Potential changes in substratum characteristics were evaluated qualitatively, based on changes in other related physical variables. Because predicted changes were typically small, no quantitative analysis was conducted.

The potential for acute and chronic effects on benthic invertebrates, caused by changes in water quality, were evaluated by comparing water quality modelling results against water quality guidelines for the protection of aquatic life. The combination of: (1) conservatism built into the predictive modelling; (2) use of toxicity data for the most sensitive test organism; and (3) conservatism inherent in water quality guidelines for the protection of aquatic life produces rigour in the impact analysis; that is, there is a very low likelihood of underestimating effects on benthic invertebrates.

E6.4.3 Acute and Chronic Effects on Fish

Changes in thermal regime, sediment loading and water quality can all potentially cause acute (i.e., short-term, usually lethal) or chronic (i.e., long-term, sublethal or lethal) effects on fish (Figure E6-1).

The magnitudes of predicted changes in monthly mean water temperatures relative to the baseline temperature regime of the Muskeg River (Section E5) were examined to determine whether they are sufficiently large to cause physiological stress in fish. Since Project-related changes in the temperature regime of the Athabasca River are extremely unlikely, this analysis was not conducted for the Athabasca River.

Suspended sediment concentrations predicted by modelling (Section E4) were examined to evaluate potential acute or chronic effects on fish.

The methods used to assess potential acute and chronic effects on fish caused by changes in water quality were the same as those used to evaluate effects of changes in water quality on benthic invertebrates (described in previous section):

1. Predicted concentrations of water quality parameters in the receiving waterbodies (Athabasca River and Muskeg rivers) were compared with water quality guidelines for protection of aquatic life.

2. Predicted toxic units (TUs) in the receiving waterbodies were compared with toxicity guidelines.

The methods used for the prediction of water quality parameters and TUs are explained in Section E5 and detailed background information is provided in Appendix VII regarding the use of toxicity data as the basis for impact predictions.

Although toxicity data were not available for the KIRs selected for the Impact Assessment, using laboratory toxicity data for the most sensitive test organisms was considered to result in a conservative analysis (Appendix V11). Furthermore, Environment Canada (1996) states that there has been sufficient research carried out to show that toxicity tests are usually predictive of effects on natural aquatic communities.

Effects on fish health, other than acute and chronic toxicity, were not included in this assessment because there are no new data on other fish health parameters for this Project and extrapolation from the available toxicity data to specific fish health parameters is inappropriate at this time. Further investigation would produce defensible links between acute and chronic toxicity data and fish health parameters.

E6.5 Key Question AR-1: Will Muskeg River Mine Project Activities Change Fish Habitat?

E6.5.1 Analysis of Potential Linkages

Linkage Between Changes in Areas of Lakes and Streams and Fish Habitat

Changes in areas of lakes and streams are described in Section E4.9 (Key Question SW-5). The Project does not impinge on the Muskeg River, Jackpine Creek, Mills Creek, Isadore's Lake or the Athabasca River.

A small pond and a shallow lake, located on the west side of the Muskeg River that cover 26 ha will be lost during construction and operation. As well, the Alsands Drain (a 3.4 ha man-made drainage system that supports forage fish) will be eliminated during the operation phase.

These waterbodies are documented to support forage fish, but not sport fish (Webb 1980, Golder 1997d). Neither the ponds or the lake are connected to the Muskeg River or any watercourses known to support sport fish.

The linkage between changes in areas of lakes and streams and fish habitat is invalid for streams but valid for ponds and lakes. Elimination of these waterbodies affects the forage fish guild but does not affect other KIRs.

Linkage Between Change in Sediment Loading and Fish Habitat

Project activities that could potentially cause changes in sediment loading are muskeg drainage and overburden dewatering, end pit lake discharge, pipeline installation and the Muskeg River crossing. The potential for these activities to cause changes in sediment loading was discussed in the Surface Water Hydrology section (Key Question SW-3; Section E4.6). Mitigation measures to prevent increase of sediment in the Muskeg River are also described in Section E4.6.

No effects on sediment levels are expected in the Muskeg River or Mills Creek during construction (Section E4.6.4). A minor change in sediment levels in Mills Creek is predicted near the end of operation when muskeg dewatering is routed through Mills Creek (from 70.1 to 70.4 mg/L). During the latter part of operation (2027 to 2030), a slight change in sediment levels (from 9.5 mg/L to 10.3 mg/L) is predicted in the Muskeg River due to end pit lake discharge. In the far future, sediment levels are expected to change minimally from 9.5 mg/L to 9.7 mg/L.

The results of the assessment indicate that the predicted changes in sediment levels in the Muskeg River and Mills Creek are negligible to low (less than 2 mg/L) during all phases of the Project (Section E4.6.4). Therefore, no effects on fish habitat are expected and this linkage is deemed invalid.

Linkage Between Change in Dissolved Oxygen Levels and Fish Habitat

The potential for muskeg and overburden dewatering to cause changes in dissolved oxygen levels was evaluated in Section D5. No changes in dissolved oxygen levels in the Muskeg River are expected. Hence, the linkage between dissolved oxygen levels and fish habitat is invalid.

Linkage Between Changes in Flows and Levels of Receiving Streams and Fish Habitat

Change in flows and levels of the Muskeg River, Mills Creek, Isadore's Lake and the Athabasca River were assessed in Section E4.4 (Surface Water Hydrology). Potential linkages between changes in flows and levels and fish habitat are assessed separately for each waterbody.

Jackpine Creek

The only potential linkage between Project activities and Jackpine Creek is the placement of two overburden stockpiles within its drainage basin. These dumps will be set back at least 100 m from the creek to avoid the potential for effects on Jackpine Creek. The portion of the drainage basin affected is small and would not result in measurable changes in flow.

Since no changes in flows of Jackpine Creek are expected, there is no linkage between changes in flows and fish habitat in Jackpine Creek.

Muskeg River

Changes in flows, depths and velocity in the Muskeg River were quantified in the Surface Water Hydrology section (Key Question SW-1; Section E4.4) and summarized are in Tables E6-4 to E6-7 for various flow conditions. Changes during 10 year flood peak flows are small (less than 2%) for all scenarios.

No changes are predicted in the pattern of flow fluctuation in the Muskeg River as shown in the hydrograph in Figure E6-3. This simulation is described in Section E4.4 and a longer time series is shown in Figure E4-14.

Since changes in flows occur, this linkage is valid for fish habitat and will be analyzed further.

Mills Creek

Changes in flows in Mills Creek are described in the Surface Water Hydrology section (Table E4-31). Decreases in mean annual flows are expected during construction (maximum 4%), operation (maximum 23%) and closure (maximum 23%). In 2020, near the end of the operation phase, muskeg drainage water will be routed through Mills Creek and flows in this watercourse will increase by about 25%.

This linkage is valid for the forage fish guild since Mills Creek is very small and would not support fish other than small forage species. No fish have been captured or observed in Mills Creek to date (Golder 1997d).

Isadore's Lake

Very minor changes in lake level are predicted for Isadore's Lake (Section E4.4.3). During construction a decrease of less than 1 cm relative to existing conditions is expected due to a slight reduction in the drainage area (Table E4-8). Early in the operation phases a decrease of 3 cm is expected, also due to drainage area reduction. Later in operation (2020), when muskeg drainage is routed through Mills Creek and into Isadore's Lake, a slight increase in lake level (about 5 cm) is expected (Table E4-7). At closure, a decrease in lake level of about 1.4 cm is predicted (Table E4-21). All of these changes represent less than 1% change in lake level in either direction relative to maximum depth. Also, no changes in the pattern of lake level fluctuation are predicted (Figure E6-4). A longer time series of lake level fluctuations in shown in Figure E4-17.

Figure E6-3 Comparison of Simulated Baseline and Future (Year 2030) Daily Flow Series on the Muskeg River (S16)

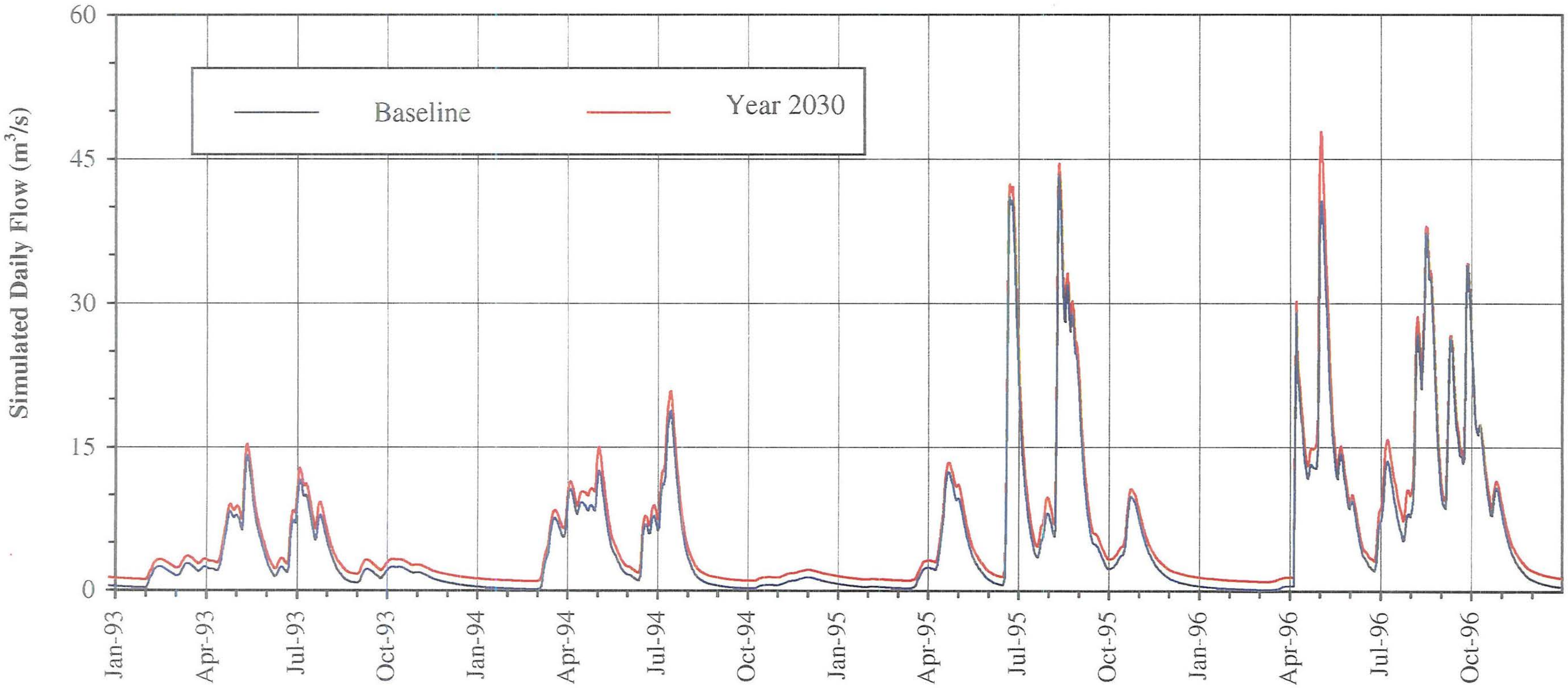


Figure E6-4 Comparison of Simulated Baseline and Future (Year 2020) Water Levels at Isadore's Lake

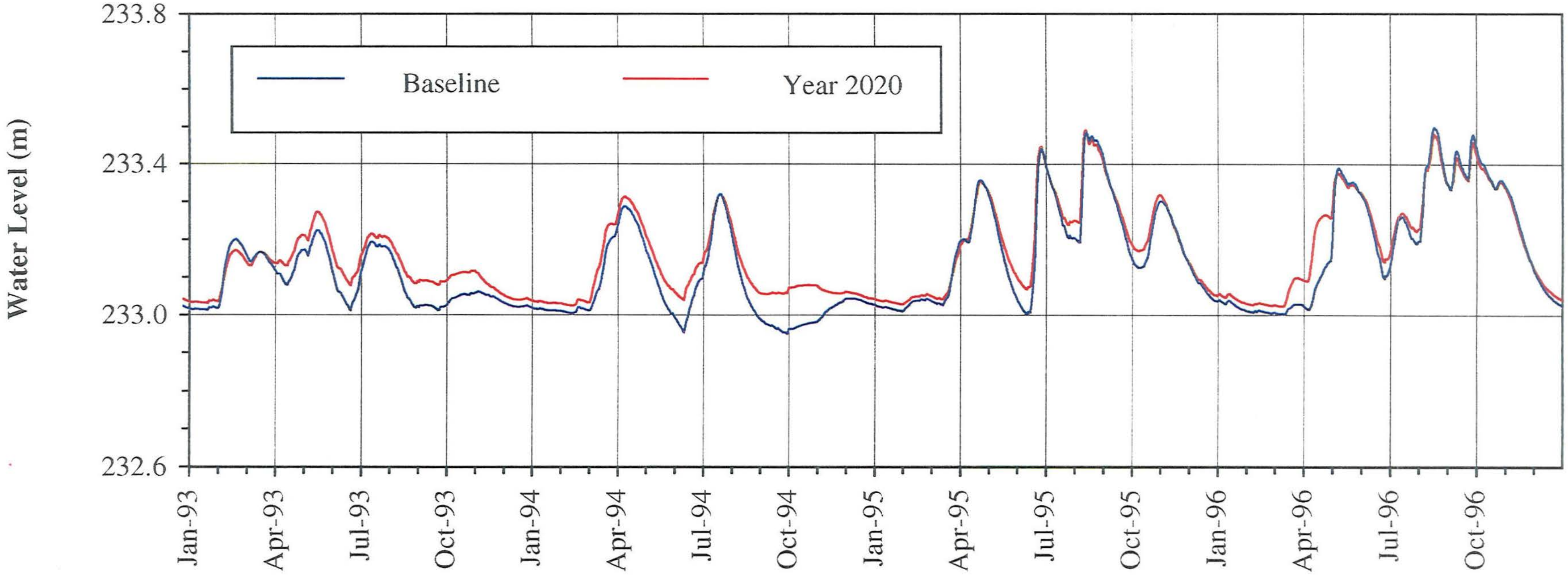


Table E6-4 Mean Open-Water Flow Parameters on Muskeg River below the Project Area (Node S16)

Year	Discharge (m^3/s)			Depth (m)			Velocity (m/s)		
	Existing	Future[a]	Difference (%)	Existing	Future[a]	Difference (%)	Existing	Future[a]	Difference (%)
2000	8.21	8.34	1.6	0.63	0.63	1.1	0.73	0.74	0.5
2002	8.21	8.29	1.0	0.63	0.63	0.7	0.73	0.73	0.3
2003	8.21	8.26	0.6	0.63	0.63	0.4	0.73	0.73	0.2
2005	8.21	8.26	0.6	0.63	0.63	0.4	0.73	0.73	0.2
2010	8.21	8.26	0.6	0.63	0.63	0.4	0.73	0.73	0.2
2020	8.21	8.1	-1.3	0.63	0.62	-0.9	0.73	0.73	-0.4
2022	8.21	8.1	-1.3	0.63	0.62	-0.9	0.73	0.73	-0.4
2025	8.21	8.09	-1.5	0.63	0.62	-1.0	0.73	0.73	-0.5
2030	8.21	9.77	19	0.63	0.70	12.5	0.73	0.77	5.7
Far Future	8.21	8.43	2.7	0.63	0.64	1.8	0.73	0.74	0.8

[a] Predicted as a result of the Muskeg River Mine Project

Table E6-5 Mean Ice-Cover Flow Parameters on Muskeg River below the Project Area (Node S16)

Year	Discharge (m^3/s)			Depth (m)			Velocity (m/s)		
	Existing	Future[a]	Difference (%)	Existing	Future[a]	Difference (%)	Existing	Future[a]	Difference (%)
2000	1.11	1.11	0.0	0.23	0.23	0.0	0.39	0.39	0.0
2002	1.11	1.11	0.0	0.23	0.23	0.0	0.39	0.39	0.0
2003	1.11	1.1	-0.9	0.23	0.23	-0.3	0.39	0.39	-0.3
2005	1.11	1.1	-0.9	0.23	0.23	-0.3	0.39	0.39	-0.3
2010	1.11	1.1	-0.9	0.23	0.23	-0.3	0.39	0.39	-0.3
2020	1.11	1.1	-0.9	0.23	0.23	-0.3	0.39	0.39	-0.3
2022	1.11	1.1	-0.9	0.23	0.23	-0.3	0.39	0.39	-0.3
2025	1.11	1.09	-1.8	0.23	0.23	-0.5	0.39	0.39	-0.6
2030	1.11	1.15	4	0.23	0.24	1	0.39	0.39	1
Far Future	1.11	1.15	3.6	0.23	0.24	1.0	0.39	0.39	1.1

[a] Predicted as a result of the Muskeg River Mine Project

Table E6-6 Open-Water 7Q10 Flow Parameters on Muskeg River below the Project Area (Node S16)

Year	Discharge (m^3/s)			Depth (m)			Velocity (m/s)		
	Existing	Future[a]	Difference (%)	Existing	Future[a]	Difference (%)	Existing	Future[a]	Difference (%)
2000	0.281	0.411	46	0.18	0.19	4.3	0.25	0.28	13
2002	0.281	0.339	21	0.18	0.19	1.9	0.25	0.27	6.2
2003	0.281	0.379	35	0.18	0.19	3.2	0.25	0.28	10
2005	0.281	0.383	36	0.18	0.19	3.4	0.25	0.28	10.4
2010	0.281	0.414	47	0.18	0.19	4.4	0.25	0.28	13
2020	0.281	0.285	1.4	0.18	0.18	0.1	0.25	0.25	0.5
2022	0.281	0.285	1.4	0.18	0.18	0.1	0.25	0.25	0.5
2025	0.281	0.275	-2.1	0.18	0.18	-0.2	0.25	0.25	-0.7
2030	0.281	1.603	470	0.18	0.26	43	0.25	0.44	74
Far Future	0.281	0.288	2.5	0.18	0.18	0.2	0.25	0.25	0.8

(a)Predicted as a result of the Muskeg River Mine Project

Table E6-7 Annual 7Q10 Flow Parameters on Muskeg River below the Project Area (Node S16)

Year	Discharge (m^3/s)			Depth (m)			Velocity (m/s)		
	Existing	Future[a]	Difference (%)	Existing	Future[a]	Difference (%)	Existing	Future[a]	Difference (%)
2000	0.052	0.052	0.0	0.17	0.17	0.0	0.15	0.15	0.0
2002	0.052	0.052	0.0	0.17	0.17	0.0	0.15	0.15	0.0
2003	0.052	0.054	3.8	0.17	0.17	0.1	0.15	0.15	1.2
2005	0.052	0.055	5.8	0.17	0.17	0.1	0.15	0.15	1.8
2010	0.052	0.056	7.7	0.17	0.17	0.1	0.15	0.15	2.4
2020	0.052	0.061	17	0.17	0.17	0.3	0.15	0.15	5.2
2022	0.052	0.061	17	0.17	0.17	0.3	0.15	0.15	5.2
2025	0.052	0.051	-1.9	0.17	0.17	0.0	0.15	0.15	-0.6
2030	0.052	0.099	90	0.17	0.17	2	0.15	0.18	23
Far Future	0.052	0.1	92	0.17	0.17	1.7	0.15	0.18	23

[a] Predicted as a result of the Muskeg River Mine Project

Northern pike spawn in Isadore's Lake when access allows. Both the embryo and fry life stages for northern pike are sensitive to water level fluctuations (Casselman and Lewis 1996). Two aspects of Isadore's Lake habitat could be affected by changes in lake level: access to the lake for spawning, and suitability for embryo and fry life stages. Access to the lake from the Athabasca River is likely related to both the lake level and Athabasca River flow. During periods when flows are low, beaver dams and debris likely prevent access to the lake. During periods of high flow in the Athabasca River when water depths exceed the beaver dams, northern pike can likely access the lake through the outlet channel at the north end of the lake. Small magnitude changes in lake level as predicted, are unlikely to affect access to the lake in either a positive or negative way.

The second way that lake level changes could affect habitat in the lake is by decreasing the suitability or amount of habitat for embryo and fry life stages. Northern pike spawn in shallow vegetated areas. The eggs are attached to vegetation. Hence, a drop in water level after spawning and before hatching could affect embryo survival (Casselman and Lewis 1996). Similarly, fry are sensitive to depth changes. For the Muskeg River Mine Project, the depth changes would result from decreased inflow to the lake but would not affect the pattern of fluctuation (i.e., there would not be decreases in lake level from the Project during the egg incubation period). As well, there would be no measurable change in the amount of littoral zone available since the lake bottom is gently sloping and the 1.4 cm decrease in lake level would not change the area of littoral zone. Hence, there would be no effects on either the quality or quantity of habitat for embryo and fry life stages.

Since no effects on either northern pike access or egg/fry survival would be expected, the linkage between lake level changes and fish habitat is invalid.

Athabasca River

Changes in flows in the Athabasca River were assessed in Section E4.4.3 (Key Question SW-1). The incremental effect of the Project was assessed based on existing conditions (i.e., natural conditions plus water withdrawals/releases from upstream municipalities, pulp mills and oil sands operations).

During construction there is no change in Athabasca River flows since there is no withdrawal of water and only a very small loss in drainage area is predicted.

During operation, water withdrawal from the Athabasca River will not cause a change in river flows during mean and high river flows. During 7Q10 low flows, maximum withdrawal rates will be about 2% of the river flow.

At closure there will be negligible effects on the Athabasca River flows. When releases from the end pit lake begin in 2030, there will be a slight (<1%) increase in Athabasca River 7Q10 flow. However, this will become negligible in the far future.

Concerns relating to fish habitat in the Athabasca River are related to reduction in flows, particularly during winter when reductions in already low flows can affect fish habitat. Neither the slight increases (< 1%) during closure nor the slight decreases (2%) at 7Q10 flows during operations would be expected to affect fish habitat. Changes of these small magnitudes would not be measurable. Hence, this linkage is invalid.

Linkage Between Changes in Channel Regime and Fish Habitat

Analysis of potential for changes in channel regime and morphology due to changes in flows in the Muskeg River and Mills Creek is described in Section E4.7. No detectable changes in the Muskeg River are predicted during construction and operation. At the beginning of closure, a change in channel regime in the Muskeg River is predicted that would result in an increase in channel dimension of about 1.7%. In Mills Creek, a change of about 3% is expected in 2020 when muskeg dewatering is routed into this watercourse. In the far future, no changes in channel regime are predicted for both the Muskeg River and Mills Creek.

The only predicted change in channel morphology is at the beginning of end pit lake discharge (end of operation). It is unlikely that a small increase in channel dimension would affect fish habitat availability. Hence, this linkage is invalid. Channel regime would have to be monitored to confirm this conclusion.

Linkage Between Changes in Thermal Regime and Fish Habitat

The potential for changes in thermal regime in the Muskeg River during construction, operation and closure was assessed in the Surface Water Quality section (Section E5). No changes in thermal regime are expected during construction and operation of the Project. A slight alteration of the temperature regime of the Muskeg River was predicted as the result of end pit lake water discharges during the closure (Key Question WQ-3). Specific predictions include slight cooling of river water in the summer, potential slower seasonal warming and cooling, and potential reduced diurnal temperature fluctuation. The magnitude of the predicted temperature changes is <1°C in mean monthly temperature throughout the year for all years modelled. These effects were predicted to occur in the lower Muskeg River, below the mouth of the end pit lake discharge channel.

The predicted small decrease in water temperature in the Muskeg River during the open-water season would not adversely affect fish habitat. Summer water temperatures would be within the preferred temperature ranges for adult longnose sucker (10°C to 15°C; Brown and Graham 1953), northern pike (4°C to 20°C; Casselman and Lewis 1996) and Arctic grayling (7°C to 17°C; LaPerriere and Carlson 1973).

Delayed warming of the Muskeg River in the spring may affect fish spawning, which is sensitive to water temperature changes. However, if more detailed analysis or monitoring suggest that spring water temperatures will be affected to a degree that is harmful to spawning, timing of water discharge from the end pit lake will be adjusted to avoid impacts.

Therefore, the linkage between changes in thermal regime of the Muskeg River and fish habitat is invalid.

Linkage Between Changes in Sediment Loading and Benthic Invertebrate Communities

Results of the sediment loading analysis indicate that changes in sediment levels will be negligible (less than 2 mg/L) in all existing watercourses in the LSA during all phases of the Project (Section E4.6.4). Therefore, the linkage between changes in sediment levels in surface waters and benthic invertebrate communities is invalid.

Linkage Between Changes in Flows in Streams and Benthic Invertebrate Communities

Project activities were predicted to cause changes in the discharge of the Muskeg River (Key Question SW-1; Section E4.4). These changes may affect benthic invertebrate communities if they are of sufficient magnitude to permanently alter substratum composition and change current velocity beyond the natural range in these streams.

Changes in current velocity were predicted in the Muskeg River based on channel characteristics and stream discharge for a number of years representing typical and maximum releases of mine-related waters (Tables E6-4 to E6-7). The predicted changes are negligible under all flow regimes modelled, with the exception of open-water 7Q10 flow in 2030, when a 74% increase in current velocity was predicted. However, the magnitude of the predicted change is <0.2 m/s and current velocity will remain below existing mean open-water velocities (Tables E6-4 to E6-7). Therefore, although current velocity is predicted to increase in the Muskeg River under open-water low-flow conditions in 2030, the increase will be insufficient to negatively affect benthic communities.

Changes in substratum composition cannot be predicted quantitatively. However, the changes in current velocity described above are unlikely to alter this habitat feature, since any Project-related increases will remain well within the natural range of velocities in the affected streams.

Based on the above information this linkage is invalid.

Linkage Between Changes in Water Quality and Benthic Invertebrate Communities

Results of the water quality analysis conducted under Key Questions WQ-1 and WQ-2, indicate that exceedance of water quality guidelines for the protection of aquatic life, other than those caused by naturally elevated levels of metals, will not result from Project activities. As well, no exceedances of toxicity guidelines were predicted. Therefore, Project-related changes in water quality are not expected to influence benthic invertebrate communities in the Athabasca and Muskeg rivers and this linkage is invalid.

E6.5.2 Analysis of Key Question

In the analysis of potential linkages between the Project and fish habitat, the following linkages were deemed invalid:

- channel regime;
- thermal regime;
- sediment loading;
- changes in flows in Athabasca River;
- changes in lake levels of Isadore's Lake; and
- changes in benthic invertebrate communities.

Hence, only a few linkages to fish habitat require assessment. They are as follows:

- Muskeg River: the effect of changes in flows;
- Mills Creek: the effect of changes in flows; and
- lakes/ponds: the effect of habitat loss.

Muskeg River

Changes in the Muskeg River from the Project include increased flow (discharge) and slight increases in depth and velocity. These physical changes to the Muskeg River are analyzed relative to habitat requirements and suitability for each KIR.

Flow, Depth and Velocity

Changes in flow, velocity and depth have the potential to change the habitat suitability for different species of fish. To evaluate the potential effects on KIRs, existing and future velocities were calculated for different years during the Project and for different flow conditions. The following flow conditions were selected that match most closely possible flow conditions occurring during significant fish life stages:

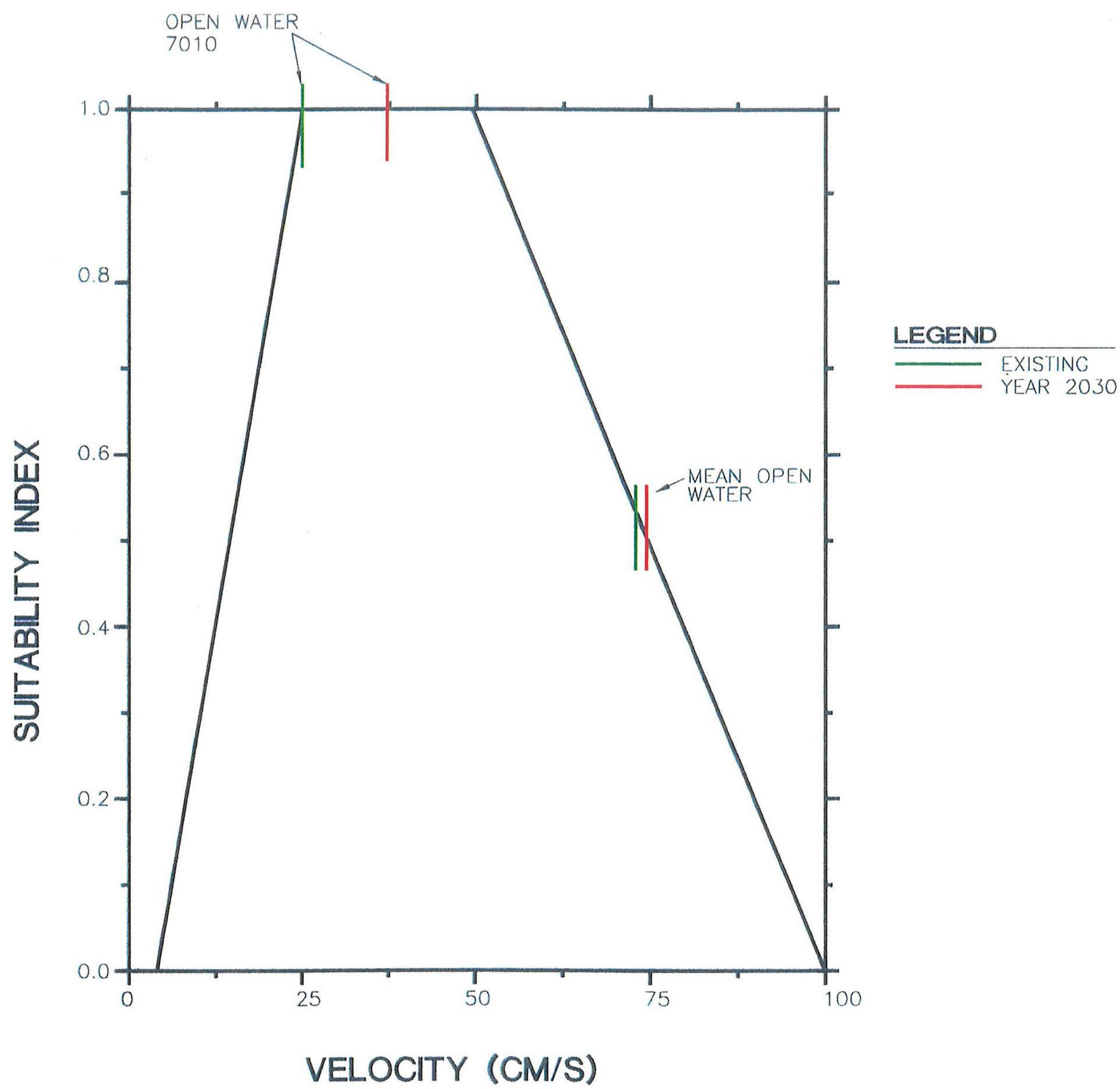
- mean open-water flow: spring spawning migration, rearing, summer feeding;
- open-water 7Q10: fall migration; and
- mean ice-cover flow, annual 7Q10: overwintering.

Discharge, velocity and depth for these flow conditions are presented in Tables E6-4 to E6-7. Changes in discharge, depth and velocity are minimal (< 3%) during mean open-water flow conditions except for the Year 2030 when flows are elevated about from 8.21 to 9.77 m^3/s due to end pit lake discharge. Corresponding increases in depth (from 0.63 to 0.70 m) and velocity (0.73 m/s to 0.77 m/s) also occur (Table E6-4).

Mean ice-cover flows vary from slight decrease (1.11 to 0.09 m^3/s) in 2025 to a slight increase (1.11 to 1.15 m^3/s) in 2030 (Table E6-5).

Fairly large increases are expected during low flow conditions. During open-water 7Q10 conditions discharge increase from existing (0.28 m^3/s) to 0.41 m^3/s in construction and operation and to 1.6 m^3/s during closure (2030) (Table E6-6). Increases in annual 7Q10 vary from no change in the construction period to a maximum of 0.061 m^3/s (existing is 0.052 m^3/s) during operation and 0.099 m^3/s at closure (Table E6-7). All Project-related increases in low flow conditions result in flows significantly lower than existing mean open-water conditions (i.e., the largest increase in open-water 7Q10 is from 0.28 to 1.60 m^3/s which is significantly less than the existing mean open-water flow of 8.21 m^3/s).

Figures D6-3 and D6-4 (in Section D6) show habitat conditions in the Muskeg River in 1995 and 1997. 1995 was a low-flow year (discharge at time of habitat mapping = 1.8 m^3/sec) whereas 1997 was a high-flow year (discharge = 21 m^3/sec). The maps illustrate the change in habitat characteristics (i.e., no riffles during high flow) and access conditions (i.e., beaver dams) under different flow conditions. Table D6-2 shows the changes in relative proportions of habitat features under different flow conditions.



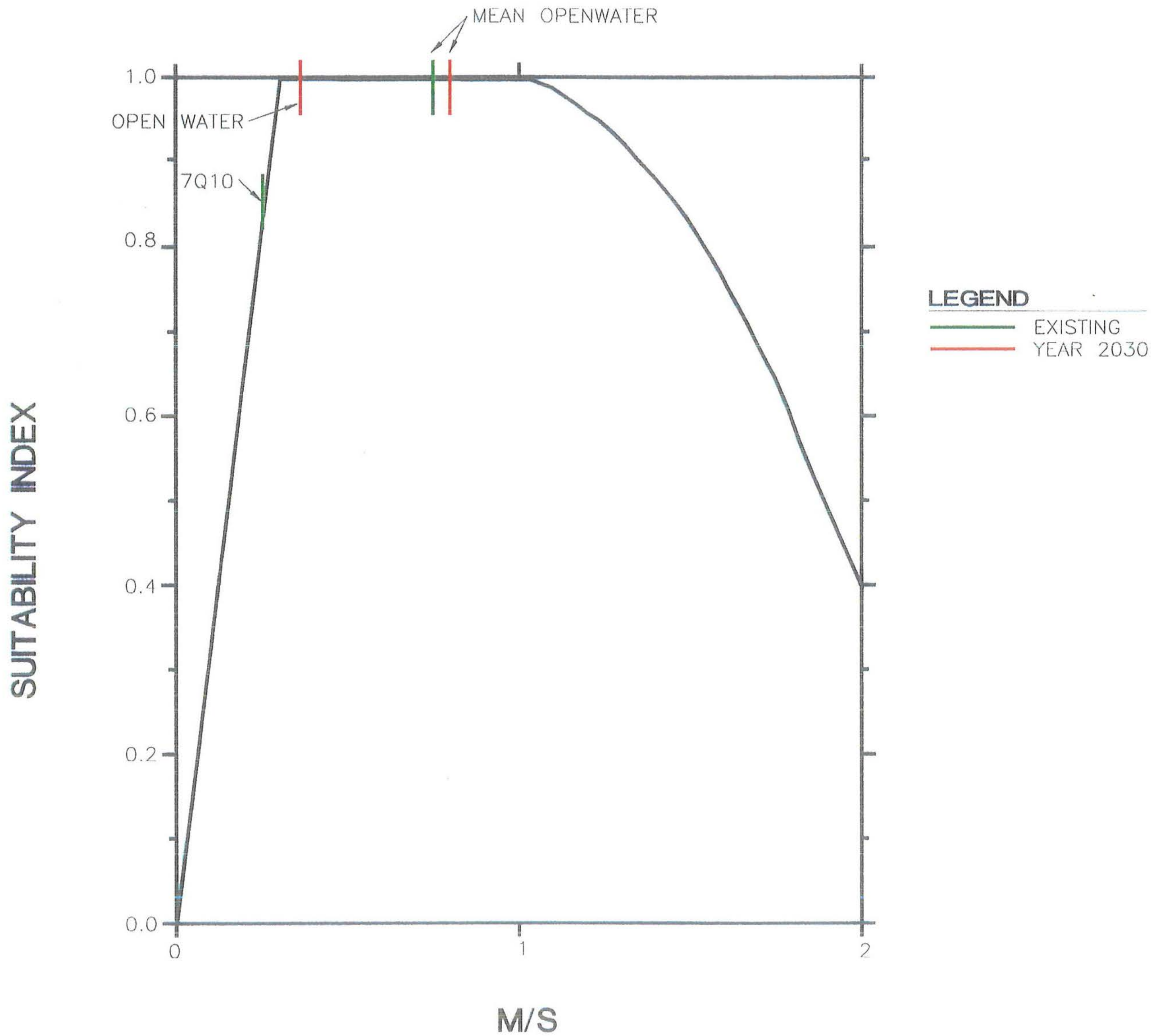
NOTES: 1. HABITAT SUITABILITY INDEX MODEL FOR ARCTIC GRAYLING (HUBERT ET AL. 1985)
2. EXISTING AND YEAR 2030 10YR. FLOOD PEAK VELOCITY = 144cm/s

Golder Associates

SHELL CANADA LIMITED

FUTURE AND EXISTING CURRENT VELOCITY WITHIN SPAWNING HABITAT COMPARED WITH HSI INDEX FOR ARCTIC GRAYLING

06 DEC 97	Figure E6-5	DRAWN BY: DC/TM



HABITAT SUITABILITY INDEX MODEL FOR LONGNOSE SUCKER (EDWARDS 1983)

Golder Associates

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FUTURE AND EXISTING CURRENT VELOCITY WITHIN SPAWNING HABITAT COMPARED WITH HSI INDEX FOR LONGNOSE SUCKER

06 DEC 97	Figure E6-6	DRAWN BY: DC/TM

Northern Pike

Habitat variables included in the habitat suitability index (HSI) model for riverine populations of northern pike include ratio of spawning habitat to summer habitat, drop in water level during embryo and fry stages, percent midsummer area with vegetation, total dissolved solids (TDS), pH, length of frost-free days, average temperature, areas of backwaters and stream gradient (Inskip 1982).

Water quality variables in the HSI model include pH, TDS and average temperature. Ideal (HSI =1) TDS ranges for northern pike are from 60 to 1000 mg/L (Inskip 1982). The range for pH is between 4.5 and 10 and maximum weekly average temperature is from 19.5 to 25 °C. Changes in these water quality variables as a result of the Project and are all within the range of an HSI of 1 for northern pike (Section E5, Appendix VI).

Other variables in the model such as length of frost-free days and stream gradient would not be affected by the Project.

The remaining variables are flow related and include ratio of spawning to summer habitat, drops in water levels during embryo and fry stages, percent mid-summer area with vegetation and areas of backwater. As shown in Table D6-2, areas of backwaters in the Muskeg River change minimally in relation to flows. Hence, no changes in backwater area would be expected from the Project.

The higher flows predicted in the Muskeg River could improve access for northern pike. Higher flows would also likely increase the amount of spawning habitat available for northern pike as more vegetation along the sides of the channels would be inundated with water (i.e., an increase in the ratio of spawning to summer habitat). Providing the water levels were sustained for the egg incubation and early fry period, these areas would provide suitable spawning areas for this species. It is unlikely that a drop in water levels would occur due to the Project since the Project is not predicted to change the pattern of water level fluctuations in the Muskeg River (Figure E6-3).

No negative effects on northern pike habitat in the Muskeg River are predicted. In fact, elevated flows during low flow years may improve access and hence, utilization of habitat in the Muskeg River.

Arctic Grayling

The HSI model for Arctic grayling includes the following variables: water temperature during spawning, minimum dissolved oxygen, percent gravel substrate, percent fines, average velocity in spawning areas, percent downstream spawning habitat, maximum water temperature, annual frequency of spring spawning access to tributary streams within 150 km of wintering areas and occurrence of winter habitat (Hubert et al. 1985).

Variables in the model that are related to water quality include water temperature during spawning, minimum dissolved oxygen concentrations, and maximum water temperature. As discussed in the thermal regime linkage, potential changes in temperature during spring will be prevented by mitigation. Maximum water temperature may decrease slightly, but a decrease in temperature would have a positive effect on Arctic grayling habitat. No changes in dissolved oxygen concentrations are expected as a result of the Project (Section E5).

Similarly, substrate variables such as percent gravel and percent fines would not be affected by the Project since negligible changes (<2 mg/L) in suspended sediment levels are expected.

Variables that are related to flow are: 1) average velocity in spawning areas; 2) percent downstream spawning habitat; 3) annual frequency of spring spawning access to tributary streams; and 4) occurrence of winter habitat.

Velocities predicted during 2030 were compared with the HSI for velocity in spawning areas during spawning and embryo development (Figure E6-5). There were no differences in the habitat suitability between existing and predicted conditions during open-water 7Q10 conditions. A slight decrease in habitat suitability (from 0.52 to 0.5 HSI units) occurs during mean open-water conditions (Figure E6-5).

The largest change in depth during the Project is in 2030 when depth is predicted to increase from 0.63 to 0.7 m (Table E6-4). Therefore, effects on availability of spawning habitat (i.e., the proportion of riffles) in the Muskeg River would not be expected in most years. There may be a slight decrease in riffle availability in 2030.

Access to spawning streams may be improved since there will be increases in low flows, Arctic grayling are known to spawn in Jackpine Creek and higher flows during low flow periods in the Muskeg River may improve access to this habitat.

Changes in discharge during mean ice-cover conditions (i.e., during winter) are less than 0.04 m^3/s. This small change in discharge is unlikely to influence availability of overwintering habitat.

Longnose Sucker

Habitat variables important for longnose sucker spawning habitat are spawning location (i.e., stream or shoreline), riffle depth, current velocity within spawning habitat, mean water temperature during spawning and incubation, percent riffles, substrate type and percent instream cover (Edwards 1983).

Spawning locations, substrate type, mean water temperature during the spawning period and percent instream cover are not predicted to change as a result of the Project.

Other variables in the model are flow related: 1) current velocity within spawning habitat, 2) riffle depth and 3) percent riffles.

Baseline and predicted velocities in the Muskeg River in 2030 during mean open-water and open-water 7Q10 flow conditions were compared with the HSI for current velocity within spawning habitat (Figure E6-6). Figure E6-6 indicates that predicted velocities for mean open-water flow conditions are suitable for longnose sucker spawning. Predicted velocities during 2030 open-water 7Q10 would improve the habitat suitability for longnose sucker spawning (HSI from 0.84 to 1.0). None of the predicted velocities is outside the range normally occurring in the Muskeg River (Table E6-4 to E6-7).

Longnose suckers are known to spawn in riffle areas within the lower reaches of the Muskeg River. Depths in the Muskeg River do not change measurably, except in 2030 (from 0.63 to 0.7 m) Therefore, there is no reason to expect changes in the availability of riffle habitat for spawning during most of the life of the Project. There is a possibility of a slight decrease in the availability of riffle habitat during 2030 due to the higher water levels. Similarly, higher water levels may result in a decrease in suitability of riffles since suitability decreases as depth increases (Edwards 1983).

Increased flows during low-flow periods in the Muskeg River could also improve access to spawning areas in Jackpine Creek. Habitat in Jackpine Creek is suitable for longnose sucker spawning and would likely be used by this species if accessible.

Forage Fish Guild

Most of the fish in the forage fish guild (brook stickleback, fathead minnow, lake chub, pearl dace) prefer still waters and are usually found in association with aquatic vegetation (Scott and Crossman 1973, Lane et al. 1996). Typically, these species are found in smaller tributaries with low flow and are not encountered in the main channel of the Muskeg River (Golder 1996b). Slimy sculpin typically inhabit rocky areas of streams and are likely adapted to flow changes (Scott and Crossman 1973). Hence, no effect on the forage fish guild are predicted.

Mills Creek

Changes in flows in Mills Creek are described in the Surface Water Hydrology section (Table E4-31). Decreases in mean annual flows are expected during construction (maximum 4%), operation (maximum 23%) and closure (maximum 23%). In 2020, near the end of operation, muskeg drainage water will be routed through Mills Creek and flows in this watercourse will increase by about 25%.

Flow changes in Mills Creek are only evaluated in relation to the forage fish guild since other KIR species would not have access to Mills Creek, nor would they be likely to use it since it is a very small stream.

Forage Fish Guild

No fish have been documented in Mills Creek. However, the habitat is suitable for the forage fish guild, particularly brook stickleback, fathead minnow and lake chub which prefer quiet waters (Scott and Crossman 1973). Hence, decreases in flows in Mills Creek which are expected during construction (4%) and part of operation (23%) and closure (23%) would not negatively affect this KIR. Increased flows during 2020 (about 25%) may affect forage fish. However, there are many wetlands areas and vegetation throughout the stream which would provide cover for forage fish. Hence, no effects on forage fish guild are expected from changes in flows in Mills Creek.

Unnamed Ponds and Lakes

The shallow unnamed pond and lake that will be lost during construction and operation total 26 ha in area. These waterbodies are located immediately south of the Alsands Drain and to the west of the Muskeg River (see Figure D6-1). About 3.4 ha forage fish habitat will be lost when the Alsands Drain is altered. This represents approximately 1.8% of the forage fish habitat in the watershed (Table E4-34; total area of streams and ponds = 1,671 ha). Hence, a low impact (less than 10%) on the forage fish guild is predicted due to loss of these two waterbodies and a portion of the Alsands Drain. No other KIRs are affected by the removal of these waterbodies (Table E6-8).

Table E6-8 Fish Habitat Losses and Gains from the Project

Habitat Type	Habitat Lost During Construction and Operation	Habitat Gained at Closure
Forage Fish	29 ha	670 ha[(a)]
Sport Fish	none	442 ha[(b)]

(a) includes wetlands/shallow lakes, streams and end pit lake
(b) includes end pit lake

Forage fish habitat loss during construction will be replaced during operation. Forage fish habitat will be created in drainage channels. Habitat will be equivalent in quality and quantity.

A net gain in fish habitat will occur at closure since the reclaimed landscape will include streams, wetlands and the end pit lake which will be designed to provide fish habitat. This represents a net gain of 670 ha (Table E6-8).

Summary

In summary, forage fish guild is the only KIR whose habitat would be adversely affected by the Project. Very minor effects on forage fish habitat are expected.

Many mitigations are in place in the Project to prevent habitat loss and ensure no net loss of fish habitat. These have been discussed throughout the analysis of potential linkages and impact analysis and are summarized in Table E6-9.

E6.5.3 Residual Impact Classification and Degree of Concern

No adverse effects on longnose sucker, Arctic grayling or northern pike habitat in the Muskeg River are predicted as a result of the Project. Low magnitude (less than 10%) effects are predicted for the forage fish guild in unnamed ponds and lakes (Table E6-9). Equivalent habitat (same quality and quantity) will be created within drainage channels during operation.

E6.5.4 Certainty

Certainty of habitat predictions is moderate and will need to be confirmed with monitoring (Section E6.10).

Table E6-9 Summary of Project Mitigation Features to Achieve No Net Loss of Fish Habitat

Design Feature/Mitigation	Result
mine footprint confined to west side of Muskeg River, setbacks of at least 100 m	no direct impacts on Muskeg River habitat
minimal Project facilities in Jackpine Creek subwatershed, setbacks of at least 100 m	no effects on Jackpine Creek
mitigation to prevent increased sediment levels in Muskeg River and Mills Creek (SW-3)	negligible increase in sediment levels (<2mg/L)
mitigations to prevent impacts on water quality (WQ-1 and WQ-2): • deposition of CT below grade to minimize seepages • CT water recycled into closed circuit system during operation • perimeter ditch surrounding the tailings settling pond to collect seepages • sand seepages from reclaimed tailings settling ponds directed through long retention wetlands into the Athabasca River at closure • wetlands systems on the reclaimed tailings ponds and CT deposits to provide retention and bio-remediation • end pit lake will receive CT flux and seepages and serve a remediation function • filling rate of end pit lake controlled so that discharges will be non-toxic	no acute or chronic effects on fish, minimal potential for tainting or bioaccumulation of chemicals
mitigations to prevent impacts on thermal regime (WQ-3): • control end pit lake discharge during critical fish life stages (e.g., spawning) if necessary	minimize changes in Muskeg River temperature during spring

Table E6-10 Residual Impact Classification and Degree of Concern for Fish Habitat in Muskeg River Watershed

KIR	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
Construction and Operation							
Forage Fish	Negative	Negligible	Local	Medium-term	Reversible	Once	Negligible
Longnose Sucker	Not Applicable	Negligible	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Negligible
Arctic Grayling	Not Applicable	Negligible	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Negligible
Northern Pike	Not Applicable	Negligible	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Negligible
Closure							
All Fish KIRs	Positive	Negligible to High[a]	Local	Long-term	Not Applicable	Not Applicable	Negligible

(a) magnitude of positive effects on habitat for different KIRs is undetermined at this time. The type of habitat created will depend on regulator and stakeholder goals and input from the end land use committee

E6.6 Key Question AR-2: Will the Muskeg River Mine Project Activities Result in Acute or Chronic Effects on Fish?

E6.6.1 Analysis of Potential Linkages

Linkage Between Water Withdrawals from the Athabasca River and Direct Effects on Fish

No direct effects on fish are expected from the water intake structure in the Athabasca River since the Project will follow relevant provincial and federal guidelines for screening. Hence, the linkage between water withdrawal and direct effects on fish is invalid.

Linkage Between Changes in Suspended Sediment Levels and Acute or Chronic Effects on Fish

The potential the Project to cause changes in sediment loading was discussed in the Surface Water Hydrology section (Key Question SW-4; Section E4.7.2). Results of the analysis of this issue indicate that changes in sediment levels will be less than 2 mg/L in all existing watercourses in the LSA during all phases of the Project. Therefore, the linkage between changes in sediment levels in surface waters and acute or chronic effects on fish is invalid.

Linkage Between Changes in Temperature Regime of the Muskeg River and Acute or Chronic Effects on Fish

The slight changes predicted in river water temperature are insufficient to cause acute or chronic effects on fish. During the summer and winter months, when extremes in natural water temperatures may cause physiological stress in fish, the directions of the predicted impacts are such that they may reduce stress relative to the natural temperature regime (i.e., slight warming in winter and slight cooling in summer, reduced diurnal fluctuation).

Based on the above evaluation, the linkage between a change in the temperature regime of the Muskeg River and acute or chronic effects on fish is invalid.

Linkage Between Changes in Water Quality and Acute or Chronic Effects on Fish

Minor changes were predicted in water quality parameters, which did not result in new guideline exceedances in addition to those caused by naturally elevated levels of certain metals under baseline conditions (Section E5). No exceedances of acute or chronic toxicity guidelines were predicted. Therefore, this linkage is invalid.

E6.6.2 Analysis of Key Question

Changes in suspended sediment levels, thermal regime and water quality were identified on the linkage diagram as factors that may contribute to acute or chronic effects on fish. Results of analyses summarized above indicate there are no valid linkages between Project activities and potential acute or chronic effects on fish.

E6.6.3 Residual Impact Classification and Degree of Concern

No acute or chronic effects were predicted on fish in the Athabasca and Muskeg rivers.

E6.6.4 Certainty

The conclusions regarding the potential for effects on fish are based on acute and chronic toxicity testing of CT waters. There are no data on the effects of CT water on fish health parameters. The lack of data on CT water effects on fish health limits the level of certainty in the evaluation of effects on fish and fish populations.

Studies on the effects of CT water on fish health would help address this concern.

These studies would address the following issues raised by stakeholders:

- bioaccumulation of hydrophobic compounds;
- provide information that has been used to predict toxicity effects of CT water on fish health; and

- effects of CT toxicity on fish population performance.

The fish health data would be added to toxicity information to produce a weight-of-evidence regarding the potential for effects of CT water on fish health. It is Shell's belief that these studies should be a collective effort by industry, using the previous work by Suncor as a starting point.

E6.7 Key Question AR-3: Will Muskeg River Mine Project Activities Change Fish Tissue Quality?

E6.7.1 Potential Linkages

Changes in fish tissue quality are linked to water quality. The two main concerns are: 1) a change in chemical concentrations in fish tissue; and 2) a change in fish flavour (tainting). The first concern is linked to possible effects on human health from consumption of fish tissue with elevated chemical levels. The second concern is linked to the aesthetic effect of off-flavours. Both concerns are linked to a possible decline in the use of the fish resource.

Linkage Between Water Quality and Chemicals in Fish Tissue

The potential for the Project to produce changes in chemical concentrations in fish tissue was evaluated by examining the bioaccumulative potential of the chemicals of concern and by interpreting available data on chemical levels in fish tissue from the area.

Walleye, goldeye and longnose sucker were collected as part of the Aurora and Steepbank aquatic baseline study (Golder 1996b). These fish were captured in the Athabasca and Muskeg rivers. Composite samples (by sex and species) of fish tissue (fillets) were analyzed for organic chemicals and metals. Uptake of oil sands related chemicals into fish tissue was also investigated as part of a laboratory fish health study, using Athabasca River water and a dilution series of TID water with a maximum concentration of 10%. Juvenile walleye and rainbow trout were held for 28 days, sacrificed and their tissues analyzed for PAHs and trace metals (HydroQual 1996a).

The results of these analyses are presented in Table E6-10. Longnose sucker composite samples showed detectable naphthalene levels of 0.40 μg/g and methyl naphthalene levels of 0.03 μg/g; however, all other PAH parameters were not detectable (detection limits range from 0.02 to 0.04 μg/g). PAH/PANH compounds were not detectable in walleye and goldeye. In the laboratory exposed fish PAH concentrations were below detection limit for nearly all chemicals except naphthalene and methyl naphthalene in rainbow trout which were at or just about the detection level (0.02 to 0.05 μg/g). Hence both field and laboratory studies indicate no significant amount of organic chemicals in fish.

Heavy metals such as cadmium and lead were not detected in juvenile walleye and rainbow trout exposed to 10% TID water or Athabasca River water or fish captured in the field (Table E6-11). Mercury levels were detectable and of low magnitude in laboratory fish exposed to both TID water and Athabasca River water. The Northern River Basin Study also identified mercury as elevated in Athabasca River water (NRBS 1996). Thus no significant incremental accumulation of metals is indicated by either the laboratory studies or from fish collected from the LSA.

Based on existing data from field and laboratory analyses, bioaccumulation of chemicals from the Project is not expected to occur. Hence, this linkage is invalid.

Linkage Between Water Quality and Tainting of Fish Tissue

The potential for the Project to produce tainting was evaluated using data from previous investigations as well as assumptions regarding the chemical composition of CT water from the Project. Previous investigations conducted for the Suncor Steepbank Mine (Golder 1996e, HydroQual 1996b) produced information for operational and reclamation waters. The studies included Suncor's Refinery Wastewater, TID seepage water and Athabasca River water. Tainting was evident in fish exposed to 0.5% refinery effluent but not in other tested waters (Golder 1996e). A followup study was conducted by HydroQual (1996b) to further examine tainting potential of refinery effluent. The study included a detailed characterization of wastewater streams and an assessment of depuration rates. The results of the study indicated that there was no tainting in the refinery effluent concentrations tested (0.01, 0.1 and 1%) or after 14-day depuration.

No operational waters similar to refinery effluent will be released from the Project. TID, the reclamation water tested by Suncor, showed no potential to taint. Compounds with the potential to cause tainting (notably PAHs) are expected to be present in CT water; however, concentrations are likely to be below those required to produce off-flavours in fish because CT water has lower levels of organic compounds than TID water. Hence, tainting would not be expected from CT water.

Table E6-11 Comparison of Chemical Concentrations in Fish Tissue to Background Concentrations at Reference Sites

Chemical	Muskeg River[a] Longnose Sucker (µg/g) Maximum	Athabasca River[a] Walleye (µg/g) Maximum	Athabasca River[a] Goldeye (µg/g) Maximum	10% TID[b] Walleye (µg/g) Maximum	10%TID Rainbow trout (µg/g) Maximum	Athabasca River[c] Walleye (µg/g) Maximum	Athabasca River[c] Rainbow trout (µg/g) Maximum
PAHs[d]							
Naphthalene	0.4	<0.02[f]	<0.02	<0.02	0.03	<0.02	0.02
Methyl naphthalene	0.03	<0.02[f]	<0.02	<0.02	0.03	<0.02	0.03
METALS							
Aluminum	11	3	2	12	12	14	18
Arsenic	<0.5	<0.5	<0.5	1.1	<0.1	2.3	<0.1
Barium	<0.5	<0.5	<0.5	0.9	<0.5	0.9	<0.5
Beryllium	<0.5	<0.5	<0.5	<1	<1	<1	<1
Boron	<5	<5	<5	<5	<5	<5	<5
Calcium	880	662	627	7660	261	7090	2260
Cadmium	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Chromium	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Cobalt	<0.5	<0.5	<0.5	<1	<1	<1	<1
Copper	<1	1	2	<1	<1	<1	<1
Iron	16	12	12	<1	4	8	23
Lead	<2	<2	<2	<5	<5	<5	<5
Magnesium	661	321	377	371	302	457	380
Manganese	0.9	1.2	<0.5	6.1	0.2	5.1	0.9
Mercury	-[e]	-[e]	-[e]	0.44	0.03	0.45	0.04
Nickel	<1	<1	2	<2	<2	<2	<2
Phosphorus	2960	2880	2590	5820	2640	6060	3620
Potassium	5190	4880	4380	4390	4880	5090	4840
Selenium	0.3	<0.5	<0.5	0.4	<0.4	0.4	0.3
Silicon	12	4	7	<50	<50	<50	<50
Silver	<0.2	<0.2	<0.2	<1	<1	<1	<1
Sodium	409	440	360	748	480	635	471
Strontium	0.9	0.6	<0.5	8	<1	8	2
Thallium	<1	<1	<1	<1	<1	<1	<1
Tin	<2	<2	<2	<5	<5	<5	<5
Vanadium	<1	<1	<1	<1	<1	<1	<1
Zinc	6	9	6	17.5	10.3	17.2	8.9

(a) Data from fish sampled by Golder during 1995 (Golder 1996b).
(b) Data from fish exposed to Tar Island Dyke Water (10%) in laboratory (HydroQual 1996a).
(c) Data from fish exposed in laboratory to Athabasca River water taken upstream of Fort McMurray (HydroQual 1996a). These are considered to be background samples.
(d) All other PAHs nondetectable (detection levels range from 0.02 to 0.04 µg/g).
(e) No data.
(f) Not detected above detection limits.

There is no evidence to suggest that CT water will cause tainting; therefore, this linkage is considered invalid. However, since tainting has been raised repeatedly as a concern by aboriginal groups and regulators, the Project is committed to followup studies to confirm this prediction.

E6.7.2 Analysis of Key Questions

Based on existing information on levels of chemicals in fish tissue, no accumulation in fish tissue is expected. Flavour impairment is also not expected. Therefore, no impacts on fish tissue quality are expected.

E6.7.3 Residual Impact Classification and Degree of Concern

No impacts on fish tissue quality are expected. However, followup studies will need to be done to confirm these predictions.

E6.7.4 Certainty

Conclusions regarding the potential for tainting of fish tissue via exposure to CT waters are based on previous investigations and the assumed presence of very low concentrations of tainting compounds. There is a moderate amount of certainty in these prediction. The Project will cooperate with regional developers to further investigate tainting.

E6.8 Key Question AR-4: Will Muskeg River Mine Project Activities Change Fish Abundance?

E6.8.1 Analysis of Potential Linkages

There are three potential linkages between the Muskeg River Mine Project and changes in fish abundance: change in access (i.e., increased fishing pressure), changes in fish habitat and acute or chronic effects on fish.

Linkage Between Change in Access and Fish Abundance

Access to fishing areas in the Muskeg River basin will be restricted during construction and operation. Hence, fishing pressure will likely be reduced during this period. At closure, access to the area will be improved from baseline conditions due to the upgraded roads.

An increase in fishing pressure during closure could cause a decrease in fish abundance. However, regulation of angling is the responsibility of Fisheries Management Division of AEP. It is assumed that decreases in fish abundance would be prevented by appropriate enforcement of legislation by AEP. Therefore, this linkage is not valid.

Linkage Between Acute and Chronic Effects on Fish and Fish Abundance

No acute or chronic effects on fish are expected as a result of the Project. Hence, linkage is invalid. However, the certainty of this prediction is limited and will be investigated and confirmed with followup studies (Section E6.7.4).

Linkage Between Change in Fish Habitat and Fish Abundance

Change in fish habitat is rated as low for forage fish habitat and negligible for other KIR species (longnose sucker, Arctic grayling, northern pike). The small effect on forage fish habitat during construction (<2%) is not expected to cause a decrease in fish abundance since these waterbodies are not connected to the Muskeg River.

E6.8.2 Analysis of Key Question

None of the linkages between the Project and fish abundance are valid. Therefore, no further analysis is required.

E6.8.3 Residual Impact Classification and Degree of Concern

No changes in fish population are expected as a result of the Project.

E6.8.4 Certainty

The available fish population data for the Athabasca and Muskeg rivers are limited because of low sample size. High-flow conditions in spring and fall of 1997 prevented collection of new pertinent population data. Therefore, conclusions about the potential for effects on fish populations are based only on acute and chronic toxicity testing. This limits the level of certainty in the evaluation of impacts on fish populations.

E6.9 Key Question AR-5: Will the Muskeg River Mine Project End Pit Lake Support a Viable Ecosystem?

Design of the end pit lake is currently at a conceptual level. The available information is inadequate to evaluate specific linkages. Therefore, this key question can not be evaluated and is ranked as undetermined at this time. Rather, issues are identified which will have to be addressed before the lake is created. Characteristics that would influence the suitability for an aquatic ecosystem to develop and the potential for establishment of fish populations for human use are discussed.

E6.9.1 Conceptual Design

Design of the end pit lake is described in the reclamation drainage report (1997i). The lake will be approximately 442 ha and the average depth will be 62 m (Figure E4-13). A littoral zone covering 20% of the lake area will be created along the east side of the lake. It's average depth will be 0.5 m. The littoral zone will be protected from wave erosion by a breakwater which will have openings along it for fish passage to and from the littoral zone.

The end pit lake will receive runoff from streams and wetlands from the reclaimed landscape. Its outlet will be a 2 km long channel that will be connected to the Muskeg River. The bottom width of the channel will be 1 m. The depth will range from 0.4 to 1 m and velocities are expected to range from 0.4 to 0.7 m/s.

E6.9.2 Potential for Long-term Viability of Aquatic Ecosystem

Water quality in the end pit lake is described in Section E5. Water quality predictions indicate that the lake will not be acutely and chronically toxic to aquatic biota after the few years after filling (by 2028) (Section E5.6). Two parameters were examined with respect to aquatic biota: naphthenic acids and total dissolved solids. Naphthenic acids are expected to drop to non-toxic levels by 2028. Total dissolved salt concentrations are expected to vary from 150 mg/L to over 1000 mg/L. These salt levels would not be expected to affect lake productivity or affect the potential diversity of aquatic macrophytes (Section E5.10.2).

A number of issues with respect to long-term viability of an ecosystem in the lake were identified in the Surface Water Quality Section E5.10. These include stratification potential, nutrient status, and the period of time over which water quality will improve.

Other characteristics that would need to be considered if it were desirable to establish fish populations in the lake include:

- habitat requirements for desired species;
- fish access to the lake from the Muskeg River;
- potential for fish flavour impairment; and
- potential for accumulation of chemicals in fish tissue.

Design criteria would have to be established for desired fish species. Habitat could be designed to increase the suitability of the lake for sports fish species such as northern pike or walleye. Appropriate amounts of spawning, rearing, feeding and overwintering habitat need to be established to provide for self-sustaining fish populations. Features such as peninsulas, islands and spawning shoals could be incorporated into the design of the lake. For example, rip-rap used in construction of breakwaters could be sized appropriately for walleye spawning habitat.

Access to the lake for fish from the Muskeg River would be through the outlet channel. This channel could also be enhanced for use by fish from the Muskeg River by inclusion of habitat features such as cover, riffles or pools.

Before establishing fish in the lake, the potential for effects on fish health, tainting and bioaccumulation would have to be further assessed. Available information indicates that it is unlikely that exposure to CT water will cause significant bioaccumulation or tainting. However, followup studies identified in Section E6.6.4 and E6.7.4 will provide information to confirm these predictions.

The conceptual features of the lake (i.e., littoral zone, development of a non-toxic aquatic environment) indicate that it is likely that an aquatic ecosystem would be viable. However, the following issues require further evaluation (in addition to those discussed in Section E5.10):

- naphthenic acid degradation rate;
- potential for health effects, bioaccumulation and tainting in fish; and
- sources of toxicity in CT water.

The Project is committed to participate in research to ensure that the end pit lake meets regulatory and stakeholder goals. As discussed in Section D5.10, this is an issue facing all oil sands operators and it is best addressed through a coordinated effort.

E6.9.3 Residual Impact and Degree of Concern

The end pit lake is likely to support a viable aquatic ecosystem and provide a positive benefit in terms of aquatic habitat. However, there are several issues that require further evaluation. Hence this impact is rated as undetermined.

Table E6-12 Residual Impact Classification and Degree of Concern for End Pit Lake Ecosystem Viability

KIR	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
All Fish KIRs	Undetermined	Undetermined	Local	Long-term	Not Applicable	Not Applicable	Undetermined

E6.10 Aquatic Resources Monitoring Program

E6.10.1 Overview

Aquatic resources monitoring will be done to confirm impact predictions and to provide feedback on the effectiveness of mitigation measures. Some components of the monitoring program are specific to the Project whereas other components could be done jointly as part of the RAMP. Monitoring programs are summarized in Table E6-13.

Table E6-13 Summary of Aquatic Resources Monitoring Programs

Waterbody	Monitoring	Program
Isadore's Lake	northern pike habitat	the Project
End Pit Lake	fish abundance and health	the Project
	chemical levels and tainting in fish	the Project
Muskeg River	benthic invertebrates	the Project
	fish habitat	the Project or RAMP
	fish populations	RAMP
	chemical levels in fish tissue	RAMP
Athabasca River	benthic invertebrates	RAMP
	fish populations	RAMP

E6.10.2 Monitoring Program for the Project

Isadore's Lake

The objective of monitoring Isadore's Lake is to confirm northern pike usage during high-flow years and to monitor for any impacts on northern pike habitat quantity or quality during these years.

Monitoring will focus on northern pike habitat because this is the only species confirmed to be present in the lake. Monitoring will take place during high-flow years when water levels are sufficiently high to allow passage of fish into the lake. During these years, pike habitat will be surveyed to confirm the predicted lack of effects. If no impacts are observed after sampling representative high-flow years, monitoring will cease.

Muskeg River

Fish habitat will be monitored to confirm the predicted absence of effects on the quantity or quality of habitat. These periodic surveys would take place during representative flow years (low, mean and high flows). If no effects are observed during representative years, monitoring programs will cease.

Monitoring programs after closure will focus on the end pit lake discharge. The primary monitoring tools will be water chemistry analysis, toxicity testing and benthic invertebrate community monitoring. Water chemistry monitoring and toxicity testing have been described in Section E5.

Benthic invertebrate community monitoring will take place upstream and downstream of the end pit lake discharge. Parameters to be monitored will include those monitored during baseline and followup studies. The frequency and extent of monitoring and the parameters to be monitored will depend on results of the first 1 to 2 years of data, plus results of chemical analysis and toxicity testing of the end pit lake discharge.

End Pit Lake

The end pit lake monitoring program will be developed once a more detailed design is produced, but it will include monitoring of fish abundance, health, bioaccumulation and tainting.

E6.10.3 Regional Aquatics Monitoring Program

Muskeg River

Fish monitoring programs in the Muskeg River will be done jointly with other operators under RAMP. It is expected that fish monitoring programs will be designed to include some or all of the fish health and fish population parameters studied during baseline and followup work. The actual nature and extent of the monitoring programs is difficult to predict because of the lack of current data on the effects of CT water on fish health and fish populations. Parameters shown to respond reliably and consistently to CT exposure will be monitored if these parameters are relevant to population-level performance. The frequency of fish monitoring will also depend on the results of chemical analysis and toxicity testing of the end pit lake discharge.

Monitoring for bioaccumulation of chemicals in fish tissue is expected to focus on metals and PAHs. This monitoring will also be done as part of the RAMP program. Monitoring would be conducted at least once in the initial five-year period following the beginning of end pit lake discharge. Additional monitoring would depend on the results of the initial study.

Athabasca River

Future monitoring of the Athabasca River will be conducted as part of the RAMP. The program currently includes:

- water quality monitoring;

- benthic invertebrate community structure and accompanying sediment monitoring; and
- fish population monitoring (presence/absence; relative abundance; size and age distribution).

The RAMP may expand its scope in future years to more fully address aquatic issues in the region.

E6.11 Summary

The Project, in combination with existing developments in the local or Regional Study Areas, is not expected to cause tainting or bioaccumulation of chemicals in fish tissue or acute and chronic effects on fish.

No habitat for sports fish will be disturbed during the life of the Project or closure. A small amount (1.7%) of available forage fish habitat will be disturbed during construction and operation but it will be replaced through reclamation. At closure the reclamation drainage system which consists of wetlands, streams and the end pit lake will provide additional habitat for sport and forage fish.

The end pit lake is expected to support a viable aquatic ecosystem and provide suitable habitat for fish. However, there are several issues that require further investigation so the impact is rated as undetermined at this time.

Residual impacts are summarized in Table E6-14. Key questions AR-2 (acute and chronic effects on fish), AR-3 (fish tissue quality) and AR-4 (fish abundance) had no valid linkages. Hence, no residual impacts to rate. The degree of concern for these three key questions is negligible.

Table E6-14 Summary of Residual Impacts and Degree of Concern for Aquatic Resources

KIR	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
Key Question AR-1 Will Muskeg River Mine Project Activities Change Fish Habitat?							
Construction and Operation							
Forage Fish	Negative	Negligible	Local	Medium-term	Reversible	Once	Negligible
Longnose Sucker	Not Applicable	Negligible	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Negligible
Arctic Grayling	Not Applicable	Negligible	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Negligible
Northern Pike	Not Applicable	Negligible	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Negligible
Closure							
All Fish KIRs	Positive	Negligible to High[(a)]	Local	Long-term	Not Applicable	Not Applicable	Negligible
Key Question AR-5 Will the Muskeg River Mine Project End Pit Lake Support a Viable Ecosystem?							
All Fish KIRs	Undetermined	Undetermined	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Undermined

[(a)] magnitude of positive effects on habitat for different KIRs is undetermined at this time. The type of habitat created will depend on regulator and stakeholder goals and input from the end land use committee

E7 ECOLOGICAL LAND CLASSIFICATION

E7.1 Introduction

This section of the EIA provides information as required by the Project Terms of Reference (TofR) issued on November 7, 1997 (AEP 1997a). Specifically, the following are addressed in this section:

- identification of the number of Ecological Land Classification (ELC) units affected in the Project Area;
- description of the mitigation measures to be implemented to offset the impacts on ELCs in the Project Area; and
- description of the impacts of the project on biodiversity based on ELC units.

Discussions on the potential cumulative effects on ELC units associated with the Project are addressed in Section F7. Section D7 provides details on the ELC baseline for the Project.

The development of the Project will have impacts on ELCs at the landscape, plant community and plant species levels (Section D7). As such, the ELC section provides an integrated classification framework for subsequent analysis in the soils and terrain (E8), terrestrial vegetation (E9) and wetlands sections (E10) for each of the key questions. The objective of this section is to assess the potential impacts on ELC units in the LSA and to provide an assessment of the effects of the Project on biodiversity.

E7.2 Methods

The impact assessment was done through a comparison of the baseline conditions of the local study area (LSA) of the Project with conditions that are expected to result from the Project development.

The severity of impacts was determined based on an impact rating system that incorporates the following parameters: direction, magnitude, geographic extent, duration, reversibility and the frequency of the impact. This rating system is detailed in Section E1.

E7.2.1 Mapping/Area Calculations

The vegetation resources of the LSA were mapped according to an ELC approach that allows the area of ecosite phases to be identified and expressed in terms of hectares, or as a percentage of the study area. A vegetation database links each map polygon with a geographical information system (GIS) system to allow the relative abundance of ecosite phases to be compared within the LSA. By superimposing the Project development plan over the vegetation polygons, the amounts of each ecosite phase affected can be quantified and an assessment of significance made using the criteria previously described. Similarly, by projecting the successive reclamation activities onto the development landscape, the progression of revegetation to plant communities can be quantified and monitored.

E7.2.2 Biodiversity Measurements

For the purpose of this EIA, the working definition of biodiversity adopted from Noss and Cooperrider (1994) is:

> "the variety of life and its processes; it includes the variety of living organisms, the genetic differences among them, the communities and ecosystems in which they occur and the ecological and evolutionary processes that keep them from functioning yet ever changing and adapting."

A description of biodiversity should include reference to the scale at which the diversity is being described (Iacobelli et al. 1995). Noss and Cooperrider (1994) state that there are four scales of biodiversity that should be included:

- landscape (macroterrain)
- plant communities (ELC, ecosite phases, wetlands)
- species (species richness)
- genes

In addition, each scale of biodiversity can be described in terms of its levels:

- composition
- structure
- function

Composition refers to the number of types and abundance of each unit (e.g., ELC units, plant communities, wetlands types and species) and can be measured using indices of richness and diversity. Structure refers to the vertical and/or horizontal layering of these units, and the abundance and distribution of these layers and/or the distribution of patches across the landscape. Function refers to the climatic, geologic, hydrologic, ecologic and evolutionary processes that occur within each scale. For the purposes of this EIA, function is discussed qualitatively.

Indices measured included patch size, polygon area, richness, expressed as the number of units or species present, and diversity, which is calculated using the Shannon Index. The Shannon Index, H, is expressed as:

$$H = \sum_{i=1}^{k} P_i \log P_i$$

Where,

k = number of categories (i.e., ELC units or species); and
P_i = proportion of the observations found in *i*.

Table E7-1 outlines the scale, level indices and measures of assessment for assessing biodiversity. Biodiversity has been evaluated in this section at the landscape scale for ELC units in the LSA. The Vegetation (E9) and Wetlands (E10) sections will discuss biodiversity at the plant community and species scale. Impacts to diversity at the species scale are only discussed conceptually since it is difficult to determine how species composition and structure will change. Discussion of genetic scale biodiversity is beyond the scope of this EIA.

Biodiversity indices were developed for: ELC richness, plant community richness, wetland richness, patch size, rare plant potential, species richness and diversity (Shannon Index).

E7.3 Potential Linkages and Key Questions

Linkage diagrams have been prepared for the Project construction and operation phases, as well as for the closure phase. The diagrams are intended to demonstrate the connections between the Muskeg River Mine Project and the environment in which the mine will be developed and reclaimed. In this section, the focus of the linkage diagrams is on the connections between the project and the ELCs of the LSA. They are used to help understand and explain the often complex interactions that can take place between the mine and the environment over the life of the Project. Impacts more specific to each biophysical resource (terrain, soils and vegetation) will be discussed in those impact assessments.

Table E7-1 Biodiversity Assessment

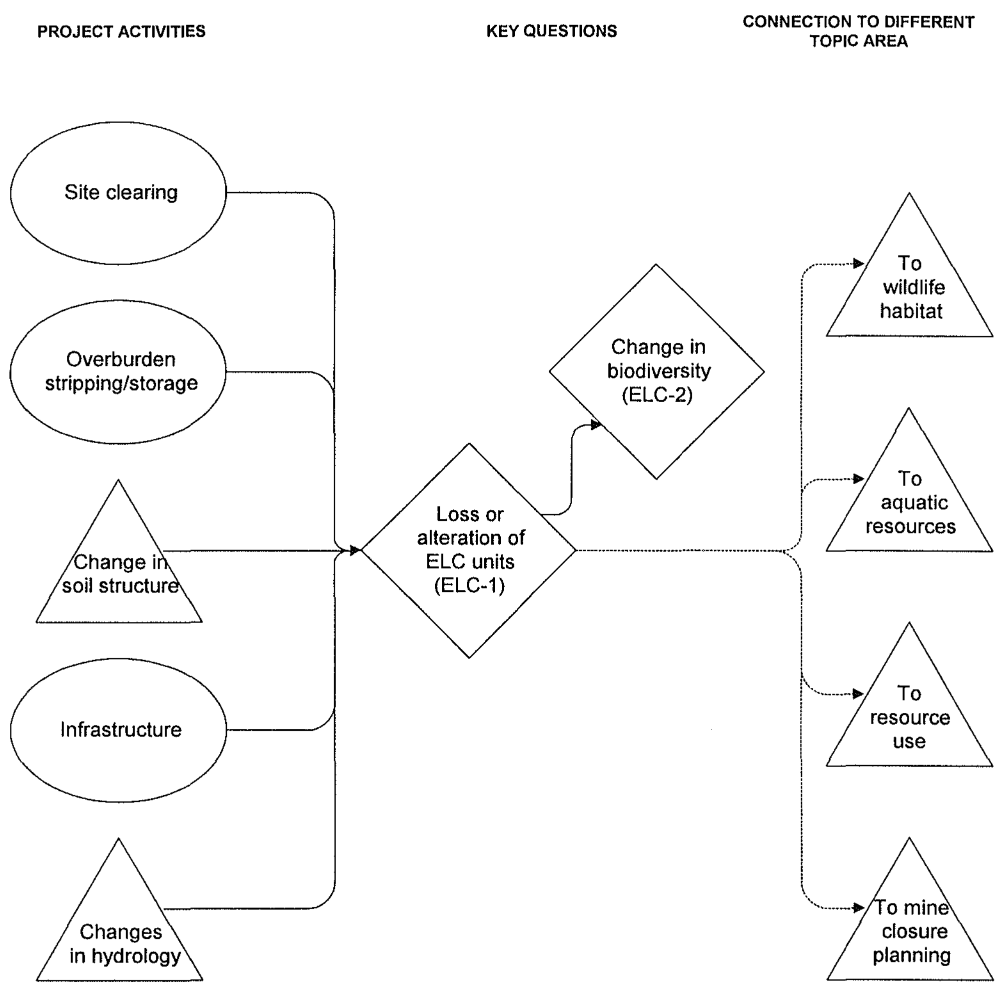
Scale	Level	Indices	Measures of Assessment
Landscape (ELC Section)	Composition	Richness • number of macroterrain units Diversity • macroterrain	decrease = loss in biodiversity decrease = loss in biodiversity
	Structure	Patch size (macroterrain) • mean • range (min-max)	increase/decrease = change in biodiversity decrease = loss of biodiversity
Community (ELC Section)	Composition	Diversity • number of types of ELC units in each macroterrain) Richness • number of polygons in each macroterrain	decrease = loss of biodiversity decrease = loss of biodiversity
	Structure	Patch size (ELC) • mean • range (min-max)	increase/decrease = change in biodiversity decrease = loss of biodiversity
Species	Composition	Species Richness and Diversity	See Vegetation (E9) and Wetlands (E10)
	Structural	Richness in Layers Diversity in Layers	

The first ELC linkage diagram (Figure E7-1) is used to demonstrate the potential impacts of Project construction and operation on the ELCs in the LSA. Project activities that may affect ELCs include, but are not limited to: site clearing, soil and overburden stripping and storage, development of Project facilities and changes to hydrology. The impacts from these activities are expected to include direct losses or alteration of ELCs as a result of site clearing and physical removal of ELCs, while the indirect losses may result from air emissions and/or water releases.

The impacts may also result in localized effects on ELCs, including changes in biodiversity. The linkage diagrams further demonstrate the potential pathways of change in other related resources, such as wildlife habitat and resource use, to the closure plan.

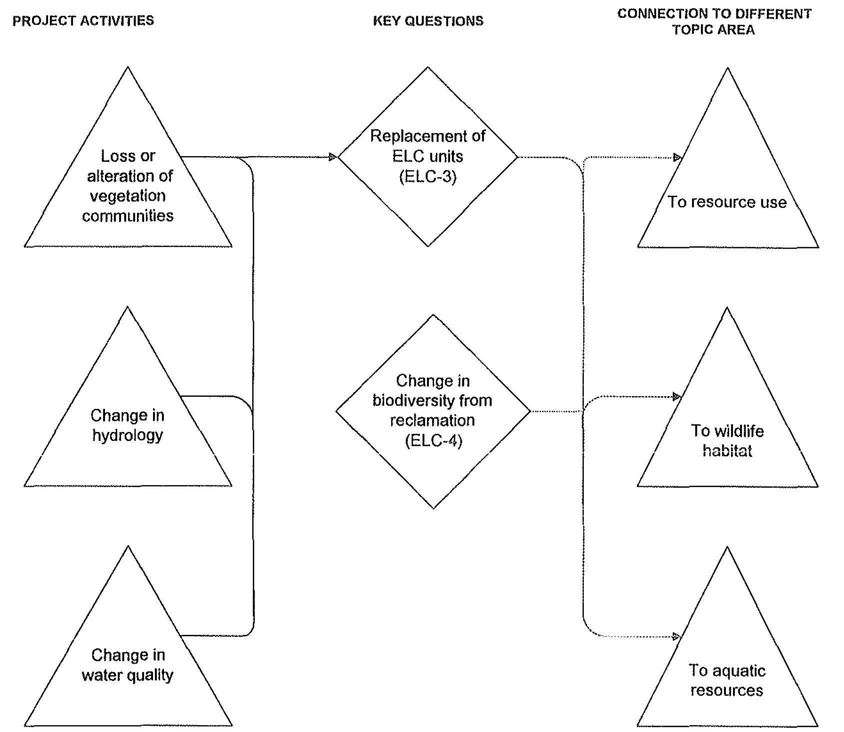
A second linkage diagram (Figure E7-2) was developed to identify the potential impacts on ELCs at (and beyond) Project closure as a result of reclamation activities.

Figure E7-1 Linkage Diagram for Ecological Land Classification for Construction and Operation Phases of Muskeg River Mine Project



r:\1997\2200\972-2237\7300\linkml.vsd

Figure E7-2 Linkage Diagram for Ecological Land Classification for Closure Phase of Muskeg River Mine Project



Project activities that will determine which ELC units will be re-established are reclamation activities that establish terrain and soils, such as grading and replacement of overburden and topsoil materials, and development of the end pit lake and surface drainage patterns. The terrain, soil type and moisture regimes established on reclamation sites will determine what plant communities will become re-established. The effects of re-established plant communities on resource use and wildlife habitat within the Project area are discussed in Sections E14 and E11.

The ELC issues may be summarized as follows:

- loss or alteration of ELCs in the LSA; and
- change in biodiversity.

Key questions for ELCs were developed based on the issues previously identified. A key question is an explicit question raised during the EIA process to guide data collection and analysis. They provide a focus to help determine the magnitude and significance of the effects of each potential impact on ELCs. Two key questions have been developed for ELCs:

ELC 1: Will the Activities From the Muskeg River Mine Project Result in a Loss or Alteration of ELC Units?

During construction and operation of the Muskeg River Mine Project, landscapes and their associated soil and vegetation may be substantially altered due to development The loss and/or alteration of ELCs are examined at the landscape level while loss of plant community and plant species level are examined in the Terrestrial Vegetation section (Section E9).

ELC 2: Will the Activities From the Muskeg River Mine Project Change Biodiversity?

The LSA is characterized by a diversity of landscapes, vegetation, soils and drainage conditions. As a consequence of the Project construction and operation phases, as well as subsequent reclamation, there is a concern that the biodiversity of the LSA will not be as diverse as the pre-development conditions. The time required for reclamation and revegetation to replace terrain, soils and vegetation conditions to a previous level of diversity is an issue.

E7.4 Key Question ELC-1: Will the Muskeg River Mine Project Result in a Loss or Alteration of ELC Units?

E7.4.1 Analysis of Potential Linkages

A loss or alteration of ELC units has been identified in the linkage diagrams (Figures E7-1 and E7-2) as a result of construction and operation phases and during mine closure, respectively. The primary direct impacts on ELC units will be through site clearing. Aquifer drawdown will primarily affect wetlands and this is discussed in Section E10.

E7.4.2 Impact Analysis

Table E7-2 presents areas of macroterrain units in the LSA, and the area and percent of each unit lost through clearing for the Muskeg River Mine Project.

The Athabasca Upland, Susan Lake Outwash Plain, Jackpine Creek Lowland and Jackpine Creek Bog macroterrain units will be unaffected by the Muskeg River Mine Project development. Impacts on the Athabasca Escarpment, Athabasca Riparian Floodpalin, Muskeg River Lacustrine Plain, Muskeg River Organic Lowland and the Muskeg River/Jackpine Creek Riparian macroterrain units will be negligible (<1% loss). Impacts to the Athabasca Terrace will be moderate (<20% loss).

Impacts on the MacKay Upland, Boucher Organic Plain, Muskeg River Midland, Jackpine Creek (Organic) plain will be high (>20% loss). The Creeburn Organic Plain will lose 77% of its pre-development area, while the MacKay Upland and the Boucher Organic Plain will lose 81% and 65%, respectively, of their pre-development areas within the LSA.

E7.4.3 Residual Impact Classification and Degree of Concern

A summary of residual impacts of the Muskeg River Mine Project on the macroterrain, or general landscape is provided in Table E7-3.

Table E7-2 Macroterrain Units Within the LSA

Macroterrain Units	Pre-Development		Development		Post-Closure	
	LSA (ha)	LSA %	Unit Lost (ha)	Unit Lost %	LSA ha	Change %
Athabasca Upland	770	7	0	0	770	0
Athabasca Escarpment	95	1	3	3	95	0
Athabasca Riparian Floodplain	251	2	7	3	251	0
Athabasca Riparian Terrace	711	6	122	17	589	17
Susan Lake Outwash Plain	517	5	0	0	517	0
Boucher Organic Plain	1,057	10	687	65	370	65
Creeburn Organic Plain	2,064	19	1,592	77	472	77
Jackpine Creek (Organic) Plain	843	8	220	26	629	26
Jackpine Creek Bog	15	<1	0	0	15	0
Jackpine Creek Lowland	171	2	0	0	171	0
Jackpine Creek Upland	75	1	0	0	75	0
MacKay Upland	815	7	657	81	158	81
Muskeg River/Jackpine Creek Riparian	488	4	3	1	488	0
Muskeg River Lacustrine Plain	212	2	15	7	212	0
Muskeg River Midland	2,511	23	1,036	42	1,472	42
Muskeg River Organic Lowland	359	3	1	<1	359	0
Reclaimed Landscapes					4,317	39
TOTAL	10,954	100%	4,343		10,954	

E7.5 Key Question VE-2: Will the Muskeg River Mine Project Change Biodiversity?

E7.5.1 Analysis of Potential Linkages

Losses or alteration of landforms or macroterrain units due to site clearing, overburden stripping and storage, and other developments associated with the Project will change biodiversity in the LSA. Biodiversity, which is an expression of landscape level heterogeneity, will be altered due to the partial removal of landforms or macroterrain units. Thus, this is a valid linkage for assessment.

E7.5.2 Impact Analysis

The key question, **Will the Muskeg River Mine change biodiversity?**, has been divided into a number of issues that examine changes at the landscape, community and species scales, and which address diversity in terms of composition and structure. Species scale biodiversity is discussed in the Vegetation section (E9) and the Wetlands section (E10). Each issue is examined by means of a table that details the current values of diversity and the changes expected during the construction and operations phases of the mine.

Table E7-3 Residual Impact Classification on the Loss/Alteration of ELC Macroterrain Units in the Local Study Area

Macroterrain Unit	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
Athabasca Upland	neutral	none	N/A	N/A	N/A	N/A	N/A
Athabasca Escarpment	negative	negligible	local	long-term	irreversible	low	low
Athabasca Riparian Floodplain	negative	negligible	local	long-term	irreversible	low	low
Athabasca Riparian Terrace	negative	moderate	local	long-term	irreversible	low	moderate
Susan Lake Outwash Plain	neutral	none	N/A	N/A	N/A	N/A	N/A
Boucher Organic Plain	negative	high	local	long-term	irreversible	low	high
Creeburn Organic Plain	negative	high	local	long-term	irreversible	low	high
Jackpine Creek (Organic) Plain	negative	high	local	long-term	irreversible	low	high
Jackpine Creek Bog	neutral	none	N/A	N/A	N/A	N/A	N/A
Jackpine Creek Lowland	neutral	none	N/A	N/A	N/A	low	N/A
Jackpine Creek Upland	neutral	none	N/A	N/A	N/A	N/A	N/A
MacKay Upland	negative	high	local	long-term	irreversible	low	high
Muskeg River/Jackpine Creek Riparian	negative	negligible	local	long-term	irreversible	low	low
Muskeg River Lacustrine Plain	negative	negligible	local	long-term	irreversible	low	low
Muskeg River Midland	negative	high	local	long-term	irreversible	low	high
Muskeg River Organic Lowland	negative	negligible	local	long-term	irreversible	low	low

E7.5.3 Landscape Level Biodiversity

The loss of areas in each macroterrain unit is presented in Table E7-2. The use of landscape or macroterrain units as a framework for the setting of landscape scale biodiversity objectives is considered by Iacobelli et al. (1995) to be the best ecological framework for the conservation of biodiversity. Such landscape units are enduring features of the earth's surface, versus the more ephemeral biotic features such as vegetation cover. The ELC developed for the Muskeg River Mine Project uses a combination of terrain, soils and vegetation features to map macroterrain units.

Eleven of the 16 macroterrain units will have portions disturbed as a result of the Project. The Athabasca River Valley (escarpment, floodplain and riparian terrace) and associated uplands (Athabasca Upland and Susan Lake Outwash Plain) will either be unaffected or marginally (<2%) affected by the Project. The areas disturbed include Creeburn Organic Plain, Boucher Organic Plain and units associated with the Muskeg River.

Compositional Biodiversity

Species richness, diversity index, and a comparison of the size of landscape units were used to determine the changes in the overall diversity at the landscape level (Table E7-4).

Table E7-4 Changes in Macroterrain at the Landscape Scale in the LSA

	Pre-Development	Far Future
Richness	16 types	16 types
Shannon Diversity Index	1.01	0.78
Range of Landscape Areas	15 to 2,481 ha	15 to 1,434 ha
Mean Landscape Size	685 ha	413 ha
CV of Landscape Size	1.03	0.85

The Project will not completely remove any one macroterrain unit, but only portions of areas within macroterrain units. As such, the Project does not alter the richness values for macroterrain units (i.e., 16 macroterrain units will still be present after construction). The Shannon Diversity Index does indicate a reduction in macroterrain diversity from 1.01 to 0.78 after construction. This is reflected in the mean macroterrain size being reduced from 685 ha to 413 ha.

Changes in the number of ELC types present in each macroterrain unit before and after Project closure is an expression of compositional biodiversity. Richness and Shannon diversity measures of ELC types are presented in Table E7-5.

The highest loss to ELC types is the Creeburn Organic Plain, which indicates a loss in richness of 20. This is expressed by the Shannon diversity index as a reduction from 1.03 to 0.86. The Athabasca Riparian Terrace (30-26; 1.07-1.04), Jack Pine Creek Organic Plain (34-31; 0.73-0.69), MacKay Upland (28-17; 0.98-0.85) and Muskeg River/Jackpine Riparian Zone (60-58; 1.13-1.18) indicate smaller losses in richness and diversity value. The richness and diversity if most ELC units does not change.

Table E7-5 ELC Richness and Diversity Indices

	Pre-Development		Closure	
Landscape Units	Richness (ELC Types)	Shannon Diversity Index	Far Future Richness (ELC Types)	Far Future Shannon Diversity
Athabasca Upland	22	0.97	22	0.97
Athabasca Escarpment	15	0.70	15	0.70
Athabasca Riparian Floodplain	29	1.09	29	1.07
Athabasca Riparian Terrace	30	1.07	26	1.04
Susan Lake Outwash Plain	19	0.56	19	0.56
Boucher Organic Plain	36	1.00	22	1.12
Creeburn Organic Plain	49	1.03	29	0.86
Jackpine Creek (Organic) Plain	34	0.73	31	0.69
Jackpine Creek Bog	1	0.00	1	0.00
Jackpine Creek Lowland	14	0.85	14	0.85
Jackpine Creek Upland	23	1.06	23	1.06
MacKay Upland	28	0.98	17	0.85
Muskeg River / Jackpine Riparian Zone	41	0.68	40	0.68
Muskeg River Lacustrine Plain	13	0.58	13	0.59
Muskeg River Midland	60	1.13	58	1.18
Muskeg River Organic Lowland	37	0.88	37	0.88
Total	446	1.98	396	1.99

Structural Biodiversity

The impacts to landscape level structural biodiversity are mainly concerned with changes in the vegetation polygon (patch) number and size distribution across the LSA. Stand level structural impacts within forested areas are focused on the changes in living and dead structure (i.e., residual patches) within the LSA.

Number of Polygon (Patch Number)

The number of ELC polygons or patches represented in the LSA before and after Project closure are presented in Table E7-6. Patch number and size provided an assessment of structural changes in biodiversity at the landscape scale.

Table E7-6 Number of ELC Polygons (Patches)

Landscape Units	Pre-Development Number of ELC Polygons	Closure Number of ELC Polygons	Percent Loss Within Landscapes	Percent of Total Units Lost
Athabasca Upland	198	198	0.0	0.0
Athabasca Escarpment	49	39	20.4	0.2
Athabasca Riparian Floodplain	171	152	11.1	0.4
Athabasca Riparian Terrace	202	141	30.2	1.2
Susan Lake Outwash Plain	88	88	0.0	0.0
Boucher Organic Plain	455	152	66.6	5.9
Creeburn Organic Plain	1022	237	76.8	15.3
Jackpine Creek (Organic) Plain	273	181	33.7	1.8
Jackpine Creek Bog	1	1	0.0	0.0
Jackpine Creek Lowland	64	64	0.0	0.0
Jackpine Creek Upland	58	58	0.0	0.0
MacKay Upland	529	145	72.6	7.5
Muskeg River/Jackpine Riparian	254	235	7.5	0.4
Muskeg River Lacustrine Plain	69	56	18.8	0.3
Muskeg River Midland	1505	867	42.4	12.4
Muskeg River Organic Lowland	206	196	4.9	0.2
Total	5144	2810	45.4	45.4

ELC types most affected, expressed as a percentage loss from the Project, are in the Boucher Organic Plain (66.8% lost), Creeburn Organic Plain (76.8%), Jackpine Creek Organic Plain (33.7%), MacKay Uplands (72.6%), Muskeg River Lacustrine Plain (18.8%), Muskeg River Midland (42.4%), and Riparian Terrace (30.2%). Five of the 16 landscape units are not altered.

Polygon Size (Patch Size)

The mean, minimum and maximum patch size of each ELC polygon or patch in the LSA is presented in Table E7-7. Patch number and patch size are used in the forest industry to assess maximum cutblock sizes and reforestation efforts. In mining, an assessment of natural patch number and size distribution provides a target for assessing and monitoring reclamation efforts.

Table E7-7 Mean, Minimum and Maximum Patch Size

	Minimum and Maximum Size of ELC Polygons Pre- and Post-Development					
Landscape Units	Baseline Mean Size (ha)	Baseline Minimum Area (ha)	Baseline Maximum Area (ha)	Impact Mean Size (ha)	Impact Minimum Area (ha)	Impact Maximum Area (ha)
Athabasca Upland	3.89	0.0005	60.72	3.89	0.0005	60.72
Athabasca Escarpment	1.93	0.0004	24.62	2.34	0.0004	24.62
Athabasca Riparian Floodplain	1.47	0.0003	38.26	1.60	0.0003	38.26
Athabasca Riparian Terrace	3.52	0.0002	54.08	4.17	0.0002	54.08
Susan Lake Outwash Plain	5.87	0.0005	292.00	5.87	0.0005	292.00
Boucher Organic Plain	2.32	0.0003	83.48	2.44	0.0003	38.59
Creeburn Organic Plain	2.02	0.0002	73.16	1.99	0.0002	34.54
Jackpine Creek (Organic) Plain	3.09	0.0004	85.39	3.44	0.0005	85.39
Jackpine Creek Bog	14.76	14.7562	14.76	14.76	14.7562	14.76
Jackpine Creek Lowland	1.48	0.0003	12.25	1.48	0.0003	12.25
Jackpine Creek Upland	1.31	0.0003	7.43	1.31	0.0003	7.43
MacKay Upland	1.75	0.0003	33.86	2.16	0.0005	33.86
Muskeg River/Jackpine Riparian	1.92	0.0002	169.40	2.06	0.0002	169.40
Muskeg River Lacustrine Plain	3.07	0.0004	31.06	3.51	0.0004	31.06
Muskeg River Midland	1.65	0.0001	62.98	1.67	0.0001	62.98
Muskeg River Organic Lowland	1.74	0.0002	37.85	1.83	0.0002	37.85
Total	2.13	0.0001	292.00	2.37	0.0001	292.00

Range and average patch sizes of ELCs will change for some of the macroterrain units as a result of the Project. The largest changes are in the Boucher Organic Plain and Creeburn Organic Plain, which indicates a decrease in variability in patch sizes. This indicates that larger patches will be lost to the Project but smaller patches will remain. Five of the 16 landscape units are not altered.

E7.5.4 Residual Impact Classification and Degree of Concern

At the landscape level of biodiversity assessment (Table E7-8), the impacts can be described as negative in direction, low to moderate in magnitude, of local geographic extent, long-term in duration, irreversible and of low frequency. The degree of concern is low to moderate.

Table E7-8 Residual Impact Classification of Landscape Level Biodiversity

Macroterrain Units	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
Athabasca Upland	negative	none	n/a	n/a	n/a	n/a	n/a
Athabasca Escarpment	negative	negligible	local	long-term	reversible	low	low
Athabasca Riparian Floodplain	negative	negligible	local	long-term	reversible	low	low
Athabasca Riparian Terrace	negative	low	local	long-term	reversible	low	low
Susan Lake Outwash Plain	negative	none	n/a	n/a	n/a	n/a	n/a
Boucher Organic Plain	negative	low	local	long-term	reversible	low	low
Creeburn Organic Plain	negative	moderate	local	long-term	reversible	low	moderate
Jackpine Creek (Organic) Plain	negative	low	local	long-term	reversible	low	low
Jackpine Creek Bog	negative	none	n/a	n/a	n/a	n/a	n/a
Jackpine Creek Lowland	negative	none	n/a	n/a	n/a	n/a	n/a
Jackpine Creek Upland	negative	none	n/a	n/a	n/a	n/a	n/a
MacKay Upland	negative	low	local	long-term	reversible	low	low
Muskeg River/Jackpine Riparian	negative	negligible	local	long-term	reversible	low	low
Muskeg River Lacustrine Plain	negative	negligible	local	long-term	reversible	low	low
Muskeg River Midland	negative	moderate	local	long-term	reversible	low	low
Muskeg River Organic Lowland	negative	negligible	local	long-term	reversible	low	low
LSA (total)	negative	negligible	local	long-term	reversible	low	low

E7.6 Monitoring

The establishment and development of revegetated plant communities on a variety of reclamation surfaces will be monitored as part of the far future environmental monitoring program for the Project. Biodiversity will be monitored at the landscape level using an ELC approach that will include an assessment of terrain (slope, slope aspect), drainage, reclamation soil type and revegetated plant community development, over time

E8 TERRAIN AND SOILS

E8.1 Introduction

This section of the Muskeg River Mine Project (the Project) EIA provides information as required by the Project Terms of Reference (TofR) issued on November 7, 1997 (AEP 1997a). Specifically, the following are addressed in this section:

- provision of an assessment of the potential changes (type and extent) to the pre-development topography, elevations and drainage patterns within the Project area resulting from surface disturbance during construction, operation and reclamation;
- provision of a pre- and post-development land capability assessment of the Project area and description of impacts to land capability due to the Project;
- identification of the distribution of pre- and post-development land capability on a map; and
- description of the availability and suitability of soils within the Project area for reclamation (TofR, Sections 4.3).

Discussions on the potential cumulative effects on terrain and soils associated with the Project are addressed in Section F8. Section D8 provides details on the terrain and soils baseline for the Project, the complete baseline report may be found in the Terrain and Soil Baseline for the Muskeg River Mine Project (Golder 1997m). Information on soil reclamation plans, soil salvaging, stockpiles and other factors associated with the reclamation of the Project development area are reviewed in Section E16 of this document (Closure Planning), as well as in Section 16.5 (Conservation and Reclamation Plan) of Volume 1 of the Application.

Evaluation of the impacts of the Project on terrain and soils included:

- the generation of impact Key Questions;
- developing linkages for each Key Question;
- delineating the Local and Regional Study Areas (LSA and RSA);
- developing impact assessment criteria;
- assessing the validity of the Key Question linkages;
- developing mitigation strategies for each valid linkage; and
- evaluating the impact assessment criteria for each valid linkage.

No key indicator resources (KIRs) were selected for the terrain and soils component of the Project.

E8.2 Key Questions and Linkages

The first phase of the evaluation of terrain and soils involved identifying Key Questions and developing linkage diagrams to illustrate possible impacts the development might have on the terrain and soils. These linkages are considered under two scenarios: construction and operation (Figure E8-1) and closure (Figure E8-2). Three Key Questions were formulated to encompass the most significant impacts associated with the Project

TS-1 Will the Activities From the Muskeg River Mine Project Result in Loss or Alteration of Terrain and Soils?

The areas and spatial distribution for each terrain and soil unit type were determined for the LSA. Next, the disposition of areas to be disturbed by the Project development were mapped and their extent calculated. Comparison of these figures allowed a quantification of Project impacts with respect to areas of terrain and soil units affected.

TS-2 Will Reclamation for the Muskeg River Mine Project Change Distribution of Terrain and Soils?

The spatial extent and distribution for each terrain and soil unit type in the post-reclamation landscapes for the LSA was determined. The number of units altered by the Project were computed.

TS-3 Will the Reclamation of the Disturbed Area for the Project Change Soil Productivity?

Forest productivity ratings were derived for each soil series in the LSA for the pre-construction landscape and compared to those for the proposed post-reclamation landscape.

E8.3 Study Area Boundaries

The spatial boundaries for the LSA and RSA are defined in Section D1 of this EIA and illustrated in Figure D1-3 and D1-2.

Figure E8-1 Linkage Diagram for Terrain and Soils for Construction and Operation Phase of Muskeg River Mine Project

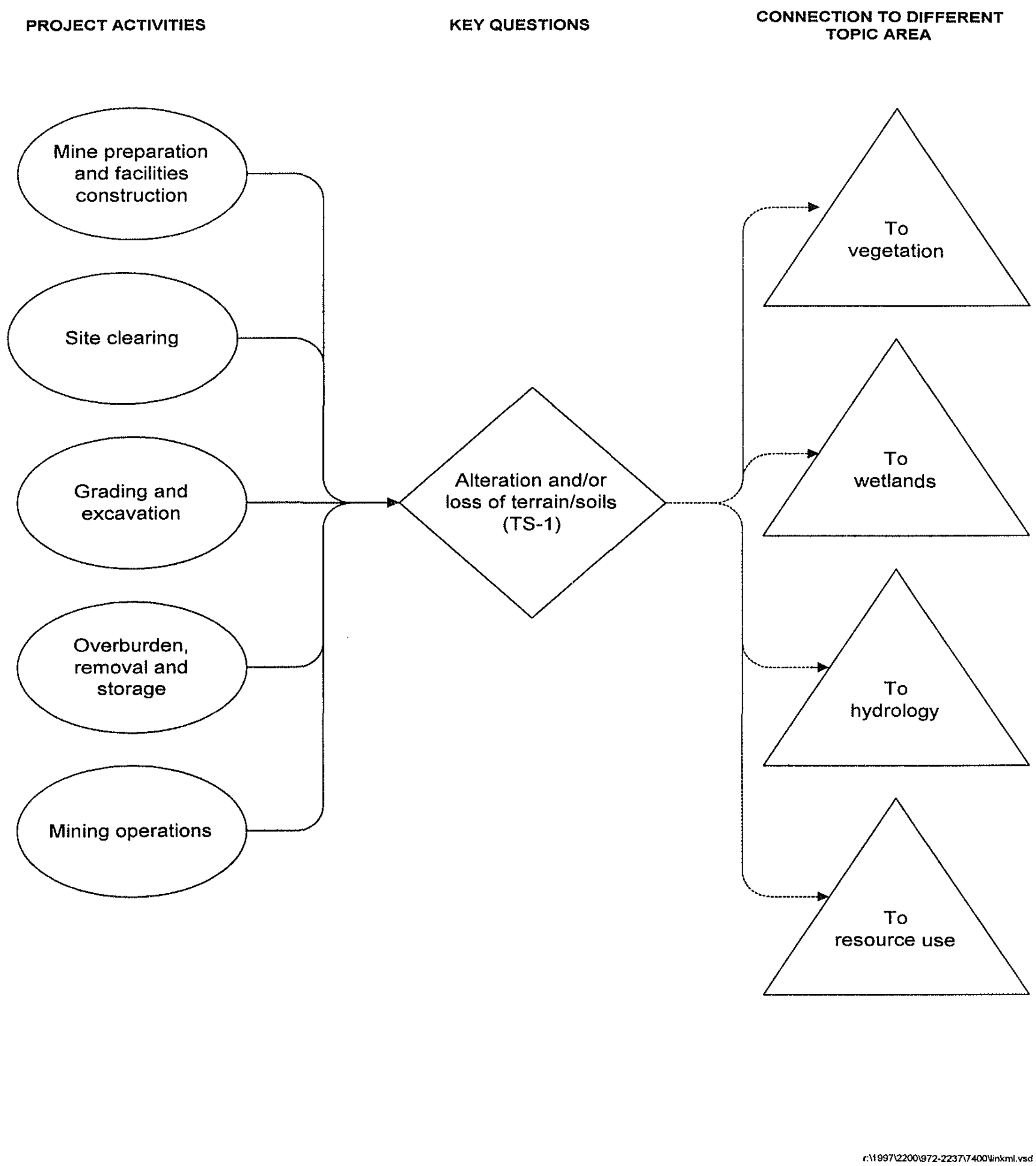
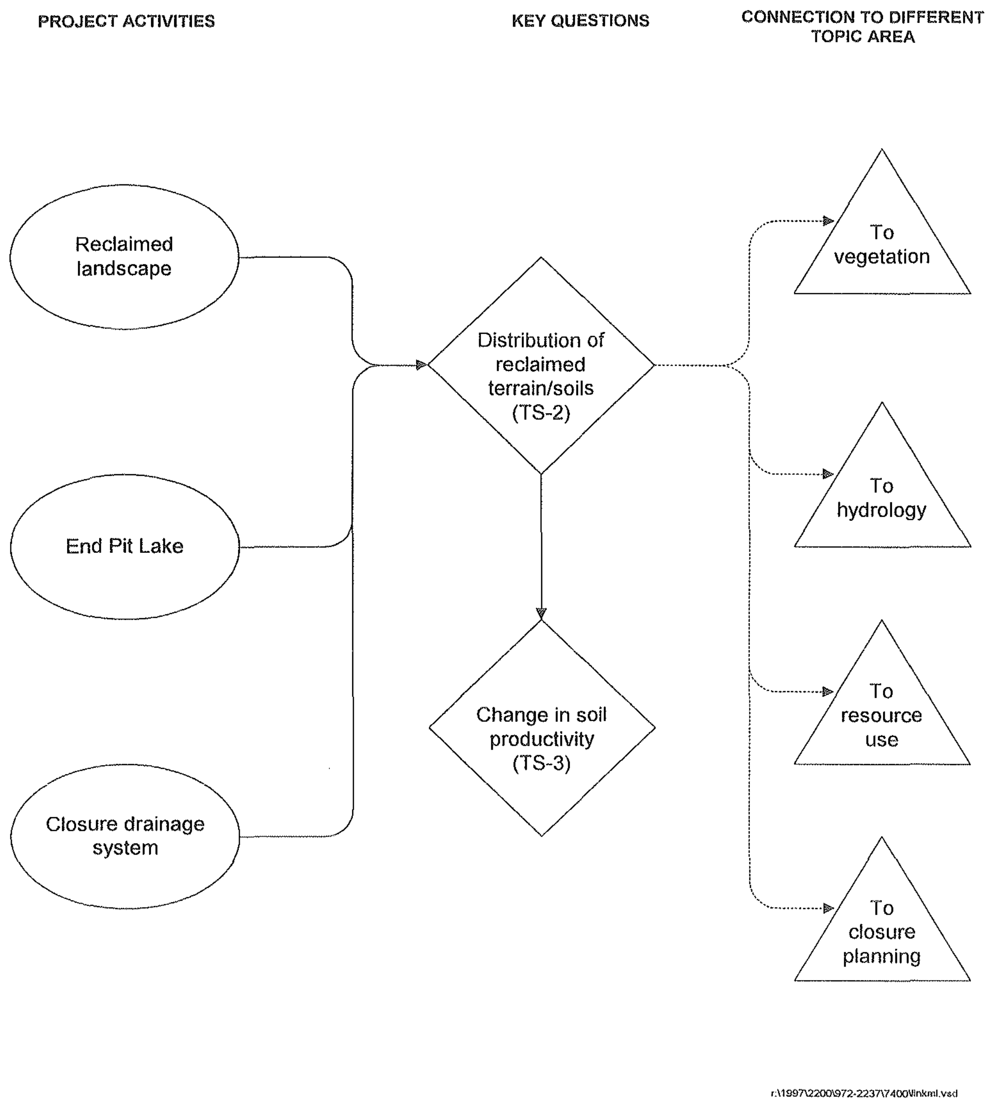


Figure E8-2 Linkage Diagram for Terrain and Soils for Closure Phase of Muskeg River Mine Project



The temporal boundaries for this EIA were defined as:

- Baseline (1997)
- Construction Phase (1999 -2002)
- Operations and Reclamation Phase (2003 - 2030)
- Closure

These timeframes were chosen because the area developed by the Project will vary between the construction and operations phases. Additionally, a longer-term view of the Project at closure is essential in evaluating the likelihood of success of the proposed mitigation and reclamation measures.

E8.4 Methods

E8.4.1 Linkage Validation

Linkages between Project activities and potential environmental changes that apply to each of the Key Questions were assessed for their validity based upon field data collected within and proximal to the LSA, review of the relevant literature, consultation with other disciplines involved in this EIA and professional judgment.

E8.4.2 Mapping Techniques

The primary tool used in this assessment was mapping of the spatial distribution of the various soil series. The soil map units, or polygons, were given specific attributes based upon the analysis of field samples collected for this evaluation. The terrain map units were derived by amalgamating all the soil polygons having similar genetic material (e.g., glaciofluvial deposits). A second level of terrain analysis was undertaken by visually examining the colour plots and, in conjunction with vegetation community data and elevations from a digital terrain model, combining units of different materials into large, heterogeneous units. These terrain macro-units were generally composed of greater than 95% from two terrain types (e.g., fen and glaciolacustrine). This process of combining terrain units is outlined in greater detail in Section D7 of this EIA.

E8.4.3 Development of Mitigation Measures

Mitigation, within the context of an EIA, may be defined as follows: "the application of design, construction or scheduling principles to minimize or eliminate potential adverse impacts and, where possible, enhance environmental quality" (Sadar 1994). Many of the impacts associated with this Project may be amenable to mitigation if appropriate environmental strategies are applied during the planning, construction and operations, and closure phases of the development. These strategies may include: a)techniques for and timing of initial soil salvage; b)sequencing of the stripping and replacement operations to minimize or eliminate stockpiling of the reclamation resources; and c)appropriate design of the reconstructed landforms to optimize the potential for returning the Project development area to a capability equivalent to the pre-development state.

Mitigation suggestions were devised for each valid linkage pathway.

E8.4.4 Impact Assessment Classification and Degree of Concern

The criteria for the impact assessment classification and degree of concern are described in Sections E1.3.8 and E1.3.9

E8.5 Monitoring

An effects monitoring program is generally deemed essential to assess whether:

- the predicted impacts occur or not; and
- the mitigation measures will achieve the objectives.

Compliance monitoring will also be required to determine whether conditions of the project approval are being met.

E8.6 Key Question TS-1: Will the Activities From the Muskeg River Mine Project Result in Loss or Alteration of Terrain and Soils?

E8.6.1 Analysis of Potential Linkages

This Key Question will deal with the direct impacts of the Project activities on the loss or alteration of terrain and soils in the LSA. Direct changes occur with the alteration of terrain features and removal of soil during construction of the mine and its associated infrastructure (Figure E8-1). These changes can be calculated and the areas of each component catalogued.

A second direct impact of Project activities on soils in the LSA, albeit one that is difficult to quantify, is the alteration in soil chemical properties due to acid deposition caused by Project operations. Soil acidification is not a simple emission-deposition-acidification correlation, rather the effects are complex, subtle, long-term and ecosystem-specific (Cheng and Angle 1993). This aspect of alterations may best be evaluated as potentials, not as direct cause and effect.

Modelling of the hydrogeology for the Project (Section E3 of this EIA) indicates surficial aquifer drawdown is likely to extend between 1 and 2 km around the Project mine footprint. The primary impact of this will be lowering of the water table which will impact soil drainage; however, this presents two potential scenarios. First, many of the LSA soils are rated as being non-productive for forest ecosystems mainly due to the high water table. Lowering this level may well enhance the capability of much of the organic soil in the LSA to support productive forest cover. A second aspect, as discussed in Section E10 is the potentially negative impact on fen systems due to reduction in through-flow resulting from the drawdown.

The direction and magnitude of this impact are undetermined at this time hence no degree of concern can be assigned.

E8.6.2 Analysis of Terrain and Soil Unit Losses/Alterations

Activities which will result in the loss or alteration of terrain and soil units in the LSA include:

- clearing and grading of the soils to permit facility construction followed by relocation and storage of the soil materials;
- grading, excavating of overburden followed by removal and storage; and
- sequential expansion of the mining operations over time.

Preparation of the areas for mining and facilities construction will involve complete removal of the organic soil cover. Reclamation will begin soon after construction, proceed incrementally throughout the operations phase of the Project and finish with closure. The preference is for direct placement of the salvaged material on newly reclaimed surfaces. If this is not feasible it will be either stored in designated stockpile areas for future reclamation applications or discarded. Organic materials will not be stripped from the locations specified for the tailings settling pond, in overburden disposal areas or where reclamation materials are stored (RMS). Similarly the excavation and storage of the overburden which is required to expose the ore body for mining will completely remove any existing terrain features in the affected areas.

The impact of these activities can be quantified by calculating the extent of each terrain and soil unit type in the pre-development landscape, then computing the areas of each that will be removed during Project construction and operation. The difference between the two will be the direct impact on these two resources. Tables E8-1 and E8-2 provide details on the areas of the terrain and soil units (respectively) in the pre-construction and closure landscapes of the LSA, which are illustrated in Figures D8-2 and E8-3 respectively.

Removal and alteration of terrain and soil units will occur as a result of the Project activities. The operation will be developed progressively across the landscape followed by phased reclamation. However, the impact on terrain and soils will be that of the maximum extent of the development footprint.

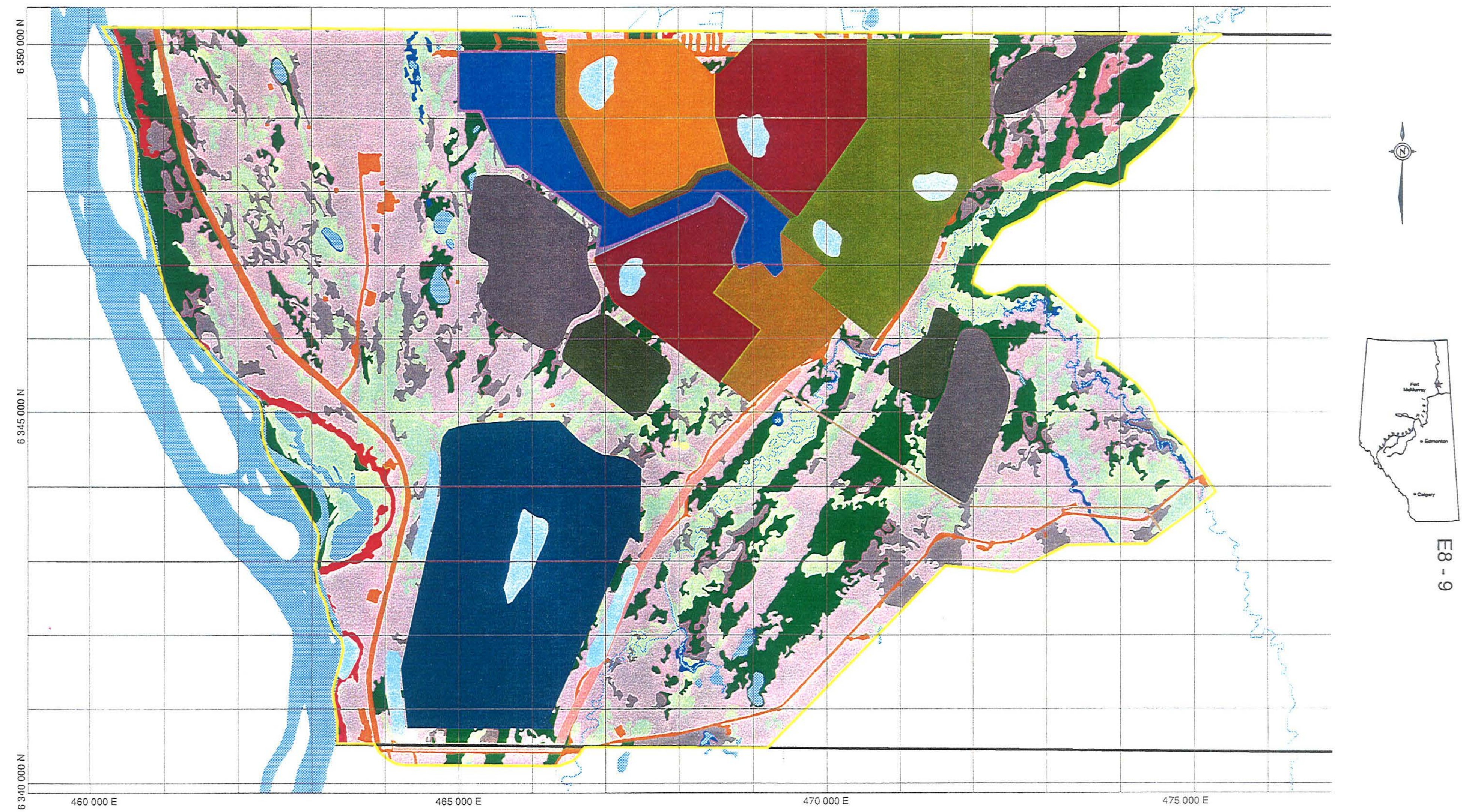
Terrain Units

As is shown in Table E8-1 the major units that will be affected by Project development will be the fens and shallow fens (organics) and glaciofluvial units. While these will be removed from the landscape much of the material will be used to recontour the surface and construct new landforms (mineral materials) in the closure phase while the organics will be salvaged for use as the reclamation soil cover in the closure landscape or discarded. It can be seen that while the pre-existing terrain units will not be restored to their original form, a suite of new more diverse landforms will take their place.

Table E8-1 Losses/Alterations of Terrain Units in the Local Study Area

Terrain Units	Pre-Development Area		Direct Loss Within the LSA		% of Terrain Unit	Closure Landscape	
	ha	% of LSA	ha	% of LSA		ha	% of LSA
Bog	4	<0.1	3	<0.1	75	1	<0.1
Shallow bog	16	0.2	13	0.1	81	3	<0.1
Fen	2,155	19.6	1,034	9.5	48	1,121	10.2
Shallow fen	2,300	21.0	880	8.0	38	1,420	13.0
Fluvial	88	0.8	12	0.1	14	76	0.7
Glaciofluvial	1,045	9.6	495	4.5	47	550	5.0
Glaciofluvial 1	2,760	25.2	1,150	10.5	42	1,609	14.7
Glaciofluvial 2	1,277	11.6	437	4.0	34	840	7.7
Glaciofluvial 3	444	4.1	0	0.0	0	444	4.1
Glaciolacustrine	42	0.4	1	<0.1	2.3	41	0.4
Rough Broken	98	0.9	5	<0.1	5	93	0.9
Disturbed lands [(a)]	540	4.9	273	2.5	50.6	267	2.4
Open water and stream channels [(b)]	185	1.7	39	0.4	21	146	1.3
Sub Total	**10,954**	**100**	**4,343**	**39.6**		**6,611**	**60.4**
Reclaimed Units:							
Overburden Capped CT							6.1
• wetlands						27	
• terrestrial						645	
Sand Capped CT							6.2
• wetlands						30	
• terrestrial						646[(c)]	
Sand Capped Overburden							3.4
• wetlands						21	
• terrestrial						354[(c)]	
Tailings Settling Pond							9.5
• wetlands						38	
• terrestrial						1,001	
End Pit Lake							
• wetlands						99	0.9
Overburden disposal areas						548	5.0
RMS (muskeg)						190	1.7
Plant site						202	1.8
Utility Corridor						87	0.8
Pipeline RoW						17	0.2
Sub-Total						**3,905**	**35.6**
Open water							
• end pit lake						343	3.1
• ditches and ponds						95	0.9
Sub-Total						**438**	**4.0**
Total New Landforms						4,343	43.1
Total	10,954	100	4,343	39.6		**10,954**	**100.0**

(a) Includes such features as gravel pits, existing roads and previous development (Alsands, OSLO).
(b) Non-soil components of the LSA.
(c) Components of the LSA.
Note: Shaded area is not applicable



LEGEND

Local Terrestrial Study Area
Lease 13
Open Water

TERRAIN UNITS

Glacio-Fluvial (Fg,Fg1,Fg2,Fg3)
Fluvial (F)
Glacio-Lacustrine (Lg)
Fen (N)
Shallow Fen (Ns)
Bog (B)
Shallow Bog (Bs)
Rough Broken (RB)
Cultural Features and Disturbed Lands

CLOSURE TERRAIN

Constructed Wetland
D2
Disposal Area
End Pit Lake
Existing
Fixed Plant
Overburden Capped CT
RMS
Riprap
Sand Capped CT
Sand Capped Overburden
Tailings Settling Pond
Littoral Zone

SOURCE: The Forestry Corp., CanAg Enterprises Ltd., Golder Associates Ltd.

1 0 1 2
Kilometers

MAP PROJECTION: Universal Transverse Mercator Zone 12 DATUM: NAD 83

Golder Associates

SHELL CANADA LIMITED

MUSKEG RIVER MINE PROJECT
CLOSURE TERRAIN
CLASSIFICATION

5 Dec. 1997	Figure E8-3	PRODUCED BY: J..S./R.P. REVIEWED BY:

/data8/oilsands/972-2237/9700/9701/final/arcview/recter50fin.apr

Soil Units

Table E8-2 describes the loss/alteration to soil units due to Project activities. The naturally occurring soils will not be restored at closure, but will be replaced by a uniform reclamation soil mix that is approximately 60% peat (organic) and 40% mineral in composition. This will be applied to a uniform depth over all the non-wetlands areas in the reclaimed landscape. Its capacity to support vegetation regrowth will vary directly with the depth of the water table below the surface. The water table depth is controlled by the geotechnical specification of the recontoured structures. Note that the main soils affected by development will be currently non-productive organics at the McLelland series and the coarse textured, low-productivity mineral soils of the Bitumount and Mildred series.

A full description of each soil unit and the techniques by which the terrain units were derived may be found in the report, Terrain and Soil Baseline for the Muskeg River Mine Project (Golder 1997m).

Table E8-2 Losses/Alterations of Soil Units in the Local Study Area

Soil Unit	Pre-Development Area		Direct Loss Within the LSA			Closure Landscape	
	ha	% of LSA	ha	% of LSA	% of Soil Unit	ha	% of LSA
Bitumount	1,915	17.5	875	8.0	45.7	1,040	9.5
Dover	42	0.4	1	<0.1	2.4	41	0.4
Fort	652	6.0	143	1.3	21.9	509	4.6
Mildred	1,895	17.3	715	6.5	37.7	1,180	10.8
McLelland	4,144	37.8	1,800	16.4	43.4	2,344	21.4
McMurray	88	0.8	12	0.1	13.6	76	0.7
Muskeg	340	3.1	175	1.6	51.5	165	1.5
Ruth Lake	445	4.1	0	0	0	445	4.1
Steepbank	610	5.6	305	2.8	50.0	305	2.8
Rough broken	98	0.9	5	≤0.1	5.1	93	0.8
Disturbed lands	540	4.9	273	2.5	50.6	267	2.4
Open water and stream channels[c]	185	1.7	39	0.4	21.1	146	1.3
Sub-Total	**10,954**	**100**	**4,343**	**39.6**		**6,611**	**60.4**
Wetlands						217	2.0
Reclamation soil						3,279	29.9
Plant site [a]						202	1.8
Muskeg dumps [b] (RMS)						190	1.7
Pipeline						17	0.15
Sub-Total						**3,905**	**35.6**
Open water						438	4.0
Sub-Total						**4,343**	**39.6**
TOTAL	**10954**	**100**	4343	39.6		**10,954**	**100.00**

[a] Will most likely be covered with reclamation soil mix.
[b] Muskeg Dumps: area will not be stripped prior to use, therefore is unlikely to have any amendments applied at closure.
[c] Non-soil components to the LSA.
Note: Shaded area is not applicable.

E8.6.3 Residual Impacts and Degree of Concern

Terrain

Approximately 40% of the naturally occurring units will be affected although to varying degrees. The principal areas lost will be in the fen and glaciofluvial units. While these may appear to be negative Table E8-1 indicates that the closure landscape will in fact be composed of a greater variety of landform types. From a terrain variability perspective the alterations brought about by the Project will be substantial in nature and increase the diversity therefore positive in direction.

Soils

Similar to the impacts on terrain, approximately 40% of the soil units in the LSA will be affected by Project activities. The majority of these soils fall into the organic and coarse glaciofluvial classes which are relatively unproductive with respect to forestry. In the closure scenario, some of these materials will have been salvaged and used as reclamation soil material in the new landscape. In concert with the greater diversity in topographic relief, these soils will enhance the overall productivity of the ecosystem. Overall this may be viewed as a positive impact of significant proportions.

E8.6.4 Mitigation

A significant aspect of the construction and operational phase of the Project is incremental reclamation which accompanies mine development. As a result, new terrain features (reclaimed landscapes) covered with a reclamation soil mixture will mitigate the losses/alterations of pre-development terrain and soil conditions. Reclamation is viewed as mitigating Project activities by replacing rather than restoring pre-development conditions. Furthermore, as outlined in Section E16 of this EIA (Closure Planning), the diversity of the landscape will be increased by the greater degree of relief and slope conditions associated with the variety of the reconstructed surface features.

E8.6.5 Monitoring

During stripping of the organic soil materials, monitoring will be conducted to ensure correct soil salvage and handling procedures. As set out in the Conservation and Reclamation document for this Project (Section 16, Volume 1), a degree of over-stripping to incorporate specified amounts of mineral substrate is required for building the reclamation soil. Monitoring will ascertain that stripping is carried out as required in the correct soil and terrain units. Once stockpiled, the salvaged materials will be allowed to naturally revegetate to minimize potential losses to wind and water erosion.

E8.6.6 Soil Acidification

The potential for changes in soil chemistry exists when acidifying emissions are introduced into an ecosystem. Soil sensitivity to such inputs is strongly correlated with pH and the sum of basic ions present (i.e. a soil's inherent buffering capacity). The two emissions with the greatest potential of causing acidification are oxides of nitrogen (NO_x) and oxides of sulphur(SO_x). However, operations of the Project will produce no sulphur emissions and negligible levels of nitrogen oxides, see Section E2 in this EIA. Even though the soils in the LSA are mapped as having moderate to high sensitivities to acid inputs, the effect of even small additional amounts of acidifying ions is uncertain. Bloom and Grigal (1985), Cheng and Angle (1993) and Holowaychuk and Fessenden (1987) all discuss exceedingly complex interactions among acidifying emissions, the atmosphere and soil chemistry that are applicable to the LSA. Although predictive modelling has been used to determine soil loading factors, there is no well defined correlation among acidic emissions, acid deposition and the rate or degree of soil acidification that may result.

The work of Holowaychuk and Fessenden (1987) on soil sensitivities to acid inputs and soil capabilities to buffer acidifying inputs serves as an excellent, although somewhat qualitative basis for assessing the impacts of the Project. Soils in the LSA are dominantly organic or brunisolic which are classed as being highly sensitive to acidic inputs due to their low pH (4.6 - 6.0), medium cation exchange capacity (50-74 cmol/kg or cmol/l, mineral or organic soils respectively) and moderate base saturation levels (25 - 70%). Analytical data from field samples indicate most of the soils sampled do fall within these ranges (Golder 1997m). The potential of the soil, or in the case of organic soils the underlying mineral substrate, to buffer acidic inputs is rated as medium which is also consistent with higher pH levels found in the C horizons of LSA soils. A third factor results from the moderate degree of throughflow in the 40% of the LSA occupied by primarily mesotrophic fen systems, to some degree this is likely to both flush out solubilized aluminum (a product of increased acidity) and partially replenish the base cation levels in the groundwater. Overall the potential for soil acidification in the LSA is rated as high.

Operational activities will release negligible SO_x (through heavy equipment) and approximately 11.9 t/d of NO_x. The potential acid input (PAI) of these emissions when combined with emissions from the existing industrial base (1.12 keg/ha/a) plus those found in the air entering the airshed (0.08 keg/ha/a) can reach 0.55 keg/ha/a. Section E2 of this EIA addresses Project emissions of SO_x. and NO_x as they relate to acidic depositon. The World Health Organization has proposed PAI critical loading factors of 0.25 keq/ha/a for sensitive ecosystems and 0.5 keq/ha/a for moderately sensitive ecosystems (WHO 1994) so in both scenarios described herein the critical loading values will be surpassed. Roberts and Reiger 1989 (cited in BOVAR 1996, Aurora Mine EIA) state that despite high predicted estimated acidity values (Ea is the precursor of PAI) no trends indicating soil acidification have been found in northeastern Alberta.

The Project proponent is presently a guest on the RACQQ committee and once operator status is achieved will become a sitting member thus participating in acidic deposition programs in the area. Given the inconclusive nature of the emissions-soil acidification relationship the degree of concern associated with this parameter must be rated as undetermined although the magnitude of the impacts should be classed as moderate to high based on PAI levels and guideline criteria. The impacts of acidifying emissions on terrain and soils is dealt at greater length in Sections F8 and G8 of this EIA.

E8.7 Key Question TS-2: Will Reclamation for the Muskeg River Mine Project Change the Distribution of Terrain and Soils?

E8.7.1 Analysis of Potential Linkages

The second key question addresses the impact on the distribution of terrain and soils features resulting from reclamation measures instituted during the closure phase. Direct assessments of the areas of both the terrain and soil units that remain undisturbed and those which are reconstructed during closure can be calculated and comparisons made with pre-development conditions. Figure E8-2 indicates this pathway.

E8.7.2 Analysis of the Distribution and Capability of the Reclaimed Terrain and Soil Unit

While a portion of the LSA will remain undeveloped during construction and operations, as discussed in Section E8.6, a significant amount will consist of reconfigured landscape features covered by a reclamation soil mix. Neither the terrain or soil units will be analogous to their pre-development counterparts.

The objectives of the conservation and reclamation plan for this Project are to restore the area to "equivalent capability" with respect to pre-development conditions; this does not mean, nor is it meant to imply an exact replication of the pre-existing state. The result of this will be a landscape that incorporates the remaining undisturbed features with new features engineered to conform with the end land use objectives set out in the Project closure goals and objectives. Overall the distribution of terrain and soil features will be substantially changed.

The reclamation of developed areas of the Muskeg River Mine Project will result in re-establishment of terrain and soil units. Table E8-3 details the areas of reclaimed terrain units, while the areas of the reclaimed soil units are detailed in Table E8-4.

Terrain

Table E8-3 outlines the distribution of terrain units in the closure landscape which is illustrated in Figure E8-3. Two main points are worthy of

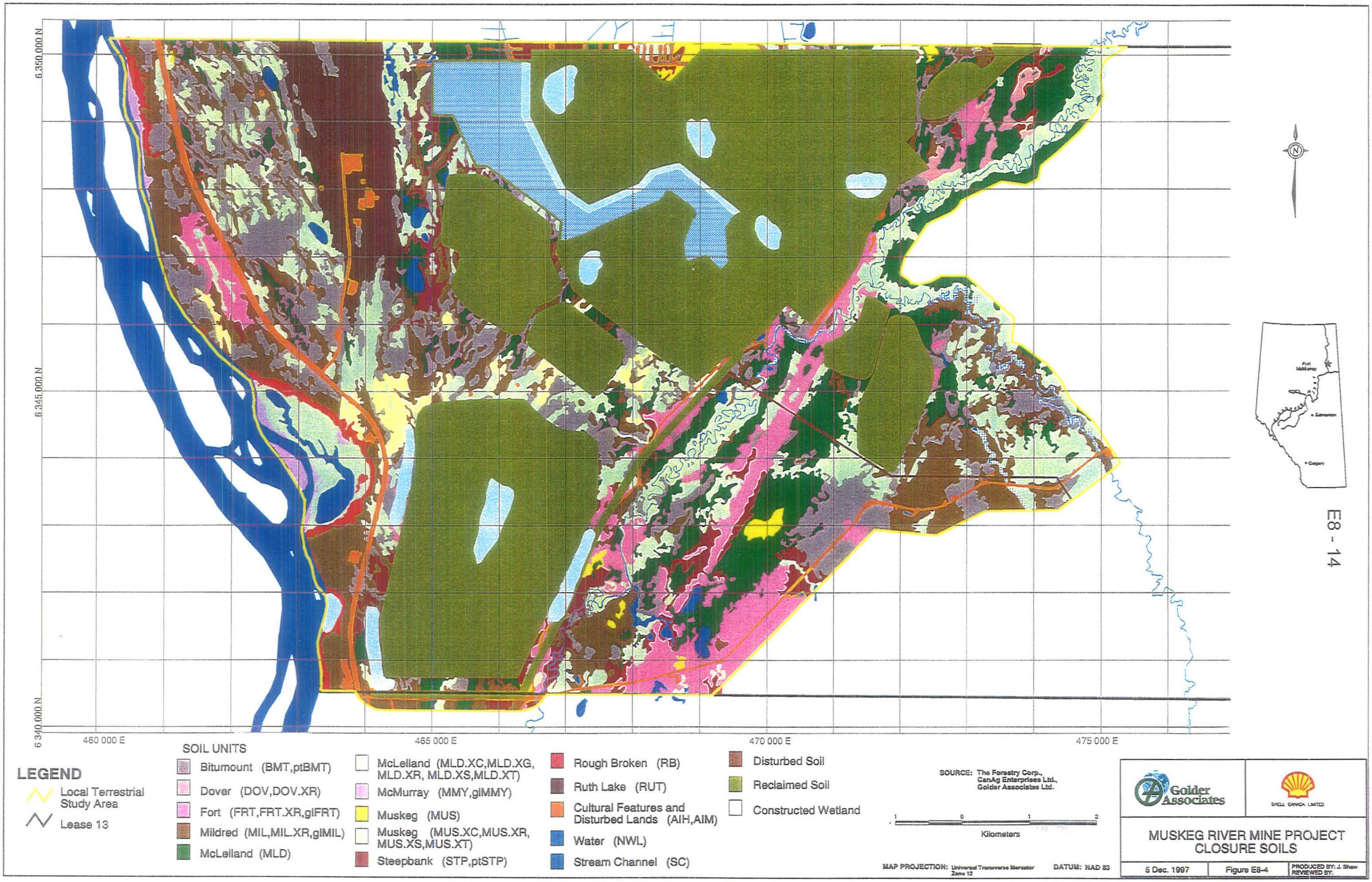

6 350 000 N
6 345 000 N
6 340 000 N
460 000 E
465 000 E
470 000 E
475 000 E
LEGEND
Local Terrestrial Study Area
Lease 13
SOIL UNITS
Bitumount (BMT,ptBMT)
Dover (DOV,DOV.XR)
Fort (FRT,FRT.XR,glFRT)
Mildred (MIL,MIL.XR,glMIL)
McLelland (MLD)
McLelland (MLD.XC,MLD.XG, MLD.XR, MLD.XS,MLD.XT)
McMurray (MMY,glMMY)
Muskeg (MUS)
Muskeg (MUS.XC,MUS.XR, MUS.XS,MUS.XT)
Steepbank (STP,ptSTP)
Rough Broken (RB)
Ruth Lake (RUT)
Cultural Features and Disturbed Lands (AIH,AIM)
Water (NWL)
Stream Channel (SC)
Disturbed Soil
Reclaimed Soil
Constructed Wetland
SOURCE: The Forestry Corp., CanAg Enterprises Ltd., Golder Associates Ltd.
Kilometers
MAP PROJECTION: Universal Transverse Mercator Zone 12
DATUM: NAD 83
Golder Associates
SHELL CANADA LIMITED
MUSKEG RIVER MINE PROJECT
CLOSURE SOILS
5 Dec. 1997
Figure E8-4
PRODUCED BY: J. Shaw
REVIEWED BY:
/data/oilsands/972-2237/9700/9701/final/arcview/reclsoilin.apr

Table E8-3 Areas of Terrain Units in the Closure Landscape of the Muskeg River Mine Project LSA

Terrain Unit	Area, ha	Area, % of LSA
Bog	1	<0.1
Shallow Bog	3	<0.1
Fen	1,121	10.2
Shallow Fen	1,420	13.0
Fluvial	76	0.7
Glaciofluvial	550	5.0
Glaciofluvial 1	1,609	14.7
Glaciofluvial 2	840	7.7
Glaciofluvial 3	444	4.1
Glaciolacustrine	41	0.4
Rough Broken	93	0.8
SubTotal	**6,198**	**56.6**
Reclaimed Units:		
1. Overburden capped CT[a]		6.1
• wetlands	27	
• terrestrial	645	
2. Sand Capped CT		6.2
• wetlands	30	
• terrestrial	646[a]	
3. Sand Capped Overburden		3.4
• wetlands	24	
• terrestrial	354[a]	
4. Tailings Settling Pond		9.5
• wetlands	38	
• terrestrial	1,001	
5. End Pit Lake		
• wetlands	99	0.9
6. Overburden disposal areas	548	5.0
7. RMS (muskeg)	190	1.7
8. Plant Site	202	1.8
9. Utility Corridor	87	0.8
10. Pipeline RoW	17	0.2
SubTotal	**3,905**	**35.6**
11. Open Water		
• end pit lake	343	3.1
• ditches and ponds	95	0.9
SubTotal	**438**	**4.0**
Total Reclaimed	4,343	43.1
Disturbed Lands[b]	267	2.4
Open Water and Stream Channels[b]	146	1.3
Total	**10,954**	**100.0**

(a) Components of the LSA
(b) Non-soil/terrain

elaboration to place these values in context. On the order of 60% of the pre-existing terrain units will remain intact at closure thus preserving a substantial area relatively undeveloped. The remaining 40% of the LSA will consist of newly reconstructed features that conform with the Project terms of reference and are described in greater detail in the C&R Plan for the Project. Examination of Table E8-3 reveals that a much greater variety of terrain types will be present at closure thereby enhancing the overall diversity of features within the LSA. In addition, the majority of the terrain is presently poorly drained, a function of the topography and surficial materials, while by comparison the closure landforms will present greater relief, varied drainage regimes and a wider variety of environmental types for vegetation recolonization and wildlife habitat.

Soils

Table E8-4 describes, and Figure E8-4 shows, the types and distribution of soil units in the closure landscape. In a similar vein to the closure terrain setting, it can be seen that the soils will be much greater in variety and offer an overall increase in potential forest ecosystem capability (this is discussed in more detail in subsection E8.8). The reclaimed soils provide a wider diversity and enhanced productivity ratings due primarily to their placement in the new landscape which results in a greater range of aspects, drainage regimes and slopes.

Reclamation of the Muskeg River Mine Project will not restore either the terrain or soils to pre-development conditions. Much of the closure landscape will be recontoured and capped with a non-naturally occurring reclamation soil mixture. Therefore reclamation will change the distribution of terrain and soils features in the LSA.

E8.7.3 Residual Impacts and Degree of Concern

The residual impacts following development and reclamation of the Project are detailed in Table E8-5 (terrain) and Table E8-6 (soils). The degree of concern for the impacts to terrain and soils are also provided in these tables.

The residual impacts of reclamation on the terrain and soils are positive in direction. The landforms are reconstructed and significantly different from the pre-existing state in that there is much more relief, i.e. changes in elevation, incorporated in their design. This provides a wider range of micro- and macro-environments by comparison and, therefore, introduces the potential for greater biodiversity in the closure landscape. This is viewed as a significant enhancement of the LSA.

Table E8-4 Areas of Soil Units in the Closure Landscape of the Muskeg River Mine Project LSA

Soil Unit	Area, ha	Area, % of LSA
Undisturbed Soils		
Bitumount	1,040	9.5
Dover	41	0.4
Fort	509	4.6
Mildred	1,180	10.8
McLelland	2,344	21.4
McMurray	76	0.7
Muskeg	165	1.5
Ruth Lake	445	4.1
Steepbank	305	2.8
Rough Broken	93	0.8
Total	**6,198**	**56.6**
Reclamation Soils Capability Class		
Class 1	0.0	0.0
Class 2	0.0	0.0
Class 3	2,744	25.1
Class 4	218	2.0
Class 5	317	2.9
Others		
Wetlands	217	2.0
Plant Site[a]	202	1.8
Muskeg Dumps[a] (RMS)	190	1.7
Pipeline	17	0.15
Total	**3,905**	**35.6**
Open water	438	4.0
Total	**4,343**	**39.6**
Disturbed Lands[c]	267	2.4
Open Water & Stream Channels	146	1.3
Total	**10,954**	**100**

(a) Will most likely be covered with reclamation soil mix.
(b) Muskeg Dumps[b]: area will not be stripped prior to use, therefore is unlikely to have any amendments applied at closure.
(c) Non-soil components of the LSA

Terrain

Table E8-5 shows the residual impacts and associated degrees of concern for terrain unit alterations in the LSA, these assessments pertain only to the areas which will be disturbed by Project development. The units sustaining the greatest degree of impact are the organics which, are the primary component of the reclamation soil. While the degree of concern related to these units is classed as high, based on the area affected, it fails to account for the "recycling" of the materials. In fact it would be more accurate to view this as a redistribution of the resource versus a complete loss. The glaciofluvial and glaciolacustrine units are somewhat less affected and again some of the resources will be used to recontour the landscape so loss is not completely accurate. The reclaimed terrain units present a very positive picture in that the variety of genetic materials at closure will be much greater than for pre-disturbance which will lead to a significant increase in overall diversity. It should be observed that "degree of concern" has been designated as not applicable to these units as it implies a negative impact that is not correct in this context (i.e., the landscape features ultimately will be altered not lost).

Table E8-5 Residual Impact Classification of Terrain Unit Change in the LSA

	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
Disburbed Terrain • bogs, shallow bogs, fens, shallow fens	Negative	High	Local	Long-term	Irreversible	Low	High
• galciofluvial/ glaciolacustrine	Negative	Moderate	Local	Long-term	Irreversible	Low	Moderate
• fluvial/rough broken	Negative	Low	Local	Long-term	Irreversible	Low	N/A
Reclaimed Terrain • overburden capped CT	Positive	High	Local	Long-term	Irreversible	Low	N/A
• sand capped CT	Positive	High	Local	Long-term	Irreversible	Low	N/A
• sand capped overburden	Positive	Moderate	Local	Long-term	Irreversible	Low	N/A
• tailings settling pond	Positive	High	Local	Long-term	Irreversible	Low	N/A
• end pit lake	Positive	Low	Local	Long-term	Irreversible	Low	N/A
• overburden disposal area	Positive	Moderate	Local	Long-term	Irreversible	Low	N/A
• RMS (muskeg)	Neutral	Low	Local	Long-term	Irreversible	Low	N/A
• plant site, utility corridor, pipeline RoW	Neutral	Low	Local	Long-term	Irreversible	Low	N/A
• open water	Neutral	Low	Local	Long-term	Irreversible	Low	N/A

N/A = not applicable

Soils

Table E8-6 enumerates the residual impacts and degrees of concern associated with soil unit changes in the LSA. These evaluations apply only to the areas disturbed by Project development. All the soil units within the footprint will be highly affected and in a negative manner in that they will be removed. However, the organic material and some of the mineral will be used in the reclaiming of the mine areas. As with the terrain units discussed above, this is an alteration not a loss of the resource, so degrees of concern are somewhat misleading. Soil capability ratings provide a more valid tool for assessing the effects of change on the soils of the LSA. This is covered in greater detail in subsection E8.8.2 but in summary, a significant area of non-productive soils (both organic and material) will be reconstructed into more productive areas, class 3 versus classes 4 and 5 for forest ecosystems. While the immediate impact may be seen as negative, by closure a very positive, highly significant improvement in the ecosystem capability will result.

Table E8-6 Residual Impact Classification of Soil Unit Changes

	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
Disturbed Soils • poorly-drained, organic dominated soils	Negative	High	Local	Long-term	Irreversible	Low	High
• moderately well-drained mineral dominated soils	Negative	High	Local	Long-term	Irreversible	Low	High
Reclaimed Soils • soil capability class 1	N/A	N/A	Local	Long-term	Irreversible	Low	N/A
• soil capability class 2	N/A	N/A	Local	Long-term	Irreversible	Low	N/A
• soil capability class 3	Positive	High	Local	Long-term	Irreversible	Low	N/A
• soil capability class 4	Negative	High	Local	Long-term	Irreversible	Low	N/A

N/A = not applicable

E8.8 Key Question TS-3: Will the Reclamation of the Landscape for the Muskeg River Mine Project Change Soil Productivity?

E8.8.1 Analysis of Potential Linkages

This key question focuses on the changes in soil productivity within the LSA brought about by the reclamation activities described in Section E8.7. These changes can be quantified by assessing the productive capabilities of the naturally occurring soils in the pre-development setting and computing overall areas per class.

A comparable process may be used for the closure setting except the soils will be a combination of those that occur naturally (i.e., undisturbed by the Project activities, and reconstructed soils used for the reclaimed landscape). Capability ratings and areas for the reclaimed soils may also be calculated to permit before and after comparisons of overall soil productivity.

E8.8.2 Linkage between Reclamation Activities and Soil Productivity

The closure landscape of the Project LSA will consist of two distinct components, undeveloped areas and those which have been significantly altered by the Project activities. Both components have been evaluated with respect to extent and spatial distribution in Section E8.7. Soils in the pre- and post-development landscape were rated for their potential capability to support productive forest ecosystems using the classification system devised by Leskiw (1996). This system employs the following capability classes:

- Class 1: high capability, no significant limitations
- Class 2: moderate capability, moderate limitations
- Class 3: low capability, moderately severe limitations

- Class 4: currently non-productive, severe limitations not practical to remediate
- Class 5: permanently non-productive, severe limitations impossible to ameliorate

Classes 1, 2 and 3 are judged to be productive forest soils, while Classes 4 and 5 are non-productive.

The areas and capability class for Project LSA soils are detailed in Table E8-7. A summary of the areas of each forest capability class in the pre-development landscape is provided in Table E8-8. Figure D8-4 shows the distribution of forest capabilities in the pre-disturbance phase while Figure E8-5 illustrates conditions at closure.

The closure distribution of soil units, their area and capability class is provided in Table E8-9. A summary of the areas of each forest capability class in the closure landscape is provided in Table E8-10. Changes between the pre-development and closure landscapes are summarized in Table E8-11.

E8.8.3 Monitoring

Once the landscape has been recontoured, capped with the reclamation soil mix and revegetated, a comprehensive, on-going monitoring regime will be instituted. As outlined in the Soil Quality Criteria (AA 1987) this will include assessments of the following soil characteristics: organic matter content (% OM); pH; cation exchange capacity (CEC); extractable cations (sodium, calcium, magnesium and potassium) and salinity; electrical conductivity (EC); sodium absorption ratio (SAR); total nitrogen, phosphorus and potassium; plant available nitrogen, phosphorus, potassium and sulphur; bulk density and particle size distribution. A ratings guide is provided in the above-cited document to permit evaluation of these parameters and determination of soil suitability for various species. Sampling will be done for the reclamation topsoil mix and the underlying subsoil, this will allow detection of any trends that may require attention. Typically a strategy of this kind would be conducted in concert with a vegetation monitoring program to detect any interactions that may indicate further remediation is in order. No time limit is specified for the monitoring plan.

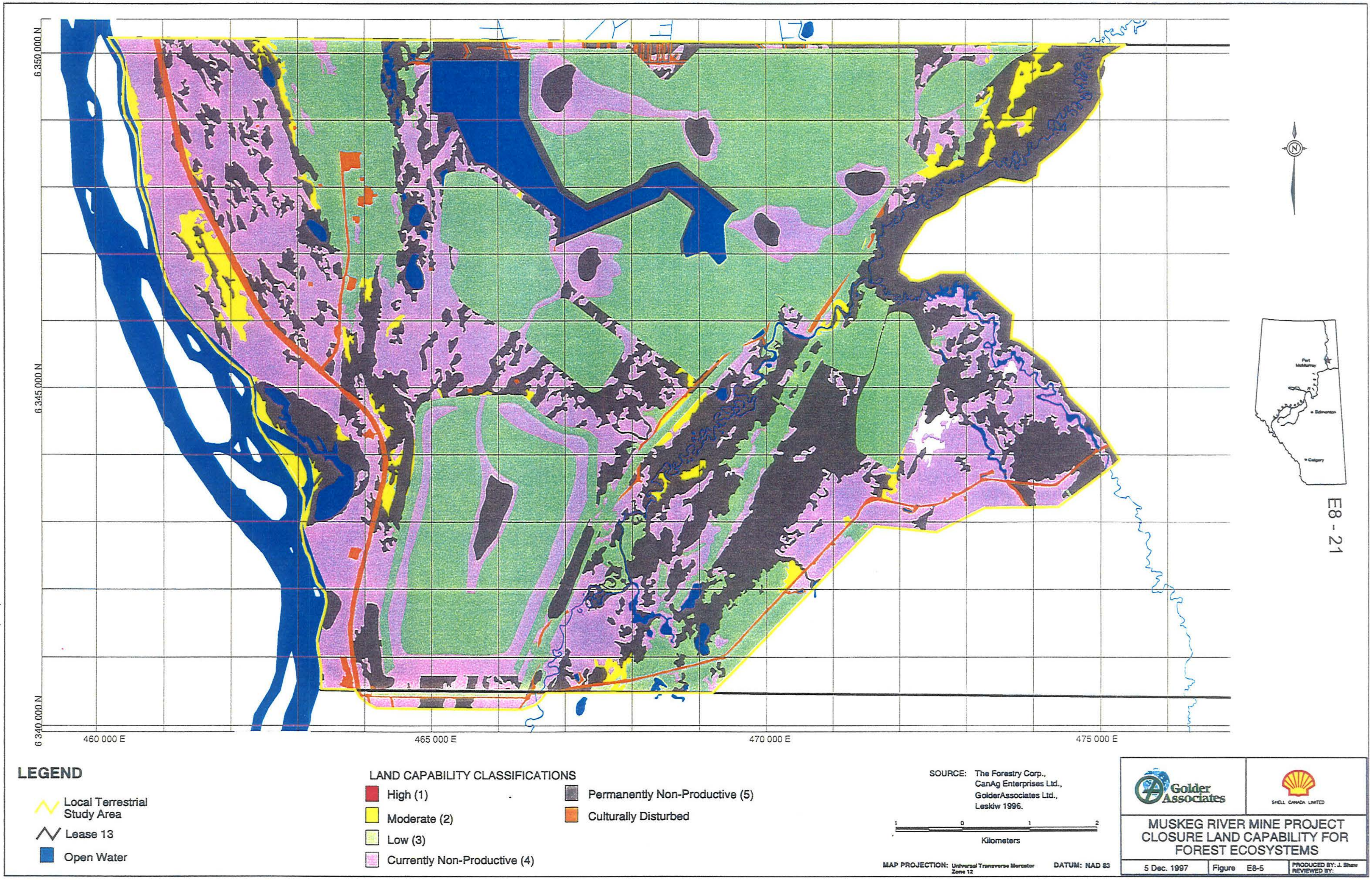

6 350 000 N
6 345 000 N
6 340 000 N
460 000 E
465 000 E
470 000 E
475 000 E
N
Fort McMurray
Edmonton
Calgary
LEGEND
Local Terrestrial Study Area
Lease 13
Open Water
LAND CAPABILITY CLASSIFICATIONS
High (1)
Moderate (2)
Low (3)
Currently Non-Productive (4)
Permanently Non-Productive (5)
Culturally Disturbed
SOURCE: The Forestry Corp., CanAg Enterprises Ltd., GolderAssociates Ltd., Leskiw 1996.
1 0 1 2
Kilometers
MAP PROJECTION: Universal Transverse Mercator Zone 12
DATUM: NAD 83
Golder Associates
SHELL CANADA LIMITED
MUSKEG RIVER MINE PROJECT
CLOSURE LAND CAPABILITY FOR FOREST ECOSYSTEMS
5 Dec. 1997
Figure E8-5
PRODUCED BY: J. Shaw
REVIEWED BY:
/data8/oilsands/972-2237/9700/9701/final/arcview/reclandcapfn.apr

Table E8-7 Pre-Development Soil Unit Forest Capability Classes in the Muskeg River Mine Project LSA

Soil Unit	Area, ha	Capability Class[(a)]
Bitumount	1,915	4 (2)
Dover	42	2
Fort	652	3 (2)
Mildred	1,895	3 (4)
McLelland	4,144	5
McMurray	88	2 (5)
Muskeg	340	5
Ruth Lake	445	3
Steepbank	610	4 (2)
Rough Broken	98	4
Disturbed Lands	540	n/a
Open Water and Stream Channels	185	n/a
Total	10,954	n/a

(a) X (Y)* : Where two classes are given the first number is the dominant class while the number in parentheses indicates a minor component of a second class.
n/a : not applicable

Table E8-8 Areas for Each Forest Capability Class in the Pre-Development Landscape for the Muskeg Mine Project LSA

Capability Class	Area, ha	Area, % of LSA
Class 1	0	0.0
Class 2	417.5	3.8
Class 3	997.5	9.1
Class 4	4,299	39.3
Class 5	4,515	41.2
Disturbed Lands	540	4.9
Open Water and Stream Channels	185	1.7
Total	10,954	100.0

The data presented in Table E8-10 indicate significant variations between the pre-development and closure phase distributions of the various capability classes. Most prominent is the conversion of 3,279 ha of non-productive class 4 and 5 lands to the moderately productive class 3. Soil productivity, as evaluated using the capability classification system for forest ecosystems, will change as a result of reclamation in the LSA.

Table E8-9 Closure Distribution of Soil Units and Forest Capabilities in the Muskeg River Mine Project LSA

Soil Unit	Area, ha	Capability Class
Bitumount	1040	4 (2)
Dover	41	2
Fort	509	3 (2)
Mildred	1180	3 (4)
McLelland	2344	5
McMurray	76	2 (5)
Muskeg	165	5
Ruth Lake	445	3
Steepbank	305	4 (2)
Reclamation Soil	3152	3
Reclamation Soil	218	4
Reclamation Soil	317	5
Plant Site[a]	202	
Pipeline RoW[a]	17	
Rough Broken	93	4
Disturbed Lands	267	n/a
Open Water and Stream Channels	584	n/a
Total	10,954	n/a

(a) Not known what type of reclamation soil will be applied.

(b) Trench will be covered with original soil, disturbance will be minimal.

Table E8-10 Summary of Areas for Each Forest Capability Class in the Post-Reclamation Landscape for the Muskeg Mine Project LSA

Capability Class	Area, ha	Area, % of LSA
Class 1	0	0.0
Class 2	295	3.0
Class 3	4033	36.8
Class 4	2697	24.6
Class 5	2838	26
Plant Site	202	1.8
Disturbed Lands	267	2.4
Open Water and Stream Channels	584	5.3
Total	10,954	100

Table E8-11 Summary of the Change in Area for Each Forest Capability Class Between the Pre-Construction and Post-Reclamation Landscapes for the Muskeg Mine Project LSA

Capability Class	Pre-Construction Area, ha	Closure Area, ha	Change in Area, ha	% Change in Class
Class 1	0.0	0	0.0	0.0
Class 2	417.5	295	-122.5	-29.3
Class 3	997.5	4,033	+3,035.5	+304.0
Class 4	4,299.0	2,697	-1,602.0	-37.3
Class 5	4,515.0	2,838	-1,677.0	-37.1
Unclassified[a]	725.0	1,091	+366.0	+50.5
Total	10,954	10,954	0.0	n/a

(a) Previously disturbed land and open water and stream channels

E8.8.4 Residual Impacts and Degree of Concern

Table E8-12 outlines the residual impacts and degrees of concern associated with reclamation and closure forest capabilities in the LSA.

The closure landscape, as described in Section E16 of this EIA, will see a significant alteration in the areas of potentially productive forest soils. Approximately 3,000 ha of soils, mostly organics, presently rated as class 4 and 5 (non-productive) will be replaced by a soil mixture rated as class 3, low productivity for forestry, which will have a positive impact on about 30% of the area of the LSA and more than 70% of the area within the development footprint. This change should be viewed as positive in direction and high in magnitude.

Reclamation and conversion of approximately 28% of the area in the LSA from non- to moderately-productive status for forest ecosystems is a significant, positive impact.

Table E8-12 Reclamation Related Residual Impacts of Change in the Areas of Forest Capability Classes in the Muskeg River Mine Project LSA

Capability Class	Direction	Magnitude	Geographic extent	Duration	Reversibility	Frequency	Degree of Concern
Class 1	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Class 2	Negative	High	Local	Long-term	Irreversible	Low	High
Class 3	Positive	High	Local	Long-term	Irreversible	Low	High
Class 4	Negative	High	Local	Long-term	Irreversible	Low	High
Class 5	Negative	High	Local	Long-term	Irreversible	Low	High

E9 TERRESTRIAL VEGETATION IMPACT ANALYSIS

E9.1 Introduction

This section of the Muskeg River Mine Project (the Project) EIA provides information as required by the Project Terms of Reference (TofR) issued on November 7, 1997 (AEP 1997a). Specifically, the following are addressed in this section:

- identify the amount of land to be developed and the types of vegetation communities affected in the Project area; and
- describe the mitigative measures to be implemented to offset the impacts on vegetation communities, including rare and endangered species in the Project Area (TofR, Section 4.4).

Discussions on the potential cumulative effects on terrestrial vegetation associated with the Project are addressed in Section F9. Section D9 provided details on the terrestrial vegetation baseline for the Project.

The development of the Muskeg River Mine Project will have impacts on vegetation at the landscape (see Section E7), plant community and plant species levels. The objective of this section is to assess the potential impacts on plant communities and species (rare plants, traditional use plants, and key indicator resources) within the Local Study Area (LSA).

E9.2 Approach

The approach used to assess potential impacts on the terrestrial vegetation utilized the ELC developed for the LSA. The basis for the assessment at the Plant Community level of analysis is the Ecosite Phase ELC unit (see Section D7). At this scale of mapping (1:20,000) vegetation is grouped within Ecosite phases according to characteristic plant communities. Impacts in terms of loss/alteration of plant communities can therefore be quantified using the GIS database by overlaying the mine development plan. In addition, the sequential development and reclamation of the mine can be followed in both a spatial and temporal context.

The advantage of using an ELC approach to evaluate vegetation impacts lies in its ability to integrate landscape, soils, vegetation and drainage conditions into generally homogeneous map units at a variety of scales. At the plant community level, this allows vegetation losses/alterations, potential impacts due to air emission, water releases and impacts on plant diversity to be analyzed in a more comprehensive manner. Emphasis is placed on the impacts to the ecosystem rather than to sectors of it. This approach is particularly relevant when discussing issues such as biodiversity. In terms of reclamation, the ELC data base provides the basis of comparison for the reclamation landscapes. As reclamation and revegetation techniques develop to a more detailed level of ecosystem restoration, plant communities will be increasingly reclaimed on the basis of habitat conditions at both the macro and micro scale.

E9.3 Key Indicator Resources

The identification of Key Indicator Resources (KIRs) provides a focus for impact analysis and assessment of the Muskeg River Mine Project. KIRs are representative of key plant communities or species within the LSA and RSA. An analysis of the potential impacts on KIRs can be applied to Project construction, operation and closure phases.

The terrestrial vegetation KIRs at the Plant community level include:

- old-growth forest communities including:
  - white spruce communities,
  - jack pine - lichen communities.
- plant communities of economic importance
  - aspen - white spruce communities

Vegetation KIRs at the plant species level include:

- rare plants; and
- traditional use plants, including:
  - medicinal plants,
  - spiritual use plants.

At the Landscape level of vegetation analysis, the potential impacts on environmentally significant areas, wetlands riparian areas and old-growth forests are addressed in the Ecological Land Classification (ELC) Impact (Section E7).

E9.4 Methods

The terrestrial vegetation resource impact assessment was completed through a comparison of the baseline conditions of the LSA of the Muskeg River Mine Project to conditions within the LSA that are expected to result from the Muskeg River Mine Project development.

The severity of impacts was determined based on an impact rating system which incorporates the following parameters: direction, magnitude, geographic extent, duration, reversibility and the frequency of the impact.

Vegetation was mapped using a geographical information system (GIS) to allow the relative abundance of plant communities to be compared within the LSA and also to the RSA. By superimposing the Muskeg River Mine Project development plan over the existing vegetation polygons, the amounts of each plant community affected can be quantified and an assessment of significance made using the criteria previously described. Similarly, by superimposing the successive reclamation activities onto the Project development area, the progression of revegetation can be quantified and monitored.

E9.4.1 Biodiversity Measurements

Biodiversity was assessed for plant species by two main indices: species richness and species diversity (Shannon Index). These indices can be used to describe diversity in terms of composition and richness in various vegetation layers.

Compositional biodiversity is commonly described using measures of richness (species number) and evenness (relative abundance). Species richness is the total number of species present in the area (Krebs 1989). Species richness was calculated for herb, shrub and tree layers in each plot surveyed. Community richness was calculated by averaging the species richness recorded for each community type.

Species diversity was measured using the Shannon Index, which describes both species richness and evenness (Krebs 1989). Similar to species richness, diversity was measured at the plant species and community levels.

E9.4.2 Modelling Methods

Modelling of reclaimed landscapes was completed by using data and observations regarding vegetation growth and establishment from over 25 years of reclamation research in the Fort McMurray oil sands area. Based on landform and reclamation soil capability ratings, the revegetated areas of the Muskeg River Mine Project were modelled for a variety of scenarios and conditions. Modelling was also completed for different hydrologic regimes and for air emission scenarios.

E9.5 Potential Linkages and Key Question

E9.5.1 Linkage Diagrams

Linkage diagrams have been prepared for the Project construction and operation phase, as well as for the closure phase. The diagrams are intended to demonstrate the connections between the Muskeg River Mine Project and the environment in which it will be developed and reclaimed. In this section, the focus of the linkage diagrams are on the connections between the Project and the vegetation resources of the LSA and RSA. They are used to help understand and explain the often complex interactions which can take place between the Project and the environment over the life of the Project.

E9.5.2 Potential Linkages: Construction and Operation

The first vegetation resources linkage diagram (Figure E9-1) is used to demonstrate the potential impacts of Project construction and operation on the terrestrial vegetation and plant communities of both the LSA and RSA. Project activities that may affect the vegetation resource include, but are not limited to: site clearing, soil and overburden stripping and storage, changes in soil properties, development of Project facilities and infrastructure, changes to hydrology and emissions and releases to the air, ground and water. The impacts from these activities are expected to include direct losses or alteration of vegetation as a result of site clearing and physical removal of vegetation, while the indirect losses may result from air emissions and/or water releases.

The impacts may also result in localized effects on vegetation, including changes in plant diversity and plant tissue quality. The linkage diagrams also detail the potential pathways of change in other related resources, as a result of potential impacts to vegetation, including changes in resource use, wildlife habitat and human health.

E9.5.3 Potential Linkages: Closure

A second linkage diagram (Figure E9-2) was developed to identify the potential impacts on the vegetation resource at (and beyond) Project closure. Project activities which affect plant communities and species at closure include, but are not limited to: reclamation activities, such as grading and replacement of overburden and topsoil materials, development of an end pit lake and alterations to surface drainage patterns. These activities will result in a variety of reclamation surfaces which will be revegetated to meet end land use objectives. Revegetation efforts will eventually replace plant communities displaced during development constructions and operation.

Figure E9-1 Linkage Diagram for Vegetation Resources for Construction and Operation Phase of the Muskeg River Mine Project

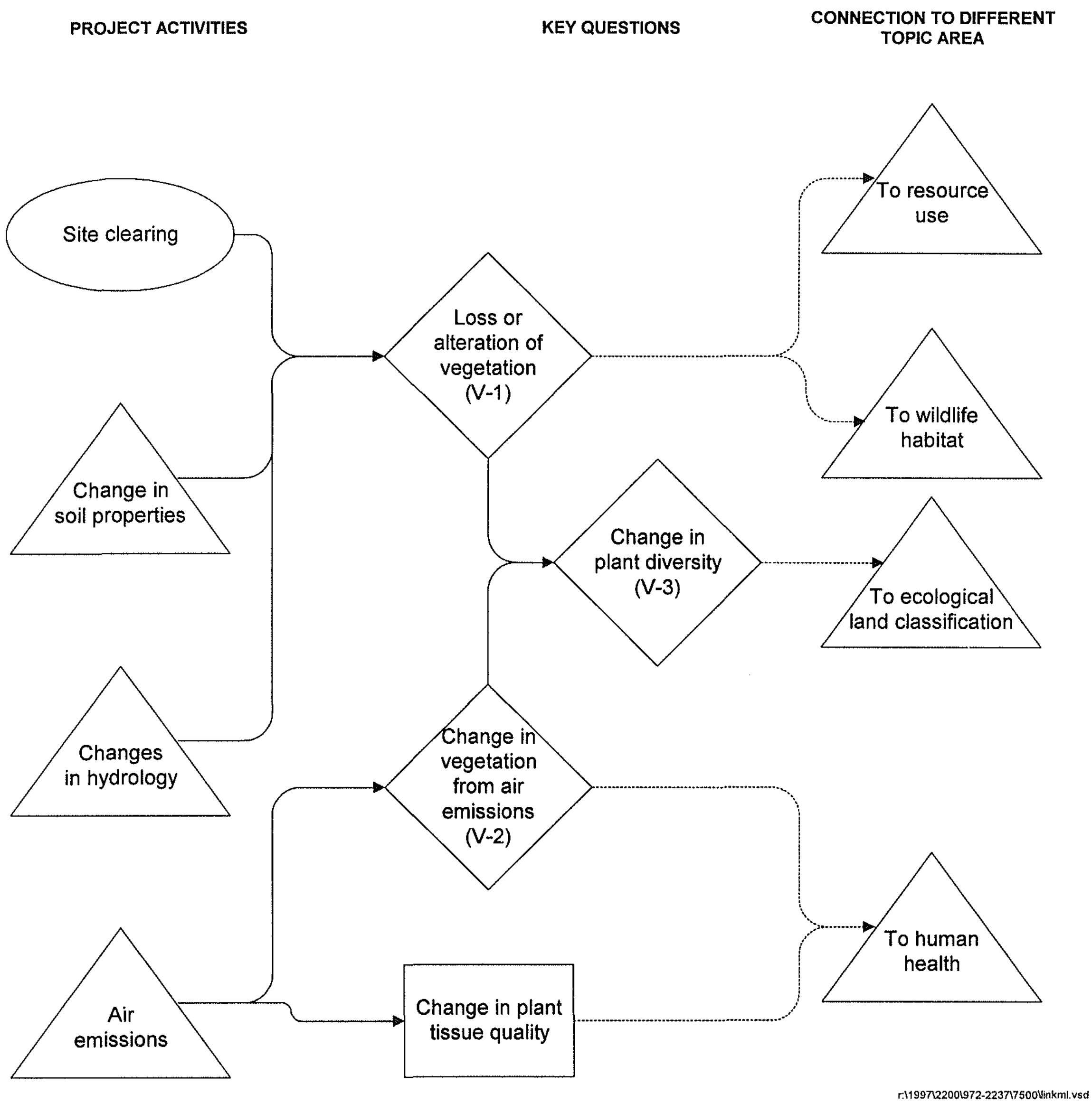
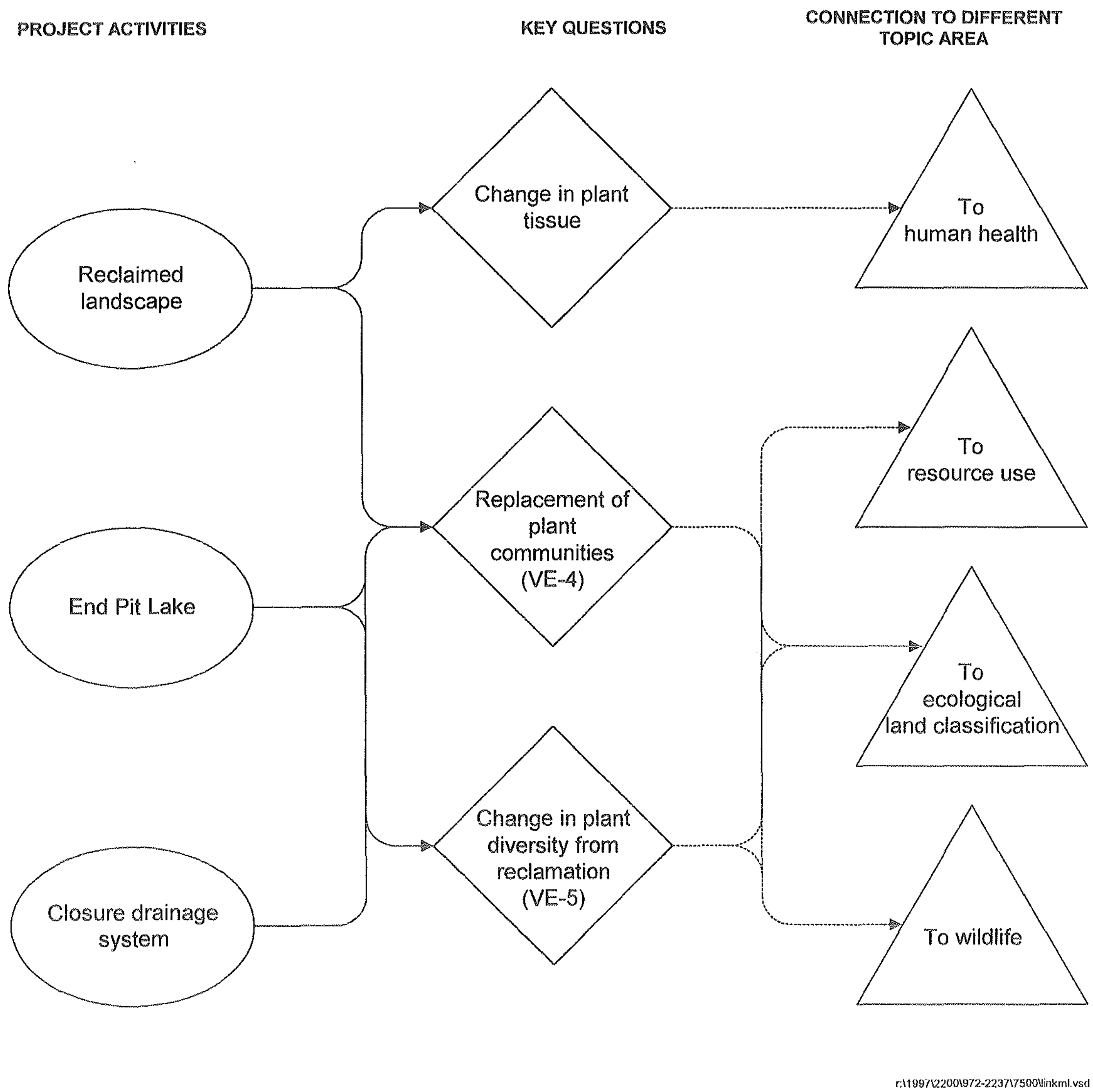


Figure E9-2 Linkage Diagram for Vegetation Resources for Closure Phase of the Muskeg River Mine Project



However, the reclaimed vegetation will initially result in changes in vegetation successional stage within and among the reclaimed communities. The effects of reclamation on resource use and wildlife habitat within the Project area are depicted in the second linkage diagram.

The potential effects identified in the linkage diagrams were used as a framework to focus the assessment issues. Key Questions regarding the potential impact of the Muskeg River Mine Project on the vegetation resources of the Project area were also identified using the linkage diagrams.

E9.5.4 Key Vegetation Issues

The key vegetation issues may be summarized as follows:

- alteration of the vegetation of the Athabasca River Valley including the floodplain (i.e., riparian), and the escarpment;
- direct vegetation loss/alteration due to overburden removal/disposal, grading and other construction and operational activities;
- indirect vegetation loss/alteration due to local changes in hydrology (e.g., desiccation, inundation), soil erosion and contamination;
- loss or degradation of rare or endangered plant species and their habitats;
- loss or degradation of vegetation due to air emissions; and
- loss or degradation of medicinal/spiritual plants used by aboriginal peoples.

E9.6 Key Questions

Key vegetation impact questions were developed based on the issues previously identified. A key impact question is an explicit question raised during the EIA process which guides data collection and analysis to determine the magnitude and significance of the effects of the potential impact on the terrestrial vegetation. Five key questions have been developed for terrestrial vegetation. Each one is briefly described as follows:

VE-1 Will Muskeg River Mine Project Activities Result in a Loss or Alteration of Vegetation Communities?

During construction and operation of the Muskeg River Mine Project, landscapes and their associated vegetation may be substantially altered as part of the development plan for the Project. The loss and/or alteration of vegetation communities is examined at the plant community and plant species level within this section, while this question is examined at a much broader level of generalization in the ELC section (Section E7).

VE-2 Will Muskeg River Mine Project Air Emissions or Water Releases Alter Vegetation Health?

Vegetation health may be affected through air and water releases as a result of the construction and operation of the Muskeg River Mine Project. Air emissions are primarily associated with the operational phase of the Project while water releases are a consequence of both operational and closure phases.

VE-3 Will the Muskeg River Mine Project Change Plant Diversity?

The LSA is characterized by a diversity of landscapes, vegetation, soils and drainage conditions. As a consequence of the Project construction and operation phase, as well as the subsequent closure phase, there is a concern that the vegetation of the LSA will not be as diverse as the pre-development conditions.

VE-4 Will Landscape Reclamation and Closure of the Muskeg River Mine Project Result in Replacement of Plant Communities?

The objective of reclamation is to return the developed landscape to a condition of "equivalent capability" or better, similar to the naturally functioning ecosystems in the LSA. Various stakeholders identified the replacement of plant communities as an issue with respect to reclamation. This question lends itself to an examination of the vegetation resources of the LSA at a series of scales so that broad landscape types, their component plant communities and plant species can be examined in the context of successive development and reclamation over time. In general, the diversity of reclaimed plant communities increases over time, eventually resulting in vegetation associations and plant communities more similar to the pre-development conditions than that found immediately following reclamation.

E9.7 Key Question VE-1: Will Muskeg River Mine Project Activities Result in a Loss or Alteration of Vegetation Communities?

E9.7.1 Analysis of Potential Linkages

Development of the Muskeg River Mine Project will result in construction and operational activities that could affect vegetation as summarized in the linkage diagrams shown in Figure E9-1 and E9-2.

Project activities are identified as having either a direct or indirect effect on the types and distribution of vegetation communities, due to direct losses as a result of site clearing for Project development and overburden muskeg or storage, or indirect as a result of changes in surface water hydrology affecting soil moisture conditions (e.g., changes to the hydrological regime of sites located near the Project pits, along access roads and near drainages or wetlands).

E9.7.2 Analysis of Key Question

Loss/Alteration of Plant Communities

The vegetation resources of the LSA will be affected by the Project through both direct and indirect loses/alterations. The potential impacts are identified for both the Project area (development area) and for existing impacts from previous developments in the LSA (Table E9.1).

Table E9-1 Losses/Alteration of Existing Vegetation, Rivers and Lakes Within the Project Area and LSA

General Community Types (terrestrial)	LSA Area (ha)	LSA (%)	Direct Loss Within the Project Area (ha)	Direct Loss Within the Project Area %	Indirect Loss Aquifer Drawdown Area (ha)	Indirect Loss Aquifer Drawdown (%)	Total Area Loss (ha)	Total Loss LSA (%)
Upland Vegetation	3527	32.2	962	8.8	NA	0	962	8.8
Wetlands and Riparian	6766	61.8	3076	28.1	655.8	5.6	3732	34.1
Lakes	114	1.0	32	0.3	9.3	<.1	41	<1
Rivers	7	0.1	0	0	NA		0	0
Existing Disturbance	540	4.9	273	2.5	NA		273	2.5
TOTAL	**10954**	**100.0**	**4343**	**39.7**	**665.1**	**5.6**	**5,008**	**45.7**

Direct Losses/Alterations:

Construction of the Muskeg River Mine Project will result in the clearing of 4343 ha (39.7 of the LSA) for the mine, tailings settling pond, overburden disposal sites, reclamation material storage areas, roads, plant site, linear infrastructures such as roads and pipelines, and other associated facilities including ponds and drainage structures.

Approximately 540 ha of the LSA has been previously cleared, and almost all of it will be incorporated into the Project (development) area. Existing disturbances account for almost 5% of the LSA (Table E9-1).

The vegetation types (Ecosite Phases) occupying the LSA at present and those that will be cleared for the Muskeg River Mine Project are outlined in Table E9-2. The greatest impact will occur within the wetlands Ecosite Phases, especially the Shrubby Rich Fen (K2) where 1084 ha will be cleared (9.9% of the LSA) and the (Treed Rich Fen) (K1) where 739 ha will be cleared (6.7% of the LSA). Within the Uplands (terrestrial) plant communities, the greatest impacts occur within the Blueberry and Low bush cranberry ecosite phases (b1), where 335 ha will be cleared (3% of the

LSA) and in ecosite phase d1, where 359 ha will be cleared (3% of the LSA). The lichen-jack pine communities (a1) will experience a loss of 49 ha, less than 0.5% of the LSA. (Table E9-2).

In general, the direct and indirect impacts to the vegetation resources are primarily associated with wetlands and riparian vegetation types (Section E10).

The direct losses/alterations to vegetation will be phased over the mine construction and operation schedule. Substantial increases in ecosite e3 (Dogwood-White Spruce) and b4 (Blueberry-White Spruce - Jack Pine are foreseen following mine closure (1,550 ha, 596 ha, respectively, Table E9-2).

As development proceeds, so sequential reclamation and revegetation will take place to minimize the area of disturbance at any one time and to initiate revegetation in conjunction with mine construction and operation. Reclamation and revegetation will therefore result in a series of multi-aged revegetation communities at a variety of successional stages. This is important for wildlife habitat utilization and resource use. Further details as provided in the Mine Closure Plan (Section E16).

Indirect Losses/Alterations

The indirect losses/alterations to the vegetation of the LSA include the area around the perimeter of the development which may be affected by mine dewatering or local aquifer drawdown. The effects have been calculated for a buffer zone around the development area of 1.5 km (Section E3, Hydrology). The effects are restricted to the wetlands and lake margins (Section E10) and are not expected to affect the terrestrial or upland vegetation communities.

The indirect losses/alteration of vegetation due to air emissions are discussed in Section E9.8.

Clearing of vegetation may lead to wind throw or blowdown effects in the surrounding forest resulting in further vegetation disturbances. This damage may extend many meters into the forest (Mavratil 1995) and will generally occur for a period of approximately 15 years following development (Busby 1966). Spruce, especially black spruce, is susceptible because it is shallow rooted. Blowdown of trees around the existing oil sands projects in the area has; however, been infrequent, and thus this effect should be minor for the Muskeg River Mine Project.

Table E9-2 Vegetation (Ecosite Phases) Types Within the Local Study Area and Areas to be Cleared and Reclaimed for the Muskeg River Mine Project

Vegetation Type		LSA Area (ha)		Cleared Area		Reclaimed Area		Change From Pre-development Conditions
Map Code	**Ecosite Phases**	**Area (ha)**	**% LSA**	**Area (ha)**	**% LSA**	**Area (ha)**	**% LSA**	**Area (ha)**
a1	Lichen Pj	106	0.97	49	0.45	0	0.00	-49
a1/g1 complex	Pj-Lt	21	0.19	4	0.04	0	0.00	-4
b1	Blueberry Pj-Aw	878	8.02	335	3.06	218	1.99	-117
b2	Blueberry Aw(Bw)	0	0.00		0.00	102	0.93	+102
b3	Blueberry Aw-Sw	67	0.61	11	0.10	72	0.66	+61
b4	Blueberry Sw-Pj	286	2.61	98	0.89	596	5.44	+498
c1	Labrador Tea-mesic Pj-Sb	20	0.18	3	0.03	0	0.00	-3
d1	Low Bush Cranberry Aw	1,525	13.92	359	3.28	96	0.88	-263
d2	Low Bush Cranberry Aw-Sw	169	1.54	38	0.35	729	6.66	+691
d3	Low Bush Cranberry Sw	15	0.14	0	0.00	0	0.00	0
e1	Dogwood Pb-Aw	61	0.56	9	0.08	0	0.00	-9
e1/f1	Pb-Aw	66	0.60	0	0.00	0	0.00	0
e2	Dogwood Pb-Sw	4	0.04	0	0.00	0	0.00	0
e2/f2	Pb-Sw	9	0.08	2	0.02	0	0.00	-2
e3	Dogwood Sw	93	0.85	0	0.00	1,550	14.15	+1,550
g1	Labrador Tea-subhygric Sb-Pj	8	0.07	6	0.05	0	0.00	-6
h1	Labrador Tea/Horsetail Sw-Sb	123	1.12	53	0.48	0	0.00	-53
i2	Shrubby Bog	20	0.18	0	0.00	0	0.00	0
j1	Treed Poor Fen	356	3.25	168	1.53	0	0.00	-168
j1/g1 complex	Lt/Sb-Pj	27	0.25	0	0.00	0	0.00	0
j1/h1 complex	Sb/Sw-Lt	74	0.68	0	0.00	0	0.00	0
j2	Shrubby Poor Fen	1,182	10.79	532	4.86	0	0.00	-532
j2/h1 complex	Sw/Sb-Fen Complex	2	0.02	0	0.00	0	0.00	0
k1	Treed Rich Fen	1,370	12.51	739	6.75	0	0.00	-739
k2	Shrubby Rich Fen	2,136	19.50	1084	9.90	17	0.16	-1067
k3	Graminoid Rich Fen	51	0.47	6	0.05	0	0.00	-6
l1	Marsh	85	0.78	4	0.04	119	1.09	+115
STNN, SFNN, SONS	Swamp (coniferous, deciduous and shrub)	1359	12.41	531	4.85	308	2.81	+223
WONN	Shallow Open Water	57	0.52	6	0.05	0	0.00	-6
AIH, AIG, AIM	Cultural Disturbance	471	4.30	232	2.12	0	0.00	-232
NMC	Cutbanks	12	0.11	0	0.00	0	0.00	0
NWL	Lakes and Ponds	114	1.04	32	0.29	536	4.89	+504
NWR	Rivers	7	0.06	0	0.00	0	0.00	0
shrub	Shrubland	119	1.09	12	0.11	0	0.00	-12
Sb/Lt	Sb/Lt Complexes	61	0.56	30	0.27	0	0.00	-30
TOTAL		10,954	100.00	4343.2	39.65	4343	39.65	

differences between Vitt (1997) and beckingham and Archibald (1996) Wetland is due to criteria for classifying shrubby and treed fens.

Loss/Alteration of Terrestrial Vegetation KIRs

Old-growth Forests

The LSA supports very little forest communities classified as "old-growth". This conclusion is based on field inventory results and a search of forest age records maintained by Alberta Environmental Protection(AEP). Tree age criteria for old-growth forests has been defined for this area as outlined in Table E9-3 (BOVAR 1996a). As part of the vegetation inventory of the LSA, old-growth sites were sought out for age determination.

The two forest communities most likely to support old-growth forests included aspen-white spruce forests and lichen-jack pine forests.

Aspen-White Spruce Forests

The definition of mature, old-growth forests currently includes both the age of the dominant trees as well as structural features such as height, diameter, density and spacing patterns, snag density, cavity characteristics, nutrient cycling, energy flow patterns and structural heterogeneity (Franklin et al. 1981, Green 1988, Old-growth Definition Task Force 1986). Fairbarns (1991) used the definition identified through much of North America, i.e., the oldest 10% of the vegetation community within a given natural successional sequence (Golder 1996).

Old-growth white spruce forest is uncommon in the LSA and RSA and generally confined to river valley terrain and flood plains (Westworth 1990). Old-growth spruce forests have been designated as significant natural features in northeastern Alberta (Westworth 1990). These forests are generally considered to be diverse, maintaining a variety of age classes and stand structure components. These sites are very sensitive to physical development, taking more than 150 years to re-establish (BOVAR 1996a). Older spruce forests (>125 years of age) are valued for their commercial products as well as their values as an uncommon natural resource in the province. The diversity of these forests attracts a similar diversity of other resources, including uncommon wildlife species. This factor makes these forests important for hunting, trapping and non-consumptive resource uses.

The aspen-white spruce forests are found within ecosite phases e1/f1 and e2/f2, occupying an area of 66 ha and 9 ha respectively (Table E9-2). Neither of these communities meet the age class criteria for old-growth forests, nor are they affected to a large extent by clearing.

Lichen-Jack Pine Forests

Mature jack pine plant communities represent a KIR given the criteria previously described for vegetation communities; however, in their old age or mature stage, their open canopy and characteristic understorey are particularly important in providing a diversity of vegetation conditions and wildlife habitat within both the LSA and RSA. Jack pine communities are located in small stands on rapidly-drained, sandy deposits along slope crests. They are generally uncommon within the LSA and RSA. The open canopy of the lichen jack pine ecosite phase is dominated by jack pine. The shrub understory is typically composed of blueberry, bearberry, green alder, bog cranberry, Labrador tea, twin-flower, jack pine and sand heather. Wild lily-of-the-valley is commonly found in the herb layer. On the forest floor, reindeer lichen is dominant and Schreber's moss, awned hair cap and brown-foot cladonia are also found. Many of the understory species found within the lichen jack pine plant community are used by aboriginal people.

The lichen-jack pine forests are found within ecosite phases a1, a1/g1 complex, b1 and g1, occupying areas of 106 ha, 21 ha, 878 ha and 47 ha of the LSA, respectively (Table E9-2). Of these communities, only portions of the b1 ecosite phase (Blueberry, Jack Pine - White Spruce) meets the age class criteria of old-growth forest. Of the 878 ha of the b1 ecosite phase, 335 ha will be cleared; however, the cleared area does not include the area supporting old-growth forest within the LSA, which is located on the northern portion of the Athabasca River escarpment. Approximately 218 ha will be reclaimed within this ecosite phase (Table E9-2).

Table E9-3 Tree Age Criteria for Dominant Tree Overstory Species to Determine Old-growth Forest Stands From Phase III Forest Inventory Data

Dominant Forest Canopy Tree Species	Minimum Age
Balsam fir	160
White spruce	160
Black spruce	200
Tamarack	200
Jack pine	120
Trembling aspen	100
Balsam poplar	160

In summary, the impact of the Muskeg River Mine Project on old-growth forests is minimal. Therefore, the impact is defined as neutral in direction and negligible in magnitude, given that no old-growth forest communities will be cleared by the project.

Plant Communities of Economic Importance

The aspen-white spruce communities and the successionally less mature aspen communities are common within the LSA. These communities have no special status because of their abundance, (BOVAR 1996a); however, they are economically very important as a resource in the forest industry. The aspen-white spruce vegetation communities have a diversity of plant species because of a mixture of immature and mature species composition and structure. This diversity makes these communities resilient to natural or man-induced change. Aspen and white spruce are currently highly valued as economic species for the forestry industry. This type of mixed wood forest is also of high value for recreational pursuits such as hunting and camping.

Forest communities suitable for harvesting and utilization for economic purposes are common throughout the LSA. The areas of those vegetation types which support productive forest within the LSA and the areas to be cleared within the Project (development) area are shown in Table E9-4. The greatest area of clearance within the Project (development) area is associated with ecosite phase d1 (Low Bush Cranberry, White Spruce) where 358 ha of a total of 1,525 ha within the LSA will be cleared. This vegetation type has a Timber Productively Rating (TPR) of "moderate to good". Other ecosite phases with a moderate to good TPR rating which will be cleared include the b1 (Blueberry, Jack Pine, White Spruce) type, where 335 ha of a total of 878 ha within the LSA will be cleared (Table E9-4).

A total of 868 ha of productive forest (moderate to good TPR) will be cleared as a result of the Muskeg River Mine Project. This represents approximately 20% of the total cleared area (4,343 ha) within the Project area.

In summary, the impact of the Muskeg River Mine Project on the plant communities of economic importance is negative in direction and low to moderate in magnitude given that less than 30% of the productive forest within the LSA will be cleared for development. The geographic extent is local and restricted to the local study area. The duration of impact is long-term, greater than 30 years but is considered reversible. The frequency of impact is low, occurring only during the initial clearing of the forest.

Following mine closure, reclamation will result in a substantial increase in the productive forest capability in the LSA.

Rare or Endangered Terrestrial Plant Species or Communities

Rare plants often require unique habitat types, a number of which were observed in the Muskeg River Mine Project LSA. Rare plants are found to a limited extent in upland locations depending upon the species requirements (Table E9-5). Further details on rare plants and their habitats within the Local and Regional Study Areas are presented in "The Terrestrial Vegetation Baseline for the Muskeg River Mine Project" (Golder 1997n).

Table E9-4 Timber Productivity Ratings (TPR) of Terrestrial Vegetation (Ecosite Phases) Types Within the Local Study Area and Areas to be Cleared for the Muskeg River Mine Project

Vegetation Type			TPR[a]	LSA		Cleared Area	
Vegetation Cover	Map Code	Ecosite Phases		Area (ha)	% of LSA	Area (ha)	% of LSA
Uplands (terrestrial) Plant Communities	a1	Lichen Pj	F - G	106	1.0	49	0.4
	a1/g1 complex	Pj-Lt	F - G	21	0.2	4	0.1
	b1	Blueberry Pj-Aw	M - G	878	8.0	335	3.1
	b3	Blueberry Aw-Sw	M - G	67	0.6	11	0.1
	b4	Blueberry Sw-Pj	M - G	317	2.9	125	1.1
	c1	Labrador Tea-mesic Pj-Sb	F - M	27	0.2	7	0.1
	d1	Low-Bush Cranberry Aw	M - G	1,525	13.9	358	3.3
	d2	Low-Bush Cranberry Aw-Sw	M - G	175	1.6	39	0.4
	d3	Low-Bush Cranberry Sw	F - M	19	0.2	0.1	<0.1
	e1	Dogwood Pb-Aw	F - M	61	0.6	9	0.1
	e1/f1	Pb-Aw	F - M	66	0.6	0.1	<0.1
	e2	Dogwood Pb-Sw	F - M	4	0.0	0.0	0.0
	e2/f2	Pb-Sw	F - M	9	0.1	2.0	<0.1
	e3	Dogwood Sw	F - M	93	0.8	0.0	0.0
	g1	Labrador Tea-subhygric Sb-Pj	U - F	47	0.4	21	0.2
	h1	Labrador Tea/Horsetail Sw-Sb	U - F	310	2.8	131	1.2
TOTALS	**Moderate - Good**			**2,962**		**868**	
	Fair - Good			**127**		**53**	
	Fair - Moderate			**279**		**182**	
	Unproductive - Fair			**357**		**152**	
	Total Terrestrial Plant Communities			**3725**		**1255**	

Source: AVI Manual Version 2.2, 1996
(a)TPR
G-Good
M-Moderate
F-Fair
U-Unproductive

Riparian areas, which were also surveyed, provide considerably more unique microhabitats for rare plants, ranging from the associated bogs and fens along the wetlands margins. Impacts on rare plants within wetlands habitats are discussed in Section E10.

Within the LSA, fourteen rare plants have been identified at eleven sites (Table E9-5). Four of the rare plants identified are associated with uplands (terrestrial) habitat, none of which will be affected by the Project.

In summary, the impact of the Muskeg River Mine Project on rare or endangered terrestrial plant species or communities is neutral in direction and negligible in magnitude, given that none have been identified within the Project (development) area.

Table E9-5 Rare Plants Observed Within the LSA During 1995 and 1997 Field Surveys

Botanical Name	Common Name	Ecosite Phase	Location Plot	
			1995 (BOVAR)	1997 (Golder)
Carex lacustris	lakeshore sedge	e2, i1	217	18, 22, 30
Clintonia uniflora	corn lily	j2	223	
Barbarea orthoceras	American winter cress	r1		18
Scirpus cyperinus[(a)]	wool-grass	d2		26
Lycopus uniflorus	northern water-horehound	e2	217	11, 26
Drosera anglica	Oblong-leaved sundew	k2	214	
Coptis trifolia[(a)]	goldthread	g1		16
Kalmia polifolia	northern laurel	k3	186	
Monotropa uniflora[(a)]	indian pipe	b1	54	
Rhamnus alnifolia[(a)]	alder-leaved buckthorn	i2, g1		10, 33
Carex tenuiflora	thin flowered sedge	j2	180	
Sparganium fluctuans		i2		30
Nymphaea tetragona leibergii	small water-lily	i1		30
Carex hystricina	porcupine sedege	r1		18

[(a)] Denotes rare plants found primarily in uplands (terrestrial) ecosite phases, the remainder are primarily found in wetlands

Traditional Plants (Food, Medicinal and Spiritual)

A variety of plants are used in the area of the Muskeg River Mine Project, for medicinal, spiritual and consumptive purposes. An investigation conducted by the Fort McKay First Nations people was used to develop a list of plants used for such purposes. This information, in addition to recently acquired information, was used to create a summary table of plant species that are currently used or may be used in the future (Table E9-6).

As described in the Terrestrial Vegetation Baseline Report (Golder 1997n), a literature review, and past interviews were used to identify the use of plants in the area by aboriginal people. Plants identified included those used for food, medicinal or spiritual purposes (Table E9-6). Each plant species was ranked as high (H), high-medium (MH), medium (M) or low (L), according to importance (Table E9-6). Ranking was based on a review of traditional land use completed by the Fort McKay First Nations (Fort McKay Environmental Services, 1995). High, medium or low were assigned to each species based on the number of times a species was indicated within a specific region of the traditional land use maps (Golder Associates 1996).

Beckingham and Archibald's (1996) classification system was used to assign ecosites to each identified plant species. The ecosites listed for each traditional plant are based on the list of *dominant* vegetation species for each ecosite. As such, a traditional plant species may not always be found in the assigned ecosites, although the probability is high that they will.

Conversely, traditional plant species may be found outside of the assigned ecosites. In short, assigning ecosites to each plant species is a tool to approximate the area where traditional plants may be found.

Using traditional plant species rankings for each ecosite within the LSA, impacts on traditional plant species were assessed by comparing predisturbance and reclaimed areas for each of the ecosites (Table E9-7). It is possible to quantify impacts on traditional plant species, by assessing ecosite losses associated with high, moderate and low traditional plant rankings.

Most of the traditional use of plants identified can be found in multiple ecosite phases within the LSA. Accordingly, many of the plants can potentially be found over large areas within the LSA. For example, rose hips, which are used for food or medicinal purposes, may be found in 30% of the LSA (Golder 1996). A few traditional plants, including mint, strawberry, pin- and chokecherry and cattail are found in only one ecosite. In addition, seven of the plants are only found in a small area (<5%) of the LSA (Table E9-7).

As most of the traditional plants are widespread in the LSA losses associated with construction and operation are equally distributed across all species. Many wetland ecosites are lost during construction and operation; however, traditional plant species associated with wetland areas are not severely impacted. Again, this was largely due to the wide distribution of most of the traditional plants. In addition, none of the plants occurring within only one ecosite, or having a limited distribution, will be severely affected. Indeed, none of the traditional plants suffered more than a 50% loss in areas where they can be found.

Plans to establish plant communities on reclamation landscapes involve the introduction of 'starter species' (see Section E16 - Mine Closure Plan). Succession then acts as the mechanism for establishing the desired community type. As such, the diversity of reclaimed plant communities increases over time, resulting in vegetation associations and communities more similar to the pre-development conditions than immediately following reclamation. Once ecosites have re-established, it is assumed that traditional plant populations will eventually be similar to those found in pre-development ecosites.

Landscapes in the Project Area will largely be reclaimed to upland communities. As such, traditional plants associated with upland communities, such as balsam fir, balsam poplar, white spruce, prickly rose, currents, pin- and chokecherry and raspberry, will potentially be found over a much larger area in the future. Those traditional plants associated with wetland areas such as, Labrador tea, moss, sweet flag and tamarack will have a more limited range than before project development. However, all of

Table E9-6 Plants Gathered for Food, Medicine and Spiritual Purposes in the Area of the Muskeg River Mine Project

Plant	Food	Medicine	Spiritual	Score
Balsam Fir		x		high
Bearberry	x		x	high
Black Poplar		x		high
Blueberry	x			high
Cranberry (Lowbush and Bog)	x			high
Labrador Tea		x		high
Mint	x	x		high
Moss		x		high
Rose hips	x	x		high
Senega Snakeroot		x		high
Spruce (White and Black)	x	x		high
Strawberry	x	x		high
Sweet flag		x		high
Sweet Grass		x	x	high
Tamarack		x		high
Birch (White and Bog)	x	x		high-medium
Buffaloberry	x	x		low
Common Juniper	x	x		low
Currants (Gooseberry Red and Black)	x	x		low
Twisted Stalk	x			low
Dogwood	x			medium
Frying Pan Plant		x		medium
Green Frog Plant		x		medium
Hazelnuts	x			medium
nettles	x	x		medium
Pin- and Chokecherry	x	x		medium
Raspberry (Dwarf and Trailing)	x	x		medium
Saskatoon berry	x	x		medium
Fungi (Puffball and Willow)		x		medium-high
Cattail	x			high

these species are widespread at present and therefore losses are not considered significant.

Table E9-7 Traditional Plant Species, Associated Ecosites, and Pre and Part Disturbance Areas Within the LSA
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Plant	Importance	Ecosite	Pre Disturbance LSA		Disturbance Impact		Post Closure Reclaimed	
			Area (ha)	% LSA	Area (ha)	% LSA	Area (ha)	% LSA
Balsam Fir	H	d1, d2, d3, e2, e3, f2, f3	1815.0	16.6	399.1	3.6	2279.0	20.8
Bearberry	H	a1, b1, b2, b3, b4	1337.0	12.2	493.0	4.5	988.0	9.0
Balsam Poplar	H	d1, d2, d3, e1, e2, e3, f1, f2, f3	1942.0	17.7	408.2	3.7	2375.0	21.7
Blueberry	H	a1, b1, b2, b3, b4, c1, g1	1365.0	12.5	502.0	4.6	988.0	9.0
Cranberry (low-bush and bog)	H	a1, b1, b2, b3, b4, c1, d1, d2, d3, e1, e2, e3, f1, f2, f3, g1, h1, i1, i2, j1, j2	5091.0	46.5	1663.2	15.2	3499.0	31.9
Labrador Tea	H	b1, b2, b3, b4, c1, g1, h1, i1, i2, j1, j2, k1	4413.0	40.3	1945.0	17.8	1124.0	10.3
Mint	H	l1	85.0	0.8	4.0	0.0	119.0	1.1
Moss	H	a1, b1, b2, b3, b4, c1, d2, d3, e2, e3, f2, f3, g1, h1, i1, i2, j1, j2, k1, k2, k3, l1	6700.0	61.2	3039.1	27.7	1124.0	10.3
Rose hips	H	b1, b2, b3, b4, d1, d2, d3, e1, e2, e3, f1, f2, f3, g1, h1	3304.0	30.2	911.2	8.3	3363.0	30.7
Senega Snakeroot	H	n/a						
Spruce (white and black)	H	b1, b2, b3, b4, c1, d1, d2, d3, e2, e3, f1, f2, f/3, g1, h1, i1, i2, j1, j2, k1	6228.0	56.9	2344.1	21.4	3499.0	31.9
Strawberry	H	b3	67.0	0.6	11.0	0.1	72.0	0.7
Sweet flag	H	Shallow open water, j1, j2, k1, k2, k3, l1	5340.0	48.7	2539.0	23.2	136.0	1.2
Tamarack	H	j1, j2, k1, k2	5147.0	47.0	2523.0	23.0	17.0	0.2
Birch (white and bog)	MH	b1, b2, b3, b4, d1, d2, d3, e1, e2, e3, f1, f2, f3, h1, j1, j2, k1, k2	8443.0	77.1	3428.2	31.3	3380.0	30.9
Buffaloberry	L	b1, d1, d2, d3	2587.0	23.6	732.1	6.7	1043.0	9.5
Common Juniper	L	a1, b1, b2, b3, b4, c1, d1	2903.0	26.5	859.0	7.8	1084.0	9.9
Currants (gooseberry, red and black)	L	e1, e2, e3, f3	233.0	2.1	11.1	0.1	1550.0	14.2
Twisted stalk	L	b1, b2, b3, b4, c1, d1	2776.0	25.3	806.0	7.4	1084.0	9.9
Dogwood	M	e1, e2, e3, f1, f2	233.0	2.1	11.1	0.1	1550.0	14.2

Table E9-7 Traditional Plant Species, Associated Ecosites, and Pre and Part Disturbance Areas Within the LSA
Page 2 of 2

Plant	Importance	Ecosite	Pre Disturbance LSA		Disturbance Impact		Post Closure Reclaimed	
			Area (ha)	% LSA	Area (ha)	% LSA	Area (ha)	% LSA
Frying Pan Plant	M	n/a						
Green frog plant	M	n/a						
Hazelnuts	M	d1, d2	1694.0	15.5	397.0	3.6	825.0	7.5
nettles	M	shrub/variable	590.0	5.4	244.0	2.2	354.0	3.2
Pin- and Chokecherry	M	d2	169.0	1.5	38.0	0.3	729.0	6.7
Raspberry (Dwarf and Trailing)	M	e1, e2, e3, f1	233.0	2.1	11.1	0.1	1550.0	14.2
Saskatoon berry	M	b4, d1, d2	1980.0	18.1	495.0	4.5	1421.0	13.0
Fungi (puffball and willow)	MH	variable						
Cattail	H	l1	85.0	0.8	4.0	0.0	119.0	1.1
TOTALS			4751	43.4	1189.1	10.7	4998	45.7

n/a - no information available

E9.7.3 Residual Impact Classification and Degree of Concern

A total of 4,343 ha of vegetation will be removed to develop the Muskeg River Mine project.

A summary of the residual impacts affecting the Key Indicator Resources for terrestrial vegetation due to loss or alteration of habitat as a result of construction and operation is found in Table E9-8.

Table E9-8 Residual Impacts That Result in the Loss or Alteration of Terrestrial Plant Communities

KIR	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
old-growth forests	neutral	negligible	local	long-term	reversible	low	low
plant communities of economic importance aspen-white spruce forest	negative	low to moderate	local	medium-term	reversible	low	low
rare/endangered plants or communities	neutral	negligible	local	long-term	reversible	low	low
traditional use plants	negative	low to moderate	local	medium-term	reversible	low	low

E9.8 Key Question VE-2: Will Air Emissions or Water Releases From the Muskeg River Mine Project Change Vegetation Health?

E9.8.1 Analysis of Potential Linkages

Deposition of acid forming substances can affect vegetation in northern Alberta environments as discussed in Malhotra and Blauel (1980), Torn et al. (1987), Treshow (1984) and Legge et al. (1988). Vegetation communities that are sensitive to acidic deposition are primarily those growing on soil with low buffering capacity such as peatlands (see Section E8).

Sources of acidifying emissions associated with the Project include NO_x from extraction, boilers and from vehicles. No SO_2 emissions are associated with the Project. Modelled values for annual potential acid input (PAI) exceed the interim Critical Load of 0.25 keq/ha/yr in an area of 7 to 8 km diameter, just north of the confluence of the Muskeg River and Jackpine Creek (Section E2). A moderate increase in NO_x deposition accounts for the exceedance of the interim Critical Load. Based on this predicted exceedance, this linkage is valid.

E9.8.2 Analysis of Key Question

Airborne emissions from oil sands can have both short and long-term effects on vegetation vigour and health. Short-term exposure effects are usually restricted to a localized area and can include chlorosis or necrosis of plant tissues which can decrease growth rates or eventually result in plant mortality. Long-term effects can occur over a much larger area and may result from the accumulation of contaminants in plant issues, either by direct absorption into plant tissues from the air, or indirectly through deposition into the soil and into the roots. Once incorporated in the plant tissues, the chemicals can alter internal biochemical processes and consequently can reduce productivity, vigour or health. Other chemicals (and dust) may be adsorbed onto the surface of the plant tissues, reducing respiration and reception of radiation or photosynthesis. These processes may again reduce plant vigour and productivity.

Water-borne pollutant releases can also result in changes to vegetation productivity, vigour and health. Water emissions may include the release of light to heavy hydrocarbons during Project development. These chemicals, once released into water systems and soils can affect plant health and vigour once they are adsorbed onto the plant tissues.

NO_X emissions are predicted to have a moderate impact on air quality in the LSA (Air Quality Impact Assessment, Section E2.2). NO_X emissions occur primarily as NO and are converted to NO_2 through reactions with ambient ozone. As such, NO_X emissions are the only valid linkage potentially affecting terrestrial vegetation in the LSA. A comparison of the Alberta and Federal Government air quality objectives for NO_2 is presented in Table E9-9

Affects of NO_x on lakes, rivers and streams are addressed in the Aquatic Resources Impact Section (E6). Affects of air emissions on the quality of soils are undetermined. Therefore, this section will only focus on the direct affects of NO_x on terrestrial vegetation.

Nitrogen oxide concentrations predicted for the Muskeg River Mine Project processing facilities are predicted in Table E9-10 (as detailed in Section E2). The maximum predicted concentrations identified in Table E9-12 are situated directly over the plant site in the LSA (see Figures E2-2 to E2-5 of the Air Quality Impact Assessment).

Table E9-9 Province of Alberta Guidelines and Federal Government of Canada Air Quality Objectives for NO_2

Contaminant	Alberta	Federal Government		
		Desirable	Acceptable	Tolerable
NO_2 ($\mu g/m^3$)				
Annual	60 (0.03 ppm)	60	100	n/a
24 Hour	200 (0.11 ppm)	n/a	200	300
1 Hour	400 (0.21 ppm)	n/a	400	1000

Table E9-10 Maximum Predicted NO_x and NO_2 Concentrations Associated With the Muskeg River Mine Project

Muskeg River Mine Project and Existing Facilities			
	Hourly	Daily	Annual
NO_x ($\mu g/m^3$)	2,271 (1.1ppm)	965 (0.48 ppm)	224 (0.11 ppm)
NO_2 ($\mu g/m^3$)	207 (.11 ppm)	117 (0.06 ppm)	65 (0.03 ppm)

NO_2 does not exceed guidelines for hourly, daily and annual concentrations. Annual NO_2 concentrations are predicted to range from 76 mg/m³ within 1 km of the mine site to 65 mg/m³ up to 4.5 km, to the NNW.

Physiological functions in plants are not negatively influenced until short-term concentrations of NO_x reach 2 ppm or greater (Malhotra and Kham 1984). These are not predicted to be exceeded by the Project (Table E9-10). Hanson and Turner (1992) indicate that NO_2 concentrations seldom occur at concentrations high enough to induce injury to plants (>0.5 ppm). Studies of plant species native to Alberta indicate that, at low concentration levels, NO_x may be beneficial to plants (Malhotra and Khan 1984, BOVAR 1996).

E9.8.3 Residual Impact Classification and Degree of Concern

NO_x is the only air component contributing to acidifying emissions as a result of the Project. Effects of acidifying emissions are discussed in the Soil Section (E8) and Wetlands Section (E10).

The impacts of NO_2 on vegetation are summarized in Table E9-11.

Table E9-11 Residual Impact Classification and Degree of Concern for Effects of Emmissions on Vegetation

Impact	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
Concentrations of NO_X on terrestrial vegetation	Negative	Undetermined	Local	Short-term	Reversible	Low	Undetermined
Acidification of wetlands	Negative	Undetermined	Local	Short-term	Reversible	Low	Undetermined
Acidification of fens	Negative	Undetermined	Local	Short-term	Reversible	Low	Undetermined

E9.8.4 Monitoring

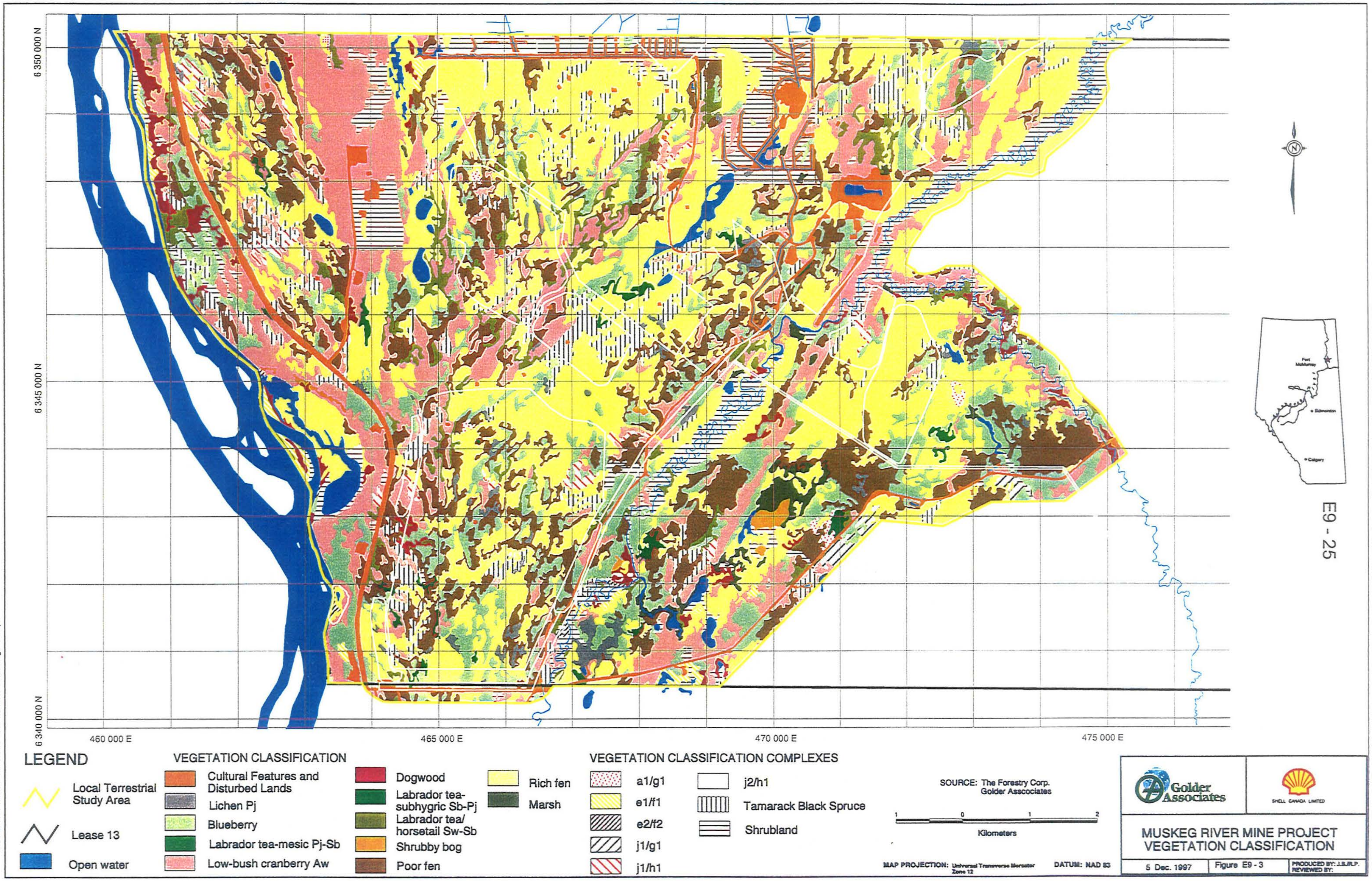
Monitoring air emission effects on terrestrial vegetation within the LSA and RSA will determine if there are direct impacts to plant communities as a result of NO_X emissions. This monitoring program could be linked to the existing environmental effects monitoring program of the Regional Airshed Monitoring Plan for Southern Wood Buffalo Zone (RAQCC 1996). To date, the site selection for regional monitoring does not consider NO_x emissions since they were determined to be relatively low compared to SO_2 emissions from Suncor and Syncrude operations (BOVAR 1997). However, since NO_X is the primary air emission resulting from the Muskeg River Mine Project it may be necessary to amend the sample design to include NO_X.

E9.9 Key Question VE-3: Will the Muskeg River Mine Project Change Plant Diversity?

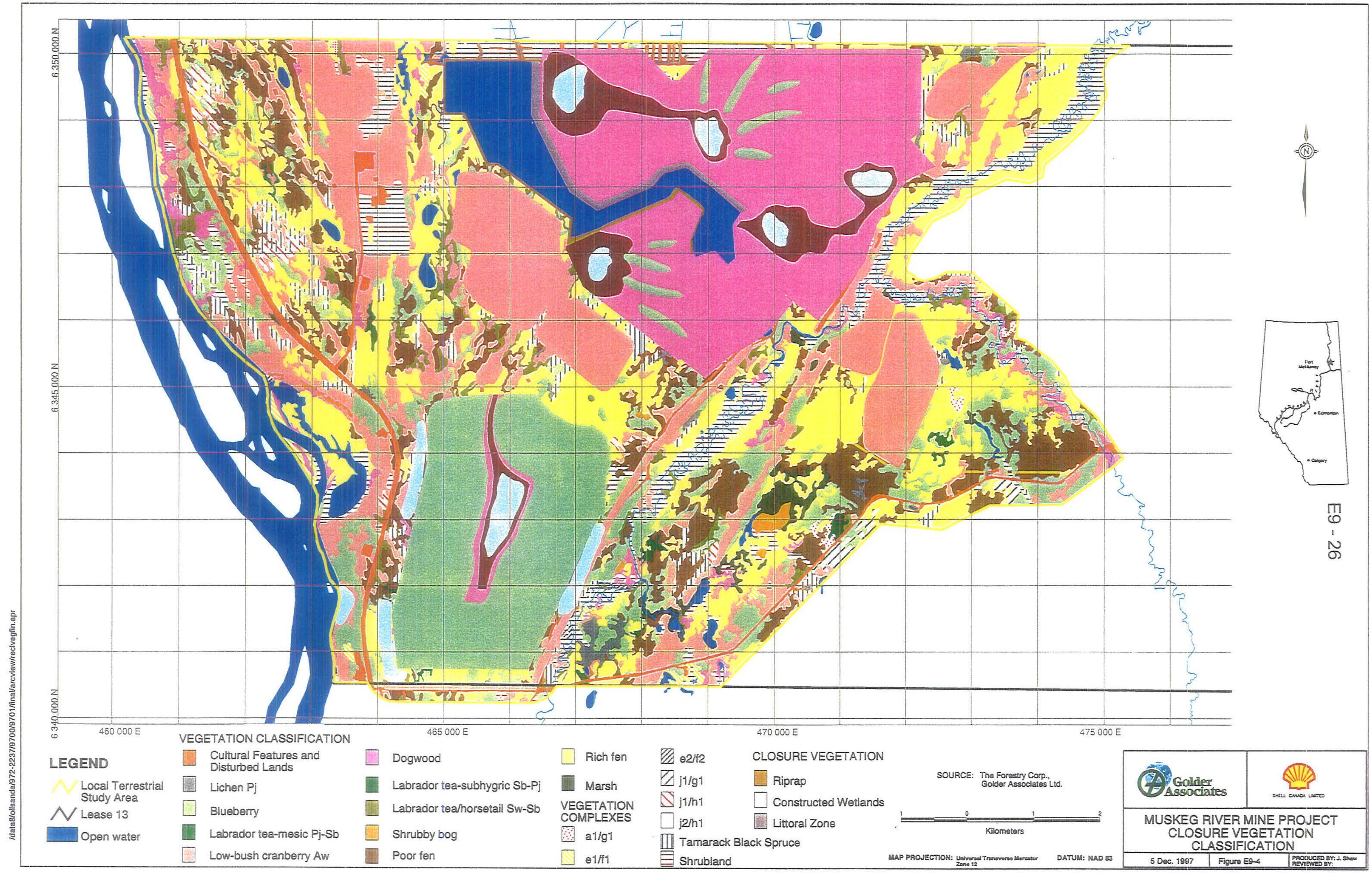
E9.9.1 Analysis of Potential Linkages

Plant diversity is a measure of the variability within plant communities and can result from variation in plant species numbers, abundance, genetic code (i.e., plant varieties and local ecotypes), structure, or spatial arrangement within the community. Diversity is commonly measured by indices, including richness (number of species, structures, varieties or genetic codes), various indices which blend the importance of richness and abundance, and other indicators of patterns within the community. Diversity can also be measured by the composition and abundance of all species within a plant community. In this sense, diversity also includes the presence or absence (and abundance) of key species such as rare or traditionally important plants. Composition and abundance may be analyzed by various multivariate techniques which demonstrate the position of the community within a conceptual space defined by environmental gradients and/or multivariate species loadings.

The direct loss of vegetation from mining developments and the changes in vigour or plant health can result in changes to the pre-existing levels of diversity within plant communities (Figures E9-3 and E9-4). These changes



/data8/oilsands/972-2237/9700/9701/fna/arcview/veg50fin.apr


6 350 000 N
6 345 000 N
6 340 000 N
460 000 E
465 000 E
470 000 E
475 000 E
N
LEGEND
Local Terrestrial Study Area
Lease 13
Open water
VEGETATION CLASSIFICATION
Cultural Features and Disturbed Lands
Lichen Pj
Blueberry
Labrador tea-mesic Pj-Sb
Low-bush cranberry Aw
Dogwood
Labrador tea-subhygric Sb-Pj
Labrador tea/horsetail Sw-Sb
Shrubby bog
Poor fen
Rich fen
Marsh
VEGETATION COMPLEXES
a1/g1
e1/f1
e2/f2
j1/g1
j1/h1
j2/h1
Tamarack Black Spruce
Shrubland
CLOSURE VEGETATION
Riprap
Constructed Wetlands
Littoral Zone
SOURCE: The Forestry Corp., Golder Associates Ltd.
1 0 1 2
Kilometers
MAP PROJECTION: Universal Transverse Mercator Zone 12
DATUM: NAD 83
Golder Associates
SHELL CANADA LIMITED
MUSKEG RIVER MINE PROJECT
CLOSURE VEGETATION
CLASSIFICATION
5 Dec. 1997
Figure E9-4
PRODUCED BY: J. Shaw
REVIEWED BY:
/data8/oilsands/972-2237/9700/9701/final/arcview/reclvegfin.apr

may be mitigated by relative changes in the abundance of species used in reclamation. Changes to genetic diversity can occur as species are lost in local areas, since local adaptations often result in spatial distributions of genetically different plant types. These losses may result in a restricted gene pool within the remaining individuals of the species.

Structural diversity and patterns of species within communities may be mitigated through reclamation and revegetation design. Structural diversity refers to the arrangement and size of plant species at various canopy heights within a vegetation type. Pattern refers to the interspersion and degree of uniformity of similar species. These changes can result from selective removal of individuals within a community, and changes to recruitment and mortality of individuals.

Vegetation diversity has implications to other topic areas (see Figure E9-2) including resource use, wildlife habitat and ecological land classification for the Project.

E9.9.2 Analysis of Key Question

This question will be addressed by assessing the current levels of diversity from ground based field measurements of plant species throughout the LSA. Community scale diversity with respect to structure was assessed by comparing ecosite phase patch number and size before and after the Project.

The indices used for vegetation species richness were expressed as the number of species present, and the species diversity, which was calculated using the Shannon Index. The Shannon Index, H, can be expressed as

$$H = - \Sigma P_i \log P_i$$

where k is the number of categories (i.e., species) and P_i is the proportion of the observations found in category i. In this case, the percent coverage of the plot area, expressed as a decimal, was used to approximate P_i.

E9.9.3 Community Diversity

Community level biodiversity can be assessed by comparing the number of vegetation polygon (patches) within the LSA before and after the Project (Table E9-12). The percent loss of polygons for each ecosite phase is negligible for el/fl, e2 and e3. All other ecosite phases; however, will have a high loss of polygons. (Table E9-12).

Table E9-12 Number of Vegetation Type (Ecosite Phase) Polygons or Patches

		Baseline	Closure	
Map Code	Ecosite Phase (Vegetation Types)	Number of Vegetation Polygons	Number of Vegetation Polygons Remaining	Percent Loss within Vegetation Types
a1	Pj lichen	62	23	62.9
b1	Aw/Sw blueberry	30	25	16.7
b3	Pj/Aw blueberry	351	190	45.9
b4	Sw/Pj blueberry	129	82	36.4
c1	Pj/Sb lab tea mesic	9	6	33.3
d1	Aw low-bush cranberry	342	228	33.3
d2	Aw/Sw low-bush cranberry	57	39	31.6
d3	Sw low-bush cranberry	10	9	10.0
e1	Pb/Aw dogwood	31	25	19.4
e1/f1	Pb/Aw dogwood horsetail	21	20	4.8
e2	Pb/Sw dogwood	3	3	0.0
e2/f2	Pb/SW dogwood horsetail	7	5	28.6
e3	Sw-dogwood	20	20	0.0
g1	Sb/Pj lab tea subhygric	4	1	75.0
h1	Sw/Sb lab tea horsetail	43	23	46.5
Pj/Lt complex	Pj/Lt complex	7	5	28.6
Sb/Lt upland	Sb/Lt upland	16	9	43.8
shrub	shrub upland	14	9	35.7
Total		1162	728	37.3

Patch size (or polygonsize) provides another measure of biodiversity (Table E9-13). In some ecosite phases, mean patch size changes after development but the range is constant. Changes in the range of patch size is an expression of heterogeneity in ecosite phase polygons. A reduction in patch size ranges, as a result of the Project, could equate to a temporary loss in biodiversity. Marginal reductions in patch size range are recorded in ecosite phases b3, el/fl and g1 (Table E9-13).

Species Richness and Diversity

Composition

Table E9-14 shows the total number of different species present in all of the plots in each of the ecosite phases, as well as the total number of species present in each of three structural layers (tree, shrub and herb). These data represent overall species richness in each ecosite phase when taken as a whole. The sum of the species present in each of the layers does not necessarily equal the total for the ecosite phase because of species

Table E9-13 Mean, Minimum and Maximum Vegetation Polygon or Patch Size

		Baseline			Impact			
Map Code	Eco Site Phase (Vegetation Types)	Mean Patch Size (ha)	Min. Patch Size (ha)	Max. Patch Size (ha)	Mean Patch Size (ha)	Min. Patch Size (ha)	Max. Patch Size (ha)	Percent Change to Mean
a1	Pj_lichen	1.7	<0.1	18.8	2.4	<0.1	18.8	43.9
b1	Aw/Sw_blueberry	2.2	<0.1	6.3	2.2	<0.1	6.3	0.2
b3	Pj/Aw_blueberry	2.5	<0.1	15.6	2.9	<0.1	13.8	14.2
b4	Sw/Pj_blueberry	2.2	<0.1	11.3	2.3	<0.1	11.3	3.3
c1	Pj/Sb_lab_tea_mesic	2.3	0.2	6.6	2.9	0.2	6.6	29.5
d1	Aw_low_bush_cranberry	4.5	<0.1	47.2	5.1	<0.1	47.2	14.7
d2	Aw/Sw_low_bush_cranberry	3.0	<0.1	12.2	3.4	0.1	12.2	13.4
d3	Sw_low_bush_cranberry	1.5	0.1	4.4	1.7	0.4	4.4	10.2
e1	Pb/Aw_dogwood	2.0	<0.1	7.7	2.1	0.1	7.7	5.6
e1/f1	Pb/Aw_dogwood_horsetail	3.1	0.1	10.8	3.3	0.4	10.8	4.8
e2	Pb/Sw_dogwood	1.5	1.1	1.9	1.5	1.1	1.9	0.0
e2/f2	Pb/Sw_dogwood_horsetail	1.3	0.1	2.3	1.3	0.3	2.3	4.0
e3	Sw_dogwood	4.6	0.6	19.4	4.6	0.6	19.4	0.0
g1	Sb/Pj_lab_tea_subhygric	1.9	1.0	3.3	1.0	1.0	1.0	-44.0
h1	Sw/Sb_lab_tea_horsetail	2.9	<0.1	16.6	3.0	<0.1	16.6	5.7
Pj/Lt_complex	Pj/Lt_complex	3.1	0.3	7.9	3.4	0.3	7.9	11.4
Sb/Lt_upland	Sb/Lt_upland	3.9	<0.1	21.4	3.5	<0.1	21.4	-9.7
shrub	shrub_upland	8.5	0.3	60.5	12.0	0.3	60.5	40.3
Upland Total		3.1	<0.1	60.5	3.6	<0.1	60.5	15.4

duplications between layers. Using this index, the d2 ecosite phase exhibits the greatest species richness both overall and in the herb layer. The highest shrub species richness, is in d1 and d2, and the highest tree species richness is in e1. The a1 ecosite phase has the fewest species overall as well as in each of the layers.

The mean and range of species richness values for individual plots within the ecosite phases are also shown in Table E9-14. These data provide an indication of the species richness that is characteristic of small areas within ecosite phases. The highest mean and maximum of total species richness are in the d1, d2 and e1 ecosite phases. The highest mean richness in the herb layer is in d1 and d2; in the shrub layer it is in d2 and e1; and in the tree layer it is in b3. Mean richness is lowest in a1 overall and in the herb layer. The lowest mean richness in the tree layer is in d3. The lowest mean richness in the shrub layer is in h1.

Structure

In terms of structure, species richness is highest in the herb layer and lowest in the tree layer for all ecosite phases except b3, and b4. Structurally, both mean and maximum richness are lowest in the tree layer in each ecosite phase. Generally, mean and maximum richness are higher in the herb layer than in the shrub layer. The differences in relative species richness among ecosite phases, may result from differences in internal compositional variability among ecosite phases.

Table E9-14 Species Richness

	Total Species Richness	Total Species			Herb-Layer			Shrub-Layer			Tree-Layer		
Eco-Phase	Class Name	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
a1	Lichen Pj	9.9	4	18	2.9	0	6	5.9	2	12	1.5	0	3
b1	Blueberry Pj-Aw	15.7	8	31	6.3	1	15	7.4	5	14	2.1	0	4
b3	Blueberry Aw-Sw	14.8	13	18	5.3	4	6	7.3	5	10	3.0	2	4
b4	Blueberry Sw-Pj	14.3	12	17	4.7	3	6	8.0	7	10	2.0	2	2
c1	Labrador Tea mesic Pj-Sb	12.8	4	26	5.2	0	15	6.3	3	10	2.0	1	3
d1	Low Bush Cranberry Aw	18.7	8	25	10.5	2	16	7.4	3	13	1.3	0	3
d2	Low Bush Cranberry Aw-Sw	19.5	8	29	10.0	2	16	8.2	2	13	2.2	1	3
d3	Low Bush Cranberry Sw	15.0	13	17	7.5	7	8	7.0	5	9	0.5	0	1
e1	Dogwood Pb-Aw	19.0	11	29	9.2	3	15	8.2	3	14	2.0	0	4
e2	Dogwood Pb-Sw	16.3	14	18	8.5	6	11	6.0	5	8	2.0	2	2
e3	Dogwood Sw	18.0	13	23	9.0	6	12	7.5	5	10	1.5	1	2
g1	Labrador Tea subhygric Sb-Pj	13.9	5	24	6.6	1	12	6.5	4	11	1.3	1	2
h1	Labrador Tea/Horsetail Sw-Sb	12.8	6	25	6.0	2	12	5.7	2	11	1.8	1	4

Diversity

Table E9-15 gives the mean and range of species diversity values for individual plots within the ecosite phases. The d1 and d2 low bush cranberry and the e1 and e2 dogwood ecosite phases have the highest mean overall diversities and along with e3, the highest mean diversities in the herb layer. The highest mean diversities are in d2, d3, e1, e2 and e3 for the shrub layer and in b3 for the tree layer. Mean diversity is lowest in g1 overall and also in the shrub. The lowest mean diversity in the tree layer is in d3 and d3. The lowest mean diversity in the herb layer is in a1. There is little difference in mean diversity between the shrub and herb layers in many of the ecosite phases and there is no discernible overall trend to higher diversity in either layer. Mean diversity is lowest in the tree layer for all ecosite phases.

Table E9-15 Species Diversity

	Total Species Diversity	Total Species			Herb-Layer			Shrub-Layer			Tree-Layer		
Eco-Phase	Class Name	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
a1	Lichen Pj	0.69	0.22	1.28	0.25	0.00	0.57	0.58	0.04	1.00	0.09	0.00	0.41
b1	Blueberry Pj-Aw	0.92	0.64	1.39	0.47	0.00	0.84	0.65	0.36	0.84	0.22	0.00	0.52
b3	Blueberry Aw-Sw	0.91	0.81	0.97	0.48	0.25	0.67	0.60	0.53	0.70	0.37	0.29	0.47
b4	Blueberry Sw-Pj	0.96	0.81	1.16	0.48	0.42	0.62	0.70	0.64	0.82	0.21	0.15	0.24
c1	Labrador Tea mesic Pj-Sb	0.68	0.38	1.13	0.31	0.00	0.84	0.52	0.20	0.81	0.23	0.00	0.29
d1	Low Bush Cranberry Aw	1.03	0.75	1.55	0.70	0.28	1.02	0.66	0.30	1.01	0.05	0.00	0.47
d2	Low Bush Cranberry Aw-Sw	1.06	0.48	1.54	0.70	0.06	1.10	0.71	0.24	0.95	0.23	0.00	0.42
d3	Low Bush Cranberry Sw	0.83	0.65	1.02	0.66	0.64	0.68	0.70	0.61	0.80	0.00	0.00	0.00
e1	Dogwood Pb-Aw	1.03	0.77	1.23	0.73	0.14	0.97	0.70	0.40	0.96	0.18	0.00	0.44
e2	Dogwood Pb-Sw	1.04	0.94	1.19	0.76	0.63	0.97	0.72	0.63	0.88	0.28	0.23	0.30
e3	Dogwood Sw	0.95	0.80	1.09	0.73	0.67	0.80	0.72	0.63	0.81	0.04	0.00	0.09
g1	Labrador Tea subhygric Sb-Pj	0.58	0.25	1.00	0.45	0.00	0.75	0.40	0.18	0.74	0.06	0.00	0.30
h1	Labrador Tea/Horsetail Sw-Sb	0.71	0.46	1.29	0.46	0.29	0.77	0.43	0.22	0.83	0.14	0.00	0.34

E9.9.4 Residual Impact Classification and Degree of Concern

The residual impact classification of changes in biodiversity of terrestrial vegetation communities during construction, operation and closure is presented in Table E9-16.

Predisturbance biodiversity indicies (e.g., ELC richness and diversity, patch size, plant species richness and diversity), along with end land use objectives assisted in the design of the final reclamation plan.

E9.9.5 Monitoring

Biodiversity indicies will be monitored for both terrestrial and aquatic ecosystems as the development areas are reclaimed.

E9.10 Key Question VE-4: Will the Reclamation of the Landscape for the Muskeg River Mine Project Result in Replacement of Plant Communities?

E9.10.1 Analysis of Potential Linkages

Reclamation of plant communities on the Muskeg River Mine Project is dependent on the capability of the various reclamation landscapes to support vegetation establishment and growth. Plant communities typically vary in their sensitivity and capacity to re-establish on reclaimed sites. Re-establishment is also dependent upon the availability of plant seed and rhizomatous plant material from the reclaimed organic storage materials.

Table E9-16 Residual Impact Classification of Terrestrial VegetationBiodiversity

Scale	Level	Impact	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
Community	Composition	Loss of ecosite phases	negative	high	local	long-term	reversible	low	low
Community	Structure	Loss of patch number	negative	moderate	local	medium-term	reversible	low	low
Community	Structure	change in patch size	negative	low-moderate	local	medium-term	reversible	low	low

E9.10.2 Analysis of Key Question

Loss/Alteration of Vegetation Communities as a Result of Muskeg River Mine Development

Analysis of loss/alteration of plant communities as a result of the Project are presented in Section E9.7. Terrestrial and wetlands communities will be lost as a result of site clearing, infrastructure development and change in hydrology. Replacement of plant communities through reclamation will be phased within the LSA throughout the development.

Reclamation Landscapes

The Closure Plan identifies the vegetation communities that will be re-established to meet specific land use objectives. Generally, this process involves the following steps:

- identifying vegetation communities that can be established on a variety of reclaimed landscapes;
- identifying techniques to establish vegetation communities on reclaimed landscape;
- identifying land use objectives for reclaimed landscapes;
- identify design criteria for selected land use;
- design monitoring program; and
- design research program.

Community types that naturally occur in the oil sands region (i.e., native species) were identified during baseline investigations. Of the communities present in the area, 15 have been identified as possible replacement communities. (Table E9-17). Establishment of vegetation communities on the reclaimed landscape is dependent upon type of landform, slope, aspect, soil type/capability, and soil drainage conditions. Table E9-18 presents a summary of parameters corresponding to vegetation community types and predicted replacement areas upon closure of the Project.

Reclamation techniques are evolving as the oil sands industry grows. However, current plans are based upon existing oil sand reclamation research. This research suggests introduction of 'starter vegetation' and then, by the process of succession, target plant communities will develop. 'Starter vegetation' will include both tree and shrub species at an approximate total density of 2400 stems/ha. Specific techniques and information is provided in the Conservation and Reclamation plan for the Project (Section 16, Volume 1 of the Application).

Table E9-17 Potential Replacement Plant Communities for the Developed Area

Landscape Features	Soil Capability and Moisture Regime	Target Ecosite phase	Tree Species	Shrub Species	Predicted Replacement Area (Ha)	% LSA
Ponds (water depth >1m)	N/A	NWL	n/a	?	488	4.5
Shallow water (littoral zone)	N/A	WONN/Constructed Wetlands	n/a	?	119	1.5
Riparian shrub complexes	Soil Class 5	Shrubland/SONS	n/a	?	308	2.8
Tailings Sand Mid-Slope	Soil Class 4 Subxeric, Submesic	b1 Blueberry Pj-Aw	Jack Pine, Aspen, White Spruce	Blueberry, Bearberry, Labrador Tea, Green Alder	218	2.0
Tailings Sand Upper Slope	Soil Class 3 Subxeric, Submesic	b2 Blueberry Aw (Bw)	Aspen, White Spruce, White Birch	Blueberry, Bearberry, Labrador Tea, Green Alder	102	0.9
Tailings Sand Lower Slope	Soil Class 3, Subexeric, Submesic	b3 Blueberry Sw-Pj	Aspen, White Spruce, White Birch	Blueberry, Bearberry, Labrador Tea, Green Alder	72	0.7
Tailings Sand Plateau	Soil Class 3, Subxeric, Submesic	b4 Blueberry Sw-Pj	White Spruce, Jack Pine, White Birch, Aspen	Blueberry, Bearberry, Labrador Tea, Green Alder	596	5.4
Overburden, South Aspect	Soil Class 3, Mesic	d1 Low-bush Cranberry Aw-Sw	Aspen, White Spruce, Balsam Poplar, White Birch	Low-bush Cranberry, Canada buffalo-berry, Saskatoon, Green Alder, Rose, Raspberry	96	0.9
Overburden, Plateau or North Aspect	Soil Class 3, Mesic	d2 Low-bush Cranberry Aw-Sw	Aspen, White Spruce, Balsam Poplar, White Birch	Low-bush Cranberry, Canada buffalo-berry, Saskatoon, Green Alder, Rose, Raspberry	729	6.7
Near Level, Overburden or Tailings Sand, Lower Slope Position	Soil Class 3, Subhygric, mesic	e3 Dogwood Pb Aw	White Spruce, Aspen, Balsam Poplar, White Birch	Dogwood, Low-bush, Cranberry, Raspberry, Green Alder, Rose	1550	14.2
		j2			17	0.2
TOTAL					4343	39.8

Total Density (tree and shrub species combined) approximately 2400 stems/Ha

Table E9-18: Summary of Vegetation Community Baseline, Construction and Operation and Reclaimed Areas within the LSA

Map Code	Vegetation Type Ecosite Phase	Pre Disturbance Area (ha)	Pre Disturbance % LSA	Disturbance Impact Area (ha)	Disturbance Impact % LSA	Post - Closure Reclamation Area (ha)	Post - Closure Reclamation % LSA	Change from Pre-disturbance conditions Area (ha)
a1	Lichen Pj	106	0.97	49	0.45		0.00	-47
a1/g1 complex	Pj-Lt	21	0.19	4	0.04		0.00	-4
b1	Blueberry Pj-Aw	878	8.02	335	3.06	218	1.99	-117
b2	Blueberry Aw(Bw)	0	0.00		0.00	102	0.93	+102
b3	Blueberry Aw-Sw	67	0.61	11	0.10	72	0.66	+61
b4	Blueberry Sw-Pj	286	2.61	98	0.89	596	5.44	+498
c1	Labrador Tea-mesic Pj-Sb	20	0.18	3	0.03		0.00	-3
d1	Low Bush Cranberry Aw	1,525	13.92	359	3.28	96	0.88	-263
d2	Low Bush Cranberry Aw-Sw	169	1.54	38	0.35	729	6.66	+691
d3	Low Bush Cranberry Sw	15	0.14	0.1	0.00		0.00	0
e1	Dogwood Pb-Aw	61	0.56	9	0.08		0.00	-9
e1/f1	Pb-Aw	66	0.60	0.1	0.00		0.00	0
e2	Dogwood Pb-Sw	4	0.04	0	0.00		0.00	0
e2/f2	Pb-Sw	9	0.08	2	0.02		0.00	-2
e3	Dogwood Sw	93	0.85	0	0.00	1550	14.15	+1550
g1	Labrador Tea-subhygric Sb-Pj	8	0.07	6	0.05		0.00	-6
h1	Labrador Tea/Horsetail Sw-Sb	123	1.12	53	0.48		0.00	-53
i2	Shrubby Bog	20	0.18	0	0.00		0.00	0
j1	Treed Poor Fen	356	3.25	168	1.53		0.00	-168
j1/g1 complex	Lt/Sb-Pj	27	0.25	0	0.00		00.00	0
j1/h1 complex	Sb/Sw-Lt	74	0.68	0	0.00		0.00	0
j2	Shrubby Poor Fen	1,182	10.78	532	4.86		0.00	-532
j2/h1 complex	Sw/Sb-Fen Complex	2	0.02	0	0.00		0.00	0
k1	Treed Rich Fen	1,370	12.51	739	6.75		0.00	-739
k2	Shrubby Rich Fen	2,136	19.50	1084	9.90	17	0.16	-1069
k3	Graminoid Rich Fen	51	0.47	6	0.05		0.00	-6
l1	Marsh	85	0.78	4	0.04	119	1.09	+115
Stnn, Sfnn	Swamp (coniferous, deciduous and shrub)	1359	12.41	531	4.85		0.00	-531
Wonn	Shallow Open Water	57	0.52	6	0.05		0.00	-6
AIH, AIG, AIM	Cultural Disturbance	471	4.30	232	2.12		0.00	-232
NMC	Cutbanks	12	0.11	0	0.00		0.00	0
NWL	Lakes and Ponds	114	1.04	32	0.29	536	4.89	+504
NWR	Rivers	7	00.6	0	0.00		0.00	0
shrub	Shrubland	119	1.09	12	0.11	308	2.81	+296
Sb/Lt	Sb/Lt Complexes	61	0.56	30	0.27		0.00	-30
TOTAL		10954	100%	4343	39.6	4343	39.6	

difference between Vitt (1997) and Bechingham and Archibald (1996) wetland classification criteria differ.

Two primary end land use objectives have been identified for the reclaimed landscapes.

- Commercial Forest revegetation to a mixed wood boreal forest, using native species, with equal or better forest capability than pre-development conditions. As such, communities that support species of merchantable timber, as well as accessibility issues (e.g. steeper slopes) will be addressed.

- Moose Habitat: moose have been identified as an important wildlife species, from both an economic and social point of view. As such, maintenance of historic moose populations, restoration of moose habitat capability and populations to pre-development levels, and monitoring of moose populations upon closure, have been identified as goals. As such, reclamation landscapes will be selected that support moose populations. These would include early successional communities that support browse species, and mature mixedwood or conifer communities that provide winter shelter.

Other goals, which are complimentary to the primary goals, include: development of self-sustaining ecosystems with an acceptable level of biodiversity; and drainage systems that have an acceptable level of impact in terms of issues such as erosion rates and contaminant loadings. Analysis of Replacement of Plant Communities

As previously discussed, plans to establish plant communities on reclaimed landscapes involves the introduction of 'starter species'. Succession then acts as the mechanism for establishing the desired community type. As such, the diversity of reclaimed plant communities increases over time, resulting in associations and communities more similar to the pre-disturbed conditions than immediately following reclamation.

Eleven community types have been selected for establishment on reclaimed landscapes after the closure of the Muskeg River Mine Project (Table E9-18). These communities include:

- ponds,
- shallow water,
- shrub complexes (riparian),
- b1: blueberry, jack pine and aspen (Pj-Aw),
- b2: blueberry, aspen and white birch (Aw(Bw)),
- b3: blueberry, aspen and white spruce (Aw-Sw),
- b4: blueberry, white spruce and jack pine (Sw-Pj)
- d1: low-bush cranberry, aspen (Aw)
- d2: low-bush cranberry, aspen and white spruce (Aw-Sw)
- e3: dogwood, white spruce (Sw), and
- f1: horsetail, balsam poplar and aspen (Pb-Aw).

Eight of these communities represent upland community types. Baseline information for the LSA, indicates that 31.5% of community types identified represent uplands, while 61% represent wetland community types. During construction and operation, 22% of upland community types, and 71% of wetland community types were lost. Reclaimed landscapes will result in the replacement of 77% (3363 ha) of uplands community types and 3.1% (136 ha) of wetland community types lost. Thus, upon closure, relative to pre-disturbance areas, upland communities will increase by 53%, and wetland communities will decrease by 34% within the LSA. Clearly, a dominantly wetland fen area will be converted to a dominantly upland mixedwood forest area.

E9.10.3 Key Indicator Resources

At the plant community level, five plant community types have been identified as KIRs for the Project.

Old-growth Spruce Forest and Lichen Jack Pine Plant Communities

- Old-growth spruce forests have been designated as significant natural feature in northeastern Alberta (D.A. Westworth and Associates 1990) and are sensitive to disturbance. As well they provide diverse wildlife habitat, and are important for hunting and trapping. Old-growth lichen jack pine communities represent a diverse habitat, important for wildlife species and many plant used by aboriginal people. As old-growth spruce forests and lichen jack pine forests can take more than 150 years to re-establish, they cannot be identified as reclamation communities. However, given natural successional processes, some sites could result in re-establishment of these old-growth forest communities over time.

Plant Communities of Economic Importance

Aspen-White Spruce

- These communities have been identified due to their economic importance in the forest industry. One of the primary land use objectives outlined in reclamation plans, is the development of equal or better forest capability than pre-development conditions. Of the 11 reclamation communities, 8 (b1, b2, b3, b4, d1, d2, e3 and f1) aspen and white spruce dominate the tree canopy (Table E9-18).

End Pit Lake

The end pit lake will be located at the western side of the mine footprint at closure. Impacts on aquatic plants within end pit lake and shallow open water/marsh complexes found on the west side of the lake, are discussed in the Wetlands Impact Assessment (Section E10). Upland reclamation communities on the south shore of the lake are not expected to be impacted by the CT water in the end pit lake.

Closure Drainage System

At mine closure, a drainage system will direct drainage of CT seepage water to the end pit lake. In reclamation plans, CT deposits will be capped with either sand or overburden.

Impacts on aquatic plants, shallow open water/marsh complexes and riparian shrub communities are discussed in the Wetland Impact Assessment (E10).

Primary issues of concern for upland vegetation communities include:

- impact of the underlying CT deposits on plants;
- impact of CT water and CT drainage on plants; and
- impact of CT water and CT drainage on soils, and indirectly to plants.

Due to the depth of overlying sand and overburden layers (10-13 m), plants root systems will not penetrate to the underlying CT. Therefore, underlying CT is not expected to directly impact reclamation plant communities.

On-going research suggests that the impact of CT water on plant communities is dependent upon plant species sensitivity. Preliminary data indicates that some tolerant species are able to grow in the presence of CT water. However, due to the high variability of CT water quality and lack of information concerning the effects on plant communities as a whole, the impact of CT water on reclamation plant communities is unclear. Future research will provide more information than presently available and monitoring of reclamation communities will be needed after closure to assess plant community health.

CT seepage water may also impact soils and therefore indirectly impact plants. The presence of CT water is linked with increasing soil salinity and build up of heavy metals in soils. The impact of increasing salinity and presence of heavy metals in soils on plants is dependent upon solid type/characteristics as well as plant species sensitivity.

E9.10.4 Monitoring

Soil sampling and monitoring of reclamation plant community health will be needed after closure.

E9.10.5 Residual Impact Classification and Degree of Concern

The primary residual impacts associated with replacement of plant communities includes:

- a change in dominant vegetation type from wetlands to upland communities;
- a decrease in areas of old-growth spruce and lichen jack pine forests; and
- an increase in the plant communities of economic importance, such as aspen white spruce forest.

In summary, the residual impacts associated with replacement of plant communities on the Muskeg River Mine Project LSA is considered positive in direction, moderate in magnitude and local in geographic extent. The divation is medium to long-term and is considered reversible. The frequency of impact is low.

E9.10.6 Monitoring

A monitoring program will be designed to address:

- whether both primary (i.e., forest capability and moose habitat) and complementary (e.g. biodiversity, drainage) land use objectives are being met;
- impact of CT water on reclamation plant communities; and
- impact of CT water on soil (i.e., salinity and build-up of heavy metals) and therefore, reclamation plant communities.

Potential methods of monitoring include:

- establishment of benchmark reclamation plant communities to assess vegetation conditions and health; and
- periodic assessment of water quality (Water Resources Impact Assessment, Section E5) and soil conditions (Terrain and Soil Impact Assessment, Section E8).

E10 WETLANDS IMPACT ANALYSIS

E10.1 Introduction

This section of the Muskeg River Mine Project (the Project) EIA provides information as required by the Project Terms of Reference (TofR) issued on November 7, 1997 (AEP 1997a). Specifically, the following are addressed in this section:

- assessment of how development and mitigation of the Project will affect peatlands/wetlands in the Study Area (TofR, Section 4.4).

Discussions on the potential cumulative effects on wetlands associated with the Project will be addressed in Section F10. Section D10 provided detailed information on the wetlands for the Project. Additional details on the wetlands in the Project area can be found in the Wetlands Baseline for the Muskeg River Mine Project Report (Golder 1997o).

The development of the Muskeg River Mine Project will have impacts on wetlands at the landscape, plant community and plant species level. The objective of this section is to review the potential impacts associated with construction, operation and closure of the Project on wetlands. The analysis presented in this section is based upon issues identified by the study team through consultation with regulators, aboriginal groups and other stakeholders.

This section includes a description of the overall approach used to analyze impacts, including:

- presentation of potential linkages between Project activities and wetlands resources,
- a list of key questions regarding effects on wetlands resources;
- methods used to determine impacts;
- identification of valid linkages;
- analysis of key questions;
- a description of residual impact classification and degree of concern; and
- proposed monitoring.

E10.2 Approach

The approach used to evaluate potential impacts to wetlands is the same as for other components, as explained in section E1. The impact analysis involved the following:

- collection of baseline information relevant to the key questions and linkage diagrams;
- mapping and quantification of wetlands resources in the Local Study Area (LSA);
- mapping and quantification of wetlands resources impacted by the Project development plan; and
- mapping and quantification of reclaimed wetlands resources based on the Closure Plan.

Each impact was classified according to the degree of concern (determined by a combination of direction, magnitude, duration, and geographical extent of the impact).

E10.3 Key Indicator Resources

The identification of Key Indicator Resources (KIRs) provides a focus for impact analysis and assessment. A brief description of the wetlands KIRs at the plant community level is presented as follows:

Patterned Fens. Patterned or string fens occur within both the LSA and RSA. They provide a unique hydrogeologic habitat and support a relatively high proportion of provincially or regionally rare and uncommon plant species, including pitcher plant and slender-leaved sundew (Section D10, Golder Associates 1997n). Patterned fens are nutrient rich and many are spring fed, so that they are sensitive to disturbances that may affect the water chemistry, flow rates or levels. Recovery is very slow following disturbance.

Riparian Shrub Complexes. Riparian vegetation (i.e., willow and willow-alder shrub types) are of relatively low abundance in the LSA, but moderately abundant in the RSA. This ecosite is uncommon and of special importance for its habitat values. Riparian shrub communities are ecologically important and characterized by a diversity of vegetation communities. They are generally considered to be sensitive to disturbance because they are a transition zone between the upland, well drained sites and poorly drained wetlands. These communities are important in maintaining water quality, fish habitat and aesthetics because of their capability to stabilize streambanks and provide shade. Recreational values are also high, especially for fishing and camping.

At the plant species level, the focus of the wetlands assessment is on rare plants and traditional use species which are discussed separately.

E10.4 Methods

The key questions were developed out of the identification of the issues raised by stakeholders and the EIA study team for the Muskeg River Project. To effectively address each of the questions and issues, it was necessary to acquire baseline information which described the current conditions of the Project area. These essentially reflect the landscape, community and species level concerns about wetlands communities and their diversity (Table E10-1). The selection of biodiversity assessment measures is discussed in detail in the Ecological Landscape Classification section of the EIA (Section E7).

The impact assessment was done through a comparison of the baseline conditions of the LSA of the Project to:

- conditions within the LSA that are expected to result from the Project development.

The wetlands resources of the LSA were mapped according to the Alberta Wetlands Inventory (AWI). The area of wetlands were determined and a wetlands database, linking each map polygon with a geographic information system (GIS) was created to allow the relative abundance of wetlands to be compared within the LSA. By superimposing the Project development plan over the wetlands polygons, the area of each wetlands affected was quantified and an assessment of significance made using the criteria previously described.

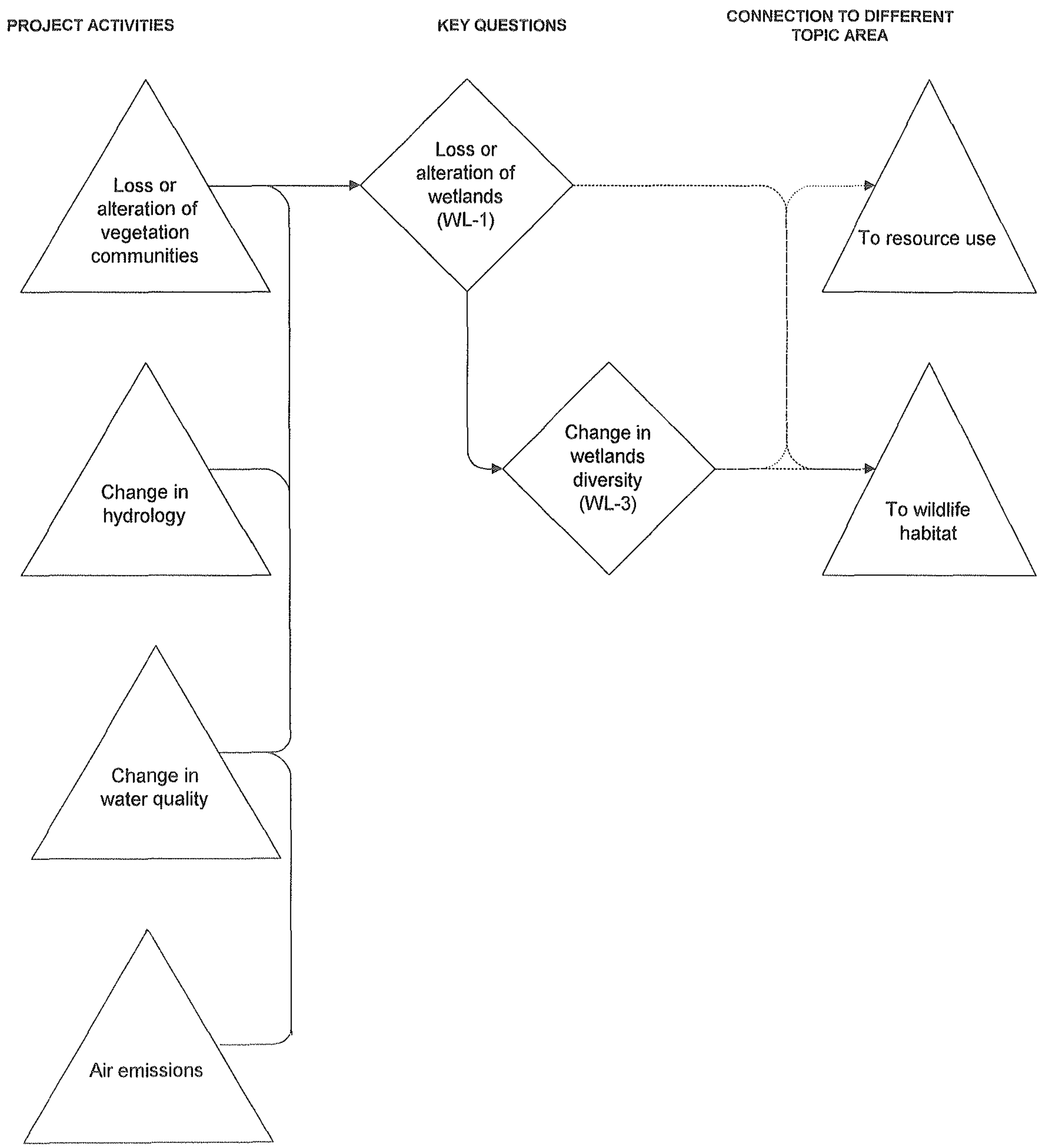
By projecting the successive reclamation activities onto the Project development area, the progression of reclamation wetlands types was quantified.

E10.5 Potential Linkages and Key Questions

Analysis of impacts on wetlands as a result of the Project have been split into two phases: 1) construction and operation impacts, key questions WL-1 and WL-3; and 2) impacts upon closure, key questions WL-2.

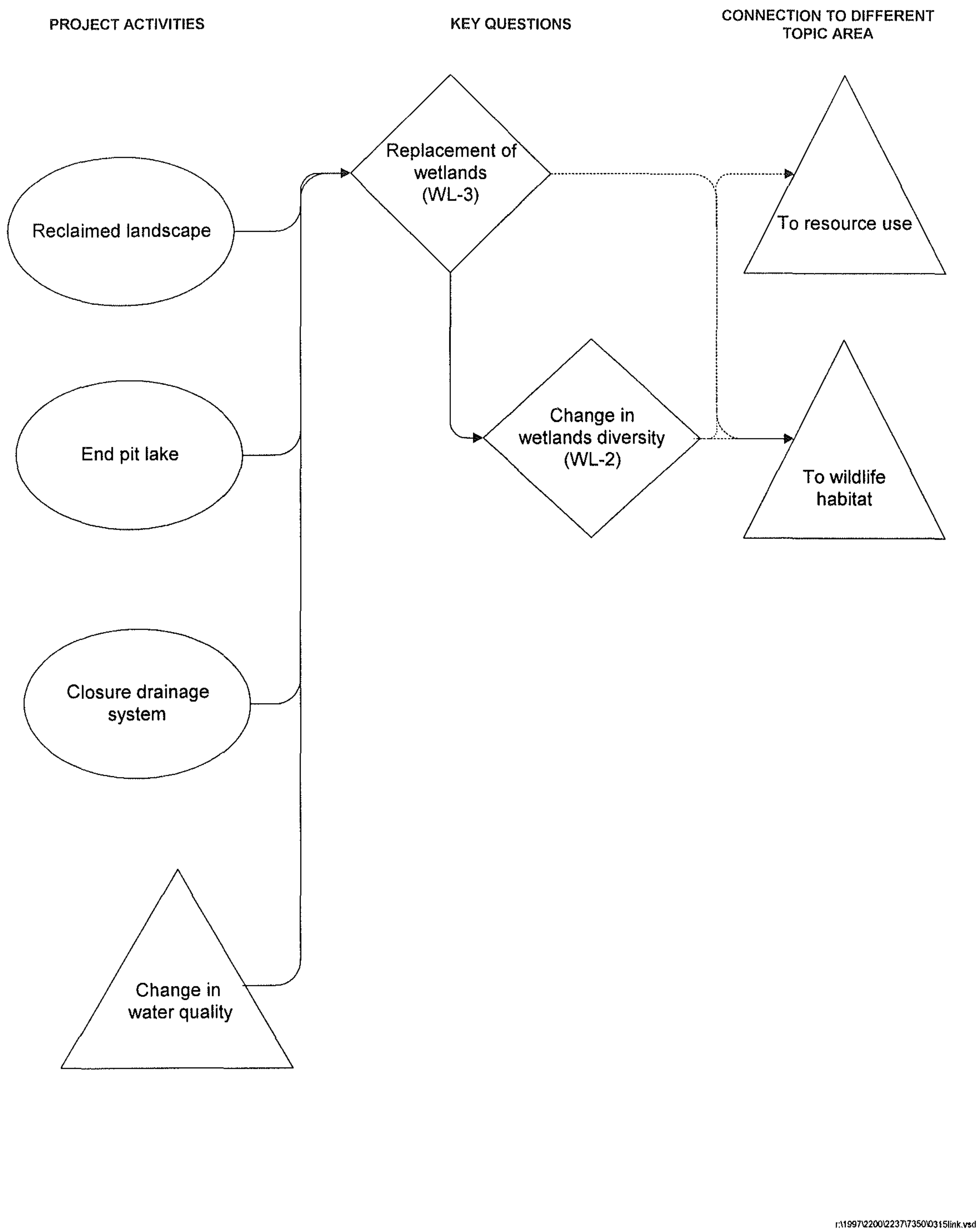
The linkage diagrams illustrating both key questions and potential linkages associated with wetlands resources is presented in (Figures E10-1 and E10-2). The wetlands classification map for the Project area is shown in Figure E10-3. The key questions identified for wetlands resources are listed below.

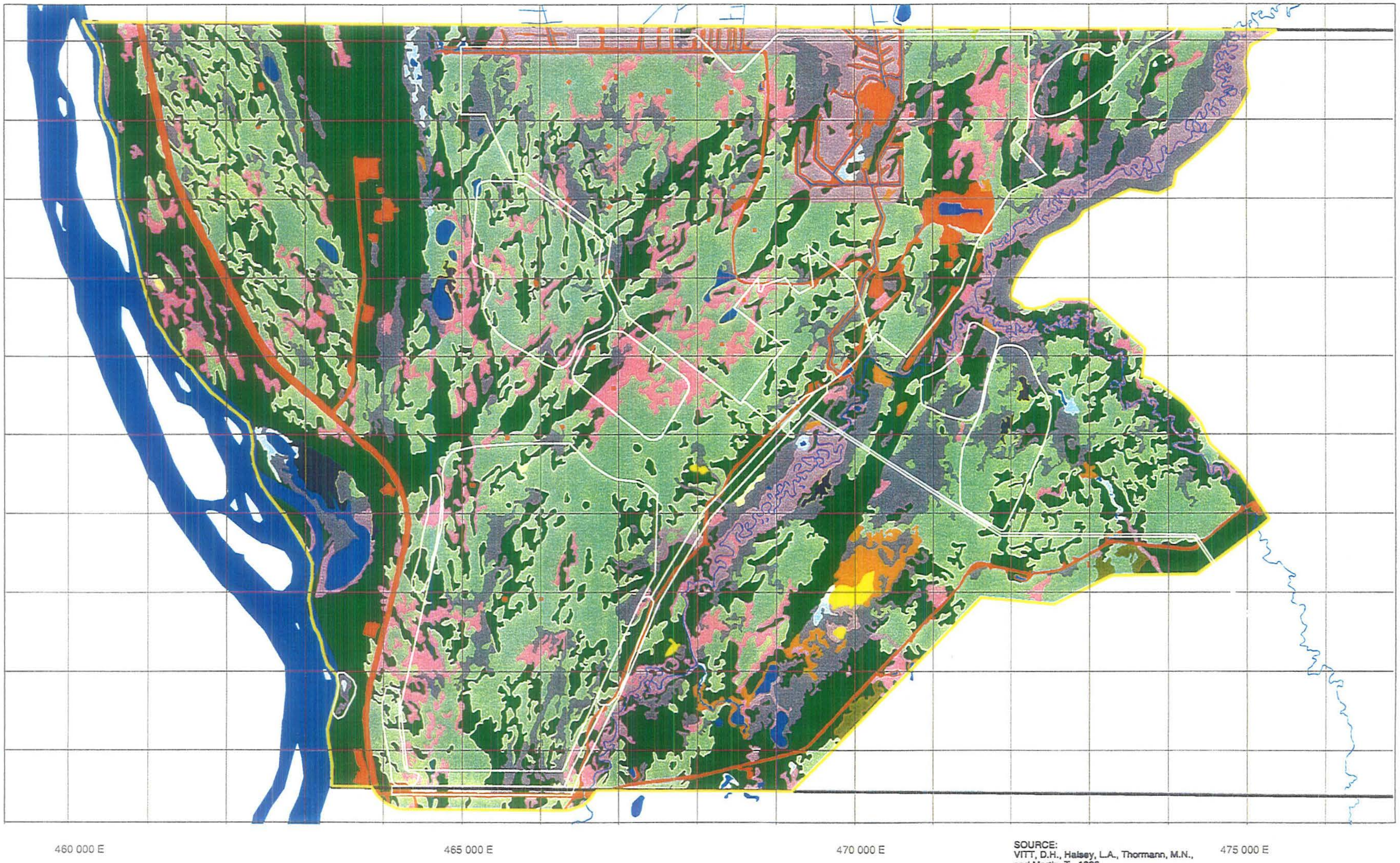
Figure E10-1 Wetlands Resources Linkage Diagram for Construction and Operation Phase of Muskeg River Mine Project



r:\1997\2200\2237\7350\0315link.vsd

Figure E10-2 Wetlands Resources Linkage Diagrams for Closure Phase of Muskeg River Mine Project





E10 - 6

SOURCE:
VITT, D.H., Halsey, L.A., Thormann, M.N., and Martin, T., 1996.
Peatland Inventory of Alberta
Phase 1: Overview of peatland resource in the natural regions and subregions of the province.
The Forestry Corp.,
Golder Associates Ltd.

1 0 1 2
Kilometers

LEGEND

- Local Terrestrial Study Area
- Lease 13
- Open Water

WETLAND CLASSIFICATIONS

- Bog treed (Btnn)
- Fen patterned (Fopn)
- Fen treed > 6 - 70% (Ftnn)
- Fen treed > 70% (Ffnn)
- Fen shrub forest (FONS)
- Fen graminoid (Fong)
- Marsh graminoid (Fong)
- Swamp (conlferous > 70%) (Sfnn)
- Swamp (coniferous > 6-70%) (Stnn)
- Swamp (shrub) (Sons)
- Shallow open water (Wonn)
- Forest
- Cultural Features and Disturbed Lands

MAP PROJECTION: Universal Transverse Mercator Zone 12   DATUM: NAD 83

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MUSKEG RIVER MINE PROJECT
WETLAND CLASSIFICATION

8 Dec. 1997	Figure E10-3	PRODUCED BY: J. Shaw REVIEWED BY:

/data8/oilsands/972-2237/9700/9701/final/arcview/wet50.apr

WL-1 Will Muskeg River Mine Project Activities Result in a Loss or Alteration of Wetlands?

During construction and operation, loss or alteration of wetlands will result from changes in hydrology and clearing of the development area. Loss or alteration of wetlands may also occur due to operational emissions (air and water).

WL-2 Will Landscape Reclamation and Closure of the Muskeg River Mine Project Result in a Replacement of Wetlands?

Successful replacement of wetlands upon Project closure is dependent upon four main factors: 1) success of reclamation efforts; 2) capability of the end pit lake to support wetlands communities; 3) effectiveness of closure drainage system; and 4) whether changes in water quality will impact the capability of wetlands to support wetlands communities.

WL-3 Will the Muskeg River Mine Project Change Wetlands Diversity?

Changes in wetlands diversity may occur due to loss or alteration of wetlands. Changes in wetlands diversity can be measured by comparing number and type of wetlands present before Project development with the number and type remaining after the Project is operational.

Potential changes in wetlands diversity may also result in changes in resources use, wildlife habitat and aquatic resources.

E10.6 Key Question WL-1: Will the Muskeg River Mine Project Activities Result in a Loss or Alteration of Wetlands?

E10.6.1 Analysis of Potential Linkages

The linkages between Project activities (construction, operations and closure) and wetlands impacts are presented graphically in Figures E10-1 and E10-2. A brief discussion of these linkages is provided as follows:

Linkage between site clearing and wetlands

Development of the Muskeg River Mine Project will result in a clearing of 4,343 ha or 39.6% (Table E10-1) of the LSA as a result of the Project tailings settling pond, overburden and, muskeg stockpiles, end pit lake, plant site and linear infrastructure such as roads and pipelines. Wetlands are the dominant landform within the Project area and therefore, the Project will result in direct losses to some wetlands.

Table E10-1 Direct Losses/Alteration of Existing Terrestrial Vegetation, Wetlands, Lakes, Rivers and Other Areas Within the Project Area and LSA

Land Cover Types	LSA Area (ha)	LSA (%)	Direct Loss Within the Project Area (ha)	Total Loss Within the LSA (%)
Terrestrial Vegetation	3,527	32.2	962	8.8
Wetlands	6,766	61.8	3,076	28.1
Lakes	114	1.0	32	<0.3
Rivers	7	0.1	0	0
Developed	540	4.9	273	2.5
TOTAL	**10,954**	**100.0**	**4,343**	**39.6**

Linkage Between Hydrogeology, Hydrology and Wetlands

In the natural setting groundwater discharges to streams and wetlands and recharges to deeper groundwater systems. The lowering of groundwater levels in the surficial aquifer will affect groundwater flow patterns by directing groundwater from surficial aquifers into the mine dewatering system and not toward natural discharge areas. Dewatering will lower groundwater levels in the surficial aquifer within 1 to 2 km of the mine area. Wetlands in this area will therefore be affected by the dewatering of the surficial aquifer. However, Basal Aquifer depressurization will have negligible effect on wetlands and lake levels in the LSA. Therefore, this linkage is valid due to surficial aquifer effects.

Wetlands are sensitive to changes in water flows and water table depths. Increases in water table depth or disruption of flow can result in water impoundment and flooding. Alternately, accelerated flow can lead to drying or, for example, creation of a fen in place of a bog. Riparian communities which occupy the floodplains adjacent to streams or river channels such as the Muskeg River are vulnerable to any large shifts, either increases or decreases in water flow. However, according to the Hydrology Impact Assessment (Section E4), changes to flood flows in the Athabasca River, Muskeg River and Jackpine Creek area are predicted to be negligible throughout the operation, construction and in the closure phases of the Project. Therefore, change in hydrology is not a valid linkage.

Linkages Between Water Quality and Wetlands

The quality of surface water, during construction and operation of the Project, is not expected to affect wetlands resources (Water Quality Impact Assessment E5). As such, there will be no direct or indirect effects on wetlands as a result of water quality.

Linkages Between Air Quality and Wetlands

The potential impacts of NO_x air emissions on vegetation, including wetlands vegetation, has been previously described in Section E9.

Peatlands, fens and bogs, may be particularly sensitive to acid forming emission. The WHO (1994) has proposed a potential acid input (PAI) critical loading factor of 0.25 keq/ha/a for sensitive ecosystems and a 0.50 keq/ha/a for moderate sensitive ecosystems. According to the Air Impact Section (E2) critical loads will exceed 0.25 keq/ha/a. Therefore, there is a valid linkage between air quality and wetlands.

E10.6.2 Impact Analysis

The analysis of potential linkages indicates that the valid linkages necessary for determining impacts to losses or alteration of wetlands are site clearing during construction and operation phases and from mine dewatering. Both will contribute to loss of wetlands in varying ways. Site clearing involves the direct removal of landforms, and associated soils and vegetation communities including wetlands. Surficial aquifer drawdown may result in indirect changes to wetlands.

Direct Losses

Wetlands, including bogs, fens, marshes, swamps and shallow open water wetlands occupy approximately 62% of the Muskeg River Mine LSA (described in Section D1).

Direct Losses to Wetlands Resources

Development of the Project will result in a clearing of 4,343 ha or 39.6% of LSA as a result of construction of the tailings settling pond, overburden and muskeg stockpiles, end pit lake, plant site and linear infrastructure such as roads and pipelines. Approximately 540 ha or 5% of the Project area has been previously cleared, therefore the total disturbance within the LSA due to the Project is 3,802 ha. Table E10-1 shows the proportion of general land cover types lost to mine development. Wetlands are the dominant community types lost to mine development because they occupy 61.8% of the LSA. Mine development will remove 3,076 ha or 46% of wetlands of the Project area. This comprises a loss of 28.1% of the LSA wetlands.

Each wetlands type and associated areas lost to mine development are listed in Table E10-2. Non-patterned, open treed (Ftnn) and shrub fens (Fons) are the dominant wetlands types in the LSA that collectively occupy 47.1% (5,155 ha). Mine development will remove 52.5% (1,965 ha) of non-patterned, open treed fens and 38.4% of non-patterned shrub fens. This represents a collective loss of 22.8% of the LSA. Similarly, 52.2% of all open canopy coniferous swamps will be directly lost from mine development. However, since coniferous swamps occupy a small percentage (713 ha or 6.5%) of the LSA, the loss is only a 3.4% reduction.

Clearing of closed canopy coniferous and deciduous swamps will result in a loss of 26.2% and 25.1%, respectively. This represents a loss of less than 2% in the LSA.

Treed bogs without patterning or internal lawns (Btnn) represents 0.2% (20 ha) of the LSA and will not be affected by mine development.

Shallow open water and marshes represent less than 2% of the LSA. Losses due to mine development, will affect 10.8% of the shallow open water areas and 4.1% of marshes available in the LSA. This represents a loss of less than 0.1% of the LSA. Lakes, generally associated with these wetlands types, represent less than 1% of the LSA. Lakes lost to the Project development comprise less than 1% of the LSA.

KIRs

Patterned Fens

Patterned fens, a KIR, occur on less than 2 ha of the LSA; however, direct losses from Project development will result in the loss of 0.4 ha of these patterned fens.

Riparian Shrub Complex

Riparian wetlands which include fens, marshes and swamps that occur along the Athabasca and Muskeg rivers and Jackpine Creek drainages will not be affected due to the Project development. The ELC section provides a detailed discussion of riparian wetlands and impacts.

Rare Plants

Field surveys conducted by BOVAR (1996a) and Golder Associates (1997o) identified 14 rare plant species within the LSA (Table E10-3). Of these 14 species, only three will be directly impacted within wetlands habitat as a result of the Project.

Rare plant potential was assigned to each ecosite phase based on field observations and literature review. As a result, three criteria were used to rank rare plant potential (Table E10-4). Regional rare plant surveys have linked rare plants with fen ecosites (Westworth 1990). As such, all fens were ranked as having high rare plant potential, regardless of whether rare plants were identified within these ecosites.

Table E10-2 Wetlands Losses and Alteration During the Construction and Operation Phase of the Muskeg River Mine Project

Wetlands Type		LSA (ha)	Loss due to Clearing (ha)	Loss due to Surficial Aquifer Drawdown (ha)	Total Loss (ha)	% Loss of Wetlands in LSA
AWI Class	**AWI Subclass**					
Shallow Open Water **(Wonn)**	Shallow Open Water **(SW)**	56.7	6.1	13.8	19.9	35.1
Marsh **(M)**	Marsh **(M)**	84.6	4.1	0.8	4.9	5.8
Swamps **(S)**	Coniferous swamp **(Stnn)**	713.1	372.3	75.4	447.7	62.8
	Coniferous swamp **(Sfnn)**	6.5	1.7	0.1	1.8	27.7
	Deciduous swamps **(Sons)**	650.5	156.6	69.1	225.7	34.7
Subtotal	Swamps	1,370.1	530.6	144.6	675.2	49.3%
Fens **(F)**	Open patterned fen **(Fop)**	1.9	0.4	1.5	1.9	100.0
	Open non-patterned shrubby fens **(Fons)**	1,387.4	532.2	141.6	637.8	48.6
	Open non-patterned graminoid fen **(Fong)**	51.0	6.2	1.4	7.6	14.9
	(Ffnn)	26.3	0.0	0.0	0.0	0.0
	Wooded fen, no internal lawns **(Ftnn)**	3,767.7	1,959.1	350.4	2,308.5	61.3
Subtotal	Fens	5,234.3	2,497.9	494.9	2,955.8	56.5%
Bogs **(B)**	Wooded bog (>10%, ≤ 70% tree cover) not internal lawns **(Btnn)**	20.1	0.0	1.7	1.7	8.5
Total Wetlands		6,886.4	3,070.5	665.1	3,735.6	54.2
Non-Wetlands		4,188.2	1,272.5	0.0	1,272.5	N/A
Total		10,954.0	4,343.0	665.1	5,008.1	N/A

Table E10-3 Rare Plants Observed Within the LSA During 1995 and 1997 Field Surveys

Botanical Name	Common Name	Plot Location	
		1995	1997
Carex lacustris	lakeshore sedge	217	18, 22, 30
Clintonia uniflora	corn lily	223	
Barbarea orthoceras	American winter cress		18
Scirpus cyperinus	wool-grass		26
Lycopus uniflorus	northern water-horehound	217	11, 26
Drosera anglica	Oblong-leaved sundew	214	
Coptis trifolia	goldthread		16
Kalmia polifolia	northern laurel	186	
Monotropa uniflora	indian pipe	54	
Rhamnus alnifolia	alder-leaved buckthorn		10, 33
Carex tenuiflora	thin flowered sedge	180	
Sparganium fluctuans			30
Nymphaea tetragona leibergii	small water-lily		30
Carex hystricina	porcupine sedge		18

Twelve ecosites were found to have high rare plant potential (Table E10-4). Impacts on rare plants was assessed by comparing baseline, impact, reclaimed and total change areas for each of these ecosites. Finally, ecosites were grouped together according to their rare plant potential (i.e., high, low, insufficient data or not applicable), and areas for baseline, impact, reclaimed and total change for each of rare plant potential ranks was calculated (Table E10-5). It is possible to assess impacts on rare plant species in a general sense by assessing ecosite losses associated with high rare plant potential. Three of the rare plants observed during 1995 and 1997 field surveys occur in the mine development area, and will therefore be lost during construction and operation. All three rare plants were found in fens ecosites; northern laurel and indian pipe were found in wooded fens (Ftnn), and corn lily was found in a shrubby fen (Fons). Both wooded fens and shurbby fens are found throughout the LSA and RSA (Section F10). As such, all ecosites were automatically categorized as having high rare plant potential. The three rare species are:

- corn lily — *Clintonia uniflora*
- northern laurel — *Kalmia polifolia*
- indian pipe — *Monotropa uniflora*

Of the 9,046 ha identified as having high rare plant potential, 3,757 ha, or 41.5%, will be lost as a result of Project construction and operation.

Table E10-4 Wetlands Ecosite Phase Rare Plant Potential

Map Code	Ecosite Phase	Rare Plant Potential[a]
a1	Lichen Pj	L
a1/g1 complex	Pj-Lt	ID
b1	Blueberry Pj-Aw	H
b2	Blueberry Aw	ID
b3	Blueberry Aw-Sw	ID
b4	Blueberry Sw-Pj	L
c1	Labrador Tea-mesic Pj-Sb	H
d1	Low Bush Cranberry Aw	H
d2	Low Bush Cranberry Aw-Sw	L
d3	Low Bush Cranberry Sw	ID
e1	Dogwood Pb-Aw	ID
e1/f1	Pb-Aw	H
e2	Dogwood Pb-Sw	ID
e2/f2	Pb-Sw	ID
e3	Dogwood Sw	L
g1	Labrador Tea-subhygric Sb-Pj	ID
h1	Labrador Tea/Horsetail Sw-Sb	L
i2	Shrubby Bog	ID
j1	Treed Poor Fen	H
j1/g1 complex	Lt/Sb-Pj	H
j1/h1 complex	Sb/Sw-Lt	H
j2	Shrubby Poor Fen	H
j2/h1 complex	Sw/Sb-Fen Complex	H
k1	Treed Rich Fen	H
k2	Shrubby Rich Fen	H
k3	Graminoid Rich Fen	H
l1	Marsh	ID
Stnn, Sfnn	Swamp (coniferous, deciduous and shrub)	H
Wonn	Shallow Open Water	ID
AIH, AIG, AIM	Cultural Disturbance	L
NMC	Cutbanks	L
NWL	Lakes and Ponds	N/A
NWR	Rivers	N/A
shrub	Shrubland	ID
Sb/Lt	Sb/Lt Complexes	ID

[a] H = High, L= Low, ID= Insufficient Data, N/A= Not Applicable

Using the BOVAR (1996a) and Golder Associates (1997o) field surveys, 14 rare plant species were identified at 11 sites, within the LSA (Table E10-3). In addition, 12 ecosites, totaling 9,046 ha of the LSA (83%) were identified as having rare plant potential (Table E10-4).

At mine closure, 331 ha, or 3% of ecosites with high rare plant potential habitat will be reclaimed. This relatively small area is a result of the inability to reclaim fens, which make up a large portion of the area identified as having rare plant potential. Typically, peat accumulations associated with these fen communities take several hundred years to develop. Given suitable landform and drainage conditions, these communities may eventually re-establish; however, the long periods of time associated with their development renders them outside the scope of closure analysis. As such, no ecosites associated with either high or moderate rare plant potential will be re-established on reclamation landscapes.

Table E10-5 Rare Plant Habitat Potential Impact Within the LSA

	Baseline		Impacts		Reclaimed		Remaining	
Rare Plant Potential	Area (ha)	% LSA	Area (ha)	% LSA	Area (ha)	% LSA	Area (ha)	% LSA
High	9,046	82.6	3,757	34.3	331	3.0	5,620	51
Low	1,260	11.5	470	4.3	2,875	26.2	3,665	33
Insufficient Data	527	4.8	84	0.8	601	5.5	1,044	10
Not Applicable	121	1.1	32	0.3	536	4.9	625	6
Total	10,954	100.0	4,343	39.6	4,343	39.6	10,954	100

While communities identified as having rare plant potential will be established at closure, in the short term, their ability to support rare plant may be limited. Plans to establish plant communities on reclamation landscapes involves the introduction of 'starter species'. Succession then acts as the mechanism for establishing the desired community type. As such, the diversity of reclaimed plant communities increases over time, resulting in associations, communities and rare plant potential more similar to the pre-disturbed conditions than immediately following reclamation. Once ecosites have re-established, it is assumed that rare plant potential will be similar to that found in pre-disturbance in certain wetlands ecosites.

To improve the analysis of the rare plant potential ranking system, more detailed field investigations are required. For example, there is insufficient data for 12 of the ecosites identified in the LSA, to assess rare plant potential.

Indirect Losses to Wetlands Resources

In the Hydrogeology Section (E3), it was predicted that the surficial aquifer drawdown could extend 1 to 2 km around the Mine area (Table E10-2). The rate of drawdown will be variable. The drawdown is predicted to have an indirect affect on some wetlands. Accordingly, wetlands within a 1.5 km buffer around some of the development area (excluding the plant site, CT, sand and overburden disposal sites, and linear corridors) were evaluated by overlying the 1.5 km buffer onto the vegetation types identified during the mapping process.

Swamps in the LSA are located adjacent to floodplains or along the margins of peatland complexes. Swamps, associated with peatland margins, are the vegetation types primarily affected by surficial aquifer drawdown. The affects of drawdown may result in a change in species composition in swamps. For example, plant species adapted to moister soil conditions may decline in abundance and vigour. In time, swamps may change to upland communities as species associated with moister conditions become replaced with those adapted to drier conditions. In addition, tree growth may increase and become more productive as a result of reduced soil moisture (Hillan et al. 1990). This drawdown is expected to affect 144.6 ha or approximately 11% of swamps with the Project area (Table E10-2).

Marshes and shallow open-water wetlands may change to dry grassland or shrub communities. Aquatic plants, such as some sedges and rushes, may be reduced. These areas may over time become invaded with upland shrub communities. Shallow open water may be reduced by 13.8 ha and marshes by less than 1 ha.

Fens will be affected from a change in surficial aquifer drawdown. All fen types may shift in species composition. Hydric adapted shrubs and herbs such as crowberry and bog cranberry usually decline in abundance following a decrease in soil moisture whereas, tall shrubs such as willows and alder generally increase (Hillan et al. 1990). Moreover, studies have found that drawdown on peaty soils resulted in a net increase in the abundance of shrub and deciduous trees such as aspen (Hillan et al. 1990, Leiffers and Rothwell 1987 and Leiffers 1984). Rare plant habitat associated with the fen system may also be reduced. The indirect loss to fens (excluding forested fens without internal lawns) from drawdown are expected to be 494.9 ha.

KIRs

Patterned Fens

There are 1.5 ha of patterned fens that are not affected by clearing but are located in the aquifer drawdown. The indirect affects of drawdown will cause change in species composition as described above. The characteristic wet flarks and string may not be apparent. This may result in a reduction of rare plant habitat.

Riparian Wetlands

Riparian wetlands will be lost in areas adjacent to the Muskeg River as a result of clearing but probably not as a result of drawdown. These wetlands include fens, swamps and marsh complexes situated in floodplains which derive moisture from rivers and creeks. According to the Hydrology Section (E4), changes to water levels will however be negligible.

Rare Plants

Fourteen rare plants were identified in the LSA by BOVAR (1996a) or Golder (1997o). Five rare plants were observed in fen habitats which will be most affected by drawdown. All these rare plants will be lost due to Project development.

Air Emissions

The Air Impact Section (E2.5) addresses emissions related to acid forming deposition as a result of the Muskeg River Mine Project. Operational activities of the Project will release no So_x but 11.9 t/d of No_x into the atmosphere which is predicted to result in peak surface level deposition values in the immediate vicinity of the plant site. This will exceed PAI 0.4 keq/ha/a, 0.08 keq ambient background and 0.30 keq from the Project. The World Health Organization (1994) has proposed potential acid input (PAI) critical loading factor of 0.25 keq/ha/a for sensitive ecosystems and 0.5 keq/ha/a for moderately sensitive ecosystems. Predicted PAI values therefore, exceed guidelines. Studies (Robers and Reiger 1989) have not found any trends of peatland or soil acidification in northeastern Alberta. Therefore, the relationship between acid emissions and peatland is currently undetermined.

Ongoing monitoring during operation and reclamation phases are necessary to determine impacts to peatland in the LSA.

E10.6.3 Residual Impact Classification and Degree of Concern

The impact classification associated with specific wetlands types is shown in Table E10-6. It is predicted that impacts to marshes and bogs will be low since they are situated away from the mine development area and outside the aquifer drawdown area. The Hydrology Impact Section (E4) provides a detailed analysis of impact to rivers and lakes.

Impacts to swamps, including coniferous, deciduous and shrub, are expected to be high. There will be less of an impact to riparian swamps as discussed in the ELC Section of this EIA. Swamps in the RSA are well-represented accounting for approximately 20% (Vitt et al. 1996).

Impacts to all fens except forested fens and graminoid fens are high both in magnitude and duration in the LSA. Shallow open-water wetlands are largely associated with fens systems. Impacts to these systems are also high. The fens remaining in the LSA are 2,239 ha or 43%. This represents 20% of the LSA. Fens in the RSA, discussed in the Cumulative Effects Section of this EIA, represent approximately 40% of the RSA (Vitt et al. 1996).

The patterned fens adjacent to McLelland Lake, for example, are proposed to be protected under the Special Places 2000 initiative. This is a large contiguous patterned fen system that supports a number of rare plants (Westworth 1990). Government initiatives to protect large patterned fens will allow for the preservation of the wetlands and ensure protected habitat for rare species.

E10.7 Key Question WL-2: Will Landscape Reclamation and Closure of the Muskeg River Mine Project Result in a Replacement of Wetlands?

E10.7.1 Analysis of Potential Linkages

Following closure, replacement of wetlands communities will depend upon the success of reclamation activities, as summarized in the linkage diagram shown in Figure E10-2. Specifically, replacement of wetlands communities will depend on the ability of the reclamation landscapes and end pit lake to support wetlands species and communities. The closure drainage system will also affect the ability, as well as the type of wetlands communities able to re-establish within the reclaimed landscape.

Successful replacement of wetlands communities after closure will also impact the type, number and distribution (i.e., the diversity) of wetlands communities (Figure E10-2). This will reflect changes in resource use and wildlife habitat availability.

E10.7.2 Impact Analysis

An analysis of the predicted reclamation landscape following closure, including wetlands, is provided in the Mine Closure Plan (Section E16). Replacement of some wetlands communities, namely marsh, riparian shrub complexes and shallow open-water complexes, will occur within the LSA upon closure (Table E10-7). However, none of the fens or bogs disturbed during construction and operation will be replaced.

The closure plan identifies the process for establishing (replacing) vegetation to meet specific land use objectives. This process involves the following: identifying vegetation communities that can be established on reclaimed landscapes; identifying techniques to establish vegetation communities on reclaimed landscapes; identifying land use objectives for reclaimed landscapes, identifying design criteria for selected land use; designing monitoring program; and design research program.

Community types that naturally occur in the oil sands region (i.e., native species) were identified during baseline investigations. Of the communities present in the area, 15 have been identified as possible replacement communities (Section E16). Establishment of vegetation communities on the reclaimed landscape is dependent upon the type of landform, slope, aspect, soil type/capability and soil drainage conditions.

Wetlands communities, which make up 61.8% of the LSA, are not included in the vegetation communities suitable for establishment on reclaimed landscapes. Typically, peat accumulations integral to the structure of wetlands communities such as fens take several hundreds of years to develop. While it is not impossible that, given suitable landform and drainage conditions, these communities may re-establish, the long periods of time associated with their development renders them outside the scope of closure analysis. However, some marsh communities will be developed on reclaimed landscapes.

As discussed in Section E16, plans to establish wetlands communities on reclamation landscapes involves the introduction of 'starter species'. Succession then acts as the mechanism for establishing the desired community type. As such, the diversity of reclaimed wetlands communities increases over time, resulting in associations and plant communities more similar to the pre-development conditions than immediately following reclamation.

Eleven community types have been selected for establishment on reclaimed landscapes after the closure of the Muskeg River Mine Project (Table E10-7). Of these, three are considered wetlands communities: ponds (waterbodies with depth >1m), shallow water (littoral zone) and shrub complexes (riparian).

KIRs

Patterned Fens

Patterned Fens: have been identified due their unique hydrological regime, relatively high proportion of rare plants and sensitivity to disturbance. As previously mentioned, wetlands communities have not been identified as potential reclamation communities, due to the length of time required for community development. As such, patterned fens disturbed during construction and operation will not be replaced.

Riparian Wetlands

Riparian Wetlands: have been identified due to their habitat value, importance in maintaining water quality and fish habitat, ability to stabilize streambanks, ability to provide shade and sensitivity to disturbance.

Table E10-6 Residual Impact Classification in the Local Study Area and Degree of Concern

Wetlands Type			Impact Assessment Criteria						
AWI Class	**AWI Subclass**	**Field Guide**	**Direction**	**Magnitude**	**Geographic Extent**	**Duration**	**Reversibility**	**Frequency**	**Degree of Concern**
Marsh **(M)**	Marsh **(M)**	Marsh **(l1)**	Negative	Low	Local	Long-term	Reversible	Low	Low
Swamp **(S)**	Coniferous swamp **(Stnn)**	Wetter end of horsetail **(f)**	Negative	High	Local	Long-term	Reversible	Low	Moderate
	Coniferous swamp **(Sfnn)**	Wetter end of horsetail **(f)**	Negative	High	Local	Long-term	Reversible	Low	Moderate
	Deciduous swamps **(Sons)**		Negative	High	Local	Long-term	Reversible	Low	Moderate
Fen **(F)**	Open patterned fen **(Fop)**		Negative	High	Local	Long-term	Irreversible	Low	High
	Open non-patterned shrubby fen **(Fons)**	Shrubby poor fen **(j2)** and Shrubby rich fen **(k2)**	Negative	High	Local	Long-term	Irreversible	Low	High
	Open non-patterned graminoid fen **(Fong)**	Graminoid rich fen **(k3)**	Negative	Moderate	Local	Long-term	Irreversible	Low	High
	Wooded fen, no internal lawns **(Ftnn)**	Treed poor fen **(j1)** and treed rich fen **(k1)**	Negative	High	Local	Long-term	Irreversible	Low	High
Bog **(B)**	Wooded bog (>10% ≤70% tree cover), no internal lawns **(Btnn)**	Treed bog **(i1)**	Neutral	Low	Local	Long-term	Irreversible	Low	Nil

Approximately 156 ha (1.4%) of riparian shrub complexes will be lost during construction and operation of the Project. A total of 308 ha (2.8%) will be replaced during reclamation (Table E10-7).

End Pit Lake

The end pit lake will be located along the western edge of the mine footprint at closure. It will have a surface area of 442 ha and will store about 13 million m^3 of water. End pit lake will contain consolidated tailings (CT) water and will also collect CT seepage water from the surrounding reclaimed landscapes. Far future analysis predicts that levels of CT within end pit lake will decrease over time.

Constructed Ponds/Wetlands

About 119 ha of marsh wetlands will be reconstructed in the reclaimed area. Ponds and wetlands (i.e., mean depth = 1.5 m) will be constructed in three areas: on the surface of CT deposits; in association with the drainage ditch around the reclaimed tailings settling pond area and within the internal slopes of that storage structure. Future details are provided in Section E16.

Closure Drainage System

At closure a drainage system will direct drainage and CT seepage water to end pit lake and the Athabasca River. In reclamation plans, CT deposits will be capped with either sand or overburden. In certain cells seepage water from CT will travel upwards through the overlying sand layer. Dyke systems will then direct seepage water into a series of ponds, and finally into End Pit Lake. As such, riparian shrub complexes surrounding the ponds and primary drainage channels, may be impacted by CT water. In other cells, overburden overlies CT. Here, CT seepage water will draw upwards through a series of sand trenches, which direct water towards drainage ponds and, finally, into end pit lake. As such, CT seepage will be primarily limited to the sand drainage trenches and the riparian shrub complexes surrounding the ponds and primary drainages. Drainage into the Athabasca River will be directed through a series of constructed wetlands before release into the river. Far future analysis predicts that CT seepage water will not impact reclamation landscape water quality.

E10.7.3 Residual Impact Classification and Degree of Concern

The primary residual impacts include:

- a change in dominant vegetation type from wetlands to upland communities;
- a decrease in areas of patterned fens;
- an increase in riparian shrub communities; and
- an increase in areas of ponds/wetlands and lakes.

These impacts are considered to be negative in direction for the patterned fen KIR with a high magnitude of impact but is restricted to a local geographic extent. The duration of impact is long-term, irreversible and of low frequency. The degree of concern is high. For the riparian shrub complex, the direction of impact is positive and the magnitude is moderate. The geographic extent of the impact is local, of long-term duration, reversible and low in frequency.

E10.8 Key Question WL-3: Will the Muskeg River Mine Project Change Wetlands Diversity?

Changes in wetlands diversity is assessed here by examining changes in plant communities and species. For a discussion of changes in diversity at the Landscape level of generalization readers are referred to the ELC Section (E7).

Species Richness and Diversity

Table E10-8 shows the total number of different species present in all wetlandsplots in six ecosite phases and four AWI classes, as well as the total number of species present in each of three structural layers (tree, shrub and herb). No plot surveys were undertaken in marsh (Mong), shallow open water (Wonn), patterned fens (Fopn) or swamps.

Composition

The data represent overall species richness in each ecosite phase (AWI) when taken as a whole. The sum of the species present in each of the layers does not necessarily equal the total for the ecosite phase because of species duplications between layers. Using this index, the k2 (Fons) ecosite phase exhibits the greatest species richness both overall and in the herb layer. The k3 ecosite phase has the fewest species overall and in each of the layers.

The mean and range of species richness values for individual plots within wetlands is also presented in Table E10-8. These data provide an indication of the species richness that is characteristic of small areas within ecosite phases. The highest mean and maximum of total species richness are in the j1 (Ftnn/Ffnn) wetlands. The highest mean richness in the herb layer is in d1 and d2; in the shrub layer it is in d2 and e1; and in the tree layer it is in b3. Mean richness is lowest in k3 (Fong) overall and in the shrub and tree layers. The lowest mean richness in the herb layer is in the treed bog (i1).

Structure

In terms of structure, species richness is highest in the herb layer and lowest in the tree layer for all ecosite phases except i1. Structurally, both mean and maximum richness are lowest in the tree layer in each ecosite phase.

Table E10-7 Comparison of Ecosite Phases Lost/Altered and Reclaimed at Mine Closure

Vegetation Type		Baseline		Impact		Reclamation		Final	
Map Code	Ecosite Phases	Area (Ha)	% LSA	Area (ha)	% LSA	Area (ha)	% LSA	Area (ha)	% LSA
a1	Lichen Pj	106	0.97	49	0.45		0.00	57	0.52
a1/g1 complex	Pj-Lt	21	0.19	4	0.04		0.00	17	0.16
b1	Blueberry Pj-Aw	878	8.02	335	3.06	218	1.99	761	6.95
b2	Blueberry Aw(Bw)	0	0.00		0.00	102	0.93	102	0.93
b3	Blueberry Aw-Sw	67	0.61	11	0.10	72	0.66	128	1.17
b4	Blueberry Sw-Pj	286	2.61	98	0.89	596	5.44	784	7.16
c1	Labrador Tea-mesic Pj-Sb	20	0.18	3	0.03		0.00	17	0.16
d1	Low Bush Cranberry Aw	1,525	13.92	359	3.28	96	0.88	1,262	11.52
d2	Low Bush Cranberry Aw-Sw	169	1.54	38	0.35	729	6.66	860	7.85
d3	Low Bush Cranberry Sw	15	0.14	0.1	0.00		0.00	14.9	0.14
e1	Dogwood Pb-Aw	61	0.56	9	0.08		0.00	52	0.47
e1/f1	Pb-Aw	66	0.60	0.1	0.00		0.00	65.9	0.60
e2	Dogwood Pb-Sw	4	0.04	0	0.00		0.00	4	0.04
e2/f2	Pb-Sw	9	0.08	2	0.02		0.00	7	0.06
e3	Dogwood Sw	93	0.85	0	0.00	1,550	14.15	1,643	15.00
g1	Labrador Tea-subhygric Sb-Pj	8	0.07	6	0.05		0.00	2	0.02
h1	Labrador Tea/Horsetail Sw-Sb	123	1.12	53	0.48		0.00	70	0.64
i2	Shrubby Bog	20	0.18	0	0.00		0.00	20	0.18
j1	Treed Poor Fen	356	3.25	168	1.53		0.00	188	1.72
j1/g1 complex	Lt/Sb-Pj	27	0.25	0	0.00		0.00	27	0.25
j1/h1 complex	Sb/Sw-Lt	74	0.68	0	0.00		0.00	74	0.68
j2	Shrubby Poor Fen	1,182	10.79	532	4.86		0.00	650	5.93
j2/h1 complex	Sw/Sb-Fen Complex	2	0.02	0	0.00		0.00	2	0.02
k1	Treed Rich Fen	1,370	12.51	739	6.75		0.00	631	5.76
k2	Shrubby Rich Fen	2,136	19.50	1,084	9.90	17	0.16	1,069	9.76
k3	Graminoid Rich Fen	51	0.47	6	0.05		0.00	45	0.41
l1	Marsh	85	0.78	4	0.04	119	1.09	200	1.83
Stnn, Sfnn Sons	Swamp (coniferous, deciduous and shrub)	708.5	6.47	374.4	3.4		0.00	334.1	3.0
Sons	Riparian Shrub Complex	650.5	5.91	156.6	1.43	308	2.81	415	3.79
Wonn	Shallow Open Water	57	0.52	6	0.05		0.00	51	0.47
AIH, AIG, AIM	Cultural Disturbance	471	4.30	232	2.12		0.00	239	2.18
NMC	Cutbanks	12	0.11	0	0.00		0.00	12	0.11
NWL	Lakes and Ponds	114	1.04	32	0.29	536	4.89	618	5.64
NWR	Rivers	7	0.06	0	0.00		0.00	7	0.06
shrub	Shrubland	119	1.09	12	0.11	308	2.81	415	3.79
Sb/Lt	Sb/Lt Complexes	61	0.56	30	0.27		0.00	31	0.28
GRAND TOTAL		10954	100.00	4,343.2	39.65	4,343	39.65	10,953.8	100.00

Mean and maximum richness are higher in the herb layer than in the shrub layer ecosite phases, respectively. The differences in relative species richness among ecosite phases or AWI may result from differences in internal compositional variability among ecosite phases.

E10.8.2 Monitoring

As part of the reclamation monitoring program for the Project, a specific program will be designed to evaluate the success of wetlands re-establishment. Permanent sampling transects and plots will be established within representative reclamation wetlands types and the nature and rate of re-colonization recorded and compared against natural wetlands type analogs. Plant species composition, diversity and structure will be recorded as part of the reclamation monitoring database. Species richness and diversity objectives will be established and compared with the existing (pre-development) conditions.

Table E10-8 Species Richness

		Total Species Richness	Total Species			Herb-Layer			Shrub-Layer			Tree-Layer		
AWI	Eco-Phase	Class Name	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.
Btnn	i1	Treed Bog	7.3	5	10	1.9	0	4	4.6	4	6	1.0	1	1
Ftnn/Ffnn	j1	Treed Poor Fen	12.9	6	25	6.0	2	14	5.9	3	11	1.6	1	2
Fons	j2	Shrubby Poor Fen	11.3	7	18	4.8	3	7	6.1	3	11	0.5	0	1
Ftnn/Ffnn	k1	Treed Rich Fen	12.0	6	23	6.6	3	16	4.6	2	8	1.3	1	2
Fons	k2	Shrubby Rich Fen	8.7	2	23	5.4	1	16	3.3	1	7	0.1	0	1
Fong	k3	Graminoid Rich Fen	3.0	1	5	2.3	1	3	0.8	0	2	0.0	0	0

Diversity

Table E10-9 gives the mean and range of species diversity values for individual plots within the ecosite phases. The Ftnn/Ffnn and Fons treed and shrubby fens have the highest mean overall diversities and have the highest mean diversities in the herb layer. Mean diversity is lowest in graminoid fens (FONG) overall and also in the shrub and herb layers. There is little difference in mean diversity between the shrub and herb layers in many of the wetlands and there is no discernible overall trend to higher diversity in either layer. Mean diversity is lowest in the tree layer for all wetlands.

The number and distribution of wetlands types before and after mining provides a measure of wetlands diversity. Table E10-10 shows the number of plots surveyed according to Ecosite Phase.

Table E10-9 Species Diversity

	Total Species Diversity	Total Species			Herb-Layer			Shrub-Layer			Tree-Layer		
AWI	Class Name	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Btnn	Treed Bog	0.57	0.41	0.74	0.13	0.00	0.49	0.39	0.15	0.51	0.00	0.00	0.00
Ftnn/Ffnn	Treed Poor Fen	0.69	0.48	1.06	0.42	0.20	0.79	0.44	0.04	0.67	0.13	0.00	0.29
Fons	Shrubby Poor Fen	0.66	0.55	0.78	0.43	0.35	0.54	0.50	0.37	0.70	0.00	0.00	0.00
Ftnn/Ffnn	Treed Rich Fen	0.72	0.37	1.09	0.47	0.16	0.97	0.41	0.07	0.69	0.07	0.00	0.30
Fons	Shrubby Rich Fen	0.58	0.15	1.03	0.39	0.00	0.86	0.29	0.00	0.69	0.00	0.00	0.00
Fong	Graminoid Rich	0.22	0.00	0.54	0.16	0.00	0.43	0.08	0.00	0.30	0.00	0.00	0.00

Diversity can be measured by assessing the number of individual wetlands, their size and shape. Table E10-11 shows these characteristics. Species level assessment of diversity examines species richness and rare plant potential lost to the mine development.

Table E10-10 Wetlands Plots Surveyed

AWI	Ecosite Phase	Class Name	Number of Plots
Btnn	I1	Treed Bog	10
Ftnn/Ffnn	j1	Treed Poor Fen	14
Fons	j2	Shrubby Poor Fen	8
Ftnn/Ffnn	k1	Treed Rich Fen	21
Fons	k2	Shrubby Rich Fen	36
Fong	k3	Graminoid Rich Fen	4
		Total Plots	93

Species Richness and Diversity

The indices used were species richness, expressed as the number of species present, and species diversity, which was calculated using the Shannon Index. The Shannon Index, H, can be expressed as

$$H = \sum P_i \log P_i$$

where k is the number of categories (i.e., species) and P_i is the proportion of the observations found in category i. In this case, the percent coverage of the plot area, expressed as a decimal, was used to approximate P_i. Extensive recalculations to account for incomplete coverage and overlapping would be required to find the true values of P_i. Table E10-10 show the total number of wetlands plots surveyed which was the basis of the richness and diversity assessment.

E10.8.3 Analysis of Potential Linkages

Losses to wetlands diversity is assessed here by examining potential impacts at the plant community and plant species level. At the plant community level, the number and distribution of wetlands types before and after mining provides a measure of comparative wetlands diversity. Species level assessment of diversity examines species richness and rare plant potential lost to the mine development. Landscape level changes in biodiversity is discussed in the ELC Impact Section (E7).

E10.8.4 Impact Analysis

Diversity can be discussed in terms of patch number and size and species richness for each wetlands type, i.e., how diverse are wetlands types, and how do losses of particular wetlands types impact species diversity? Table E10-13 summarizes the wetlands diversity in the LSA before and after disturbances. In the LSA, the number of wetlands are reduced from 1,145 to 862, a loss of 26%. The average patch size is reduced from 5.7 ha to 3.8 ha. Average patch size is reduced for every wetlands type except graminoid fens (Fong) which increased from 8.5 to 11.2 ha.

E10.8.5 Residual Impact Classification and Degree of Concern

The residual impacts on wetlands are summarized in Table E10-12. Species richness and species diversity can not be assessed for impacts but can be monitored during reclamation. Accordingly, the impact classification is based on wetlands number and patch size.

Table E10-11 Impacts to Wetlands Diversity in the LSA

Wetlands Classes	Code	Number of Wetlands Types	Minimum Patch Size	Maximum Patch Size	Average Patch Size	Wetlands Diversity (wetlands polygons remaining)	Minimum Patch Size	Maximum Patch Size	Average Patch Size
Shallow Open Water	Wonn	19	0.3	14.8	3.0	17	0.3	14.8	3.0
Marsh, open, graminoid-dominated	Mong	19	0.8	41.5	4.5	16	0.8	41.5	5.0
Coniferous Swamp	Stnn	180	0.1	38.5	4.0	123	<0.1	30.5	2.8
Coniferous Swamp	Sfnn	4	0.4	2.8	1.6	3	0.4	2.8	1.6
Deciduous Swamp	Sons	80	0.04	130.6	8.1	72	<0.1	130.6	6.9
Pattern Fen, open, shrub or graminoid dominant	Fopn	2	0.1	1.8	0.9	0	NA	NA	NA
Non-patterned Fen, open, shrub-dominated	Fons	170	0.1	70.3	7.9	135	<0.1	70.3	6.0
Non-patterned Fen, open, graminoid-dominated	Fong	6	1.7	31.9	8.5	4	1.7	31.9	11.2
Non-patterned Fen, wooded fens with no internal lawns	Ftnn/ Ffnn	661	0.01	63	5.7	489	<0.1	50.6	3.8
Wooded Bog without internal lawns	Btnn	4	1.7	14.8	5.0	4	1.7	14.8	5.0
Total Wetlands		**1145**				**848**			
Lake	L	17				14	0.1	38.2	5.8
Total		**1162**				**862**			

Table E10-12 Residual Impact Classification on Wetlands Diversity in the Local Study Area and Degree of Concern

Wetlands Type			Impact Assessment Criteria						
AWI Class	**AWI Subclass**	**Field Guide**	**Direction**	**Magnitude**	**Geographic Extent**	**Duration**	**Reversibility**	**Frequency**	**Degree of Concern**
Shallow open water **(Wonn)**	Shallow open water **(SW)**		Negative	High	Local	Long-term	Reversible	Low	Moderate
Marsh **(M)**	Marsh **(M)**	Marsh **(l1)**	Negative	Low	Local	Long-term	Reversible	Low	Low
Swamp **(S)**	Coniferous swamp **(Stnn)**	Wetter end of horsetail **(f)**	Negative	High	Local	Long-term	Reversible	Low	Moderate
	Coniferous swamp **(Sfnn)**	Wetter end of horsetail **(f)**	Negative	High	Local	Long-term	Reversible	Low	Moderate
	Deciduous swamps **(Sons)**		Negative	High	Local	Long-term	Reversible	Low	Moderate
Fen **(F)**	Open patterned fen **(Fop)**		Negative	High	Local	Long-term	Irreversible	Low	High
	Open non-patterned shrubby fen **(Fons)**	Shrubby poor fen **(j2)** and Shrubby rich fen **(k2)**	Negative	High	Local	Long-term	Irreversible	Low	High
	Open non-patterned graminoid fen **(Fong)**	Graminoid rich fen **(k3)**	Negative	Moderate	Local	Long-term	Irreversible	Low	High
	Wooded fen, no internal lawns **(Ftnn)**	Treed poor fen **(j1)** and treed rich fen **(k1)**	Negative	High	Local	Long-term	Irreversible	Low	High
Bog **(B)**	Wooded bog (>10% ≤70% tree cover), no internal lawns **(Btnn)**	Treed bog **(i1)**	Neutral	Low	Local	Long-term	Irreversible	Low	Nil

E11 WILDLIFE

E11.1 Introduction

This section of the Muskeg River Mine Project (the Project) EIA provides information as required by the Project Terms of Reference (TofR) issued on November 7, 1997 (AEP 1997a). Specifically, the following are addressed in this section:

- commenting on the sensitivity of key species and significant habitat areas impacted by the Project;
- discussion of the regional and temporal effects and the potential of the area to return to pre-development wildlife habitat conditions;
- provision of a mitigation plan and schedule for wildlife and significant wildlife habitat areas; and
- identification and discussion on any monitoring programs that will be implemented to assess wildlife impacts from the Project and the effectiveness of mitigation strategies to ensure the protection of wildlife resources in the area (TofR, Section 4.5).

Discussions on the potential cumulative effects on wildlife associated with the Project are addressed in Section F11. Section D11 provided details on the wildlife baseline for the Project. Additional details on the wildlife baseline for the Muskeg River Mine Project Area are provided in Winter Wildlife Surveys conducted on Shell Lease 13 - March 1997 (Golder 1997f) and Wildlife Baseline Conditions for Shell's Proposed Muskeg River Mine Project (Golder 1997g).

The approach for the evaluation of impacts for wildlife included:

- confirmation of Key Indicator Resources (KIRs);
- development of impact Key Questions;
- development of linkage diagrams for each Key Question;
- delineation of Local and Regional Study Areas (LSAs and RSAs);
- development of impact assessment criteria;
- determination of the validity of each linkage within each Key Question for each KIR;
- development of mitigation strategies for each valid linkage;
- evaluation of the impact assessment criteria for each valid linkage; and
- risk assessment of exposure to chemicals that may be released in water or that may accumulate in plants, fish and invertebrates.

E11.2 Potential Linkages And Key Questions

As the first stage of the assessment, all possible interactions between the KIRs and the proposed development were identified and discussed. This component of the assessment used Key Questions and flow charts, or linkage diagrams (Figures E11-1 and E11-2) to detail potential impacts of the proposed development on wildlife. The EIA process involved formulation and assessment of eight Key Questions that describe the potentially significant effects of the project on wildlife.

W-1 Will Activities From the Muskeg River Mine Project Change Wildlife Habitat?

The amount of suitable habitat within the LSA for each KIR was calculated using Habitat Suitability Index (HSI) procedures (see Section E11.5.2 and Golder 1998b). This was then contrasted with the amount of habitat projected to be changed due to construction and operation of the Project. Changes considered included direct habitat loss due to physical disturbance, habitat change due to changes in hydrology, indirect habitat loss due to barriers to movement and indirect loss due to sensory disturbance (habitat within a zone of disturbance is less effective to many species of wildlife) (Figure E11-1).

W-2 Will Water Releases From the Muskeg River Mine Project Change Wildlife Health?

Water releases from the Project are expected to have some influence on the receiving water quality. This question examines whether such releases may affect the health of wildlife that drink water from potentially affected waterbodies, such as the Athabasca and Muskeg rivers. In addition to consumption of water, some animals may also consume fish and/or aquatic invertebrates from affected waterbodies. For these reasons, exposure to water and aquatic food sources was evaluated in the assessment of wildlife health (Figure E11-1).

W-3 Will Consumption of Plants From the Muskeg River Mine Project Change Wildlife Health?

This question examines whether herbivorous and omnivorous animals (e.g., moose, snowshoe hare, black bear, ruffed grouse) may become exposed to chemicals via consumption of local plants affected by the Project. (Figure E11-1).

Figure E11-1 Linkage Diagram for Wildlife for Construction and Operation Phases of Muskeg River Mine Project

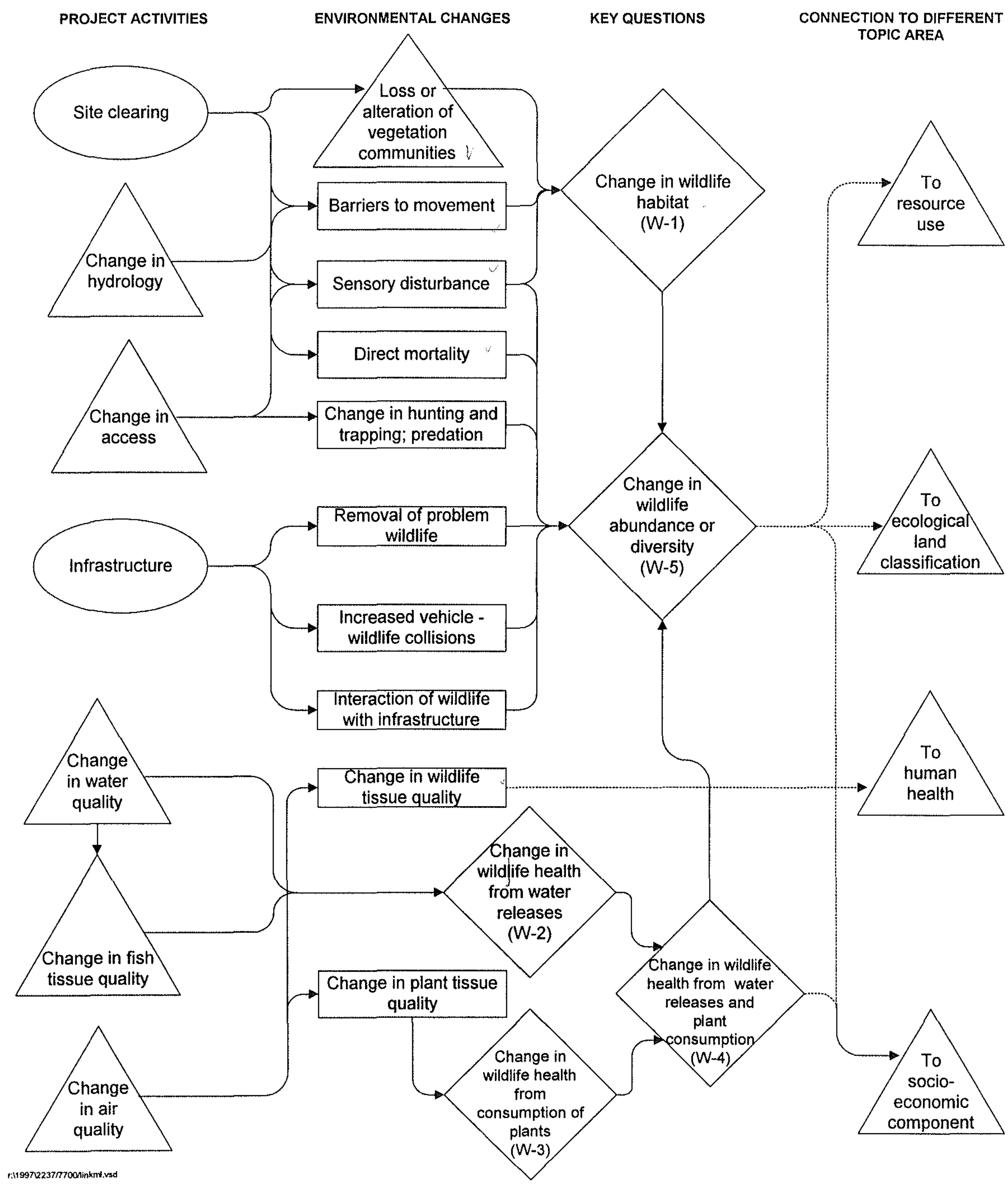
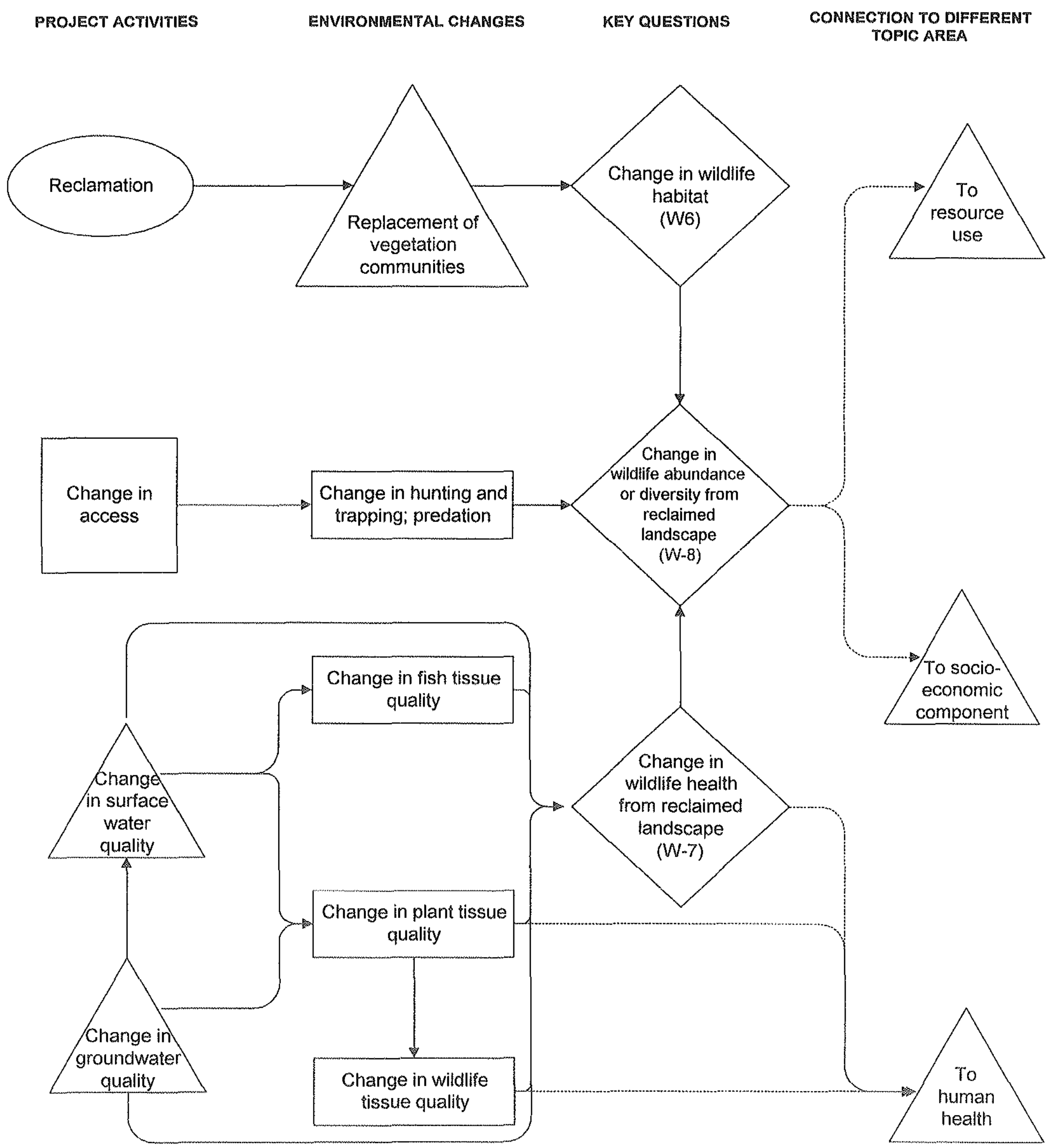


Figure E11-2 Linkage Diagram for Wildlife for the Closure Phase of Muskeg River Mine Project



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W-4 Will the Combined Exposure to Water, Aquatic Prey and Plants Affected by the Muskeg River Mine Project Change Wildlife Health?

Pursuant to W-2 and W-3, local wildlife may be exposed to chemicals through a variety of different media. For this reason, it is necessary to evaluate the combined exposure likely to be incurred by local wildlife that are exposed through water, aquatic prey and/or plant ingestion (Figure E11-1).

W-5 Will the Muskeg River Mine Project Change Wildlife Abundance or Diversity?

Potential impacts to wildlife can be categorized as leading to either direct or indirect mortality, which in turn leads to a change in wildlife populations (Figure E11-1). Indirect impacts can include the removal or alteration of vegetation communities, creation of barriers to movement and sensory disturbance (discussed under Key Question W-1), and the release of air or water emissions (Key Question W-4). Direct mortality impacts can include the effects of increased hunting (legal and illegal) and trapping due to increased access, removal of problem wildlife such as beavers and bears, increased traffic-caused mortality of wildlife and interaction of wildlife with mine infrastructure (e.g., bird collisions with transmission lines or towers) and facilities (e.g., waterfowl use of tailings settling ponds; Figure E11-1). Both wildlife abundance and diversity (species richness and diversity) are considered under this question. Ultimately, changes in wildlife populations can lead to changes in the consumptive and non-consumptive use of the wildlife resource and to changes in biodiversity (ELC Key Question 2).

W-6 Will the Reclaimed Landscape From the Muskeg River Mine Project Change Wildlife Habitat?

Replacement of vegetation communities during reclamation of the development site will lead to a change in wildlife habitat (Figure E11-2). Assumptions regarding the habitat variables for the KIR habitat models were made for each proposed reclamation vegetation community so that quantity and quality of wildlife habitat could be estimated at closure.

W-7 Will the Reclaimed Landscape From the Muskeg River Mine Project Change Wildlife Health?

Following closure of the Project, the land will be reclaimed and revegetated. Eventually, wildlife will be attracted to these areas and will feed on the local vegetation and prey species, and drink from the water sources on the reclaimed landscape. For these reasons, it is necessary to evaluate the potential for adverse health effects to wildlife that may use the reclaimed landscape in the future (Figure E11-2).

W-8 Will the Reclaimed Landscape and Post-Disturbance Activities From the Muskeg River Mine Project Change Wildlife Abundance or Diversity?

Changes in wildlife habitat (Key Question W-6) and changes in hunting and trapping pressures due to increased access can lead to changes in wildlife abundance and diversity. Impacts were assessed in a qualitative manner for this Key Question.

E11.3 Study Area Boundaries

The spatial boundaries for assessing wildlife included consideration of both a local study area (LSA) and a regional study area (RSA). These areas for wildlife are defined in Section D1.

The temporal boundaries for the EIA were defined as follows:

- Baseline (1997)
- Construction Phase (2000 - 2002)
- Operational Phase (2003 - 2029)
- Closure (2030 and beyond)

These periods were selected because the characteristics of the project's impacts are quite different between the construction and operational phases, and a long-term view of the project at project closure is required to assess the likely success of proposed reclamation/mitigation measures. Two main phases of the development were selected for detailed analysis: Construction and Operation phase, and Closure phase.

E11.4 Key Indicator Resources

As it is nearly impossible to study all species within an area however, species representative of public and scientific values can be chosen for management purposes. Species selected in this fashion are known as Management Indicator Species (MIS) (Salwasser and Unkel 1981), Valued Ecosystem Components (VECs) (Sadar 1994), key species and other terms. They will be termed Key Indicator Resources (KIRs) for the purposes of this EIA, following the terminology of the Aurora EIA (BOVAR 1996a). Species chosen as KIRs for the Aurora Mine EIA were selected based on a scoring of species' political importance (endangered status), commercial and subsistence economic importance, non-consumptive importance and ecological importance (BOVAR 1996a). Rather than repeat this process, the study team reviewed the selection process and adopted the KIRs of the Aurora Mine EIA for the Muskeg River Mine EIA (see Section E1). Following review of this list with Alberta Environmental Protection (AEP) personnel, two additional KIRs were selected: the western tanager and the pileated woodpecker. In addition to representing their respective species groups, KIRs were chosen for the reasons listed in Table E11-1.

Additional information on selection of KIRs is provided in Section E1.

Table E11-1 Key Indicator Resources and the Selection Rationale

KIR	Selection Rationale
moose	economic importance, early successional species
red-backed vole	importance in food chain
snowshoe hare	importance in food chain
black bear	economic importance, carnivore
beaver	economic importance, semi-aquatic habits
fisher	use of late seral stages, economic importance, carnivore
dabbling ducks	importance in food chain, economic and recreational importance
ruffed grouse	economic and recreational importance
Cape May warbler	use of white spruce forests, neotropical migrant
western tanager	use of open forest mixedwood, neotropical migrant
pileated woodpecker	use of late seral stages, large-diameter trees and snags
great gray owl	raptor, use of wetlands

E11.5 Methods

E11.5.1 Validation of Linkages

Linkages between project activities and environmental changes that affect each of the Key Questions were assessed as to their validity for each of the KIRs. Assessments were based on the literature, field data collected within and adjacent to the Muskeg River Mine Project, and professional judgment.

E11.5.2 Habitat Suitability Index Modelling

Habitat Suitability Index (HSI) models were used to assess the baseline habitat conditions for KIRs in the LSA. Baseline conditions included existing disturbed areas (roads, Alsands project area). Effects of disturbance on wildlife due to existing roads was also accounted for in determining baseline conditions. Models were adapted from AXYS (1996a), Westworth (1996) and, in some cases, were developed by Golder Associates. A brief description of the HSI process follows. Detailed model descriptions are found in the above-mentioned reports and a more detailed description of the HSI process for the Project is found in Golder (1998b).

HSI models are analytical tools for determining the relative potential of an area to support individuals (or populations) of a wildlife species. They are frequently used to quantify potential habitat losses and gains for wildlife species as a result of various land use activities. Today, many EIAs use HSI modelling to determine potential impacts of Project activities on wildlife resources.

HSI models evaluate the potential of an area to support a wildlife species, based on a number of known or assumed relationships between elements of habitat structure and their ability to support a species' biological needs (e.g., food, cover, reproduction). These relationships are then combined mathematically into models. They are referred to as HSI models because the rating they provide is a relative value ranging from 0 to 1, where 0 indicates that an area is unsuitable and 1 indicates optimum suitability. HSI values for each habitat type are multiplied by the area (ha) of the habitat type or area under consideration to determine the number of habitat units (HU) for each wildlife species. The number of HUs both pre- and post-development can then be compared to assess impacts of habitat change on wildlife.

Disturbance Coefficients

Wildlife species may avoid or reduce their use of habitat adjacent to areas of human activity. Impacts are greater if the adjacent habitat is of high quality and if the total supply of habitat in the area is limiting. One way to estimate the amount of habitat affected by disturbance (i.e., habitat effectiveness) is to assume disturbance Zones of Influence (ZI) and Disturbance Coefficients (DC) for each KIR and each activity type. A ZI is the maximum distance to which a disturbance (e.g., traffic noise) is felt, and a DC is the effectiveness of the habitat within the ZI in fulfilling the requirements of the species (e.g., a DC of 0.9 represents 90% habitat effectiveness). ZIs and DCs can be used with HSI mapping within a Geographic Information System (GIS) to estimate the quantity and quality of habitat (expressed in HUs) that could be affected by a development.

Different species react differently to developments. Most work on this subject has been done for grizzly bears. Numerous studies (e.g., Mattson et al. 1987, McClellan and Shackleton 1988, McClellan and Shackleton 1989a, 1989b, Purves et al. 1992, Mace et al. 1996) have measured the displacement of grizzly bears by different levels of human activities.

Horejsi (1979) found that moose were disturbed by active seismic line work to within one km, while other researchers have found that moose avoid areas of human activity but did not determine a zone of influence (e.g., Hanock 1976, Rolley and Keith 1980). Still others have found that moose can habituate to human disturbance (e.g., Pauls 1987).

Unfortunately, results of such studies are often highly variable due to the difficulties associated with studying a wide-ranging and reclusive species such as the grizzly bear, and most study designs are based on rather arbitrary buffer distances around disturbance features (e.g., analyze bear locations less than and greater than 500 m from roads: Mace et al. 1996). Therefore, most displacement models have relied on professional judgment, using empirical data as a guide only.

BOVAR (1996a) used a ZI of 500 m for moose and 100 m for snowshoe hares for the Aurora Mine EIA. They made a conservative assumption that displacement was complete within the ZI for these species (i.e., DC was zero for all activity types). In contrast, they assumed that all other KIRs were not displaced by the Aurora Mine development.

Westworth (1996) used a ZI of 250 m and a DC of zero for all KIRs for the Suncor EIA, due to sensory disturbance, reduced hiding and thermal cover, reduced forage palatability due to the accumulation of dust, and, for breeding birds, increased risk of nest predation from edge-adapted species.

The ZIs and DCs used for the Muskeg River Mine EIA are shown in Table E11-2. These variables were determined through professional judgment, based on literature review and other oil sands EIAs. Habitat alienation from disturbance was not considered to be a factor for either red-backed voles or beavers (Section E11.6.1).

For moose and black bears, different DCs were established depending on whether or not the vegetation adjacent to the disturbance represented adequate cover or not (USDA Forest Service 1990). Cover for these species was defined by the cover component of the moose HSI model (Golder 1998b). The DC for cover was used for habitats that had an HSI for cover of > 0.5.

E11.5.3 Wildlife Health Analysis

Sources of Data

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

Table E11-2 Displacement Variables for Wildlife KIRs for the Muskeg River Mine Project

						Zone of Influence (m)						
Activity Code	Use Level	Motorized	Use Duration	DC (cover)	DC (noncover) [(a)]	Moose	Red-Backed Vole/ Beaver	Black Bear	Fisher/ Hare	Ruffed Grouse/D uck	Breedin g Birds	Raptor
main road	high	yes		0.25	0.05	500	0	100	200	100	100	500
secondary road	low	yes		0.75	0.375	500	0	100	200	100	100	500
utility corridor	incidental	yes		0.9	0.8	250	0	50	100	50	50	250
active mine areas, gravel pits, dumps	high	yes	24 h	0.1	0.0	500	0	100	200	100	100	500
plant, camp	high	yes	24 h	0.2	0.1	500	0	100	200	100	100	500
tailings pond	low	no	24 h	0.9	0.8	250	0	50	100	50	50	250

[(a)] Noncover Disturbance Coefficients used for moose and black bear only.

- Water, aquatic invertebrate and fish quality data summarized in Sections E5 and E6;

- Plant tissue quality data summarized in Section E11.8 and Appendix X.4; and

- Plant and invertebrate tissue data summarized in Section E11.12.

The first step of the wildlife health impact analysis was to determine whether a certain project-related activity has the potential to cause a chemical change that might affect wildlife health.

Initially, potential links between environmental changes (e.g., water releases) and wildlife health were qualitatively evaluated using principles of risk assessment (i.e., problem formulation) to determine the validity of each linkage based on specific activities of the Project (i.e., whether a certain project-related activity could result in an environmental change that might affect wildlife health).

The overall risk assessment approach used to evaluate the linkages is summarized in the following section. Supporting documentation for the risk assessment is provided together with human health risk assessment documentation in Appendix X.

E11.5.4 Wildlife Health Risk Assessment

General Concepts

A risk assessment was conducted to evaluate the likelihood of unacceptable effects to wildlife health resulting from exposure to chemicals on the Project site. This risk assessment was conducted according to established ecological risk assessment protocols endorsed by the Canadian Council of Ministers of the Environment and Environment Canada (CCME 1996, Environment Canada 1994). The potential for a health risk to arise from environmental substances is predicated on the co-existence of three elements, as illustrated in Figure E11-3: i) chemicals must be present at hazardous concentrations; ii) receptors (i.e., animals) must be present; and iii) exposure pathways must exist between the source of the chemicals and the receptor. In the absence of any one of the three elements outlined in Figure E11-3, wildlife health risks cannot occur.

The process followed a widely recognized framework for ecological risk assessment, as illustrated in Figure E11-4. The framework progresses from a quantitative initial phase (Problem Formulation), through Exposure and Toxicity Analysis and culminates in quantitative Risk Characterization. The following sections provide further details with respect to these phases.

Problem Formulation

The Problem Formulation is a screening level assessment of the likelihood for health risks. The objective of the Problem Formulation was to develop a focused understanding of how chemical releases from the Project might contribute to health risks for wildlife that currently live in areas near the Project area, and/or may in the future use the reclaimed landscape. This was achieved by considering the attributes of the site, by identifying the wildlife that are expected to inhabit nearby off-site areas, by focusing on the chemicals likely to be present at concentrations that may be hazardous, and identifying the plausible exposure pathways between chemicals and receptors.

Problem Formulation is the critical initial phase of the risk assessment and is conducted by completing three major steps, illustrated in Figure E11-4:

- Preliminary Considerations: characterization of the site and scope of the problem.
- Screening Process: identification of the chemicals, exposure pathways and wildlife receptors of greatest concern.
- Development of the Conceptual Model: a visual representation of the environmental fate and exposure pathways by which a chemical may come in contact with the receptors of concern.

A further consideration in ecological risk assessment is the selection of assessment and measurement endpoints for the receptors of concern. This is discussed in more detail in the sections that follow.

A detailed problem formulation process (or screening level assessment) was conducted for each wildlife health key question. Where the problem formulation indicated a potential linkage between project activities and wildlife health (i.e., presence of elevated chemical concentrations, receptors and exposure pathways), a detailed risk assessment was carried out to further investigate the potential impact. Where the results of the problem formulation indicated no potential linkage between project activities and wildlife health, no further evaluation was necessary.

Figure E11-3 Risk Components

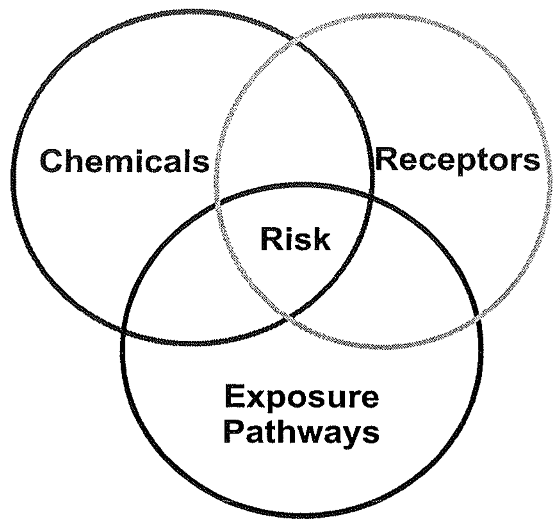
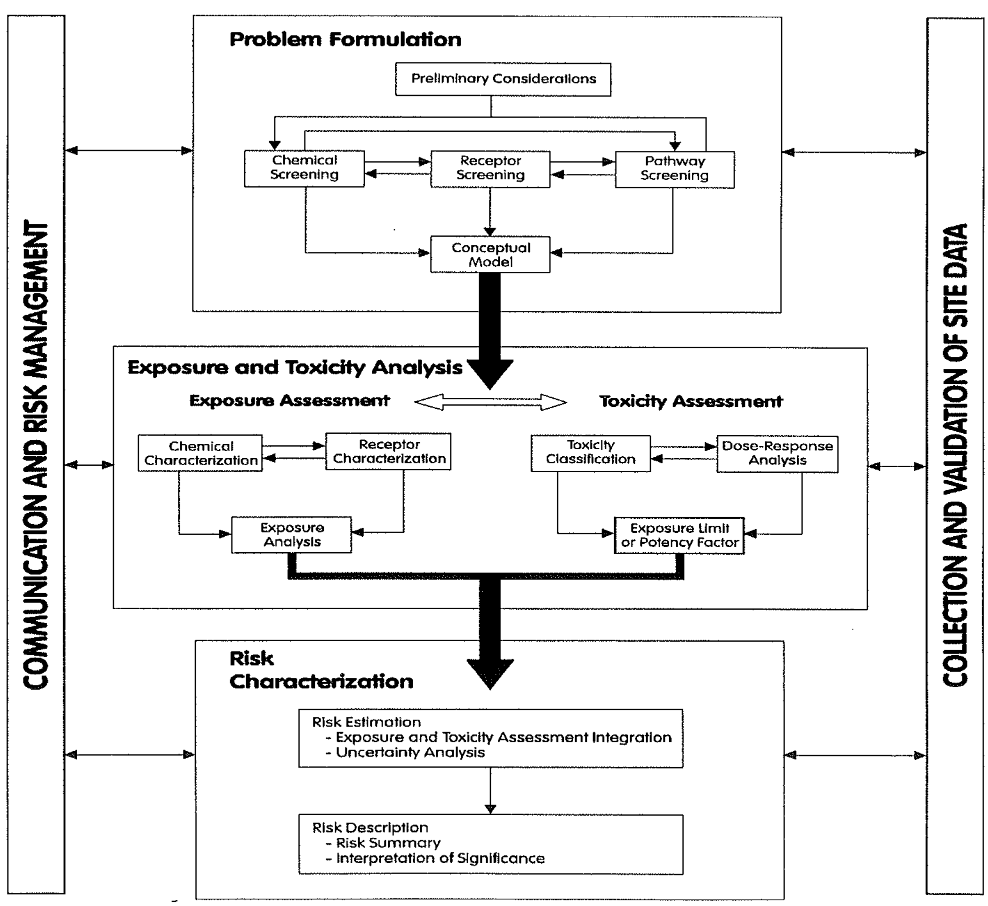


Figure E11-4 Risk Assessment Framework



Preliminary Considerations

Details of activities during construction, operation and closure of the Project have been fully described in Volume 1 and Section B, Volume 2 of the Application.

Use of the Project site by wildlife will change over the life of the Project. During the construction and operation phase, wildlife will not have direct access to the site, but may inhabit nearby areas. Nearby watercourses, such as the Athabasca and Muskeg rivers, and forested areas, may be used as sources of drinking water, fish and invertebrates by aquatic wildlife. In addition, terrestrial wildlife may feed on local plants and animals near the site. Following closure, wildlife will be attracted to the reclaimed landscape. Aquatic wildlife will continue to use local water courses, such as the Athabasca and Muskeg rivers, following closure.

The wildlife health component focused on the operation stage because of it's substantially lower time frame, additional emission sources and larger area of effect compared to the construction phase.

In respect of applicable and relevant regulatory policies/criteria, the approach adopted here embraced both federal and various provincial environmental quality standards, including AEP and Environment Canada.

Screening Process

In a risk assessment, it is not possible or practical to evaluate every potential chemical, receptor and exposure pathway. Therefore, for the current assessment, a comprehensive screening process was carried out in the problem formulation phase to focus the assessment on those chemicals, receptors and exposure pathways of greatest concern (i.e., chemicals with the greatest toxic potential; receptors with the greatest likelihood of being exposed and with the greatest sensitivities; exposure pathways that account for the majority of exposure to the chemical releases). If no unacceptable health risks are predicted for these, it is highly likely that no unacceptable health risks would exist for other chemicals, receptors or exposure pathways.

Three screening procedures were conducted in the problem formulation phase:

- chemical screening
- receptor screening
- exposure pathway screening

Chemical Screening

The objective of the chemical screening process was to focus the list of chemicals measured in various media (e.g., water, fish, soil, plants) on those chemicals that may be a concern because of their concentrations and their potential to cause adverse wildlife health effects. This list of chemicals of potential concern was used to assist in receptor and exposure pathway screening, and the chemicals identified here were carried forward into the Risk Analysis phase. The screening process used for the wildlife health risk assessment followed a methodical, step-wise process, shown schematically in Figure E11-5, and described in detail in Appendix X.1. Briefly, measured or predicted chemical concentrations were compared with background concentrations (i.e., in areas not affected by oil sands activities), regulatory screening level criteria (SLC) and risk-based concentrations (RBC) for the protection of wildlife health. Detailed screening tables are also presented in Appendix X.1. The chemicals of potential concern retained for further evaluation in the risk assessment are listed according to key question in Sections E11.7, E11.8, E11.9 and E11.12.

The chemical screening process incorporated several protective assumptions to ensure that chemicals of concern would not be excluded erroneously. These assumptions include:

- the maximum observed, or a conservative predicted concentration of each chemical was used;
- the SLC were based on published criteria designed to prevent any adverse wildlife health effects over a lifetime exposure;
- if no SLC was available for a chemical, it was retained and carried forward to the next chemical screening step; and
- RBCs were based on conservative exposure scenarios for each animal (e.g., wildlife were assumed to be exposed every day of the year throughout their lifetime) and were calculated assuming a target exposure ratio of 0.1 (i.e., one-tenth of the concentration considered to be acceptable to allow for multi-media chemical exposure).

While this screening focused on chemicals related to the operations of the Project, by reviewing background concentrations in the Athabasca and Muskeg rivers, it also inherently includes some chemicals from other sources. However, some chemicals, such as chlorinated organics derived from pulp mills, were not investigated here because the Project is not a source for those chemicals and they are closely monitored and managed by the pulp industry. Given their extremely low levels and dissimilarity to the Project - related chemistry, it is unlikely that these substances interact to form a hazard. In addition, there may be natural hazards, such as pathogens, associated with river water that could pose a health hazard to wildlife.

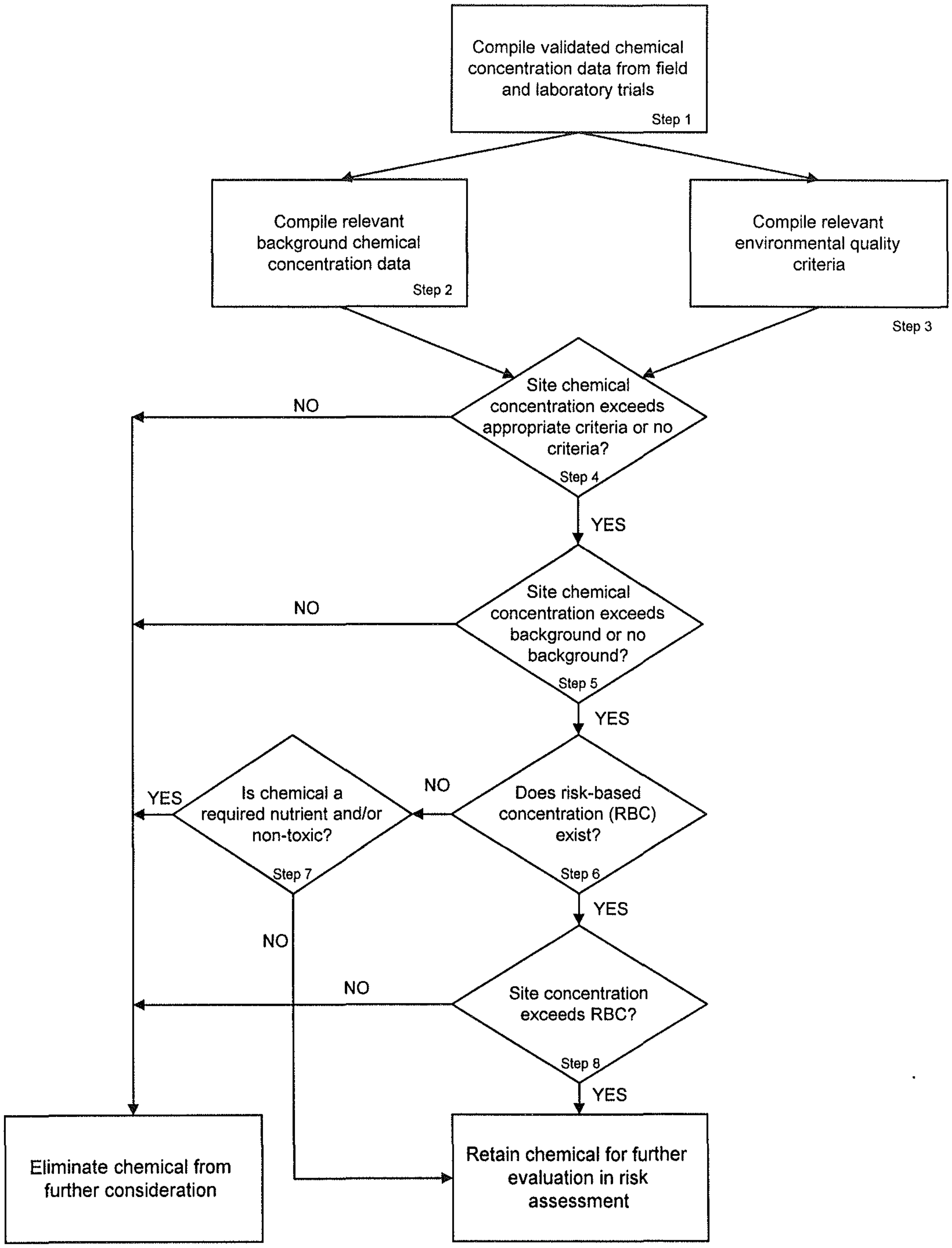
Receptor Screening

The objective of the receptor screening process was to identify wildlife receptors currently using the area or that may use the reclaimed landscape in the future. The receptors identified here were carried forward into the Risk Analysis phase.

All receptors were selected based on a wildlife inventory of the area, discussions with wildlife biologists conducting baseline studies and guidance from the literature (Suter 1993, Algeo et al. 1994). 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. Consideration was also given to include animals that have societal relevance and that are a food source for people. Wildlife KIRs for the Project EIA were given extra weight in the evaluation. An attempt was also made to represent various tropic levels and to maintain continuity with previous oil sands EIAs.

Details of the receptor screening process are provided in Appendix X. Briefly, a different set of wildlife receptors was selected for evaluation of each key question, based on maximum likely exposure to the media being evaluated. For key question W-2 (water releases), aquatic wildlife (i.e., water shrew, killdeer, river otter, great blue heron) were selected for evaluation of exposure through ingestion of water, aquatic invertebrates and fish. In addition, several terrestrial wildlife species were evaluated for key question W-2, since they may drink water from local rivers. For key question W-3 (plant ingestion), herbivorous or omnivorous wildlife species were selected. Combined exposure (W-4) was evaluated for all receptors assessed under W-2 and W-3. For the reclaimed landscape scenario (W-7), a variety of terrestrial and wetland wildlife species were selected. These wildlife species are likely to inhabit the reclaimed landscape following closure of the Project and represent various tropic levels of the food chain. Table E.11-3 lists the wildlife species selected for each key question.

Figure E11-5 Process for Chemical Screening



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Exposure Pathway Screening

The objective of the exposure pathway screening process was to identify the major pathways by which the receptors of concern may be exposed to chemicals from the site. The exposure pathways identified here were carried forward into the Risk Analysis phase. Details of the exposure pathway screening process are provided in Appendix X.3. Table E11-4 lists the potential exposure pathways identified for each key question.

Table E11-3 Potential Receptors for Each Key Question

W-2 Water Releases	W-3 Plant Consumption	W-4 Combined Exposure	W-7 Reclaimed Landscape
water shrew	moose	moose	moose
river otter	snowshoe hare	snowshoe hare	snowshoe hare
killdeer	black bear	black bear	beaver
great blue heron	ruffed grouse	ruffed grouse	deer mouse
moose	mallard	mallard	ruffed grouse
black bear			mallard
snowshoe hare			American robin

Table E11-4 Potential Exposure Pathways for Evaluation

Exposure Pathway	W-2	W-3	W-4	W-7
ingestion of water	X		X	X
ingestion of fish	X		X	X
ingestion of aquatic invertebrates	X		X	X
ingestion of terrestrial plants		X	X	X
ingestion of aquatic plants		X	X	X
ingestion of terrestrial invertebrates				X

Conceptual Models

The results of chemical, receptor and exposure pathway screening were used to develop conceptual models for the risk assessment. Separate conceptual models were developed for evaluation of each key question and are presented in Sections E11.7, E11.8, E11.9 and E11.12. The exposure pathways and receptors indicated in the conceptual models were assessed where chemicals of concern were identified through the chemical screening process.

Assessment and Measurement Endpoints

Information compiled in the first stage of problem formulation was used to help select ecologically based endpoints relevant to decisions about protecting the environment (U.S. EPA 1992a). Endpoints are characteristics of ecological components that may be affected by exposure to a stressor (e.g., chemical). Assessment endpoints are explicit expressions of the actual ecological value that is to be protected and are the ultimate focus in risk characterization. For this investigation, the assessment endpoints included protection of the viability of populations of wildlife previously selected as receptors. Since these receptors encompass different taxa and tropic levels, it was assumed that these receptors also serve as surrogates to other levels of organization and/or receptors not directly included in this evaluation. However, assessment endpoints tend to be qualitative or semi-qualitative, and are rarely directly measurable. As a result, measurement endpoints are usually defined as surrogates for assessment endpoints. Measurement endpoints are the quantitative response of the receptor to the stressor, which is related to the characteristics of the assessment endpoint. In other words, it is the response to which exposure to the chemicals of potential concern is related, so that one can identify whether a specific exposure scenario might adversely affect the receptor. For this study, measurement endpoints were based on laboratory, field and modelling studies of sub-lethal adverse health effects (e.g., reproduction, growth) on surrogate species that are relevant for stabilizing adverse effects on populations or communities.

Exposure Assessment

Exposure assessment is the process of estimating the daily intake rate (dose) of a chemical received by a receptor under a given exposure scenario. An exposure assessment was conducted for each key question where chemicals of concern, receptors and exposure pathways were identified. Exposure equations and wildlife receptor parameter profiles used in the exposure assessment are provided in Appendix X.4. Further details of the exposure assessment conducted for each wildlife health key question are provided in Sections E11.7 to E11.9 and Section E11.12.

Bioavailability

Bioavailability is a concept referring to the amount of chemical that will enter the bloodstream following contact with a chemical. It is important because most chemicals exert their toxic effects only following absorption. For the wildlife health risk assessment, the bioavailability of each chemical via ingestion was assumed to be 100%. This is a conservative assumption that inflates risk estimates, since this implies that 100% of a chemical ingested is also absorbed into the blood. A more accurate assessment of bioavailability may indicate that absorption is significantly less than 100%, with a resultant reduction in hazard.

Figure E11-6 Water Releases Scenarios: Conceptual Model for Wildlife

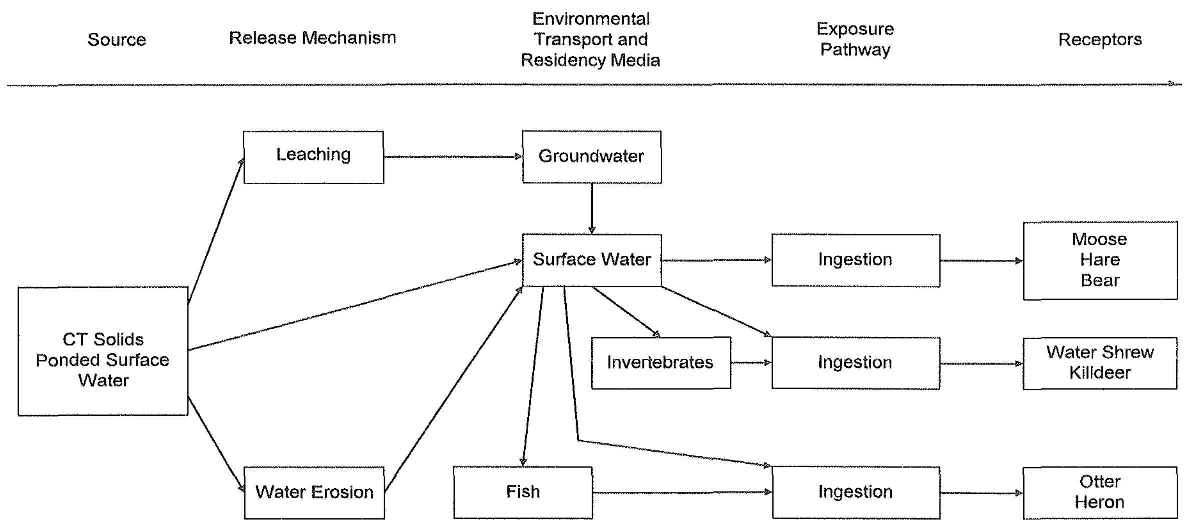


Figure E11-7 Local Plant Scenarios: Conceptual Model for Wildlife

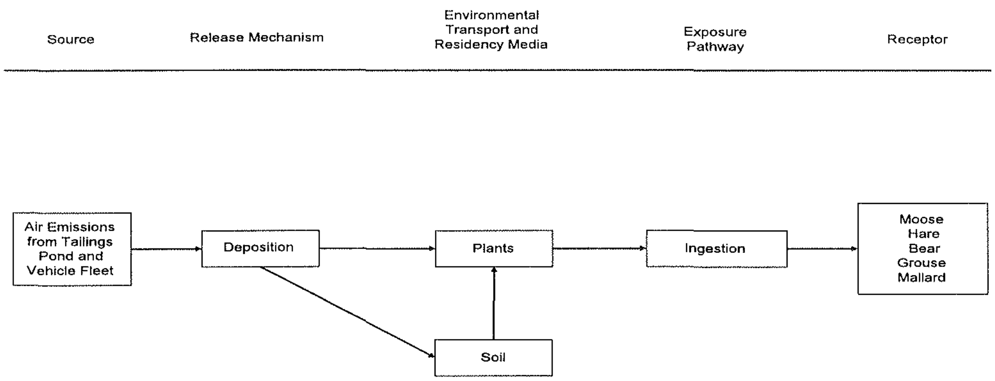
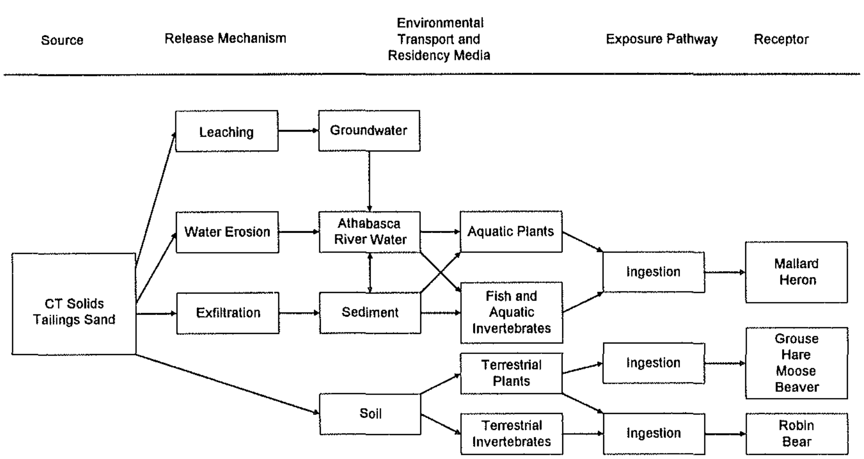


Figure E11-8 Reclaimed Landscape Scenarios: Conceptual Model for Wildlife



Toxicity Assessment

Toxicity Assessment is the identification and quantification of the chemical concentration or dose (i.e., daily intake), above which exposure to a receptor might cause an adverse effect (U.S. EPA 1988a).

In the toxicity assessment, toxicity information for each chemical was used to provide qualitative and quantitative estimates of health effects associated with exposure to site chemicals. The toxicity assessment for wildlife health differs from that conducted in a human health risk assessment, since the concern level for wildlife health is directed toward protection of populations, while the concern level for human health is directed toward protection of the individual. The toxicity assessment for wildlife health was based primarily on consideration of the threshold for adverse reproductive effects in each receptor evaluated. Reproductive effects were chosen, where data were available, as the most relevant endpoint to use for evaluating potential adverse health effects to wildlife populations, since adverse effects on reproduction have a direct impact on maintenance of populations.

Toxicity reference values for wildlife are daily exposure rates that could occur over a lifetime of an animal without causing any measurable, adverse reproductive effects. These values are based on dose-response toxicity evaluations available through the toxicological databases for wildlife (Sample et al. 1996) and various other sources in the toxicological literature.

Carcinogenic endpoints are not typically considered in an ecological risk assessment for several reasons:

- carcinogenic effects occur on an individual level rather than a population level;
- carcinogenic effects may not necessarily lead to reduction of populations;
- due to the relatively short lifespan of some animals, other types of adverse effects may be manifested earlier than carcinogenic effects; and
- there is limited toxicological information concerning carcinogenic effects in wildlife.

Toxicity reference values were derived for each wildlife receptor evaluated in the risk assessment. Toxicity reference values for mammalian wildlife were calculated based on estimated No-Observed-Adverse-Effect-Levels (NOAELs) reported for laboratory animals using appropriate dose-scaling techniques to extrapolate from laboratory animals to mammalian wildlife as described in Sample et al. (1996). Dose-scaling for mammalian wildlife receptors is a common practice and 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, toxicity reference values for avian wildlife species are equivalent to NOAELs reported for avian test species.

Based on insight from previous oil sands EIAs, it was recognized that naphthenic acids, a component of CT water, would be of interest for evaluation of wildlife health. However, to date, there are insufficient mammalian toxicological data to calculate defensible wildlife toxicity reference values for naphthenic acids, a component of CT water. Toxicity reference values are normally calculated based on chronic or subchronic studies in laboratory animals; however, there are only acute toxicity mammalian data available for naphthenic acids. The acute toxicity data suggests that naphthenic acids have a relatively low potency under acute exposures.

Tables E11-5 and E11-6 provide summaries of the toxicity reference values used in this assessment for mammals and birds, respectively. Further details on the toxicology of these chemicals and selection of the toxicity reference values for this assessment are provided in Appendix X.5.

Risk Characterization

In the risk characterization step, Exposure Ratios (ERs) were calculated as the ratio of the predicted chemical intake (dose) to the toxicity reference value, according to the following equation:

ER = estimated daily intake / toxicity reference value

An ER is calculated for each chemical of concern and for each exposure pathway, based on the estimated intake rates (dose) and the toxicity reference values.

An ER value of less than 1 represents exposure scenarios that do not pose a significant health risk to exposed receptors (CCME 1996). When the ER is greater than 1, the scenarios pose a potential concern and require further investigation. *It is important to note that ER values greater than 1 do not necessarily indicate that adverse health effects will occur. Rather, they are a signal for closer scrutiny of the potential for such risks.*

Ecological risks are a function of the severity of ecological effects, the area over which effects occur, and the duration of effects (Suter et al. 1995). However, there is no standard scale for defining bounds that represent *de minimis* or *de manifestis* risk. *De minimis* risks include mild, transient or localized effects on ecological entities. *De manifestis* risks include risks that are severe, long-lasting or widespread. The severity, extent and duration of estimated effects on these entities are attributes that help define whether risks are *de minimis* or *de manifestis* (Suter et al. 1995).

Suter et al. (1994) outlined a convincing argument suggesting that a 20% reduction in ecological parameters (e.g., growth, fecundity) would be indistinguishable from normal variability and should be considered as an "effect threshold" in characterizing ecological risks. This argument is based on a practical assessment of the limitations in measuring changes in wild populations, statistical changes in laboratory studies, and the basic principles of population ecology.

Citing examples from currently accepted practices in aquatic and terrestrial assessments, a change of 20% or greater is required to distinguish the change from normal background variability, implying that a 20% or less reduction in ecological parameters could be considered *de minimis* with respect to potential severity of the estimated effect.

Similarly, the extent of the potential impact also is important in characterizing risk. For example, a potential effect on only a few individuals is insignificant with respect to populations of small mammals such as deer mice but may be significant with respect to threatened and endangered species. For this assessment, *de minimis* risks were defined as those in which 20% or fewer of the individuals in a non-threatened or endangered population are potentially affected by exposure to the site.

Similarly, the duration of exposure and the effect is of importance in characterizing risks. For example, potential effects that are short-lived (e.g., less than one generation) will have no long-term impact on a population. In contrast, the same effect sustained over several generations may pose significant ecological risks to the population.

This information is brought together in the Risk Characterization phase of the assessment, using a weight of evidence approach to assess whether the site poses a significant health risk to wildlife populations.

E11.5.5 Development of Mitigation

Mitigation, within the context of an EIA, can be defined as "the application of design, construction or scheduling principles to minimize or eliminate potential adverse impacts and, where possible, enhance environmental quality" (Sadar 1994). Thus mitigation can be used to lessen the impacts of developments. This task recognizes that many impacts are mitigable given a commitment to environmental protection during planning, construction and operation stages of a development. Mitigation may involve changes in planning, design and engineering, and project management. Mitigation could include changes in site and route selection, timing windows for seasons critical to certain wildlife or plant species, minimizing disturbance caused by construction, and potential enhancement of habitat through progressive reclamation techniques and progressive closure planning.

Table E11- 5 Mammalian Toxicity Reference Values Used in the Risk Assessment

Chemical	Reference Study NOAEL (mg/kg/d)	Extra Polated Receptor-Specific NOAELs (mg/kg/d)	Measurement Endpoint (effect)	Reference
antimony	0.125 (mice)	hare: 0.047 moose: 0.012 bear: 0.015	lifespan and longevity	Schroeder et al. 1968, Sample et al. 1996
barium	5.06 (rats)	shrew: 12.2 hare: 3.7 moose: 0.93 bear: 1.2 mouse: 11.1	growth; food and water ingestion; hypertension	Perry et al. 1983
boron	28 (rats)	moose: 4.9	reproduction	Weir and Fisher 1972
cadmium	1 (rats)	moose: 0.018	reproduction	Sutou et al. 1980
cobalt	0.24 (cattle)	shrew: 3.0	maximum tolerable dose	NAS 1980
copper	11.7 (mink)	shrew: 34.6 hare: 10.6 moose: 2.7 bear: 3.5	reproduction	Aulerich et al. 1982
manganese	88 (rats)	shrew: 200.5 hare: 61.1 moose: 15.3 bear: 20	reproduction	Laskey et al. 1982
mercury	1 (mink)	mouse: 2.7	reproduction	Aulerich et al. 1974
molybdenum	0.26 (mice)	moose: 0.024 bear: 0.03 mouse: 0.29	reproduction	Schroeder and Mitchener 1971, Sample et al. 1996
nickel	80 (rats)	mouse: 83.2	reproduction	Ambrose et al. 1988
selenium	0.2 (rats)	moose: 0.035 mouse: 0.4	reproduction	Rosenfeld and Beath 1954
strontium	263 (rats)	mouse: 547	body weight changes	Skoryna 1981
vanadium	0.21 (rats)	moose: 0.034 mouse: 0.41 bear: 0.04 hare: 0.14	reproduction	Domingo et al. 1986, Sample et al. 1996
zinc	160 (rats)	shrew: 346.5 mouse: 333	reproduction	Schlicker and Cox 1968

Table E11-6 Avian Toxicity Reference Values Used in the Risk Assessment

Chemical	Reference Study NOAEL (mg/kg/d)	Extrapolated Receptor-Specific NOAELs (mg/kg/d)	Measurement Endpoint (effect)	Reference
barium	20.8 (chicken)	killdeer: 20.8 grouse: 20.8 mallard: 20.8	mortality in day-old chicks	Johnson et al. 1960; Sample et al. 1996
chromium	1 (black duck)	killdeer: 1	reproduction	Haseltine et al. unpublished
cobalt	0.7 (chicken)	killdeer: 0.7 grouse: 0.7	maximum tolerable dose	NAS 1980
copper	47 (chicken)	killdeer: 47 grouse: 47	mortality in day-old chicks	Mehring et al. 1960
zinc	14.5 (chicken)	killdeer: 14.5 mallard: 14.5 grouse: 14.5	reproduction	Stahl et al. 1990

E11.5.6 Degree of Concern

In the case of each impact Key Question for which linkages were judged to be valid, potential residual impacts were classified according to their direction, magnitude, geographic extent, duration, reversibility, frequency and geographic extent (see Section E1.3). A range of impact classes (e.g., impacts of Low to Moderate magnitude) were attached where impacts were expected to range between classes. Potential residual impacts were evaluated for both construction/operation and closure phases of the development. An overall degree of concern was then derived for each impact based on impact magnitude, duration and geographic extent as detailed in Table E1-7, Section E1.

For the wildlife health component, the degree of concern was primarily determined by the magnitude of impact, although duration and geographic extent were also factors (See Section E1). For this assessment, magnitude of impact is based exclusively on whether or not the Project activity might adversely affect wildlife health. The magnitude of impact was based on quantitative risk estimates for Key Questions W-2, W-3, W-4 and W-7. ER values greater than 1 represent scenarios that pose a potential concern. However, since many conservative factors are typically used to derive both the intake rates and the toxicity reference values, the ER estimates will tend to overestimate the potential for risk. This is consistent with a protective approach to risk evaluation. Thus, an ER value of greater than 1 indicates a potential health concern that needs further scrutiny to identify the reason for the elevated ER; this may lead to additional data collection to more accurately quantify risks. In addition, ER values that are greater than 1 for individual animals may not necessarily result in measurable effects to wildlife populations. Hence, the magnitude of impact has been defined as follows:

Negligible — ER < 1 and no data gaps, or ER marginally >1 due to naturally elevated background exposures and/or conservative exposure assumptions. Individual risk estimates would not be expected to result in a significant impact (i.e., >20% change to the population).

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

Moderate — ER > 1 and impacts likely to result in a significant impact (i.e., >20% change) to the population, with mitigating factors that would likely result in exposures or toxic pathways to be less than used in the ER calculations, but additional information needed to support this conclusion.

High — ER > 1 and impacts likely to result in a significant impact (i.e., >20% change) to the population, without mitigating factors; hence exposure has potential to adversely affect the health of wildlife populations.

Unresolved — Insufficient information to draw any conclusions.

E11.5.7 Monitoring

Effects monitoring is generally required to assess whether:

- the predicted impacts occur or not; and
- the mitigation program achieves its objectives.

Compliance monitoring may also be required to determine whether conditions of the project approval are being met.

Key aspects of monitoring programs are an effective experimental design (Salwasser et al. 1983, Rose and Smith 1992), and a feedback mechanism to ensure that mitigation can be improved over time (i.e., the adaptive management process). Good monitoring programs take into account (Bernstein et al. 1993):

- public concerns;
- management objectives;
- measurement goals; and
- sound technical plans and methods.

Recommendations regarding monitoring are provided for each Key Question as appropriate.

E11.6 Key Question W-1: Will Activities from the Muskeg River Mine Project Change Wildlife Habitat?

E11.6.1 Analysis of Potential Linkages

This Key Question will focus on the effects of direct and indirect alteration of wildlife habitat. Direct habitat change occurs with the direct removal or alteration of vegetation communities during construction of project facilities (Figure E11-1). These changes can be calculated with a GIS and the number of HUs (see Section 11.5-2 and Golder 1998b) affected can be reported. Indirect habitat change can occur through 1) changes in hydrology, 2) creation of barriers to movement, and 3) sensory disturbance (see Section 11.6.4). These impacts can be assessed using predicted changes to surface water hydrology (Section E4), habitat modelling and assuming zones of disturbance around project facilities. Direct and indirect impacts on each of the KIRs will be discussed.

Linkage Between Site Clearing and Removal or Alteration of Vegetation Communities

Background

Mining activities that may result in habitat loss, alteration and fragmentation include:

- clearing vegetation and surface grading to accommodate facility construction (e.g., mine pits, storage dumps, gravel pit, service roads, mining and haul roads, drainage ditches, infrastructure);
- overburden dewatering adjacent to the mine;
- dewatering of streams and aquatic habitats;
- utility and pipeline (e.g., product and dilutent return) construction;
- road upgrading and construction for access requirements; and
- air emissions.

Direct habitat loss is the most visible impact and occurs when land is allocated for other uses. Of all possible sources of impact from facility construction to wildlife, permanent habitat loss can be considered one of the most important in that it ultimately reduces the landscape's capability to support wildlife. Facilities such as roads tend to be permanent and habitat loss is long-term. For other types of facilities, habitat loss can be considered temporary, such as for construction of buried pipelines and other utilities where the terrestrial habitat is reclaimed and restored following construction. For extractive industries such as mining, reclamation and restoration are the first steps in re-establishing a natural ecosystem from landscape alteration. At the end of a project's life, successful restoration can to some extent reverse the long-term effects of habitat loss.

Habitat alterations typically include changes in successional stages of vegetation (i.e., changes in structure and species composition) and changes in spatial patterns of vegetation communities. The term habitat alienation refers to loss of habitat effectiveness as a result of sensory disturbances from human activities at disturbed sites. This alienation effect on wildlife can be short term, or long term depending on the nature of the facilities and available mitigation techniques. Habitat alienation is discussed later under the topic of sensory disturbance (see Section E11.4).

Habitat fragmentation is another habitat-related effect that occurs when land is allocated to other uses. Fragmentation occurs when extensive, continuous tracts of habitat are reduced by habitat loss to dispersed and usually smaller patches (reduced interior size) of habitat. A major contribution to habitat fragmentation in forested habitats is the construction of roads (Reed et al. 1996).

Habitat fragmentation has two components:

- reduction in total amount of available habitat; and
- reduction of remaining habitat into smaller, more isolated patches (Meffe and Carroll 1994).

In other words, fragmentation has the result of increasing the amount of edge in the habitat, decreasing the amounts of habitat interior and increasing the distance between habitat patches.

Forest edges differ from forest interiors in both microclimatic and biotic aspects. A cline, or transition, in microclimatic variables such as light intensity, temperature, wind and humidity occurs from an edge to a forest interior. Both vegetation and wildlife species respond to these microclimatic differences. The zone of influence of edges can be greater for wildlife species as they are mobile and can penetrate further into the forest. Some fragmentation changes can be positive for some wildlife species (such as habitat generalists that thrive on edge conditions), but they can be negative for species that require large extensive tracts of habitat (e.g., interior nesting birds and large carnivores, Weaver et al. 1996).

Another important issue regarding fragmentation effects on wildlife is the maintenance of movement and dispersal corridors, which are essential for mammals and birds with large ranges. This is discussed further in Section 11.6.3.

The effects of roads on wildlife are well-documented (e.g., Lynch 1973, McLellan and Shackleton 1988, 1989, Reed et al. 1996, Jalkotzy et al. 1997). Roads generally have several effects on ungulate populations. Permanent roads represent a permanent loss of habitat for all wildlife to the extent of the width of the road surface. In addition, the effectiveness of habitat adjacent to the roads may be reduced because of disturbance effects. Temporary roads represent a temporary loss of habitat, but a potentially different habitat may evolve over a long period, because of the loss of site productivity from road construction. Areas adjacent to roads typically possess a different vegetation community from the surrounding forest; the width of this edge effect can vary with the size and permanency of the road. The extent of the effect of loss and alteration of habitat from roads depends on road density and pattern.

For many species, human behavior and development of compensating management programs (mitigation) play a central role in managing the effects on wildlife of habitat loss, alteration and fragmentation (e.g., Powell 1993, Mech 1996).

Impacts of air emissions on vegetation communities were addressed in Section E9. It was concluded that air emissions from the Project will not impact the vegetation within the LSA. Therefore, impacts to wildlife habitat were also assumed to be negligible.

Habitat changes for three KIRs are highlighted in this document: moose, beaver and western tanager. Full analyses for all KIRs are found in Golder (1998b).

Moose

Moose habitat within the LSA, taking into account disturbance, is currently composed of 955 HUs (20%) of low quality habitat, 1,483 HUs (32%) of Moderate quality habitat and 2,240 HUs (48%) of High quality habitat (Figure E11-6). The overall suitability of the LSA (total number of HUs divided by total number of ha) for moose is 43%, or 4,679 HUs. Direct habitat loss is projected to impact moose habitat by removing some 22% of the HUs present (Figure E11-7; Table E11-7). 36% of low, 47% of Moderate and 60% of High quality habitat will be lost due to clearing.

Development of the Project is predicted to impact moose directly through loss of High-Moderate suitability aspen-dominated habitat, key areas of preferred browse availability and winter habitat use (Golder 1998b, see also review by AXYS 1996, Mytton and Keith 1981, Westworth et al. 1989, Renecker and Hudson 1992). Removal of Low suitability habitat through development of the proposed project in itself is not considered detrimental to moose because these areas do not substantially contribute to the long-term habitat carrying capacity of the area for this species.

The impact of High-Moderate habitat loss is not expected to result in direct mortality or to occur in direct proportion to the area of habitat removed. This is because moose have the ability to disperse ahead of construction activities. However, loss of winter range to moose can represent an important impact because moose tend to be highly traditional in their use of

Table E11-7 Habitat Losses Due to Clearing, Drawdown and Disturbances Associated With Muskeg River Mine Development and the Change due to Reclamation Post Mining

Species	Habitat Rating	Baseline Habitat Units	Clearing Loss or Gain (%)	Drawdown Loss or Gain (%)	Disturb-ance Loss or Gain (%)	Total Loss or Gain (%)	Total Change After Reclam-ation (%)
Moose	Low	955	-60.7	+6.2	+20.0	-34.6	-33.8
	Medium	1483	-26.8	+0.1	-29.7	-56.4	+12.6
	High	2240	-1.3	-17.6	-42.5	-61.4	+26.1
	Total	4679	-21.5	-7.1	-25.6	-54.3	+9.6
Beaver	Low	8	-37.5	+50.0	0.0	+12.5	-25.0
	Medium	121	-29.8	+52.9	0.0	+23.1	-19.8
	High	1295	-24.9	-10.9	0.0	-35.8	-4.6
	Total	1424	-25.3	-5.3	0.0	-30.5	-6.0
Western	Low	357	-34.2	-1.4	0.0	-35.6	-28.9
Tanager	Medium	417	-30.5	-5.5	0.0	-36.0	+73.6
	High	330	-26.4	-4.5	0.0	-30.9	+571.8
	Total	1105	-30.4	-3.9	0.0	-34.3	+189.2

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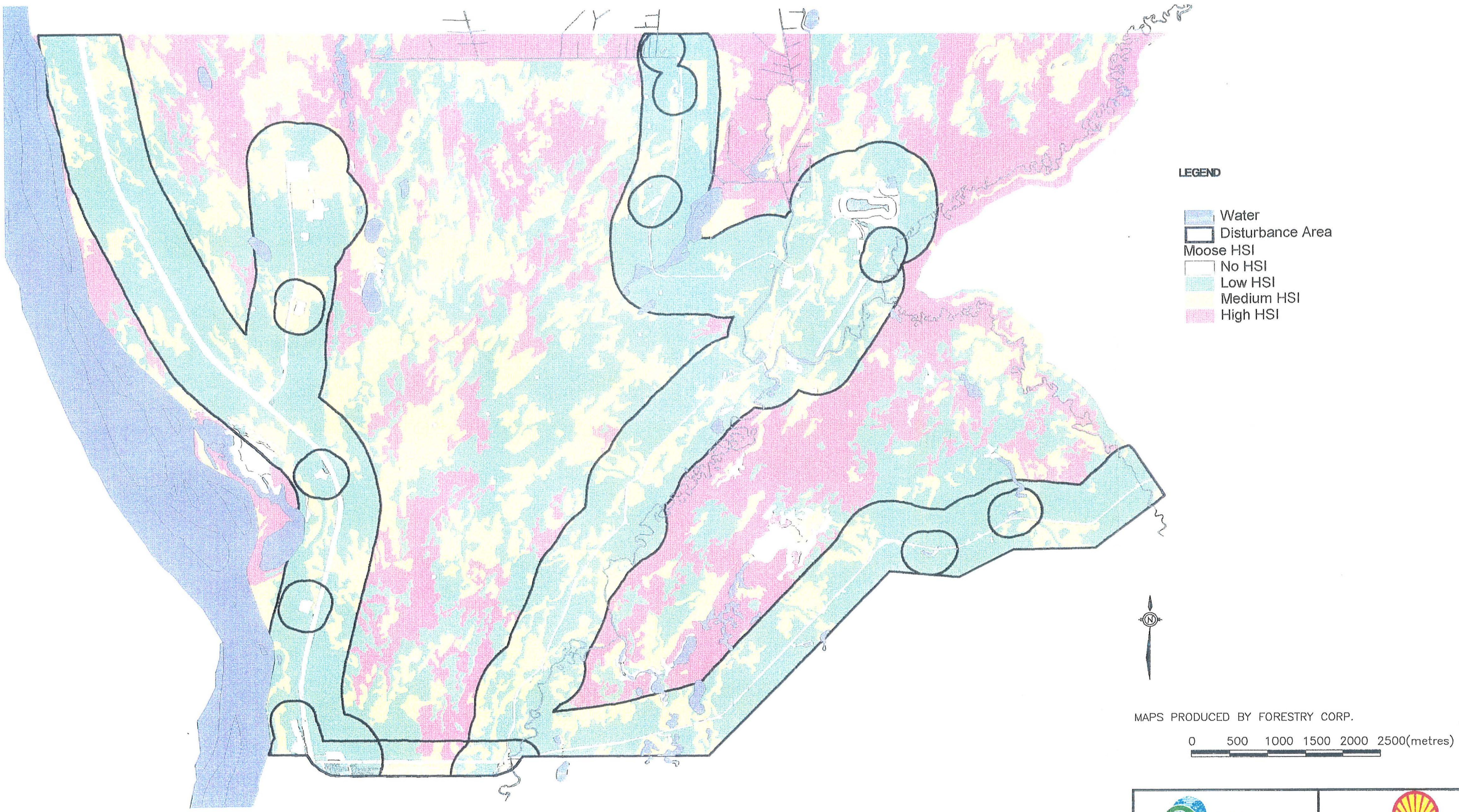

LOCAL STUDY AREA
BASELINE MOOSE HSI
DISTURBANCE INCLUDED

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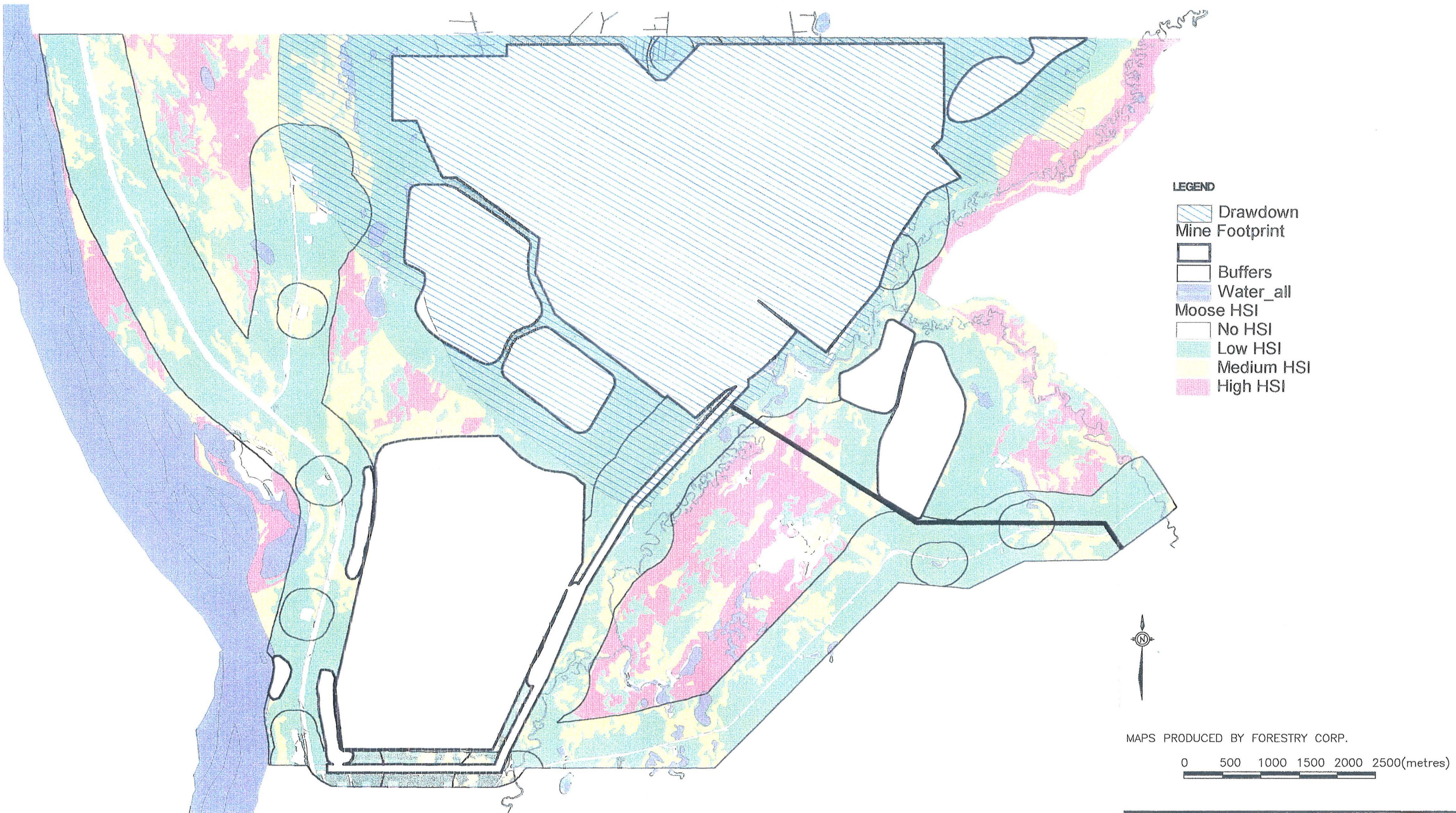

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LOCAL STUDY AREA
FULL IMPACT MOOSE HSI
DRAW DOWN INCLUDED DISTURBANCE INCLUDED

12 DEC 97	Figure E11 - 7	DRAWN BY: RFM/GIS

seasonal ranges, particularly moose in boreal habitats that move seasonally (Mytton and Keith 1981). Seasonal ranges of moose tend to be relatively small (LeResche 1975). Winter ranges in northeastern and north-central Alberta have been observed to vary from 2 to 54 km^2 and 3 to 111 km^2 (Mytton and Keith 1981, Hauge and Keith 1981). In west-central Alberta, female home ranges of non-migratory moose varied from 16 to 56 km^2 (Horejsi and Hornbeck 1987). Moose displaced to Low suitability habitat may experience suboptimal nutrition, which can have the effect of slowing growth rates in ungulates (Renecker and Hudson 1993). And moose displaced from optimal habitat to Low suitability habitat may experience reduced physical condition, which may in turn reduce calf production and survival (Thorne et al. 1976, Ballard et al. 1988).

Furthermore, the conversion of mature habitat to early successional habitat through disturbances such as clearing of vegetation can restrict ungulate movements during the critical winter period. This can occur in two important ways. First, the reduced canopy density of early successional forests intercepts less snowfall, resulting in increased snow depths which, at certain depths, restricts ungulate movement. Studies of cervid species such as mule deer, elk (Parker et al. 1984), white-tailed deer, caribou (Fancy and White 1985), mountain goats and bighorn sheep (Dailey and Hobbs 1989) have shown that increasing sinking depth relative to brisket height leads to an exponential increase in locomotion energy expenditures. Specifically for moose, snow increase in thicknesses of 70 cm or more (about 66% of chest height) restricts movement and influences habitat selection (Telfer 1970, Peek 1971). Snow depths exceeding 90 cm may contribute substantially to mortality (Coady 1975).

During winter, disturbed sites often experience greater crusting of snow, which can impair ungulate movement. The increased severity of ice crusts is due to the absence of an intact canopy. An intact canopy provides shade which minimises the development of a crust layer on the snow. The energy expenditure by a cervid moving through crusted snow is approximately twice that for locomotion through encrusted snow (Fancy and White 1985). Increased snow thickness and crusts due to the reduction of canopy cover also present ungulates with increased energy costs when catering for food (Thing 1977, Fancy and White 1985).

In addition, displacement of moose from High-Moderate suitability habitat could lead to concentrations of moose surrounding the development, depending on adjacent habitat conditions (Westworth et al. 1989). While the fate of displaced moose is highly speculative because to our knowledge this aspect has not been studied for moose, one possibility is that moose would be exposed to increased levels of local hunting pressure. This could be an important issue if hunting regulations were not modified to compensate for the increased vulnerability. In the case of the Project, public access to the LSA will not be permitted until following closure, therefore hunting pressure should be nil (Section 11.10.4). However, in general, survival rates of individuals displaced from optimal habitat is expected to be relatively low (Ballard et al. 1988).

In the long term, at the end of the Project, restoration and reclamation should produce favourable conditions for moose to repopulate the site (Fuller and Keith 1980). This is based on the fact that moose thrive in secondary forest succession (Peterson 1955), providing other habitat components are present. Patches of more mature habitat must be associated with good browsing habitat to provide cover and decrease predation risk. Simply generating habitat with abundant browse will not provide viable moose populations. Habitat suitability not only involves environmental conditions within and among vegetation communities, but also includes factors at the landscape level. The landscape can be viewed as a patchwork (matrix) of different vegetation communities that represent a gradient of habitat suitability to moose and deer (i.e., prime to marginal habitat). Some habitats are more suitable for cover, while other habitats provide more and better quality food. In areas where this habitat matrix is greatly disrupted by marginal or disturbed habitat, travel corridors can be important for successful movement of individuals among habitats. Effective movement corridors, such as riparian areas, can also facilitate recolonization of recently disturbed areas that contain suitable ungulate habitat (see Section E11.6.3).

Habitat loss, alteration and fragmentation through a variety of mechanisms are predicted to have an impact on moose. The difficulty with this prediction is that, while the local population change by displacement may be measurable, depending on the scale of habitat loss, changes over the longer term in the regional population may be subtle and immeasurable. Wildlife-habitat relationships are complex and the complexity should be evaluated on a site-specific basis.

Red-Backed Vole

Details on changes to habitat available for red-backed voles within the LSA are provided in Golder (1998b).

Red-backed voles are small mammals that are widespread throughout Alberta, except for the arid southeastern corner of the province (Smith 1993). Red-backed voles are habitat generalists, inhabiting mesic habitats within mature coniferous, deciduous and mixed forests that contain abundant downed woody debris and dense vegetation (Golder 1997b). These small mammals have high reproductive rates (three or four litters per year) and the life expectancy is usually about one year (Banfield 1974). Red-backed voles occupy overlapping home ranges that vary from 1.5 ha in summer to 0.24 ha in winter (Stevens and Lofts 1988).

Based on predictions for habitat loss due to clearing and alteration of forest habitats, the proposed development will have an impact on red-backed voles. The impact will be approximately in proportion to the spatial extent of habitat lost because these small mammals do not have the ability to disperse ahead of construction activities. In terms of habitat alterations, such as rights of way created along roads, red-backed voles will also be impacted because they tend not to be abundant in regeneration sites (Millar et al. 1985). Red-backed voles avoid fields, clearings and other nonforested habitat (AXYS 1996). As discussed for ungulates, to some extent habitat loss can be mitigated by ensuring that movement corridors are maintained to allow for gene flow across a wider landscape.

Snowshoe Hare

Details on changes to habitat available for snowshoe hares within the LSA are provided in Golder (1998b).

Snowshoe hares are relatively sedentary animals that live within a limited home range (typically <10 ha, Forsyth 1985). The average home range diameter of snowshoe hares in central Alberta is about 200 m (Keith et al. 1984). Studies suggest that habitat alteration such as forest cutting will eliminate hares (in the medium-term) if suitable habitat with forest cover is not provided within 200 m to 400 m (Conroy et al. 1979). Snowshoe hares avoid open habitats of all types (Pietz and Tester 1983). The avoidance of open habitat is a complex function of shelter from the physical environment (weather) and concealment from predators. Dispersal beyond established home ranges between habitat patches results in increased predation (Sievert and Keith 1985). In the medium and longer term, habitat alterations such as forest removal can rejuvenate understory vegetation with the potential of improving habitat for snowshoe hares (Litvaitis et al. 1985). As a generalized observation, reduced habitat quality and availability can reduce energy balance and affect reproductive success, which can also affect predation rates.

Habitat loss, alteration and fragmentation as a result of development of this project will have an impact on snowshoe hares. As discussed for red-backed voles, and for small mammals in general because of a limited ability to disperse ahead of construction activities, habitat loss can be expected to affect the abundance of this species in approximate proportion to the amount of habitat lost. However, to our knowledge, there has been no research on dispersal capability of snowshoe hares from habitat loss. Prospects for individuals that can disperse ahead of land clearing are speculative, based on the uncertainty of finding suitable habitat conditions for food, shelter and security from predators.

As discussed for ungulates, to some extent habitat loss and alteration can be mitigated by ensuring that movement corridors are maintained to allow for gene flow across a wider landscape. At the end of the Project, reclamation and restoration can potentially replace favourable habitat for this species.

Black Bear

Details on changes to habitat available for black bears within the LSA are provided in Golder (1998b).

The effects of habitat loss, alteration and fragmentation by allocating bear habitat to human uses can be expected to displace bears from otherwise suitable habitat. The displacement of black bears from preferred habitat may have negative consequences for their long-term survival. Several mechanisms may be involved, such as:

- lower survival of bears when displaced from familiar natal home ranges through increased hunting mortality as hunter access is improved (Manville 1983);
- lower survival of bears if displaced from preferred denning sites (Horejsi et al. 1984); and
- negative effects on reproduction (i.e., fewer cubs born) from nutritional stress if access to high quality food sources is restricted (Rogers 1976, Elwoe et al. 1989).

During the construction phase, ecological options for feeding and denning may be destroyed as indicated by habitat modelling (Golder 1998b). In northeastern Alberta, black bears enter dens from mid-September to late October, selecting mixed stands of mature aspen and spruce, or mature spruce stands (Fuller and Keith 1980, Tietje and Ruff 1980). The loss of abundant food supplies and home range territories for exclusive feeding areas will ultimately reduce individual bear's prospects for long-term survival and reproduction (Rogers 1976).

Beaver

Details on changes to habitat available for beavers within the LSA are provided in Golder (1998b).

Currently, there are 1,424 HUs of beaver habitat within the LSA (8 HUs of low, 121 HUs of Moderate and 1,295 HUs of High habitat suitability; Figure E11-8). Of these, some 25% of the total HUs will be lost due to clearing (38% of low, 30% of moderate and 25% of high quality habitat: Figure E11-9; Table E11-7).

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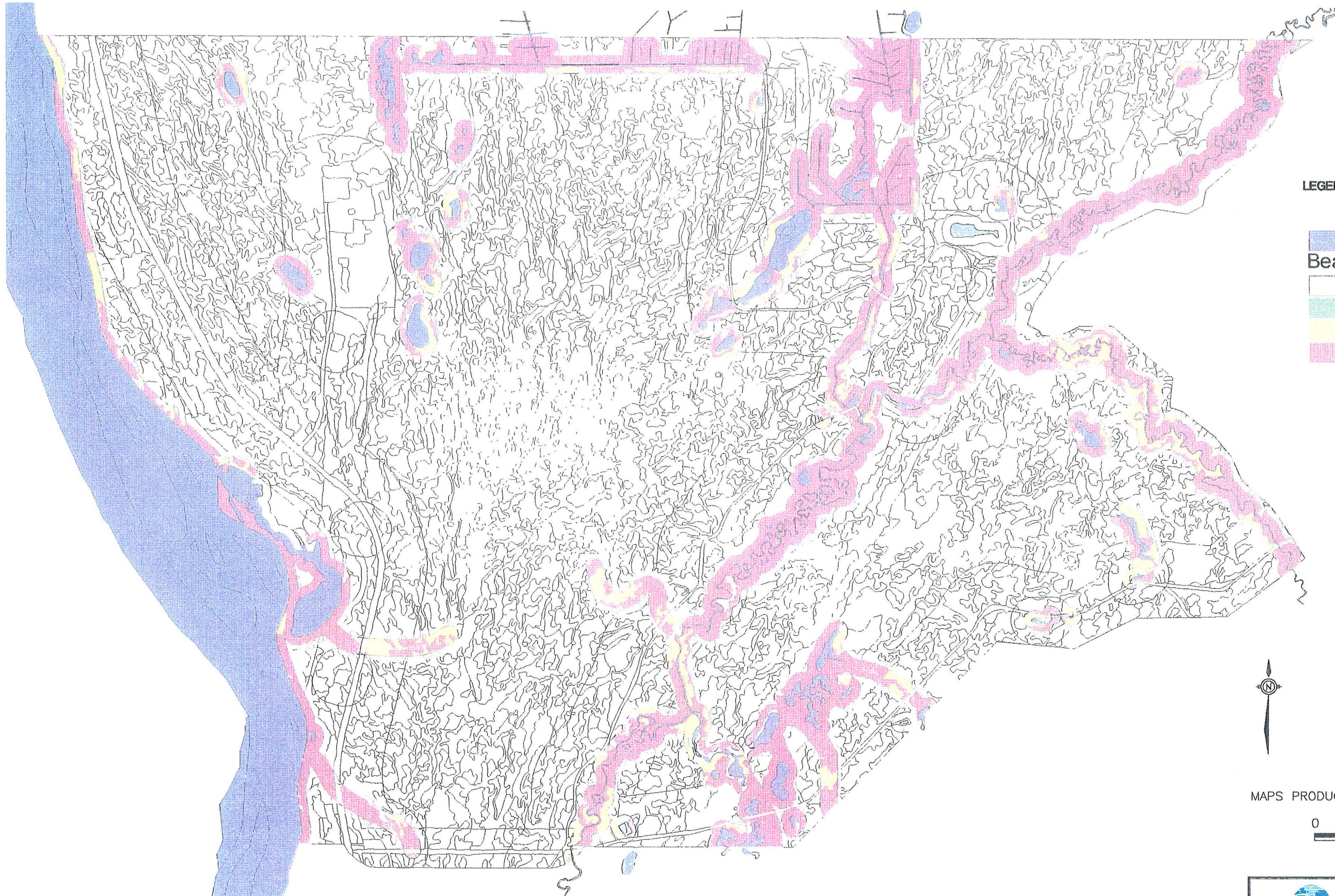

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LOCAL STUDY AREA
BASELINE BEAVER HSI

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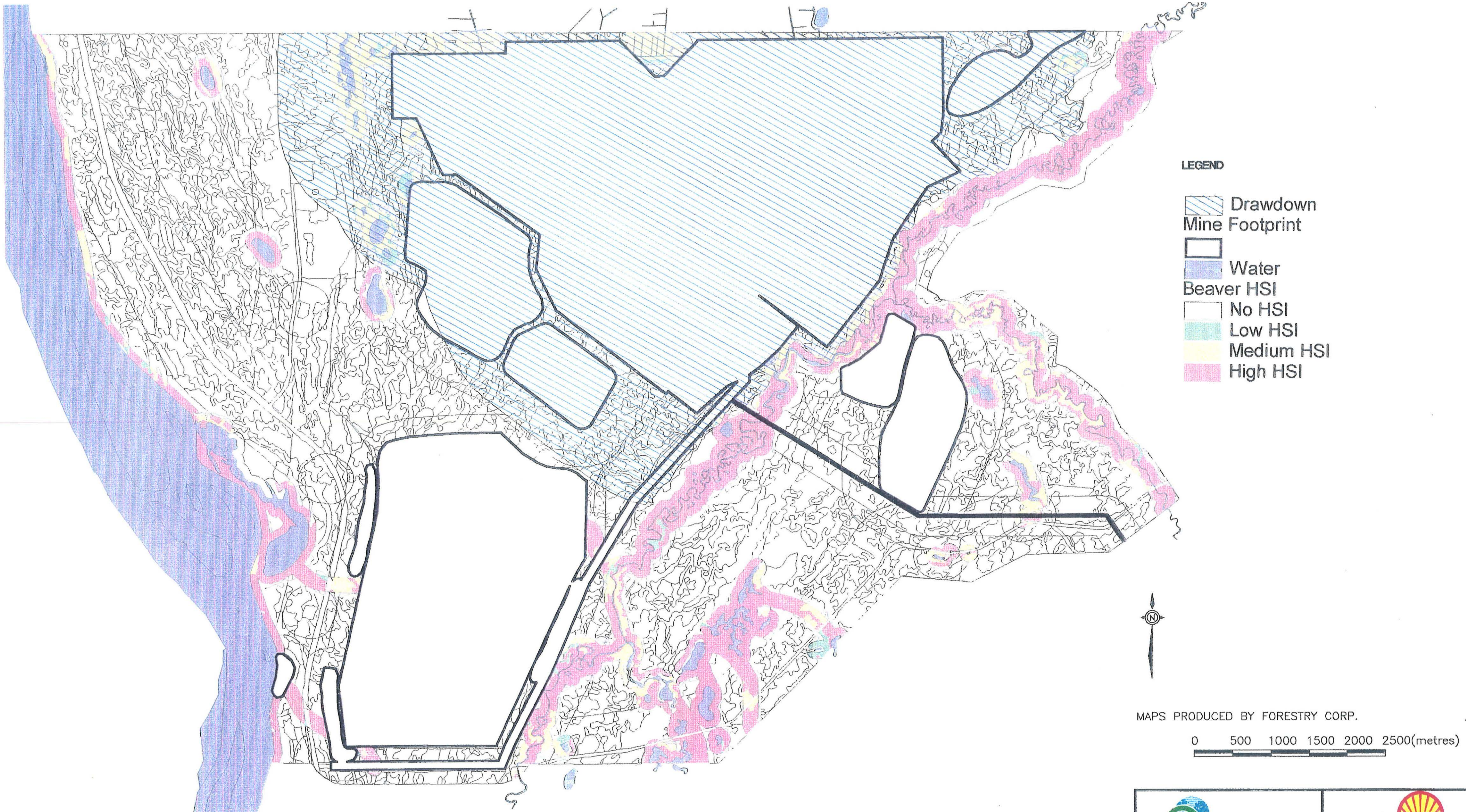

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LOCAL STUDY AREA
FULL IMPACT BEAVER HSI
DRAW DOWN INCLUDED

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Beavers, while resilient to human activities, are limited by the distribution of aspen and willow for food and suitable aquatic habitat for protection and critical parts of their life cycle (Nietfeld et al. 1984).

Habitat loss, alteration and fragmentation from site grading, site drainage and stream diversions (Section 11.6.2) can all be expected to have a negative impact on beaver populations in the LSA. Improved access, without compensating management programs, may also result in increased trapping pressure on adjacent populations (Section 11.10.4). For the Project, commercial trapping will only occur in the LSA following closure.

Fisher

Details on changes to habitat available for fisher within the LSA are provided in Golder (1998b).

Relative to many other mammals, reproductive rates and population density of fishers are low. Low-density populations can be expected to recover slowly, and populations isolated by fragmentation of habitat are susceptible to extirpation (Powell and Zielinski 1994).

Fishers are forest animals; a dominant characteristic of all habitat preferred by fisher is high canopy closure (80 to 100% closure) of late successional conifer-dominated forests (Powell 1993). Fishers use open areas selectively, and mostly in proximity to forest cover. Habitat selection appears to be based on habitat selection of preferred prey, snowshoe hares, carrion and a variety of small mammals (Powell 1993, Kuehn 1989, Arthur et al. 1989). Old snags and hollow trees are important habitat components for den sites. Fishers are also easily trapped and combined with habitat loss, fisher populations in many areas have been reduced to near extinction (Powell 1979). Winter track counts indicated that fishers are relatively abundant in the LSA (Golder 1997f).

For these reasons, fishers are sensitive to habitat loss, alteration and fragmentation and the Project can therefore be expected to have an initial negative impact on fisher populations in the LSA. A long-term forest management strategy is needed to maintain viable populations of fishers (Banci 1989).

Dabbling Ducks

High quality dabbling duck habitat is relatively limited within the LSA compared to areas such as Kearl Lake to the east. Isadore's Lake, the water body of greatest value to waterfowl within the LSA, will not be impacted by site clearing. Details on changes to habitat available for dabbling ducks within the LSA are provided in Golder (1998b).

Alberta's resident dabbling ducks include the mallard, pintail, northern shoveler, blue-winged teal, green-winged teal, gadwall and American widgeon (Nietfeld et al. 1984). The most current status of North American duck populations (excluding scoters, eiders, oldsquaws, mergansers and wood ducks) indicates that 1996 populations were 16% higher than the long-term average of 1955-1995 (Caithamer and Dubovsky 1996). Improved population levels are consistent with favourable habitat conditions during recent years.

Optimal habitat for dabbling ducks is represented by high interspersion with land of aquatic habitats such as shallow marshes, open-water marshes and potholes. Limiting factors include lack of permanent and semi-permanent water, extensive water fluctuations and lack of nesting cover, usually near water but also in adjacent upland habitats including agricultural lands.

Dabbling ducks are limited by suitable aquatic habitats and habitat loss, alteration and fragmentation from site grading, site drainage and stream diversions, have visible and obvious effects by reducing the amount of aquatic habitat. Therefore, these impacts can all be expected to have a negative effect on dabbling duck populations in the project area by reducing overall carrying capacity.

Ruffed Grouse

Details on changes to habitat available for ruffed grouse within the LSA are provided in Golder (1998b).

Ruffed grouse are non-migratory, ground-nesting birds that occupy aspen-dominated and mixedwood habitats with substantial shrub understories (Francis and Lumbis 1979). Ruffed grouse reach their highest densities in central Alberta, in aspen forests (Semenchuk 1992). Spatial requirements of ruffed grouse are relatively small with mean daily movements during winter of <400 m (Thompson and Fritzell 1989).

Response of ruffed grouse to habitat loss, alteration and fragmentation is difficult to predict; however, some displacement to adjacent, suitable habitat is likely to occur (Francis and Lumbis 1979). To our knowledge there are no studies documenting the survival and reproductive performance of ruffed grouse that have been displaced from preferred habitat by human developments. Food limitation and increased susceptibility to predation may be two mechanisms that reduce overall reproduction and survival of ruffed grouse displaced from familiar home ranges or displaced to suboptimal habitats. Snow roosting conditions are also believed to improve overwinter survival, and such conditions may be habitat-specific (Gullion 1970).

Loss of High-Moderate habitat suitability from the LSA, and associated alteration and fragmentation accompanying the proposed development, can be expected to have a negative impact on the ruffed grouse population by reducing the overall carrying capacity of the LSA. However, impacts would be minimized if clearing and construction activities avoided the breeding season, approximately late March to late July.

Cape May Warbler

Details on changes to habitat available for Cape May warbler within the LSA are provided in Golder (1998b).

The Cape May warbler is a neotropical migratory songbird of the woodland habitat guild and is known as a tree-nesting wood warbler. General declines observed in neotropical songbirds have two possible explanations: 1) tropical deforestation of winter range; and/or 2) habitat loss and fragmentation of temperate forests on breeding range. Generally, there is evidence that both are occurring and for this species specifically, loss of neotropical wintering habitat has been noted (AEP 1996). The long-term range-wide trend from 1966-1988 for this species has been negative (Sauer and Droege 1992). As a general observation pertinent to breeding birds within the forest guild, isolated forest habitat of <20 ha can be expected to have few neotropical migrant species.

During the breeding season in northeastern Alberta, Cape May warblers prefer mature mixedwood forests dominated by tall white spruce (Francis and Lumbis 1979). Their breeding habitat has been defined as dense mature white spruce stands in coniferous and mixedwood forests (Semenchuk 1992), "especially more open types and edges" (Godfrey 1979). Nests are usually built in the crowns of tall conifers, within 2 m of the top (Semenchuk 1992).

To our knowledge, species-specific research has not been done on the Cape May warbler; however, habitat loss and fragmentation effects on songbirds is an active area of research (Kuhnke 1993). In general, habitat loss and fragmentation expose migratory birds to a number of impacts, including predators, cowbird parasitism, avian competitors and human disturbances (Finch 1993).

Based on habitat modelling that indicates the project area supports a high percentage of High-Moderate habitat suitability for this species habitat loss and alterations from removal of mature coniferous forest overstory accompanying the proposed development can be expected to have a negative impact on Cape May warbler populations in the LSA. The impact will be related to the size and permanence of habitat loss. However, impacts would be minimized if clearing and construction activities avoided the breeding season, approximately 1 May to 30 July.

Western Tanager

Details on changes to habitat available for western tanager within the LSA are provided in Golder (1998b).

There are currently some 1,105 HUs of western tanager habitat in the LSA (357 HUs of low, 417 HUs of moderate and 330 HUs of high quality habitat; Figure E11-10). Of these, some 30% of the total HUs will be impacted (34% of low, 30% of moderate and 26% of high quality habitat; Figure E11-11; Table E11-7).

The western tanager is a neotropical migratory songbird of the woodland habitat guild. General declines observed in neotropical songbirds have two possible explanations: 1) tropical deforestation of winter range; and/or 2) habitat loss and fragmentation of temperate forests on breeding range. Generally, there is evidence that both are occurring (Hagan and Johnston 1989).

During the breeding season, western tanagers prefer mature mixedwood forests in northeastern Alberta (Francis and Lumbis 1979). They nest usually in coniferous trees, on branches at various heights (Godfrey 1979). However, during the winter season, they migrate to Guatemala, Mexico and Belize (Terborgh 1989). Declines during the breeding season were reported to have occurred before 1973, but since then and until 1979 their populations in major states and provinces have been stable (Robbins et al. 1986). The long-term trend from 1966-1987 for this species has been -0.8% change per year (Droege and Sauer 1989). An observation pertinent to the western tanagers in east-central Alberta is that the species was only found in aspen forest fragments of 40 ha or more (Hannon 1993).

To our knowledge, species-specific research has not been done on the western tanager; however, as discussed for the Cape May warbler, habitat loss and fragmentation effects on songbirds is an active area of research. In general, habitat loss and fragmentation expose migratory birds to a number of impacts, including predators, cowbird parasitism, avian competitors and human disturbances (Finch 1993).

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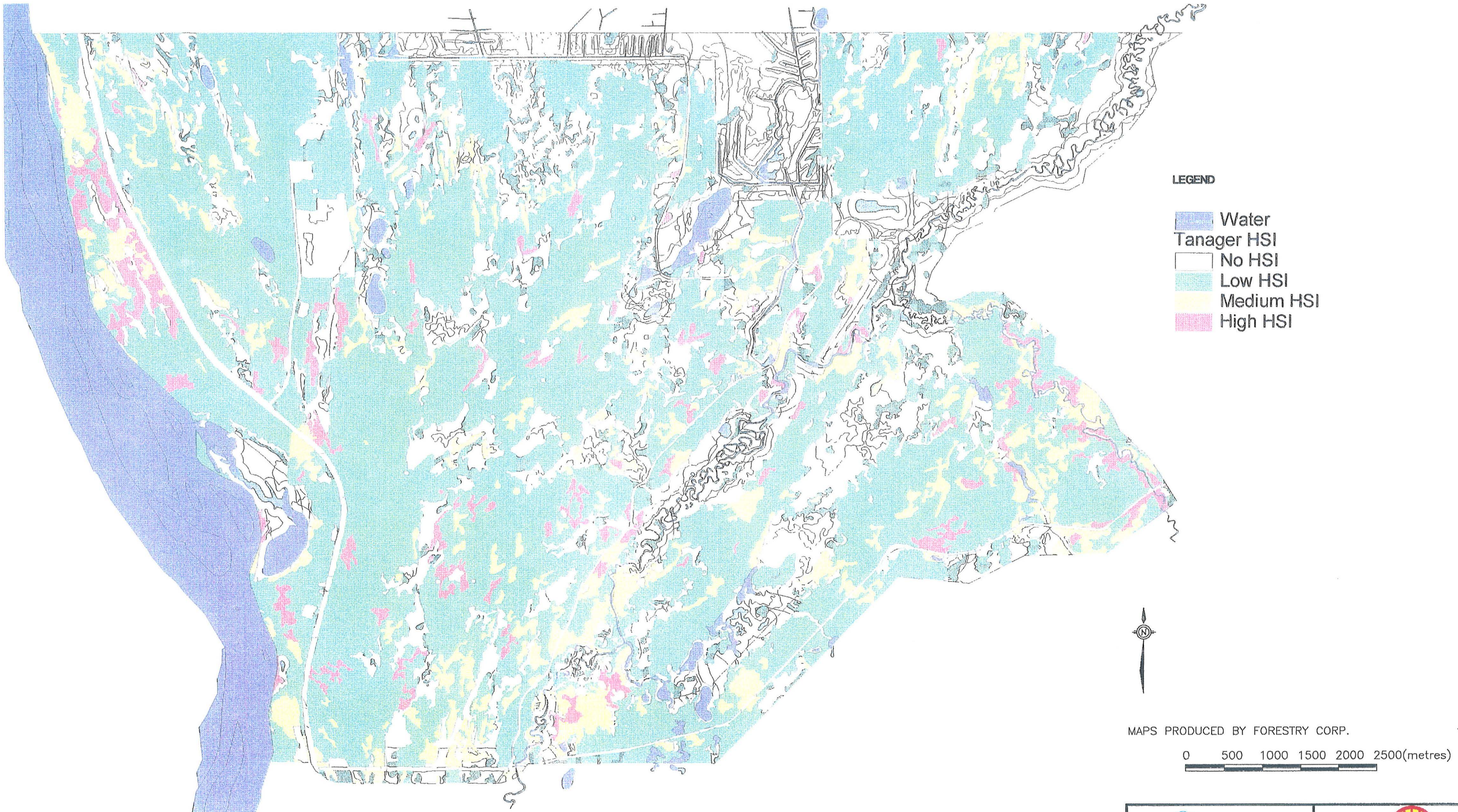

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LOCAL STUDY AREA
BASELINE TANAGER HSI

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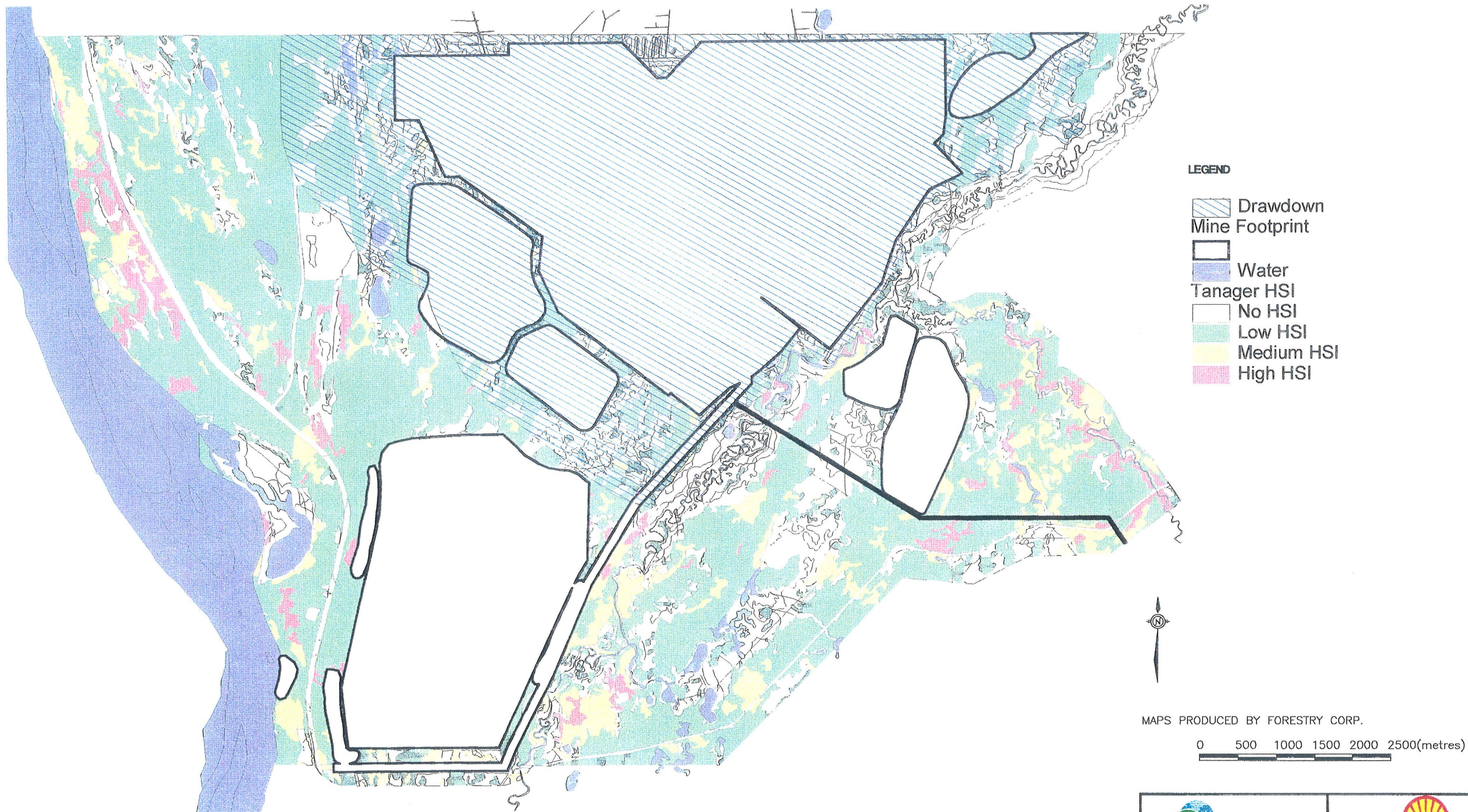

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LOCAL STUDY AREA
FULL IMPACT TANAGER HSI
DRAW DOWN INCLUDED

12 DEC 97	Figure E11 - 11	DRAWN BY: RFM/GIS

Based on habitat modelling that indicates the project area supports a high percentage of High-Moderate habitat suitability for this species. Habitat loss and alteration from removal of mature coniferous forest overstory accompanying the proposed development can be expected to have a negative impact on western tanager populations in the project area. The impact will be related to the size and permanence of habitat loss. However, impacts would be minimized if clearing and construction activities avoided the breeding season, approximately 1 May to 30 July.

Pileated Woodpecker

Details on changes to habitat available for pileated woodpecker within the LSA are provided in Golder (1998b).

Pileated woodpeckers excavate nests in large dead trees, and feed on insects in large-diameter live, standing-dead or downed trees. The best habitat is mature forest of mixed conifer with >2 canopy layers, large live trees and dead and downed woody debris (Ball 1987). Recently developed forest management plans call for managing 243 ha areas, designed to provide nesting and foraging habitat (Ball et al. 1992).

If the proposed development involves removal of large blocks of habitat including large-diameter nest and roost trees, a negative impact on pileated woodpecker populations in the LSA is expected. Impacts would be minimized if clearing and construction activities avoided the breeding season, approximately 1 May to 30 July.

Great Gray Owl

Details on changes to habitat available for great gray owl within the LSA are provided in Golder (1998b).

Forest cover is a prerequisite for the viability of great gray owls. This habitat type is used primarily for nesting (AXYS 1996). Nesting occurs in mature stands of balsam or aspen poplar, mixed with spruce or jack pine and including tamarack and black spruce. In general, adults are sedentary with relatively small home ranges (1.3 to 6.5 km^2), but they display complex patterns of seasonal and annual movements influenced by prey availability (Duncan 1994). The common description of great gray owl habitat is mature forests near openings (Habeck 1994). Human activities that reduce the abundance of nest trees will negatively affect this species.

For these reasons, great gray owls are sensitive to habitat loss, alteration and fragmentation. The Project can therefore be expected to have an initially negative impact on populations of this owl in the LSA. Impacts would be minimized if clearing and construction activities avoided the breeding season, approximately late March to mid-May in Alberta (Johnsgard 1988).

Validity of Linkage

Removal or alteration of vegetation communities will occur as part of project development. Existing disturbance within the LSA amounts to 470 ha (4.3%). The maximum area to be disturbed through clearing for the Project is 4,313 ha, or 39% of the LSA (Section E9). Moose habitat will be impacted by 21%, beaver habitat by 25% and western tanager habitat by 30% (Table E11-7).

While these totals are not expected to ever exist simultaneously on the LSA due to the phased approach of development, the figures represent the total amount of land that will be disturbed over time. A conservative assessment considers impacts as if all the land was impacted at the same time. Change in habitat due to removal or alteration of vegetation communities is therefore a valid linkage for all KIRs.

Mitigation

Mitigation measures to minimize habitat loss included:

- locating the development away from important wildlife habitat (e.g., 100 m to Muskeg River, 300 m to Athabasca River escarpment, 800 m to Isadore's Lake);
- minimizing the footprint of the development (e.g., restricting dump size, use of common access and utility corridors); and
- pursuing progressive reclamation of the development area.

Shell will reclaim disturbed areas to equivalent pre-development habitat capability. The positive impacts of reclamation are discussed in Section E16.

Site clearing will be timed to avoid most wildlife breeding or nesting periods; most clearing will occur during winter. Most KIRs give birth, or nest and raise their young from May to July, while the ruffed grouse and the great gray owl initiate breeding in mid-March. Female black bears give birth in their dens in mid-winter. Moose calve from mid-May to early June. The use of no-disturbance buffer zones around known raptor nest sites can also minimize impacts of site clearing (Section E.11.6.4).

Linkage Between Change in Surface Water Hydrology and Removal or Alteration of Vegetation Communities

Background

Hydrological changes caused by project development can impact habitat quality and/or quantity. Mine development will include diversion of drainages around the Project perimeter and pumping out of runoff from the mine pits. Impacts will include drawdown of the local groundwater table in the Project vicinity (Section E3).

Changes to wetlands as a result of changes to surficial aquifers from dewatering of the mine pits are discussed in detail in Section E10. A 1.5 km zone of influence around the mine pits was assumed for indirect impacts to wetlands. Within this zone, changes to wetlands communities are likely to occur during the operation phase of the mine. It was conjectured that swamps may succeed to upland conditions, marshes and shallow open water wetlands may change to dry grassland or shrub communities, and fens may change to bogs.

Impacts of groundwater drawdown on vegetation communities adjacent to the Project are poorly understood. While some studies have shown that drainage or partial drainage of wetlands can enhance tree growth, the impacts of such actions on the KIRs for this project are speculative at best. For the purposes of this EIA, a conservative assumption was made that habitat quality for all KIRs was reduced by 50% within the 1500 m zone of groundwater table drawdown influence.

Validity of Linkage

The linkage between hydrological changes and changes to vegetation communities was considered to be valid for all KIRs due to the presumed negative effect of a drying out of the local vegetation. A summary of the reduction in the number of HUs affected by changes in groundwater table levels for each KIR is provided in Golder (1998b). Moose habitat will be reduced by 73% (over and above impacts from clearing), beaver habitat by 5% and western tanager habitat by 4% due to groundwater drawdown (Table E11-7).

Mitigation

Mitigation for this impact will primarily be through reclamation. An end pit lake and numerous small wetlands are proposed for closure. This will have a net positive effect on wildlife. Cessation of mine dewatering at closure will also permit the groundwater table to return to its pre-development level.

Linkage Between Site Clearing and Barriers to Movement

Background

Blockage of wildlife movement and dispersal corridors is an increasing concern among conservation biologists and the public. Soule (1991) defined a conservation (wildlife) corridor as a "linear landscape feature that facilitates the biologically effective transport of animals between "larger patches of habitat." With increasing development pressure and fragmentation of wildlife habitat, species are often confined to such patches of habitat or "habitat islands". It is therefore critical to maintain connectivity among habitat patches at the landscape level. If isolated populations are not able to interact, a decrease in genetic diversity could result, reducing variability among individuals, leading to an overall decrease in the adaptability of the regional population. Provision of corridors when allocating land to other uses facilitates dispersal of individuals between local populations and is important for ensuring genetic diversity at the landscape level.

Wildlife movements can be affected not just by the large disturbances such as the Project pits and infrastructure, but linear corridors can also impact movements. Generally, disturbance corridors (linear transport systems otherwise referred to as cleared rights of way such as roads, seismic lines, pipelines and electrical transmission lines) have the potential to impose barriers or act as filters to wildlife movements. The topic has been discussed widely in a generic sense (e.g., Bromley 1985, Berger 1995, Jalkotzy et al. 1997), and for a few individual species literature reviews have been done (e.g., barren ground and woodland caribou, Horejsi 1981; Shideler et al. 1986 Eccles et al. 1991, Jalkotzy et al. 1997). Scale (structure and dimensions of corridor relative to the wildlife species in question), particular biophysical environment and intensity of corridor use are important factors that influence corridor effects on wildlife. Some barrier effects on wildlife are relatively short term and limited to the construction period, while other effects can be long term depending on the permanence of the facility.

Recent and ongoing studies have confirmed the importance of maintaining effective corridors. The Eastern Slopes Grizzly Bear Project has shown that the Trans-Canada Highway is an effective barrier to the movement of adult female grizzly bears (Gibeau and Heuer 1996). Genetic analyses suggest the highway has already restricted gene flow in grizzly bears (Gibeau 1995). Paquet and Callaghan (1996) also demonstrated that the Trans-Canada Highway acts as a barrier to wolves in the Bow Valley, and that highway deaths were one of the most important causes of wolf mortality in the Bow Valley (Paquet 1993).

The objective in planning for conservation corridors is to allow for sufficient movement between habitat islands such that a species can persist in the region. Corridors can be used by wildlife for daily, seasonal, annual and/or dispersal movements. In the context of the Project, corridors can also expedite the recolonization of reclaimed habitats following mine closure.

Very few data exist on how best to design corridors for different species. However, Beier and Loe (1992) state that corridors that act as dispersal routes for species must be able to fulfill five functions:

- permit wide-ranging animals to travel, migrate and meet mates;
- allow plants to propagate;
- allow for genetic interchange to occur;
- allow populations to move in response to natural disasters; and
- allow individuals to recolonize habitats from which populations have been locally extirpated.

If the Project does create barriers to movements, it could result in: 1) decreased gene flow between segments of a population, 2) preclusion of movement to critical habitat such as summer range, winter range, denning areas, etc. or 3) localized loss of populations due to restricted movement. Any of these conditions could impact the KIRs within the LSA. Cumulative effects of multiple oil sands developments on wildlife movements within the RSA are of particular concern and are addressed in Section F11.

The literature on effects of barriers to movement on wildlife is disproportionate for large mammals and species otherwise managed for harvest. For many species that comprise the biodiversity of the project area, considerably fewer data are available.

Moose

Evidence collected in the oil sands region indicates that moose may not use well-defined corridors such as may be found in mountainous habitats where animal movements are often channeled by topography. However, moose within the region do make seasonal movements. Westworth (1980, 1996) showed that moose often use riparian habitats for foraging and travel routes during seasonal shifts in habitat use. Hauge and Keith (1981), using radio-telemetry, found that many moose (62%) made seasonal, short-range movements in response to changing snow conditions. These moose moved an average of 6 km to winter range when snow conditions became thick and soft in December-January. Thirty-eight percent of radio-collared moose made greater movements (i.e., more than 20 km) between summer ranges in the Birch Mountains and/or the Muskeg Mountain area and winter ranges near the Fort Hills and the Athabasca River. Movements along or parallel to the Athabasca River valley were not evident. The annual home range of non-migratory moose was 97 km^2 (range 60 to 183 km^2). While this study was done before oil sands development (only seismic lines were noted in the study area), seasonal movement patterns of moose revealed the spatial habitat requirements for the species in this area of the province. The proposed development presents a number of potential disturbances to moose.

While detailed studies of moose movements within the LSA have not been done, it is apparent that the Project could act as a blockage to moose movements. If key riparian and upland habitats that connect habitat patches are left undeveloped, such areas would serve to channel moose movements the way topography does in mountainous areas.

Other KIRs

Little information is available regarding movement of the KIRs within the LSA. It has been conjectured that wolves and black bears use the Muskeg and Athabasca River valleys as travel routes (BOVAR 1996a), but no empirical data exist. During baseline field studies, however, many KIRs were found to use riparian areas more often than expected by chance alone (Golder 1997f, g).

Construction of roads can act as a barrier to dispersal for certain small mammal species, possibly due to an anti-predator response in open spaces (Burnett 1992). Douglas (1977) found that northern red-backed vole activity decreased on winter roads. Similarly, Adams and Geis (1983) found that forest species such as the red-backed vole tended to avoid roadside areas. Conversely, deer mice and meadow voles, animals that prefer dry grassland habitat, showed elevated levels in the clearings provided by road construction (Douglas 1977, Adams and Geis 1983).

Birds often use riparian areas as travel corridors for dispersal and migration. Juvenile birds can be reluctant to cross open areas such as recently disturbed areas (Lens and Dhondt 1994). The combination of minimal cover and unfamiliar habitat in recently disturbed habitats increases exposure to predators and makes traversing such habitat risky.

Validity of Linkage

While specific data on wildlife movement corridors within the LSA is lacking, the development footprint will preclude most animals from using the development area for travel until closure. Animals that are far-ranging, such as ungulates, large carnivores and small carnivores, will be most affected. Small mammals will be less affected; but any mitigation for larger mammals should include small mammals. The opportunity for beavers to disperse will also be affected.

Migratory bird species such as dabbling ducks are not likely to be affected since few waterbodies are proposed to be impacted. However, the migration of migratory breeding birds such as the Cape May warbler and the western tanager could be impacted to some extent as such species are less likely to fly over large disturbed areas. However, due to the phased nature of the development, migration around the active mining areas will likely occur.

Mitigation

Linear strips of relatively undisturbed vegetation should be left intact to allow passage of ungulates and carnivores around the development area. Design criteria for corridors is provided in Appendix VIII.

Beier and Loe (1992) developed a checklist for planning wildlife corridors, as follows:

- identify the habitat areas the corridor is designed to connect;
- select several species of interest for which to design the corridor;
- evaluate the relevant needs of each selected species;
- evaluate how the corridor will accommodate movement of each selected species;
- draw the corridor on a map to fully describe it; and
- design a monitoring program to determine the use of the corridor over time.

Each of these items are discussed below.

In the case of the Muskeg River Mine Project, key habitat areas that should be left connected are the Athabasca River valley and the mouth of the Muskeg River (ALI 1973), and upland and lowland habitats east of the development site. East-west movements will be particularly important to maintain given that the Aurora North development will be juxtaposed to the northern edge of the Muskeg River Mine Project. Thus, east-west movements will be restricted over two development footprints.

The species of interest for the proposed corridors are, as previously stated, moose, black bears and fishers.

Since moose are considered to be affected by developments at distances of up to 500 m (AXYS 1996), a 1 km average corridor width is recommended for moose to ensure that habitat in the centre of the corridor is relatively disturbance free. While this is the optimal minimum width, it is recognized that corridors can be narrower in places and still be effective. Thus, it is suggested that the corridors can be restricted to as narrow as 350 m in places as long as these narrow sections are less than 500 m long.

The proposed corridor design for the LSA and adjacent lands is shown in Figure E11-12. The Athabasca and Muskeg River corridors will function as north-south conduits (as well as representing important habitat patches in their own right), while the corridor formed by Jackpine Creek and lands between the tailings location and the west dump will serve as an east-west corridor. The focus on the use of riparian areas is due to the fact that they have been found to serve as travel corridors for ungulates (Brewster 1988).

Moose, for example, were found to use riparian areas more often than expected during 1997 studies (Golder 1997f, g).

In addition, it is recommended that an additional east-west corridor to the south of the tailings facility be planned. This corridor would extend south off of Lease 13. This will be important if oil sands development occurs south of Lease 13, before closure of the Muskeg River Mine Project.

Access and utility corridors can cross wildlife corridors without jeopardizing their integrity. The following mitigation strategies are proposed to reduce the impacts of these features on wildlife corridors:

- common access and utility corridors should be planned to minimize the number of crossings; and
- crossings should be at right angles to the wildlife corridors wherever possible.

A monitoring program should also be initiated to determine wildlife use of the corridors and to assess the impacts of variable corridor widths on wildlife (Section E11.6.7).

It is prudent to plan for multiple wildlife corridors as natural and man-made disturbances are often unpredictable. Soule (1991) also notes that maintaining existing corridors is much less expensive than restoring ones that have been destroyed or blocked. Corridor redundancy has been provided for in the proposed corridor plan, with two north-south and two east-west conduits. It should also be recognized that the corridors as depicted in Figure E11-9 represent a minimum network of wildlife movement areas. The actual network will be larger at any given point in time, due to the progressive nature of both mining and subsequent reclamation.

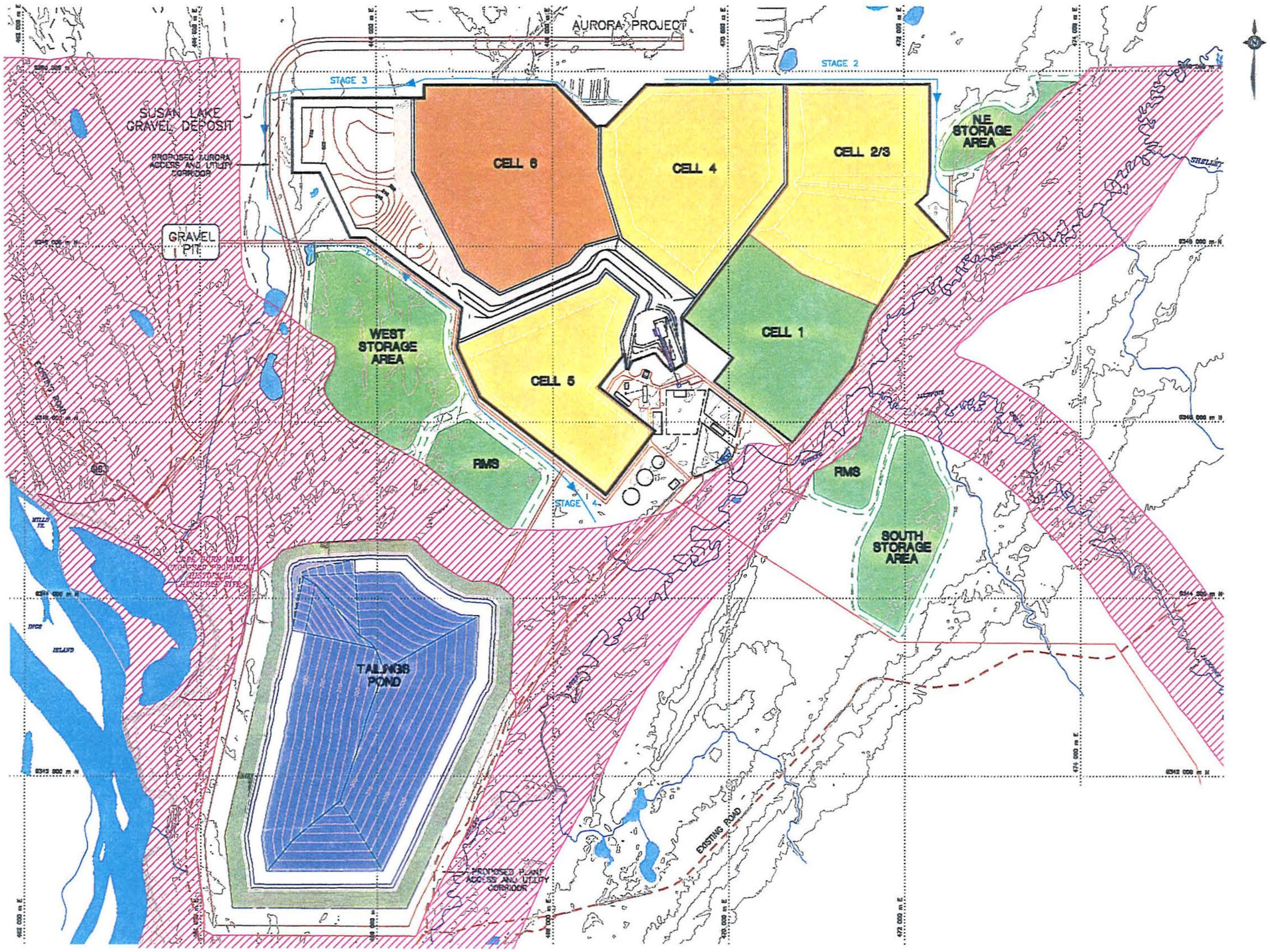
Linkage Between Site Clearing and Change in Access and Sensory Disturbance

Background

Sensory disturbance is a potential project-related impact to wildlife. Project-related activities that will result in sensory disturbances include:

- clearing vegetation and surface grading for mined areas;
- truck and shovel operations during mining activities; and
- construction of infrastructure for utilities, water supply and access requirements.

J:\1997\2237\7750\corridor.dwg



LEGEND

PROPOSED WILDLIFE MOVEMENT CORRIDOR

REFERENCE

DRAWING FROM NORWEST, TITLED "MINE AND TAILINGS PLAN STATUS AT YEAR 2022", DATED 22-10-97, ORIGINAL SCALE 1:20000

0 500 1000 1500 2000

SCALE IN METERS

NOTE: RMS – RECLAMATION MATERIAL STOCKPILE
COORDINATE SYSTEM: NAD27

Golder Associates

SHELL CANADA LIMITED

PROPOSED WILDLIFE MOVEMENT CORRIDORS ON ADJACENT TO THE LOCAL STUDY AREA

14 DEC 97	Figure E11–12	DRAWN BY: TM

Sensory disturbance results from human and mechanical activities during mining that elicit behavioural responses from wildlife. If human actions cause wildlife to change their behaviour in a way that may affect survival, disturbance has occurred (Shank 1979). While short-term evidence of disturbance is often apparent, long-term effects, while appearing to be self-evident, are difficult to observe. Several reviews of the topic in different environments and with select species have been done (Shank 1979, Prism 1982, Bromley 1985, Brusnyk and Westworth 1988, KOMEX 1995).

Two types of sensory disturbance will be considered in this EIA: 1) reduced habitat effectiveness due to alienation of habitat; and 2) increased mortality due to changes in the energy balance of individuals (Section E11.10.2). Habitat effectiveness due to sensory disturbance is discussed below, and in Appendix IX.

Moose

There have been few empirical studies of the effects of disturbance on moose. The literature contains more references to the effects of disturbance on caribou, deer and elk, and the effects are numerous and varied. A study on cervid distribution in Alberta indicated that while deer and elk habitat use was influenced by human disturbances, moose were more strongly influenced by browse yield (Telfer 1978). While this was not a study of disturbance effects, reference was made to the importance of disturbance as a factor in habitat use and the use of topographic barriers in reducing disturbance. Rolley and Keith (1980) observed that moose in central Alberta avoided agricultural clearings, roads and residences. Ferguson and Keith (1982) studied the effects of nordic skiing on the distribution of elk and moose in Elk Island National Park, Alberta. Movements and changes in distribution of moose away from areas of human activity were observed.

Ballard et al. (1988) expected that, apart from habitat loss, hydroelectric developments would cause behavioural displacement of moose from calving and winter habitat with resulting negative impacts. A study at an open-pit copper mine in north-central British Columbia has demonstrated that moose are attracted to areas of browse abundance in proximity to mining activities (Westworth et al. 1989). Moose in that study area apparently habituated to the human activities at the mine while using adjacent clearcuts that were 2 to 10 years old. The highest pellet group densities were recorded within 100 m of the open pit. Westworth et al. (1989) speculated that hunting restrictions in the vicinity of the mine and perhaps the aversion of predators such as wolves to areas of human activity may have provided a degree of security for moose, allowing habituation to occur.

Sensory disturbances and the mechanism of habitat avoidance are therefore predicted to have an impact on moose. The difficulty with this prediction is that, while the local population change by displacement may be measurable, changes over the longer term in the regional population may be precipitated by other factors. Wildlife-habitat relationships are complex and the complexity should be evaluated on a site-specific basis.

Red-Backed Vole

To our knowledge, there has been no research that would suggest a sensory avoidance response by red-backed voles. The distribution of red-backed voles and many other small mammals in relation to human activities (e.g., cities, airports) suggests these wildlife are not particularly sensitive to noise and activities. This is probably because they do not have the hearing physiology, ability to learn and mobility to respond.

In areas not affected by habitat loss, red-backed voles are not expected to demonstrate an avoidance response to sensory disturbances. Therefore, this link is considered invalid for red-backed voles.

Snowshoe Hare

Based on the limited literature, snowshoe hares can be expected to avoid habitat within 100 to 200 m of snowmobile trails and roads (BOVAR 1996a). Lack of site-specific study means that potential effects of displacement from preferred habitat are speculative. The general expectation is that wildlife that are displaced experience higher mortality rates.

A limited amount of evidence suggests this link is valid for snowshoe hares.

Black Bear

Black bears are highly mobile, wide-ranging animals, and they are also tolerant of human activities if they are not hunted, as evidenced by their propensity to feed on human sources of garbage. Overall, black bears are tolerant of people which allows them to co-exist with people (Herrero 1983, Manville 1983, Lynch 1993). Rights of way along roads are often cited as positive impacts of human activities on black bears because of the early successional vegetation that black bears take advantage of (Manville 1983). However, there are consequences for black bears' tolerance of humans. Black bears readily habituate to humans and then are often subject to management actions as "problem bears" and also become in the process more vulnerable to hunting and illegal kills.

Tietje and Ruff (1983) studied the response of black bears to oil sands development in east-central Alberta. While they observed a general pattern of tolerance for development activities, they observed that a female with cubs lessened her activity in the vicinity of oil construction activity. These authors suggested the topic needed more study. Their overall conclusion was that secondary impacts of in situ oil extraction such as new roads, increased harvest and human habituation may produce greater consequences than the primary impacts of habitat loss and alienation (Tietje and Ruff 1983). In an earlier report of this research, denning behavior was studied and, although disturbance to denning bears from oil development was not observed, the possibility was discussed with reference to possible abandonment and overwinter weight loss (Tietje and Ruff 1980).

In areas affected by construction activities, black bears are expected to initially demonstrate an avoidance response to sensory disturbances but then habituate to the facilities, resulting in numerous indirect consequences for long-term survival. Disturbances during denning are considered problematic for survival. Therefore, this link is considered valid for black bears.

Beaver

Beavers are highly adaptable animals that live in close association with humans providing minimum habitat requirements of food and aquatic habitat are met (Nietfeld et al. 1984).

Based on the close association of beaver and human activities in both urban and agricultural areas, this link is not considered valid for beavers.

Fisher

The reaction of fishers to humans is usually one of avoidance, although fishers are curious animals and are easily trapped (Powell 1993). Fishers generally are more common where human density is low and human disturbances are reduced. Although not strictly regarded as a wilderness animal, as a species it avoids humans (Powell and Zielinski 1994).

This link is considered valid for fishers based on the theoretical expectation that displacement reduces foraging efficiency and may affect long-term survival.

Dabbling Ducks

Alberta's resident dabbling ducks include mallard, pintail, northern shoveler, blue-winged teal, green-winged teal, gadwall and American widgeon (Nietfeld et al. 1984). Interactions that disrupt normal behavior, particularly during the nesting season, are subtle and are difficult to observe, but may be no less harmful than habitat loss (Dahlgren and Korschgen 1992). Possible mechanisms include abandonment of eggs and young, impaired selection of habitat to pass through the molting stage and impaired habitat use during fall staging (Nietfeld et al. 1984).

Human disturbance can be a factor in waterfowl reproductive success so therefore this link is considered valid for this guild of ducks.

Ruffed Grouse

Ruffed grouse respond numerically to intensive forest management practices such as frequent clearcutting of relatively small tracts (e.g., 0.4 to 2.0 ha) of aspen forest (McCaffery et al. 1996). This suggests they are tolerant of human and mechanical activities such as logging, and can benefit from habitat manipulations. A threshold of disturbance, however, can be expected to disrupt the breeding season (Francis and Lumbis 1979).

Human disturbance can be a factor in reproductive success of upland game birds so this link is considered valid for ruffed grouse.

Cape May Warbler

During the breeding season in northeastern Alberta, Cape May warblers prefer mature mixedwood forests dominated by tall white spruce (Francis and Lumbis 1979). Their breeding habitat has been defined as dense mature white spruce stands in coniferous and mixedwood forests (Semenchuk 1992). They usually build nests in the crowns of tall conifer, within 2 m of the top (Semenchuk 1992). The Cape May warbler is susceptible to sensory disturbances during the breeding season when males are vocalizing on territory. Ambient industrial sounds may have the effect of masking the bird songs and could possibly disrupt breeding performance. Also, thresholds of disturbance may be reached that could cause nest abandonment, preventing reproductive success (Francis and Lumbis 1979).

Human disturbance can be a factor in reproductive success of forest songbirds so this link is considered valid for Cape May warblers.

Western Tanager

During the breeding season, western tanagers prefer mature mixedwood forests in northeastern Alberta (Francis and Lumbis 1979). They usually nest in coniferous trees. During the breeding season, songbirds rely on vocal communication for territorial spacing and breeding performance. Sensory disturbances and chronic sounds from industrial activities can mask auditory signals and may disrupt patterns of breeding behavior.

Human disturbance can be a factor in reproductive success of forest birds so this link is considered valid for western tanagers.

Pileated Woodpecker

Pileated woodpeckers are considered uncommon in the Project area, but are expected to occur in areas of mature and mixed forest (Francis and Lumbis 1979). Pileated woodpeckers are primary cavity nesters that require large snags for nests (Schroeder 1983). They are considered a key indicator species for retention of a complete community of cavity nesting birds. Like other birds, they are susceptible to sensory disturbances during the breeding season. Buffer strips of 100 to 150 m are recommended around large snags and important wildlife habitat features (Backhouse 1993).

Human disturbance can be a factor in reproductive success of forest birds so this link is considered valid for pileated woodpeckers.

Great Gray Owl

Great gray owls are expected to occur throughout the LSA, in mixed forests and muskeg habitat (Francis and Lumbis 1979). Great gray owls hunt primarily by listening for their prey, therefore human-related noises may interfere with their ability to hunt. Like other birds, they are susceptible to sensory disturbances during the breeding season particularly when incubating on the nest (Francis and Lumbis 1979). In Alberta, the sensitive period extends from late March to mid-May. SERM (1996) recommends that buffers of 500 to 1000 m are provided for active raptor nests in Saskatchewan.

Human disturbance can be a factor in reproductive success of forest birds so this link is considered valid for great gray owls.

Validity of Linkage

While little information is available in the literature regarding the effects of sensory disturbance on some KIRs, a conservative approach to the assessment was taken. Therefore, sensory disturbance was assumed to affect the effective habitat for all KIRs except for red-backed voles and beavers. Zones of Influence and Disturbance Coefficients used in the assessment of this impact are described in Section E11.5.2.

The Project is predicted to decrease 26% of the baseline moose HUs through sensory disturbance, an impact of High magnitude (Golder 1998b). Predicted impacts for other KIRs range from Nil to Moderate.

Mitigation

The following mitigation is recommended to reduce the impacts of sensory disturbance on wildlife:

- berms, residual and/or planted vegetation and buildings should be used to reduce the transmission of noise to adjacent habitats;
- if possible, activities should be timed to avoid critical seasons for wildlife (see Section E11.6.1);
- during the brooding and nesting season, activities within 250 m of active raptor nests should be prohibited (Westworth 1996, Environment Canada 1997) if feasible;
- staff should not be permitted to carry firearms or hunt on the LSA; and

- use of private vehicles and ATVs within the LSA should be prohibited.

E11.6.2 Analysis of Key Question: Impacts of Change in Wildlife Habitat

This section details the impacts of changes in wildlife habitat (Key Question W-1; Figure E11-1) due to:

- removal or alteration of vegetation communities through site clearing;
- alteration of vegetation communities through changes in hydrology;
- barriers to movement; and
- sensory disturbance.

Most impacts related to change in habitat result from the removal or alteration of vegetation communities through site clearing and dewatering. Sensory disturbance can also be important for some KIRs. The impacts of barriers to movement on wildlife are difficult to predict, however, due to the current lack of knowledge concerning wildlife movements in the LSA. It is presumed that the mitigation proposed to address barriers to movements (Section E11.6.3) is adequate for this issue. Therefore, the impact assessment for Key Question W-1 focused on the quantity and quality of habitat impacted by the development due to habitat change from removal or alteration of vegetation communities, dewatering and/or sensory disturbance.

The total habitat potentially affected by the Project was thus considered to be the sum of the HUs impacted by habitat loss, habitat alteration due to changes in hydrology and reduced habitat effectiveness due to disturbance (Table E11-7). It should be noted that these totals represent the total extent of the impact of the Project over its 30 year life. Due to the phased nature of the development, the number of HUs impacted for any KIR is actually much less than the totals indicated.

Table E11-7 summarizes the residual impacts of change in wildlife habitat. Impacts were predicted to be Negative in direction and High in magnitude for all KIRs.

While most of the impact magnitudes were High, it should be noted that no rare or unique wildlife habitats are present in the LSA; all habitats are distributed both within and outside of the areas that are projected to be impacted. In the case of waterfowl habitat, little habitat of High quality will be affected. Areas of High quality in the LSA, such as Isadore's Lake, or outside the LSA, such as Kearl Lake, will not be impacted by the Project.

The Geographic Extent was considered to be Local to Regional for all KIRs for this Key Question as impacts will be confined to the LSA or the immediate vicinity. While some species with greater mobility, such as moose, may be displaced outside the LSA, these impacts will be of relatively short duration.

Areas adjacent to the LSA may therefore experience a short-term increase in the populations of mobile species during project construction. Increased mortality through hunting, trapping and/or predation will likely cause these populations to revert to their former equilibrium levels in the short term.

The duration of the impact was classified as Medium as the impacts will be felt for the life of the Project (approximately 30 years). Impacts were considered to be Reversible as, with appropriate reclamation, habitat quantity and quality should be restored to a capability equivalent (although not identical) to that of pre-development levels. The Frequency of the impact was determined to be Low-High for all KIRs, as some events (e.g., site clearing) will take place only once while others (e.g., traffic, mining) will take place numerous times or continuously over long periods. Seasonal Timing was considered to be All Seasons since, even though some activities will be timed to avoid critical wildlife seasons, some construction and operation activities are expected to occur at all times of the year.

E11.6.3 Degree of Concern

The degree of concern for impacts on wildlife habitat were considered to be Moderate to High for moose, black bears, fishers and dabbling ducks and Moderate for all other KIRs.

E11.6.4 Monitoring

Monitoring required to assess the effects of habitat change on wildlife include evaluating the use of designed wildlife corridors by wildlife.

Monitoring of vegetation (and hence wildlife habitat) will also be required, and is discussed in Section E9.

All monitoring programs should have a sound scientific design such that effects of the Project are clearly separated from those of natural variation and other effects. Results of the monitoring should be used to improve the mitigation programs as appropriate.

E11.7 Key Question W-2: Will Water Releases from the Muskeg River Mine Change Wildlife Health?

E11.7.1 Analysis of Potential Linkages

The linkage between project activities and water quality has been previously addressed in Section E5. This section addresses the potential linkage between water quality changes and wildlife health.

Linkage Between Changes in Water Quality and Wildlife Health

Since the Project is not yet in operation, measured data specific to the Project could not be evaluated. However, surrogate data from other oil sands facilities in the area (i.e., Syncrude and Suncor) was used to provide an estimate of the chemistry of release waters during operation, at closure and in the far future after closure under equilibrium conditions.

In order to determine whether changes in water quality may affect wildlife health, a problem formulation was conducted including chemical, receptor and exposure pathway screenings as described in Section E11.5.4 and Appendix X.1 to X.3.

Potential receptors include both aquatic wildlife (i.e., water shrew, river otter, killdeer, great blue heron) and terrestrial wildlife (i.e., moose, snowshoe hare, black bear). These animals may be exposed through ingestion of Athabasca and Muskeg River water as a drinking water source

Table E11-8 Construction and Operation Related Residual Impacts of Change in Wildlife Habitat (Key Question W-1)

KIR	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency
moose	Negative	High	Local-Reg.	Moderate	Reversible	Low-High
red-backed vole	Negative	High	Local	Moderate	Reversible	Low-High
snowshoe hare	Negative	High	Local	Moderate	Reversible	Low-High
black bear	Negative	High	Local-Regional	Moderate	Reversible	Low-High
beaver	Negative	High	Local	Moderate	Reversible	Low-High
fisher	Negative	High	Local-Regional	Moderate	Reversible	Low-High
dabbling ducks	Negative	High	Local-Regional	Moderate	Reversible	Low-High
ruffed grouse	Negative	High	Local	Moderate	Reversible	Low-High
Cape May warbler	Negative	High	Local	Moderate	Reversible	Low-High
western tanager	Negative	High	Local	Moderate	Reversible	Low-High
pileated woodpecker	Negative	High	Local	Moderate	Reversible	Low-High
great gray owl	Negative	High	Local	Moderate	Reversible	Low-High

Chemical screening was conducted based on predicted future water concentrations in the Muskeg and River for mean open water flow at Node S16 (refer to Section E5 for further details). Detailed screening tables are presented in Appendix X.1. No chemicals of concern in water were identified for water shrew, river otter, killdeer, great blue heron or snowshoe hare. For moose and black bears, molybdenum was identified as a potential chemical of concern in water. The naphthenic acid group was also identified as a potential chemical of concern to wildlife due to a lack of regulatory or risk-based criteria for evaluation.

Since chemicals, receptors and exposure pathways have been identified, a potential linkage exists between water quality changes and wildlife health.

Linkage Between Changes in Fish Tissue Quality and Wildlife Health

To determine whether changes in fish tissue quality may affect wildlife health, a problem formulation was conducted including chemical, receptor and exposure pathway screenings as described in Section E11.5.4 and Appendix X.1 to X.3.

Aquatic wildlife species, such as the river otter and great blue heron, consume large quantities of fish daily. In fact, fish make up close to 100% of the diet of these two species. For this reason, the river otter and great blue heron were selected as representative receptors for evaluation of this key question.

A combined field and laboratory study was completed to address the potential for accumulation of chemicals in fish tissue. These data are summarized in Section E6 and briefly described below.

Walleye, goldeye and longnose sucker were collected in 1995 as part of a baseline aquatics study in the oil sands region (Golder 1996b). Walleye and goldeye were captured in the Athabasca River near Suncor and longnose sucker were captured as they moved up the Muskeg River to spawn. All three species spend part of the open water season in the vicinity of existing oil sands operations. Composite samples of fish fillets were analyzed for organic chemicals and metals (data presented in Section E6). Samples from longnose sucker contained trace concentrations of naphthalene (0.02 to 0.04 μg/g) and methylnaphthalene (<0.02 to 0.03 μg/g); however, other polycyclic aromatic hydrocarbons (PAHs) were not detectable (detection limits range from 0.02 to 0.04 μg/g). No PAHs were detected in walleye and goldeye samples. Levels of trace metals in fish tissue were generally low.

Uptake of oil sands-related chemicals into fish tissue was also investigated during a laboratory fish health study where juvenile walleye and rainbow trout were exposed to a variety of waters, including a dilution series of water collected from Suncor's Tar Island Dyke drainage system (0.1 to 10% strength), laboratory control water and Athabasca River water collected upstream of existing oil sands operations. The fish were exposed to these waters in a flow-through system for 28 days, sacrificed and their tissues analyzed for PAHs and trace metals (HydroQual 1996a). PAH concentrations in juvenile walleye and rainbow trout were generally below detection; naphthalene and methyl naphthalene levels in rainbow trout were at or just above the detection level in both control and treatment samples (0.02 to 0.03 μg/g; Section E6). Concentrations of most metals were generally below detection limits in both treatment and control samples. The only notable exceptions were for arsenic and mercury where concentrations of <0.1-2.3 μg/g and 0.03-0.45 μg/g, respectively, were measured. However, the highest concentrations were associated with control fish exposed to the Athabasca River water. Thus, no significant accumulation of PAHs or metals (relative to detection limits or levels in control fish) is indicated by either laboratory exposure of fish to Tar Island Dyke water or from fish captured in the Athabasca River.

Notwithstanding the lack of evidence of accumulation of chemicals in fish tissue, a chemical screening was conducted to determine whether ingestion of fish from the Athabasca River might potentially pose a hazard to river otters or great blue herons. The chemical screening process followed the same screening protocol as for drinking water. No chemicals of concern in fish tissue were identified for river otter or great blue heron.

It should be noted that levels of mercury in fish tissues are elevated and may pose a health risk to wildlife eating fish from this region of the river. Elevated levels of mercury in fish tissues have also been noted by the Northern River Basin Study (NRBS), and have been attributed to natural sources (NRBS 1996). Finally, water quality modelling suggests the Project will not significantly change the waterborne mercury levels. For these reasons, mercury was not evaluated further in the risk assessment.

In summary, based on the data and results of the problem formulation, release waters do not appear to contribute to increases in chemical concentrations in fish within the Local or Regional Study Area to concentrations that would be associated with adverse health effects in wildlife. Hence, a linkage between changes in fish tissue quality associated with the Project and wildlife health does not exist.

Linkage Between Changes in Aquatic Invertebrate Tissue Quality and Wildlife Health

To determine whether changes in aquatic invertebrate tissue quality may affect wildlife health, a problem formulation was conducted including chemical, receptor and exposure pathway screenings as described in Section E11.5.4 and Appendix X.1 to X.3.

The diet of aquatic wildlife species, such as the water shrew and killdeer, is largely composed of aquatic invertebrates. Therefore, in addition to direct exposure from water, these species may also be exposed through ingestion of aquatic invertebrate prey. For this reason, the validity of the linkage between aquatic invertebrate tissue quality and wildlife health was evaluated.

Data for evaluation of this pathway were limited, consisting of a few samples of benthic invertebrates collected in 1995 from potentially impacted areas of the Athabasca River near existing oil sands facilities (Appendix X.1; Table X-7). No data were available for surface water invertebrates (such as insects), which would be more typical of the diet of water shrew and killdeer.

However, for the purposes of this assessment, the benthic invertebrate data was used as a conservative surrogate of potential tissue concentrations in surface water invertebrates. Chemical screening of these data identified the following six chemicals of potential concern to water shrew and killdeer:

- barium (water shrew, killdeer)
- chromium (killdeer)
- cobalt (water shrew, killdeer)
- copper (water shrew, killdeer)
- manganese (water shrew)
- zinc (water shrew, killdeer)

Since chemicals, receptors and exposure pathways have been identified, a potential linkage exists between aquatic invertebrate quality and wildlife health.

E11.7.2 Analysis of Key Question

To further investigate the potential linkage between water quality, aquatic invertebrate quality and wildlife health, a quantitative wildlife health risk assessment was conducted for conceptual model W-2 (Figure E11-13), according to the method described in Section E11.5.4.

Wildlife Health Risks From Water Quality

The only chemical of potential concern to wildlife health in water is molybdenum. Molybdenum concentrations were predicted for the Muskeg and Athabasca Rivers, immediately downstream of the Project at mean open water flow, according to the methods described in Section E5. The maximum concentrations predicted to occur during operation (2000-2029), at closure (2030) and post-closure (under equilibrium conditions) were used in the risk assessment.

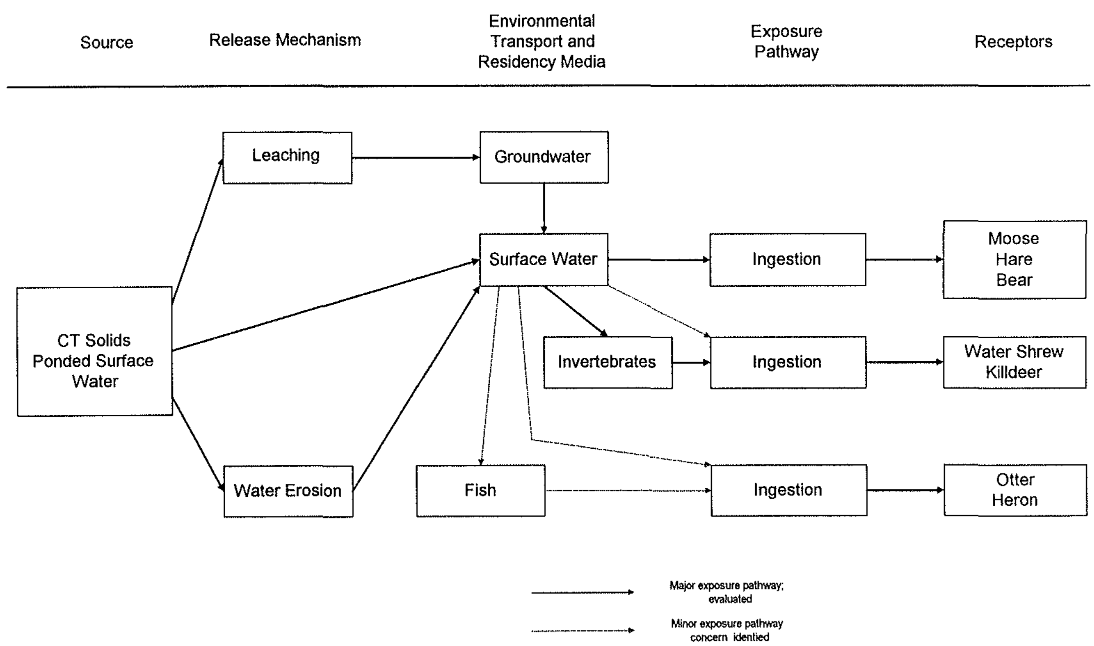
Molybdenum was identified as a potential chemical of concern to moose and black bears. In the exposure assessment, it was conservatively assumed that these animals would ingest their total daily water requirements from the Muskeg or Athabasca Rivers, every day of the year for their entire lifespan.

The maximum exposure ratios for moose and black bears based on exposure to Muskeg River water (at closure in 2030) were less than 1.0

(i.e., ER = 0.13 and 0.11, respectively). Chemical contributions to the Athabasca River from the Project are less than contributions to the Muskeg River, due to increased dilution as a result of the larger water volume and flow rate of the Athabasca River compared to the Muskeg River. Therefore, since no wildlife health impacts were identified for exposure to Muskeg River water, none would be expected via exposure to Athabasca River water. Thus, no impact to wildlife health is indicated due to consumption of water from the Athabasca or Muskeg Rivers.

Due to the lack of chronic mammalian toxicological data for naphthenic acids, the potential for wildlife health effects could not be evaluated for this group of substances. However, the acute mammalian toxicity studies indicate low toxicity for this group of substances. The available toxicity data for naphthenic acids indicates these substances are low in potency; however this data does not enable assessment of chronic low level exposure.

Figure E11-13 Conceptual Model for the Water Release Scenario



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Wildlife Health Risks From Aquatic Invertebrate Quality

Exposures to water shrew and killdeer from ingestion of aquatic invertebrates, were estimated based on measured tissue concentrations in benthic invertebrates collected from potentially impacted areas of the Athabasca River (Appendix X.1; Table X-7).

It was conservatively assumed that 100% of the diet of water shrews and killdeer consisted of aquatic invertebrates from the Athabasca River, every day of the year for their entire lifespan. Since water shrews and killdeer may also be exposed to these chemicals in drinking water, ER values were also calculated for the water ingestion pathway. ER values for water shrew and killdeer are presented in Table E11-9.

E11-9 Exposure Ratio Values for Water Shrew and Killdeer

Receptor/Chemical	ER for Invertebrate Diet	ER for Water Ingestion (Muskeg River)
Water Shrew		
Barium	2.26	0.0005
Cobalt	0.44	no data[(a)]
Copper	1.24	0.000009
Manganese	1.49	0.00005
Zinc	0.35	0.000005
Killdeer		
Barium	0.22	0.0004
Chromium	1.63	0.0004
Cobalt	0.31	no data[(a)]
Copper	0.15	0.00002
Zinc	1.43	0.00023

(a) Future predictions of cobalt in the Muskeg River were not available, but evidence suggests ER values would be similar to those predicted for other metals.

All ER values were less than or marginally greater than 1.0. Based on the conservative assumptions used in the assessment (i.e., 100% of the diet from impacted areas; benthic invertebrate tissue concentrations used as a surrogate for surface water invertebrate tissue concentrations), the marginal exceedance over 1.0 does not indicate a health risk to wildlife. Furthermore, these risk estimates were calculated based on effects to individual organisms. For effects to occur at the population level (i.e., 20% change in the population), ER values would have to be much greater than 1.0. ER values for water ingestion were much less than 1.0 and represent a minor exposure pathway relative to aquatic invertebrate ingestion. Therefore, no impacts to wildlife health are predicted due to consumption of water and aquatic invertebrates from the Athabasca or Muskeg rivers.

E11.7.3 Residual Impact Classification and Degree of Concern

Based on the information assessed, no wildlife health impacts were identified. However, due to the uncertainty regarding the potential chronic effects of naphthenic acids present in water releases, the magnitude of impact and resultant degree of concern are rated as follows:

Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
negative	low	local	long-term	reversible	medium	low

Currently there is an industry initiative to collect the required data to resolve the issue of chronic toxicity of naphthenic acids.

Certainty

The assessment of potential impacts to local wildlife was based on a number of highly conservative assumptions. The conservative assumptions related to chemical screening are discussed in Section E11.5.4. These assumptions provide assurances that no chemicals were excluded from the screening step except those that clearly pose no incremental risk to wildlife

health. Risk estimates were calculated deterministically to provide single value estimates of Exposure Ratios; however, a significant degree of uncertainty is associated with most ER values. To ensure that this assessment yields a sufficiently protective answer in light of this uncertainty, the assessment was based on protective input values. Hence, the actual risks to wildlife health will likely be even lower than those suggested by ER estimates because of the multiple protective assumptions as outlined below:

- reasonable worst case exposure point concentrations in the Muskeg and Athabasca rivers were used, assuming no decay or degradation of chemicals;
- exposure locations were set within the mixing zone of the Muskeg and Athabasca rivers, downstream of all potential water emissions;
- measured tissue concentrations in benthic invertebrates were used as surrogates for surface water invertebrates;
- exposure parameter values for wildlife receptors represent reasonable maximum exposure values;
- oral bioavailability was set to a maximum of 100%; and

- receptor-specific toxicity reference values were developed to be protective of wildlife under chronic exposure conditions.

E11.7.4 Monitoring

As part of the RAMP, a suite of chemical substances, including the chemicals of concern discussed here, will be monitored in surface waters, benthic invertebrates and fish periodically at predetermined locations to validate the exposure and risk assessment.

In addition, consideration will be given to resolve data gaps in toxicity data for naphthenic acids as part of CONRAD.

E11.8 Key Question W-3: Will Consumption of Plants Affected by the Muskeg River Mine Project Change Wildlife Health?

E11.8.1 Analysis of Potential Linkages

Herbivorous and omnivorous wildlife species (such as moose, snowshoe hare, black bears and ruffed grouse) consume large quantities of plants daily. Air emissions from the Project may deposit onto plant surfaces and soils and subsequently be taken up into plant tissues. Stakeholders have expressed concern over the potential for chemical uptake by wildlife who consume plants growing in areas close to the Project. For this reason, the potential for adverse effects to wildlife health from ingestion of local plants was evaluated.

Linkage Between Project Activities and Changes in Plant Tissue Quality

Because the Muskeg River Mine Project does not yet exist, direct assessment of this linkage is not possible. Consequently, a vegetation sampling program involving surrogate sites was conducted for the purpose of addressing this key question. This sampling program was originally designed to address the potential for chemical exposure to people and therefore focused on plants that are consumed by humans (i.e., blueberries, Labrador tea leaves and cattail roots; see Section E12.8 for more details regarding the human health assessment). Since these plant species may also be consumed by local wildlife, these data were used to address wildlife health issues. Samples of the three species of plants, along with corresponding soil and/or sphagnum samples at the base of the plants were collected during August 1997 in four areas:

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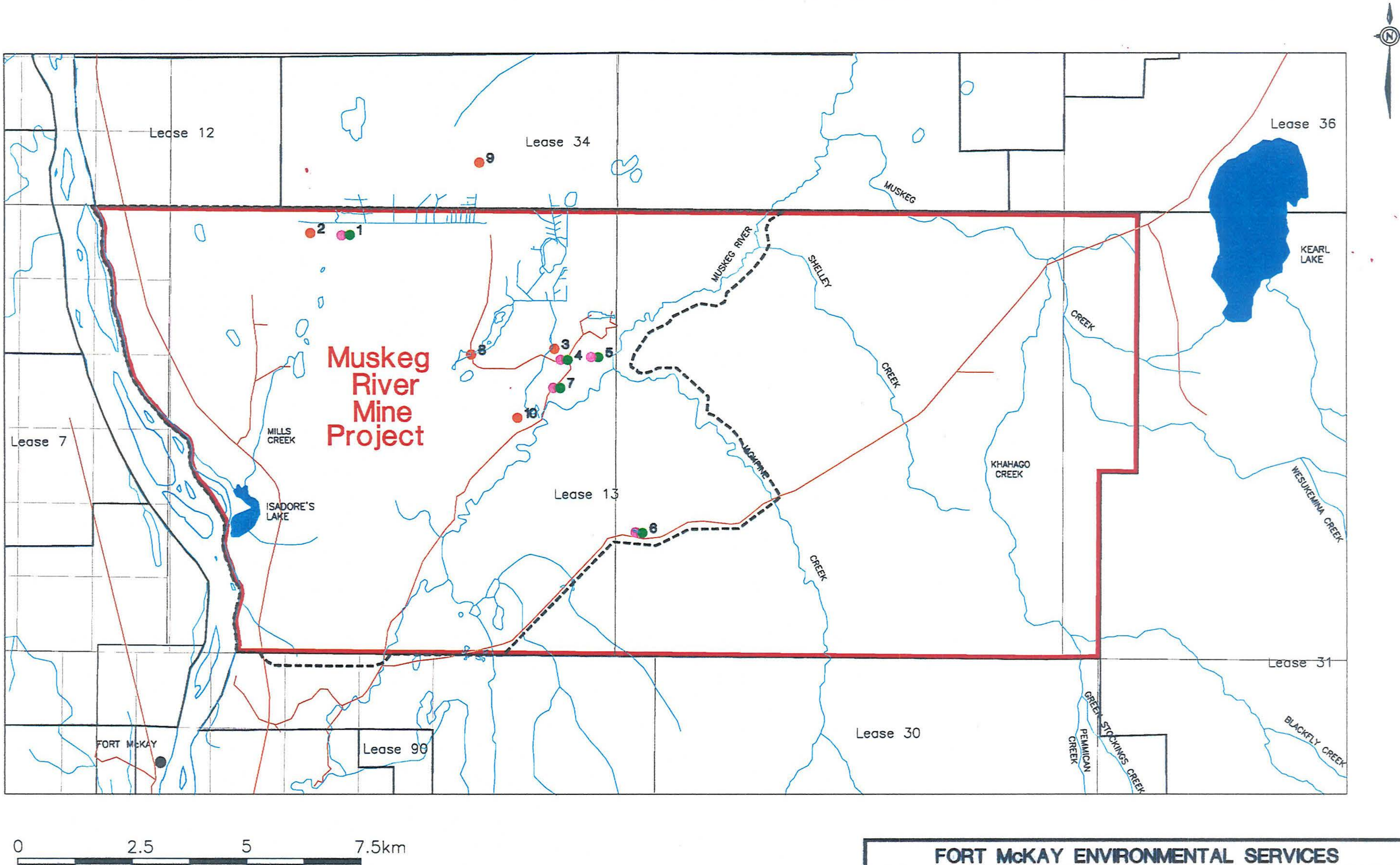


E11-70

REFERENCE

DIGITAL DATA SETS 74D, 74E, 74I 84A AND 84H FROM RESOURCE DATA DIVISION ALBERTA ENVIRONMENTAL PROTECTION, 1997.

LEGEND

- LABRADOR TEA LEAVES
- BLUEBERRIES
- CATTAIL ROOTS

FORT McKAY ENVIRONMENTAL SERVICES

Golder Associates

SHELL CANADA LIMITED

VEGETATION SAMPLING LOCATIONS

14 DEC 97	Figure E11-14	DRAWN BY: CG

- Suncor Lease 25 (area within the deposition zone of air emissions from existing oil sands operations and used as a surrogate of potential impacts from the Muskeg River Mine Project);

- Mariana Lakes area, approximately 65 km south of Fort McMurray (control location); and

- West of Syncrude, outside the zone of influence of air emissions (control location).

Collection of plant and soil samples on the Muskeg River Mine Project site was conducted by Golder Associates in collaboration with Fort McKay Environment Services Ltd. Collection at potentially impacted areas and control locations was conducted by Golder Associates. The plant and soil samples were collected and analyzed for metals and PAHs according to the protocols presented in Appendix X.7. Analysis results are also summarized in Appendix X.7.

PAHs were not detected in all samples of blueberries or cattail roots. Small quantities (i.e., levels at or slightly exceeding the limit of detection) of naphthalenes and phenanthrene/anthracene were detected in some samples of Labrador tea leaves collected on the Muskeg River Mine Project site and in potentially impacted areas. However, these PAHs were also detected in control samples of Labrador tea leaves, and concentrations in the test areas do not differ significantly from concentrations found in control areas. It is possible that these observations reflect the natural prevalence of petroleum hydrocarbons in this region. There is historical evidence of a forest fire in the Mariana Lakes region, which may have contributed to the observed concentrations of PAHs in Labrador tea leaves from this region, since PAHs may be released naturally from burning wood. It should also be noted that naphthalenes, phenanthrene and anthracene are non-carcinogenic PAHs, which have relatively low toxic potency compared with other carcinogenic PAHs, such as benzo[a]pyrene, and they are not bioaccumulative. Observed levels in Labrador tea leaves are much less than those that would be associated with adverse wildlife health effects.

Inorganic chemical concentrations in blueberries collected from the Muskeg River Mine Project site and in potentially impacted areas were generally within the range of measured concentrations in control locations, with the exception of copper, sodium and zinc, which were slightly elevated in samples from the Muskeg River Mine Project site and potentially impacted areas. All of these compounds are essential dietary elements and the measured concentrations in blueberries from test areas would not be associated with any adverse effects to wildlife health.

Several inorganic chemical concentrations in Labrador tea leaves and cattail roots were elevated in samples from the Muskeg River Mine Project site and potentially impacted areas in comparison to control samples. As discussed previously for blueberries, many of these compounds are essential dietary elements and the measured concentrations in test samples would not be associated with adverse effects to wildlife health.

In summary, plant tissue residues were not consistently elevated in areas where oil sands air emissions are a factor. In addition, among the three plant species tested, there was no consistent subset of metals that were elevated compared to control plant concentrations. Therefore, the observed plant concentrations cannot be solely attributed to oil sands operations and the linkage cannot be fully validated.

Linkage Between Changes in Plant Tissue Quality and Wildlife Health

Notwithstanding the weak evidence in the above noted linkage, a chemical screening process was conducted to evaluate whether the observed concentrations in plant samples may have any adverse effect on the health of herbivorous and omnivorous wildlife species. This was pursued in light of explicit interests expressed by the Fort McKay Band (Fort McKay First Nation 1997).

The following herbivorous and omnivorous wildlife receptors were identified: moose, snowshoe hare, black bear, ruffed grouse and mallards. The diet of moose and snowshoe hare may consist of 100% vegetation, while the diet of black bears, ruffed grouse and mallards consists of approximately 75, 80 and 25% vegetation, respectively. Concentrations in aquatic vegetation (i.e., cattail roots) were screened for exposure to moose and mallards, since these are the only two selected species that would consume aquatic plants. Concentrations in terrestrial vegetation (i.e., blueberries and Labrador tea leaves) were screened for exposure to moose, snowshoe hare, black bear and ruffed grouse.

The chemical screening was based on the above data and receptor-specific vegetation ingestion rates for moose, snowshoe hare, black bears, mallards and ruffed grouse (see Appendix X.4 for wildlife receptor parameters).

Chemical concentrations in plant tissues were screened against risk-based concentrations (RBCs), based on the following conservative assumptions:

- 100% of the daily vegetation requirements for each receptor were assumed to consist of blueberries, Labrador tea and/or cattail root; and
- chemical concentrations in plant tissue were conservatively compared against receptor-specific RBCs, based on a target exposure ratio (ER) of 0.1 (i.e., ten-fold lower than levels associated with risk).

The following chemical was identified as a potential chemical of concern in *blueberries* for the wildlife species indicated in parentheses:

- manganese (moose, snowshoe hare, black bear)

The following four chemicals were identified as potential chemicals of concern in *Labrador tea leaves* for the wildlife species indicated in parentheses:

- antimony (moose, snowshoe hare, black bear)
- barium (moose, snowshoe hare, black bear, ruffed grouse)
- copper (moose, snowshoe hare, black bear, ruffed grouse)
- manganese (moose, snowshoe hare, black bear)

The following seven chemicals were identified as potential chemicals of concern in *cattail root* for moose (no chemicals of concern in cattail root were identified for mallards):

- barium (moose)
- boron (moose)
- cadmium (moose)
- cobalt (moose)
- molybdenum (moose)
- selenium (moose)
- vanadium (moose)

Detailed screening tables are presented in Appendix X.1. It should be noted that these chemicals were selected based on prevalence in plant tissues; however, these residues were not significantly elevated in areas where oil sands air emissions are a factor. In addition, among the three plant species tested, there was no consistent subset of metals that were elevated compared to control plant concentrations. Thus, it does not appear that oil sands operations are the cause for the observed exceedances.

A potential linkage does not exist for mallards since no chemicals of concern were identified for this species. However, since elevated chemical concentrations, other receptors and exposure pathways may apparently coexist, a potential linkage exists between plant quality changes and wildlife health. The evidence does not associate this linkage solely with oil sands operations. However, in light of interest articulated by the Fort McKay Band and regulators concerning elevated chemicals concentrations in plants (Human and Ecological Health Component Focus Workshop, October 30, 1997), the plant tissue/wildlife health linkage was retained for further consideration.

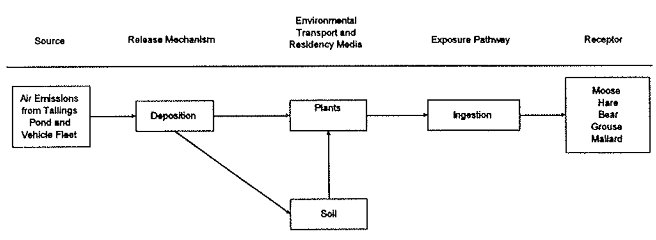
E11.8.2 Analysis of Key Question

To further investigate the potential linkage between plant tissue quality and wildlife health, a quantitative ecological health risk assessment was conducted for conceptual model W-3 (Figure E11-15) according to the method described in Section E11.5.3. Key aspects of the risk assessment are presented here; additional details are presented in Appendix X.

Snowshoe hares, black bears and ruffed grouse were assumed to consume equal amounts of blueberries and Labrador tea leaves to satisfy their total daily vegetation requirements, every day of the year for their entire lifespan. Moose were assumed to consume equal amounts of blueberries, Labrador tea leaves and cattail root to satisfy their total daily vegetation requirements, every day of the year for their entire lifespan. Maximum measured concentrations in plants from either the Project site or potentially impacted areas from other oil sands facilities were used in calculating the risk estimates to ensure a conservative assessment. In addition, although a chemical may have only screened on because of concentrations in one plant type, it was conservatively evaluated in all plant types, where concentrations were measurable, to address concerns associated with combined exposure to all plant types.

Exposure ratios for each species are presented in Table E11-10 for the combined exposure to all relevant plant types.

Figure E11-15 W-3: Conceptual Model for the Local Plant Scenario



E11-10Exposure Ratio Values for Wildlife

Chemical	Moose	Snowshoe Hare	Black Bear	Ruffed Grouse
Antimony	0.33	0.57	0.39	not applicable [a]
Barium	1.13	1.44	0.98	0.24
Boron	0.07	not applicable [a]	not applicable [a]	not applicable [a]
Cadmium	0.11	not applicable [a]	not applicable [a]	not applicable [a]
Cobalt	0.14	not applicable [a]	not applicable [a]	not applicable [a]
Copper	0.20	0.29	0.20	0.09
Manganese	0.83	1.06	0.72	not applicable [a]
Molybdenum	0.46	not applicable [a]	0.07	not applicable [a]
Selenium	0.12	not applicable [a]	not applicable [a]	not applicable [a]
Vanadium	1.24	not applicable [a]	not applicable [a]	not applicable [a]

[a] These chemicals were not identified in the screening process for these wildlife species and therefore were not evaluated in the risk assessment.

All ER values for black bears and ruffed grouse were less than 1.0, indicating that predicted conservative exposures likely to be incurred by bears and grouse who consume local plants are well within acceptable limits. Most ER values for moose and snowshoe hare were also less than 1.0, with a few chemicals marginally exceeding 1.0 (i.e., barium, manganese, vanadium). Based on the conservative assumptions used in the assessment (i.e., 100% of the diet consisting of these three plant species from impacted areas), the marginal exceedance over 1.0 does not indicate a health risk to moose or snowshoe hare. Furthermore, these risk estimates were calculated based on effects to individual organisms. For effects to occur at the population level (i.e., >20% change in the population), ER values would have to be much greater than 1.0. Therefore, no impacts to wildlife health are predicted due to consumption of plants.

E11.8.3 Residual Impact Classification and Degree of Concern

Based on the information assessed, no residual impacts were identified. Therefore the degree of concern is rated as negligible.

Certainty

This assessment was based on a number of conservative assumptions including the following:

- maximum concentrations measured in plant tissue were used;
- animals were assumed to only ingest these three types of plants;
- daily ingestion estimates for these local plants represent reasonable maximum exposure values for the wildlife species evaluated;

- oral bioavailability was set to a maximum of 100%;
- combined exposure to all relevant plant types was considered; and
- receptor-specific toxicity reference values were set to be protective of wildlife species under chronic exposure conditions.

Due to the conservatism involved in the risk assessment for consumption of local plants, the degree of certainty associated with the risk predictions is high.

E11.8.4 Monitoring

Shell anticipates becoming a member of the Regional Air Quality Coordinating Committee (RAQCC) for South Wood Buffalo Region. The Environmental Effect Monitoring (EEM) Committee is currently planning a study to be implemented in 1998 which will involve sampling of game and plant tissue for analysis and interpretation respecting wildlife health.

E11.9 Key Question W-4: Will the Combined Exposure to Water, Aquatic Prey and Plants Affected by the Project Change Wildlife Health?

E11.9.1 Analysis of Potential Linkages

Stakeholders have expressed concerns over the combined exposure of local wildlife to chemicals from various media potentially affected by emissions from the Project. The identified wildlife receptors may be exposed to chemicals from a number of sources, including water, aquatic invertebrates and plants. The potential for adverse wildlife health effects from each of these sources has been evaluated separately in key questions W-2 and W-3. No wildlife health impacts were identified in these assessments. However, in light of the validity of individual linkages, a potential linkage exists between the combined exposure to these media and wildlife health. For this reason, combined exposure was evaluated in the risk assessment.

E11.9.2 Analysis of Key Question

To calculate risk estimates for the combined exposure to all media, incremental risk estimates (ER values) for each media were summed, resulting in a total ER value for each chemical. For each receptor, chemical screening for each media identified different chemicals. However, for the purposes of this linkage analysis, any chemical that was retained for one media was evaluated in all media, where data were available, to ensure a conservative assessment of combined exposure. The same values used in the previous linkage analyses for behavioural exposure parameters also apply in the present case.

ER values are presented in Table E11-11 for each media and for all media combined for the receptors evaluated. All ER values for black bears and ruffed grouse were less than 1.0, indicating that predicted conservative exposures likely to be incurred by bears and grouse who ingest local water and plants are well within acceptable limits. Most ER values for moose, snowshoe hare, water shrew and killdeer were also less than 1.0, with a few chemicals marginally exceeding 1.0. Based on the conservative assumptions used in the assessment (i.e., 100% of the diet consisting of water, invertebrates and/or plants from impacted areas), the marginal exceedance over 1.0 does not indicate a health risk to these wildlife receptors. Furthermore, these risk estimates were calculated based on effects to individual organisms. For effects to occur at the population level (i.e., >20% change in the population), ER values would have to be much greater than 1.0. These results indicate that even with combined exposure to water, aquatic invertebrates and plants, no wildlife health impacts are expected.

E11.9.3 Residual Impact Classification and Degree of Concern

Based on the information assessed, no wildlife impacts were identified. However, due to the uncertainty regarding the potential chronic effects of naphthenic acids present in water releases, the magnitude of impact and resultant degree of concern are rated as follows:

Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
negative	low	local	long-term	reversible	medium	low

Currently there is an industry initiative to collect the required data to resolve the issue of chronic toxicity of naphthenic acids.

Certainty

In addition to the conservative assumptions described under each of the preceding key questions, the assessment of combined exposures was also exceptionally conservative in that it assumed wildlife would be exposed to maximum measured or estimated chemical concentrations in all media at the same time.

Table E11-11 Exposure Ratio Values for Wildlife

Receptor/ Chemical	Water[(a)]	Aquatic Invertebrates	Plants	All Sources
Water Shrew				
Barium	0.00005	2.26	not applicable[(c)]	2.26
Cobalt	no data[(b)]	0.44	not applicable[(c)]	0.44
Copper	0.000009	1.24	not applicable[(c)]	1.24
Manganese	0.00005	1.49	not applicable[(c)]	1.49
Zinc	0.000005	0.35	not applicable[(c)]	0.35
Killdeer				
Barium	0.0004	0.22	not applicable[(c)]	0.22
Chromium	0.0004	1.63	not applicable[(c)]	1.63
Cobalt	no data[(b)]	0.31	not applicable[(c)]	0.31
Copper	0.00002	0.15	not applicable[(c)]	0.15
Zinc	0.0002	1.43	not applicable[(c)]	1.43
Moose				
Antimony	0.0005	not applicable[(c)]	0.33	0.38
Barium	0.002	not applicable[(c)]	1.13	1.13
Boron	0.004	not applicable[(c)]	0.07	0.07
Cadmium	0.002	not applicable[(c)]	0.11	0.11
Cobalt	no data	not applicable[(c)]	0.14	0.14
Copper	0.00004	not applicable[(c)]	0.20	0.20
Manganese	0.0003	not applicable[(c)]	0.83	0.83
Molybdenum	0.19	not applicable[(c)]	0.46	0.65
Selenium	0.0003	not applicable[(c)]	0.12	0.12
Vanadium	0.02	not applicable[(c)]	1.24	1.26
Snowshoe Hare				
Antimony	0.0002	not applicable[(c)]	0.57	0.57
Barium	0.001	not applicable[(c)]	1.44	1.44
Copper	0.00002	not applicable[(c)]	0.29	0.29
Manganese	0.0001	not applicable[(c)]	1.06	1.06
Black Bear				
Antimony	0.0004	not applicable[(c)]	0.39	0.39
Barium	0.002	not applicable[(c)]	0.98	0.98
Copper	0.00003	not applicable[(c)]	0.20	0.20
Manganese	0.0002	not applicable[(c)]	0.72	0.72
Molybdenum	0.17	not applicable[(c)]	0.07	0.24
Ruffed Grouse				
Barium	0.0003	not applicable[(c)]	0.24	0.24
Copper	0.000009	not applicable[(c)]	0.09	0.09

(a) ER values for water are the maximum predicted for wildlife species at closure in 2030
(b) future predictions of cobalt in the Muskeg River were not available, but evidence suggests ER values would be similar to those predicted for other metals
(c) this is not a relevant exposure pathway for the receptor indicated.

Due to the conservatism involved in the risk assessment for combined exposure, there is a high degree of confidence in the results of the assessment with the exception of two potential issues:

- lack of a toxicity reference value for naphthenic acids and corresponding health risks; and
- possible interactions in chemical mixtures (e.g., additive and synergistic effects).

As noted in the discussion for key question W-2, it is unlikely that evaluation of naphthenic acids will affect the conclusions presented above. Further toxicity studies should be undertaken to address this issue.

With respect to chemical mixtures, interactions may occur that may increase or decrease toxic effects. For example, additive effects occur when the combined effect of chemicals are equal to the sum of each agent alone; this is believed to be the most common type of chemical interaction (Health Canada 1995). Synergistic effects occur when the combined effect of chemicals are greater than the sum of each agent alone. In contrast, antagonistic effects occur when chemicals interfere with each other, thereby decreasing adverse effects associated with each chemical acting separately. None of these interactions can be fully ruled out or demonstrated to exist. Because of the complexity of these interactions and present limitations in the science of toxicology, it is difficult to take into account the interactive effects of chemicals in risk assessment. We have, however, explicitly incorporated the potential for additive effects among PAHs, by grouping PAHs into functional groups based on those with similar molecular structure and modes of toxicity. In addition, the conservative nature of both the screening and risk estimates serve to provide additional protection against possible toxicological interactions among other chemicals.

E11.9.4 Monitoring

Monitoring as previously noted for the individual linkages will provide appropriate data for integration in the context of this multimedia assessment.

E11.10 Key Question W-5: Will the Muskeg River Mine Project Change Wildlife Abundance or Diversity?

E11.10.1 Analysis of Potential Linkages

Linkage Between Site Clearing/Change in Access and Direct Mortality Due to Sensory Disturbance

Background

This linkage deals with direct mortality due to sensory disturbance, as opposed to the effects of habitat displacement due to disturbance, which was discussed in Section 11.6.4.

Harassment can be defined as any activity that precipitates excitement in an animal, and causes it to prepare itself physiologically for flight (Geist 1971). This can result in increased levels of stress and energy expenditure, disruption of feeding and/or mating behaviour, etc., which in turn can lead to increased mortality and/or lower reproductive rates. It has been reported that changes in endocrine activity, blood pressure, glucose levels, adrenal activity, respiration and digestion may occur as the result of noise (Bommer and Bruce 1996). Reduction in milk and egg production in cattle and chickens has been documented (Bommer and Bruce 1996).

Noise can also impact animal behavior. It may cause physical stress and energy loss when they flee. In many cases animals may habituate to sound but this varies between individuals and species. Other activities may increase the effects of noise. For example, animals that are hunted are more likely to flee because of noise (Bommer and Bruce 1996).

Sensory disturbances can vary in intensity and duration, from passive and benign activities to direct and persistent harassment. Reactions to sensory disturbances varies among wildlife species, based on their ability to learn and respond, and on past experience (Geist 1971). Typically, wildlife that are highly social and live in open habitat are most susceptible. And while single-disturbance effects may be insignificant, the effects can be cumulative. Mammals and some birds tend to be most strongly affected, but may habituate to disturbances that are predicable and non-threatening (Geist 1971, Stephenson et al. 1996). In general, many wildlife species have been shown to be highly adaptable.

Benign disturbances generally elicit subtle responses from wildlife, which may include elevated heart rates but no overt reaction. Direct and persistent harassment often results in panic, flight and withdrawal from preferred habitat. Sensory disturbances may cause abandonment of habitat and reduced survival and reproductive rates (Geist 1971). The mechanism linking sensory disturbances to wildlife survival and reproduction is energy balance. Disturbance effects raise the cost of living, for example by increasing home range size (Dorrance et al. 1975, Stephenson et al. 1996), disrupting social behavior and family groups (Bartelt 1987), foraging behavior (Klein 1993), changing daily activity patterns (Vogel 1989), pair bonds and abandonment of young, which can change the energy balance of an individual(s) from positive to negative. The literature on disturbance effects on wildlife is large and growing, but unfortunately many early references are incidental to other work and are methodologically flawed (Shank 1979). A growing body of research on wildlife response to disturbance is being conducted on an experimental basis (e.g., Macarthur et al. 1982, Kuck et al. 1985, Yarmoloy et al. 1988, Klein 1993, Weisenberger et al. 1996)

In general, sensory disturbances tend to be most detrimental at critical times of the year, such as during late-winter periods of bioenergetic stress when wildlife tend to be in poor body condition, and during the spring reproductive season when wildlife are attempting to raise young-of-the-year (Kuck et al. 1985, Yarmoloy et al. 1988). Ungulate calves are considered to be the most vulnerable age class because energy costs are relatively greater because of smaller body size (Kuck et al. 1985). Sensory disturbance is not as visible an impact to wildlife as habitat loss when land is allocated for other uses, but can be no less harmful (Dahlgren and Korschgen 1992). Similar to habitat loss, sensory disturbances can reduce the landscape's capability to support wildlife. As mentioned in Section E11.6.4, sensory disturbances can result in habitat alienation.

Validity of Linkage

Due to the relative lack of knowledge concerning the physiological effects of disturbance on wildlife species, this linkage was assumed to be valid for all KIRs.

Mitigation

Mitigations for this linkage are identical to those for Section 11.6.4, impacts of sensory disturbance on habitat alienation.

Linkage Between Site Clearing and Direct Mortality

Background

Approximately 3,289 ha of land will be cleared as a result of the Project. Clearing of vegetation and removal of overburden could kill animals that are not mobile or that have small home ranges. Juvenile animals, including those in nests, are particularly sensitive to mortality through site clearing.

Validity of Linkage

This linkage is considered valid for KIRs that have small home ranges and for KIRs whose young may be susceptible in their early life stages. Table

E11-12 presents a summary of the linkage validity for this component. This linkage was considered invalid only for moose, due to the mobility of both adults and calves. Potential impacts to black bears were considered Moderate in the winter when females give birth to young in dens. Adults disturbed from dens can generally escape and den elsewhere. Tietje and Ruff (1980) found that bears disturbed from their dens in winter were able to den in other areas and survive the winter.

Table E11-12 Susceptibility of Key Indicator Resources to Mortality During Site Clearing

	Susceptibility to Mortality		
KIR	**All Year**	**Winter**	**Spring**
moose	Low	Low	Low
red-backed vole	High	Low	Low
snowshoe hare	Moderate	Low	Low
black bear	Low	Moderate	Low
beaver	Low	Low	High
fisher	Low	Low	High
dabbling ducks	Low	Low	High
ruffed grouse	Low	Low	High
Cape May warbler	Low	Low	High
western tanager	Low	Low	High
pileated woodpecker	Low	Low	High
great gray owl	Low	Low	High

Mitigation

Mitigation for impacts on direct mortality due to site clearing include:

- timing of site clearing to avoid sensitive seasons for wildlife; and
- pre-development surveys for active raptor nests and the establishment of 250 m buffers around such nests.

Linkage Between Change in Access and Change in Hunting, Trapping and Predation

Background

Of the KIRs identified for this project, the ungulates, carnivores, furbearers, dabbling ducks and upland game birds are harvested under provincial license. KIRs hunted include moose, black bears, dabbling ducks and ruffed grouse. KIRs that are trapped for fur include beaver and fishes. While not listed in the Wildlife Act as a furbearer, snowshoe hare are harvested by local and aboriginal people for food. The other KIRs not considered to be influenced by hunting and trapping include red-backed voles and the other four forest birds: Cape May warbler, western tanager, pileated woodpecker and great gray owl.

Improved access after site closure will open areas previously inaccessible to hunting and trapping. Whether or not this becomes detrimental depends on the regulations in effect. Legal hunting and trapping is relatively easy to control and monitor, providing the manpower and resources are made available by regulatory authorities.

An important effect of roads on wildlife populations is increased mortality from humans (hunters, poachers and defense-of-life, Brody and Pelton 1989, McLellan 1988), and wolves because roads and other linear corridors such as seismic lines provide access to previously less accessible landscapes (Horejsi 1979, Bergerud et al. 1984). There is evidence for the decline of ungulates in areas where access has been created (Shideler et al. 1986). Moose have been shown to be very susceptible to hunting pressure in logged areas (Lynch 1973, Fleming and Koski 1976, Eason et al. 1981, Timmerman and Gollat 1982, Eason 1985), probably as a result of a combination of greater visibility of the animals within cut blocks and increased access for hunters. Road mortalities may be accentuated during winter because ungulates are drawn there to ingest road salt (Fraser 1980), because natural sources of salt are generally not available during winter.

Moose, Black Bear, Dabbling Ducks, Ruffed Grouse, Snowshoe Hare

In the short term, improved access via a number of linear disturbance corridors will result in increased harvest of wildlife in the LSA. Lynch (1973) estimated that in west-central Alberta, 80% of all moose hunters and 28% or all moose kills occurred within 2 km of roads; hunters with all-terrain vehicles were most successful. In Alberta, moose management has become increasingly controversial, based on the perception that moose populations have declined (Todd and Lynch 1992). The majority of hunters interviewed (n = 409) had the impression that moose numbers had declined in areas where they hunt. Specific factors in the perceived declines included native harvest, illegal hunting, habitat loss or change and excessive harvest.

Brody and Pelton (1989) observed that the primary effect of roads in bear habitat was increased vulnerability to hunting.

The number of these species available for harvest in the Project area is predicted to decline, at least in the short term.

Because access by humans is required for harvest, and harvested species are more vulnerable to hunters with improved access, the link is considered valid for these KIRs.

Beaver and Fisher

In the short-term, improved access via a number of linear disturbance corridors will result in increased harvest of licensed furbearers in the project area. Both KIR furbearing species are relatively easy to trap, and both species historically have been overtrapped in local areas (Hill 1987, Powell and Zielinski 1994). Therefore, the number of these species available for harvest in the project area is predicted to decline. Long-term population levels will depend to a great extent on whether or not compensating management programs are instituted. Trapping seasons should be monitored and re-evaluated as needed.

Validity of Linkage

This linkage is valid for those species normally hunted and/or trapped in the area. However, effective mitigation for this linkage (see below) is achievable. Increased wolf predation on ungulates within the LSA in winter due to increased access (i.e., cleared roads) is not likely to be a concern due to the disturbance effect of the development. Wolves are unlikely to use roads in close proximity to the Project.

Mitigation

Mitigation for this linkage will include:

- no personnel will be permitted to carry firearms on the LSA;
- no hunting or trapping will be permitted on the LSA; and
- access by the public to the LSA will be prohibited.

Linkage Between Infrastructure and Removal of Nuisance Wildlife

Background

Of the KIRs selected for this project, two species have the potential to become "nuisance" wildlife: beavers and black bears. Beavers can become problems in local areas of linear corridor construction if their activities obstruct the flow of water and cause flooding and erosion at facilities. When this occurs, beavers are trapped and moved, or they are destroyed. Dewatering of the Project site will also have the side-effect of reducing the habitat suitability of the area to beavers for the life of the mine.

Black bears become a problem when they are attracted to food odors and have access to human sources of food. Habituated bears tend to become aggressive and can be a threat to life and property. When this occurs, black bears are usually destroyed to resolve the situation. Management actions are additive to natural mortality and harvest levels. Management of these sources of mortality can be a significant burden on limited enforcement personnel. Bear relocation tends to be very expensive since it requires considerable manpower, and benefits are uncertain as relocation is frequently not successful (Miller and Ballard 1982, Tietje and Ruff 1983, Rogers 1986). Bear relocation efforts may have a role in some circumstances (Rogers 1986, Blanchard and Knight 1995).

A number of nuisance bear incidents are likely to occur in the LSA. It is difficult to predict the magnitude of this potential problem, but it should be viewed as a wildlife management issue. The experience of Suncor with nuisance bears is of interest. Two to three bears are trapped and moved per year from Suncor (Leo Paquin, Suncor, pers. comm., November 24, 1997). In 1997, nine bears were trapped. The higher number for 1997 may be related to the clearing of land for the Steepbank Mine. Most bear problems in the Fort McMurray area occur from June to September (Cory Craig, AEP, Fort McMurray, pers. comm., November 27, 1997).

Solutions to bear problems are usually available, simple and straightforward, although often difficult to implement (Follmann and Hechtel 1990). Food and waste management are obvious steps to be implemented within the greater context of a Protection Plan. The value of a Protection Plan is the advanced planning it represents; it is a commitment to be proactive. The Protection Plan acknowledges potential problems and identifies appropriate solutions and actions. Work force education and prompt action as problems arise can also be effective in reducing impact on bears. There is also the additional burden of research and monitoring that accompanies a Protection Plan (Herrero 1989).

Validity of Linkage

This linkage is considered valid for beavers and black bears As mentioned, management actions directed at "nuisance" wildlife add natural mortality and harvest levels.

Mitigation

Mitigation for nuisance wildlife will include:

- use of beaver deterrence devices on culverts;
- regular monitoring and removal of beaver dams at culverts;
- incineration or storage of all food wastes in bear-proof containers and transport off-site;
- instruction and education of Project workers to not feed wildlife; and
- implementation of a nuisance wildlife management plan in cooperation with Fish and Wildlife Service, AEP.

Linkage Between Infrastructure and Increased Vehicle-Wildlife Collisions

Background

The Muskeg River Mine project will involve construction of 17 km of new roads and the upgrading of 6 km of existing roads within the LSA. Construction truck traffic will involve some 20 vehicles per day. Predictions of general traffic to the Project are 260 daily trips during construction and 170 during operations. The use of camps on site will keep such trips to a minimum. Overall traffic levels on the highway north of Fort

McMurray are expected to increase by 8% south of the Suncor turnoff and up to 34% for the highway north of Mildred Lake (Syncrude turnoff).

Virtually all species of wildlife are subject to road mortality. This topic has been the subject of various literature reviews (e.g., Kelsall and Simpson 1987, Jalkotzy et al. 1997), and has been an important concern in construction of energy projects (Priddle 1996). The question is: can road mortality cause a decline in local populations? The answer is yes, but the effects are site-specific, depending on the species and the circumstances (e.g., type of road, volume of traffic etc.). In most cases, the linear extent of roads within a landscape may not be sufficient to significantly affect most species. In specific cases, expensive mitigation plans are being implemented to prevent population declines (e.g., the Trans-Canada Highway through the Bow Valley and Banff National Park). Road mortality adds to the effects of habitat fragmentation and in some cases can threaten the viability of subpopulations of ungulates (Groot Bruinderink and Hazebroek 1996).

Another important issue is that road mortalities are difficult to quantify, and only a fraction of the mortalities that occur are ever reported (Kelsall and Simpson 1987). One reason for low reporting of this information is that mortality data are difficult to obtain; it can be chronic since they are dispersed along many kilometers of complex road networks. Carcasses of small mammals and birds killed on roads are also often quickly scavenged.

Reports of wildlife road mortalities are usually only received if collisions result in human injuries, or if the collision results in expensive repair to the vehicle. Human injuries and vehicle damage only occur with collisions involving large mammals. An important point to emphasize is that road mortalities are similar to "problem" wildlife in that it is largely a management issue. A proactive approach with development of Protection Plans can be effective in reducing wildlife road mortalities over construction and during the longer term. For example, frequencies of road mortalities appear to be related to specific locations, and traffic volume and speed (Oxley et al. and, Jalkotzy et al. 1997). Although mitigation efforts tend to be expensive, they can be applied in a cost-effective manner if information about the potential problem is available or can be obtained.

Ruediger (1996) analyzed the relationship between rare carnivores and highways in the United States, and hypothesized that extirpation of carnivores in the lower 48 states is partially a factor of highway densities. He stated that carnivores are particularly vulnerable to highway habitat fragmentation due to their large home range sizes. He also suggested that impacts to carnivores are positively correlated to highway grade and traffic speed.

The discussion of wildlife road mortalities is common to many different kinds of wildlife. For evaluation purposes, this discussion is divided among large mammals (moose and black bears), small mammals (red-backed voles, snowshoe hares, beavers and fishers) and avifauna.

Moose and Black Bear

Moose and black bears are vulnerable to road mortality (Jalkotzy et al. 1997), partly because they are attracted to roadside verges that have high production of preferred browse/forage and/or they are attracted to salt (Fraser 1979). Moose are subject to highway mortality on the Trans-Canada highway through the Bow Corridor (Woods 1988 and 1990). Other ungulates, such as elk and deer, are attracted to palatable forage on roadsides and use these areas heavily during winter (Hornbeck 1989). Moose have been known to intercept ploughed corridors and use them as travel lanes, increasing their vulnerability to this type of mortality (Child 1983). Although population effects are difficult to determine, road mortalities have been observed to threaten the persistence of a black bear population (Jalkotzy et al. 1997).

Eleven years of wildlife mortality data for roads immediately north of Fort McMurray (Table E11-13) indicate that 67 moose and 19 black bears were killed between 1985 and 1996. The highest number of kills was recorded in 1994/95 for moose (n=18) and 1991/92 and 1995/96 for black bears (n=4). These figures indicate that highway mortality can be substantial. Unreported kills also likely occur.

However, the incremental increase in road kills of moose and black bear can be minimized with appropriate mitigation (see below).

Red-Backed Vole, Snowshoe Hare, Beaver and Fisher

The literature on the impacts of road mortalities on small mammals is sparse, probably because this kind of information is extremely difficult to obtain. Small mammals killed by vehicles may be largely unnoticed and are quickly scavenged. As discussed previously, wildlife of all kinds are subject to road mortality, but the topic has not been researched widely (e.g., Oxley et al. and). In one study that addressed the effects of roads on small mammals, the conclusion was that small mammal mortality on highways did not appear to be detrimental to populations studied (Adams and Geis 1983).

Dabbling Ducks, Ruffed Grouse, Great Gray Owl and Forest Songbirds

Birds of all kinds are frequently killed on roads (Jalkotzy et al 1997). While all bird species whose habitat is bisected with roads are vulnerable to some extent, specific levels of impact are not common in the literature. Dabbling ducks are considered more vulnerable than diving ducks because these birds make greater use of seasonal wetlands along roads (Jalkotzy et al. 1997). Raptors and owls are particularly susceptible to road kills because of their propensity for hunting small mammals within road allowances. Great gray owls have been known to feed on small mammals in road allowances.

Validity of Linkage

This link is considered valid for moose, black bears, snowshoe hares, beavers and fishers because of their relatively large movement and dispersal capabilities. The link is not considered valid for red-backed voles. Road mortalities to red-backed voles are not expected to have population effects because suitable habitat (forested mesic habitats) does not generally occur in close proximity to roads. This link is considered valid for ruffed grouse and great gray owls but not for Cape May warblers, western tanagers or pileated woodpeckers.

Mitigation

Mitigation regarding vehicle-wildlife collisions will include:

- design of straight roads with long lines-of-site where feasible;
- regular mowing of rights of way to increase visibility;
- signage and reduced speed limits (60 km/h) at key wildlife crossing areas within Lease 13;
- use of buses to transport staff;
- construction of camps on-site to reduce traffic volumes;
- minimize size of snow berms along roads during winter; and
- prohibition of the use of salt (NaCl) on roadways during winter.

Linkage Between Wildlife and Interactions With Infrastructure

Background

Project-related infrastructure, other than linear disturbance corridors, that may be responsible for interactions with wildlife, include:

- two 13.9 kv overhead electrical power lines;
- a communication tower;
- out-of-pit tailings pond;
- steam stacks at the extraction facility; and
- in-pit sumps and tailings ponds and external tailings pond for contaminated water.

Table E11-13 Wildlife Mortality Due to Vehicle Collisions, North of Fort McMurray

Year	Wildlife Mortality	Year	Wildlife Mortality
1985-1986[b]	1 wolf - past Alsands bridge 1 deer[a] - between Fort McMurray and Suncor	1991-1992	4 bears - black 7 coyotes 1 fox - swift 2 wolves 6 deer - whitetail 6 deer - unknown 6 moose 1 other mammal 2 other migratory birds
1986-1987	1 deer - half mile north of Suncor gate 1 deer - top of Supertest Hill 1 miscellaneous bird (raven?) - between Suncor and Syncrude site 1 bear cub - bottom of Supertest Hill 1 deer - between AOSTRA and Suncor	1992-1993	2 bears - black 12 coyotes 2 dogs 2 foxes - red 1 wolf 1 fisher 10 deer - whitetail 9 deer - unknown 7 moose 1 other migratory bird 1 other bird
1987-1988	1 coyote - at Syncrude turnoff 1 adult bear - black - sawmill 1 adult bear - black - 1 km past Suptertest Hill 1 moose - at Suncor turnoff 1 moose SE 11-92-10 W4M 1 deer - south of Suncor site 1 deer - south of Syncrude site 1 moose - sawmill	1993-1994	3 bears - black 3 foxes - red 1 weasel - short tail 14 deer - whitetail 10 deer - unknown 10 moose 1 hawk - sharp-shinned
1988-1989	1 night hawk - between Syncrude and Suncor sites 1 horned owl - Suncor turnoff 1 raven - Suncor turnoff 2 deer - sawmill 1 deer - Suncor and AOSTRA turnoff	1994-1995	3 bears - black 3 coyotes 1 squirrel - tree 9 deer - whitetail 4 deer - unknown 3 elk 18 moose 1 bird - other
1989-1990	1 horned owl - between Syncrude and Fort McKay 1 fox - 12-92-10-W4M 1 merlin - bottom of Supertest 1 moose - between first and second bridges, Canterra road 1 lynx - 14 km for Kearl Lake on Canterra road toward Canterra 1 coyote - on Canterra road 1 moose - 19-90-94 - Mobil's winter road by the Clearwater River 1 fox - permanent road 55 km off AOSTRA road	1995-1996	4 bears - black 1 dog 1 fox - red 3 wolves 11 deer - whitetail 8 deer - unknown 8 moose
1990-1991[c]	2 beavers 1 muskrat 1 rabbit 5 deer - whitetail 2 deer - unknown 13 moose		

(a) Likely white-tailed deer.
(b) Source: J. Songhurst, Fish and Wildlife Officer, Alberta Fish and Wildlife, Fort McMurray, pers. comm.
(c) Data collected after 1990 Source: Fort McMurray Fish and Wildlife District. Various locations in Fort McMurray Fish and Wildlife District.

Adapted from BOVAR (1996a).

There are two main aspects of infrastructure that can be expected to interact with wildlife. The two main impacts result from the physical presence of structures and involve:

- bird strikes to towers and poles and associated overhead power lines and other vertical towers, and
- bitumen contamination to wildlife at tailings ponds.

Potential impacts from construction activities involving infrastructure are not included in this discussion. The external, out-of-pit tailings ponds are of primary concern in this regard. Birds are the primary concern with overhead lines, while all vertebrate groups (reptiles, amphibians, birds and mammals) may be affected by the contaminated ponds.

Impacts of other infrastructures such as pipelines and roads have been considered under linkages concerning change in wildlife habitat, change in hunting, trapping and predation, and increased vehicle-wildlife collisions.

Tailings Ponds

The tailings pond for the Project will be 1,039 ha in area, which is much smaller than the tailings ponds of other surface mine oil sands operators. The tailings pond is expected to have a 4-5% bitumen content. The bitumen is expected to float until cool, then it is expected to sink to the bottom of the pond. Before cooling, floating bitumen and bitumen that occurs along shoreline habitats of ponds represents a hazard to amphibians, birds and mammals. Water birds (primarily loons, grebes, pelicans, cormorants, herons, waterfowl, shorebirds and gulls) could be affected during spring and fall migration when they are using waterbodies as stopover, staging and feeding areas. Water birds could also be affected during the breeding season when they are selecting nesting sites. Other birds that use carrion could also be affected by feeding on contaminated birds. Mammals that use shoreline habitats could also be affected.

Effects on wildlife from contaminated ponds associated with oil recovery projects is not well documented in the published literature. However, the mechanism of impact for all vertebrates would be loss of insulating qualities of skin, fur and feathers from body contact by bitumen products. Ingestion and systemic poisoning of bitumen is a secondary concern, but would be a factor for wildlife attempting to groom if the body surface was contaminated. Overall, tailings ponds are considered relatively unattractive to wildlife, as observed at the existing Mildred Lake facility (BOVAR 1996a). Tailings settling basins at Syncrude's Mildred Lake facility impact some 61 birds per year. Similar numbers of birds are reported to have been recovered from Suncor's Lease 86 tailings ponds during 1984, 1987 and 1988 as shown in Table 11-14.

Transmission Lines, Communication Towers and Stacks

An electrical transmission line will be built to provide power to the proposed plant. An electrical substation will be required at the site entrance that will contain breakers and transformers. Mining areas will be supplied with 13.8 kv power lines.

Electrical transmission lines tend to impact birds, particularly large raptors (hawks and eagles), but also other bird species such as cranes and waterfowl. Birds can also be impacted by communication towers and stacks.

Transmission lines generally impact wildlife by electrocution and collision. Electrocution is predominant in large raptors because of their size and behavior. However, electrocution is generally not a problem with high-voltage lines as the conductors are placed far apart (Kroodsma 1978). This prevents birds from touching two conductors at once and being electrocuted. Electrocution can be a problem with low-voltage lines. However, a number of mitigation strategies can be used to lessen this impact (e.g., insulation of ground wires, perch guards to deter birds from perching, use of wooden cross braces instead of steel, APLIC 1996).

Raptors are attracted to transmission lines because they provide perches for hunting and resting and also provide nesting structures. Ravens will also use power line towers as nesting habitat. The effect is amplified in areas where nesting and perching structures are limited (i.e., disturbed areas).

Birds tend to prefer towers with relatively dense lattice work. In one study, 133 pairs of birds used towers along 596 km of power line over 10 years (Steenhof 1994). If transmission lines are constructed properly (i.e., do not electrocute wildlife) they can actually enhance habitat for some raptors.

Collisions with power lines can have an impact on waterfowl as well as other species. The support structures for these facilities are not considered as particularly hazardous although birds can be expected to strike these on occasion (Stout and Cornwell 1976). Bird strikes to wires have been well documented in the literature (Thompson 1978, Savereno et al. 1996). Bird strikes most often occur during spring and fall migration when large flocks of birds are moving, and strikes with wires may occur if flocks take wing during disturbances (Blokpoel and Hatch 1976 in Berger 1995). Such

Table E11-14 Birds Recovered from Suncor's Lease 86 Tailings Ponds During 1984, 1987 and 1988 [(a)]

Species	1984	1987	1988
Waterfowl			
Common Loon			1
Horned Grebe		2	4
Greater White-fronted Goose	1		
Green-winged Teal			2
Teal spp.	1		
Mallard	6	5	2
Northern Pintail	2	3	3
Northern Shoveler	3	2	1
American Widgeon	3	2	2
Aytha spp.	7	10	2
Lesser Scaup		1	4
Common Goldeneye			1
Bufflehead	1	3	1
Canvasback		1	
American Coot	5	4	12
Unidentified Duck		7	
Total	29	42	35
Shorebirds			
Killdeer	4	2	1
Lesser Yellowlegs		3	3
Greater Yellowlegs		1	
Lesser Golden Plover		6	
Caladris spp.	3	13	2
Total	7	25	6
Passerines			
Cliff Swallow			2
Swallow spp.		2	
American Crow		1	
Lapland Longspur		1	
Water Pipit	1		1
Unidentified Passerine	6	3	4
Total	7	7	7
Other			
Red-tailed Hawk			1
American Kestrel	1		1
Great Horned Owl	1		
Snowy Owl			1
California Gull			1
Northern Flicker		1	
Total	2	1	4
Total All Species	45	75	52

(a) Source: Gulley 1985, 1987a, b.

events are likely to be rare. Strikes may occur to a variety of birds, including songbirds, waterbirds and raptors. In a study on migrating waterfowl, 200 to 400 waterfowl, representing 0.2 to 0.4 % of total migrants, were killed during fall migration by a transmission line crossing 32 ha of water (Anderson 1978).

In another study, the effect of stabilizing structures like ground wires was studied. Ground wires can cause more collisions than conducting wires because they tend to be thinner and, therefore, more difficult to detect (Alonso et al. 1994). Ground wires primarily are expected to impact non-migratory, terrestrial birds such as ruffed grouse.

The impact of such hazards is difficult to predict, since such numbers are hard to obtain and often incomplete when available (Berger 1995). Bird strikes are largely unnoticed and hence unreported. One estimate of the number of annual bird strikes against transmission lines was approximately 1 bird/ km (in Berger 1995).

Waterfowl mortality against transmission lines has also been recognized, with the majority of strikes occurring during spring and fall migration. In Manitoba, hawks and eagles accounted for 22% of mortalities on distribution lines (Berger 1995). Birds of prey injured by transmission lines are not uncommon at bird rehabilitation facilities where they are treated and released if possible. Compared to mortality from nonhunting sources, 89% of deaths resulted from disease and botulism poisoning (Stout and Cornwell 1976). Of the 0.1% of waterfowl deaths caused by collision with facilities, 0.065% were caused by collision with wires (other collisions were with vehicles, towers, fences and buildings).

Validity of Linkage

Tailings Ponds

This linkage is valid for dabbling ducks, breeding birds (Cape May warbler, western tanager) and great gray owls. Impacts to beavers from tailings basins were considered to be negligible and impact to moose and black bears extremely low for the Aurora EIA (BOVAR 1996a). The linkage, however, is also valid for animals such as coyotes that may scavenge on oil-contaminated birds on the shores of ponds.

Transmission Lines, Communication Towers and Stacks

Dabbling ducks and other waterfowl are impacted by colliding with power lines (Anderson 1978). Songbirds and woodpeckers may be expected to collide with them, although the incidence of such collisions is likely low (BOVAR 1996a). Upland game birds such as the ruffed grouse do not normally fly high enough to collide with, or be electrocuted by, transmission lines.

Transmission lines may impact great gray owls and other raptors due to their predilection for using transmission lines and posts or towers as perching and/or nesting structures (APLIC 1996).

Mitigation

Mitigation regarding interactions of wildlife with Project infrastructure includes:

- use of an oil recovery system (e.g., booms, skimming devices) on tailings pond;
- use of bird deterrence devices, particularly during the spring and fall migration periods, such as human effigies and propane-fueled cannons;
- maintain vegetation free shoreline in tailings pond;
- participation in the Oil Sands Bird Protection Committee to discuss mitigation results and strategies;
- use markers such as aviation spheres to mark lines;
- use markers such as PVC spirals to mark ground wires;
- insulation of power line ground wires;
- perch guards on power line poles to deter birds from perching; and
- use of raptor-safe construction standards (APLIC 1996);

Monitoring

The following monitoring programs are recommended to assess the efficacy of mitigation for impacts on wildlife mortality:

- direct mortality during site clearing;
- wildlife-tailings pond interactions;
- wildlife-transmission line interactions; and
- wildlife-traffic mortalities.

E11.10.2 Analysis of Key Question: Impacts of Changes in Wildlife Abundance or Diversity

This section details the residual impacts on wildlife abundance and diversity. Section E7 discusses the residual impacts on the overall biodiversity of the LSA. No attempt has been made to estimate the number of animals that may be affected by the development as such estimates are subjective and may be misleading. Rather, the results of the habitat supply analysis and professional judgment were used to classify the magnitude of the impacts.

Impacts are predicted to be Negative in direction and High in magnitude (within the context of the LSA) for all KIRs. Most impacts are related to habitat loss, as most other impacts related to mortality (sensory disturbance, direct mortality due to site clearing, hunting, trapping, vehicle collisions, infrastructure interactions) are mitigable. The geographic extent of the impacts are ranked as Local to Regional for moose, black bears, fishers and dabbling ducks. Impacts on all other KIRs are considered to have a Local geographic extent. Duration is considered to be Moderate for all KIRs and the impacts are considered to be Reversible (see Key Question W-8). Frequency of impacts are considered to be Low, High and season timing to be All Seasons for all KIRs.

E11.11 Key Question W-6: Will the Reclaimed Landscape From the Muskeg River Mine Project Change Wildlife Habitat?

E11.11.1 Analysis of Potential Linkages

Linkage between Reclamation and Replacement of Vegetation Communities

Background

Reclamation of development sites has been shown to be an effective means of replacing vegetation communities, and hence wildlife habitat (e.g., McCallum 1989, Roe and Kennedy 1989).

Use of HSI models to determine the value of reclaimed habitats is an accepted tool for assessments (e.g., Williams 1988, BOVAR 1996). Williams (1988) reviewed fifteen U.S. Bureau of Reclamation projects that used HSI models. He concluded that, while such models represent a definite improvement over the use of professional judgment in reclamation projects, many projects focused on high priority game species at the expense of other, less visible, species. Also, including ubiquitous species with low priority for management as indicators increases HU losses and therefore reclamation needs. He recommended that any reclamation program should include careful assessment of the program's goals and objectives.

The 13-year-old site of the former Alsands project is an example of how the Muskeg River Mine Project site might be reclaimed. While the site is in the early stages of revegetation, it is evident that the land has good potential as wildlife habitat (Golder 1997b). Beavers, in particular, have recolonized the site and are present in large numbers (Fort McKay Environment Services 1996).

Table E11-15 Construction and Operation Related Residual Impacts of Change in Wildlife Abundance or Diversity (Key Question W-5)

KIR	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency
moose	Negative	High	Local - Regional	Moderate	Reversible	Low-High
red-backed vole	Negative	High	Local	Moderate	Reversible	Low-High
snowshoe hare	Negative	High	Local	Moderate	Reversible	Low-High
black bear	Negative	High	Local - Regional	Moderate	Reversible	Low-High
beaver	Negative	High	Local	Moderate	Reversible	Low-High
fisher	Negative	High	Local - Regional	Moderate	Reversible	Low-High
dabbling ducks	Negative	High	Local - Regional	Moderate	Reversible	Low-High
ruffed grouse	Negative	High	Local	Moderate	Reversible	Low-High
Cape May warbler	Negative	High	Local	Moderate	Reversible	Low-High
western tanager	Negative	High	Local	Moderate	Reversible	Low-High
pileated woodpecker	Negative	High	Local	Moderate	Reversible	Low-High
great gray owl	Negative	High	Local	Moderate	Reversible	Low-High

The Oil Sands Vegetation Reclamation Committee is currently preparing guidelines for reclamation of terrestrial vegetation in the oil sands region of Alberta. Objectives of reclamation are to return the land base to equivalent levels of pre-disturbance land use. Important land uses in the region include forestry, wildlife habitat, watershed functions, wetlands, gathering of traditional foods and medicinal plants, and recreation. An integrated approach is being used that will allow for many land uses from the same land base.

The closure planning process for the Muskeg River Mine Project is described in Section E16.

HSI analysis was conducted, using an assumed vegetation community mix, to determine the impacts to wildlife (Golder 1998b).

Reclamation of the Project area and replacement of vegetation communities will affect all KIRs. Early successional species will be immediately affected in that their habitat requirements will be met shortly after reclamation. KIRs that require late seral stages are not expected to recolonize the reclaimed area until the vegetation matures.

Mitigation

The reclamation program itself should be considered as mitigation. However, certain reclamation procedures should be followed to maximize reclamation results:

- design reclaimed landforms to include diversity and microtopographic relief;
- ensure that all slopes are not greater than 4:1;
- design reclaimed vegetation communities to provide key wildlife habitat variables for KIRs;
- use native species in reclamation wherever possible; and
- plan for vegetation community patch size, shape and juxtaposition that approximate those of pre-disturbance conditions.

E11.11.2 Analysis of Key Question: Change in Wildlife Habitat

Moose habitat within the LSA is expected to increase 10% over baseline conditions following closure (Figure E11-16). This is in part due to the recreations of upland habitats preferred by moose that will occur during closure. Impacts to moose over baseline conditions were therefore considered to be positive in direction and low in magnitude (Table E11-16).

Beaver habitat will not be reclaimed to its former extent (Figure E11-17) as some wetlands will be converted to uplands. The total change in HUs for beavers is expected to be -6%. Overall impacts to beavers were considered to be Negative in direction but Low in magnitude. Conversely, habitat for the western tanager (Figure E11-18, a species that prefers uplands, is predicted to increase 189% over baseline conditions. Thus overall impacts to the tanager were considered to be Positive in direction and High in magnitude.

Full details of the changes in habitat for all KIRs is provided in Golder (1998b).

Table E11-16 Change in Wildlife Habitat, Over Baseline Conditions due to Reclamation (Key Question W-6)

KIR	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency
moose	Positive	Low	Local - Regional	Long-Term	Reversible	Low-High
red-backed vole	Positive		Local	Long-Term	Reversible	Low-High
snowshoe hare	Positive		Local	Long-Term	Reversible	Low-High
black bear	Positive		Local - Regional	Long-Term	Reversible	Low-High
beaver	Negative	Low	Local	Long-Term	Reversible	Low-High
fisher	Positive		Local - Regional	Long-Term	Reversible	Low-High
dabbling ducks	Positive		Local - Regional	Long-Term	Reversible	Low-High
ruffed grouse	Positive		Local	Long-Term	Reversible	Low-High
Cape May warbler	Positive		Local	Long-Term	Reversible	Low-High
western tanager	Positive	High	Local	Long-Term	Reversible	Low-High
pileated woodpecker	Positive		Local	Long-Term	Reversible	Low-High
great gray owl	Positive		Local	Long-Term	Reversible	Low-High

E11.11.3 Degree of Concern

The degree of concern for impacts on changes in wildlife habitat due to reclamation were considered to be Low-Moderate Positive for moose, Low-Negative for beavers and High-Positive for western tanagers.

E11.11.4 Monitoring

Monitoring of KIR habitat will be required to 1) determine the success of establishment of early successional communities; and 2) determine that the communities are established on a successional pathway that will result in the desired late successional communities. Monitoring include measurement of KIR HSI variables.

E11.12 Key Question W-7: Will the Reclaimed Landscape From the Muskeg River Mine Project Change Wildlife Health?

E11.12.1 Analysis of Potential Linkages

Following closure of the Muskeg River Mine Project and reclamation of the site, wildlife may be attracted into the area. This key question addresses the potential for impacts to the health of wildlife that forage within the LSA following closure of the Project under far future equilibrium conditions. The wildlife receptors selected for evaluation of this key question include: deer mouse, snowshoe hare, moose, ruffed grouse, beaver and mallard.

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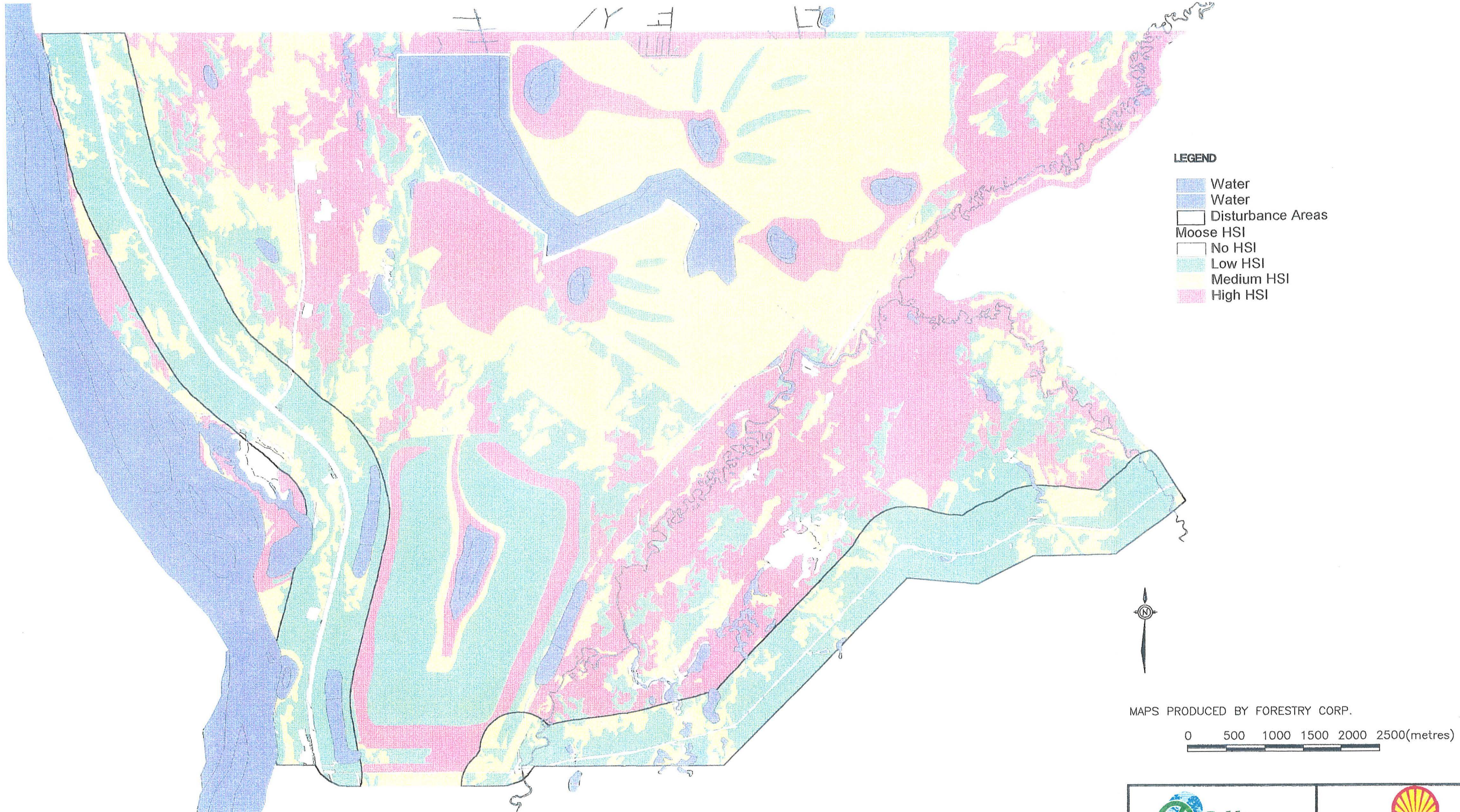

Golder Associates

SHELL CANADA LIMITED

LOCAL STUDY AREA
RECLAIMED MOOSE HSI
DISTURBANCE INCLUDED

12 DEC 97	Figure E11 - 16	DRAWN BY: RFM/GIS

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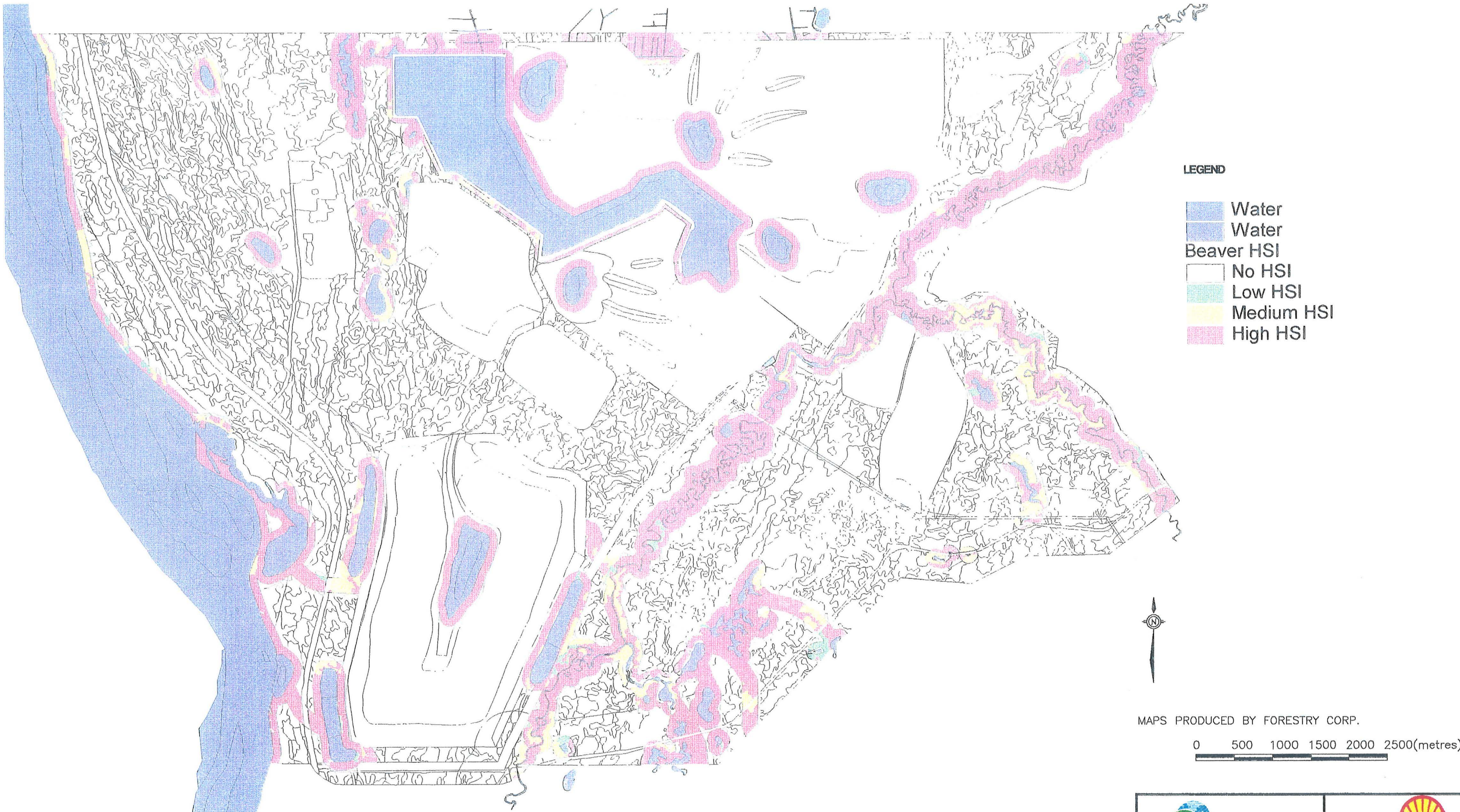

Golder Associates

SHELL CANADA LIMITED

LOCAL STUDY AREA
RECLAMATION BEAVER HSI

12 DEC 97	Figure E11 - 17	DRAWN BY: RFM/GIS

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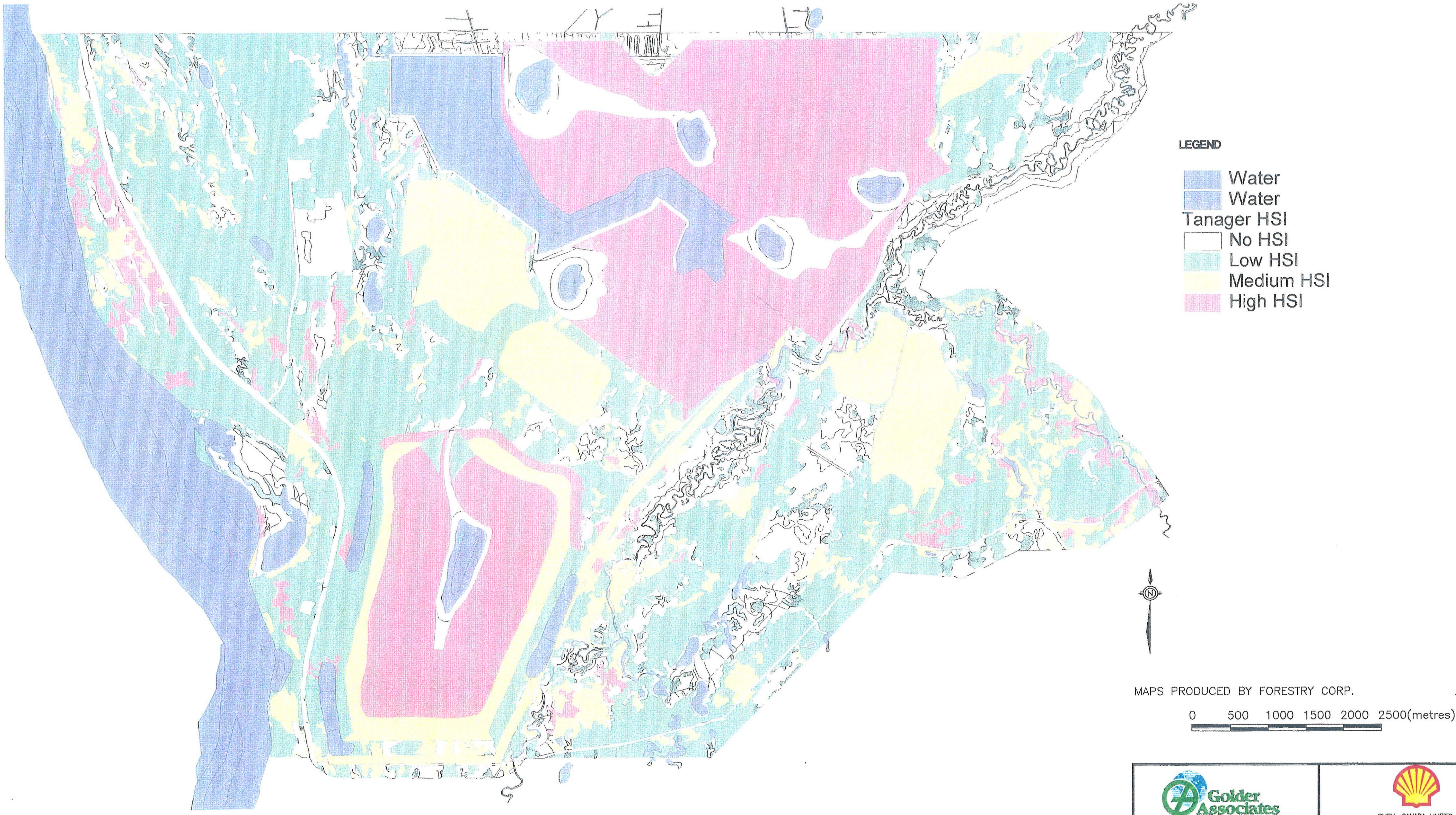


Golder Associates

SHELL CANADA LIMITED

LOCAL STUDY AREA
RECLAIMED TANAGER HSI

12 DEC 97	Figure E11 - 18	DRAWN BY: RFM/GIS

Linkage between Changes in Water Quality and Wildlife Health

The linkage between closure design and potential changes in water quality has been addressed in Section E5. The linkage was considered valid. This section evaluates the validity of the linkage between changes in water quality and wildlife health.

Potential sources of drinking water associated with the reclaimed landscape include ponded surface water, streams, wetlands, ponds and rivers, such as the Muskeg and Athabasca. The validity of the linkage between Muskeg River water quality changes and wildlife health was discussed previously for key question W-2. This linkage was determined to be valid both during operation and after closure, based on the results of chemical, receptor and exposure pathway screenings. However, only one chemical, molybdenum, was identified in the chemical screening process for exposures to moose and black bears. No chemicals of concern were identified in Muskeg River water for the other wildlife species evaluated.

Wildlife foraging on the reclaimed landscape may also drink water from other sources (i.e., ponded surface water, streams, wetlands). In the short-term, some CT seepage will occur on reclaimed areas of the LSA, but predictions indicate that CT seepage will not impact the reclaimed landscape water quality in the far future. Therefore, since this linkage analysis investigates 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. Therefore, a secondary chemical screening was also conducted using undiluted sand seepage concentrations. No chemicals of concern were identified for all wildlife species evaluated (Appendix X.1).

Since elevated molybdenum concentrations, receptors and exposure pathways may apparently co-exist, a potential linkage exists between water quality changes and wildlife health following closure.

Linkage between Changes in Soil Quality and Wildlife Health

It is unlikely that wildlife will be directly exposed to CT, because these deposits will be buried below a thick capping layer of sand, muskeg and vegetation. Soil concentrations that wildlife may be exposed to will be comparable to natural background levels; hence incidental ingestion of soils will not be a significant source of Project-related chemicals. For this reason, a linkage between soil quality and wildlife health was considered invalid.

Linkage between Changes in Terrestrial Plant Quality and Wildlife Health

Wildlife may be exposed to chemicals from the reclaimed landscape via ingestion of plants. Some of these plants may be growing on top of capped CT deposits. At equilibrium, the CT will be consolidated below 11 to 13 metres of overburden or tailings sand and a surface layer (i.e., 20 cm) of muskeg. Therefore, plant roots may extend into the layer of overburden or tailings sand overlying the CT deposit, but will not extend into the CT deposit itself.

Limited measured data are available for plants growing in overburden or tailings sand. In a recent study, metal concentrations in poplar leaves, spruce needles and cattail shoots were measured. These plants were growing in the Tar Island Dyke area of Suncor, in soils consisting of tailings sand capped with 15 cm of muskeg (Golder 1997r). The geometric mean of these data were used for chemical screening of inorganic chemicals. Since no measured data were available for PAHs in plants growing on reclaimed landscapes, plant tissue concentrations were estimated based on the chemistry of overburden and tailings sand and bioconcentration factors (BCF) for plant uptake (Travis and Arms 1988), according to the following equation:

$$\text{plant concentration} = \text{BCF} * \text{soil concentration}$$

A chemical screening process was conducted to determine whether the measured and/or predicted plant concentrations may have any adverse effect on wildlife health. Detailed screening tables are presented in Appendix X.1. The following nine chemicals were identified for further evaluation in the risk assessment for the wildlife species indicated in parentheses:

- barium (moose, snowshoe hare, deer mouse)
- boron (moose)
- mercury (deer mouse)
- molybdenum (moose, deer mouse)
- nickel (deer mouse)
- selenium (moose, deer mouse)
- strontium (deer mouse)
- vanadium (moose, snowshoe hare, deer mouse)
- zinc (deer mouse, ruffed grouse)

Since elevated chemical concentrations, receptors and exposure pathways may apparently co-exist, a potential linkage exists between plant quality changes and wildlife health following closure.

Linkage between Changes in Terrestrial Invertebrate Quality and Wildlife Health

Some of the wildlife species selected as receptors for this assessment feed on terrestrial invertebrates (i.e., deer mouse, ruffed grouse). On reclaimed areas of the site, a 20 cm layer of muskeg will be applied to all disturbed areas. Most terrestrial invertebrates would live within this layer, which is considered to be equivalent in chemistry to the muskeg soils in natural areas of the LSA. Since terrestrial invertebrate exposures in the capping layer of reclaimed areas of the site would be similar to exposures in undisturbed areas of the site, a linkage between terrestrial invertebrates and wildlife health was considered to be invalid.

Linkage between Changes in Aquatic Plant Quality and Wildlife Health

Some of the wildlife species selected as receptors for this assessment feed on aquatic plants (i.e., moose, mallard and beaver). For these receptors, a chemical screening process was conducted to determine whether there is a potential for adverse health effects in these wildlife species from ingestion of aquatic plants growing in wetlands and open water areas of the reclaimed landscape. Data from a study in which plants were growing in constructed wetlands on a reclaimed landscape were used for chemical screening. Detailed screening tables are presented in Appendix X.1. No chemicals of concern were identified for mallards or beavers. The following two chemicals were identified for further evaluation in the risk assessment for moose:

- barium
- boron

Since elevated chemical concentrations, receptors and exposure pathways may apparently co-exist, a potential linkage exists between potential changes in aquatic plant quality and wildlife health following closure.

Linkage between Changes in Aquatic Invertebrate Quality and Wildlife Health

A certain portion of the diet of mallards and other waterfowl consists of aquatic invertebrates. Therefore, a chemical screening process was conducted to determine whether there is a potential for adverse health effects to mallards from ingestion of aquatic invertebrates from wetlands and open water areas of the reclaimed landscape. Data from a study in which aquatic invertebrates were living in constructed wetlands on a reclaimed landscape were used for chemical screening. Detailed screening tables are presented in Appendix X.1. The following two chemicals were identified for further evaluation in the risk assessment for mallards:

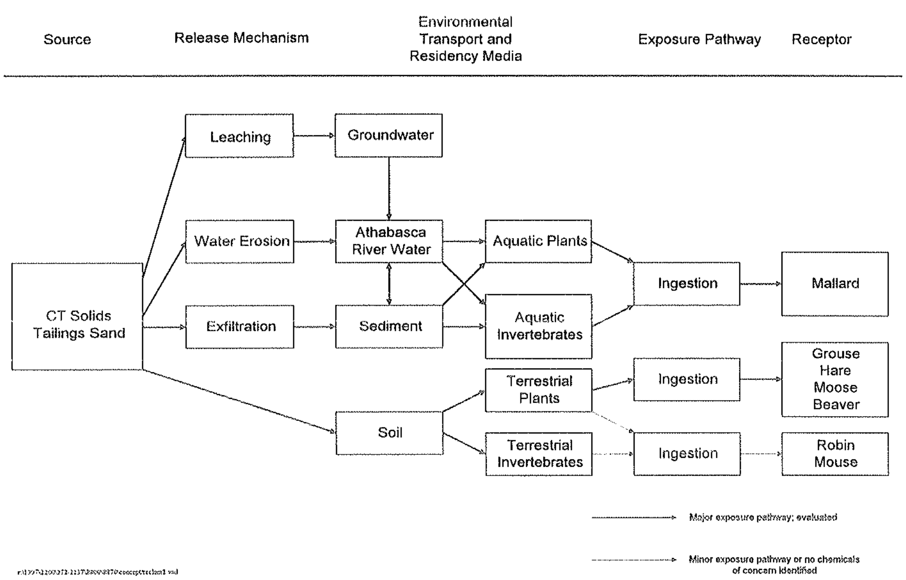
- barium
- zinc

Since elevated chemical concentrations, receptors and exposure pathways may apparently co-exist, a potential linkage exists between potential changes in aquatic invertebrate quality and wildlife health following closure.

E11.12.2 Analysis of Key Question

Several chemicals were identified for further evaluation in the risk assessment for conceptual model W-7 (Figure E11-19), based on chemical screening of measured or predicted concentrations in water, terrestrial plants, aquatic plants and aquatic invertebrates. For the purposes of this linkage analysis, any chemical that was retained for one media was evaluated in all media (i.e., water, terrestrial plants, terrestrial invertebrates, aquatic plants and aquatic invertebrates), where data were available, to ensure a conservative assessment of combined exposure on the reclaimed landscape. Although the linkage between terrestrial invertebrates and wildlife health was considered invalid, to ensure that the complete diet of all wildlife receptors was evaluated in the exposure model, exposures to terrestrial invertebrates were considered for animals that consume this food source.

Figure E11-19 W-7: Conceptual Model for the Reclaimed Landscape Scenario



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. 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 assessment, a wildlife species population was defined as a hypothetical population foraging within the boundaries of the LSA following closure under far future equilibrium conditions. This area 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.

The wildlife exposure model was developed to compute chemical intake for wildlife populations, taking into account spatial differences in chemical concentrations and use of the reclaimed landscape. 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. 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 Ecological Land Classification (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 as a result of foraging uptake (refer to Appendix X.3 for equations).

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.

Results of the exposure modelling therefore provide probabilistic distributions of the intake rate distribution expected for all individuals of a hypothetical population for a given species foraging within the LSA boundaries following closure of the Muskeg River Mine Project. For further details of the model, refer to Appendix X.3.

ER values (median and 90th percentile) for the hypothetical wildlife populations are presented in Table E11-17. Further details of daily intake rates and probability distributions of ER values for each animal are provided in Appendix X.3.

Table E11-17 Exposure Ratio Values for the Reclaimed Landscape Scenario

Chemical	Median ER	90th Percentile ER
Ruffed Grouse		
Zinc	0.10	0.46
Mallard		
Barium	0.05	0.08
Zinc	0.20	0.30
Deer Mouse		
Barium	1.16	1.44
Mercury	0.0014	0.0018
Molybdenum	0.47	0.60
Nickel	0.0019	0.0056
Selenium	0.03	0.07
Strontium	0.000016	0.000077
Vanadium	2.94	3.62
Zinc	0.01	0.10
Snowshoe Hare		
Barium	0.24	0.46
Vanadium	0.25	0.66
Moose		
Barium	0.04	0.10
Boron	0.06	0.15
Molybdenum	0.60	1.63
Selenium	0.00029	0.0055
Vanadium	0.28	0.74

ER values for boron, mercury, nickel, selenium, strontium and zinc were less than 1.0 for all simulations and wildlife species modelled. Therefore, no impacts to wildlife health were predicted for these chemicals. In some cases, ER values marginally exceeded 1 (i.e., barium and vanadium for the deer mouse and molybdenum for the moose). However, based on the number of conservative assumptions employed in the risk assessment (i.e., exposure-based and toxicity-based), it is unlikely that the predicted exposures would result in adverse effects to wildlife populations.

E11.12.3 Residual Impact Classification and Degree of Concern

No residual impacts were identified for mallards, ruffed grouse, beaver or snowshoe hare. The residual impact classification for the health of deer mice and moose inhabiting the reclaimed landscape in the far future is considered to be negligible in magnitude due to the conservatism used in the assessment. However, due to the uncertainty regarding the potential chronic effects of naphthenic acids present in water releases, the impact is classified as follows:

Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
negative	low	local	long-term	reversible	medium	low

Currently there is an industry initiative to collect the required data to resolve the issue of chronic toxicity of naphthenic acids.

Certainty

The assessment of potential impacts to wildlife foraging within the LSA following closure was based on a number of conservative assumptions, including the following:

- it was assumed that the foraging areas of all wildlife species would be confined to the LSA;
- distributions of measured or conservatively predicted concentrations in water, plants and invertebrates were used;
- daily ingestion estimates for water, plants and prey represent reasonable maximum exposure values for the wildlife evaluated;
- oral bioavailability was set to a maximum of 100%;
- combined exposure to water, terrestrial plants, aquatic plants, terrestrial invertebrates and aquatic invertebrates was considered, according to the dietary requirements of each wildlife species evaluated; and
- toxicity reference values were developed to be protective of wildlife populations under chronic exposure conditions.

Due to the conservatism involved in the risk assessment for wildlife foraging within the LSA following closure of the Project, it is very unlikely that potential risks have been underestimated. However, some uncertainty exists with respect to the following:

- limited available data for tissue concentrations in plants growing in overburden or tailing sand;
- use of bioconcentration factors for uptake of chemicals into plants grown in overburden or natural soils;
- limited available data for metal and PAH concentrations in overburden, tailings sand and natural soils;
- lack of a toxicity reference value for wildlife concerning naphthenic acids; and
- possible interactions of chemical mixtures.

As noted previously for key questions W-2 and W-4, it is unlikely that evaluation of naphthenic acids or interactions of chemical mixtures will affect the conclusions presented above. However, some uncertainty exists with respect to chemical uptake into plants grown in overburden or tailings sand and chemical concentrations in reclamation materials.

E11.12.4 Monitoring

Due to the uncertainty associated with uptake of chemicals by plants growing in overburden and tailings sand and the distribution of chemical concentrations in reclamation soils, further study may be initiated to address this issue. Shell anticipates becoming a member of the Environmental Effects Monitoring (EEM) Subcommittee of the Regional Air Quality Coordinating Committee (RAQCC) for South Wood Buffalo. The EEM Subcommittee is presently planning a plant and animal tissue study in 1998.

E11.13 Key Question W-8: Will the Reclaimed Landscape From the Muskeg River Mine Project Change Wildlife Abundance or Diversity?

E11.13.1 Analysis of Potential Linkages

Linkage Between Change in Access and Change in Hunting, Trapping and Predation

Background

Following successful reclamation and closure of the Muskeg River Mine Project, the development area will be opened to the public for those land uses deemed appropriate. It is likely that hunting and trapping will be among such land uses.

While the majority of the roads and other corridors within the development area will be reclaimed, some roads will remain. These will provide access to the wildlife resources in the LSA. While it is well-known that increased access to an area can have impacts on wildlife populations due to uncontrolled hunting, it is not the Project's responsibility to control hunting within the reclaimed lands. Rather, it is a provincial government responsibility to manage the wildlife resource through harvest limits. Similarly, setting trapping harvest levels is a government responsibility.

Roads can increase wolf access to prey, particularly in winter if the roads are cleared of snow. As most roads within the LSA will be reclaimed, and since removing roads will not be ploughed in winter, impacts of increased predation by wolves on ungulates will not be a factor after closure.

Validity of Linkage

This linkage is valid for game (moose, black bears, ducks, grouse) and furbearer (beavers, fishers) species.

Mitigation

Mitigation for the effects of access will be reclamation of all roads and other linear corridors to vegetation communities that will support the desired end land uses. Setting of game and furbearer harvest levels is the responsibility of the provincial government.

E11.13.2 Analysis of Key Question: Change in Wildlife Abundance

Impacts of closure on wildlife will primarily be due to changes in habitat as discussed for Key Question W6. changes due to hunting and trapping will be regulated by the government and increased predation due to increased access will not occur.

Impacts were therefore estimated to be Low in magnitude and Positive in direction for moose, Low and negative for beavers and High and Positive for western tanagers (Table E11-18).

E11.13.3 Degree of Concern

The degree of concern for this Key Question was considered to be Low-Moderate Positive for moose, Low Negative for beavers and High Positive for western tanager.

Table E11-17 Impact of Reclamation on Wildlife Abundance and Diversity (Key Question W-8)

KIR	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency
moose	Positive	Low	Local	Moderate	Reversible	Low-High
red-backed vole	Negative		Local	Moderate	Reversible	Low-High
snowshoe hare	Negative		Local	Moderate	Reversible	Low-High
black bear	Negative		Local	Moderate	Reversible	Low-High
beaver	Negative	Low	Local	Moderate	Reversible	Low-High
fisher	Negative		Local	Moderate	Reversible	Low-High
dabbling ducks	Negative		Local	Moderate	Reversible	Low-High
ruffed grouse	Negative		Local	Moderate	Reversible	Low-High
Cape May warbler	Negative		Local	Moderate	Reversible	Low-High
western tanager	Positive	High	Local	Moderate	Reversible	Low-High
pileated woodpecker	Negative		Local	Moderate	Reversible	Low-High
great gray owl	Negative		Local	Moderate	Reversible	Low-High

E11.13.4 Monitoring

Monitoring of wildlife numbers will be required on reclaimed lands. As many KIRs depend on mid to late forest seral stages, monitoring of these species numbers will not be useful, at least not in the short-term. Rather, monitoring for these KIRs in the short-term should be based on whether the reclaimed area has been successfully set on a successional pathway that will eventually result in good habitat for the KIR of concern. Certification should be achieved once it has been demonstrated that early successional wildlife species have recolonized the development site and that the vegetation has been set on its desired successional pathway.

E11.14 Summary of Wildlife Residual Impacts and Degrees of Concern

A summary of residual impacts and degrees of concern are provided in Table E11-19.

Table E11-19 Summary of Wildlife Residual Impacts and Degrees of Concern

Key Question	KIR	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
W-1	moose	Negative	High	Local-Reg.	Moderate	Reversible	Low-High	Moderate-High
	red-backed vole	Negative	High	Local	Moderate	Reversible	Low-High	Moderate
	snowshoe hare	Negative	High	Local	Moderate	Reversible	Low-High	Moderate
	black bear	Negative	High	Local-Reg.	Moderate	Reversible	Low-High	Moderate-High
	beaver	Negative	High	Local	Moderate	Reversible	Low-High	Moderate
	fisher	Negative	High	Local-Reg.	Moderate	Reversible	Low-High	Moderate-High
	dabbling ducks	Negative	High	Local-Reg.	Moderate	Reversible	Low-High	Moderate-High
	ruffed grouse	Negative	High	Local	Moderate	Reversible	Low-High	Moderate
	Cape May warbler	Negative	High	Local	Moderate	Reversible	Low-High	Moderate
	western tanager	Negative	High	Local	Moderate	Reversible	Low-High	Moderate
	pileated woodpecker	Negative	High	Local	Moderate	Reversible	Low-High	Moderate
	great gray owl	Negative	High	Local	Moderate	Reversible	Low-High	Moderate
W-2	all	Negative	Low	Local	Long-term	Reversible	Medium	Low
W-3	all	not applicable	not applicable	not applicable	not applicable	not applicable	not applicable	Negligible
W-4	all	Negative	Low	Local	Long-term	Reversible	Medium	Low
W-5	moose	Negative	High	Local-Reg.	Moderate	Reversible	Low-High	Moderate-High
	red-backed vole	Negative	High	Local	Moderate	Reversible	Low-High	Moderate
	snowshoe hare	Negative	High	Local	Moderate	Reversible	Low-High	Moderate
	black bear	Negative	High	Local-Reg.	Moderate	Reversible	Low-High	Moderate-High
	beaver	Negative	High	Local	Moderate	Reversible	Low-High	Moderate
	fisher	Negative	High	Local-Reg.	Moderate	Reversible	Low-High	Moderate-High
	dabbling ducks	Negative	High	Local-Reg.	Moderate	Reversible	Low-High	Moderate-High
	ruffed grouse	Negative	High	Local	Moderate	Reversible	Low-High	Moderate
	Cape May warbler	Negative	High	Local	Moderate	Reversible	Low-High	Moderate
	western tanager	Negative	High	Local	Moderate	Reversible	Low-High	Moderate

E12 HUMAN HEALTH IMPACT ANALYSIS

E12.1 Introduction

This section of the Muskeg River Mine Project (the Project) EIA provides information as required by the Project Terms of Reference (TofR) issued on November 7, 1997 (AEP 1997a). Specifically, the following are addressed:

- discussions on the potential implications of expected air quality for environmental protection and public health (TofR, Section 4.2);
- discussions of the implications for any differences with surface water quality guidelines for short- and long-term water quality and existing users (TofR, Section 4.8);
- description of the aspects of the Project that may have implications for public health, discussing the measures to be taken to prevent or minimize the potential for adverse health effects;
- description of plans to participate in the Alberta Oil Sands Community Exposure and Health Effects Assessment Program currently under way in the Fort McMurray area;
- provision of an outline of the proposed emergency response plan; and
- discussion of mitigation plans that will be implemented to ensure work force and public safety during construction and operation of the Project (TofR, Section 7.0); and
- identification of components of the Project that might have the potential for creating increased noise levels and discuss the implications and measures to mitigate (TofR, Section 4.2).

Section D1 and D12 provide details on the human health baseline for the Project. Discussions on the potential cumulative effects on health associated with the Project and regional operations are addressed in Section F1 and F12.

The human health impact assessment was conducted to evaluate the potential for adverse effects to human health as a result of activities of the Muskeg River Mine Project (the Project). Concerns have been raised by stakeholders regarding the potential for adverse human health effects on people from exposure to chemicals in water releases, air emissions and local country foods (i.e., berries, leaves, medicinal vegetation and game meat).

This human health impact analysis considers the following major items:

- chemical release sources:
  - water releases from the Project during operation and following closure,
  - air releases from the Project during operation, including: (i) extraction and utilities; (ii) vehicle emissions; (iii) emissions

from tailings settling ponds; and (iv) volatile emissions from mine surfaces,
- observed concentrations in fish from the Athabasca River,
- observed concentrations in plants growing off-site in potentially impacted areas,
- predicted concentrations in plants to be grown on the reclaimed landscape, and
- observed concentrations in bison pastured on reclaimed landscape;

- pathway-specific and multimedia exposures for local residents;
- traditional land use, including hunting/trapping/gathering activities;
- reasonable maximum exposures likely to be incurred by local residents under various scenarios; and
- evaluation of carcinogenic and non-carcinogenic endpoints for health effects.

E12.2 Potential Linkages and Key Questions

Linkages between Project activities and human health impacts are presented in Figures E12-1 and E12-2. Triangles indicate links to other components. If further clarification of these environmental changes is necessary, please refer to the appropriate component. Key questions were defined to guide the subsequent analyses for the human health component and are listed below. The information which follows in parentheses refers to whether the postulated effect is: (a) incremental (i.e., Project-based) or cumulative (i.e., all regional sources); (b) caused by exposure from a single medium or multimedia exposure; and (c) due to the operational or closure phase of the Project.

HH-1: Will Water Releases From the Muskeg River Mine Project Change Human Health? ***(incremental/single medium/operation and closure phases)***

Water releases from the Project may result in exposure of people who use off-site waterbodies for recreational activities, such as swimming, boating, fishing and hiking, during operational and following closure of the Project. The waterbodies affected by the Project are currently not used as a regular source of drinking water for local residents, but recreational users may occasionally drink water from these sources in off-site areas.

HH-2: Will Air Emissions From the Muskeg River Mine Project Change Human Health? ***(incremental/single medium/operation phase)***

This question focuses on all air emissions from the Project that may be dispersed by winds to nearby residential communities, such as Fort McKay and Fort McMurray.

HH-3: Will Consumption of Local Plants and Game Animals Affected by the Muskeg River Mine Project Change Human Health? *(incremental/single medium/operation phase)*

Area residents are concerned about the quality of the country foods that are harvested in close proximity to oil sands activities. For this reason, the potential for adverse effects due to the consumption of local plants (i.e., berries, leaves and roots) and game animals (e.g., moose, snowshoe hare, ruffed grouse) was evaluated.

HH-4: Will the Combined Exposure to Water, Air, Plants and Game Animals Affected by the Muskeg River Mine Project Change Human Health? *(incremental/multimedia/operation phase)*

Area residents may be exposed to chemicals through a variety of different media. For this reason, it is necessary to evaluate the combined exposure that might be incurred by area residents who are exposed to water, air, plants and game animals affected by the Project.

HH-5: Are Sufficient Procedures in Place to Assure Worker Health and Safety During Construction and Operation of the Muskeg River Mine Project? *(operation phase)*

Shell Canada Limited has extensive corporate and facility-based programs in worker health and safety. This key question examines how these programs integrate with the Project.

HH-6 Will Noise From Muskeg River Mine Project Activities During Construction and Operation Unduly Affect People Who Reside in the Local Area?

Heavy machinery and other on-site activities are likely to increase the background and peak noise levels during construction and throughout the operational phase. Hence it is of interest to understand the scope and magnitude of the potential impacts arising from Project noise.

HH-7: Will the Release of Chemicals From the Reclaimed Landscape Change Human Health? *(incremental/multimedia/closure phase)*

Following closure of the Project, the land will be reclaimed and revegetated, eventually attracting wildlife into the area. Hunters and trappers may live on these reclaimed landscapes for extended periods of time, and possibly incur exposures to local water, plants and game animals. Local plants and game meat may also be dietary components for future local residents. For these reasons, it is necessary to evaluate the potential for adverse health effects from use of the reclaimed landscape.

E12.3 Study Area Boundaries

The study area boundaries for human health are defined by the water and air components and are discussed in detail in Section D1.

E12.4 Key Indicator Resources

The key aspect for this component of the impact assessment is human health. For the operation and closure phases of the Project, potential human health effects include consideration of adults and children that may live in local residential communities and remote sites within the RSA.

E12.5 Methods

E12.5.1 Sources of Data

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

- water quality data summarized in Section E5;
- fish quality data summarized in Section E6;
- air quality data summarized in Section E2;
- plant tissue quality data summarized in Sections E12.8 and E12.12 and Appendix X.7;
- game meat tissue quality data summarized in Sections E12.8 and E12.11 and Appendix X.4;
- public health information from the Northern River Basins Study (NRBS); and
- Shell Canada Limited health and safety documentation.

E12.5.2 Impact Analysis

The first step of the human health impact analysis was to determine whether a certain Project-related activity has the potential to cause a change in environmental chemical exposure that might affect human health. Figures E12-1 and E12-2 show the linkages between Project activities, environmental changes and key questions.

Each potential link between environmental changes (e.g., water releases, air releases) and human health was initially evaluated qualitatively using principles of a screening level risk assessment to determine the validity of each linkage based on specific activities of the Project (i.e., whether a certain Project-related activity could result in an environmental change that might adversely affect human health). Subsequently, quantitative risk assessments were conducted, and the results were evaluated against criteria

Figure E12-1 Linkage Diagram for Human Health for Construction and Operation Phases of the Muskeg River Mine Project

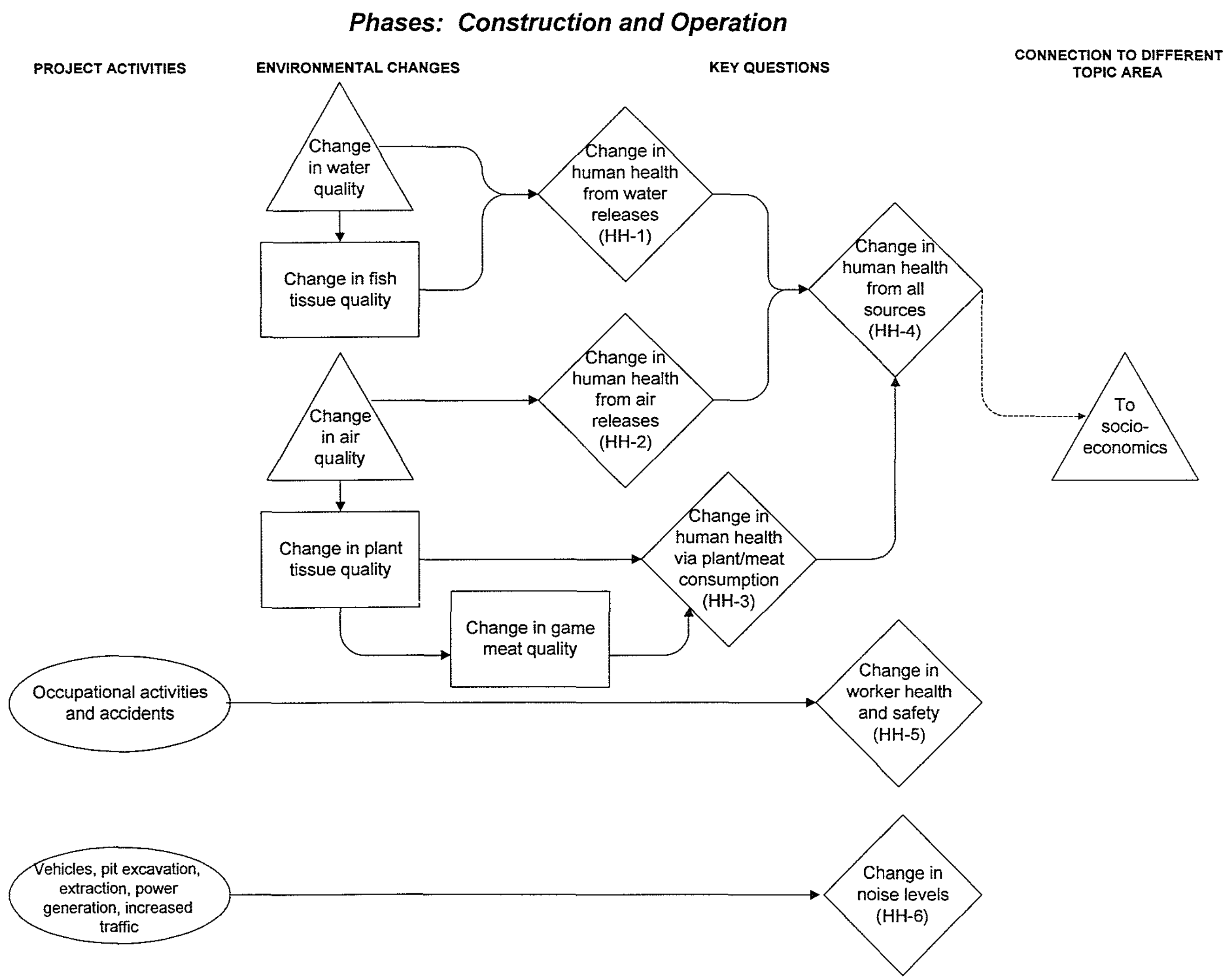
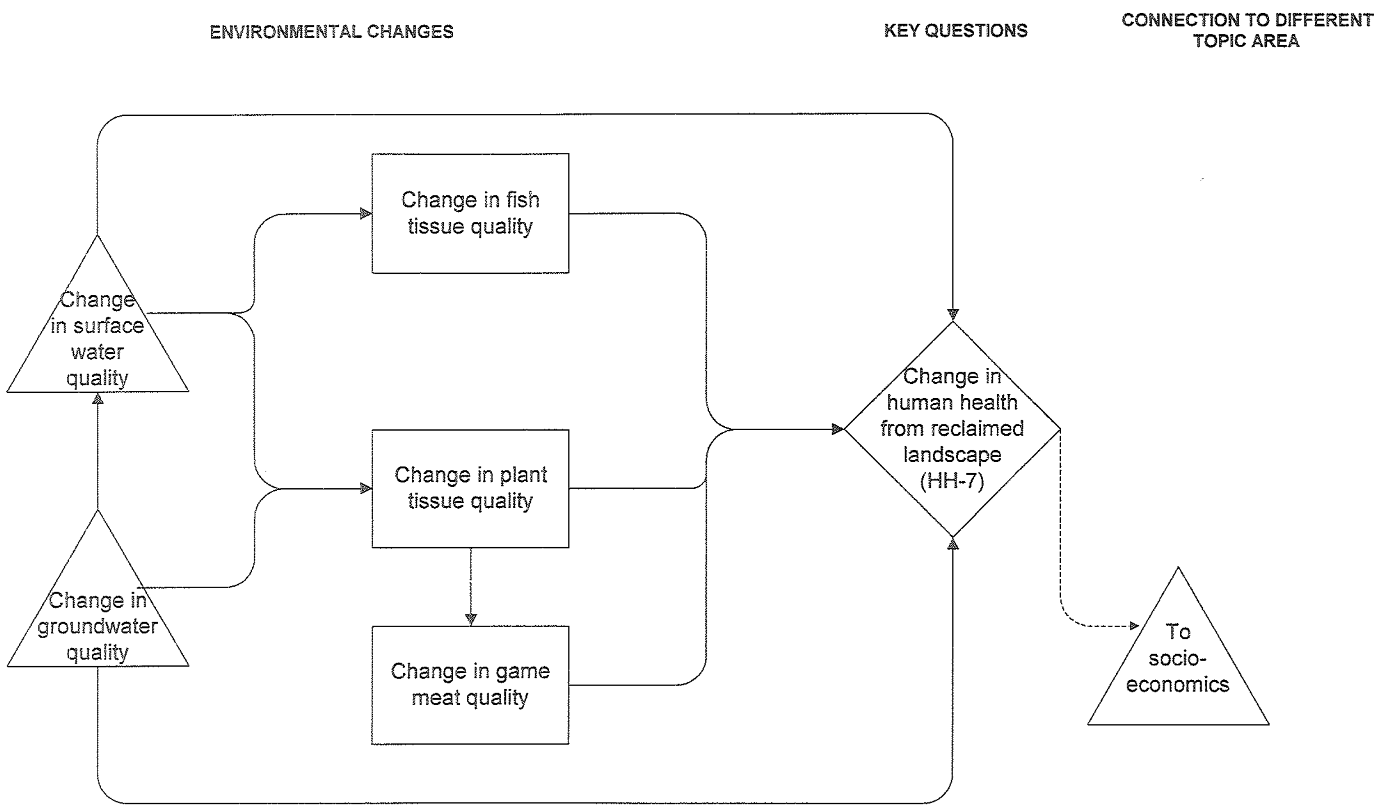


Figure E12-2 Linkage Diagram for Human Health for Closure Phase of the Muskeg River Mine Project

Phase: Closure



which define the degree of concern that should be ascribed to the findings. These criteria are defined later (Section 12.5.4).

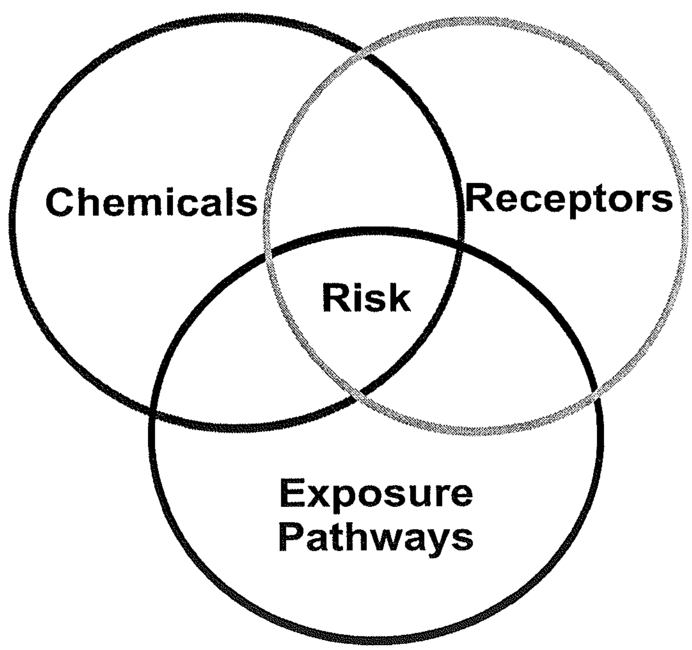
The overall risk assessment approach used to evaluate the linkages is summarized in the following section. Supporting documentation for the risk assessment is provided in Appendix X.

E12.5.3 Risk Assessment

General Concepts

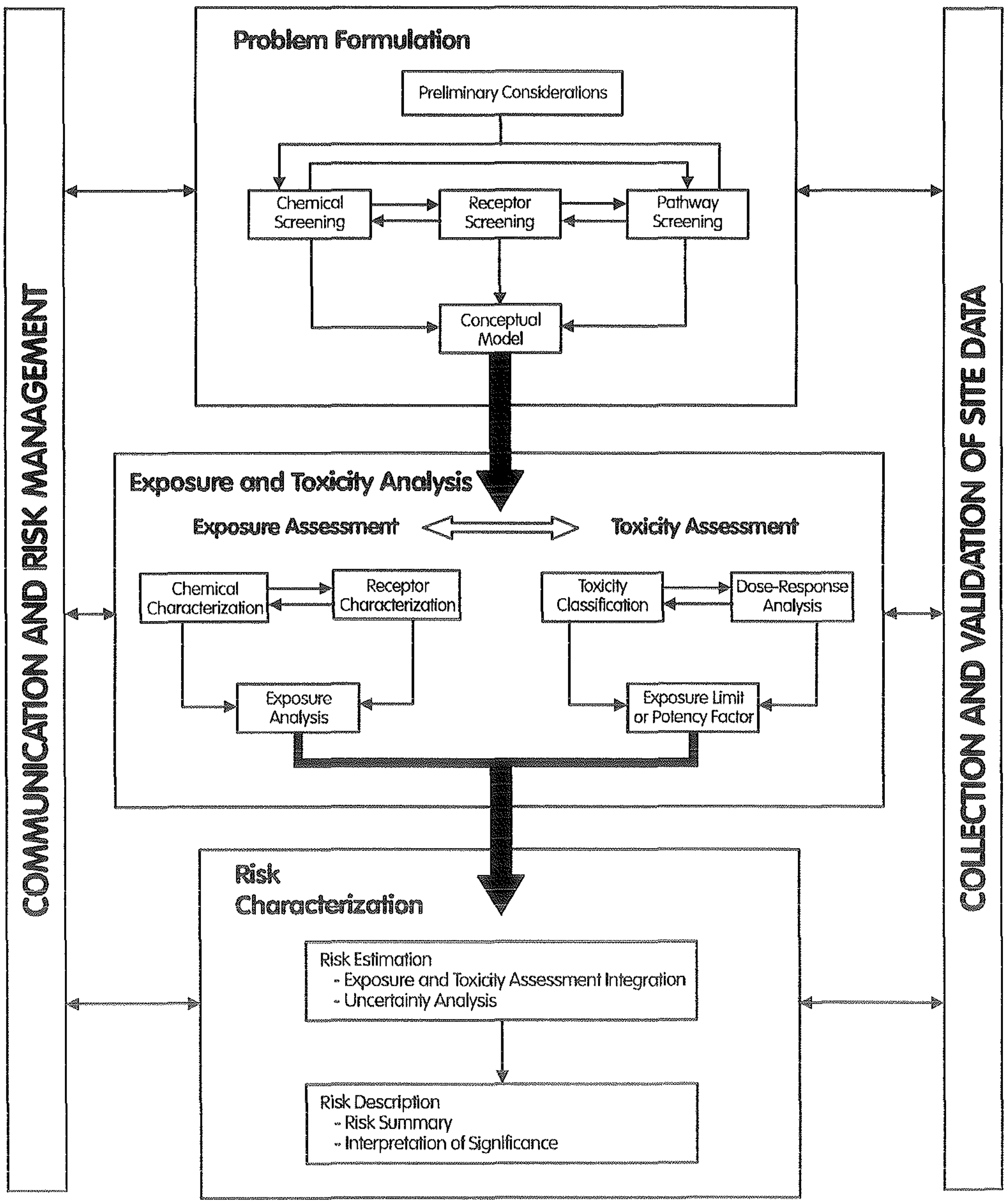
A risk assessment was conducted to evaluate whether activities associated with the Project might adversely affect people. This risk assessment was done according to established human health risk assessment protocols endorsed by Health Canada (Health Canada 1994) and risk assessment principles as outlined in a report to Health Canada (Health Canada 1995). The potential for a health risk to arise from environmental substances is predicated on the co-existence of three elements, as illustrated in Figure E12-3: i) chemicals must be present at hazardous concentrations; ii) receptors (i.e., people) must be present; and iii) exposure pathways must exist between the source of the chemicals and people. In the absence of any one of the three elements outlined in Figure E12-3, health risks cannot occur.

Figure E12-3 Risk Components



The process followed a widely recognized framework for environmental health risk assessment, as illustrated in Figure E12-4 (Health Canada 1995). The framework progresses from a quantitative initial phase (Problem Formulation), through Exposure and Toxicity Analysis and culminates in quantitative Risk Characterization. The following sections provide further insight to these specific phases.

Figure E12-4 Risk Assessment Framework



Problem Formulation

The Problem Formulation phase of a risk assessment is a conservative screening-level assessment of possible impacts on health. The objective of the Problem Formulation was to develop a focused understanding of how chemical releases from the Project might affect the health of people that currently use adjacent areas for recreation, live in nearby residential communities, and/or may in the future use the reclaimed landscape. This was achieved by considering the attributes of the site, identifying the human activity that is expected to occur on-site and in nearby off-site areas, focusing on the chemicals that are likely to be present at concentrations that may be hazardous, and identifying the plausible exposure pathways between chemicals and receptors.

Problem Formulation is the critical initial phase of the risk assessment and involves consideration of three major elements, as illustrated in Figure E12-4:

- Preliminary Considerations: characterization of the site and scope of the problem;
- Screening Process: identification of the chemicals, exposure pathways and human receptors of greatest concern; and
- Development of the Conceptual Model: a visual representation of the environmental fate and exposure pathways by which a chemical may come in contact with the receptors of concern.

The problem formulation process (or screening level assessment) was conducted for each key question. Where the problem formulation indicated a potential linkage between Project activities and human health (i.e., presence of elevated chemical concentrations, receptors and exposure pathways), a detailed risk assessment was carried out to further investigate the potential impact. Where the results of the problem formulation indicated no potential linkage between Project activities and human health, no further evaluation was done.

Preliminary Considerations

Details of activities during construction, operation and closure of the Project have been fully described in Volume 1 of the Application.

Human use of the site will change over the life of the Project. During the construction and operation phases, use of the site will be restricted to occupational uses. Nearby water courses, (i.e., off-site) such as the Athabasca and Muskeg rivers and forested areas, may also be used for recreation (e.g., swimming, boating, hiking) and harvesting of local plants and game animals by the general public during the construction and operation phases. The human health component focused on the operation phase because of its substantially longer time frame, additional emission sources and larger area of effect compared with the construction phase. Following closure of the Project, use will likely shift from occasional recreational use to intermittent residential use for hunters and trappers, who may live in cabins directly on the reclaimed landscape for extended periods.

For this reason, the exposure scenarios for the operation and closure phases are different.

In respect of applicable and relevant regulatory policies/criteria, the approach adopted here embraced both federal and various provincial environmental quality standards, including AEP and Environment Canada where possible. Unique concerns or information that could be gleaned from aboriginal residents was incorporated for consideration (e.g., use of native plants, consumption rates).

Screening Process

In a risk assessment, it is not possible or practical to evaluate every potential chemical, receptor and exposure pathway. Therefore, for the current assessment, a comprehensive screening process was carried out in the problem formulation phase to focus the assessment on those chemicals, receptors and exposure pathways of greatest concern (i.e., chemicals with the greatest toxic potential; receptors with the greatest likelihood of being exposed and with the greatest sensitivities; exposure pathways that account for the majority of exposure to the chemical releases). If no unacceptable health risks are predicted for these, it is highly likely that no unacceptable health risks would exist for other chemicals, receptors or exposure pathways.

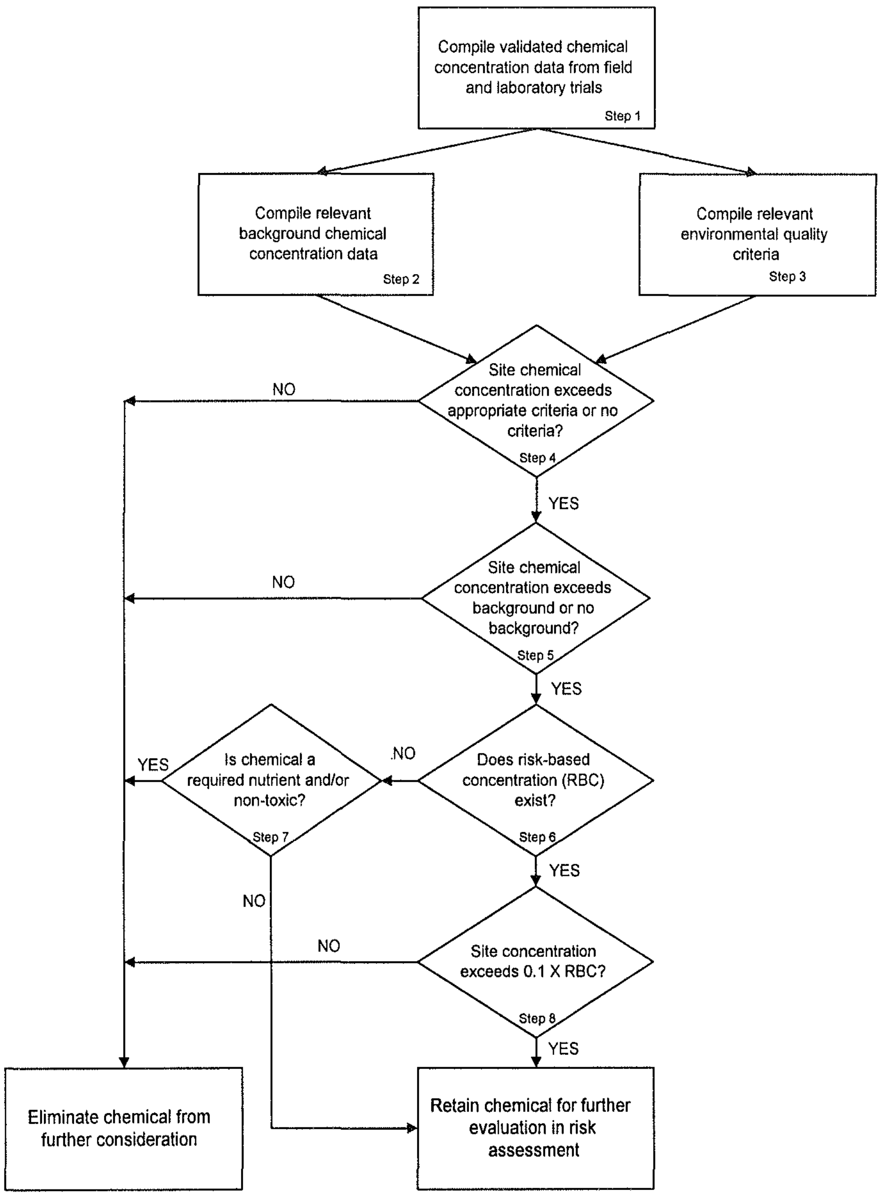
Three screening procedures were conducted in the problem formulation phase:

- chemical screening;
- receptor screening; and
- exposure pathway screening.

Chemical Screening

The objective of the chemical screening process was to focus the list of chemicals measured in various media (e.g., water, air, fish, soil, and meat) on those chemicals that may be a concern because of their concentrations and their potential to adversely affect human health. This list of chemicals of potential concern was used to assist in receptor and exposure pathway screening, and the chemicals identified here were carried forward into the Risk Analysis phase. The screening process used for the human health risk assessment followed a methodical, step-wise process, as shown schematically in Figure E12-5, and described in detail in Appendix X.1. Measured or predicted chemical concentrations were compared with background concentrations (i.e., in areas not affected by oil sands activities), regulatory screening level criteria (SLC) and risk-based criteria (RBC, i.e., media concentrations considered acceptable based on principles of health risk assessment) for the protection of human health. Detailed screening tables are also presented in Appendix X.1. The chemicals of potential concern retained for further evaluation in the risk assessment for each key question are listed according to key question in Sections E12.6 to E12.12.

Figure E12-5 Process for Chemical Screening



The chemical screening process incorporated several protective assumptions to ensure that chemicals of concern would not be excluded erroneously. These assumptions include:

- maximum observed or conservative predicted chemical concentrations were used;
- SLC were based on published criteria that are designed to prevent any adverse health effects over a lifetime exposure;
- if no SLC was available for a chemical, it was retained and carried forward to the next chemical screening step; and
- RBCs were based on conservative exposure scenarios, assuming child exposure and a target exposure ratio of 0.1 for non-carcinogenic chemicals; for carcinogenic chemicals, RBCs were calculated at a risk level of one-in-one-million (i.e., one-tenth of the cancer risk considered acceptable by provincial and federal agencies).

This screening focused not only on chemicals related to the operations of the Project, but additionally on background concentrations of other substances (e.g., naturally occurring or anthropogenic) in the Muskeg and Athabasca rivers. Some chemicals, such as chlorinated organics derived from pulp mills, were not investigated here because the Project is not a source for those chemicals and they are closely monitored and managed by the pulp industry. Given their extremely low levels and dissimilarity to the Project-related chemistry, it is unlikely that these substances interact to form a hazard. In addition, there may be natural pathogenic hazards, such as bacteria and viruses, associated with river water that could pose a health hazard to people who drink untreated river water.

Receptor Screening

The objective of the receptor screening process was to identify people who are currently using the area or may use the reclaimed landscape in the future. The receptors identified here were carried forward into the Risk Analysis phase. For non-carcinogenic chemicals, a hypothetical child and adult were chosen for evaluation for all land use scenarios. Although a child is unlikely to live on the reclaimed landscape like an adult hunter/trapper, a hypothetical child was evaluated for HH-7 at the request of regulators at the Human and Ecological Health Component Workshop (October 30, 1997), since children may still be exposed through ingestion of plants and game meat harvested from the reclaimed landscape. 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.

Senior citizens were also considered as potential receptors for the risk assessment due to concerns expressed at the Health Component Workshop. A comparison between Canadian exposure parameters for seniors (age 60+) and adults (age 20+) revealed no significant difference in terms of body weight, skin surface area, water intake rate and dietary composition (Richardson 1997). Inhalation and food intake rates are slightly lower for seniors than for adults, and seniors are also more likely to spend more time indoors (Richardson 1997), thereby lowering their exposure. Seniors may be more sensitive to chemical exposure due to compromised health; however, safety factors of 100 to 1000-fold were applied to No-Observed-

Adverse-Effect-Levels (NOAELs) in the determination of toxicity reference values for the current assessment to ensure that sensitive members of the human population, such as seniors, would be protected (refer to the Effects Assessment for further explanation). In essence, while seniors may potentially be more sensitive to a substance, the toxicity reference value employed during risk estimation accommodates this, and the use of a child and adult maximizes exposure potential over that expected for a senior. For these reasons, 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. Details of the receptor screening process are provided in Appendix X.2. Table E12-1 lists the potential receptors and land use scenarios for each key question.

Exposure Pathway Screening

The objective of the exposure pathway screening process was to identify the major pathways by which people may be exposed to chemicals from the site. The exposure pathways identified here were carried forward into the Risk Analysis phase. Details of the exposure pathway screening process are provided in Appendix X.3. Table E12-2 lists the potential exposure pathways identified for each key question.

Conceptual Models

The results of chemical, receptor and exposure pathway screening were used to develop conceptual models for the risk assessment. Separate conceptual models were developed for evaluation of each key question and are presented in Sections E12.6 to E12.12. The exposure pathways and receptors indicated in the conceptual models were assessed where chemicals of concern were identified through the chemical screening process.

Exposure Assessment

Exposure assessment is the process of estimating the daily intake rate (dose) of a chemical received by a person under a given exposure scenario. An exposure assessment was conducted for each key question where chemicals of concern, receptors and exposure pathways were identified. Exposure equations, receptor parameters and chemical-specific parameters used in the exposure assessment are provided in Appendix X.4. Further details of the exposure assessment conducted for each key question are provided in Sections E12.6 to E12.12.

Table E12-1 Potential Receptors and Land Use Scenarios

HH-1	HH-2	HH-3	HH-4	HH-7
Receptors				
Adult[(a)]	Adult[(a)]	Adult[(a)]	Adult[(a)]	Adult[(a)]
Child[(b)]	Child[(b)]	Child[(b)]	Child[(b)]	Child[(b)] (food ingestion only)
Composite[(c)]	Composite[(c)]	Composite[(c)]	Composite[(c)]	Composite[(c)]
Land Use Scenarios				
Recreational[(d)]	Off-site Air Inhalation[(f)]	Local Plant and Game Meat Consumption[(g)]	Recreational[(d)]	Hunting or Trapping[(h)]
Swimming[(e)]			Swimming[(e)]	
			Off-site Air Inhalation[(f)]	
			Local Plant Consumption[(g)]	

(a) Adults are defined as 20 years of age up to a lifespan of 70 a (Health Canada 1994).

(b) Children are defined as between the ages of 7 months and 4 a for HH-1, HH-3 and HH-6, (maximum ingestion rate to body weight ratio); children between the ages of 5 to 11 a were evaluated for HH-2 (maximum inhalation rate to body weight ratio) (Health Canada 1994)

(c) Composite receptors are lifetime receptors evaluated from birth to 70 years of age (Health Canada 1994) with appropriate weighting of life phases.

(d) Recreational scenario includes occasional use of local rivers in off-site areas for drinking water during recreational activities (i.e., hiking, boating, fishing, etc.)

(e) Swimming scenario includes occasional use of the local rivers in off-site areas for swimming, with incidental ingestion and dermal contact.

(f) Off-site air inhalation scenario includes year-round inhalation at residential communities within the Regional Study Area (i.e., Fort McKay, Fort McMurray and Fort Chipewyan).

(g) Local plant and game meat consumption includes year-round harvesting of local plants and game animals (e.g., blueberries, Labrador tea, cattail/ratroot, moose, snowshoe hare, grouse, etc.) by members of nearby residential communities.

(h) Hunter/trapper scenario includes year-round occupation of the reclaimed landscape for hunting and trapping activities.

Table E12-2 Potential Exposure Pathways for Evaluation

Exposure Pathway	HH-1	HH-2	HH-3	HH-4	HH-7
dermal contact with water	✓			✓	✓
ingestion of water	✓			✓	✓
ingestion of fish	✓			✓	✓
inhalation of volatile chemicals		✓		✓	
inhalation of airborne particulate matter		✓		✓	
ingestion of plants			✓	✓	✓
ingestion of game meat			✓	✓	✓

(a) Note: Key questions HH-5 and HH-6 are excluded from this table because they do not include chemical exposure.

Bioavailability

Bioavailability is a concept referring to the amount of chemical that will enter the bloodstream following contact with a chemical. It is important because most chemicals exert their toxic effects only following absorption. For the human health risk assessment, the bioavailability of each chemical via ingestion or inhalation was assumed to be 100%. This is a conservative assumption that inflates risk estimates, because it implies that 100% of a chemical ingested or inhaled is also absorbed into the blood. A more accurate assessment of bioavailability may indicate that absorption is significantly less than 100%, with a resultant reduction in hazard.

For dermal exposures, it is necessary to determine the amount of chemical that would be absorbed by the body following exposure to chemicals in the water (i.e., while swimming). The parameter that describes the extent of absorption is the dermal permeability constant, Kp. Chemical-specific dermal permeability constants were identified from U.S. EPA (1992b) and are listed in Appendix X.4.

Toxicity Assessment

Toxicity Assessment is the identification and quantification of the chemical concentration or dose (i.e., daily intake), above which exposure to a receptor might cause an adverse effect (U.S. EPA 1988).

In the toxicity assessment, toxicity information for each chemical was used to provide qualitative and quantitative estimates of health effects associated with exposure to site chemicals. The toxicity assessment considered both the cancer or non-cancer (threshold) effects that a chemical may cause. The quantitative toxicity reference values (i.e., exposure limits) used to evaluate carcinogens are called Risk Specific Doses (RsDs) and for this assessment describe daily intake rates that correspond to a lifetime cancer risk of one-in-one-hundred-thousand (i.e., 1×10^{-5}), a level of societal risk generally considered acceptable by provincial and federal agencies. This is distinctly different from the risk level used during the chemical screening process where the RBC was set to one-in-one-million (i.e., $1x10^{-6}$) as a conservative measure to ensure that substances of marginal concern were not excluded. Toxicity reference values used to evaluate non-carcinogens are called Reference Doses (RfDs) and describe a daily intake rate considered to be without adverse effect to sensitive members of the population over a lifetime.

These values are based on dose-response toxicity evaluations available through toxicological databases such as IRIS (Integrated Risk Information System); RTECS (Registry of Toxic Effects of Chemical Substances); TOXLINE (Toxicology information on-line); MEDLINE (Medlars on-line); HSDB (Hazardous Substances Databank); OHMTADS (Oil and Hazardous Materials/Technical Assistance Data System), and the Total Petroleum Hydrocarbon Criteria Working Group.

It should be recognized that toxicity reference values are typically derived through extrapolation of toxicity data from animal studies for application to humans. In such cases several uncertainty factors (i.e., cautionary assumptions) are integrated into the extrapolation process to ensure an adequate margin of safety will exist irrespective of the uncertainties in the toxicity data. To this end, uncertainty factors typically range from 100 to 1000, and routinely address protective measures for potentially sensitive members of the human population. For some of the chemicals addressed in this assessment, uncertainty factors as high as 3000 were involved. Therefore, in addition to the conservatism derived from the exposure assessment, toxicity reference values provide an additional and substantive element of conservatism that is intrinsic to the numerical risk estimates.

Based on insight from previous oil sands EIAs, it was recognized that naphthenic acids, a component of CT water, would be of interest for evaluation of human health. Although the process to be employed on the Project differs from other oil sands operations, naphthenic acids remain a component of interest for evaluation of human health. However, to date, there are insufficient mammalian toxicological data to calculate a defensible RfD for naphthenic acids. RfDs are normally calculated based on chronic or subchronic studies in laboratory animals. Currently, there are only acute toxicity mammalian data available for naphthenic acids. The acute toxicity data suggests that naphthenic acids have a relatively low potency under acute exposure conditions.

Methylcyclohexane has been used as a surrogate for determining the RfD for naphthenates (Syncrude 1993). Had methylcyclohexane been used to derive a surrogate RfD for naphthenates, then the resultant risk estimates would indicate that naphthenates pose no unacceptable risk to human health under the exposure scenarios discussed above. However, due to the differences in chemistry, methylcyclohexane was not used as a surrogate for naphthenates (i.e., differences in ring chemistry (e.g., planarity, number of rings), substituted side chains (methyl versus carboxylic acid, alkyl, allyl, aryl and functional-substituted chains), polarity (nonpolar versus polar/bipolar), surfactant properties (hydrophobic versus bipolar with high degree of surfactant action), molecular weight (low versus medium to high) and salt formation capacity (none versus high probability).

Further characterization of chronic toxicity posed to mammals by naphthenates or CT solids/water is needed to resolve this data gap. Some Canadian researchers are undertaking preliminary work in this area through sponsorship, in part, by members of the oil sands industry.

Table E12-3 provides a summary of the toxicity reference values used in this assessment. Further details on the toxicology of these chemicals and selection of the toxicity reference values for this assessment are provided in Appendix X.5.

Risk Characterization

In the risk characterization step, Exposure Ratios (ERs) were calculated as the ratio of the predicted chemical intake (dose) to the toxicity reference value, according to the following equation:

ER = estimated daily intake / toxicity reference value

An ER is calculated for each chemical of concern and for each exposure pathway, based on the estimated intake rates (dose) and the toxicity reference values.

For non-carcinogenic chemicals, an ER value of less than 1 represents exposure scenarios that do not pose a significant health risk to exposed receptors (Health Canada 1995). For carcinogenic chemicals, an ER value that is less than 1 indicates that the rate of intake for a chemical or group of chemicals is less than that attributed to an incremental lifetime risk of cancer of 1 per 100,000 individuals ($1x10^{-5}$), which does not pose a significant health risk to exposed individuals (Health Canada 1995).

When the ER is greater than 1, the scenarios pose a potential concern and require further scrutiny. *It is important to note that ER values greater than 1 do not necessarily indicate that adverse health effects will occur due to the conservatism employed in their estimation.*

When interpreting the results of the risk assessment, it is necessary to consider the uncertainty associated with ER estimates. An examination of each of the input parameter values indicates that they are biased in a way that tends to overestimate the predictions (also known as a conservative or protective bias). For example, exposure point concentrations represent a 95% confidence limit on the mean annual concentration. Exposure parameter values represent reasonable maximum exposure values; that is, they are reasonable upper bounds and not average values. Bioavailability is set to a maximum value (100%). In addition to these conservative biases of the individual input parameters, the use of multiple conservative assumptions itself mathematically compounds the conservative bias in the ER values. *Consequently, risk estimates are likely to be lower than those reported here, and ER values greater than 1 do not necessarily represent a human health concern.*

Table E12-3 Toxicity Reference Values Used in the Risk Assessment

CHEMICAL	Toxicity Reference Value		Slope Factor	Type of Health Effect	Reference
	Type	Value[a]	(mg/kg*d)$^{-1}$		
Metals					
antimony	RfD	4.00E-04	not applicable	no toxicity observed; tolerable daily dose	U.S. EPA 1997
arsenic	RsD	6.70E-06	1.5[b]	skin & lung tumors	U.S. EPA 1997
barium	RfD	7.00E-02	not applicable	cardiovascular disease	U.S. EPA 1997
beryllium	RsD	2.30E-06	4.3[b]	lung tumors	U.S. EPA 1997
boron	RfD	9.00E-02	not applicable	testicular atrophy & spermatogenic arrest	U.S. EPA 1997
cadmium (water)	RfD	5.00E-04	not applicable	nephrotoxicity, carcinogenicity	U.S. EPA 1997
cadmium (food)	RfD	1.00E-03	not applicable	nephrotoxicity, carcinogenicity	U.S. EPA 1998
chromium (III)	RfD	1.00E+00	not applicable	NOAEL, body weight & food consumption	U.S. EPA 1997
copper	RfD	0.05-0.1	not applicable	no toxicity observed; tolerable daily dose	CCME 1997
lead (child)	RfD	3.57E-03	not applicable	neurological effects	Health Canada 1996
lead (adult)	RfD	7.14E-03	not applicable	neurological effects	Health Canada 1997
molybdenum	RfD	5.00E-03	not applicable	serum uric acid levels	U.S. EPA 1997
nickel	RfD	2.00E-02	not applicable	nasal & lung carcinogenicity, body weight	U.S. EPA 1997
selenium	RfD	5.00E-03	not applicable	clinical selenosis	U.S. EPA 1997
vanadium	RfD	7.00E-03	not applicable	chronic toxicity	HEAST 1995
Organics					
acetaldehyde	RsD	1.30E-03	7.7E-06[b]	nasal metaplasia	U.S. EPA 1997
acetone	RfD	1.00E-01	not applicable	increased liver weight & renal toxicity	U.S. EPA 1997
acrolein	RfC	2.00E-05	not applicable	squamous metaplasia	U.S. EPA 1997
anthracene	RfD	3.00E-01	not applicable	no treatment effects	TPHCWG 1997
benz(a)anthracene	RsD	1.40E-05	7.3E-01[d]	tumors	TPHCWG 1997/U.S. EPA 1997
benzene	RsD	3.40E-04	2.9E-02[c]	leukemia in humans	U.S. EPA 1997
benzo(a)pyrene	RsD	1.40E-06	7.3	stomach/respiratory tract tumors	TPHCWG 1997/U.S. EPA 1997
benzo(b)fluoranthene	RsD	1.40E-05	7.3E-01[d]	tumors	TPHCWG 1997/U.S. EPA 1997
benzo(k)fluoranthene	RsD	1.40E-05	7.3E-02[d]	tumors	TPHCWG 1997/U.S. EPA 1997
chrysene	RsD	1.40E-04	7.3E-01[d]	tumors	TPHCWG 1997/U.S. EPA 1997
dibenz(a,h)anthracene	RsD	1.40E-06	7.3	tumors	TPHCWG 1997/U.S. EPA 1997
fluoranthene	RfD	4.00E-02	not applicable	nephropathy, hepatotoxicity	TPHCWG 1997
fluorene	RfD	4.00E-02	not applicable	hematological effects	TPHCWG 1997
formaldehyde	RsC	8.00E-04	4.5E-02[c]	squamous cell carcinoma	U.S. EPA 1997
formaldehyde	RfD	2.00E-01	not applicable for oral	reduced weight gain, histopathalogy	U.S. EPA 1998
indeno(1,2,3)pyrene	RsD	1.40E-04	7.3E-02[d]	tumors	TPHCWG 1997/U.S. EPA 1997
naphthalene	RfD	4.00E-02	not applicable	decreased body weight	TPHCWG 1997
pyrene	RfD	3.00E-02	not applicable	nephropathy	TPHCWG 1997
TPH: C>7 - C8 aromatic	RfC	4.00E-01	not applicable	hepatotoxicity, nephrotoxicity	TPHCWG 1997
TPH: C>7 - C8 aromatic	RfD	2.00E-01	not applicable	hepatotoxicity, nephrotoxicity	TPHCWG 1997
TPH:C>8-C16 aromatic	RfC	2.00E-01	not applicable	decreased body weight	TPHCWG 1997
TPH:C>8-C16 aromatic	RfD	4.00E-02	not applicable	decreased body weight	TPHCWG 1997
TPH:C5-C8 aliphatic	RfC	1.84E+01	not applicable	neurotoxicity	TPHCWG 1997
TPH:C5-C8 aliphatic	RfD	5.00E+00	not applicable	neurotoxicity	TPHCWG 1997
TPH:C8-C10 aliphatic	RfC	1.00E+00	not applicable	hepatic, hematological effects	TPHCWG 1997
TPH:C8-C10 aliphatic	RfD	1.00E-01	not applicable	hepatic, hematological effects	TPHCWG 1997

[a] Units are (mg/kg*d) for RfD & RsD; & (mg/m^3) for RfC & RsC.
[b] Based on oral exposure.
[c] Based on inhalation exposure.
[d] Based on U.S. EPA potency factors relative to benzo(a)pyrene.
RfD: oral reference dose, unless stated otherwise.
RfC: reference concentration for non-carcinogens.
RsD: risk-specific dose equating to 1:100000.
RsC: risk-specific air concentration equating to 1:100000.

E12.5.4 Degree of Concern

For the human health component, the *degree of concern* was primarily determined by the *magnitude of impact*, although *duration* and *geographic extent* were also factors (See Section E1). For this assessment, *magnitude of impact* is based exclusively on whether or not the Project activity might adversely affect human health. The magnitude of impact was based on the quantitative risk estimates for key questions HH-1, 2, 3, 4 and 7. ER values greater than 1 represent scenarios that pose a potential concern. However, since many conservative factors are typically used to derive both the intake rates and the toxicity reference values, the ER estimates will tend to overestimate the potential for risk. This is consistent with a protective approach to risk evaluation. Thus, an ER value of greater than 1 indicates a potential health concern that needs further scrutiny to identify the reason for the elevated ER; this may lead to additional data collection to more accurately quantify risks. Hence, magnitude of impact has been defined as follows:

Negligible	ER < 1 and no data gaps, or ER marginally greater than 1 due to naturally elevated background exposures and/or conservative exposure assumptions.
Low	No ER because of lack of data, although enough evidence to suggest that exposure unlikely to adversely affect health; additonal information is necessary to support this conclusion,
Moderate	ER > 1, however mitigating options are available that would likely result in exposures to be less than used in the ER calculations, but additional information needed to support this conclusion.
High	ER > 1, however mitigating options are unavailable; hence exposure has potential to adversely affect people's health.
Unresolved	Insufficient information to draw any conclusions.

For key question HH-5, which involves a subjective review, rather than risk estimation, the *degree of concern* was defined as follows:

Negligible	Sufficient procedures are in place to ensure worker health and safety.
High	Insufficient procedures are in place to ensure worker health and safety.

Key question HH-6 involves a comparative evaluation of noise levels and does not assess health risks. Therefore, the magnitude of impact was defined as follows:

Negligible	Predicted noise level unlikely to exceed permissible sound level.
Low	Predicted noise level likely to periodically exceed permissible sound level, but mitigation is possible.
Moderate	Predicted noise level likely to consistently exceed permissible sound level, but mitigation is possible.
High	Predicted noise level likely to consistently exceed permissible sound level and no mitigation is possible.

For a full description of the criteria surrounding impacts and degree of concern, the reader is referred to Section E1.

E12.6 Key Question HH-1: Will Water Releases From the Muskeg River Mine Project Change Human Health?

E12.6.1 Analysis of Potential Linkages

The linkage between the Project activity and potential changes to water quality has previously been established under Section E5. The present section therefore focuses on whether a valid linkage exists between potential water quality changes and human health.

Linkage Between Changes in Water Quality and Human Health

Since the Project is not yet in operation, measured data specific to the Project could not be evaluated. However, surrogate data from other oil sands facilities in the area (i.e., Syncrude and Suncor) were used to provide an estimate of the chemistry of release waters during operation, at closure and in the far future after closure under equilibrium conditions and, in turn, predicted water quality in receiving waters.

To determine whether changes in water quality may affect human health, a problem formulation was conducted including chemical, receptor and exposure pathway screenings as described in Appendix X.3. The chemical screening was conducted using predicted future water concentrations in the Muskeg River. Detailed screening tables are presented in Appendix X.1. Results of chemical screening identified the following eight chemicals of potential concern:

- benzo[a]anthracene
- benzo[a]pyrene
- naphthenic acids
- boron
- cadmium
- lead
- molybdenum
- vanadium

In addition to these chemicals, baseline concentrations of arsenic and beryllium appear to be naturally elevated in the Muskeg River, because they exceeded the conservative RBC screening step. Although the Project will not contribute to significantly increased concentrations of these chemicals, they were carried forward for further analysis in light of interest articulated by regulators concerning elevated background chemical concentrations (Human and Ecological Health Component Focus Workshop, October 30, 1997).

Potentially exposed people and land uses were identified. Both adults and children may use local rivers (such as the Athabasca and Muskeg rivers) for recreational activities, such as swimming, boating or hiking. During these activities, people may become exposed through ingestion of river water and dermal contact with water while swimming.

Since elevated chemical concentrations, receptors and exposure pathways may apparently co-exist, a potential linkage exists between water quality changes and human health.

Linkage Between Changes in Fish Tissue Quality and Human Health

A combined field and laboratory study was completed to address the potential for accumulation of chemicals in fish tissue. These data are summarized in Section E6 and briefly described below.

Walleye, goldeye and longnose sucker were collected in 1995 as part of a baseline aquatics study in the oil sands region (Golder 1996b). Walleye and goldeye were captured in the Athabasca River near Suncor and longnose sucker were captured as they moved up the Muskeg River to spawn. All three species spend part of the open-water season in the vicinity of existing oil sands operations. Composite samples of fish fillets were analyzed for organic chemicals and metals (data presented in Section E6). Samples from longnose sucker contained trace concentrations of naphthalene (0.02 to 0.04 µg/g) and methylnaphthalene (<0.02 to 0.03 µg/g); however, other PAHs were not detectable (detection limits range from 0.02 to 0.04 µg/g). No PAHs were detected in walleye and goldeye samples. Levels of trace metals in fish tissue were generally low.

Uptake of oil sands related chemicals into fish tissue was also investigated during a laboratory fish health study where juvenile walleye and rainbow trout were exposed to a variety of waters, including a dilution series of water collected from Suncor's Tar Island Dyke drainage system (0.1 to 10% strength), laboratory control water and Athabasca River water collected upstream of existing oil sands operations (i.e., background controls). The fish were exposed to these waters in a flow-through system for 28 days, sacrificed and their tissues analyzed for PAHs and trace metals (HydroQual 1996). PAH concentrations in juvenile walleye and rainbow trout were generally below detection; naphthalene and methyl naphthalene levels in rainbow trout were at or just above the detection level in both control and treatment samples (0.02 to 0.03 µg/g; Section E6). Concentrations of most metals were generally below detection limits in both treatment and control samples. The only notable exceptions were for arsenic and mercury where concentrations of <0.1-2.3 µg/g and 0.03-0.45 µg/g, respectively, were measured. However, the highest concentrations were associated with the background control fish exposed to the Athabasca River water. Thus, no significant accumulation of PAHs or metals (relative to detection limits or levels in background control fish) is indicated by either laboratory exposure of fish to Tar Island Dyke water or from fish captured in the Athabasca River.

It should be noted that there may be changes in fish tissue quality with respect to chemicals that create off-flavours in fish tissue, and these chemicals might be present at concentrations below analytical detection limits. Although tainting is an important issue from the perspective of use of the fish resource, it is not strictly speaking a health issue. Therefore, the potential for tainting of fish tissue is discussed in Section E6.

Notwithstanding the lack of evidence of accumulation of chemicals in fish tissue, a chemical screening was conducted to determine whether ingestion of fish from the Athabasca River might potentially pose a hazard to people's health. The chemical screening process followed the same screening protocol as for drinking water and employed data from the two studies noted above. Nickel was the only chemical identified in the conservative chemical screening process. Further examination of the fish tissue data indicated that nickel was only detected in the Athabasca Goldeye sample at low concentrations and was not measurable in fish exposed to Tar Island Dyke water in the laboratory accumulation study. For this reason, nickel was not carried forward for further evaluation in the risk assessment.

It should also be noted that levels of mercury in fish tissues are elevated upstream of the oil sands region and may pose a health risk to people eating fish from this region of the river. Elevated levels of mercury in fish tissues have also been noted by NRBS, and have been attributed to natural sources (NRBS 1996). Water quality modelling suggests that the Project will not significantly change the waterborne mercury levels Therefore, over the long-term operation, mercury levels in fish tissue are not anticipated to be significantly increased by the Project activities. For these reasons, mercury was not evaluated further in the risk assessment.

In summary, based on the data and results of the screening level assessment discussed above, release waters do not appear to contribute to increases in chemical concentrations in fish within the LSA or RSA to levels that would be associated with adverse health effects. *Hence, it is concluded that a linkage between changes in fish tissue quality associated with the Project and human health does not exist.*

E12.6.2 Analysis of Key Question

To further investigate the linkage between off-site water quality and human health, a quantitative human health risk assessment was conducted for conceptual exposure model HH-1 (Figure E12-6) using methods described in Section E12.5.3. Key aspects of the risk assessment are discussed here; additional details are provided in Appendix X.

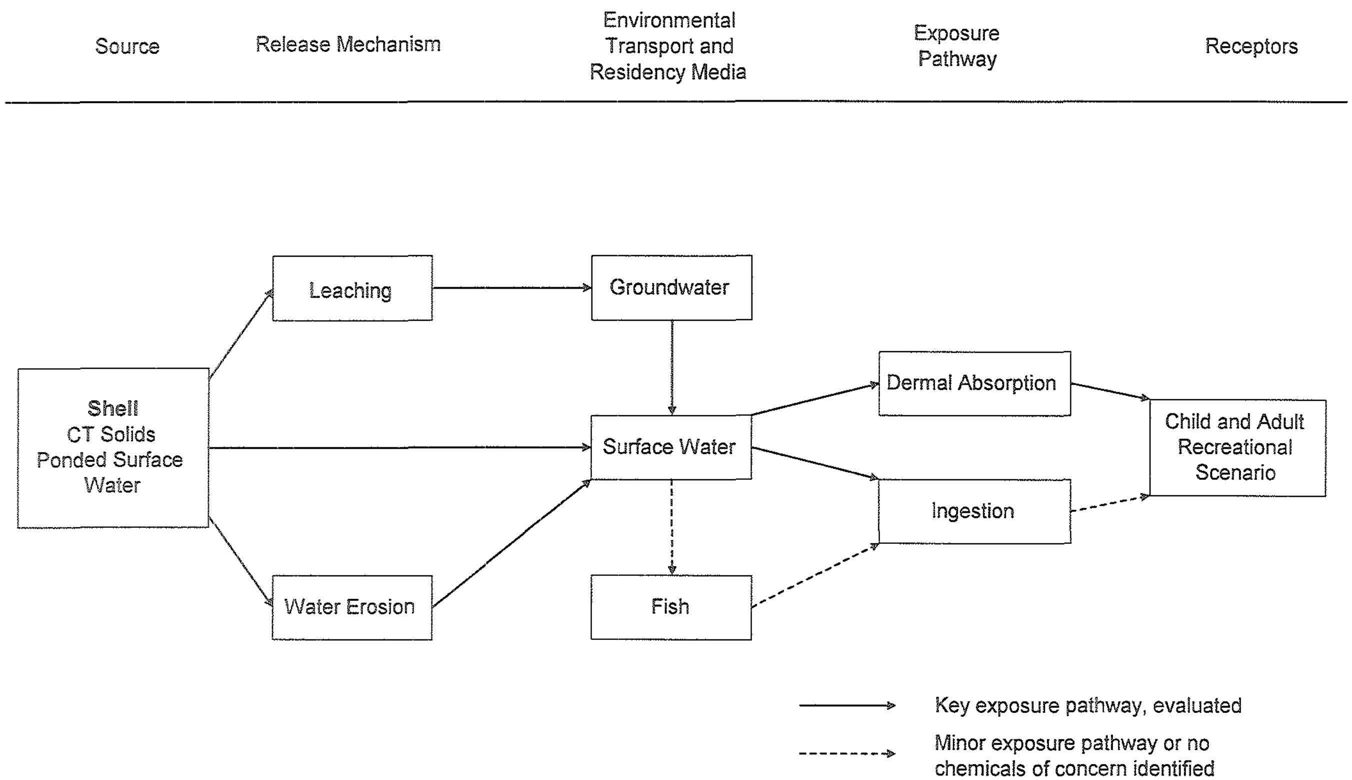
Concentrations of the chemicals of potential concern were predicted for the Muskeg and Athabasca rivers, immediately downstream of the Project, according to the method described in Section E5. The maximum concentrations predicted to occur during operation (2000-2025), at closure (2030) and the far-future (under equilibrium conditions) are presented in Appendix X.1. These concentrations were used as exposure concentrations to estimate daily intake rates for off-site exposures during operation, at closure and in the far future.

For the swimming scenario, it was assumed that people could absorb chemicals across the skin (i.e., dermal absorption) and could incidentally ingest small quantities of water. People were assumed to swim in the Athabasca or Muskeg two days per week for two months during the summer (i.e., 16 times per year). Children and adults were assumed to spend 2.5 h and 1 h, respectively, in the water per event.

The major route of exposure for recreational use (i.e., hiking, boating, fishing) was assumed to be occasional consumption of river water during recreational activities. People were assumed to drink from the river two days a week, year round. It was also assumed that recreational users would occasionally swim in the Muskeg or Athabasca rivers. Therefore, exposures for recreational receptors include both drinking water and occasional swimming exposure.

These scenarios are the same as those used in previous EIAs for the Steepbank and Aurora mines (Golder 1996a; BOVAR 1996a). A residential drinking water scenario was not included in the assessment because people in the area do not use untreated water from the Athabasca or Muskeg rivers as a primary drinking water source (Golder 1996a).

Figure E12-6 HH-1: Conceptual Model for the Water Releases Scenario



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Consumption of fish caught downstream of the Project was assumed to pose no incremental risk above background based on previous studies indicating no significant difference in fish quality from fish caught upstream (Golder 1996b). However, fish consumption has been evaluated for several chemicals in the multimedia exposure assessment for key question HH-4.

Exposure ratios for the Muskeg River swimming and recreational scenarios are presented in Tables E12-4 and E12-5 below. Intermediate calculations such as intake rates appear in Appendix X.4.

Table E12-4 Exposure Ratio Values for the Swimming Scenario (Muskeg River)

Receptor/Chemical	Operation (2000-2025)	Closure (2030)	Post-Closure (Equilibrium)
Child			
boron	0.0002	0.002	0.0002
cadmium	0.0002	0.0007	0.0002
lead	0.00005	0.0002	0.00005
molybdenum	0.00002	0.008	0.00002
vanadium	0.000009	0.000005	0.000009
Adult			
boron	0.00002	0.0002	0.00002
cadmium	0.00001	0.00006	0.00001
lead	0.000002	0.000007	0.000002
molybdenum	0.000002	0.0007	0.000002
vanadium	0.000002	0.00007	0.000002
Composite			
benzo[a]pyrene	0[(a)]	0.07	0.0004
benzo[a]anthracene	0[(a)]	0.02	0.0004
total PAHs	0[(a)]	0.09	0.0008

(a) No release of benzo[a]pyrene or benzo[a]anthracene is expected during operation of the Project; hence no risk is predicted for these chemicals (ER = 0).

Table E12-5 Exposure Ratio Values for the Recreational Scenario (Muskeg River)

Receptor/Chemical	Operation (2000-2025)	Closure (2030)	Far future (Equilibrium)
Child			
boron	0.008	0.07	0.01
cadmium	0.007	0.03	0.007
lead	0.002	0.009	0.002
molybdenum	0.0007	0.3	0.0007
Adult			
boron	0.003	0.02	0.003
cadmium	0.002	0.01	0.002
lead	0.0003	0.001	0.0003
molybdenum	0.0002	0.01	0.0002
Composite			
benzo[a]pyrene	0[(a)]	0.06	0.0007
benzo[a]anthracene	0[(a)]	0.02	0.0006
total PAHs	0[(a)]	0.08	0.013

(a) No release of benzo[a]pyrene or benzo[a]anthracene is expected during operation of the Project; hence no risk is predicted for these chemicals (ER = 0).

All ER values for water exposure were less than 1, indicating that these predicted conservative exposures resulting from recreational activities (including occasional ingestion of water and swimming exposure) during operation and following closure are well within acceptable limits. Therefore, no impacts to human health are predicted due to water releases from the Project.

In addition to the chemicals evaluated above, baseline concentrations of arsenic and beryllium were also evaluated due to naturally elevated concentrations in the Muskeg River. For risk estimation, it was conservatively assumed that arsenic and beryllium behave as non-threshold carcinogens, and therefore the toxicity reference values selected for these substances are extremely low. The resultant ER values for the recreational scenario marginally exceeded 1 (i.e., ER values = 3.5 and 1.5, respectively), while ER values for the swimming scenario were less than 1. As stated previously, the Project is not expected to contribute to increased concentrations of these chemicals in the Muskeg River. Arsenic and beryllium are natural constituents of the earth's crust and therefore may be found naturally in surface water. Typical background concentrations of arsenic in Canadian rivers range from 1 to 8 μg/L, and some rivers have reported concentrations as high as 50 μg/L (CCREM 1987). The median of the observed baseline arsenic concentrations in the Muskeg River was 3 μg/L, which is well within the range for Canadian rivers. The average concentration of beryllium in Canadian surface fresh waters has been estimated to be less than 1 μg/L, but concentrations in Western Canada were reported to range up to 5 μg/L (CCREM 1987). The observed baseline and predicted future beryllium concentrations in the Muskeg River were <1 μg/L, which is within the range reported for surface waters in Western Canada. Finally, it should be noted that arsenic concentrations in the Muskeg River were much lower than the Canadian Drinking Water Guideline of 25 μg/L. There is no Canadian drinking water guideline for beryllium; however, U.S. EPA has specified a guideline of 4 μg/L. Beryllium concentrations in the Muskeg River were lower than this drinking water guideline. For these reasons, the naturally elevated concentrations of arsenic and beryllium in the Muskeg River are considered acceptable for drinking water purposes.

Chemical contributions to the Athabasca River from the Project are less than contributions to the Muskeg River, due to increased dilution as a result of the larger water volume and flow rate of the Athabasca River compared with the Muskeg River. Therefore, since no human health impacts were identified for exposure to Muskeg River water, none would be expected based on exposure to Athabasca River water.

Due to the lack of data on mammalian chronic toxicity of naphthenic acids, the potential for human health effects could not be evaluated for this group of substances. The available toxicity data for naphthenic acids indicates these substances are low in potency, however, this data does not enable assessment of chronic low level exposure.

E12.6.3 Residual Impact Classification and Degree of Concern

Based on the quantitative information assessed, no human health impacts were identified. Although the acute toxicity of naphthenic acids is generally low, hazards of chronic low level exposure could not be evaluated due to lack of toxicity data. Due to the uncertainty regarding the potential chronic effects of naphthenic acids, the magnitude of impact is rated as low, rather than negligible. This results in a low degree of concern as follows:

Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
Negative	Low	Local	Long-Term	Reversible	Medium	Low

Currently there is an industry initiative to collect the required data to resolve the issue of chronic exposures.

Certainty

The assessment of potential impacts to users of the Athabasca and Muskeg rivers was based on a number of highly protective assumptions. The protective assumptions related to chemical screening are discussed in Section E12.5.3. These assumptions provide assurances that no chemicals were excluded from the screening step, except those that clearly pose no incremental risk to human health. Risk estimates were calculated deterministically to provide single value estimates of Exposure Ratios; however, a significant degree of uncertainty is associated with most ER values. To ensure that this assessment yields a sufficiently protective answer in light of this uncertainty, the assessment was based on protective input values. Hence, the actual risks to human health will likely be even lower than those suggested by ER estimates because of the multiple protective assumptions as outlined below:

- reasonable worst case exposure point concentrations in the Muskeg and Athabasca rivers were used, assuming no decay or degradation of chemicals;
- exposure locations were set within the mixing zone of the Muskeg and Athabasca rivers, downstream of all potential water emissions;
- exposure parameter values for human receptors represent reasonable maximum exposure values;
- oral bioavailability was set to a maximum of 100%; and
- toxicity reference values adopted are protective of sensitive members of the population (e.g., seniors) under chronic exposure conditions.

E12.6.4 Monitoring

A suite of chemical substances, including the chemicals of concern discussed here will be monitored periodically in water and fish at predetermined locations in the Muskeg, Jackpine and Athabasca rivers to validate the exposure and risk assessment. This will be a component of the RAMP program.

In addition, consideration will be given to resolve data gaps in toxicity data for naphthenic acids as part of CONRAD.

E12.7 Key Question HH-2: Will Air Emissions From the Muskeg River Mine Project Change Human Health?

E12.7.1 Analysis of Potential Linkages

The effect of the Project activity on air quality has been examined and reported previously in Section E.2. Air emissions and dispersion modelling have confirmed this linkage and characterized the change in air quality anticipated from Project activities.

Linkage Between Air Quality and Changes in Human Health

As previously noted, for the linkage to be valid three essential components of environmental health risk must co-exist; these are: i) chemicals at potentially hazardous concentrations; ii) human receptors; and iii) operable exposure pathways. The latter two are intuitively evident in the form of local residents and visitors who are exposed to the local/regional air quality. The remaining issue then, is to determine whether the predicted changes in air quality are potentiality hazardous.

Section E2 (Tables E2-18 to E2-20) provides predicted chemical concentrations for conventional air quality parameters (NO_2, SO_2, CO, PM_{10} and $PM_{2.5}$) along with a variety of organic chemicals associated with the Project activities. These were provided in the form of expected maximum concentrations averaged over intervals of one hour, one day and one year, and compared with corresponding health based regulatory criteria. The results of the analysis indicated that predicted NO_2, SO_2 and CO would be compliant with applicable air quality criteria. Hence, for these chemicals the linkage is not valid.

For particulate matter, maximum predicted 24 h averaged ambient concentrations of PM_{10} (32 $\mu g/m^3$) and $PM_{2.5}$ (20 $\mu g/m^3$) arising from the mine fleet exhaust emissions were within the recently amended U.S. EPA guidelines of 150 $\mu g/m^3$ and 65 $\mu g/m^3$, respectively. However, the PM_{10} value is about 2/3 of the more stringent BC Environment value of 50 $\mu g/m^3$. Further, Health Canada has recently proposed for public consultation, several draft Air Quality Objectives (AQO) for PM_{10} and $PM_{2.5}$, and while these are not yet finalized the maximum predicted PM levels exceed the draft Canadian AQOs. Therefore a linkage is considered to exist for particulate matter as PM_{10} and $PM_{2.5}$.

Various other predicted airborne chemical concentrations (e.g., petroleum hydrocarbons, volatile organics and polycyclic aromatic hydrocarbons) were also predicted in Section E2; however, these were not compared against screening level criteria (i.e., regulatory criteria) because in many cases such criteria are lacking and the predicted concentrations reflect *specific* Project emissions rather than *cumulative* Project emissions. Screening source-specific concentrations could potentially underestimate the cumulative Project-related exposure concentration and lead to erroneous exclusion of chemicals because of an apparent lack of perceived hazard. Therefore, although the linkage for these chemicals was neither validated nor invalidated, it was considered prudent to retain them for further analysis of key question HH-2.

In summary, the linkage between human health effects and concentrations of particulate matter and select air quality parameters is considered valid and warrants further quantitative analysis.

E12.7.2 Analysis of Key Question

To further investigate the potential linkage between air quality and human health, a quantitative human health risk assessment was conducted for conceptual model HH-2 (Figure E12-7) using methods described in Section E12.5.3. Key aspects of the risk assessment are discussed here; additional details are provided in Appendix X.

Analysis of this key question was approached from three perspectives. These perspectives involved: i) the predicted ambient concentrations of vapour phase chemicals; ii) consideration of particulates and conservative assumptions of chemicals that may be adsorbed to airborne respirable particulates; and iii) predicted concentrations of odiferous substances and odour threshold levels.

Step 1: Vapour Phase Chemicals

Concentrations of chemicals of concern in air were predicted using dispersion modelling, as described in Section E2. The major sources of airborne chemicals included: off-gassing from the tailings settling pond and cut mine surfaces, emissions from the vehicle fleet, and emissions from stationary combustion sources. Maximum ground level air concentrations for the chemicals of concern were estimated (Section E2) for Fort McKay, the closest residential community to the Project, along with Fort McMurray and Fort Chipewyan (Appendix X.4). These concentrations were then used in exposure modelling to determine the estimated daily intake of these chemicals by local residents.

For non-carcinogenic chemicals, potential residential exposure was estimated for children of age 5-11 years; a lifestage at which the greatest exposure via inhalation (per unit body mass) occurs (Health Canada 1994). The adult exposure scenario assumed the adult was exposed on-site as a worker (without personal protective gear), in addition to exposure that may subsequently be experienced at the residence. The latter scenario was requested at the Human and Ecological Health Component Workshop (October 30, 1997). Finally, for potentially carcinogenic chemicals, exposure was estimated on the assumption that the individual lives their entire life in the aforementioned communities, again with a scenario that includes worker exposure .

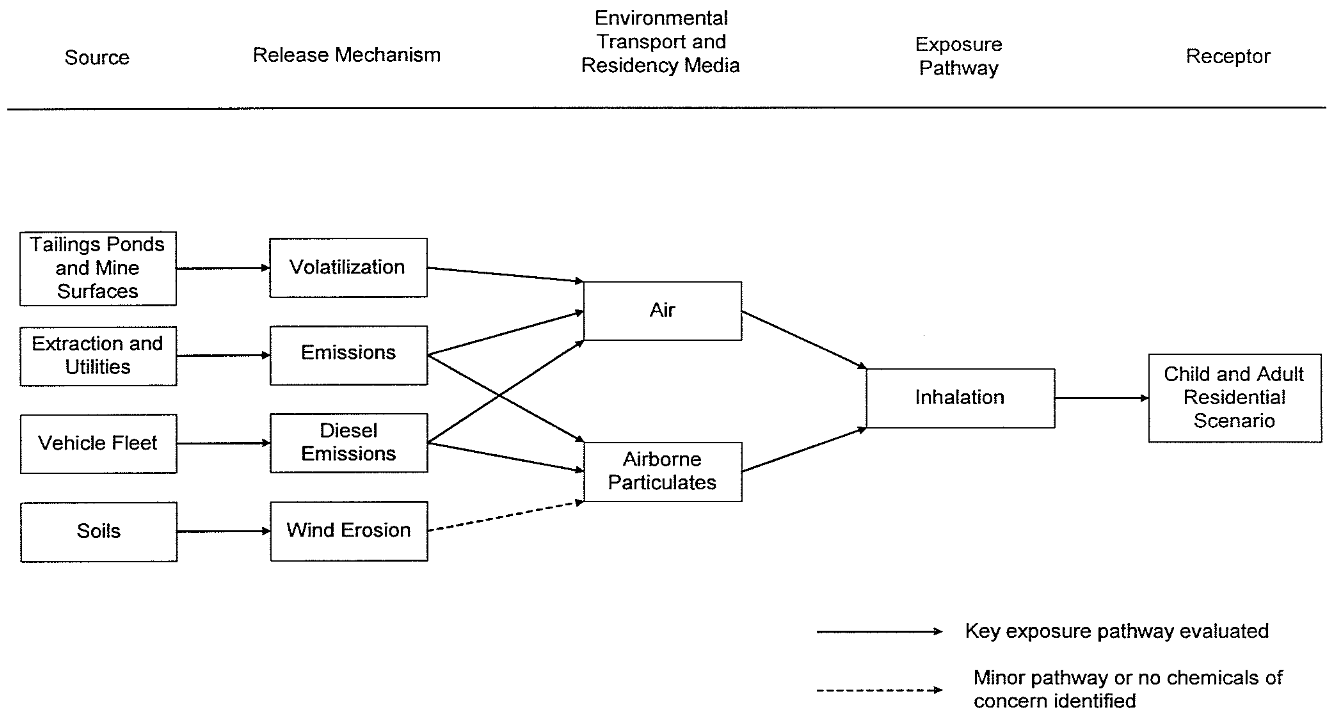
Daily intake rates were estimated for individual chemicals where possible and also on a grouped basis. For some chemicals, particularly the so-called Total Petroleum Hydrocarbons, (TPH) toxicity data are not available for all components of the hydrocarbon spectrum. Therefore, such chemical exposure and risks were conservatively estimated through the recent methods of the Total Petroleum Hydrocarbon Criteria Working Group (TPHCWG 1997) involving hydrocarbon fractions and surrogate or fraction-specific toxicity reference values (see Appendices X.4 and X.5 for a detailed description).

Exposure assessment was conducted on the basis of the contribution from individual sources to elucidate source-specific health risks and results were expressed as exposure ratios (ER). Where feasible, source-specific health risks were summed to provide an overall measure of personal health risk.

Note, however, that for the air pathway this is a significant conservative assumption because it presupposes that the maximum annually averaged chemical concentration arising from each of the four emission sources occur and converge concomitantly on the community of interest, an unlikely event.

Results of the analysis and the corresponding exposure ratios are presented in Table E12-6. The risk estimates provided in Table E12-6 are the sum of exposures ratios (i.e., Sum ER) among the individual sources, where applicable. Where chemical substances are known to have similar potential effects, the risk estimates were also summed to provide a measure of the collective air quality health risk. Where the potential effect endpoint is unique, the risk estimate remains as a stand alone measure. Further details of the exposure assessment and source-specific or chemical-specific risk estimates can be examined in Appendix X.6.

Figure E12-7 HH-2: Conceptual Model for the Air Releases Scenario



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Non-carcinogenic substances in the family of aldehydes were modelled after acrolein, the dominant form of non-carcinogenic aldehyde predicted in ambient air, and are not expected to pose a significant risk to lifetime residents of Fort McKay or other communities located further away. The Sum ER value for children is less than 1. In the case of an adult who may also work on-site, the very conservative exposure estimate results in an ER of approximately 5.1. This is virtually entirely due to the potential occupational contribution made from on-site vehicle emissions and is reflected by the similarity in Sum ER's for each of the communities (i.e., the exposure and risk estimate are independent of the exposure concentrations from the different communities). The work component of the exposure is based on continuous worst case conditions; in reality the ER is expected to be substantially less than 1. In addition to the conservatism in the exposure assessment, an uncertainty factor of 1000 is intrinsic to the toxicity reference value which confers an additional margin of safety to the risk estimate.

For non-carcinogenic ketones, the majority of predicted ambient concentrations was in the form of acetone and therefore this substance was used as the model compound for this group. The Sum ER for this group of chemicals is four to five orders of magnitude less than 1 for residents in all communities, and consequently is not expected to pose an adverse health risk.

The Sum ER values for non-carcinogenic aliphatics and aromatics using a conservative modification of the TPHCWG (1997) method for petroleum hydrocarbons (see Appendix X.4 and X.5 for details) were below 1 for both residents and worker-residents in all communities. The risk estimates indicate that in the case of the worker-resident, the majority of estimated exposure derives from the workplace under the conservative modelled conditions. Nevertheless, estimated exposures from this class of substances are not anticipated to present an adverse health risk.

For non-carcinogenic PAHs, the Sum ER values were substantially less than 1 for both residents and worker-residents in all communities; hence, this group of PAHs is not expected to present an adverse health risk.

Exposure ratios for individual substances that are potentially carcinogenic (including formaldehyde, acetaldehyde, benzene, and select PAHs) were summed to give the tabulated Sum ER for lifetime carcinogenic risk (Table E12-6). The ER ratios relate to an acceptable level of environmental risk of one in one hundred thousand (i.e., 10^{-5}), a value recognized amongst AEP and Health Canada as being acceptable. For lifetime residents of all communities, the Sum ER is one to two orders of magnitude less than the accepted value. In the case of the worker-resident, the Sum ER is noticeably larger and marginally equivalent to the accepted value (i.e:, 1).

Table E12-6 Exposure Ratios (Sum ER) for the Inhalation Pathway

Chemical/Group	Fort McKay		Fort McMurray		Fort Chipewyan	
	Child[e]	Adult[f]	Child[e]	Adult[f]	Child[e]	Adult[f]
Non-Carcinogens						
aldehydes[a]	2.0E-01	3.6	6.0E-02	3.6	2.0E-02	3.6
ketones[b]	2.8E-05	3.9E-04	8.3E-06	3.8E-04	2.8E-06	3.8E-04
aliphatics	1.9E-02	3.4E-01	2.5E-03	3.3E-01	7.2E-04	3.3E-01
aromatics[c]	2.2E-03	6.9E-02	2.0E-04	6.8E-02	5.1E-05	6.7E-02
PAH non-carcinogenic[d]	3.3E-06	4.6E-05	9.7E-07	4.5E-05	3.3E-07	4.4E-05
Carcinogens						
formaldehyde	6.3E-02	8.6E-01	1.9E-02	8.3E-01	6.3E-03	8.2E-01
acetaldehyde	3.4E-03	4.7E-02	1.2E-03	5.1E-02	3.9E-04	5.1E-02
benzene	1.4E-03	1.9E-02	4.2E-04	1.8E-02	1.4E-04	1.8E-02
PAH non-carcinogenic[g]	1.8E-04	2.4E-03	5.4E-05	2.4E-03	1.8E-05	2.3E-03
Total Carcinogens [h]	6.8E-02	9.3E-01	2.1E-02	9.0E-01	6.9E-03	8.9E-01

(a) modelled as acrolein
(b) modelled as acetone
(c) excludes benzene
(d) ER values for all non-carcinogenic PAHs
(e) denotes a child of 5-11 years for non-carcinogens, and composite resident for carcinogens
(f) denotes an adult who resides in community and works at mine site
(g) ER value for all carcinogenic PAHs combined, using B(a)P toxicity equivalent factors
(h) the sum of all carcinogen ERs

This is virtually entirely due to the on-site occupational exposure associated with fleet vehicle emissions, as exemplified by the similarity in Sum ERs for each community. This component of exposure was estimated for continuous worst case conditions on-site, from age 20 to 70 years, and assumes a seven day work week. In reality the risk estimate is expected to be significantly less. In light of these results, the incremental exposure to these substances is not anticipated to present a level of health risk that is considered unacceptable by provincial and federal agencies in Canada.

Step 2: Airborne Particulates and Adsorbed Chemicals

Particulate Matter (PM)

Maximum ambient air concentrations of particulate matter in the form of PM_{10} and $PM_{2.5}$ were predicted for the mine stacks and also the mine fleet exhaust emissions, however it is not appropriate to sum these because the stack and vehicle emissions will not mix due to the differing heights of emission release. The predicted overall maximum incremental levels at the mine site and in the local communities are presented in Appendix X.1. While *on-site* concentrations may attain a peak *hourly* concentration of 48 and 75 $\mu g/m^3$ for $PM_{2.5}$ and PM_{10}, respectively, the *24-h averaged* values (relevant for compliance and risk estimation purposes), do not exceed even the most conservative *draft* objectives proposed by Health Canada (WGAQOG 1997), either off-site or on-site.

Health Canada states that there is no evidence that supports the concept of a threshold effect level for PM_{10} and $PM_{2.5}$ substances; PM is viewed essentially as having no threshold with respect to the positive associations between particulate matter and morbidity and mortality. However, they recognize that at levels below 15 μg/m^3, the association cannot reliably be predicted (WGAQOG 1997). Available information suggests total particulates less than 30μm in diameter at Fort McMurray average 9-15μg/m^3 over the period 1990 to 1994 (Golder 1996f). In the present case the incremental 24 h averaged particulate concentrations predicted for Fort McKay and Fort McMurray range from 1 to 3 μg/m^3, and less than 0.5 μg/m^3 for Fort Chipeywan. These levels are significantly lower than the typical levels measured in Canadian urban centres and well within compliance of existing provincial guidelines in British Columbia, but may occasionally cause a marginal increase over the Health Canada reference level of 15 μg/m^3, noted above. It should be noted that forest fires may also easily elevate PM concentrations to exceed this reference level.

Presently, the true incremental contribution to health risk that can be attributed to these levels is subject to wide debate and requires consideration of the patterns of long-term averaged (i.e., monthly and annual) site-specific measurements, since this cannot be extrapolated from data for other urban centres (WGAQOG 1997). In light of these considerations and information presented by Health Canada (WGAQOG 1997), we conclude that while the predicted PM levels cannot be viewed entirely without association with health effects, the predicted PM increments in the local communities would be small in light of average observed particulate levels in Fort McMurray.

Chemicals Potentially Adsorbed to Fugitive Particulates

The forgoing discussion of health effects of PM is based on studies of association between PM levels with observed levels of hospitalization and population mortality. The particulate matter in these studies inherently include typical urban chemicals associated with the respirable particulates. However, to provide added insight, this step in the analysis focuses on the potential *chemical* exposure that may arise from inhalation of fugitive particulates.

There are no direct measurements of ambient concentrations of chemicals associated with airborne particulates in the oil sands area, thus, it is not possible to explicitly quantify off-site health risks associated with this exposure pathway. There is, however, indirect evidence that suggests that exposures to particulates from dust derived on-site pose no health hazard to people who may reside near the Project site. This is illustrated in the following screening-level assessment that was previously conducted by Golder in respect of the Steepbank Mine EIA (Golder 1996f) for chemicals that may be associated with fugitive particulates. The rationale is reproduced here:

Syncrude maintains two high volume samplers, one located near Fort McMurray and the other on Syncrude's existing site (Tailings North). (Suncor has no comparable samplers). These samplers collect air samples for a 24-h period, once every six days (~61 samples per year) and typically collect particles that are less than 30 μm in diameter. From 1990 to 1994, the annual, maximum recorded concentrations ranged from 34 to 79 $\mu g/m^3$ at Fort McMurray and 88 to 273 $\mu g/m^3$ at Tailings North; and geometric means ranged from 9.4 to 14.9 $\mu g/m^3$ at Fort McMurray and from 10.5 to 19.0 $\mu g/m^3$ at Tailings North. The particles sampled are presumably derived from natural sources (forest fires, off-site dust), dust generated on-site and from air emissions from Suncor's and Syncrude's plants.

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

It was assumed that the relative amounts of PAHs and metals measured in tailings sand are representative of relative concentrations in particulates collected at Tailings North and at off-site locations. It was further assumed that the worst-case particulate level of 273 $\mu g/m^3$ (i.e., maximum concentrations recorded from 1990 to 1994 at Tailings North) was representative of typical off-site particulate levels that might occur adjacent to existing or future operations. Then, worst-case concentrations of PAHs and metals associated with respirable particulates can be estimated as shown in Table E12-7.

Predicted worst-case exposure concentrations were compared with RBCs for air, where the RBCs are set at levels to protect the health of sensitive individuals who are exposed for 24 hours per day, 350 days per year for 30 a. (Table E12-7). As evident from Table E12-7, predicted concentrations are considerably lower than RBCs. Considering the multiple protective assumption built into this analysis, it is reasonable to conclude that dust generated from the proposed Project operations does not pose an off-site health hazard.

Step 3: Odiferous Chemicals and Odour Thresholds

To evaluate the impact of air emissions in the context of esthetic quality, air dispersion modelling was conducted for a series of reduced sulphides known to have low odour thresholds. Maximum ambient air concentrations were derived on an hourly, daily and annually averaged basis for the communities of Fort McKay, Fort McMurray and Fort Chipewyan. The major emission source for these substances is the tailings ponds. Table E12-8 summarizes the predicted concentrations; and the occurrences of exceedances.

The results suggest that short-term (i.e., hourly data) air concentrations may occasionally reach peaks that are detectable on-site and possible in Fort

McKay. The pattern suggests that overall the likelihood for detection of odours off-site is low.

E12.7.3 Residual Impact Classification and Degree of Concern

Although in two cases the estimated exposure ratios marginally exceed 1 (see Step 1); closer scrutiny of these occurrences indicates they are driven by a highly conservative worker-related exposure and are not reflective of predicted societal exposure. In light of the conservatism arising from the air dispersion modelling and exposure modelling, it is anticipated that exposures and associated risks would, in reality, be considerably lower. In light of the foregoing conservative analyses, no unacceptable human health risks are predicted from changes in air quality that may arise solely from Project activities. Therefore, the magnitude of impacts to human health as a result of predicted air quality is negligible, and hence the degree of concern is also negligible.

Distinct from the potential for impact to human health per se, conservative air dispersion modelling suggests that the likelihood for detection of odours off-site is low.

Certainty

This assessment was based on a variety of conservative assumptions including the following:

- *maximum* predicted ambient air exposure concentrations which derive from conservative air dispersion modelling methods;
- exposure assumes people reside entire life in the communities;
- assumption that worker exposure occurs 7 days/week from ages 20 to age 70;
- assumption that worker exposure is consistently in the zone of maximum predicted chemical concentrations on-site;
- bioavailability via inhalation is 100 %; summation of risk estimates from various emissions assumes maximum air concentrations from each source occur and converge concurrently at the receptor location; and
- where exposure assessment involves summation of concentrations across a group of chemicals, the most conservative toxicity reference value was employed (i.e., assumes greater potency for most substances in the group).

Table E12-7 Predicted Concentration of Airborne Containment Adsorbed to Particulates and RBCs[(a)]

Chemical	Concentration in Tailings sand (mg/kg)	Predicted Concentration in Air ($\mu g/m^3$)	EPA Risk-Based Concentration (air) (mg/m^3)
PAHs			
acenaphthene	0.01	0.0000027	220
anthracene	0.01	0.0000027	1100
benzo(a)anthracene	0.15	0.000041	0.01
benzo(a)pyrene	0.01	0.0000027	0.001
benzo(b&k)fluoranthene	0.03	0.0000082	0.01
biphenyl	0.01	0.0000027	180
dibenzo(a,h)anthracene	0.01	0.0000027	0.001
fluoranthene	0.01	0.0000027	150
fluorene	0.01	0.0000027	150
naphthalene	0.01	0.0000027	150
pyrene	0.04	0.0000109	110
INORGANICS			
aluminum	172	0.047	3700
antimony	0.05	0.000014	1.5
arsenic	0.63	0.00017	1.1
barium	4.9	0.0013	0.52
beryllium	0.1	0.000027	0.0075
boron	0.1	0.000027	21
cadmium	0.3	0.000082	0.00099
chromium	0.5	0.00014	0.00015
cobalt	2	0.00055	220
copper	0.5	0.00014	140
lead	2	0.00055	0.00037
manganese	56.5	0.015	0.052
mercury	0.03	0.0000082	0.31
molybdenum	2	0.00055	18
nickel	2	0.00055	73
phosphorus	22	0.0060	0.0073
selenium	0.02	0.0000055	18
vanadium	2.8	0.00076	26
zinc	5.8	0.0016	1100

[(a)]Reproduced from Golder 1996f

Collectively, these assumptions weigh heavily towards exposure ratios that over-estimate the true risk that is likely to be manifested by the Project.

The main areas of uncertainty associated with this analysis include:

- the uncertainty inherent with estimated fugitive emissions and air dispersion modelling (Section E2) that manifest as uncertainty in the predicted exposure concentrations; and

Table E12-8 Reduced Sulphides Ambient Air Concentrations (μg/m³) for Odour Threshold Analysis

Chemical	Odour Thresholds[a]		Overall Maximum Predicted			Fort McKay			Fort McMurray			Fort Chipeywan		
	Low	High	1 hour	1 day	annual	1 hour	1 day	annual	1 hour	1 day	annual	1 hour	1 day	annual
2,5-dimethyl thiophene			3.69E+00	2.06E+00	7.73E-01	5.42E-01	8.27E-02	9.82E-03	1.76E-01	3.22E-02	8.35E-04	9.79E-02	4.82E-03	2.04E-04
2-ethylthiophene			1.21E+00	6.77E-01	2.54E-01	1.78E-01	2.72E-02	3.23E-03	5.80E-02	1.06E-02	2.75E-04	3.22E-02	1.58E-03	6.71E-05
2-methyl thiophene			2.56E+00	1.43E+00	5.37E-01	3.77E-01	5.74E-02	6.81E-03	1.22E-01	2.24E-02	5.80E-04	6.80E-02	3.34E-03	1.42E-04
3-methyl thiophene			1.27E+00	7.10E-01	2.67E-01	1.87E-01	2.85E-02	3.39E-03	6.09E-02	1.11E-02	2.88E-04	3.38E-02	1.66E-03	7.03E-05
carbon disulphide	2.43E+01	2.31E+04	1.39E-01	7.75E-02	2.91E-02	2.04E-02	3.11E-03	3.69E-04	6.64E-03	1.21E-03	3.14E-05	3.68E-03	1.81E-04	7.67E-06
carbonyl sulphide			2.50E-01	1.39E-01	5.23E-02	3.67E-02	5.60E-03	6.64E-04	1.19E-02	2.18E-03	5.65E-05	6.63E-03	3.26E-04	1.38E-05
di-n-butyl sulphide	8.97E+01	8.97E+01	1.01E+01	5.65E+00	2.12E+00	1.49E+00	2.27E-01	2.69E-02	4.84E-01	8.84E-02	2.29E-03	2.69E-01	1.32E-02	5.60E-04
diallyl sulphide	5.00E-01	1.49E+02	9.10E-01	5.08E-01	1.91E-01	1.34E-01	2.04E-02	2.42E-03	4.35E-02	7.95E-03	2.06E-04	2.42E-02	1.19E-03	5.03E-05
diethyl sulphide	1.77E+01	1.77E+01	1.21E-01	6.75E-02	2.54E-02	1.78E-02	2.71E-03	3.22E-04	5.79E-03	1.06E-03	2.74E-05	3.21E-03	1.58E-04	6.69E-06
hydrogen sulphide	7.00E-01	1.40E+01	9.95E-01	5.56E-01	2.09E-01	1.46E-01	2.23E-02	2.65E-03	4.76E-02	8.69E-03	2.25E-04	2.64E-02	1.30E-03	5.50E-05
isobutyl mercaptan	2.00E+00	2.00E+00	1.23E-01	6.88E-02	2.58E-02	1.81E-02	2.77E-03	3.28E-04	5.90E-03	1.08E-03	2.79E-05	3.27E-03	1.61E-04	6.82E-06
methyl mercaptan	4.00E-02	8.20E+01	3.32E-02	1.86E-02	6.97E-03	4.89E-03	7.46E-04	8.85E-05	1.59E-03	2.90E-04	7.52E-06	8.82E-04	4.34E-05	1.84E-06
n-amyl mercaptan	1.00E-01	1.80E+00	8.38E-01	4.68E-01	1.76E-01	*1.23E-01*	1.88E-02	2.23E-03	4.01E-02	7.33E-03	1.90E-04	2.23E-02	1.10E-03	4.64E-05
thiophene	2.60E+01	2.60E+01	3.26E-01	1.82E-01	6.84E-02	4.80E-02	7.32E-03	8.68E-04	1.56E-02	2.85E-03	7.38E-05	8.66E-03	4.26E-04	1.80E-05

Note:
[a] Odour thresholds from Ruth (1986).
Exceeds low odour threshold

- the uncertainty associated with the health risk of low levels of particulate matter in the form of PM_{10} and $PM_{2.5}$.

In both cases, the uncertainty exists both in the form of incomplete information (e.g., adequacy of source emissions data, or dose-response relationship associated with PM_{10} and $PM_{2.5}$), and as variability inherent in various parameters associated with these issues (e.g., meteorological variation).

E12.7.4 Monitoring

Although the impact level and degree of concern is low for the linkage between air quality and human health, air quality remains a paramount issue that requires regular monitoring to ensure that i) health risks remain low, and ii) comprehensive data exists to facilitate validation of the present findings. Therefore, ambient air monitoring, and periodically personal air monitoring, should be effected to provide comprehensive baseline measurements of air quality at the communities examined in this assessment. The monitoring should address conventional air parameters and also characterize additional parameters including $PM_{2.5}$, and a suite of organic chemicals considered to be markers of the various emission sources. To achieve this Shell is committed to be an active member and provide leadership in the following programs:

- Regional Air Quality Coordination Committee for the Southern Wood Buffalo Region: A multiparty group representing communities, industry and government which address concerns about air quality in the Fort McMurray/Fort McKay region.

- Alberta Oil Sands Community Exposure and Health Effects Assessment Program: A multiparty initiative involving community, industry and government participation in characterizing environmental exposure and effects associated with the oil sands industry.

E12.8 Key Question HH-3: Will Consumption of Local Plants and Game Animals Affected by Activities of the Project Change Human Health?

E12.8.1 Analysis of Potential Linkages

Certain local plants (i.e., berries, leaves and cattail/ratroot) are harvested and consumed on a regular basis by members of nearby residential communities. Air emissions from the Project may deposit onto plant surfaces and soils and subsequently be taken up into plant tissues. Stakeholders have expressed concern over the potential for chemical uptake by people who consume these local plants. For this reason, the potential for adverse effects to human health from ingestion of local plants was evaluated.

Linkage Between Project Activities and Changes in Plant Tissue Quality

Because the Muskeg River Mine Project does not exist, direct assessment of this linkage is not possible. Consequently, a vegetation sampling program involving surrogate sites was conducted specifically for the purpose of addressing this key question. Samples of blueberries, Labrador tea leaves and cattail roots, along with separate but corresponding soil and/or sphagnum samples at the base of the plants, were collected during August, 1997 from the following areas:

- Muskeg River Mine Project area (baseline chemical concentrations; Figure E11-10);
- Suncor Lease 25 (area within the deposition zone of air emissions from existing oil sands operations and used as a surrogate of potential impacts from the Muskeg River Mine Project);
- Mariana lakes area, approximately 65 km south of Fort McMurray (control location); and
- West of Syncrude, outside the zone of influence of air emissions (control location).

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 the chemical concentrations in ratroot would be equivalent to chemical concentrations in the cattail root samples collected in this field study.

Collection of plant and soil samples on the Muskeg River Mine Project 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. The plant and soil samples were collected and analyzed for metals and PAHs according to the protocol presented in Appendix X.7. Analytical results are also summarized in Appendix X.7.

PAHs were not detected in blueberries or cattail roots. Small quantities (i.e., levels at or slightly exceeding the limit of detection) of naphthalenes and phenanthrene/anthracene were detected in some samples of Labrador tea leaves collected in the Muskeg River Mine Project area and in potentially impacted areas. However, these PAHs were also detected in control samples of Labrador tea leaves, and concentrations in the test areas do not differ significantly from concentrations found in control areas. It is possible that these observations reflect the natural prevalence of petroleum hydrocarbons in this region. There is historical evidence of a forest fire in the Mariana Lakes region, which may have contributed to the observed concentrations of PAHs in Labrador tea leaves from this region, since PAHs may be released naturally from burning wood. It should also be noted that naphthalenes, phenanthrene and anthracene are non-carcinogenic PAHs, which have relatively low toxic potency compared with other carcinogenic PAHs, such as benzo[a]pyrene, and they are not bioaccumulative. Observed levels in Labrador tea leaves are much less than those that would be associated with adverse human health effects.

Inorganic chemical concentrations in blueberries collected from the Project area and in potentially impacted areas were generally within the range of measured concentrations in control locations, with the exception of copper, manganese, sodium and zinc, which were slightly elevated in samples from the Muskeg River Mine Project area and potentially impacted areas. All of these compounds are essential elements for human nutrition and the measured concentrations in blueberries from test areas would not be associated with any adverse effects to human health.

Several inorganic chemical concentrations in Labrador tea leaves and cattail roots were elevated in samples from the Project area and potentially impacted areas in comparison to control samples. As discussed previously for blueberries, many of these compounds are essential elements for human nutrition and the measured concentrations in test samples would not be associated with adverse effects to human health.

In summary, plant tissue residues were not consistently elevated in areas where oil sands air emissions are a factor. In addition, among the three plant species tested there was no consistent subset of metals that were elevated compared with control plant concentrations. Therefore, the observed plant concentrations cannot be solely attributed to oil sands operations and the linkage cannot be fully validated.

Linkage Between Changes in Plant Tissue Quality and Human Health

Notwithstanding the lack of evidence in the above-noted linkage, a chemical screening process was conducted to evaluate whether the observed concentrations in plant samples may have any adverse effect on human health. This was pursued in light of explicit interests expressed by the Fort McKay Band (Fort McKay First Nations 1997). The chemical screening was based on the above data and the typical consumption patterns of nearby residential communities. Country food consumption patterns for communities within the Regional Study Area were reviewed based on historical documentation (Fort McKay Environmental Services (Ltd.) 1995, 1997a, Aquatic Resources Management Ltd. 1989, Wein 1989).

Berries may be eaten year-round, either fresh, frozen or in preserves (Fort McKay Environmental Services (Ltd.) 1997). The reported mean frequency of berry consumption in the communities of Fort Smith and Fort Chipewyan was 63 times per person per year, with an upper maximum of 128 times per person per year (Wein 1989). The average daily consumption rate of berries was reported to be five grams per person per day, assuming consumption every day throughout the year (i.e., 1825 grams per year, Wein 1989). Berry consumption within Fort McKay was suggested to be approximately one cup per day when berries are available and smaller quantities throughout the winter months in jams, pies and baked goods (Fort McKay Environmental Services (Ltd.), pers. comm.).

The mean consumption frequency of Labrador and mint tea was reported as seven times per year, with an upper maximum of 31 times per year (Wein 1989). Fort McKay Environmental Services (Ltd.) (1997) also reported rare use of Labrador tea in the area. Ratroot and cattail root are picked, dried and used year-round as medicines (i.e., ratroot) and as a source of starches and sugars (i.e., cattail). These roots may be boiled and consumed as a liquid or chewed (Fort McKay Environmental Services (Ltd.) 1995 and 1997). Although ratroot is used by virtually all members of the aboriginal communities within the Regional Study Area, it is used very sparingly, and yearly consumption would not likely exceed 1 cup (Fort McKay Environmental Services (Ltd.), pers. comm.).

Chemical concentrations in plant tissues were screened against risk-based concentrations (RBCs), based on the following conservative assumptions:

- children were assumed to ingest 5 to 20 g of berries every day and 1-5 g of Labrador tea and cattail/ratroot once per week throughout the year;
- adults were assumed to ingest 5 to 15 g of berries every day and 1-5 g of Labrador tea and cattail/ratroot once per week throughout the year; and
- chemical concentrations in plant tissue were conservatively compared against RBCs for child exposure, based on a target exposure ratio (ER) of 0.1 (i.e., ten-fold lower than levels associated with acceptable risk).

The chemical screening process identified the following nine chemicals for further evaluation in the risk assessment:

- antimony (Labrador tea leaves);
- barium (Labrador tea leaves and cattail root);
- boron (blueberries and cattail root);
- cadmium (blueberries);
- copper (blueberries, Labrador tea leaves and cattail root);
- lead (blueberries, Labrador tea leaves and cattail root);
- molybdenum (cattail root);
- nickel (Labrador tea leaves); and
- vanadium (cattail root).

Detailed screening tables are presented in Appendix X.1. It should be noted that these chemicals were selected based on prevalence in plant tissues; however, these residues were not significantly elevated in areas where oil sands air emissions are a factor. In addition, among the three plant species tested, there was no consistent subset of metals that were elevated compared with control plant concentrations. Thus, it does not appear that oil sands operations are the cause for the observed exceedances. This, however, may also be a consequence, in part, of the relatively small number of replicates.

Since elevated chemical concentrations, receptors and exposure pathways may apparently co-exist, a potential linkage exists between plant quality changes and human health. The evidence does not associate this linkage solely with oil sands operations. Notwithstanding these observations, in light of interest articulated by the Fort McKay Band and regulators concerning elevated chemicals concentrations in plants (Human and Ecological Health Component Focus Workshop, October 30, 1997), the plant tissue/human health linkage was retained for further consideration.

Linkage Between Changes in Game Meat Quality and Human Health

Since game animals (i.e., moose, snowshoe hare, ruffed grouse and ducks) form a significant portion of the diet of nearby communities, the potential for adverse effects to human health from ingestion of game meat was raised as a concern by local residents. Game animals may be exposed to chemical emissions from the Project primarily through air inhalation and ingestion of water and plants. As stated in the wildlife health assessment (Section E11), direct air inhalation is considered to be a minor exposure pathway for wildlife. However, the indirect effects of chemical deposition from air onto plant surfaces and soils and subsequent uptake by plants, which are in turn consumed by herbivorous game animals, may be a valid exposure pathway.

As stated above, PAHs were not detected in plant samples, with the exception of naphthalenes and phenanthrene/anthracene in Labrador tea leaves, which were present at low concentrations and are not bioaccumulative. Metal concentrations in plants from test areas were generally within the range of concentrations in control areas, with some minor exceedances. The only potentially bioaccumulative chemicals identified in plant tissues are cadmium, lead and mercury. Cadmium was detected in two of the 15 cattail root samples and one of the 15 Labrador tea samples at low concentrations and was not detected at all in blueberry samples. Lead and mercury were detected in several plant samples in both test areas and control areas at levels marginally exceeding the detection limit. Therefore, even with bioaccumulation, it is not likely that these chemicals would reach concentrations in game meat tissue that would be of concern to human health.

Tissue concentrations in game animals harvested near operating oil sands facilities were not available for quantitative evaluation of the potential for human health effects. However, concentrations in the meat and liver of a bison, which had been grazing on a capped tailings pond area near the Syncrude oil sands facility, were determined to be low and would not result in any adverse effects to human health if consumed (Pauls et al. 1995). Notwithstanding this finding the bison tissue data were incorporated into the multimedia risk assessment for the *reclaimed landscape scenario* (see Key Question HH-7 for further details).

In summary, oil sands operations do not appear to contribute to increases in chemical concentrations in plants and therefore would not be likely to reach concentrations in game meat that would be associated with adverse human health effects. Limited field data of bison tissue residues supports this position. Hence, a linkage between changes in the tissue quality of game meat associated with the Project and human health was considered invalid.

E12.8.2 Analysis of Key Question

To further investigate the linkage between plant tissue quality and human health, a quantitative human health risk assessment was conducted for conceptual model HH-3 (Figure E12-8) according to the method described in Section E12.5.3. Key aspects of the risk assessment are presented here; additional details are presented in Appendix X.

Children and adults were assumed to consume 20 and 15 g of blueberries, respectively, every day throughout the year and five grams each of Labrador tea leaves and cattail root, once a week throughout the year. Maximum measured concentrations in plants from either the Project area or potentially impacted areas from other oil sands facilities were used in calculating the risk estimates to ensure a conservative assessment. In addition, although a chemical may have only screened on because of concentrations in one plant type, it was conservatively evaluated in all plant types where concentrations were measurable to address concerns associated with combined exposure to all plant types.

Exposure ratios are presented for each plant separately and for the combined exposure to all three plant types in Table E12-9.

For both child and adult receptors, ER values were less than 1 for exposure to each plant separately and for combined exposure to all plants, indicating that predicted conservative exposures likely to be incurred by residents who consume local plants are well within acceptable limits. Therefore, no impacts to human health are predicted due to ingestion of local plants.

Figure E12-8 HH-3: Conceptual Model for Local Plant and Game Animal Scenarios

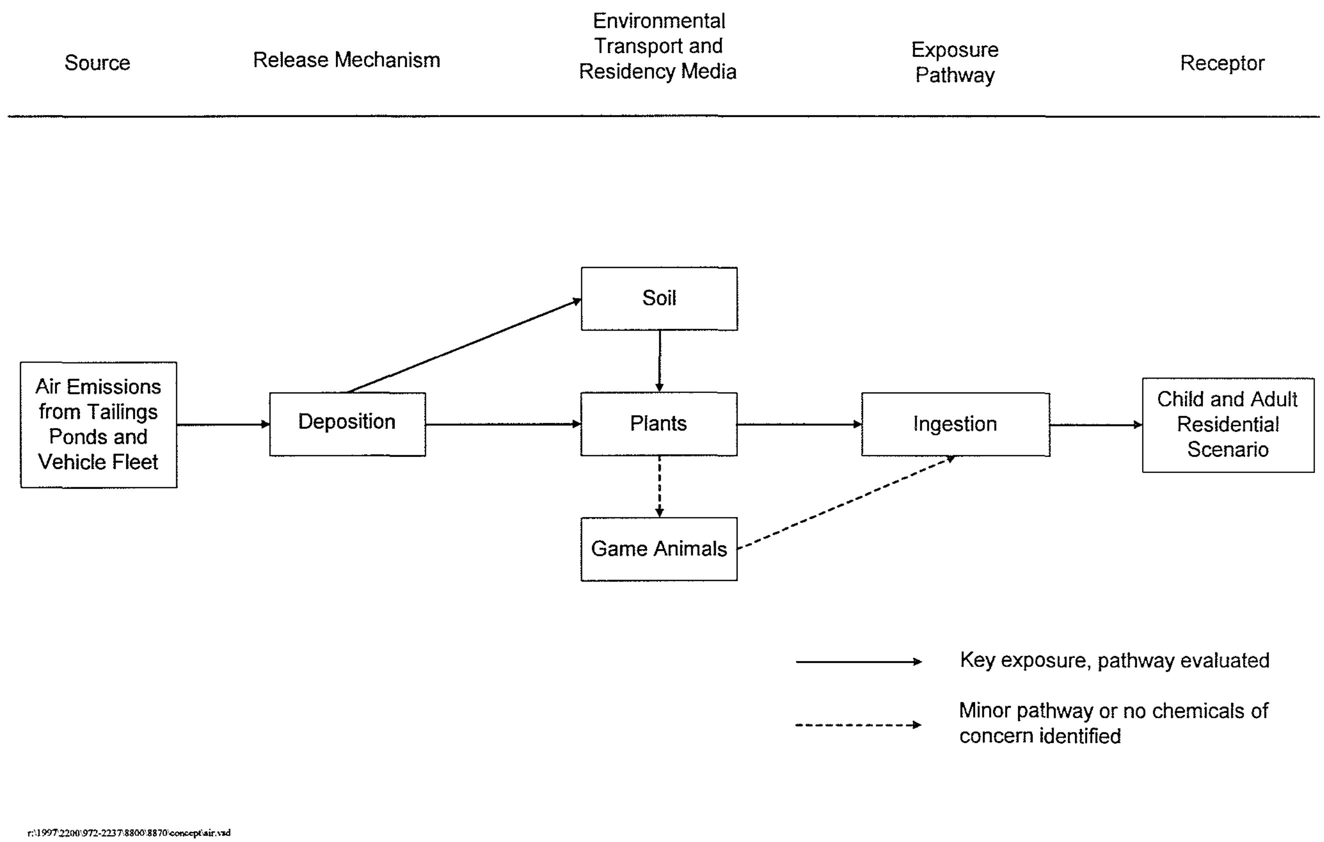


Table E12-9 Exposure Ratio Values for Children and Adults

Receptor/Chemical	Blueberries	Labrador Tea Leaves	Cattail Root	All Plants Combined
Child				
antimony	0[(a)]	0.02	0[(a)]	0.02
barium	0.07	0.02	0.007	0.097
boron	0.02	0.003	0.004	0.027
cadmium	0.03	0.001	0.002	0.033
copper	0.003	0.002	0.0003	0.0053
lead	0.03	0.009	0.008	0.047
molybdenum	0.007	0.0003	0.004	0.011
nickel	0.01	0.004	0.006	0.02
vanadium	0[(a)]	0.0002	0.01	0.0102
Adult				
antimony	0[(a)]	0.003	0[(a)]	0.003
barium	0.09	0.003	0.001	0.094
boron	0.03	0.0006	0.0007	0.031
cadmium	0.04	0.0002	0.0003	0.041
copper	0.004	0.0003	0.00006	0.0044
lead	0.02	0.0008	0.0007	0.0215
molybdenum	0.009	0.00005	0.0007	0.0098
nickel	0.01	0.0007	0.001	0.012
vanadium	0.02	0.00004	0.002	0.022

(a) not detected

E12.8.3 Residual Impact Classification and Degree of Concern

Based on the information assessed, the magnitude of impact is negligible. Therefore the degree of concern is also rated as negligible.

Certainty

This assessment was based on a number of conservative assumptions including the following:

- maximum concentrations measured in plant tissue were used;
- daily ingestion estimates for these local plants represent reasonable maximum exposure values for the communities evaluated;
- oral bioavailability was set to a maximum of 100%;
- combined exposure to all plant types was considered; and
- toxicity reference values were set to be protective of sensitive members of the population (i.e., seniors) under chronic exposure conditions.

Due to the conservatism involved in the risk assessment for consumption of local plants, the degree of certainty associated with the risk predictions is high. However, some uncertainty exists with respect to consumption of game animals due to a paucity of data available for assessment. As stated above, however, since plant tissue concentrations do not appear to be increased in potentially impacted areas compared with control areas, it is likely that game animals that consume these plants (e.g., moose, snowshoe hare, waterfowl and grouse) would also not accumulate higher concentrations in their tissues than animals foraging in unimpacted areas.

E12.8.4 Monitoring

Shell anticipates becoming a member of the Regional Air Quality Coordinating Committee (RAQCC) for Southern Wood Buffalo Region. The Environmental Effect Monitoring (EEM) Committee is currently planning a study to be implemented in 1998 which will involve sampling of game and plant tissue for analysis and interpretation respecting human health.

E12.9 Key Question HH-4: Will the Combined Exposure to Water, Fish, Air, Plants and Game Animals Affected by the Project Change Human Health?

E12.9.1 Analysis of Potential Linkages

Stakeholders have expressed concerns over the combined exposure of local residents to chemicals from various media potentially affected by emissions from the Project. People living in the area may be exposed to chemicals from a number of sources, including water, fish, air, plants and game animals. The potential for adverse human health effects from each of these sources have been evaluated separately in key questions HH-1 to HH-3. No human health impacts were identified in these assessments. However, in light of the validity of individual linkages, a potential linkage exists between the combined exposure to these media and human health. For this reason, combined exposure was evaluated in the risk assessment.

E12.9.2 Analysis of Key Question

To calculate risk estimates for the combined exposure to all media, incremental risk estimates (ER values) for each media were summed, resulting in a total ER value for each chemical. Chemical screening for each media identified different chemicals. However, for the purposes of this linkage analysis, any chemical that was retained for one media was evaluated in all media, where data were available, to ensure a conservative assessment of combined exposure. Although fish tissue quality was not identified as a concern for human consumption on its own, chemical contributions from ingestion of fish were also considered in the combined exposure calculations. ER values for the recreational water scenario were used, since these are more conservative than ER values for the swimming scenario. The same exposure parameters and pathways used in the previous linkage analyses also apply in the present case (Figures E12-6 to E12-8). ER values are presented for each media and for all media combined in Table E12-10.

Virtually all ER values related to the sum of the Project activities are less than 1. These results indicate that even with combined exposure to water, fish, air and plants, no human health impacts are expected. A few exposure ratios, as noted and discussed previously, are marginally greater than 1, however these are very likely to be much less in light of the conservatism employed.

For carcinogenic risks, arsenic and beryllium present a naturally elevated health risk as discussed in Section 12.6.2. When combined with the conservative carcinogenic risk from substances emitted from the vehicle fleet, the sum ER is approximately 5 to 6. This apparent level of health risk is a reflection of conservative assumptions that are unlikely to exist. Further, it should be noted that the main driver of the risk is background exposure to waterborne arsenic and beryllium which are actually less than the Canadian Drinking Water Guidelines.

Finally, with respect to the potential for chemical interactions, the following points are offered:

- It is not appropriate to simply sum all the individual metal-related ERs because they do not all have the same effect or act in the same way. Nevertheless, if the exercise is carried out for either the child, or adult, the sum of the ERs for metals remains less than 1, suggesting that even if they were additive in nature the exposure would not be adverse.

- For PAHs we have explicitly incorporated the potential for additive effects by grouping PAHs into functional groups based on those with similar molecular structure and modes of toxicity, and among carcinogenic chemicals, by summing the indicated carcinogenic risk estimates for each carcinogenic chemical evaluated.

- Potential synergistic, or antagonistic, chemical interactions cannot be entirely ruled out, however, with the exception of barium, the metal ERs are typically one to two orders of magnitude below 1, in spite of the conservative factors employed. Further, each toxicity reference value has a substantive conservative uncertainty factor associated with it (e.g., 100 to 1000 fold) making it highly unlikely that a synergistic effect would be significant. If antagonistic interaction occurred, this would simply reduce the risks of health effects further.

- A similar argument can be made for the other organic substances in light of their low ER values.

Table E12-10 Exposure Ratio Values for Children and Adults during Operation

Receptor/Chemical	Water	Fish	Air	Plants	All Sources
Child[a]					
antimony	0.0002	0	0	0.02	0.02
arsenic [b]	3.5		0		3.5
barium	0.008	0.004	0	0.1	0.112
beryllium[b]	1.5		0		1.5
boron	0.008	0	0	0.003	0.011
cadmium	0.007	0	0	0.03	0.037
copper	0.00004	0.002	0	0.005	0.007
lead	0.002	0	0	0.05	0.052
molybdenum	0.0007	0	0	0.01	0.011
nickel	0.0004	0.06	0	0.02	0.08
vanadium	0.001	0	0	0.01	0.011
acetaldehyde [b]	0	0	3.4E-03	0	0
aldehydes [c]	0	0	2.0E-01	0	0
aliphatics	0	0	1.9E-02	0	0
aromatic [e]	0	0	2.2E-03	0	0
benzene [b]	0	0	1.4E-03	0	0
benz(a)anthracene [b]	0	0		0	0
benzo(b)fluoranthene	0	0		0	0
benzo(k)fluoranthene	0	0		0	0
benzo(a)pyrene	0	0		0	0
chrysene	0	0		0	0
dibenz(h)anthracene	0	0		0	0
formaldehyde [b]	0	0	6.3E-02	0	0
indeno(1,2,3)pyrene	0	0		0	0
ketones [d]	0	0	2.8E-05	0	0
PAH carcinogenic [b]	0	0	1.8E-04	0	0
PAH non-carcinogenic [f]	0	0	3.3E-06	0	0
Total Carcinogenic	*5.0E+00*	*0*	*6.8E-02*	*0*	*5.068*
Adult-Worker [g]					
antimony	0.00007	0	0	0.003	0.003
arsenic [b]	3.5		0		3.5
barium	0.003	0.002	0	0.09	0.095
beryllium [b]	1.5		0		1.5
boron	0.002	0	0	0.03	0.033
cadmium	0.001	0	0	0.04	0.042
copper	0.00001	0.001	0	0.004	0.005
lead	0.0003	0	0	0.02	0.021
molybdenum	0.0002	0	0	0.0097	0.01
nickel	0.0001	0.03	0	0.02	0.05
vanadium	0.0003	0	0	0.02	0.02
acetaldehyde	0	0	4.7E-02	4.7E-02	4.7E-02
aldehydes [c]	0	0	3.8E+00	3.8E+00	3.8E+00
aliphatics	0	0	3.4E-01	3.4E-01	3.4E-01
aromatic [e]	0	0	6.9E-02	6.9E-02	6.9E-02
benzene [b]	0	0	1.9E-02	1.9E-02	1.9E-02
formaldehyde	0	0	8.6E-01	8.6E-01	8.6E-01
ketones [d]	0	0	3.9E-04	3.9E-04	3.9E-04
PAH non-carcinogenic[f]	0	0	4.6E-05	4.6E-05	4.6E-05
PAH carcinogenic [b]			2.4E-03	2.4E-03	2.4E-03
Total Carcinogenic	*5.0E+00*	*0*	*9.3E-01*	*9.3E-01*	*5.93*

(a) the ER values which follow are for a child, except for carcinogens where they apply to a composite resident receptor
(b) denotes a substance with carcinogenic effects
(c) aldehydes modelled as acrolein
(d) ketones modelled as acetone
(e) aromatics exclude benzene
(f) refers to the sum ER for grouped non-carcinogenic PAHs
(g) the ER values which follow are for an adult, except for carcinogens where they apply to a composite resident receptor that works at the mine site

E12.9.3 Residual Impact Classification and Degree of Concern

In light of the results foregoing discussion, and recognition of toxicity data lacking for assessment of naphthenic acids, the magnitude of impact and degree of concern are summarized as follows:

Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
Negative	Low	Local	Long-term	Reversible	Medium	Low

Certainty

In addition to the conservative assumptions described under each of the preceding key questions, the assessment of combined exposures was also exceptionally conservative in that it assumed people would be exposed to maximum measured or estimated chemical concentrations in all media at the same time. Due to the conservatism involved in the risk assessment for combined exposure, there is a high degree of confidence in the results of the assessment with the exception of the lack of a toxicity reference value for naphthenic acids and corresponding health risks.

The reader is also referred to discussions of certainty associated with the analyses of previous key questions, as they are applicable here.

E12.9.4 Monitoring

Monitoring as previously noted for the individual linkages will provide appropriate data for integration in the context of this multimedia assessment. Similarly, further characterization of the chronic toxicity of naphthenic acids, as previously noted, applies here.

E12.10 Key Question HH-5: Are Sufficient Procedures in Place to Assure Worker Health and Safety During Construction and Operation of the Project?

E12.10.1 Analysis of Potential Linkages

Worker Health and Safety for the Project will be managed under Shell Canada Limited's "Health, Safety and Sustainable Development (HSSD) Management System" and by Occupational Health and Safety personnel. Resources will be provided by Shell's Canada Limited Corporate Health, Safety and Environment department (HSE), which includes expertise in occupational medicine and nursing, industrial hygiene, toxicology, safety, transportation of dangerous goods, emergency response and HSE audit. In addition, health and safety personnel located on-site will include expertise in occupational health, industrial hygiene and safety. The HSSD Management System requires that Project operations are in compliance with all relevant local, provincial and federal laws and regulations to ensure a safe and healthy workplace for all employees.

The Hazards and Effects Management component of the management system requires that potential workplace hazards associated with each employee's work environment are identified and addressed. Whenever possible, engineered controls, alternative work procedures and administrative controls are used to minimize or eliminate these potential hazards. When these types of controls are not practical, mitigation measures, such as personal protective equipment, are used to minimize human exposure to the potential hazards. Proactive occupational health and safety activities such as employee training, regular equipment inspections and routine monitoring of workplace hazards and employee health will help protect worker health and safety for the Muskeg River Mine Project. In addition, appropriate emergency response plans will be developed before work commences on the Project to allow appropriate and timely response to potentially harmful events.

The HSSD Management System includes policies, objectives, targets, standards and guidelines for the protection of worker health and safety and is regularly reviewed for currency. Requirements and recommendations for managing occupational health and safety at all Shell Canada Limited facilities are specified. In cases where legislation imposes more stringent or additional requirements, the legislative requirements will take precedence. Shell Canada Limited has a long history of safe operation of major petroleum facilities and is committed to active participation of staff at all levels in their health and safety management program.

Standards and Guidelines

Legislative Compliance

Health and safety procedures will comply with all local, provincial and federal requirements. Occupational health and safety staff will monitor changes to legislation, so that programs and procedures are always in compliance. All employees will receive training in applicable health and safety legislation related to their job activities, such Transportation of Dangerous Goods, Workplace Hazardous Materials Information System and New Substance Notification under the Canadian Environmental Protection Act (CEPA).

Workplace Hazardous Materials Information System

The Workplace Hazardous Materials Information System (WHMIS) is the national system of identification and management of hazardous materials in the workplace, regulated by the federal Hazardous Products and the Hazardous Information Review Acts and by the provincial Occupational Health and Safety Act. All hazardous materials at the facility will be managed according to WHMIS requirements and workers will receive appropriate training in the proper use, handling and symptoms of exposure to these substances. While complying with WHMIS is a responsibility of all Shell Canada Limited employees, the overall administrative role is the responsibility of local site management.

Workplace Controls

Safe work permits, regular inspections, work observations and routine monitoring are all essential components of Shell Canada Limited's health and safety management system. All incidents will be reported, investigated and closely monitored. Standard procedures will be developed for critical tasks or activities that, if performed incorrectly, may have significant potential for harming people or the environment.

Health and Safety Protection

General Personal Protection

Workplace hazards will be identified and the potential risk for personal injuries will be assessed within each operating area. These types of hazards may include falling objects, fires and explosions, cuts and abrasions, exposure to corrosive or toxic chemicals, contact with electricity, sun exposure, heat and cold stress, infection, etc. Potential hazards will be minimized or eliminated using engineered controls, alternate work procedures/materials or administrative controls, whenever possible. Personal protective equipment (e.g., head protection, foot protection, fire retarding clothing, protective clothing) will be used in instances where other types of control are impractical. All protective equipment will meet the standards set by the Canadian Standards Association (CSA). Workers will receive training in the nature, extent and effects of workplace hazards, the selection, correct usage and limitations of the personal protective equipment, and the care, maintenance and storage of protective equipment.

Vision Conservation

Vision hazards will be identified and assessed at regular intervals (at least every five years or whenever significant change has occurred). Engineered controls or alternate work procedures will be implemented to minimize or eliminate vision hazards, whenever possible. In areas where vision hazards cannot be controlled by these means, vision hazards will be mitigated by the mandatory use of protective eyewear (e.g., safety glasses, goggles, full-face shields, welding shields) as specified by CSA. Vision tests will be carried out using standard equipment and protocols before employment and at regular intervals thereafter to ensure the safety of the employee. Levels of illumination in the work environment will meet Illumination Engineering Society (IES) guidelines.

Hearing Conservation

Noise hazards will be identified and assessed at regular intervals (at least every five years or whenever significant change has occurred), according to CSA standards. Whenever possible, noise control equipment or alternate work procedures will be implemented to keep worker's exposure to noise below levels requiring hearing protection (i.e., less than 85 dBA). Areas with noise levels exceeding 85 dBA will be designated as noise hazard areas with mandatory requirements for use of hearing protection equipment. Hearing equipment will meet CSA requirements and will be properly fitted and maintained. Workers will receive training in how to recognize a noise hazard area, procedures to follow when working in a noise hazard area, effects of overexposure to noise, and the proper use, selection and care of hearing protection. Hearing tests will be carried out using standard equipment and protocols before employment and at regular intervals thereafter to ensure the safety of the employee.

Respiratory Protection

Respiratory hazards (i.e., oxygen deficient atmosphere, chemical exposure, dust exposure) will be identified and assessed before commencement of operations. Whenever practical, engineered controls or alternate work procedures will be used to minimize hazards. Respiratory protective equipment, as specified by CSA, will be used as mitigation in cases where alternative controls are not available. Workers will receive training in the nature, extent and effects of respiratory hazards, operation and limitations of the respiratory protective equipment, how to inspect, properly fit and use protective equipment, the care, maintenance and storage of protective equipment, and use of respiratory protective equipment in emergency situations. Fit testing will be carried out at least every three years. Health assessments will be conducted before commencement of employment and at regular intervals thereafter, with documentation of results. Emergency training and procedures will be in place before any work taking place in areas where potential respiratory hazards have been identified.

Heat and Cold Stress

Potential health impacts related to temperature extremes will be identified and evaluated. Legislated limits and guidelines will be strictly adhered to. Temperature extremes will be minimized or eliminated using engineered controls (e.g., ventilation, shielding, cooling equipment) and administrative controls, whenever practical. Workers will receive training regarding the symptoms of heat and cold stress. Facilities and supplies (i.e., protective clothing and equipment) will be provided to workers to allow for protection and recovery from temperature stress, if necessary.

Reproductive Hazards

Potential reproductive hazards (i.e., any chemical, biological or physical factors which may cause reproductive impairment to the employee or developmental impairment to an unborn child) will be identified and assessed. Hazards will be minimized or reduced using engineered controls or alternate work procedures, whenever possible. All employees will be informed of potential reproductive hazards in their work environment and possible preventative measures if any are required.

Potable Water

Drinking water sources at the Muskeg River Mine Project area will comply with the Guidelines for Canadian Drinking Water Quality. Water quality will be routinely monitored for microbiological and chemical parameters. In addition, the water system will be regularly cleaned and inspected monthly. If potable water sources are determined at any time to be unsafe for human consumption, employees and the local health authority will be immediately notified and alternative drinking water sources will be supplied.

Driver and Public/Visitor Safety

As well as on-site safety for employees and contractors, special attention will be paid to visitor and driver safety. In particular, provisions such as special safety training, limited site access and enhanced visibility markers for common vehicles will be used to maximize safety around operation of large pay-load vehicles on-site. Preventative measures will be implemented by Shell to maximize Public Safety during construction and operation of the Project. This will include, but not be limited to, controlled vehicle access to the site, controlled access of people to the site, signage to alert visitors and by-standers of potential hazards and procedures on or near the site. Shell will also implement a communication program with the community and facilitate controlled visits/tours. Emergency response plans will be developed for various potential events that may arise during construction and operation, with a component directed towards public safety.

Fitness to Work and Health Surveillance

A pre-placement health assessment will be conducted, based on job requirements. Final hiring is contingent upon successful completion of the health assessment. Employee health, depending on the nature of exposure, will continue to be monitored throughout their term of employment at the Muskeg River Mine Project area to ensure that exposure to chemical, biological or physical agents in the workplace does not pose an adverse effect to their health.

Emergency Preparedness

Effective management of emergency preparedness and response will minimize the impacts of an emergency. Potential emergency situations will be identified for each work area. Emergency Response Plans will be developed to address each of the identified emergency situations. Emergency Response Plans include procedures for activating the warning and response system, a current contact list and identified responsibilities, emergency-specific action plans, a list of resources (i.e., specialist personnel or equipment), a response management plan, procedures for prompt notification and reporting of emergency incidents to workers and appropriate jurisdictional authorities, and delegation and backup requirements. The Project will have an in-house Emergency Response Team comprised of fire fighters, rescue personnel, first-aid trained staff and nurses to facilitate an appropriate and immediate response to an emergency situation. In addition, workers will receive training in emergency response procedures.

Summary

In summary, Shell Canada Limited's worker health and safety management system provides a wide array of appropriate elements and measures for this undertaking to comply with all relevant laws and regulations and to ensure a safe and healthy workplace for all employees. Providing these measures are diligently practiced by workers, no unacceptable level of risk to worker health or safety is anticipated; hence this link is considered to be invalid for human health.

E12.10.2 Residual Impact Analysis and Degree of Concern

Based on the information assessed, no residual impacts were identified. Therefore the degree of concern is rated as negligible.

E12.10.3 Monitoring

Shell Canada Limited is committed to monitoring worker health and safety throughout the life of the Project. Specific monitoring strategies will be developed by occupational health and safety personnel.

E12.11 Key Question HH-6: Will Noise From Project Activities During Construction and Operation Unduly Affect People Who Reside in the Local Area?

E12.11.1 Analysis of Potential Linkages

Linkage Between Project Activity and Ambient Noise

The Project will involve a variety of mechanical noise generating activities including, for example, truck and shovel activities. Hence the linkage is valid.

Linkage Between Changes in Ambient Noise and Impact to Local People

The noise generated on-site (e.g., truck and shovel operations) may carry off-site and be perceptible to local residents. Similar scenarios have been examined for the Aurora Mine by Syncrude (BOVAR, 1996a) where it was established that increases in ambient noise near Fort McKay would occur as a result of noise sources on-site. Hence the linkage is valid.

E12.11.2 Analysis of Key Question

People in the Local Study Area who may be affected by the noise from the Project are primarily residents of Fort McKay, the closest community to the

Project (approximately 11 km southwest of the site). The local population around Fort McKay is approximately 365.

Noise may be generated from a variety of activities on-site including engine noise from truck and shovel operations, pit excavation, extraction, on-site power generation and increased traffic within the local communities. Additionally, similar activities at the Aurora Mine which is to the north of the Project site will also contribute to the ambient noise levels experienced in Fort McKay.

Examination of this key question is fundamentally different from the other health questions in this section because unlike the former cases, which are heavily dependent on quantification of a physiological health effect, noise effects have a strong subjective component to them. Thus, while a measured or predicted noise level may or may not exceed a regulatory guideline, the perception of the exposed person (or community) towards the noise may be quite different.

A detailed noise assessment conducted for the Aurora Mine (BOVAR 1996a) provides good insight to the present case. The Aurora Mine is reported to be approximately 12 km from Fort McKay which lies to the southwest. The proposed Muskeg River Mine pit is estimated to be about 11 km from Fort McKay and effectively lies in-line between the Aurora Mine and Fort McKay. The Syncrude noise assessment was conducted on hydraulic shovel and electric shovel operations at Mildred Lake North Mine, the latter having been established as the loudest noise source on-site. They assumed a similar noise source for Aurora Mine and then predicted noise levels in Fort McKay using the following conservative assumptions:

- noise transfer was via direct line travel from source to receptor (i.e., Fort McKay) and ignored the attenuation that would occur if the machinery was 10 to 15 m below mine surface-grade; and
- during transfer, noise was attenuated with a theoretical attenuation of 6 dBA per doubling of distance.

The resultant calculations suggested that the predicted noise due to the mine and background noise would be 48 dBA during the day (Permissible Sound Level = 53 dBA) and 38 dBA during the night (Permissible Sound Level = 40 dBA), with the greatest increment occurring at night. In the case of the Muskeg River Mine Project, one may intuitively expect a slightly larger contribution to noise levels in Fort McKay due to its closer proximity, all other things being equal. With the proposed Project, the anticipated noise levels in Fort McKay would need to consider the collective contribution of both mine operations in addition to background.

Because of the close similarity of the above study to the Muskeg River Mine Project, inference can be made that with the additional noise input from the

Project, it is possible, perhaps likely, that the permissible noise levels in Fort McKay will be exceeded from time to time.

E12.11.3 Residual Impact Classification and Degree of Concern

By inference, the foregoing discussion suggests ambient noise levels in Fort McKay may exceed permissible sound levels from time to time. However, this is likely to be intermittent as machinery at both the Aurora Mine and Muskeg River Mine Project are moved to different locations on their respective sites. Additionally, the noise can be effectively managed through monitoring and measures that will attenuate noise. Therefore, the magnitude of impact and degree of concern are summarized as follows:

Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
Negative	Low	Local	Long-Term	Reversible	Medium	Low

E12.11.4 Monitoring

Noise monitoring will be conducted as needed to achieve effective management and mitigation.

E12.12 Key Question HH-7: Will the Release of Chemicals From the Reclaimed Landscape Change Human Health?

E12.12.1 Analysis of Potential Linkages

Following closure of the facility and site, hunters and trappers may occupy the reclaimed landscape for extended periods of time. Under this scenario, they may be exposed to chemicals through ingestion of water, fish, plants and game meat and inhalation of air.

The linkage between closure design and potential changes in water quality has been addressed in Section E5. The linkage was considered valid. This section evaluates the validity of the linkage between changes in various media and human health.

Linkage Between Changes in Water Quality and Human Health

Potential sources of drinking water associated with the reclaimed landscape include groundwater, surface water associated with wetlands, snow, the End Pit Lake and nearby rivers, such as the Muskeg and Athabasca. Groundwater derived from the site was excluded as a source of drinking water since the associated hydrocarbon odours would likely deter potential users. Wetlands are expected to be intermittently dry and stagnant and would not offer good quality water considering the potential for anoxia, warm temperatures and naturally occurring pathogens. Snow is also a potential source of drinking water but only during winter. Although users of the reclaimed landscape may potentially drink water from the End Pit Lake, there is considerable uncertainty associated with the water quality of the End Pit Lake at equilibrium and therefore this drinking water source cannot be evaluated at this time. Thus, it was assumed that the primary source of drinking water would be from the Muskeg River, since it offers a constant and accessible source of water near the reclaimed landscape. Hunters and trappers may also occasionally swim or bathe in the Muskeg River.

The validity of the linkage between Muskeg River water quality changes and human health was discussed previously for key question HH-1 in Section E12.6. This linkage was determined to be valid both during operation and after closure, based on the results of chemical, receptor and exposure pathway screenings. The following eight chemicals were identified for further evaluation with respect to exposures to Muskeg River water:

- benzo[a]anthracene
- benzo[a]pyrene
- naphthenic acids
- boron
- cadmium
- lead
- molybdenum
- vanadium

Hunters and trappers may become exposed to these chemicals via ingestion of drinking water and/or dermal absorption while swimming/bathing. Children are not expected to live in remote locations on the reclaimed landscape (due to educational and social requirements) and therefore are unlikely to be exposed to Muskeg River water, except during occasional recreational activities, which have been evaluated previously for key question HH-1 in Section E12-6.

Since elevated chemical concentrations, receptors and exposure pathways may apparently co-exist, a potential linkage exists between water quality changes and human health following closure.

Linkage Between Changes in Fish Quality and Human Health

The validity of the linkage between changes in fish quality and human health was discussed previously for key question HH-1 in Section E12.6. *This linkage was determined to be invalid, since Project-related chemicals were not elevated in fish tissue;* however monitoring of fish tissue residues was recommended for future validation.

Linkage Between Changes in Air Quality and Human Health

Following closure of the Muskeg River Mine Project, there will be no air emissions from extraction, utilities or vehicles. In addition, 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. *Since no human health risks were predicted to occur as a result of the release of volatile chemicals from the tailing settling ponds during the operation phase of the Project (HH-2, Section E12.7), and since emissions are expected to decrease over time, this linkage is considered to be invalid following closure of the Project.*

Linkage Between Changes in Soil Quality and Human Health

It is unlikely that people will be directly exposed to CT, because these deposits will be buried below a capping layer of sand, muskeg and vegetation. Soil concentrations that people may be exposed to will be comparable to natural background levels; hence incidental ingestion of soils will not be a significant source of Project related chemicals. *For this reason, a linkage between soil quality and human health was considered invalid.*

Linkage Between Changes in Plant Quality and Human Health

Hunters and trappers living on the reclaimed landscape may harvest local plants for food. Some of these plants may be growing on top of capped CT deposits. At equilibrium, the CT will be consolidated below 11 to 13 m of overburden or tailings sand and a surface layer (i.e., 20 cm) of muskeg. Therefore, plant roots may extend into the layer of overburden or tailings sand overlying the CT deposit, but will not extend into the CT deposit itself.

Limited measured data are available for plants growing in overburden or tailings sand. In a recent study, metal concentrations in poplar leaves, spruce needles and cattail shoots were measured. These plants were growing in the Tar Island Dyke area of Suncor, in soils consisting of tailings sand capped with 15 cm of muskeg (Golder 1997r). The geometric mean of these data were used for chemical screening and exposure modelling of inorganic chemicals. Since no measured data were available for PAHs in plants growing on reclaimed landscapes, plant tissue concentrations were estimated based on the chemistry of overburden and tailings sand and bioconcentration factors (BCF) for plant uptake (Travis and Arms 1988), according to the following equation:

$$\text{plant concentration} = \text{BCF} * \text{soil concentration}$$

A chemical screening process was conducted to determine whether the measured and/or predicted plant concentrations may have any adverse effect on human health. Detailed screening tables are presented in Appendix X.1. The following seven chemicals were identified for further evaluation in the risk assessment:

- benzo[a]anthracene
- benzo[a]pyrene
- arsenic
- barium
- beryllium
- boron
- cadmium

Since elevated chemical concentrations, receptors and exposure pathways may apparently co-exist, a potential linkage exists between plant quality changes and human health following closure.

Linkage Between Changes in Game Meat Quality and Human Health

Hunters and trappers may hunt and trap animals from the reclaimed landscape. Mammals and birds exposed to the reclamation deposits may accumulate certain chemicals, thus providing an exposure pathway for people who might eat wild game. For this reason, the potential linkage between game meat quality and human health was evaluated.

Limited tissue data are available from bison pastured on tailings sand as well as ducks and muskrat exposed to CT release water within wetlands. Results of chemical screening of these data indicated the following five chemicals for further evaluation in the risk assessment:

- cadmium
- chromium
- copper
- molybdenum
- selenium

Since elevated chemical concentrations, receptors and exposure pathways may apparently co-exist, a linkage exists between potential changes in game meat quality and human health following closure.

E12.12.2 Analysis of Key Question

Several chemicals were identified for further evaluation in the risk assessment, based on chemical screening of measured or predicted concentrations in water, plants and game meat. For the purposes of this linkage analysis, any chemical that was retained for one media was evaluated in all media (i.e., water, plants and game meat), where data were available, to ensure a conservative assessment of combined exposure on the reclaimed landscape. A quantitative human health risk assessment was conducted for conceptual model HH-7 (Figure E12-9) according to the method described in Section 12.5.3. Key aspects of the risk assessment are presented here; additional details are presented in Appendix X.

It was assumed that a hypothetical hunter/trapper would reside on the reclaimed site throughout the year, obtaining a portion of his food (both meat and plants) directly from the site and all drinking water from the Muskeg River. This is likely to be a conservative assumption given the probable seasonal nature of hunting and trapping activities. In addition, it was assumed that children of hunters/trappers would be exposed through consumption of game meat and country plants which were harvested from the reclaimed landscape and brought back to the family.

For carcinogenic chemicals (i.e., benzo[a]pyrene, benzo[a]anthracene, arsenic and beryllium), a composite receptor was evaluated from birth to 70 years of age. This hypothetical composite receptor was assumed to consume plants and game meat from the reclaimed landscape during childhood and become a hunter/trapper at 20 years of age, with exposures to water, plants and game animals from the reclaimed landscape.

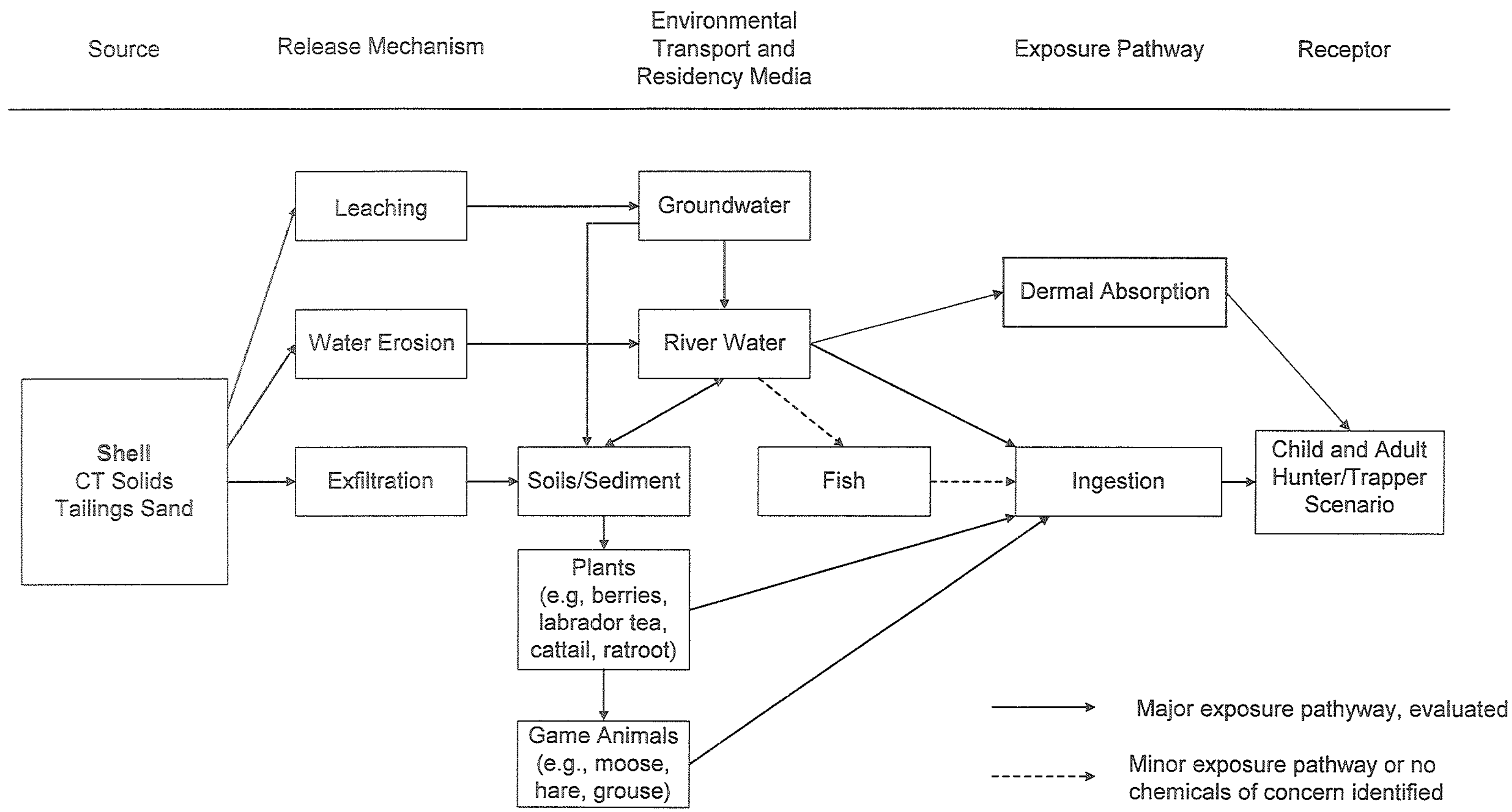
It was assumed that meat would be consumed by hunters/trappers and their families every day of year for their entire lifespan. The fraction of meat that was assumed to be derived from and affected by the reclaimed landscape was 25%. This value was selected based on the following considerations:

- some meat consumed over the course of the year may be derived from outside the region (e.g., retail purchased meat);
- it is unlikely that many of the game animals will live and obtain all food from within the reclaimed area; and
- it is unlikely that on-site residents will obtain a large portion of their food from the relatively small area of the reclaimed site.

Chemical concentrations assumed for meat were based on concentrations measured in the muscle of a wood bison that grazed in a pasture in a reclaimed tailing sands area. It is reasonable to use muscle data for this assessment because muscle tissue represents the largest source of edible meat from a bison. Several chemicals were not detected in bison tissue and were thus set at zero for multimedia exposure modelling.

It was assumed that local plants would only be available for harvest on a seasonal basis (i.e., 3 months per year) and that plants grown on the reclaimed landscape would account for 10% of the fruit and vegetable component of the diet of hunters/trappers and their families. Chemical

Figure E12-9 HH-7: Conceptual Model for the Reclaimed Landscape Scenario



r:\1997\2200\972-2237\8800\8870\concept\reclam.vsd concentrations in plants were estimated from observed concentrations in plants growing on reclaimed areas or on chemical concentrations in overburden and tailings sand and bioconcentration factors for plant uptake, as discussed previously.

Drinking water was assumed to be derived from the Muskeg River, since it offers a hunter/trapper a constant and accessible source of water near the reclaimed landscape. Children were assumed to have no exposure to Muskeg River water since they would not live on-site with hunters/trappers. In the far future after closure, equilibrium chemical concentrations in the Muskeg River were predicted according to the method described in Section E5.

ER values for the hypothetical adult hunter/trapper, child and composite receptor are presented in Table E12-11. Further details of daily intake rates are provided in Appendix X.4.

Table E12-11 Exposure Ratio Values for the Reclaimed Landscape Scenario

Chemical	Adult	Child	Composite
barium	0.06	0.18	not applicable
boron	0.07	0.25	not applicable
cadmium	0.08	0.24	not applicable
chromium	0.0003	0.001	not applicable
copper	0.04	0.12	not applicable
lead	0.006	0.04	not applicable
molybdenum	0.02	0.08	not applicable
selenium	0.04	0.12	not applicable
vanadium	0.01	0.04	not applicable
benzo[a]pyrene[(a)]	not applicable	not applicable	0.29
benzo[a]anthracene[(a)]	not applicable	not applicable	0.14
total PAHs[(a)]	not applicable	not applicable	0.43
arsenic[(a)]	not applicable	not applicable	8.4
beryllium([a)]	not applicable	not applicable	1.3
Total Carcinogens	*not applicable*	*not applicable*	*10.1*

[(a)] denotes a substance with carcinogenic properties

ER values predicted for adults and children were less than 1 for all chemicals. ER values predicted for the composite receptor for benzo(a)anthracene and benzo(a)pyrene were also less than 1. Therefore, predicted exposures to these chemicals on the reclaimed landscape are well within acceptable limits.

ER values for arsenic and beryllium were marginally greater than 1. Ingestion of drinking water from the Muskeg River is a major exposure pathway and accounts for about 50% of the estimated risk. This is largely due to the naturally elevated background concentrations of these metals in the Muskeg River, as discussed previously for key question HH-1 in Section E12.6. In addition, it was conservatively assumed that hunters/trappers would drink Muskeg River water every day of the year. Since hunting and trapping are typically seasonal activities, it is likely that exposures to Muskeg River water would be at least one-quarter to one-tenth of that assumed for this assessment. Ingestion of local plants is the other major exposure pathway contributing to the predicted risks. There is some uncertainty associated with predicted plant tissue concentrations on the reclaimed landscape and limited measured data are available to validate predicted concentrations. Arsenic and beryllium were not detected in bison muscle or liver tissue and therefore are not expected to be present at concentrations above the detection limit in the tissues of other game animals.

These conservative results suggest that virtually all the substances flagged during the screening process do not present unacceptable health risks under the closure scenario. Two naturally elevated substances, arsenic and beryllium, may present marginally elevated health risks, consistent with present natural conditions, although the likelihood is low given the conservatism of the estimate.

With respect to end pit lake water quality, concentrations of the benzo(a)pyrene and benzo(a)anthracene groups in 2030 and the far future are predicted to be safe for consumption and dermal exposure by people. The highest concentrations predicted to occur in the end pit lake before discharge (refer to Section E5.10) may pose a potential health risk to users of the end pit lake during this time (i.e., ER values are marginally greater than 1 if end pit lake water before discharge is used as a drinking water source). However, human use of the end pit lake will likely be restricted until after discharge, thereby eliminating exposure during this time. It should be noted that this assessment is based on the assumptions and modelled water concentrations presented in Section E5.10. With various mitigation options, water concentrations in the end pit lake may differ from those modelled. For further details on end pit lake water quality, refer to Section E5.10.

E12.12.3 Residual Impact Classification and Degree of Concern

Based on the information assessed, a potential impact has been identified for people occupying the reclaimed landscape for extended periods of time. Due to the conservative assumptions used in the assessment and the uncertainty involved with respect to uptake of chemicals by plants growing on the reclaimed landscape, and the uncertainty arising from the limited naphthenic acids toxicity database, the residual impact may be classified as follows:

Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
Negative	Low	Local	Long-Term	Reversible	Medium	Low

Certainty

The assessment of potential impacts to users of the reclaimed landscape was based on a number of conservative assumptions, including the following:

- reasonable maximum measured or predicted concentrations in water, plants and game meat were used;
- daily ingestion estimates for local foods represent reasonable maximum exposure values for the communities evaluated;
- hunters/trappers were assumed to bring both local plants and game meat home to feed their children;
- oral bioavailability was set to a maximum of 100%;
- combined exposure to water, local plants and game animals was considered; and
- toxicity reference values were set to be protective of sensitive members of the population (i.e., seniors) under chronic exposure conditions.

Due to the conservatism involved in the risk assessment for users of the reclaimed landscape, it is very unlikely that potential risks have been underestimated. However, some uncertainty exists with respect to the following:

- limited available data for tissue concentrations in plants growing in overburden or tailings sand;
- use of bioconcentration factors for uptake of PAHs into plants grown in reclamation materials;
- lack of a toxicity reference value for naphthenic acids; and
- possible interactions of chemical mixtures.

As noted in Sections E12.6 and E12.9, it is unlikely that evaluation of naphthenic acids or interactions of chemical mixtures will affect the conclusions presented above. However, some uncertainty exists with respect to chemical uptake into plants grown in overburden or tailings sand.

E12.12.4 Monitoring

Due to the uncertainty associated with uptake of chemicals by plants growing in overburden and tailings sand, it is expected that further monitoring will be initiated by the oil sands industry to address this issue. Shell will participate in these research efforts.

As discussed previously, consideration will be given to address data gaps in toxicity data for naphthenic acids as part of CONRAD.

E12.13 Summary of Predicted Impacts and Concern Level

In light of the foregoing assessments of the seven key questions addressed in the health component, Table E12-12 summarizes the predicted impacts and corresponding concern levels.

Table E12-12 Predicted Impacts and Corresponding Concern Levels Summary

Key Question	Direction	Magnitude	Geographic Location	Duration	Reversibility	Frequency	Degree of Concern
HH-1	Negative	Low	Local	Long-Term	Reversible	Medium	Low
HH-2	Negative	Negligible	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Negligible
HH-3	Negative	Negligible	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Negligible
HH-4	Negative	Low	Local	Long-Term	Reversible	Medium	Low
HH-5	Negative	Negligible	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Negligible
HH-6	Negative	Low	Local	Long-Term	Reversible	Medium	Low
HH-7	Negative	Low	Local	Long-Term	Reversible	Medium	Low

E13 HISTORICAL RESOURCES IMPACT ANALYSIS

E13.1 Introduction

This section of the Muskeg River Mine Project (the Project) EIA provides information as required by the Project Terms of Reference (TofR) issued on November 7, 1997 (AEP 1997). Specifically, the following are addressed:

- completion of a field investigation of the Study Area, with the investigation meeting the requirements of Alberta Community Development;
- development of appropriate mitigation plans for historical resources; and
- discussions on the consultation efforts with Alberta Community Development and Aboriginal communities, specifically the Fort McKay community to establish the process to assess the historical, archaeological and palaeontological significance of the Project Area (TofR, Section 10.0).

Discussions on the regional implications of oil sands development on historical resources is presented in Section F13. Section D13 provided details on the historical resources baseline for the Project.

Historical Resources are non-renewable resources that may be located at or near ground level, or may be deeply buried. Alteration of the landscape can result in the damage or complete destruction of historical resources. These alterations may involve the displacement of artifacts, resulting in the loss of valuable contextual information, or the destruction of the artifacts and features themselves, resulting in the complete loss of important site information. The loss of historical resources is permanent and irreversible. Impacts to historical resources as a result of development projects are generally described as falling into two categories: direct and indirect.

Direct impact occurs during construction and operations stages of any project and are a direct result of activities associated with the project. Indirect impacts occur as a result of the development, but are not directly related to it, and can take place outside direct impact zones. For example, development of an industrial project of this nature can result in increased use of surrounding facilities, thereby resulting in unaccounted for surface disturbance, and can lead to an increased possibility of vandalism or accidental impact.

The frequency and intensity of these kinds of impacts can be accelerated in areas where numerous developments of a similar or related type are proposed. Together with direct development impacts, assessment of these impacts form as basis for estimating the cumulative effects of development of any particular region.

The construction activities associated with development of the Muskeg River Mine Project will have varying physical effects on historical resources within proposed development zones. The specific effects of various development activities associated with the Project are detailed below.

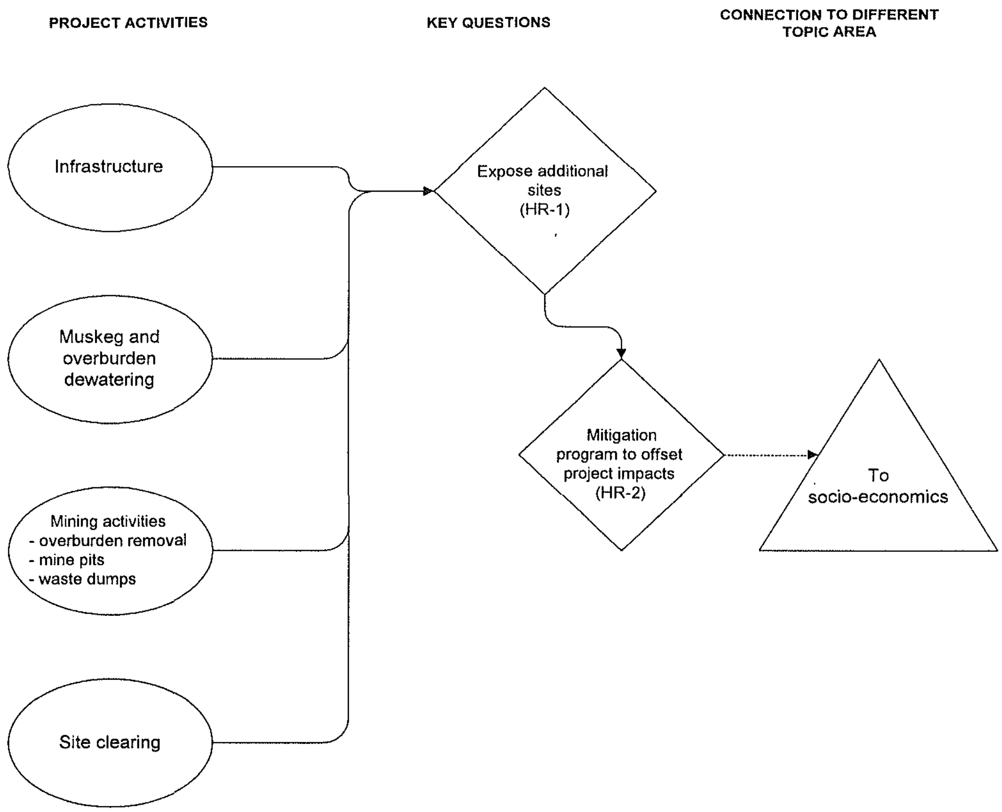
E13.2 Key Questions and Potential Linkages

Two key questions have been established relating to potential impact to historical resources that may be affected by the Project. The key questions and linkages are shown in Figure E13-1.

HR-1 Will Development Activities Associated With the Muskeg River Mine Project Change Sites, Warranting Avoidance or Further Information Recovery?

Assessment of this question requires detailed information in three areas of concern: the types of impacts entailed in project development, the numbers and types of historical resources that might be affected and the significance of these resources. Development of the Project will take place in several stages and will involve numerous activities that could potentially have negative impacts on the historical resources present throughout the development area. Most of these activities will disturb the existing surface, which contains the evidence of historic and prehistoric human use of the landscape. Some activities will affect subsurface deposits that contain palaeontological resources relating to past natural ecosystems. Understanding the nature and location of the resources that might be affected is critical to developing an assessment of the direct physical impacts of the Project. Because historical resources are widely distributed within and adjacent to the development area, determining the magnitude of the anticipated impacts requires an understanding of the comparative significance of the historical resources that might be affected. These understandings are critical to development of an appropriate mitigation strategy designed to offset development impacts and to fulfill the requirements of the Alberta Historical Resources Act, which governs management of historical resources throughout Alberta. Mitigation options generally involve, avoidance or further information recovery intended to compensate for impacts.

Figure E13-1 Linkage Diagram for Historical Resources for Construction, Operation and Closure Phases of Muskeg River Mine Project



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The linkages associated with this question are as follows:

Linkage HR-1.1. What are the historical resources impacts associated with the various stages of development of the Muskeg River Mine Project?

Linkage HR-1.2. What are the character and locations of the historical resources that might be affected?

Linkage HR-1.3. What is the significance of the resources that might be affected?

HR-2 Will the Mitigation Program Designed for Muskeg River Mine Project Effectively Offset Project Affects?

Development activities associated with the Project will result in physical impact to a series of historical resources situated within proposed development area. These will take place according an extended schedule that may involve much of the 26 year life span of the project. Some of the sites to be affected currently have requirements set by Alberta Community Development for mitigation procedures intended to offset these impacts. For others, these requirements remain to be established. The historical resources impacts associated with the Project are numerous and diverse. Therefore, a recommended program, which integrates with the Project development schedule, is proposed to recover significant historical resources and information from the Project area during construction activities. This program should offset the negative impacts of the proposed development through permanent conservation of materials and information and through analysis and interpretation, thereby fulfilling the requirements of the Alberta Historical Resources Act.

The linkages associated with this question are as follows:

Linkage HR-2.1. Are any historical resources present in proposed impact zones that would require permanent avoidance?

Linkage HR-2.2. What types of mitigation procedures are appropriate to offset the negative historical resources impacts of the project?

Linkage HR-2.3 How would these procedures articulate with the proposed development schedule?

E13.3 Key Question HR-1: Will Development Activities Associated With the Muskeg River Mine Project Change Sites, Warranting Avoidance or Further Information Recovery?

E13.3.1 Analysis of Potential Linkages

Potential Impacts to Historical Resources

The Project construction activities will have varying physical effects on historical resources within proposed development area. Negative effects can be identified at two levels of intensity, direct and indirect. Positive impacts are a general outcome of the results of these studies and subsequent implementation of a program of mitigation studies. These latter will be discussed in relation to key question HR-2.

Direct Impacts

Direct impacts to historical resources will result from the numerous ground disturbing activities associated with development of the Project. For the purposes of this discussion, it is useful to group development activities into types that will result in disturbance or partial destruction of historical resources and those that will result in total destruction of historical resources within the development area.

The forest clearance stage of development is a critical stage in relation to historical resources, because it is the only activity that will result in disturbance or partial destruction of archaeological sites. Forest removal is usually conducted in winter, under frozen ground conditions. In these circumstances, bulldozer cutter bars used for this purpose occasionally strike the ground, exposing the upper surface of the mineral soil horizon and their treads displace the forest litter, but do not disturb much of the frozen sands that lie below.

These disturbances have both positive and negative effects on archaeological sites and materials. Most of the archaeological record of the region is contained in the upper horizons of the current sediment profile, reflecting the long term stability of the vegetative regimes in the Boreal Forest. Archaeological materials may become exposed as a result of these activities, some may be removed, and others may be displaced from their original positions. This type of impact has a negative effect on the sites affected but, in a positive sense, previously unknown sites may be revealed so that undisturbed portions may be studied and sampled. Post-clearance archaeological studies in the former Alsands project area (Ives 1982) has served to confirm these positive and negative aspects of forest clearance procedures. The mitigation program recommended to off set the effects of the Project includes a component that would recover and assess any historical resources that might become exposed during these activities. Forest clearance will however result in total removal of above ground historic period resources and many of the traditional resources related to aboriginal use of the landscape. Palaeontological resources are unlikely to be affected by this type of activity since it rarely intersects bedrock formations where these resources most commonly occur.

For the most part, the magnitude of direct impact associated with forest clearance can be considered either moderate or low (see Table E13-1) depending on the inherent scientific and or cultural significance of the resources affected. It may be negligible if no sites are present within impact zones. High magnitude impacts are possible if an extremely significant site is affected and disturbance happens to be severe. As is the case with all historical resources, the geographical extent of these impacts is localized to actual physical impact zones and their duration is immediate to the sites affected. All physical impacts to historical resources are irreversible.

Excavations for drainage ditches, installation of water wells, trenching for pipelines, grading for facility locations and for road construction, overburden removal and mining all represent the types of disturbances that will destroy near surface archaeological and above ground historic period resources. Those activities, particularly mining, that intersect deeply buried sediments, including loosely consolidated McMurray Formation sands are likely to affect to palaeontological resources if they are present. Because the physical impacts of these activities on historical resources is severe, their overall magnitude is based entirely on the significance of the resources affected and ranges from high through moderate to low and negligible (Table E13-1). Again, the geographical extent of these impacts is localized to actual physical impact zones, their duration is immediate and the impacts are irreversible.

Areas selected for muskeg storage would also be affected. If forest clearance is to take place to prepare storage areas, the impacts described for forest clearance would apply. If pre-storage leveling is required, impacts would vary and could be rated as having a high, moderate, or low magnitude depending of the significance of the site to be affected. Impacts to historical resources would be localized to those areas subject to these activities, would be immediately felt and would be both permanent and irreversible.

Table E13-1 Impact Classification Definitions

Resource	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency
Historical Resources	**Negative** - disturbance or destruction of historical resources	**High**: In areas of severe physical impact when resources of high scientific or interpretive value are affected. **Moderate**: In areas of moderate or partial physical impact when high or moderate value resources are affected **Low**: In areas of minimal physical impact or when few or low value resources are affected **Negligible**: In areas where no physical impact takes place or no sites occur	**Local**: Sites in the immediate development area are directly affected. **Regional**: Sites in the region may be indirectly affected by increased use or demand for other facilities	**Immediate**: Direct physical impacts are felt immediately **Long-Term**: Indirect impact occurs over the life of the project	**Irreversible**	N/A
Historical Resources	**Positive** - increase in the understanding of the character and distribution though information recovered in Impact Assessment and Mitigation phases of study	**High**: If a unique or highly significant site(s) is identified and information is recovered before development impact occurs. **Moderate**: If sites similar to others in the region are found and information is recovered before development impact occurs. **Low**: If few, low value or even no sites are found.	**Local**:- Specific information is recovered from sites within the immediate development area **Regional**: Comparisons with information obtained in others studies improves understanding of regional history and prehistory	**Short Term**: submission of project report to Alberta Govt. allows improved regional management decisions **Long-Term**: Information and artifacts are available to other researchers	**Reversible** - if information is lost or is not collected or not curated properly	N/A

Overburden removal in the development area will result in removal of all archaeological sites. The physical impacts of these activities on historical will be severe. Their overall magnitude is based entirely on the significance of the resources affected and ranges from high through moderate to low and negligible (Table E13-1). Again, the geographical extent of these impacts would be restricted to the actual physical impact zones, their duration is immediate and the impacts are irreversible. Within areas scheduled as overburden stockpiles, similar impacts to those described above for muskeg storage sites would apply. Removal of the Clearwater Formation Shales which overlie oil sands in this region will affect any palaeontological materials they might contain. The scientific significance of the fossils in this deposit (fossil ammonites pelecypods and calcareous foraminifera; Carrigy 1974a) is considered to be relatively low. Physical impacts to these deposits would be localized to areas affected but, would be severe, immediate and irreversible.

An essential component of the Muskeg River Mine Project will be a pipeline to transport the diluent and bitumen produced by the Project for final processing outside the Project area. When the field studies were completed for the HRIA of the Muskeg River Mine Project the final alignment of a this pipeline had not been determined, but several alternative routes had been selected. The historical resources impacts associated with this development will vary depending on the whether known historical resources or areas of high potential would be affected. If historical resources are encountered , negative physical impacts would result from initial forest clearance, topsoil stripping, trench excavation, materials storage, vehicle traffic and reclamation activities. Impact magnitude could vary between high and negligible depending on the character of the resources encountered. The geographical extent would be localized to direct impact zones; impact duration would be immediate and would be irreversible.

The potential for historical resources impacts associated with each of the alternates through Lease 13 has been evaluated, and this information will be considered in selection of a final route alignment. No known significant hsitorical reources would be affected by any of the alternate routes considered. When a decision has been taken, detailed project information will be forwarded to Alberta Community Development for determination of the requirements of the Alberta Historical Resources Act in relation to the project. Completion of any required studies would be integrated with mitigation program undertaken for the Muskeg River Mine Project and the results incorporated in any comparative analysis undertaken.

Mining activities may have limited affect on archaeological and historic period resources because all will have been removed during site preparation. However, palaeontological materials may be directly affected by removal of McMurray Formation sands. This Formation is not especially rich in fossils, but is reported to contain mollusks agglutinated foraminifera, fish teeth, spores and pollen grains (Carrigy 1974a). The scientific significance of these deposits is reflected in the rating for this area provided on the sensitivity map issued by the Royal Tyrrell Museum of Palaeontology. More significant are the fossils contained in the Devonian Waterways formation which underlies the oil bearing strata of the McMurray formation. This significance is reflected in the high sensitivity rating provided by the Royal Tyrrell Museum of Palaeontology for areas that contain natural exposures of this formation, along the Athabasca River and the lowest section of the Muskeg River in this area. Planned mining activities will not affect these deposits.

Indirect Impacts

While related to the project, construction of specific infrastructural facilities not included in the application such as highway upgrades, gas and power transmission line and gravel extraction will be undertaken by other developers and will be subject to separate regulatory review processes. Managing the specific impacts associated with developments will be the responsibilities of those developers and are not dealt with directly in this application. The non-specific indirect impacts of the Project are difficult to predict, however, because it is not possible to forecast the levels of other activities that may ensue within the general region as a result of increased commercial or recreational activity. These potential impacts are considered part of the combined effects of regional development and are discussed in Section F13.

Character and Location of Historical Resources

1997 Study Area and Procedures

As detailed in section D13, the Project area and the balance of Lease 13 has been subject historical resources studies over the course of several development proposals beginning as early as 1974. This has resulted in a complex situation with respect to management of existing known areas and resources and the need to assess concerns in areas not previously examined. A focused program of studies was adopted in 1997 to meet these needs.

Objectives

The objective of the 1997 historical resources program was to bring all areas scheduled for development in the Project to a level of having the requirements of an Historical Resources Impact Assessment (HRIA) completed. To accomplish this objective it was necessary to review the historical resource status of the entire lease area. Combining this information with consideration of current development plans provided the basis for design of a program that focused the efforts on outstanding historical resource concerns throughout proposed development area. The intended outcome of these investigations was the design of an effective mitigation strategy that would incorporate all existing concerns, that could be implemented as various stages of the development proceed and that, will comply with the requirements of the Alberta Historical Resources Act.

The first step toward achieving these objectives was to review previous archaeological research conducted in and adjacent to the proposed Project development area, and to establish the status of the areas examined as well as the resources identified within them. This information has been provided in Section D13. The second step is to establish the area requiring additional examination before the requirements of an HRIA could be considered complete

Study Area

On the basis of the review of the Historical Resources Act status of the various areas encompassed by the Project, a study area was established for the 1997 program. It excluded the areas examined for the 1980 Alsands Mine and Tailing area Project (Ronaghan 1981a) as well as the 1981 Energy Corridor area examined for the Alsands Project Group (Ronaghan 1981b). It also excluded areas examined both by Conaty for the 1979 Alsands study (Conaty 1979) and by the Archaeological Survey of Alberta in 1982 and 1983 (Ives 1982, 1988). In addition, it excluded a pipeline corridor examined for C. U. Engineering in 1980 (Ronaghan 1981c). This study area is illustrated in Figure E13-2 and formed one of the supporting documents submitted to the Archaeological Survey, Provincial Museum (Alberta Community Development) as part of an application for an Archaeological Research Permit to conduct the 1997 program. The objectives and methods to be employed in the proposed study, including significant ranking criteria, were discussed in advance with that agency. After review of this application, permit number 97-107 was assigned to this project.

Background Research

Background research conducted prior to the 1997 field work entailed review of the previous historical resource studies in the vicinity of the Project area, recovery of the available original field notes and records produced for archaeological studies in the areas proposed for development area, and review of the models used in previous studies to establish the significance of the sites identified in the region. Field records were available for the 1980 Alsands Project, for the 1980 pipeline study and for the work completed by the Archaeological Survey of Alberta in survey 1981 and 1982, but not for the 1979 Alsands project or the 1973 Lease 13 survey. These latter omissions are not considered a serious problem because much of the data are contained in reports. Only in the case of the 1973 Lease 13 Survey was there insufficient information to allow relocation of the sites identified. These information sources allowed for accurate plotting of the areas investigated in previous studies and the sites identified during their field components. Sites identified in these programs that fall within the Muskeg River Mine development area have been evaluated for the 1997 HRIA and we included in the mitigation program discussed below. The previous historical resources impact associated studies for the Project area are shown in Figure E13-2.

Archaeological Potential Model

One of the more important aspects of the background research conducted for the 1997 program was development of a predictive model, based on terrain variables, that served as a means of structuring the in-field investigations. Geographic Information Systems (GIS) technology was used to develop and display this model. Based on the results of previous studies it is evident that archaeological sites within the study area are strongly correlated with certain subtle terrain variations expressed throughout the area. Sites tend to exist on the raised landforms between intervening areas of water saturated terrain. This correlation was established by the 1980 Alsands Mine and Tailings pond studies (Ronaghan 1981), has been confirmed by subsequent studies (Ives 1982, 1988). Features on which sites are located generally rise 1 to 3 m above the surrounding muskeg and, although they vary in shape, appear to be oriented along a northerly direction. They consist of boulder/gravel fill and are thought to represent braided channel deposits left in the wake of a massive palaeoflood that took place 9,900 years ago, when a stand of glacial Lake Aggasiz breached a drainage divide near the Alberta/Saskatchewan border and spilled huge volumes of water down the Clearwater and Athabasca rivers over a 78 day period (Smith and Fisher 1993). All of these features are mantled with a blanket of sand of aeolian origin.

Regardless of their origin, the raised features in Project area and north of the Muskeg River exhibit characteristics that distinguish them from surrounding terrain and proved to have been attractive for prehistoric use. The small differences in elevation manifest in these features correlate directly with distinct differences in drainage characteristics, soil types and vegetation communities supported. As a consequence, elevation, soil types or vegetation communities could all be used as proxy indicators of archaeological potential, as each is linked to the same set of environmental parameters. Digitized information on the distribution of vegetation communities within the study area, based on classifications made on 1:20,000 scale air photographs, was the most detailed information available at the beginning of the field season. This parameter was chosen as the basis for modelling archaeological potential. All communities considered to reflect well-drained terrain were ranked as having at least moderate potential. Communities reflecting poorly drained or water saturated conditions were considered to have low or no potential for site discovery.

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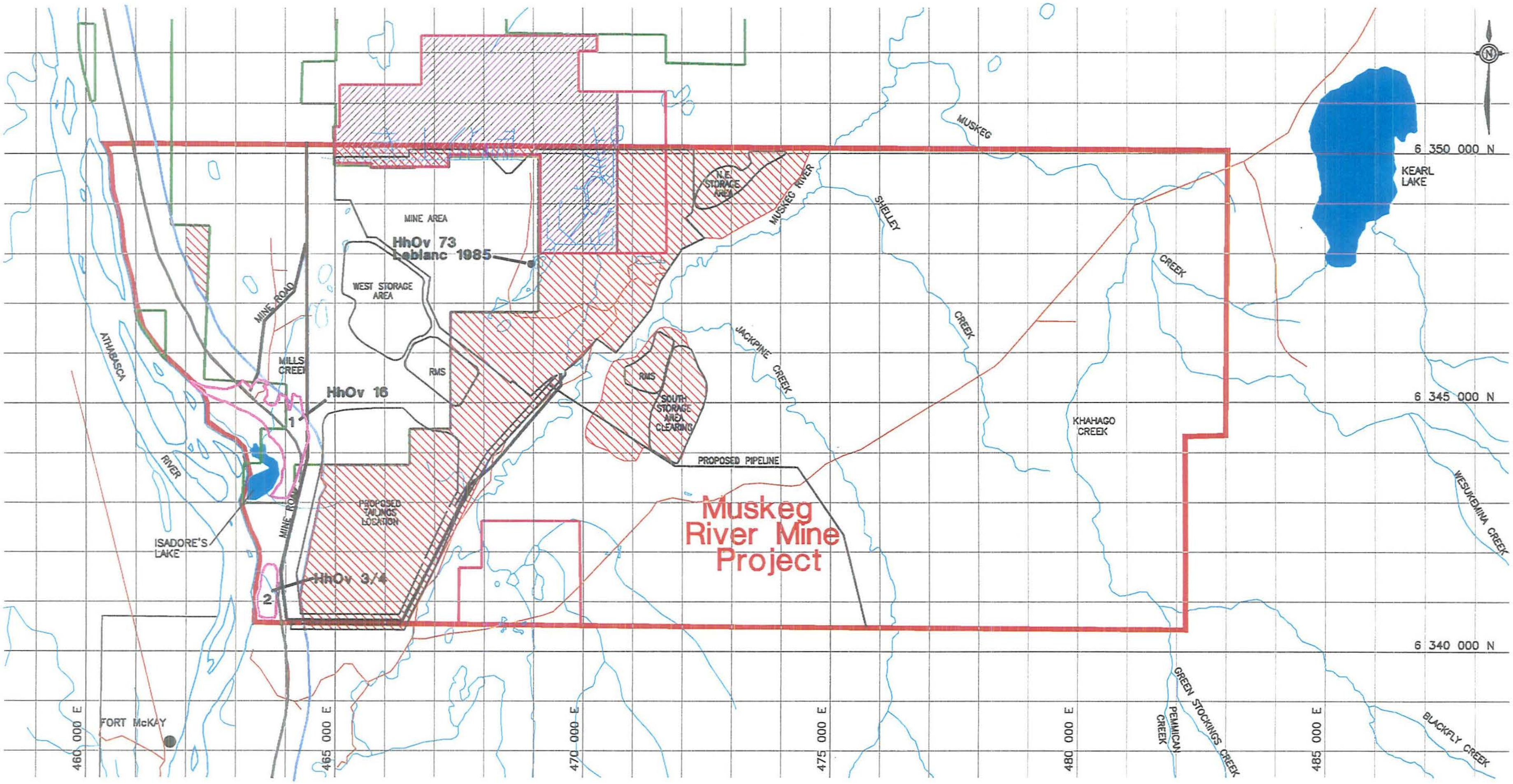


0 1000 2000 3000 4000 5000

SCALE IN METERS

REFERENCE

DIGITAL DATA SETS 74D, 74E, 74I
84A AND 84H FROM RESOURCE DATA DIVISION
ALBERTA ENVIRONMENTAL PROTECTION, 1997.

LEGEND

- 1 Mallory 1980, Head 1979, Head and VanDyke 1990, Ronaghan 1980,1982
- 2 Mallory 1980, Head 1979
- Conaty 1979
- Ronaghan 1981B
- Energy Corridor – Ronaghan 1981A
- Highway 963 – McCullough and Reeves 1978
- Ives 1981,1982
- 1997 HRIA

Golder Associates

SHELL CANADA LIMITED

PREVIOUS HISTORICAL RESOURCES IMPACT ASSOCIATED STUDIES AND 1997 HRIA

07 DEC 1997	Figure E13-2	DRAWN BY: TM

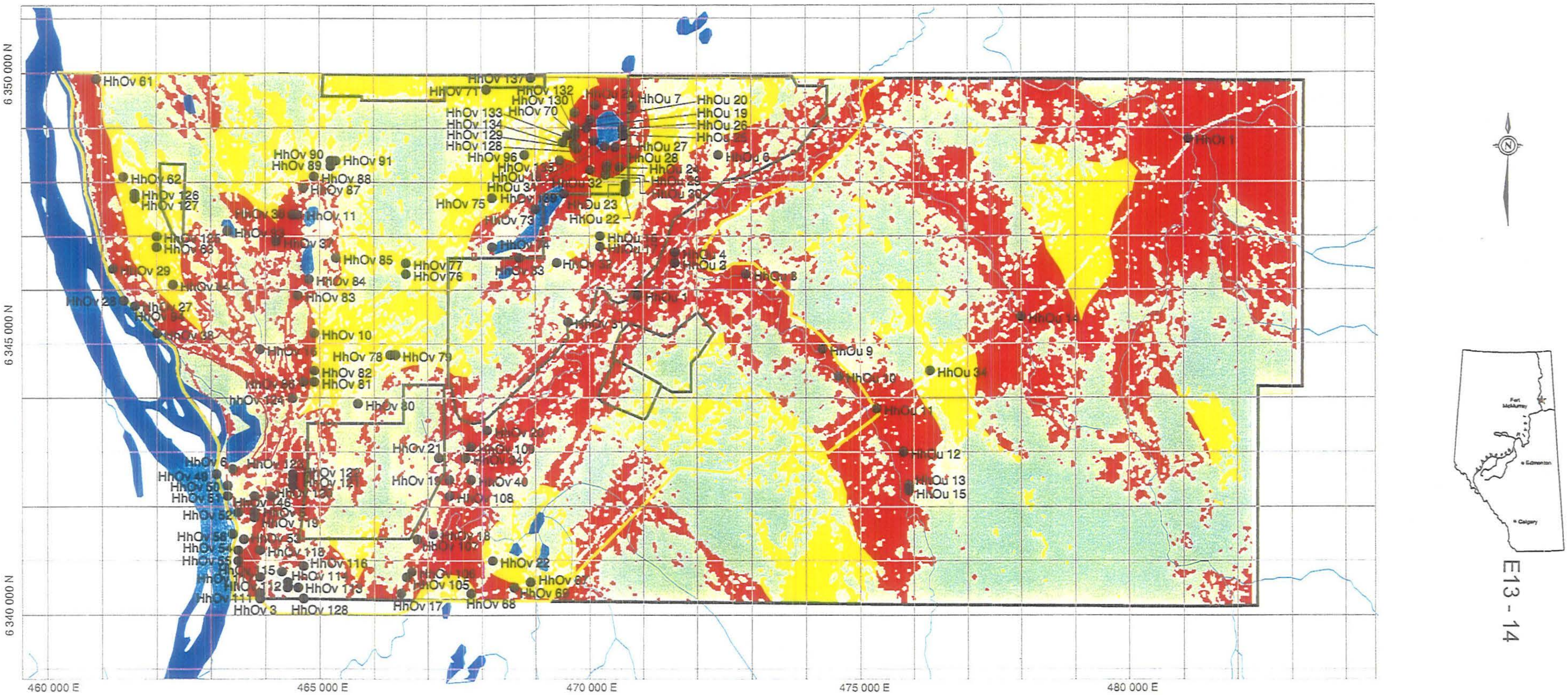
A further discrimination of potential was included by ranking communities in proximity to water as having higher potential than hinterlands locations. Well drained locations within 1 km of flowing water and 500 m of standing water were considered to exhibit high potential, while those at greater distance retained a moderate ranking for archaeological potential. Figure E13-3 displays the archaeological potential throughout Lease 13. These rankings were then overlain with the study area boundaries as a basis for structuring field investigations. Subsequently, communities ranked as having high and moderate potential were transferred to 1:20,000 air photographs to plan access routes for field studies.

Procedures

Design of an appropriate mitigation program to offset project impacts is best based on an effective comparison of the significance of resources involved. Consequently, the strategy of inventory and assessment comparable to highly the successful 1980 Alsands HRIA was employed in areas of new impact in 1997 (see Figure E13-2). This strategy involved intensive investigations of raised terrain features. Use of a similar approach provides an equivalent level of assessment of terrain potential in these areas and an analogous level of site assessment, so that comparative site evaluation is possible.

Features selected for examination were chosen on the basis of a GIS sensitivity analysis as discussed above. Sample selection was weighted toward the highest ranked features but also provided coverage of a reasonable number of moderately ranked features. In consideration of the results of previous studies, however, no investigations took place in areas known to have little or no potential for archaeological sites. A change in proposed mine facilities locations after the field program was underway resulted in examination of some areas that are no longer proposed for development.

The 1997 assessment employed the same techniques applied in the 1980 study. Features were covered on foot by walking linear transects oriented according to the shape of feature, usually along its long axis. Transects were placed 10 to 20 m apart depending on the size of the feature. Any natural or man-made exposure present on features (e.g., tree throws, cut lines etc.) were closely examined. Tests measuring 40 to 50 cm on a side were excavated at 10 to 20 m intervals along each transect, again depending of the size of the feature. Notes were kept regarding the distribution and numbers of test conducted on each feature. Tests were excavated into the C horizon or until glacial deposits were encountered. Since, with one exception, all sites recorded to-date in this region have been limited to the upper soil horizons, this program is considered more than adequate to identify all significant archaeological sites in the areas examined.



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/data8/oilsands/972-2237/9840/working/arcview/archy11x17.apr

LEGEND

- Local Terrestrial Study Area
- Lease 13
- Proposed 1997 HRIA Boundary
- Existing Archaeological Sites
- Water

Rating
- Low
- Medium
- High

SOURCE: Golder Associates Ltd.
Alberta Environmental Protection (1997)

500 0 500 1000 1500 2000 2500 3000
Metres

MAP PROJECTION: Universal Transverse Mercator Zone 12 DATUM: NAD 83

Golder Associates

SHELL CANADA LIMITED

MUSKEG RIVER MINE PROJECT
HISTORIC RESOURCE
SITE POTENTIAL RATINGS

04 Dec. 1997	Figure E13-3	PRODUCED BY: J. Shaw REVIEWED BY:

Site assessment also followed the techniques adopted in the 1980 program. Shovel tests that produced artifacts were expanded to 1x1 m in size to obtain information on the depth and density of cultural materials present. Site size was estimated by placement of shovel tests on the four cardinal directions outward from the find until cultural materials were no longer encountered. Transect shovel tests fulfilled most of the objectives in this regard.

Seven previously recorded sites exist in the 1997 assessment area. Five were identified in the initial 1973 survey (Sims and Losey 1975) and two were recorded in the 1980 Alsands HRIA (Ronaghan 1981b). Attempts were made to relocate these sites in the 1997 program.

New site locations were fixed by global positioning system (GPS) readings and were plotted on Project aerial photo and contour maps. Standard recording procedures were followed and resulted in completion of sketch maps and Archaeological Survey site forms. Materials were curated according to standards outlined in the Guidelines for Archaeological Permit Holders in Alberta. Analysis has been conducted according to Guideline standards but considers previous studies with a view toward recording attributes that will facilitate effective comparison with existing collections.

Results

This section will review the results of the four major studies that constitute HRIA level studies completed in the LSA as they directly relate to the proposed Muskeg River Mine development. Site specific details can be found in the original reports cited. The detailed results of the 1997 studies are provided in the main Historical Resources Impact Assessment report prepared for this project and submitted to Alberta Community Development under permit 97-107 (Golder 1997q).

1973 Lease 13 Pilot Survey

The Survey completed by Sims (Sims and Losey, 1975) for the initial proposal to develop an oil sands extraction facility on Lease 13, identified 47 sites clustered along the Muskeg River and Jackpine Creek in their eroding banks. Of these, 20 are located in proximity to the Muskeg River Mine Project development area.

1979 Alsands HRIA

This study examined four specific proposed development component areas of the proposed Alsands Project (Conaty 1979, see Figure E13-1). for the whole lease area. Only two of the areas examined correspond with those proposed for development by the Project.

A narrow strip along the southern boundary of the proposed Alsands plant and campsite area would be developed for the Muskeg River Mine Project.

A single archaeological site was recorded on a slightly raised feature in this largely water saturated terrain. About 60% of the first five year Mine area proposed for the Alsands project falls within the Project development area. No archaeological sites were encountered in this area.

1980 Alsands HRIA

This study examined eight development areas for the proposed Alsands Project. A mine area and portions of the tailings pond and gravel resource mining localities and mine access road included in the study area for that program fall within areas scheduled for development by the Muskeg River Mine Project.

In total 25 prehistoric archaeological sites and one historic period cabin appear to be situated within or near areas proposed for development during the Muskeg River Mine Project. The final HRIA report submitted to Alberta Community Development (Golder 1997q) an illustration of the areas and features covered within the Project development area during this program.

Alsands Energy Corridor HRIA

This study focused on examination of a 695 m wide corridor, 90 m of which had been cleared in advance of highway construction in support of the Alsands project (Ronaghan 1981a). Only a small portion of the corridor study area intersects areas proposed for development in the Muskeg River Mine Project. Nine sites appear to be situated in these areas. The final HRIA report submitted to Alberta Community Development includes (Golder 1997q). Provides an illustration of the areas and features covered during this program fall within the Project development area.

Northwest Utilities Pipeline Right of Way

This project involved an HRIA conducted along a proposed alignment of a natural gas pipeline (Ronaghan 1981c). When corresponds with the proposed access road into the Muskeg River Mine Project area, and correspondingly, provides historical resources coverage for that portion of the proposed road.

In that area, one new archaeological site and one previously recorded site were identified and assessed. The right-of-way areas and features covered within the Muskeg River Mine development area are illustrated in the final HRIA report submitted to Alberta Community Development (Golder 1997q).

Archaeological Survey of Alberta Post -Clearance Examination

In the winter of 1979/80, the Alsands project group completed preliminary development within their proposed plantsite and initial five year mine area by clearing the forest and excavating drainage ditches.

J. W. Ives of the Archaeological survey of Alberta undertook a surface inspection of these cleared areas and was able to identify large numbers of archaeological sites on elevated features that had been examined previously with no returns (Ives 1982, 1988). In this process Ives (1988) recorded a total of 33 prehistoric sites, of which, 25 are situated in the Muskeg River Mine Project development area.

1997 Muskeg River Mine Project HRIA

This study focused its activities on those areas of the proposed Project development area that had not been examined during previous HRIA studies. It employed the investigation strategy used in the two previously completed Alsands projects, because of the success of that strategy, and to provide a comparable assessment. Elevated landforms were targeted for examination on the basis of GIS identification of vegetation communities that signify the appropriate features. During the course of the program, 90 elevated landforms and size were examined with varying numbers of transects depending on the shape of the landform (Table E13-2).

The 1997 program resulted in completion of 4,578 shovel tests and in the identification of 16 prehistoric archaeological sites and one historic, perhaps relatively recent, hunting camp. Detailed descriptions of these sites are provided in the HRIA report prepared for Alberta Community Development (Golder 1997q) and have been summarized in Table E13-3. The areas investigated during this program are illustrated in the final HRIA report submitted to Alberta Community Development and have been included in the calculations completed to gain an impression of the proportion of all elevated areas of archaeological potential that have been investigated within the Project development area.

E13.3.2 Summary

The 1980 Alsands studies and the 1997 sampling program were successful in identifying intact archaeological sites. They are considered sufficient in their execution to meet the requirements of an HRIA for the areas investigated, which comprise all of the areas proposed for development during the Project. A total of ninety nine prehistoric archaeological and one historic period sites have been identified in areas in or near the Project development area. Of these eighty one may be directly affected by construction activities. All of these sites are situated on elevated landforms throughout the project area. These sites are summarized in Table E13-4 (located at the end of Section E13) in the discussion relating to significance.

Archaeological sites found in this area are typically small in size, representing use of the resources of the area by small groups; each perhaps the result of a single episode of activity. The remains found at these sites are limited to stone tools and the debris resulting from tool production and use. All of the organic materials that may have accompanied these occupations have been removed by the destructive chemical forces inherent in the acidic soils of the region.

The ages of the sites situated within the Project development area remain largely unknown. Indications within the development area suggest that several occupations took place between 9,000 and 4,000 B.P., with later occupations better defined along the Athabasca River and in the Birch Hills, west of the Project area. This pattern is more suggestive than real, given the lack of information. The archaeological sites in this region exhibit an almost exclusive use of a distinctive material used for stone tool manufacture, Beaver River Sandstone. It has been suggested (Reeves 1997) that the most intensive development and use of the sources of Beaver River Sandstone, some of which may be in or near the Project area, took place during the a period between 2500 and 1200 years ago. Presently there is no way to assess this suggestion.

E13.3.3 Significance of the Resources that Might be Affected

Site significance is perhaps the most important element in development of an effective mitigation program. In addition to consideration of the physical site attributes, which contribute to an assessment of the scientific value of a particular resource, these evaluations need to consider project related impacts to provide a basis for developing a comprehensive program that successfully mitigates impact and meets the needs outlined in legislation.

Because sites in the region show limited variability in most of their physical attributes, redundancy of information is a significant issue of concern. In his review of the information recovered from post-clearance examination of the Alsands plant and initial mine sites, Ives (1982, 1988) suggests that site size, material density, technological variation and functional variation may be useful measures against which to judge redundancy.

For the purposes of this report, it was intended that a combination of these factors be employed to rank the significance of all sites recorded within the Project area so that all resources could be compared using the same basis. The focus of this evaluation was to attempt to recognize those sites that represent unusual information sources and hold potential to provide important information not available in the archaeological samples from the Project area. Achievement of these goals has been frustrated by the degree of variability in the specific information available for sites recorded during the different programs conducted in the Project area. Nevertheless, sufficient information was obtained from reports, site forms and other types of data to provide evaluations in a series of similar categories.

Table E13-2 1997 Muskeg River Mine Project HRIA Survey Areas

Survey Area	Transects	Shovel Tests	Results	Survey Area	Transects	Shovel Tests	Results
1	0	0	HhOv 71	46	3	54	
2	6	141		47	3	18	
3	3	6		48	3	9	
4	3	54		49	3	18	
5	3	60		50	5	250	HhOv 181
6	4	46		51	?	12	
7	2	11		52	?	36	
8	2	18	HhOu 41	53	?	30	
9	3	20		54	?	39	
10	4	86		55	?	50	
11	4	68		56	?	30	
12	4	72	HhOu 42	57	?	35	
13	3	72	HhOu 43	58	?	60	
14	5	10		59	3	30	HhOv 182
15	5	100		60	3	3	
16	5	260		61	3	48	
17	5	32		62	3	16	
18	8	80		63	3	9	
19	4	80		64	3	30	
20	2	20		65	3	75	
21	4	68		66	5	104	HhOv 186
22	5	35		67	5	36	
23	4	19		68	5	100	
24	5	90		69	?	115	
25	3	30	HhOv 179	70	3	120	
26	3	18		71	3	15	
27	4	96		72	3	126	
28	4	88		73	3	80	HhOv 185
29	3	36		74	3	60	
30	?	8		75	3	98	
31	4	48		76	4	228	
32	4	80		77	4	48	
33	4	20		78	4	33	
34	3	24		79	4	40	
35	6	36		80	3	15?	HhOv 184
36	3	30		81	4	42	HhOu 42
37	3	30		82	3	10	
38	1	15		83	6	35	HhOv 187
39	3	6	HhOv 180	84	3	23	
40	3	45		85	6	40	
41	3	30		86	3	10	
42	3	75		87	3	6	
43	3	60		88	3	12	
44	1	35	HhOv 183	89	3	8	
45	?	24		90	3	40	HhOv 188 HhOv 189 HhOv 190
				Total		4578	

Table E13-3 New Sites Recorded in the 1997 Muskeg River Mine Project HRIA

Site	Site Type	Site size	Artifacts	Positive Tests	Material
HhOu 41	Buried scatter	1 sq. m	11 debitage 1 biface fragment	One	BRS
HhOu 42	Buried scatter	1 sq. m	36 debitage	One	BRS
HhOu 43	Buried scatter	1 sq. m	10 debitage	One	BRS quartzite
HhOu 44	Buried scatter	1 sq. m	1 debitage 1 end scraper	One	BRS chert
HhOu 45	Buried scatter	5 sq. m	100 debitage	Two	BRS
HhOu 46	Buried scatter	5 sq. m	33 debitage	One	BRS
HhOv 178	Buried scatter	1 sq. m	6 debitage	One	BRS
HhOv 179	Buried scatter	1 sq. m	7 debitage 1 biface fragment	One	BRS
HhOv 180	Buried scatter	1 sq. m	7 debitage	One	BRS
HhOv 181	Buried scatter	1 sq. m	210 debitage	One	BRS
HhOv 182	Buried scatter	1 sq. m	51 debitage	One	BRS
HhOv 183	Buried scatter	1 sq. m	2 flake tools	One	BRS
HhOv 184	Buried scatter	10 sq. m	378 debitage	Six	BRS chert quartzite
HhOv 185	Buried scatter	1 sq. m	33 debitage	One	BRS
HhOv 186	Buried scatter	1500 sq. m	24 debitage	Six	BRS
HhOv 187	Buried scatter	150 sq. m	69 debitage	Three	BRS

Table E13-4 shows the archaeological sites (by their registry number in the Borden system) that fall within or adjacent to proposed impact zones and the evaluative criteria chosen to reflect the range in variation in physical site characteristics resident with these sites. The table also provides entries for each site, when sufficient information is available. However, it was not possible to provide an evaluation for all sites in all criteria and, should development plans change, the sites included in the table would also change.

Evaluation criteria

Site Type: These represent the functional classifications applied to sites by the individual researchers in reports or on site forms. The categories used are generally impressionistically assigned but reflect variation observed in the field or after assemblage analysis. The campsite designation (cs) usually represents an impression that the site represents more than the remains of a brief stop by a small hunting party, and may include materials that reflect the use of tools for domestic activities. The workshop designation (ws) generally applies to an assemblage that appears to represent the remains of tool production. A surface scatter (ss) represents the remains of a brief stop by a small party, they involve the refuse of production of a few tools, or maintenance of existing tools as part of brief episode of resource processing, that is exposed in some type of surface disturbance. If such a site exhibits intact portions in sediments buried below forest litter, a buried (bur) indication has been appended to the designation provided. An isolated find (if) represents the recovery of a single artifact either from a surface exposure or in a subsurface context. The historic designation (hist) applies to structural features, generally found on surface, that represent activities such as hunting or trapping that took place in recent time periods.

Impact Area: The various designations applied within this category were derived by overlaying the current mine plans on the site distribution map. Figure E13-3 shows this relationship. The various components of the Project are identified when a site falls within or adjacent to one of these areas.

Integrity: This category relates to the degree of existing disturbance observed at the site during the in-field inspection. Some of these designations are now seventeen years old and some changes may have been experienced. However, the exploration activities which represent the most likely source of additional impact were largely completed for the Alsands Project, and it is believed that, the conditions identified at the time of original recording probably still apply. Evaluations provided within this category include: undisturbed, partially disturbed and destroyed. These evaluations require little explanation except to say that it did not seem reasonable to break down the disturbed category further in the absence of full information on the actual extent of most sites. The designation collapsed has been used for the single historic period cabin that is present in the sample.

Site Size: Although this category has been included in the table, values could be included only for the sites recorded in the 1997 program. None of the previous studies provided detailed information in this regard.

Chronological Indicators: This category refers to the presence of artifact types that provide some indication of the time period during which site occupation occurred. Generally these are projectile point types, the styles of which are known to exhibit limited temporal time spans. Only a very few entries could be made in this category. However, because establishment of a prehistoric culture history remains a major question in this region, and few archaeological sites provide any evidence in this regard, any indications in this regard are worthy of note.

Collection: This category represents actual counts of the number of archaeological specimens recovered at each of the sites. In many cases, it was not possible to include these numbers for all sites because the information was not available in the records relating to previous projects.

Material Diversity: Assignment of values in this category was difficult given the state of the records available for each site included in Table E13-4. A "yes/no" evaluation has been provided based on the presence or absence of materials other than Beaver River Sandstone. Even one specimen of different material present in a collection resulted in a "yes" entry in the table. Although it may appear to be a relatively minor distinction, the existence of different material types within an assemblage provides some indication of the extent of the seasonal round of a group's activities or it's participation in exchange networks.

Assemblage Diversity: This category identifies variation in a series of categories, suggesting that activities other than stone tool production took place at the site, or that tool production activities represented exhibit a range of variation, suggesting more than one technique was applied. For example, if a formed tool, suggesting resource processing may have taken place or providing an indication what the final product of tool manufacture was present, a "yes" evaluation was included in the table. If an specimen was present that exhibited use wear, reflecting resource processing as well a tool production, a "yes" evaluation was tabulated. If during analysis, significant variation was noted in the types of specimens present (e.g. a bimodal distribution of specimen size), a "yes" evaluation was included in the table, reflecting the possibility that two or more types of stone tool products were produced during site occupation. It was not possible to include an evaluation in this category for all sites evaluated because of the limitations of the data available in the records for previous projects. Nevertheless all of the sites evaluated, for the Alsands Project and those identified in 1997, could be evaluated in this category.

Also included in this table are three categories of information that that may provide additional information on the relative significance of the sites evaluated. The "original assessment" category furnishes the often impressionistic evaluation provided by the original investigator, and was obtained either from reports or site forms. These evaluations may incorporate data that have not been included elsewhere and may represent a reason for altering an individual site evaluation, based on the results of other considerations, or of providing an evaluation for sites that are not fully described in the available records. The "existing recommendations" category provides the recommendations made by the researcher who originally recorded the site. In both of these categories, it was not possible to provide information for all sites included in this evaluation because of the character of the site records. The final category included in this evaluation is the "Historical Resources Act Status" of any site that has been evaluated by Alberta Community Development. The entries made in this column represent the outstanding requirements that would have to be met before a site could be released for development. It must be recognized in considering these that some requirements have not yet been completely defined and others may require modification, if preliminary results suggest changes would be appropriate.

Table E13-4 Significance of Sites Within and Adjacent to Development Zones

Borden Number [(a)]	Type[(b)]	Impact Area	Integrity	Size[(c)]	Chronological indicators	Collection	Material Diversity	Assemble Diversity	Original Assessment	Existing Recommend	H.R. Act Status/ Outstanding Requirements.	1997 Evaluation
HhOu 1[d]	cs	Musk. R. set back	disturbed	n/a	Hell Gap point	26	no	yes	not assessed	None given.		significant
HhOu 6[d]	ss	NE dump	disturbed	n/a	n/a	8	n/a	n/a	significant	Test excavate.		mod. value representative
HhOu 7[d]	cs	Mine	disturbed	n/a	n/a	13	n/a	n/a	not assessed	None given.		low value representative
HhOu 16[d]	cs/ws	Plant Site	destroyed	n/a	n/a	398	no	n/a	Significant	nfw	clearance given	destroyed
HhOu 17[d]	hist	Plant Site	collapsed	n/a	modern	n/a	n/a	n/a	low value	nfw	clearance given	low value representative
HhOu 18[d]	cs/ws	Mine	part.dist.	n/a	n/a	?	?	?	not assessed	No further work.		mod. value representative
HhOu 19[d]	ss	Mine	part.dist.	n/a	no	n/a	no	yes	not assessed	No further work.		low value representative
HhOu 20[d]	ss	Mine	part.dist.	n/a	no	n/a	n/a	yes	not assessed	No further work.		low value representative
HhOu 21[d]	bur/ ss	Mine	part.dist.	n/a	no	n/a	yes	yes	not assessed	No further work.		mod. value representative
HhOu 22[d]	if	Mine	part.dist.	n/a	no	1	no	no	not assessed	No further work.		low value representative
HhOu 23[d]	ss	Mine	part.dist.	n/a	no	3	no	no	not assessed	No further work.		low value
HhOu 24[d]	bur/ ss	Mine	part.dist.	n/a	no	n/a	no	n/a	not assessed	Test excavate.		mod. value representative
HhOu 25[d]	ss	Mine	part.dist.	n/a	no	n/a	no	n/a	not assessed	No further work.		low value representative
HhOu 26[d]	bur/ ss	Mine	part.dist.	n/a	no	n/a	no	n/a	not assessed	No further work.		low value representative
HhOu 27[d]	bur/ ss	Mine	part.dist.	n/a	no	n/a	no	yes	not assessed	Test excavate.		mod. value representative
HhOu 28[d]	bur/ ss	Mine	part.dist.	n/a	no	3	no	n/a	not assessed	No further work.		low value representative
HhOu 29[d]	bur/ ss	Mine	part.dist.	n/a	no	1	yes	n/a	not assessed	No further work.		low value representative
HhOu-30[d]	bur/ ss	Mine	part.dist.	n/a	no	1	no	n/a	not assessed	No further work.		low value representative

Borden Number [a]	Type [b]	Impact Area	Integrity	Size [c]	Chronological indicators	Collection	Material Diversity	Assemble Diversity	Original Assessment	Existing Recommend	H.R. Act Status/ Outstanding Requirements.	1997 Evaluation
HhOu-31 [d]	if	Mine	part.dist.	n/a	no	1	no	no	not assessed	No further work.		low value
HhOu-32 [d]	bur/ ss	Mine	part.dist.	n/a	no	n/a	n/a	n/a	not assessed	Test excavate.		mod value representative
HhOu 41 [d]	bur/ ss	Mine	undist.	1 m^2	no	12	n/a	yes	low value	No further work		low value representative
HhOu 42	bur/ ss		undist..	1 m^2	no	36	n/a	n/a	low value	No further work		low value representative
HhOu 43	bur/ ss		undist.	1 m^2	no	10	yes	n/a	low value	No further work		low value representative
HhOu 44 [d]	bur/ ss	RMS	undist.	1 m^2	no	2	yes	yes	low value	No further work		low value representative
HhOu 45 [d]	bur/ ss	RMS	undist.	5 m^2	no	100	n/a	n/a	mod. value	No further work		mod. value representative
HhOu 46 [d]	bur/ ss	RMS	undist.	5 m^2	no	33	n/a	n/a	mod. value	No further work		mod. value representative
HhOv 6	ss	intake facility road	part. dist.	n/a	no	13	?	yes	significant	Relocate.		mod. value representative
HhOv 10	ss		disturbed	n/a	no	12	?	yes	?			low value representative
HhOv 11	ss		disturbed	n/a	no	58	?	yes	?	Revisit.		low value representative
HhOv 16	cs/ws		part.dist.	n/a	Oxbow point	1000+	yes	yes	high	Avoid.	Avoid (Dec 2/81) Mit. unspecified (Dec 1/81)	significant
HhOv 17 [d]	ss	access road utility corridor	disturbed	n/a	no	5	?		unknown	Avoid.	Avoid (Dec 2/81) NC (Dec 1/81)	low value representative
HhOv 18 [d]	ss	access road utility corridor	disturbed	n/a	Shield Archaic & LMP dart points	1660	yes	yes	significant	Surface collection.	Avoid (Dec 2/81) NC (Dec 1/81)	mod. value representative
HhOv 19 [d]	ss	access road utility corridor	disturbed	n/a	no	?	?	?	?	?		low value representative
HhOv 20 [d]	ss	access road utility corridor	destroyed	n/a	no	10	?	?	none	No further work.	No Concern Released (NC)	destroyed

Borden Number [a]	Type [b]	Impact Area	Integrity	Size [c]	Chronological indicators	Collection	Material Diversity	Assemble Diversity	Original Assessment	Existing Recommend	H.R. Act Status/ Outstanding Requirements.	1997 Evaluation
HhOv 21 [d]	ss	Mine	destroyed	n/a	no	57	n/a	yes	not assessed	Relocate.		destroyed
HhOv 31 [d]	if	Plant site	destroyed	n/a	no	1	no	no	none	None.		destroyed
HhOv 32 [d]	ss	Plant site	destroyed	n/a	no	2	n/a	no	none	None.		destroyed
HhOv 33 [d]	if	Mine	destroyed	n/a	no	1	no	no	none	None.		destroyed
HhOv 34 [d]	if	Access road utility corridor	destroyed	n/a	no	?	no	no	none	None.		destroyed
HhOv 36	if		destroyed	n/a	no	?	no	no	none	None.		destroyed
HhOv 37	if		destroyed	n/a	no	1	no	no	none	None.		destroyed
HhOv 39	if		destroyed	n/a	no	1	no	no	none	None		destroyed
HhOv 40	if		destroyed	n/a	no	1	no	no	none	None.		destroyed
HhOv 71 [d]	bur	Mine	undist.	n/a	no	666	no	yes	none	Mitigated.	mit. complete - NC	low remaining value
HhOv 73 [d]	bur	Mine	undist.	n/a	no	1000+	yes	yes	high significance	Excavate.	significant mit. unspecified	significant
HhOv 74 [d]	cs	Mine	undist.	n/a	no	6	yes	yes	significant	Excavate.	3 2x2m units	mod. value
HhOv 75 [d]	if	Mine	undist.	n/a	no	1	no	no	none	No further work.	NC	low value
HhOv 76 [d]	if	West dump	part.dist.	n/a	no	0	no	no	none	No further work.	NC	low value
HhOv 77 [d]	if	West dump	part.dist.	n/a	no	0	no	no	none	No further work.	NC	low value
HhOv 78 [d]	if	Tailings location	undist.	n/a	no	12	no	no	none	No further work.	NC	low value
HhOv 79 [d]	if	Tailings location	undist.	n/a	no	1	no	no	none	No further work.	NC	low value
HhOv 80 [d]	if	Tailings location	undist.	n/a	no	2	no	no	none	No further work.	NC	low value
HhOv 81 [d]	ws	Tailings location	undist.	n/a	no	1000+	no	yes	significant	Excavate.	2x2m test	mod. value
HhOv 82 [d]	cs/ws	Tailings location	unknown	n/a	no	5	yes	no		Test excavate.	2 2x2m units	mod. value
HhOv 83	ss		destroyed	n/a	no	1	no	no	none	No further work.	NC	destroyed
HhOv 84	cs/ws		disturbed	n/a	no	3	no	yes	unknown	Test excavate.	Surface collection, 2x2m unit	mod. value
HhOv 85 [d]	if	West dump	undist.	n/a	no	2	no	no	none	No further work.	NC	low value

Borden Number [a]	Type[b]	Impact Area	Integrity	Size[c]	Chronological indicators	Collection	Material Diversity	Assemble Diversity	Original Assessment	Existing Recommend	H.R. Act Status/ Outstanding Requirements.	1997 Evaluation
HhOv 86 [d]	cs/ws	West dump	undist.	n/a	no	479	yes	yes	significant	Excavate.	4 3x3m units	mod. value
HhOv 87	cs		undist.	n/a	no	8	no	no	significant	Test Excavate.	5x5m excavation	mod. value
HhOv 88	ss		part.dist.	n/a	no	3	no	yes	unknown	Test Excavate.	Surface collection, 2x2m test	mod. value
HhOv 89	ss		disturbed	n/a	no	11	no	yes	none	No further work.	NC	low value representative
HhOv 90	cs/ws		undist.	n/a	no	2	no	no	unknown	Test excavate.	2x2m test	mod. value
HhOv 91	cs/ws		undist.	n/a	no	12	no	yes	unknown	Test excavate.	2x2m test	mod. value
HhOv 96 [d]	if	Mine	disturbed	n/a	no	1	no	no	none	No further work.	NC	low value
HhOv-105 [d]	if	Access road utility corridor	destroyed	n/a	no	11	no	no	none	No further work.	NC	destroyed
HhOv 106 [d]	if	Access road utility corridor	destroyed	n/a	no	1			none	No further work.	NC	destroyed
HhOv 107 [d]	cs/ws	Access road utility corridor	destroyed	n/a	no	15	no	no	none	No further work.	NC	destroyed
HhOv 108 [d]	if	Access road utility corridor	destroyed	n/a	no	1	no	no	none	No further work.	NC	destroyed
HhOv 109 [d]	cs/ws	Access road utility corridor	disturbed	n/a	no	648	yes	yes	significant	Avoid.	Avoid	mod. value
HhOv 112 [d]	if	Tailings location	undist.	n/a	no	1	no	no	none	None.	NC	low value
HhOv 113 [d]	cs/ws	Tailings location	undist.	n/a	no	5	no	no	significant	Excavate.	mit. unspecified	mod. value
HhOv 114 [d]	cs/ws	Tailings location	undist.	n/a	no	>95	no	n/a	significant	Excavate.	mit. unspecified	mod. value
HhOv 115 [d]	ws	Tailings location	undist.	n/a	no	15	no	no	unknown	Test excavate.	mit. unspecified	mod. value
HhOv 116 [d]	if	Tailings location	undist.	n/a	no	2	no	no	none	None.	NC	low value
HhOv 121 [d]	if	Tailings location	undist.	n/a	no	3	no	no	none	None	NC	low value

Borden Number [a]	Type [b]	Impact Area	Integrity	Size [c]	Chronological indicators	Collection	Material Diversity	Assemble Diversity	Original Assessment	Existing Recommend	H.R. Act Status/ Outstanding Requirements.	1997 Evaluation
HhOv 122 [d]	if	Tailings location	undist.	n/a	no	2	no	no	none	None	NC	low value
HhOv 123 [d]	if	Tailings location	undist.	n/a	no	4	no	no	none	None	NC	low value
HhOv 124	cs/ws		undist.	n/a	no	98	no	yes	significant	Excavate.	mit. unspecified	mod. value
HhOv 128 [d]	cs/ws	Access road utility corridor	undist.	n/a	no	115	no	yes	significant	Avoid.		mod. value
HhOv 129 [d]	?	Mine	disturbed	?	?	?	?	?	not assessed	No further work.		low value
HhOv 130 [d]	bur/ ss	Mine	disturbed	n/a	no	n/a	no	n/a	not assessed			low value representative
HhOv 131 [d]	?	Mine	disturbed	?	?	?	?	?	not assessed	Test excavate.		mod. value representative
HhOv 132 [d]	bur/ ss	Mine	disturbed	n/a	yes	n/a	yes	yes	not assessed	Test excavate.		mod. value representative
HhOv 133 [d]	ss	Mine	disturbed	n/a	no	4	no	no	not assessed	No further work.		low value representative
HhOv 134 [d]	if	Mine	disturbed	n/a	no	1	no	n/a	not assessed	No further work.		low value representative
HhOv 135 [d]	ss	Mine	disturbed	n/a	no	n/a	yes	n/a	not assessed	Test excavate.		mod. value representative
HhOv 137 [d]	bur/ ss	Mine	disturbed	n/a	no	n/a	yes	n/a	not assessed	No further work.		low value representative
HhOv 138 [d]	bur/ ss	Mine	disturbed	n/a	no	n/a	yes	n/a	not assessed	Test excavate.		mod. value representative
HhOv 139 [d]	bur/ ss	Mine	disturbed	n/a	no	5	no	n/a	not assessed	Test excavate.		mod. value representative
HhOv 178 [d]	bur/ ss	Mine	undist.	1 m^2	no	6	no	no	low value	No further work		low value representative
HhOv 179 [d]	bur/ ss	Mine	undist.	1 m^2	no	8	no	yes		No further work		low value representative
HhOv 180 [d]	bur/ ss	Mine	undist.	1 m^2	no	7	no	no	low value	No further work		low value representative
HhOv 181 [d]	bur/ ss	Access road utility corridor	undist.	1 m^2	no	210	no	no	significant	test excavate if impacted		mod. value representative

Borden Number [(a)]	Type[(b)]	Impact Area	Integrity	Size[(c)]	Chronological indicators	Collection	Material Diversity	Assemble Diversity	Original Assessment	Existing Recommend	H.R. Act Status/ Outstanding Requirements.	1997 Evaluation
HhOv 182 [d]	bur/ ss	Tailings location	undist.	1 m^2	no	51	no	no	low value	No further work		low value representative
HhOv 183 [d]	bur/ ss	Mine	undist.	1 m^2	no	2	no	yes		No further work		low value representative
HhOv 184 [d]	bur/ ss	Access road utility corridor	undist.	10 m^2	no	378	yes	no	significant	excavate if impacted		mod. value representative
HhOv 185 [d]	bur/ ss	Tailings location	undist.	1 m^2	no	33	no	no	low value	No further work		low value representative
HhOv 186 [d]	bur/ ss	Tailings location	undist.	1500 m^2	no	24	no		significant	excavate if impacted		mod. value
HhOv 187 [d]	bur/ ss	Tailings location	undist.	150 m^2	no	69	no		significant	test excavate if impacted		mod. value

(a) site registry number using the Borden system
(b) cs=campsite, ss=surface scatter, ws=workshop, hist.=historic, bur=buried, scat=scatter, if=insolated finds, hist=historical designation
(c) size only for sites surveyed in 1997.
(d) in or adjacent to proposed development zone

Summary

Tabular entries have been made for 98 prehistoric archaeological sites and one historic period cabin within or near proposed development area associated with the Project. This total would encompass all of the historical resource sites that are present in an area that could accommodate changes in the plans for where specific development activities would occur. Some are situated in what would be a set back zone along the Muskeg River and would not be affected in any event, however, they have been included in the table in recognition of their existence and to alert potential users of the area to their presence, so that accidental impacts may be avoided.

Of this total, 27 have been classified as isolated finds, 19 have been classified as disturbed surface scatters of stone artifacts, 14 have been classified as surface scatters that contain portions that are buried and still intact, 18 have been identified as buried scatters or buried sites, four have been classified as campsites, 14 have been classified as campsite/ workshops, and two have been classified as workshops.

Evaluations provided for these sites as a result of consideration of these characteristics are provided in the final column of Table E13-4. These represent a combination of the factors shown in the table. All sites that have been destroyed (n= 16) are not rated as they are considered to no longer exist. Isolated finds (n= 17) are rated as having low value. Surface scatters with or without buried portions and buried scatters are considered to have generally low value, but are considered to be representative of an occupation pattern that is well represented throughout the Project area (n=29). If however, the original investigator made recommendations for additional study, such sites have been included in a classification termed moderate value representative (n=17). This indicates that although the site represents typical prehistoric occupation patterns, one or more of its physical characteristics were viewed as having enough significance to warrant sample recovery. Sites classified as campsites and workshops were generally rated as having higher value. Any site with outstanding mitigation requirements were rated as having moderate value (n=17).

Finally three significant sites that stand in contrast to the typical pattern evinced within the development area are included in the table. Cree Burn Lake (HhOv 16) has been nominated as a Provincial Historical Resource. Although it technically lies outside any zones scheduled for development during the Project, it is sufficiently close that its inclusion was considered warranted. Bezya (HhOv 73) is currently on Alberta Community Development's significant site list and even though major excavations have taken place at this site, additional value is considered to be present and will require consideration prior to area development. HhOu 1 has also been included in this category because it is one of the very few sites in the region that has produced evidence that would allow an estimate of time of occupation (ca. 9,000 years). This site is situated within a setback area along the Muskeg River and would likely not be affected but it's location should be avoided.

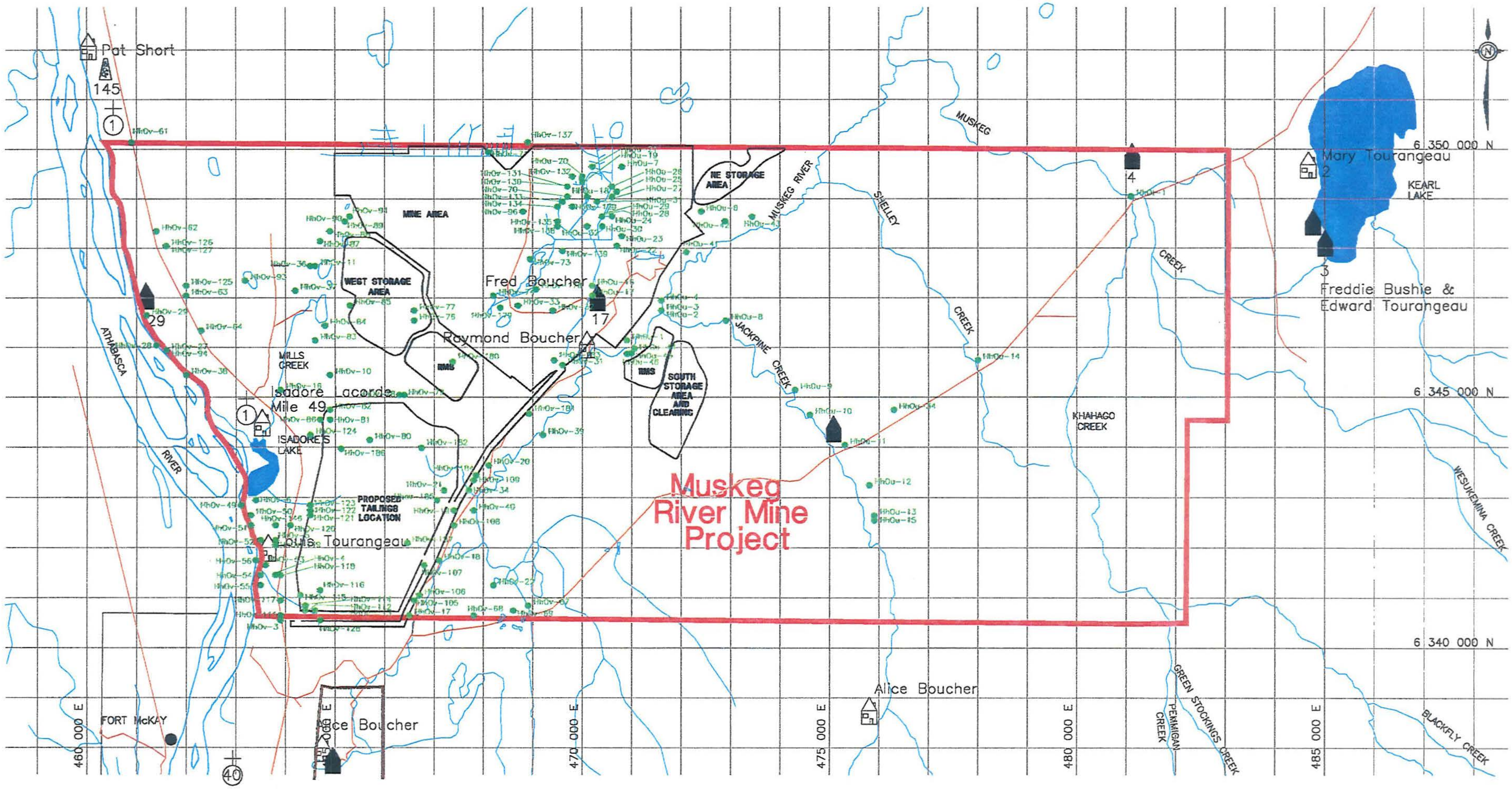
Analysis of Key Question HR-1

Development of the Project will impact a considerable number of prehistoric archaeological sites. The discussion relating to impacts indicates that negative physical effects will be experienced during a wide range of construction activities. Only the early stages of development, involving forest clearance, will result in partial disturbance of subsurface archaeological resources. Virtually all other stages of development will result in complete removal of any resources situated within development zones. These activities include excavations for drainage ditches, installation of water wells, and trenching for pipeline installation, grading for facility locations and for road construction, muskeg and overburden removal and mining. These impacts will be direct, varied in magnitude depends on site significance, immediate and irreversible, however they will be localized to actual impact zones. Determination of the magnitude of these impacts also requires consideration of the significance of the resources involved.

Information gained from earlier studies within the project area, coupled with the results of the 1997 HRIA program have identified a series of prehistoric archaeological sites and one historic period cabin that might be affected by Project development. Data on these resources have been tabulated for an area that would encompass all of the development stages associated with the Project and includes information on 99 historical resources. This area would be reduced when the actual footprint of development activities has been overlain on the historical resources distribution. Nevertheless it seemed prudent to include a slightly larger area to accommodate adjustments in the initial plan.

Figure E13-4 illustrates the relationship between historical resource sites and the proposed Muskeg River Mine Project development. Sites evaluated in Table E13-4 include all those east of the Highway 63 corridor and the Susan Lake gravel resource and all those west of the Muskeg River. Sites situated east of the Muskeg River between the plant site and the muskeg and overburden areas have also been included. Sites indicated by a [d] are those that lie within or directly adjacent to planned facility locations. These 81 sites are those that have the greatest potential to be directly affected by construction activities as currently planned.

1997\2237\[illegible] SITE\IMPACT2.DWG



0 1000 2000 3000 4000 5000(metres)

SCALE IN METRES

REFERENCE

DIGITAL DATA SETS 74D, 74E, 74I
84A AND 84H FROM RESOURCE DATA DIVISION
ALBERTA ENVIRONMENTAL PROTECTION, 1997.

LEGEND

- Trapper's Cabin – Collapsed
- Trapper's Cabin
- 29 Borden Identification Number
- Gravesite\Number of Graves
- Boiler and Rig Debris

Golder Associates

SHELL CANADA LIMITED

RELATIONSHIP BETWEEN HISTORICAL RESOURCES AND PROPOSED IMPACT ZONES

06 DEC 97	E13-4	DRAWN BY: KD

With the exception of the single historic period cabin, all of the historical resources tabulated are prehistoric archaeological sites. These latter are typically small in size and represent use of the resources of the area by small groups over short durations. Many may reflect only single episodes of activity. The remains present at these sites are limited to stone tools and the debris resulting from their production and use. The archaeological sites in this region exhibit an almost exclusive use of a distinctive material for stone tool manufacture, Beaver River Sandstone. Individually, these sites are considered to be of moderate to low scientific value.

However in their numbers and patterned distribution, the prehistoric sites in the LSA represent the densest known concentration yet identified in Alberta's forested regions. Outside the Project area this pattern extends up the Muskeg River drainage and around the Fort Hills to the north and east. As well, a significant portion of this pattern is situated along the rim of the Athabasca River Valley. It appears to be unique, involving an intensive and long term use of both a specific local source material and a particular landscape. Studies involving comparable levels of investigation conducted for the formerly proposed Canstar Project (McCullough et.al. 1982, McCullough and Wilson 1982) have demonstrated that much lower site densities are present in those study areas.

The ages of the sites situated within the Project development area remain largely unknown. Indications within the development area suggest that several occupations took place between 9,000 and 4,000 B.P. when warmer, drier climatic conditions would have increased ecological diversity throughout the area. Later occupations appear to be more well defined along the Athabasca River and in the Birch Hills to the west, but occur the Project area as well. Only three sites have produced artifacts that provide some indication the time period of occupation and one other has been radiocarbon dated.

It is evident that there is a limited degree of variation in the character of the physical remains contained within these sites. Consequently, there is a considerable potential for redundancy of information. In recognition of this fact, the evaluations tabulated above for archaeological sites have classified most of the sites in the project area as being "representative" of a typical pattern of exploitation. Within this category a range of low and moderate values have been assigned to reflect variation in the quantities or qualities of information available at each. The recommended mitigation program discussed below accounts for information redundancy and the range of variation identified in this sample.

A series of sites have been ranked as having moderate value, if more significant information is available, or if mitigation requirements have already been established by Alberta Community Development. Three sites have been given a "significant" ranking but two of these lie outside proposed development zones. Finally a large number of the sites within the project area have been destroyed or contain such limited evidence that they can be given values that warrant no further concern.

E13.4 Key Question E13-2: Will the Mitigation Program Designed for the Muskeg River Mine Project Effectively Offset Project Affects?

The linkages associated with this question are as follows:

E13.4.1 Linkage HR-2.1: Are any Historical Resources Present in Proposed Impact Zones That Would Require Permanent Avoidance?

With the single exception of the Cree Burn Lake site, none of the sites recorded during the historical resources studies associated with Project would be considered of such significance that they would warrant permanent avoidance. An appropriate mitigation program could effectively offset impacts to the individual resources, continued in the Project area. Portions of the patterns they represent will remain intact outside development zones and represent potential information sources for future study.

E13.4.2 Linkage HR2.2: What Types of Mitigation Procedures are Appropriate to Offset the Negative Historical Resources Impacts of the Project?

The mitigation program recommended to offset the negative physical effects on historical resources of the Project would take places in stages. The objectives of such a program would be:

- to identify any highly significant resources that would require special procedures such as permanent avoidance of major sample recovery;
- to recover, conserve and analyze samples from sites that represent non-typical historical behavior patterns,
- to recover, conserve and analyze a sample of information from sites that represent typical or representative components of the recognized historical land use patterns resident throughout the Project area;
- to recover in the course of these activities, palaeoenvironmental information that would provide important contextual data to help elucidate prehistoric land use patterns within the Project area; and
- to correlate and interpret this information in a cohesive study that makes a major contribution to understanding of the prehistory of the region.

This program would be accomplished in stages that correspond to the various stages of the development process.

Pre-development Mitigative Studies - Information Recovery

The first step in mitigation studies would be to complete the study requirements already established by Alberta Community Development during their review of the previous studies that have taken place in the study area. Some of these requirements have been specifically identified, at least at a preliminary level, others remains to be specified. The report prepared for Alberta Community Development, to fulfill the requirements of permit 97-107 granted for the 1997 HRIA program, details specific recommendations provided for each of the previously recorded sites that have been determined to be of concern as well as for new sites of a similar character recorded during the 1997 program. Upon review of these recommendations by Alberta Community Development, final requirements can be established for each of these sites.

The most significant site so far identified within the project area is the Bezya Site (HhOv 73). This site contained evidence of the use of an usual technology for this region of the province and is the only site that has been radiocarbon dated within the Project area. Excavations conducted by the Archaeological Survey of Alberta in 1982 and 1983 (LeBlanc 1986) recovered a detailed sample of material relating to the use of small black chert pebbles in the production of microcores and microblades. Microblades are small finely edged objects that can be embedded in wood or bone handles to fulfill a variety of cutting and penetrating tasks. This technology represents the ultimate conservation of stone source material, and is extremely portable, but is more commonly known in the archaeological assemblages of the Northwest Territories. A radiocarbon date of 3,900 years has been obtained from this site.

Although a large sample of this material has been obtained from this site, additional significant cultural deposits may yet be present and current Project Development plans will completely consume this site. A final recovery program is recommended for this site before its is destroyed during construction. This program would begin with additional testing, in an attempt to identify any additional concentrations of micorcore/blade materials or other significant information. This would be followed by conservation excavations distributed en-bloc to recover these materials. Subsequent analysis would compare the results obtained with those of previous studies and would result in permanent conservation of these materials for future study.

In all other instances information recovery procedures would involve excavation of small scale tests, the size and distribution of which reflect individual site characteristics. The intent of these procedures would be recovery a sample of material from the most productive or most representative areas of these sites to enable effective characterization of activities conducted at each, and radiocarbon dating of the occupation represented if any suitable materials are present. On the basis of the results of these preliminary studies, additional information recovery may be warranted, unless redundancy becomes evident.

These types of studies are recommended for sites that contain information that is unique or exceptional in one fashion or another and would be tailored to the specific nature of that information. For sites that represent a land use pattern that is already recognized within the Project area, a sampling approach will be adopted.

Sites exhibiting a moderate value in representing the typical land use pattern are those that are more varied in their expressions and/or may be more productive. It is recommended that these be sampled at a higher proportion than lower value sites. If none are identified, studies could be terminated.

Site that are considered to be of lower value in representing the typical land use pattern would be sampled using the same procedures but at a lower proportion.

Information Recovery in Conjunction With Construction - Monitoring

A monitoring component will be included in the mitigation program recommended for the Project. This would take place after forest clearance has created exposures on the landforms known to have high potential for archaeological sites. Its objectives would be to record and evaluate sites not discovered in the initial HRIA. Focus would be placed on identification of sites that represent sources of unique information that might help define the nature of the prehistoric use of the landscape. Sites would be classified using the same categories employed in the 1997 HRIA.

On this basis, additional information recovery would be implemented at sites of unique character in areas where adequate representative sample information is available. Sites of representative value would be sampled only if limited information is available in this regard from the area in question.

Palaeoenvironmental Sampling

Establishment of a chronology and environmental context for the distinctive prehistoric landuse pattern resident within the Project area and its surrounding environs remains an important outstanding information need. In the course of information recovery program instituted at historical resource sites throughout the Project area, specimens may be recovered that enable radiocarbon dates to be obtained for the assemblages with which they are associated. Provisions are required to obtain these dates when suitable materials are recovered.

In addition, muskeg removal may uncover bone and other materials that might enable more detailed estimates of environmental conditions in prehistoric times. These may relate to issues surrounding the onset of muskeg accumulation within the Project area and its rate of accumulation, as well as to other environmental conditions in the past. The potential for recovery of these remains is unknown, but is likely to be rare. Contractors will be made aware of the possibility that such remains could be unearthed. Any such material that is found will be collected, along with some indication of its original position within the deposits, and submitted to appropriate agencies for analysis.

E13.4.3 Linkage HR-2.3: How Would These Procedures Articulate With the Proposed Development Schedule?

The above recommended mitigation program can be integrated with the various stages of development entailed in the Muskeg River Mine Project. In fact, the incremental stages of development proposed for this project provide an excellent opportunity to use information feedback to modify the program so that it becomes more effective at offsetting project impacts.

Studies would be initially targeted at areas scheduled for forest clearance in 1999 and would commence in 1998. These areas include the plant on site area and access roads. Obtaining the sediment core from the lake west of the plant site is recommended for this stage of study.

In 1999, pre-development mitigation programming can be implemented in the areas proposed for forest clearance in the year 2000 (oil sands stockpile area, tailings settling pond, south overburden and muskeg storage areas) and, at the same time, monitoring can be conducted in the areas cleared in the winter of 1999/2000, in advance of muskeg and overburden removal.

This type of sequence would be repeated as development proceeds. For example, in the year 2000 pre-development mitigation would take place in the initial mine area scheduled for forest clearance during the winter, while monitoring studies take place in recently cleared areas.

Effective operation of this type of program requires good communication between the operator and their contractors and the organization conducting the historical resources program. The information provided in the 1997 HRIA report (Golder 1997q) should be sufficient to allow inclusion or removal of any sites from the annual study program.

Because of the extended schedule, it will be necessary to implement a program that collects information that can be effectively compared with information obtained in previous studies. The reports available for the Alsands project, the series of studies completed at the Cree Burn Lake Site

(HhOv 16), and the 1997 Muskeg River Mine Project HRIA all provide a basis for design of comparable analyses.

E13.4.4 Analysis of Key Question HR-2

Previously presented information indicates that only one historical resource site within the vicinity of the project area would require permanent avoidance: The Creeburn Lake site (HhOv 16). This site lies outside proposed development zones and will not be directly affected by the Project. The above discussions provide a description of the type of mitigation program that would be considered sufficient to offset he proposed impacts to the remaining historical resources associated with the Project. As well, this discussion provides an indication of how the recommended mitigation program can be integrated with development schedules. Implementation of an effective program of historical resource mitigation studies can offset the proposed impacts of the Project.

E14 RESOURCE USE

E14.1 Introduction

This section of the Muskeg River Mine Project (the Project) EIA provides information as required by the Project Terms of Reference (TofR) issued on November 7, 1997 (AEP 1997a). Specifically, the following are addressed:

- identification of the potential impacts of the Project on current land uses; and
- identification of possible resource use mitigation strategies (TofR, Section 6.0).

Discussions on the potential cumulative effects on resource use associated with the Project are addressed in Section F14. Section D14 provides details on the resource use baseline for the Project.

According to the Fort McMurray-Athabasca Oil Sands Subregional Integrated Resource Plan (Section D14; AEP 1996a), the proposed Muskeg River Mine Project falls within the Athabasca-Clearwater Resource Management Area (RMA) and the Mildred-Kearl Lakes RMA. The management intent of the Athabasca-Clearwater RMA is "to protect the natural landscape, which encompasses water, wildlife habitat, ecological and geological features, and to ensure aesthetic, recreational, traditional and environmental values" (AEP 1996a). The management intent of the Mildred-Kearl Lakes RMA is "to promote the orderly planning, exploration and development of resources with an emphasis on the area's oil sands reserves" (AEP 1996a).

Guidelines for the development and protection of the RMAs discussed above are listed in Table D14-2. Within the Muskeg River Mine LSA, these RMAs include such prominent features as the Athabasca River, Isadore's Lake, Mills Creek, the Muskeg River, Jackpine (Hartley) Creek, Shelley Creek, Muskeg Creek and Khahago Creek (Figure D14-2). The full environmental setting for resource use within the Muskeg River Mine Project is described in Section D14.

E14.2 Potential Linkages and Key Questions

The approach for the evaluation of impacts for resource use was described in detail in Section E1.

The purpose of this assessment is to determine the potential impacts of construction and operations on resource use, develop appropriate mitigation measures and evaluate residual impacts.

A number of resource uses could potentially be affected to differing degrees by the proposed Muskeg River Mine Project. Important resource uses in the vicinity of the Project were identified in Section D14. These resource uses include surface and mineral extraction, forestry, hunting, trapping, fishing and non-consumptive recreation.

The assessment involved identifying and discussing all possible interactions between resource use and the proposed development. Key Questions and linkage diagrams were developed to detail potential impacts of the Project on resource use (Figures E14-1 and E14-2). The Key Questions were developed to help describe the potentially significant effects of the Project on the various resource uses.

RU-1 Will There Be a Change in Surface and Mineral Materials?

Mineral and surface materials within the LSA include oil sands and surface materials (AEP 1996a). These activities are compatible with the intent of the RMAs if all guidelines are met (see Section D14). The Project has the potential to affect three surface dispositions, one of which is a gravel deposit (see Section D14). Mineral and surface material extraction may be affected by changes in the amount of area available for extraction and by changes in access.

RU-2 Will There Be a Change in Environmentally Significant Areas (ESAs)?

Environmentally Significant Areas (ESAs) contain unique or representative landforms, rare or endangered vegetation, or significant or important wildlife habitat. Several ESAs occur in the vicinity of the Project as delineated in Table D14-3 and Figures D14-5 and D14-6. These ESAs include the Muskeg River, Kearl Lake and associated moose habitat, and Jackpine (Hartley) Creek. Potential changes in vegetation, landforms and wildlife may all affect ESAs.

RU-3 Will There Be a Change in Forestry?

Forestry is one of the main resource uses in the vicinity of the Project, and harvest levels are essential for sustaining the economic health and vitality of the forest industry in the region (AEP 1996a). This question focuses on

Figure E14-1 Linkage Diagram for Resource Use for Construction and Operation Phase of Muskeg River Mine Project

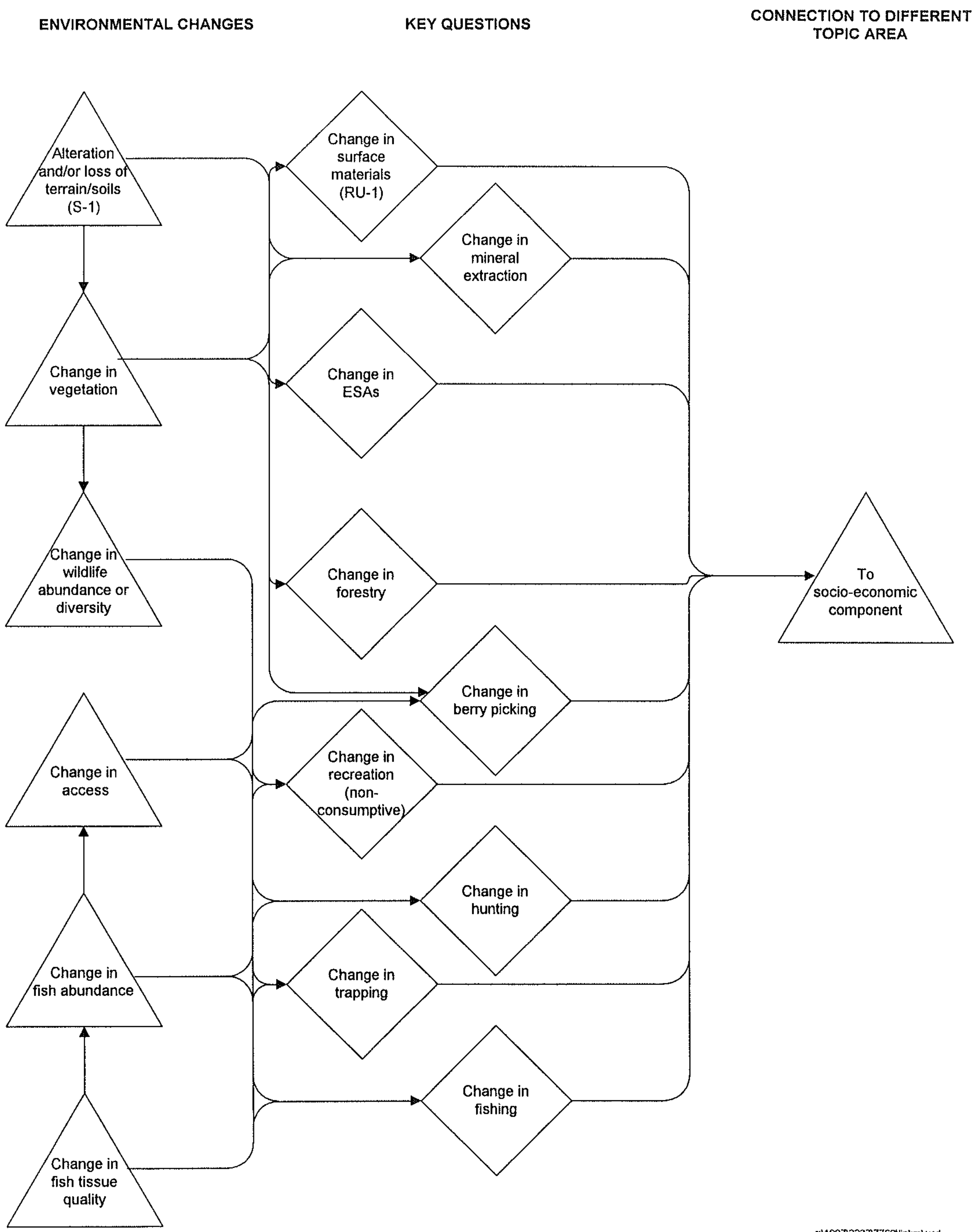

ENVIRONMENTAL CHANGES
KEY QUESTIONS
CONNECTION TO DIFFERENT TOPIC AREA
Alteration and/or loss of terrain/soils (S-1)
Change in vegetation
Change in wildlife abundance or diversity
Change in access
Change in fish abundance
Change in fish tissue quality
Change in surface materials (RU-1)
Change in mineral extraction
Change in ESAs
Change in forestry
Change in berry picking
Change in recreation (non-consumptive)
Change in hunting
Change in trapping
Change in fishing
To socio-economic component
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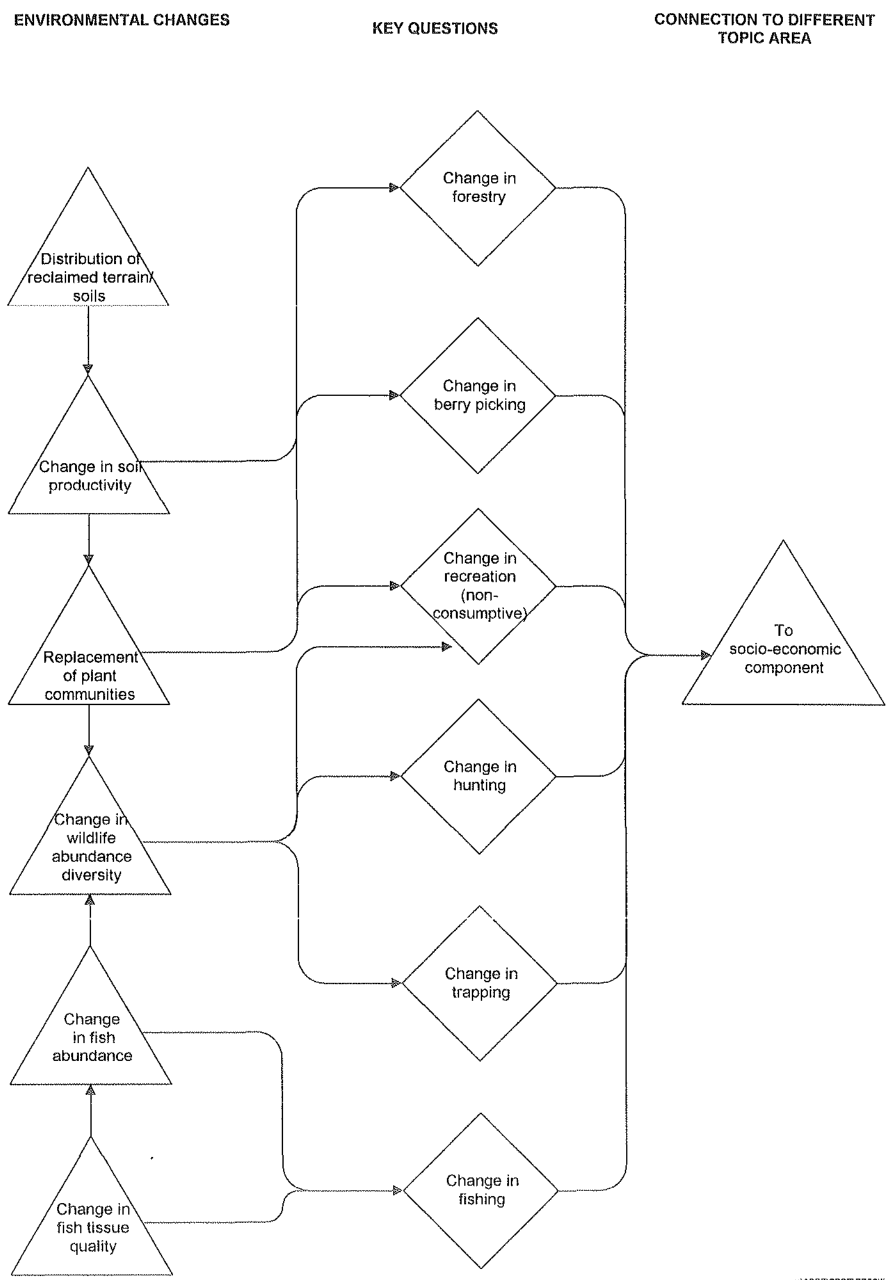
Figure E14-2 Linkage Diagram for Resource Use for Closure Phase of Muskeg River Mine Project



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whether gain, loss or alteration of vegetation or soils will lead to a change in forest productivity and timber harvest potential.

RU-4 Will There Be a Change in Berry Picking?

Many local residents regularly engage in berry picking (BOVAR 1996f). Within the LSA, the valleys of the Muskeg and Athabasca rivers were identified as two areas where berry picking occurs. Construction and operation may result in decreased opportunities for berry picking, especially due to loss of berry picking habitat and changes in access. However, reclamation may result in increased opportunities due to improved access and careful selection of vegetation for planting and reseeding.

RU-5 Will There Be a Change in Non-Consumptive Recreational Use?

Many of the local residents engage in non-consumptive recreational activities (e.g., canoeing, camping, hiking, snowmobiling). Again, the Muskeg River and the Athabasca River are two of the main locations for this resource use. Construction and operation activities may result in changes in aesthetics, changes in opportunities for these recreational uses and restricted access. All these factors may lead to changes in non-consumptive recreational use within the area.

RU-6 Will There Be a Change in Hunting?

Hunting is one of the main forms of consumptive recreation in the region and both residents and non-residents participate in this activity. Within the LSA, construction and operation of the Project may result in a decrease in the abundance of wildlife, changes in access and increased numbers of hunters. All these factors may lead to changes in hunting.

RU-7 Will There Be a Change in Trapping?

Five active traplines are located within the LSA, as described in Section D14. Trappers in the area may be affected by changes in wildlife abundance, changes in access and loss of trapping habitat. All of these factors, in turn, may lead to changes in trapping and loss of revenues.

RU-8 Will There Be a Change in Fishing?

Sport fishing is a popular activity in the LSA, and significant fish habitat is found in both the Athabasca and Muskeg rivers. Construction and operation of the proposed Muskeg River Mine Project has the potential to affect fish abundance due to alterations in water quality, decreased fisheries habitat and changes in access to preferred fishing locations. Changes in access may lead to changes in abundance leading to changes in fishing.

E14.3 Study Area Boundaries

The spatial boundaries (LSA and RSA) for the Resource Use component of the EIA were defined in Section D14.

The temporal boundaries for the EIA were defined as follows:

- Baseline (1997)
- Construction Phase (2000-2002)
- Operational Phase (2003-2029)
- Closure (2030 and after)

These periods were selected because the characteristics of the impacts resulting from the Project are quite different between the construction and operational phases. As well, a long-term view of the Project during closure is required to assess the likely success of proposed reclamation and mitigation measures. Phases of the development selected for detailed analysis are: construction, operation and closure.

E14.4 Methods

Linkages between project activities and environmental changes that affect each of the Key Questions were developed and then assessed as to their validity. In general, assessments were based on the literature and professional judgment. Project construction and operation details were evaluated to determine potential impacts. Following the assessment of the impacts, mitigation strategies were developed for each valid linkage. Residual impacts were then assessed with regard to direction, magnitude, geographic extent, duration, reversibility and frequency.

E14.5 Key Question RU-1: Will There Be a Change in Surface and Mineral Materials?

E14.5.1 Analysis of Potential Linkages

Currently there are three dispositions in the LSA (see Figure D14-6, Section D14). One disposition is a gravel pit, and the other two are Special Places 2000 nominees. These dispositions may be affected by alteration and/or loss of terrain and soils.

Linkage Between Loss or Alteration of Terrain and Soils and Change in Surface Materials and Mineral Extraction

Loss or alteration of terrain or soils may make an area unusable for other resource use (e.g., gravel, Special Places 2000). It is expected that the surface dispositions located within the LSA will not be usable following the development of this project.

The linkage is valid.

E14.5.2 Analysis of Key Question

Construction and operation of the Project will remove or delay the potential for other forms of surface or mineral extraction. In particular, site clearing will remove areas that have potential for other purposes (e.g., gravel and Special Places). Currently, three dispositions occur within the LSA. All of these dispositions will be impacted. Mitigation for this impact involves salvaging materials (e.g., gravel) during site clearing, where possible. Mineral extraction efforts may be possible following closure of the Project. Loss of potential Special Places sites cannot be mitigated, unless the area is avoided.

E14.5.3 Residual Impacts

Construction and operation of the Project will delay the potential for other forms of surface or mineral extraction. As well, areas nominated as Special Places 2000 will be impacted, if the area is disturbed. This impact is expected to be negative, of moderate magnitude, of local geographic extent, medium-term duration and reversible.

E14.5.4 Monitoring

No monitoring is recommended for this resource use.

E14.6 Key Question RU-2: Will There Be a Change in ESAs?

E14.6.1 Analysis of Potential Linkages

ESAs consist of sensitive areas that perform vital environmental, ecological or hydrological functions; contain rare or unique geological or physiographic features; contain rare or endangered species; have limited representation in the region; contain an unusual diversity of species; contain large and relatively undisturbed habitats; or provide important linking functions (i.e., wildlife movement corridors) (Westworth 1990). As such, these areas are quite sensitive and may easily be affected by loss or alteration of soil or vegetation.

The LSA contains three regionally important Environmentally Significant Areas (ESAs). These are:

- Muskeg River - important sport fishery;
- Jackpine (Hartley) Creek - important habitat for sport fish and river otters; and
- Kearl Lake - important waterfowl staging area, moose habitat and movement corridor.

The Muskeg River and Jackpine Creek will not be affected by the Project.

Linkage Between Site Clearing and Change in ESAs

Site-clearing activities may remove important habitat or may reduce the effectiveness of important habitat. The Kearl Lake wildlife movement corridor that extends into the northeast corner of the LSA, provides important habitat for moose and other wildlife species. In particular, removal of important vegetation cover may reduce the effectiveness of the ESA.

The linkage is valid.

E14.6.2 Analysis of Key Question

Although the Muskeg River and Jackpine Creek provide important habitat for sport fish, the proposed Project will not affect fish in these two watercourses.

The Kearl Lake wildlife movement corridor has the potential to be affected by Project construction and operation. Any change in soils, terrain or vegetation will reduce the effectiveness of this movement corridor. Important moose habitat is expected to be lost. Soil and vegetation loss due to site clearing will only be mitigated on Project closure. However, to minimize habitat loss, site clearing will entail the smallest area possible. When possible, revegetation will occur to enhance cover for wildlife.

E14.6.3 Residual Impacts

There may be a decrease in the effectiveness of the Kearl Lake ESA as a movement corridor for moose. This impact is expected to be negligible as most of this corridor is located outside the LSA. A small portion is located in the northeast corner of the LSA, however, site clearing is not expected to occur in this corner.

E14.6.4 Monitoring

No monitoring is recommended for this resource use.

E14.7 Key Question RU-3: Will There Be a Change in Forestry?

E14.7.1 Analysis of Potential Linkages

Change in forestry capability is directly related to alteration or loss of vegetation. In general, forest productivity is a function of soil capability and timber volume production of commercial tree species. Figure E14-3 shows the pre-development forest productivity for the Project LSA. Harvest potential of an area can be altered by the loss or gain of regeneration due to site clearing, changes in tree species, the length of time between clearing and reclamation, changes in access, changes in drainage, soil amendments and selective planting. Changes in forest productivity were discussed in the Terrestrial Vegetation Baseline for the Muskeg River Mine Project (Golder 1997n) and the Forestry Baseline for the Muskeg River Mine Project (Golder 1998c) and will be discussed in detail in the C&R (Section 16, Volume 1 of the Application).

Linkage Between Alteration or Loss of Vegetation and Change in Forestry

Vegetation, including standing timber and understory that would become merchantable on maturation, will be lost due to site clearing for the Project. As well, site clearing will affect timber harvesting to some extent. Timber will be harvested and salvaged out of the scheduled forest management sequence. Following site clearing, the area will be removed from forest production during construction and operations (i.e., 20+ years).

This linkage is valid.

Linkage Between Change in Access and Change in Forestry

Timber rights within the LSA have been granted to Alberta-Pacific Industries Inc. (Al-Pac), and a timber quota disposition has been granted to Northlands Forest Products Ltd. It is expected that access, as required, will be granted to salvage merchantable timber. Otherwise, access to the site during the Muskeg River Mine Project will be restricted to Project personnel.

This linkage is invalid.

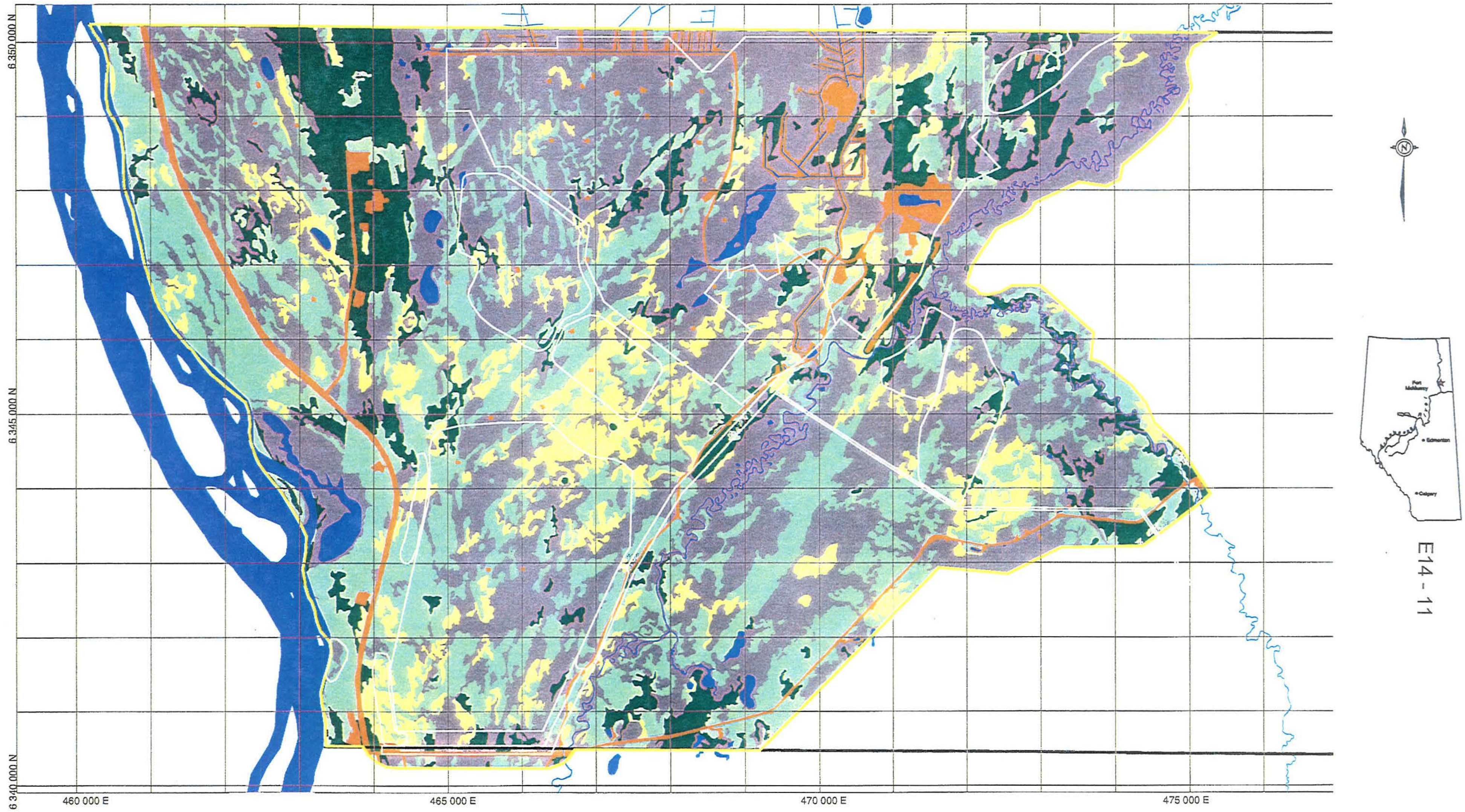
E14.7.2 Analysis of Key Question

Vegetation will be lost due to site clearing during the construction and operation phases. Where feasible, merchantable timber will be salvaged during site clearing. However, only 35% of the stands in the LSA are considered to be productive or salvageable. Thus, the area does not support high forestry capability. Reclamation of the LSA following closure is expected to return the area to equivalent or greater capability. Forest regeneration to commercial standards will require 50 years for aspen, and 80 to 100 years for coniferous species (BOVAR 1996f). However, the FMA and quota holders will be consulted regarding reclamation and closure planning. It is expected that the majority of reforested land will be planted to mixedwood forests using species that have proven most effective in past reclamation experiences.

Mitigation measures will reduce the impact of site clearing. For example, all merchantable timber will be salvaged. As well, site clearing will be kept to the smallest practical area (Section E9). Finally, the LSA will be reclaimed to equivalent or greater forest capability following closure (Section E16). This will result in a net increase in forest productivity.

E14.7.3 Residual Impacts

There will be a decrease in timber production during the construction and operation phases for the duration of the Project. This decrease is considered minor for the RSA as the productivity of the area is low and all merchantable timber will be salvaged, where possible. As well, within the Project development area, timber will be harvested, and disturbed sites will be reclaimed to equivalent or better forestry capability. The loss of timber production is negative, of low magnitude, local in geographic extent, of long-term duration, reversible and of low frequency.



/data8/oilsands/972-2237/9700/9701/final/arcview/forestry50fin.apr

LEGEND

- Local Terrestrial Study Area
- Lease 13
- Open Water

PRODUCTIVITY UNITS

- Good
- Moderate
- Fair
- Unproductive
- Cultural Features and Disturbed Lands

SOURCE: The Forestry Corp.
Golder Associates Ltd.

1 0 1 2
Kilometers

MAP PROJECTION: Universal Transverse Mercator Zone 12 DATUM: NAD 83

Golder Associates

SHELL CANADA LIMITED

MUSKEG RIVER MINE PROJECT
FOREST PRODUCTIVITY

5 Dec. 1997	Figure E14-3	PRODUCED BY: J.S.R.P. REVIEWED BY:

E14.7.4 Monitoring

A monitoring program will be designed to document the re-establishment of plant species and community types on reclaimed sites (see Section E9 and the C&R plan, Section 16.4, Volume 1 of the Application). Plots will be established to examine species composition and community structure, forest growth and shrub productivity. This program will ensure the re-establishment of a productive forest.

E14.8 Key Question RU-4: Will There Be a Change in Berry Picking?

E14.8.1 Analysis of Potential Linkages

Change in berry-picking potential is directly related to changes in vegetation and changes in access. Residents in the regional area engage in berry picking and mushroom collecting at a variety of sites throughout the region, including the valleys of the Muskeg and Athabasca rivers. Project activities may cause loss or alteration of vegetation. As well, changes in access may prevent potential berry pickers from accessing berry-picking sites. Thus, this resource may be lost or may be made unavailable to local residents during both construction and operation phases.

Linkage Between Loss or Alteration of Vegetation and Change in Berry Picking

Loss of vegetation due to site clearing, especially with regard to berry-producing shrubs, will lead to a change in berry-picking activities. Vegetation and soils must be cleared to accommodate Project construction and operation requirements.

This linkage is valid.

Linkage Between Change in Access and Change in Berry Picking

Access to the development area during the Muskeg River Mine Project will be restricted to Project personnel. Thus, access to potential berry-picking sites will be lost.

This linkage is valid.

E14.8.2 Analysis of Key Question

Loss or alteration of vegetation and changes in access will cause a change in berry-picking activities within the LSA. Berry-producing shrubs may be affected by Project activities, and potential berry-picking sites may be lost due to loss of habitat or restricted access. Berry-producing plants removed through clearing and replaced through reclamation are presented in Table E14-1. Clearing for the Project will directly affect certain berry-producing plants more than others. The percentage decrease in the area will be most prevalent for bog cranberry (11.5% loss), bunchberry (7.8% loss) and cloudberry (6.4% loss). The lowest amount of disturbance will be strawberry, currants, pin-cherry, chokecherry and raspberry (<2.2% losses). All berry types common to the LSA will be affected. Thus, berry-picking activities are expected to decrease within the LSA during construction and operation phases. This impact is expected to be minimal as berry-picking sites occur throughout the RSA.

Berry picking in the development area is expected to improve following Project closure as the availability of berries will improve. Reclamation of the development area will be phased progressively throughout the life of the Project. Where possible, areas will be revegetated to create a mosaic of vegetation communities, similar to those found before disturbance. In some areas, berry-producing shrubs may be included in the revegetation scheme.

Access to sites within the Project area will be restored following reclamation and closure. Access will improve through upgrading of existing access corridors used during the construction and operation phases. In addition, specified roads within the development area will be opened to allow public access to recreational locations, including potential berry-picking sites.

Table E14-1 Hectares of Berry-Producing Plants Removed Through Clearing and Replaced Through Reclamation

Berry-Producing Plants	Baseline	% LSA	Impact Due to Development	% LSA	Gain From Reclamation [a]	% LSA	Project Area Far Future [a]	% LSA
Blueberry	1,365	12.5	502	4.6	988	9.0	1,851	16.9
Cranberry bog	3,170	28.9	1,259	11.5	988	9.0	2,899	26.5
Cranberry low-bush	1,942	17.7	408	3.7	2,375	21.7	3,909	35.7
Strawberry	67	0.6	11	0.1	72	0.7	128	1.2
Currants (gooseberry, red and black)	233	2.1	11	0.1	1,550	14.2	1,772	16.2
Pin-cherry	169	1.5	38	0.4	729	6.7	860	7.9
Chokecherry	169	1.5	38	0.4	729	6.7	860	7.9
Raspberry (dwarf and trailing)	233	2.1	11	0.1	1,550	14.2	1,772	16.2
Saskatoon berry	1,980	18.1	495	4.5	1,421	13.0	2,906	26.5
Cloudberry	1,661	15.2	700	6.4	0	0.0	961	8.8
Bunchberry	3,201	29.2	855	7.8	3,363	30.7	5,709	52.1
Dewberry	1,942	17.7	408	3.7	2,375	21.7	3,909	35.7

[a] Projected numbers may be high because each plant type is found in more than one ecosite phase (see Table E9-9, Section E9).

E14.8.3 Residual Impacts

There will be a decrease in berry-picking activities due to loss of berry-picking habitat and restricted access during the construction and operations phase. There are no mitigation measures for site clearing within the Project footprint or for restricted access. Following closure, the number of hectares of berry production will be increased, and access to berry-producing sites will be improved. The impact resulting from loss of berry picking potential is expected to be negative, of low magnitude, local geographic extent, moderate duration, reversible and of low frequency.

E14.8.4 Monitoring

No monitoring is recommended for this resource use.

E14.9 Key Question RU-5: Will There Be a Change in Non-Consumptive Recreational Use?

E14.9.1 Analysis of Potential Linkages

Non-consumptive recreational use includes camping, hiking, boating, wildlife viewing and snowmobiling. Within the LSA, the Athabasca River is used for camping, boating and snowmobiling, and the Muskeg River is used for canoeing, kayaking and camping (BOVAR 1997f). There may be a decrease in opportunities for non-consumptive recreational use during the construction and operations phases due to decreased aesthetics, reduced opportunities for observation and photography, and restricted access.

Linkage Between Loss or Alteration of Vegetation and Change in Non-Consumptive Recreational Use

Loss or alteration of vegetation due to site-clearing activities may reduce recreational opportunities. Loss of vegetation not only removes potential recreation habitat, but also reduces the aesthetics of an area.

The linkage is valid.

Linkage Between Change in Wildlife Abundance and Diversity and Change in Non-Consumptive Recreational Use

The region supports a variety of wildlife species, including various mammals, birds and amphibians. Site clearing is expected to result in habitat loss for several species (see Section E10 and Golder 1998b) and these decreases in abundance may reduce wildlife viewing opportunities over the medium to long term.

The linkage is valid.

Linkage Between Change in Access and Change in Non-Consumptive Recreational Use

Recreational activities include camping, canoeing, boating, kayaking and snowmobiling. These activities are generally undertaken because of an enjoyment of the outdoors. It is expected that restricted access will reduce the potential for some of these activities in the area. However, most activities are concentrated along the rivers. Access to the Athabasca and Muskeg rivers will not be altered by Project development.

The linkage is valid.

E14.9.2 Analysis of Key Question

There will be a slight decrease in recreational opportunity due to loss or alteration of vegetation, resulting from site clearing. As well, reduced aesthetics may reduce the attraction of the area. However, due to the distance from Fort McMurray, non-consumptive recreational use in the LSA is currently predicted to be low, and impacts are considered minor. As well, the distance between the Project and the Athabasca River or major highways eliminates the potential for viewing of facilities, and minimizes the impact of reduced aesthetics. During reclamation and closure, it is expected that the diversity of the overall landscape will be improved. Habitat will be enhanced for both vegetation and wildlife as a mosaic of vegetation communities will be introduced. Aesthetics will improve as well. Additional discussion on potential visual impacts associated with the Project is found in Section E16.

The Athabasca and Muskeg rivers will not be altered by the proposed mine. Nor will water be drawn from these sources. Thus, these rivers will continue to provide opportunities for kayakers, canoeists, boaters and snowmobilers.

Site clearing during construction and operations will reduce wildlife abundance by reducing habitat potential. However wildlife viewing and photography were not identified as important recreational uses in the LSA. As well, reclamation will return habitat to equivalent or better capability. Although it may take wildlife species some time to recolonize an area (i.e., habitat quality establishment may take 20 years or more), non-consumptive recreational opportunities will return to equivalent or greater capability.

Restricted site access will lead to reduced opportunities for some recreational activities (e.g., camping). This impact cannot be mitigated. However, access to the Athabasca River and portions of the Muskeg River will not be affected. In addition, access to non-consumptive recreation sites will improve following Project closure. Access corridors established during the construction and operation phase will remain in place. Specified roads in the development area will be opened to allow public access to recreational sites.

E14.9.3 Residual Impacts

There will be a decrease in opportunities for resource use in the LSA during construction and operations. This will be due to reduced aesthetics and restricted access. The impact is negative, of low magnitude, local geographic extent, moderate duration, reversible and of high frequency. Following closure, opportunities for recreation are expected to improve. This will be due to the creation of a diversity of landforms, vegetation communities and aquatic habitat. Wildlife and fish resources will re-establish and access within the LSA will improve.

E14.9.4 Monitoring

No monitoring is recommended for this resource use.

E14.10 Key Question RU-6: Will There Be a Change in Hunting?

E14.10.1 Analysis of Potential Linkages

Changes in wildlife abundance and diversity and changes in access may affect hunting within the LSA. Construction and operation of the proposed Muskeg River Mine Project may result in a decrease in the abundance and distribution of game species and changes in access, thus reducing the opportunities for hunting.

Linkage Between Change in Wildlife Abundance and Diversity and Change in Hunting

The region supports several game species, including waterfowl, moose, deer, black bear, grouse and ptarmigan. Generally, removal of habitat as associated with site clearing, timber harvesting and road construction will reduce wildlife in the area and negatively affect hunting opportunities. All these activities remove or alter habitat such that it is no longer productive for wildlife. A decrease in the abundance or distribution of wildlife reduces hunting opportunities over the life of the Project.

The linkage is valid.

Linkage Between Change in Access and Change in Hunting

For safety purposes, access to the Project area will be restricted to Project personnel until closure. As well, personnel will not be allowed to carry firearms. Restricted access and various safety regulations will decrease the area available for hunting.

It is expected that improved access following Project closure will positively affect hunting.

The linkage is valid.

E14.10.2 Analysis of Key Question

The Project occurs within two Wildlife Management Units (WMUs), and these areas are actively used by resident and non-resident hunters. Changes in wildlife abundance and distribution due to habitat loss and changes in access will cause a change in hunting activities within the LSA. Wildlife species may be affected by project activities, especially loss of habitat or reduced access. The areas of wildlife habitat that will be impacted by the Project are detailed in Section E11. There is expected to be a 54% loss of moose habitat units. Detailed information on Project wildlife KIR habitat changes is provided in Golder (1998b). Hunting opportunities are expected to decrease with loss of wildlife abundance and reduced access. Thus, hunting is expected to decrease within the LSA during construction and operations.

Hunting is expected to improve following Project closure as access will improve. Access will improve through upgrading of existing access corridors used during the construction and operation phases. In addition, specified roads in the development area will be opened to allow public access to recreational locations, including potential hunting areas.

Reclamation activities are expected to return the site to equivalent or greater vegetation capability. A 10% increase in moose habitat units is expected after reclamation. Once revegetation has occurred, wildlife will return to the area. Species such as moose, bear, ruffed grouse and snowshoe hare are expected to return to reclaimed areas fairly quickly (i.e., 20 years). Species such as fisher will take much longer to return to the area (i.e., 60 years or more), due to specific habitat requirements.

E14.10.3 Residual Impacts

There will be a decrease in hunting opportunities in the LSA during the construction and operation phases of the Project. The decreased hunting opportunities will mainly be due to reduced abundance of wildlife populations and restricted access to the development area. This impact is expected to be negative, of low magnitude, local geographic extent, moderate duration, reversible and of moderate frequency.

Following closure, there will be an increase in hunting opportunities for some wildlife species and a decrease for other species over the long term (i.e., greater than 20 years). This is because some species readily use reclaimed landscapes, while others do not.

E14.10.4 Monitoring

No monitoring is recommended for this resource use.

E14.11 Key Question RU-7: Will There Be a Change in Trapping?

E14.11.1 Analysis of Potential Linkages

Changes in wildlife abundance and diversity and changes in access may affect trapping within the LSA. Construction and operation of the proposed Muskeg River Mine Project may result in a decrease in the abundance and distribution of furbearers and changes in access.

Linkage Between Change in Wildlife Abundance and Diversity and Change in Trapping

The region supports several semi-aquatic and terrestrial furbearing species, including beavers, muskrats, wolves, foxes, lynx, martens, snowshoe hares and squirrels. Generally, removal of habitat associated with site clearing, timber harvesting and road construction, will negatively affect trapping. All of these activities remove or alter habitat such that it is no longer productive for wildlife. Decreases in the abundance of wildlife reduces trapping opportunities over both the long and short term.

The linkage is valid.

Linkage Between Change in Access and Change in Trapping

For safety purposes, access to the Project area will be restricted to project personnel until closure. Restricted access will decrease the area available for trapping.

The linkage is valid.

E14.11.2 Analysis of Key Question

Five traplines are located within the LSA. Changes in wildlife abundance and distribution due to habitat loss and changes in access will cause a change in trapping activities within the LSA. Furbearing wildlife species may be affected by Project activities. Details on Project wildlife KIRs and potential loss of habitat for furbearers is discussed in Section E11 and reviewed in detail in Golder (1998b). There is expected to be a 30% loss in beaver habitat units. Traplines may be lost due to loss of habitat or reduced access. Thus, trapping is expected to decrease within the LSA during construction and operation phases. Loss of revenue can be mitigated through compensation programs, where required.

Trapping is expected to improve following Project closure as access will improve. Access will improve through upgrading of existing access corridors used during the construction and operation phases. In addition, specified roads within the development area will be opened to allow public access to recreational locations, including potential trapping sites.

Reclamation activities are expected to return the site to equivalent or greater vegetation capability. Once revegetation has occurred, wildlife will return to the area, provided there are adequate movement corridors. Some species such as snowshoe hare are expected to return to reclaimed areas fairly quickly (i.e., <20 years). Other species will take much longer (i.e., 60 years or more).

E14.11.3 Residual Impacts

There will be a decrease in trapping opportunities in the LSA during Project construction and operations. The decreased trapping opportunities will mainly be due to reduced abundance of wildlife populations and restricted access to the development area. This impact is expected to be negative, of low magnitude, local geographic extent, moderate duration, reversible and of moderate frequency.

Following closure, there will be an increase in trapping opportunities for some furbearing species and a decrease for other species over the long term (i.e., greater than 20 years). This is because some species readily use reclaimed landscapes, while others do not.

E14.11.4 Monitoring

No monitoring is recommended for this resource use.

E14.12 Key Question RU-8: Will There Be a Change in Fishing?

E14.12.1 Analysis of Potential Linkages

The region supports several fish species, including lake whitefish, mountain whitefish, northern pike, Arctic grayling, walleye, lake trout and yellow perch. Within the LSA, the Athabasca and Muskeg rivers and Jackpine Creek all have the potential to support fishing. Changes in fish abundance, changes in fish tissue quality and changes in access may have the potential to affect fishing within the LSA. Construction and operation of the Project may result in a decrease in water quality, decreased fisheries habitat, and changes in access to preferred fishing locations.

Linkage Between Change in Fish Abundance and Change in Fishing Opportunities

The Project will have no direct effect on fish habitat, fish abundance and fish health (see Sections E6 and E12). Construction and operation may result in a decrease in water quality, however, a water quality monitoring program should ensure that fish are not affected. Thus, changes in fish abundance are not expected.

The linkage is invalid.

Linkage Between Change in Fish Tissue Quality and Change in Fishing Opportunities

Changes in fish tissue quality are basically a result of changes in fish health. Fish health may be affected by changes in water quality. Reduced fish health would serve to reduce fishing opportunities. Fish tainting or changes in fish tissue quality will not occur as water quality will be carefully monitored (see Section E6).

The linkage is invalid.

Linkage Between Change in Access and Change in Fishing Opportunities

Current access roads in the area provide summer and winter access for fishing purposes on both the Athabasca and Muskeg rivers. For safety purposes, access to the Project area will be restricted to Project personnel until closure. Restricted access will decrease the sites available for fishing.

It is expected that improved access following Project closure will have a positive effect on fishing.

The linkage is valid.

E14.12.2 Analysis of Key Question

The Project will not directly affect the Athabasca River, Muskeg River or Jackpine Creek. Sport fish abundance will not be reduced as a result of the construction and operation of the Project, and access should not be reduced to these fishing areas. However, restricted access may reduce sport fishing to some extent.

Access to fishing sites will be slightly improved after reclamation and closure. Road upgrading of existing access corridors during the construction and operation phase of the Project will remain in place. Specified roads in the development area will be opened to allow public access to recreational locations, such as fishing holes. The road surfaces will allow all-season access to the Athabasca and Muskeg rivers. All-season access is currently not available. The improvement of access to existing fishing conditions could result in additional sport and subsistence fishing opportunities.

E14.12.3 Residual Impacts

Restricted access may reduce fishing opportunities over the short term. This impact is expected to be negative, of low magnitude, local geographic extent, moderate duration, reversible and of moderate frequency.

There will be a slight improvement in fishing opportunities at existing fisheries in the Athabasca and Muskeg rivers in the LSA due to the improvement of roads. There should be an increase in fishing opportunities in the LSA after closure, primarily due to increased access.

E14.12.4 Monitoring

No monitoring is recommended for this resource use.

E14.13 Resource Use Impact Summary

The assessment of the Project's effects on resource use included consideration of changes in:

- surface and subsurface minerals
- environmentally significant areas
- forestry
- use of local plants for food or spiritual and medicinal purposes
- hunting
- trapping
- fishing
- non-consumptive recreational use

Mitigation strategies to minimize the potential impacts to non-traditional resource use will include:

- salvage of surface resource materials (e.g., gravel) during site clearing;
- compensating trapline holders for loss of revenues;
- minimize site clearing areas;

- avoiding alteration of Athabasca and Muskeg rivers;
- salvaging of merchantable timber during site clearing;
- completing revegetation to improve protective cover and browse for wildlife species;
- planning reclamation to return forestry potential to equivalent or better capability, with forest management plan developed in consultation with FMA holder and government agencies;
- including within reforestation activities, the use of forest species proven to revegetate successfully; and
- including berry producing shrubs in reclamation plans, where appropriate.

Monitoring identified for resource uses in the Project area include annual monitoring for plant species and community type re-establishment. Plots will be established to examine species composition, community structure, forest growth and shrub productivity. Water quality monitoring programs will be established to minimize or eliminate potential adverse impacts to fish habitat and thus fishing capability.

It is concluded that the Project in combination with other projects in the local or regional study areas will not cause significant impacts to surface or mineral materials. Timber resources will be adequately salvaged and forest capability will be equivalent or better than pre-disturbance levels. Loss of berry picking areas will be minimized and access to the reclamation area berry picking sites will be increased after Project closure. Non-consumptive resource use will be reduced during construction and operations, however, closure plans will include the maintenance of access roads and increased landscape diversity.

Hunting and trapping potential will be reduced during construction and operations due to access restrictions and habitat disruption. Increased access to the area after closure will increase the potential for hunting and trapping in the area.

Sport fish species will not be affected by the construction and operation of the project and access to potential sport fishing sites will be improved after closure.

Overall impacts to the non-traditional land uses in the area will be affected during the construction and operational phases of the Project, however, reclamation and closure plans will mitigate the adverse impacts and in some cases improve the land use capability.

Monitoring identified for resource uses in the Project area include annual monitoring for plant species and community type re-establishment. Plots will be established to examine species composition, community structure,

forest growth and shrub productivity. Water quality monitoring programs will be established to minimize or eliminate potential adverse impacts to fish habitat and thus fishing capability.

E15 TRADITIONAL LAND USE

E15.1 Introduction

This section of the Muskeg River Mine Project (the Project) EIA provides information as required by the Project Terms of Reference (TofR) issued on November 7, 1997 (AEP 1997). Specifically, the following are addressed:

- identification of the potential impacts of the Project on current land uses; and
- identification of possible resource use mitigative strategies (TofR, Section 6.0).

Discussions on the regional implications of oil sands development on traditional land use is presented in Section F15. Section D15 provided details on the traditional land use baseline for the Project.

A comprehensive program of studies is underway that will examine traditional land use issues for the region surrounding the Muskeg River Mine Project. That study is considered part of the on-going consultation process and has not been completed at this time. Nevertheless, it is possible to provide both general and specific information relating to the traditional uses of the immediate Project area to obtain an indication of the types of traditional land use practices that have occurred here in the past and continue to take place. This information can serve as a basis for determining the specific impacts of the project and can be incorporated with regional level information to obtain an indication of the combined effects of developments planned throughout the region.

E15.2 Key Question E15-1: Will the Project Change Traditional Land Use Patterns?

The Project will change traditional land use patterns within the area scheduled for development. The information presented in this regard is based on a review of documentation relating to traditional land use in the region, with a focus on the area proposed for Project development.

E15.3 Background Information

To obtain a general impression of the types of resources that were incorporated in the traditional "bush economy" of First Nations peoples of the area, a review was conducted of the regional level traditional land use investigations completed by the Fort McKay First Nations (1994). This information was supplemented by data accumulated in specific traditional land use studies completed for the Syncrude Aurora Project (Fort McKay

Environmental Services 1996d and 1997a). Consolidating information presented in those studies, a table was created identifying plant and animal species that are mentioned as being of use in traditional lifestyle of the area (Table E15-1). Rankings (high, medium and low) were given to the individual species based on the number of times a particular species name was referred to and the number of times a species was indicated within a given region on the traditional land use maps or tables that accompany the studies. These rankings are not meant to imply that certain species are unimportant, only that some are more commonly harvested in certain regions. It is also important to remember that not all plant and animals species that would be used could be mentioned in the interviews conducted for this program. The names of plants and animals provided here are the common names as used by First Nations people.

The people who traditionally occupied the Regional Study Area were nomadic hunting and gathering groups whose seasonal round of activities covered relatively extensive areas (see Figure D15-1). These groups used a wide variety of plant and animal species found naturally throughout the region. These species were (and still are) harvested for numerous purposes including: food, drink, medicines, ceremonial uses, firewood, smoking and curing food, clothing and building materials. Recently, some of the traditional practices have become modified with the increased accessibility of some regions. For example, people traditionally used established trails for traplines and travel routes. Now people more commonly travel along seismic lines. Participants in the surveys conducted for those studies often stated that certain plants or animals were important resources, but harvesting locations and some types of uses were not always recorded. The absence of data in certain regions, therefore, does not necessarily imply that the area was not traditionally used.

FLORA

Tree species that are often mentioned include both deciduous and coniferous trees. Coniferous species include lodgepole pine, jack pine, tamarack, balsam fir, white and black spruce. The deciduous tree species mentioned include balsam poplar, aspen poplar, paper birch, willow and alder. The people interviewed speak of these species being used both presently and in the past for medicine, food, drink, construction supplies, firewood, curing and smoking meat. Birch bark is used as a fire starting material and syrup is made from the sap. Willow bark is boiled for a tea and used as a medicine to relieve colds, headaches and stomach ailments. Portions of the balsam fir, jack and lodgepole pine, birch, and poplar trees, among others were also listed as having medicinal properties. Log cabins are constructed principally of coniferous wood, although birch and balsam poplar are also used as building materials. Bear traps are also commonly constructed of large coniferous logs.

Table E15-1 Traditional Resource Use

Species	Type of Use							Use Ranking [a]
	Food	Medicine	Spiritual	Hunting	Trapping	Fishing	Other	
Vegetation								
blueberry	X							High
cranberry (lowbush)	X							High
cranberry (bog)	X							High
dewberry	X	X						Low
saskatoon	X	X					Wood	High
pincherry	X	X						Medium
chokecherry	X	X					Hard Wood	Medium
cloudberry	X	X						Low
raspberry	X	X						Medium
huckleberry	X							Low
dwarf raspberry	X							Medium
trailing raspberry	X							Medium
red currant	X	X						Low
black currant	X	X						Medium
snowberry		X						Low
strawberry	X	X						High
gooseberry	X	X						Medium
rose hip	X	X						High
twisted stalk	X							Low
red osier dogwood		X	X				dye	Medium
kinnikinnick (bearberry)	X	X	X				dye	High
dogwood (Bunchberry)	X							Medium
common juniper	X	X						Medium
common yarrow		X						Low
buffaloberry	X	X						Low
hazelnut	X						dye/arrows	Medium
balsam fir		X					construction	High
lodgepole pine		X						Low
jack pine		X						Low
green alder		X					utensil/dye	Medium
river alder		X						Medium
trembling aspen		X					utensil	Low
tamarack		X					construction/ dye	High
birch - white	X	X	X				construction /fire starter/ dye	High
birch - red (bog birch)	X	X						Medium
willow		X	X				utensil	Medium
stiff club moss			X					Low
chamomille		X						Low
white or black spruce		X		X			construction	High
black poplar		X					construction	High
harebell		X						Low

Species	Type of Use							Use Ranking [a]
	Food	Medicine	Spiritual	Hunting	Trapping	Fishing	Other	
frying pan plant		X						Medium
green frog plant		X						Medium
fly honeysuckle		X						Low
twining honeysuckle		X						Low
bracketed honeysuckle		X						Low
labrador tea	X	X						Medium
rat root (sweet flag)		X						High
wild mint	X	X						High
common pink wintergreen		X						Low
white wintergreen		X						Low
muskeg (Labrador tea)		X						High
moss		X					chinking, smudges, diapers, dressing	High
horsetail		X					utensil	Low
bulrusk	X							Low
nettles	X	X						Medium
northern bedstraw							dye	Low
sweet scented bedstraw			X				utensil	Medium
fungi - dry dead wood							fire starter/insect repellent	High
ground fungus - puffball		X						High
bracket fungus	X							Low
tuckahoe	X							Low
red touchwood fungus	X							Low
rock tripe	X							Low
seneca root		X						Medium
wild sarsaparilla		X						Low
western dock							dye	Low
willow fungus		X						Medium
showy aster		X	X					Low
sweet grass		X	X					High
common tansey	X							Low
common cattail	X							Low
Fish								
pickerel	X					X		High
northern pike	X					X		High
whitefish	X					X	dog food	High
lake trout	X					X		High
grayling	X					X	localized use	Medium
perch	X					X	localized use	Medium
ling cod	X					X		Medium
sucker	X					X		Medium
goldeye	X					X	localized use	Medium
chub	X					X		Medium

Species	Type of Use							Use Ranking [a]
	Food	Medicine	Spiritual	Hunting	Trapping	Fishing	Other	
Wildlife								
moose	X			X				High
caribou - woodland	X			X			localized use	Low
bison	X			X			localized use	Low
white-tailed deer	X			X				High
mule deer	X			X				Low
elk	X			X				Low
lynx	X				X			High
hare	X				X			High
wolf					X			High
coyote					X			Medium
marten					X			Medium
fisher					X			High
red fox					X			High
wolverine					X			Rare-Med.
beaver	X	X			X			High
muskrat					X			High
river otter					X			High
skunk		X	X		X			High
mink					X			High
red squirrel					X			High
tree (flying) squirrel					X			High
least weasel					X		fur	High
short-tailed weasel					X		fur	High
long-tailed weasel					X		fur	High
black bear	X		X	X	X			High
grizzly bear	X		X	X				Low
Canada goose	X						insulation/ stuffing/ wing duster	High
Ross' goose	X						insulation/ stuffing/ wing duster	Medium
snow goose/blue goose	X						insulation/ stuffing/ wing duster	Medium
white-fronted goose	X						insulation/ stuffing/ wing duster	Medium
canvasback	X							High
mallard	X							High
pintail (sharptail)	X							Low
redhead	X							High
teal	X							High
greater scaup	X							High
lesser scaup	X							High
goldeneye	X							High

Species	Type of Use							Use Ranking [a]
	Food	Medicine	Spiritual	Hunting	Trapping	Fishing	Other	
scoter	X							High
ruddy duck	X							High
merganser	X							High
grebe	X							High
loon	X						waterproof bag (pouch)	High
pelican							waterproof bag (pouch)	Low
cormorant								Low
swan								Low
seagull								Medium
owl	X						wing duster	High
sandhill crane								High
eagle								High
great blue heron								Low
pintail grouse	X						fan/decoration	High
spruce grouse							fan/decoration	High
ruffed grouse	X						fan/decoration	High
ptarmigan	X						fan/decoration	Low

(a)Refers to the number of times a species name was referred to and the number of times a species was indicated on traditional land use maps.

Shrubs and grasses have traditionally been used for food, drink, medicinal and ceremonial purposes. Small plants have also been used to make functional items such as twine and basketry. Some of the plants that were frequently referred to by the Fort McKay elders include blueberry, cranberry (bog and lowbush), strawberry, rose, bearberry (kinnikinnick), rat root, wild mint, muskeg (Labrador tea), moss, sweet grass and certain types of fungi.

Many of these plants (e.g., blueberry, strawberry, cranberry) were often eaten raw or as sauce or jam. Some were also boiled and consumed as tea (Labrador tea). Some were mixed with dried meat and white grease to make pemmican. Rosehips, juniper, sweet grass and rat root were some of the most widely used medicinal plants. Other medicinal plants include gooseberry, raspberry, chokecherry, saskatoon, nettles, green frog plant and seneca root. Sweet grass, and the inner bark of the red willow are important ceremonial plants as well. Fungi found on dead logs and moss are often used in smudges and insect repellents. Other berry bushes and aquatic plants (Table E15-1) are also part of the traditional environmental knowledge of the Fort McKay First Nations people, although they are not used as often.

Trees and herbaceous plants are harvested on a year-round basis, with the Athabasca River corridor and all major tributary creeks and rivers being the major sources. Berries and flowering plants are harvested in-season, with collection locals varying in location and inland locations having as much importance as drainages.

FAUNA

Animals are a critical aspect of traditional land use practices (Fort McKay First Nations 1994, Fort McKay Environment Services 1997a). Large game animals in the region include moose, bison, caribou, white-tailed and mule deer. Elk (wapiti) were formerly present in the Athabasca region, although they currently have been extirpated from this portion of their range. White-tailed deer are likely recent arrivals into the region. White-tailed deer and moose exist in moderate numbers in the Project area, although hunting has been restricted near the proposed mine site because of previous and on-going development activities. An unusual migration of woodland caribou along the east side of the Athabasca River is reported to have occurred in 1948 (Fort McKay First Nations 1994).

Until the Lougheed Bridge was built, access to the east side of the Athabasca River was limited to those with water transport or to winter, a situation that reduced the amount of hunting in the area. Other large game animals that were hunted in the region include black bear. These animals were traditionally hunted using traps made of several large logs. Bear meat was eaten, the fur used for clothing and the grease for cooking and making soap. Black bear was also listed by some of the Fort McKay Elders as an important spiritual animal (Fort McKay First Nations 1994). Grizzly bear are also spiritual animals, although they were not as plentiful as the black bear, and are not now found in the area.

First Nations people used all portions of these large animals. The meat was used for food and the hides were used as clothing as well as blankets, mattresses and robes. Bones and antlers were used to make tools such as leather punches, knife handles, hide fleshers and billets. Sites where these animals were killed or processed differ in size and location depending on whether the hunted animal was normally solitary (e.g., moose, bear) or traveled in herds (e.g., bison, caribou), and where the animal was typically found.

Some of the smaller furbearers were also important to the people of the region. Beaver, muskrat and snowshoe hare were hunted for their meat and pelts (Fort McKay Environment Services Ltd. 1996c). The beaver is still regarded as a staple in the diet of some area residents.

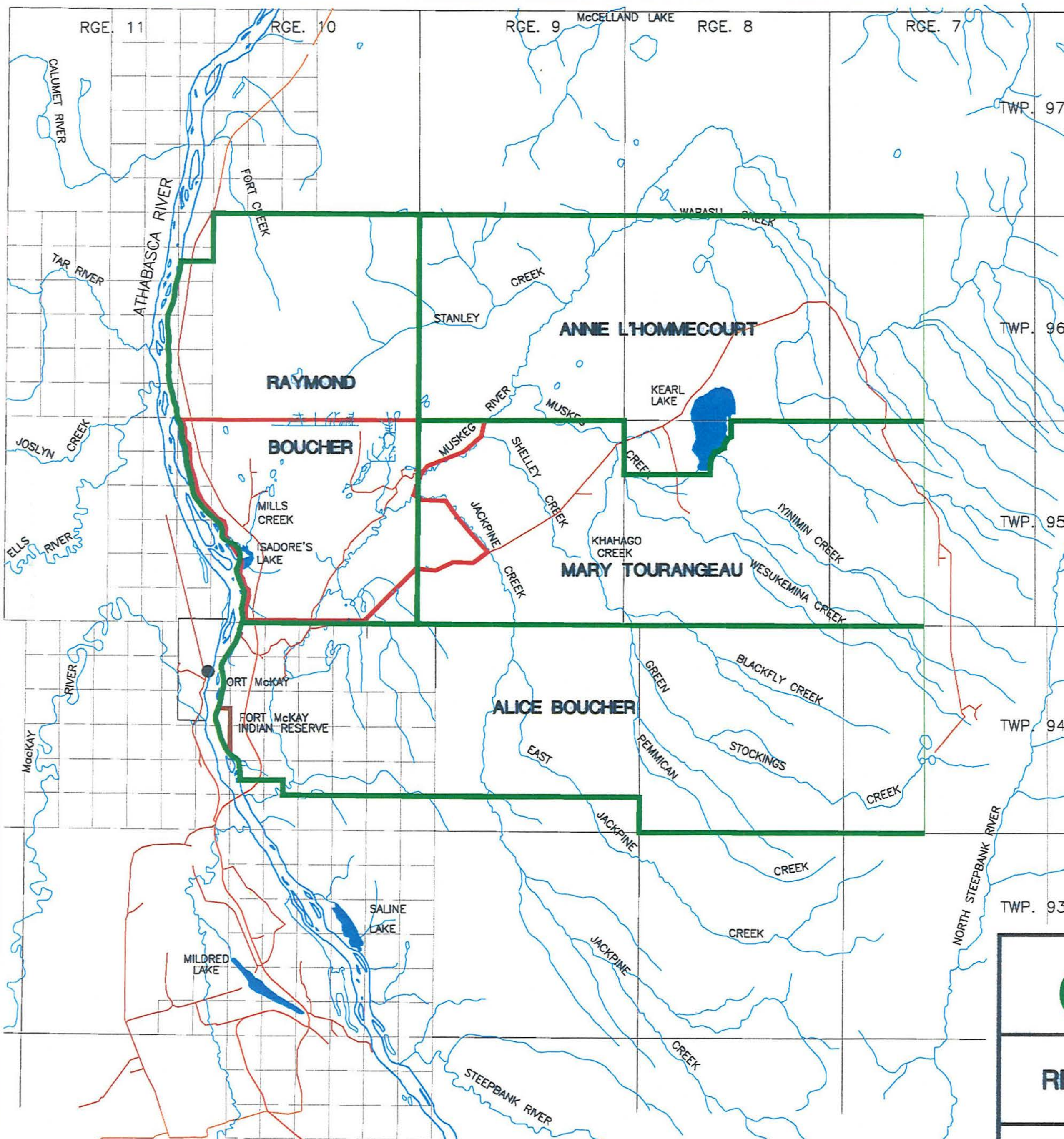
Beaver castor is also used as a medicine. Skunk were also trapped and used for spiritual and medicinal purposes. Skunk oil was (and still is) used for warding off and curing colds (Fort McKay First Nations 1994). River otter, mink, lynx, wolf, fisher, fox and weasels were also traditionally trapped by the people of the region. Trapping of fur bearing animals for trade has been an important cash supplement to the proceeds of the "bush economy" for the people of the region since the advent of the fur trade in the 1700's.

The Athabasca River valley is an important migratory route for several types of birds including ducks, geese, cranes, loons, grebes and gulls (Fort McKay Environmental Services Ltd. 1996b). The lower reaches of the Muskeg River is also is mentioned as being important in this regard. Although not specifically mentioned, Isadore's (or Cree Burn) Lake was probably also attractive to migratory waterfowl. Waterfowl were traditionally hunted by the people of the region during the spring and fall migrations. Harvesting eggs was also done during the spring. The spring is the best time for hunting migratory birds as their feathers and meat are in the best condition. The feathers are often used for clothing and bedding. The wings from owls and geese are also used for dusters and brooms. Tail feathers from grouse and ptarmigan were often fanned out and used as a fan or decoration. The pouch from pelicans and loon skins were often used as waterproof bags. Large owls, such as the great horned and great gray owls, were also hunted for food. Upland game birds including ptarmigan, spruce, pintail and ruffed grouse were hunted easily and harvested opportunistically. Long bones were traditionally made into beads and small whistles.

Fish in the region were used for food for both people and their dogs. Large numbers of fish were taken annually from the Athabasca River, but in recent times, concern for the amount of pollution in the river has significantly reduced the use of this once important source (Fort McKay Environment Services Ltd. 1996b). Major tributaries and lakes in the Birch Mountains are now more frequently mentioned (Fort McKay First Nations 1994). No particular mention of the Muskeg River is made, but it is known as a potential fishery and probably received limited use.

Whitefish were caught in the autumn and hung to dry for winter dog food. Thousands of fish may be needed to feed dogs through the winter depending on the number of dogs. Up to 2,000 fish could be caught and hung in a week. Grayling were caught on a much smaller scale. Whitefish, pickerel, northern pike, chub, lake trout, ling (burbot), goldeye, suckers, perch and grayling were all used by people in the area. Some fish such as the goldeye, grayling and perch were not available throughout the entire Regional Study Area and, therefore, had only local importance. Fish bones were also boiled to extract grease. Little or no mention was made of the importance or traditional uses of amphibians and reptiles of the region. The region has a limited number of red-sided garter snakes, (typically only in the area near Peace River) but frogs and toads are quite common.

J:\1997\22 \8500\FURMANAG.dwg



LEGEND

- MUSKEG RIVER MINE PROJECT DEVELOPMENT AREA
- REGISTERED FUR MANAGEMENT AREAS

REFERENCE

DIGITAL DATA SETS 74D, 74E, 74I 84A AND 84H FROM RESOURCE DATA DIVISION ALBERTA ENVIRONMENTAL PROTECTION, 1997.

0 5 10 15km

SCALE 1:300,000

Golder Associates

SHELL CANADA LIMITED

MUSKEG RIVER MINE PROJECT REGISTERED FUR MANAGEMENT AREAS

03 DEC 97	Figure E15-1	DRAWN BY: VS/TM

Traditional land use research suggests that the Regional Study Area contains a diverse array of plants and animals that were used by First Nations groups. Hunting and trapping in the areas inland from the Athabasca and its major tributaries, like the Firebag and Steepbank rivers, may have been limited. Hunting is difficult because of the muskeg and peat bogs which are present throughout the area (Fort McKay Environment Services Ltd. 1996c). Given the acidic nature of the soils in this region, it is unlikely that any physical evidence of this type of activity would remain to be discovered. Traditional trails were maintained in the area by local trappers and hunters until the construction of winter roads and seismic lines. These trails may have been used regularly in the past and may have high potential for archaeological materials to occur in association. Harvesting of plant materials is reported to have been carried out in the area. However, this type of activity, typically leaves behind little or no archaeological evidence and would be essentially invisible.

The above discussion relates to consumptive traditional resource use. A number of non-consumptive traditional land uses take place throughout the region. Both spiritual and recreational uses occur within the Regional Study Area. Spiritual and ceremonial special uses are personal and family matters which have not been the subject of systematic study in any of the reports prepared on traditional land uses but which, no doubt, are highly significant to local communities. The absence of this information represents a knowledge gap that can be addressed by continued consultation with local communities. Recreational use such as use of cabins and snow-mobiling occur in conjunction with trapping and hunting activities (Fort McKay Environment Services 1996c).

E15.3.1 Recorded Land Use

As part of the interview process completed for the regional Traditional Land Use and Occupancy Study (TLUOS) conducted by the Fort McKay First Nations (1994), elders and other traditional people of the region were asked to place symbols indicating use of specific resources on maps of the area. These maps serve as an indication of remembrance of use of a specific area and resource, but do not preclude other resources and uses that may have taken place in earlier times, by other aboriginal people, or those that were not particularly memorable. Nevertheless, the mapped information provides concrete data for specific areas.

The study described above produced ten clear overlays for a 1:250,000 scale topographic map for the region, displaying information for: trails and cabins, spiritual and historical sites, fur bearing animals, big game, fish, birds, berries, trees and plants, and traplines. A composite of these maps was examined to determine specific uses that had been recorded for the Project area.

Project Area

For the Project area itself, relatively limited use is indicated when compared to other nearby areas such as Kearl and McClelland lakes, and the Athabasca River corridor. Nevertheless, a trail along the west side of the Muskeg River was used. This probably corresponds, at least in part, with the current road into the development area. The frequency of archaeological sites situated along its length (see Section E13) may reinforce the interpretation that this may have been one of several traditional access corridors into the Kearl Lake area or Fort Hills. No intact sections of a pre-industrial trail have been noted in any of the on-ground archaeological investigations conducted in the development area.

Also shown are two cabins, one collapsed and one still in use. The names Fred and Raymond Bouncer respectively have been associated with these structures. The collapsed cabin was first recorded during the Alsands Historical Resources Impact Assessment in 1980 (Ronaghan 1981b) but had undoubtedly been known locally throughout its use. Although this site represents former rather than current traditional land use, additional studies, including interviews and a modest archaeological program, have been recommended to mitigate impact to this site (see Golder 1997q). The existing cabin would not be directly affected by development of the Muskeg River Mine Project, but the land use patterns it represents would be directly affected. This issue is discussed in relation to traplines, below.

A single grave is shown within the Project area. It is believed that this refers to one of possibly two archaeological sites that have been recorded within the Project area, at which the remains of ancient stone tool production and use occur, but no evidence of any human burial has been identified. Clarification of this situation has been requested from the Fort McKay First Nation.

Other indications of traditional land use have been included on the composite maps for the Project area. These include: one for moose hunting in the centre of the project area, one for cranberry harvesting around a small lake, one for muskeg moss harvesting along the northern margin of the development area and a martin trapping symbol along the Muskeg River. These suggest that big game, fur bearers and a variety of plant species were traditionally harvested from within the Project area and that this area was part of a traditional round of activities within the "bush economy" of the Fort McKay Communities.

Lease Area

The use patterns noted above have been expanded upon by uses recorded within the Lease 13 area. In this larger area, two additional collapsed cabins have been identified along the upper Muskeg River and Jackpine

Creek, toward the interior of the lease, but specific names are not associated with these. Two standing cabins associated with the names Louis Tourangeau and Isadore Lacorde have been noted along the Athabasca River within the lease. These, and an associated grave in the Isadore's (or Cree Burn) Lake area, would not be directly affected by the Project. However their presence attests to the significance of the Athabasca River Corridor in the traditional life of the Fort McKay Aboriginal Communities. Further indication of this importance is revealed in the presence of an additional collapsed cabin, with which no name has been associated, along the Athabasca River on its east bank across from Daphne Island.

A trail leading from the southern boundary of the lease, crossing Jackpine Creek and leading to Kearl Lake has also been recorded on the land use maps. Because this trail lies well outside any impact area, no on-ground studies have been conducted to verify its presence.

Traditional use of the Muskeg River is reflected by the presence of symbols indicating harvesting of fur bearing animals, including beaver, and big game animals including deer. Harvesting of plant species is indicated in areas east of the Muskeg River by inclusion of symbols representing raspberry and blueberry, as well as willow and birch trees

E15.3.2 Traplines

A summary statement made in the regional level Traditional Land Use and Occupancy Study (TLUOS) compiled by the Fort McKay First Nations (p 2: 1994) provides a clear indication of the relationship between traplines and the traditional lifestyle.

"The term trapline as used in this study means more than just a place to harvest furs for sale on the commercial market. It means the territory where people hunted, fished, picked berries, gathered duck eggs and trapped fur for local domestic consumption and trade. The trapline was the community food supply for the people interviewed in this TLUOS; it was and is synonymous with meat for the table, with stewardship of all natural resources; with extended family sharing; with socialization of children; with the role of the elders as carriers and teachers of traditional environmental knowledge; and with cultural sustainability."

Traplines in the vicinity of the project area have been registered with two individuals who are members of the Fort McKay Aboriginal Communities (Figure E15-1). Raymond Boucher harvests the resources from the area west of the Muskeg River, which would be the area developed for the Muskeg River Mine Project. Mary Tourangeau harvests the resources from that area of Lease that is east of the Muskeg River but may be affected by future developments.

To gain an impression of the fur yields from these two registered traplines, data were obtained from Alberta Environmental Protection (P. Jensen, Commercial Licensing Administrator, pers. comm., November 1997) for the period between 1984 and 1996. These data are reproduced here as Tables E15-2 and E15-3.

In reviewing this information it should be remembered that the number of species identified may not reflect the actual number harvested and that may have been used for domestic purposes. As well, these figures do not reflect the wide ranges of uses that are implied in the trapline concept discussed above. It is interesting to note, however, that the fur harvest return from the area east of the Muskeg River are considerably greater than those from the area proposed for development of the Muskeg River Mine Project. This difference may reflect the presence of Kearl Lake and extensive areas of muskeg and standing water in Ms. Tourangeau's harvest area. Alternatively, these differences may be more apparent than real. Nevertheless these figures indicate that a wide variety of fur bearing species are present within the Local Study Area and that their harvesting forms an integral part of the traditional land uses that take place in the LSA.

E15.3.3 Wildlife Productivity of the Project Area

In accordance with the view that trapline life represents use of a wide range of plant and animal resources in a particular area, information was sought on the general productivity of the Project area, as a means of determining the types of species that may have been involved in the "bush economy" and that would have accompanied the operation of a registered trapline. To accomplish this, a review was conducted of the wildlife studies completed for the Syncrude Aurora Project, which includes the area to be developed for the Muskeg River Mine Project (Fort McKay Environment Services 1996c). Basic information relating to the goals and outcome of this work has already been presented in section D15. However, some of its results were considered to have a bearing on possible traditional land use potential throughout the Project area.

During the course of this study, four survey transects were walked under snow covered conditions by both a biologist and an experienced traditional land use advisor (Figure E15-2). Tracks and other indications of wildlife species were counted to arrive at an "Abundance Index" for each area. Three of these transects fall within or are directly adjacent to the Project area. Although the general results of this study have been reported earlier, the list of species and numbers observed (Table E15-4) provide an indication of the variety that may have been incorporated into the "bush economy".

These data indicate that considerable variety, if not overwhelming abundance, characterizes the wildlife identified within the Project Area. When these species are combined with the diversity of plant communities present throughout the Project area, the potential for a rich traditional use of the Project area can be appreciated.

The results of the study completed for the Aurora project have been recently confirmed and expanded upon by a more systematic investigation of the productivity of the cleared area of the former Alsands Project area sponsored by Shell Canada Ltd. (Fort McKay Environment Services 1997b).

The objectives of his study were to delineate habitat types and successional trends in the cleared former Alsands lease area, to determine the variety of animals that currently inhabit this area, and to compare these patterns with the former vegetation and wildlife communities in this area, and finally to determine any health hazards hat might be present in the plants and animals of the area. The results of this study indicate that the regeneration this are has produced a suite of plant and animal resources that would be highly sought after as traditional resources. Certain prey species such as beaver, Sharp-tailed grouse and Snowshoe hare have been highly favored by the new drainage regime and the regenerated vegetation in his area. Larger game have also been attracted by the new food sources present in the regrowth vegetation. However in this latter case the lack of cover has made these species extremely susceptible to hunting.

Table E15-2 Furbearing Species Trapped within Raymond Boucher's Registered Fur Management Area (#1650) from 1984 to 1996

Year	Timber wolf	Red fox	Coyote	Canada lynx	Wolverine	Fisher	Marten	Weasel	Mink	River otter	Beaver	Muskrat	Squirrel
1984/1985	---	---	---	---	--	---	---	---	---	---	21	---	---
1985/1986	---	---	---	---	--	---	---	---	1	---	9	8	---
1986/1987	---	---	---	---	--	---	---	---	1	---	---	---	---
1987/1988	---	---	---	---	--	1	---	---	4	---	13	8	---
1988/1989	---	---	1	---	--	1	1	3	3	---	---	---	16
1989/1990	---	---	---	---	--	---	---	2	1	---	---	---	5
1990/1991	---	---	---	---	--	---	---	---	1	---	---	---	5
1991/1992	---	---	---	---	--	---	---	---	---	---	---	---	---
1992/1993	---	---	---	---	--	---	---	---	---	---	---	---	---
1993/1994	---	---	---	---	--	---	---	---	---	---	6	3	---
1994/1995	---	---	---	---	--	---	---	---	---	---	---	---	---
1995/1996	---	---	---	---	--	---	---	---	---	---	---	---	---
Total	0	0	1	0	0	2	1	5	11	0	49	19	26

Table E15-3 Furbearing Species Trapped within Mary Tourangeau's Registered Fur Management Area (#2172) from 1984 to 1996

Year	Timber wolf	Red fox	Coyote	Canada lynx	Wolverine	Fisher	Marten	Weasel	Mink	River otter	Beaver	Muskrat	Squirrel
1984/1985	---	1	1	---	---	2	---	---	2	2	70	60	---
1985/1986	1	1	---	3	---	7	---	1	3	1	72	136	---
1986/1987	---	3	---	---	---	3	---	---	1	---	30	14	---
1987/1988	---	---	---	1	---	5	---	9	18	---	10	91	6
1988/1989	---	2	1	3	1	1	---	1	5	---	4	---	---
1989/1990	---	---	---	8	---	3	---	---	1	---	13	---	---
1990/1991	---	---	---	1	---	---	1	---	---	---	---	---	---
1991/1992	1	3	1	5	---	6	1	---	1	---	20	---	---
1992/1993	---	2	---	---	---	7	2	3	3	---	6	---	8
1993/1994	---	1	---	---	---	2	2	3	---	---	19	---	32
1994/1995	---	---	---	---	---	---	---	---	---	---	---	---	---
1995/1996	---	---	---	---	---	---	---	---	---	---	---	---	---
Total	2	13	3	21	1	36	6	17	34	3	244	301	46

E15.4 Summary

It can be assumed that the data available for the 12 year use of the registered traplines in the area reveal only a small portion of the traditional use of the area. The information above, both in terms of regional use patterns and the specific species currently present within the Project area, suggest that development of the Muskeg River Mine Project will have a negative impact on Traditional Land Use in the area.

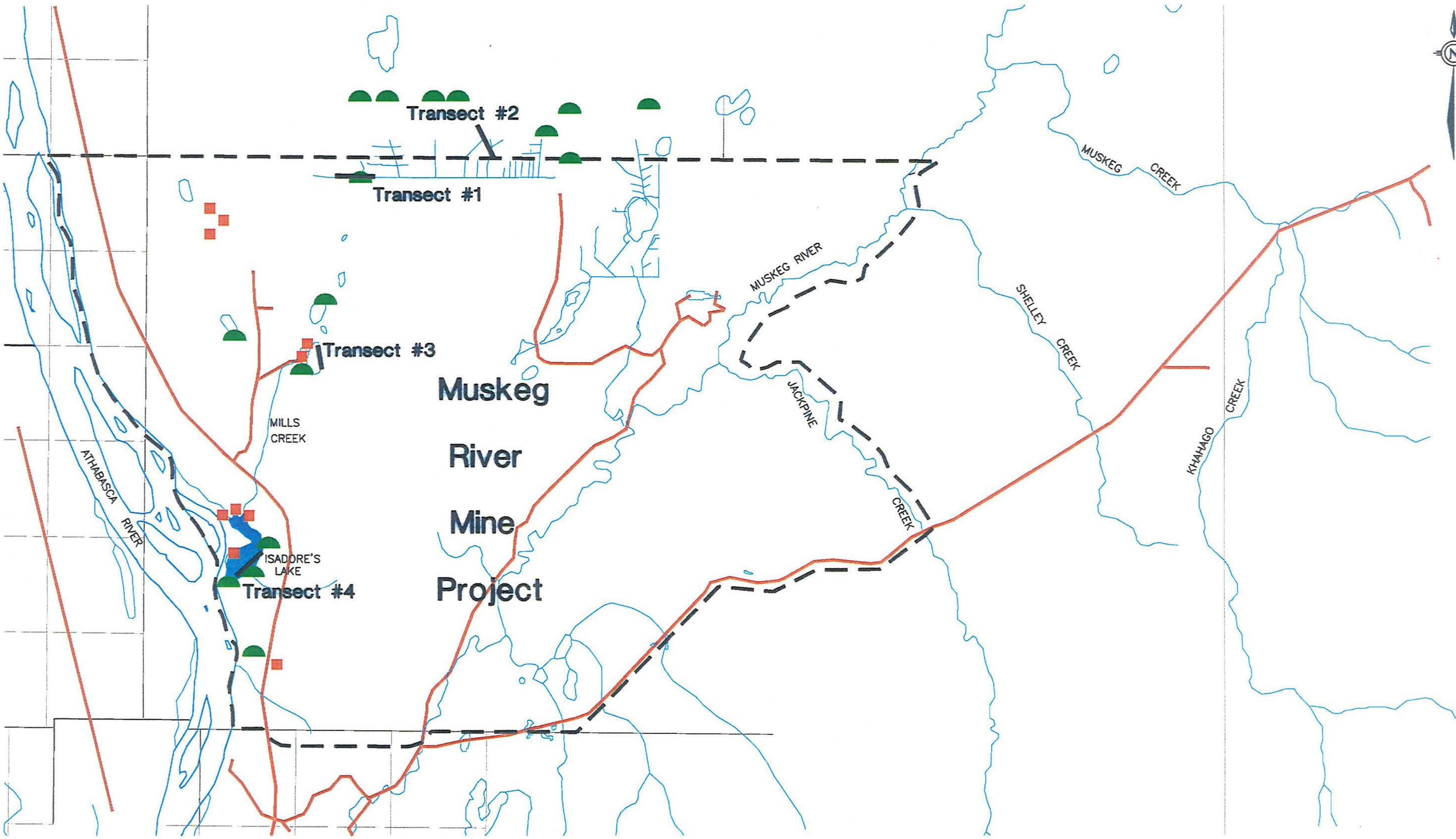
Mitigation plans intended to compensate for some of the specific impacts of the Muskeg River Mine Project are currently in place between Shell and the known traditional users of the Project area. These have been instituted for early stages of project development and are briefly discussed in section E16.8.1 of this application. Later stages of development, particularly mine closure, will require detailed planning and consultation, which has not yet been completed. Shell will ensure that closure planning considers the on-going sustainability of traditional land uses.

The patterns of traditional use identified encompass a much wider area than is contained within the immediate development zone. Mitigative measures appropriate for offsetting these impacts should be designed with a firm understanding of the combined effects of regional development planned within the area. Effective planning in this regard will require completion of the regional level of study that will be completed during the consultation portion of the Traditional Land Use program adopted for the Muskeg River Mine Project.

A number of consultative meetings have taken place between representatives of Shell Canada Ltd. and representatives of the Fort McKay Communities regarding the overall effects of the proposed Muskeg River Mine Project on the community. These are detailed in Section 12, Volume 1 of the application.

More specifically relating to traditional land use issues, a meeting took place, October 8, 1997, with representatives of the Fort McKay communities at which agreement was reached on a program of studies that would expand upon the results of previous studies and would clarify regional traditional land use impacts anticipated by community members. The results of this program will reported as part of the supplemental information provided for this application and will be incorporated in the overall mitigation program designed for the Muskeg River Mine Project and in plans for Project closure.

J:\1997\223 \8500\BEAVLODG.DWG



E15 - 17

LEGEND

- TRANSECTS CURRENT
- ACTIVE BEAVER LODGES WITH FOOD CACHE
- INACTIVE BEAVER LODGES

REFERENCE

DIGITAL DATA SETS 74D, 74E, 74I
84A AND 84H FROM RESOURCE DATA DIVISION
ALBERTA ENVIRONMENTAL PROTECTION, 1997.

0 1 2 3 4 5km

SCALE 1:100,000

Golder Associates

SHELL CANADA LIMITED

SYNCRUDE CANADA LTD. AURORA MINE WILDLIFE STUDY SHOWING THE ACTIVE BEAVER LODGES WITH FOOD CACHES, INACTIVE BEAVER LODGES, INACTIVE BEAVER LODGES, AND LOCATIONS OF THE GROUND SURVEY TRANSECT SITES

04 DEC 97	Figure E15-2	DRAWN BY: RFM

Table E15-4 1995 Wildlife Survey Transects, Muskeg River Mine Project Area.

	Site 1		Site 2		Site 3		TOTAL	
SPECIES	No.	%	No.	%	No.	%	No.	%
beaver	1	3	2	1	0	0	3	1
coyote	0	0	0	0	0	0	0	0
fisher	5	15	11	6	2	33	18	8
fox	1	3	2	1	0	0	3	1
lynx	0	0	0	0	0	0	0	0
marten	0	0	0	0	0	0	0	0
mink	2	6	0	0	0	0	2	1
muskrat	0	0	0	0	0	0	0	0
otter	0	0	0	0	0	0	0	0
rabbit (a)	3	9	130	72	2	33	135	62
weasel	17	52	13	7	2	33	32	15
wolf	0	0	4	2	0	0	4	2
wolverine	0	0	0	0	0	0	0	0
moose	0	0	6	3	0	0	6	3
deer	3	9	1	1	0	0	4	2
caribou	0	0	0	0	0	0	0	0
white-tailed deer	0	0	0	0	0	0	0	0
mule deer	0	0	0	0	0	0	0	0
ruffed grouse	0	0	0	0	0	0	0	0
spruce grouse	0	0	0	0	0	0	0	0
ptarmigan	0	0	4	2	0	0	4	2
sharptailed grouse	1	3	7	4	0	0	8	4
TOTAL	33	100	180	100	6	100	219	100
Tracks < 24 h (b)	21	64	170	94	0	0	191	87

(a) Snowshoe hare.
(b) Number and percentage of snow tracks less than 24 hours old.

Although he Muskeg River Mine Project Area represents a small portion of the area that is currently considered to be the traditional lands of the resident aboriginal communities, the above discussions indicate that it is currently used for a wide variety of traditional land use practices. Project development will impact these practices over 23 years period from the initiation of development through to project closure. Mitigative procedures, which will include direct compensation to known users, staged development to provide a transition period and closure planning that will incorporate traditional land use needs, will effectively offset many of these effects. Consequently, the residual impacts to traditional land use are considered to be low in magnitude, localized within the Local Study Area, of long term duration and reversible, at least partially, by appropriate closure planning.

E16 CLOSURE PLAN

E16.1 Introduction

This chapter describes the conceptual Closure Plan for the Muskeg River Mine Project (the Project). The Closure Plan presents a final "snapshot" of the landscape after completion of reclamation activities. It includes an initial assessment of the final landform structures for their geotechnical, environmental, and end use performance in terms of final end use objectives and regulatory requirements. This Closure Plan is not intended to be a final document, but rather it initiates a process which will provide a framework for ongoing evaluation of Closure Plan scenarios. The closure scenarios will evolve due to changing stakeholder requirements for specific end uses, revised standards for regulatory certification, as well as the introduction of new oil sands operational and reclamation technologies.

This Closure Plan utilizes much of the expertise and methodology obtained from related projects undertaken for existing oil sands operations. Many closure issues such as reclamation of CT landscapes are generic to the oil sands area. Future iterations of this planning process will be based on increasing knowledge of material behavior and landform reclamation.

The Closure Plan focuses on an initial prediction of post development landforms and a methodology for the continuing assessment of these landforms in terms of the feedback received from reclamation practices and evolving land use expectations. The initial performance assessment provides a screening level review of the engineering, environmental, and land use issues. This assessment is used to document data gaps and provide recommendations for ongoing monitoring that will be required to achieve the Project end use objectives.

E16.1.1 Terms of Reference

The Closure Plan is an integral component of the project planning and the environmental impact assessment for the Project. The Final Terms of Reference for the Project reclamation/mine closure tasks include requirements to:

- provide a comprehensive conceptual reclamation plan which describes anticipated land capability and end land use, land stability, erosion control, revegetation, development phasing, pit backfill sequencing and time frames for reclamation completion;
- describe how the final landform will be incorporated into mine planning;

- describe reclamation implications with respect to water quality and other relevant ecosystem components of the technology selected for managing fine tails, as well as, for the alternative technologies considered;

- describe the reclamation plans for management and disposal of water to be released and for processing wastes from the Project area;

- describe how the proposed reclamation plan addresses objectives outlined in the Fort McMurray Integrated Regional Plan and any other pertinent government initiatives;

- describe how reclamation plans will impact biodiversity in the study area. Include a comparison of the pre-disturbed species list with the anticipated species list used for reclamation. Describe any differences in type, size, variety or distribution of terrestrial and aquatic landscape units on wildlife habitat, traditional uses, aesthetics, recreation or commercial forest operations;

- describe the physical and biological parameters in the reclaimed landscape (terrestrial and aquatic) that will be monitored and evaluated. Provide an outline of the key milestones for reclamation and how progress will be measured. Describe plans to demonstrate reclamation success to public stakeholders and government; and

- provide a review of relevant reclamation research and experience and a description of future research initiatives to be undertaken by Shell and other oil sands operators to further reclamation technology in the oil sands regions (Terms of Reference, Section 5, AEP 1997a).

E16.1.2 Objectives

The overall goal of the Closure Plan is to provide a description and systematic evaluation of the predicted performance of the final reclaimed landscape compared with the Project's environmental and final land use goals and policies. Specific objectives are to:

- provide a description of the final reclamation units;

- summarize key issues which are most significant to the success of the Closure Plan;

- analyze landform and vegetation sustainability, including geotechnical, geomorphic, terrestrial and aquatic considerations; and

- provide recommendations for monitoring and research to assure the success of the closure process.

E16.2 Closure Planning Approach

The approach utilized for the Closure Plan is based on similar, interactive work that has been conducted by the existing oil sands operators. Many of the key issues are generic, with reclamation concerns that are comparable to existing oil sands operations. However, there are some issues that are specific to this submission such as the degree of impact on specific watershed basins and the site-specific configuration of reclaimed landforms.

Figure E16-1 provides a schematic representation of the closure planning process. The pre-development condition is assessed to provide baseline environmental capability upon which to compare the capability of the final landscape (Step 1). Following definition of the overall mine plan (Step 2), the final closure landscape is developed (Step 3). This design includes consideration of the anticipated performance of the various closure units both in terms of platform stability and environmental expectations (e.g. the use of wetlands for water treatment). In Step 4, a performance assessment is made based on the final closure landscape with the results compared to the pre-development condition, land use objectives, or regulatory requirements. If the predicted long-term physical and environmental performance or the anticipated land uses do not meet the objectives for the site, then alternative reclamation designs are considered (Loop a). Depending on the degree to which the objectives are met, it may be necessary to consider an alternative form of project development (Loop b). After an acceptable closure design has been attained, performance monitoring and maintenance recommendations can be made to demonstrate that the reclamation process is in harmony with the closure objectives. The final step of estimating the cost of implementing closure and thus the financial assurance requirements are outside the scope of this plan.

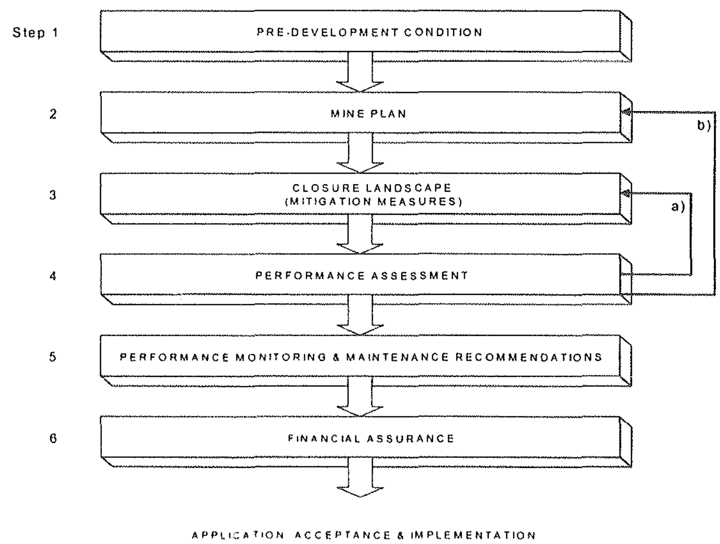
E16.2.1 Closure Plan Framework

The Closure Plan provides a framework scenario to assess the major physical features of the development area and to predict how the area will be reclaimed to achieve desired end uses. These environmental and engineering issues are analyzed as they are expected to exist in a final "snapshot" of the project area (year 2030). Key issues are discussed in terms of the likelihood that the Closure Plan will be successful in meeting the closure goals and objectives.

E16.2.2 Closure Plan Definition

The closure landscape design is derived from the current mine plan upon which are placed post-mining landforms which are consistent with the proposed project reclamation practices and closure objectives. These post-closure landforms are described in terms of reclamation units (e.g., disposal areas, tailing sands areas, backfilled mine cells) with the anticipated end uses and functions (e.g., wetlands water treatment) described for these units. Factors such as slope, drainage, parent material and soil capability are building blocks for the establishment of vegetation communities and wildlife distributions. Material balances and handling considerations represent constraints related to both landform construction and long-term performance. The goal of establishing a landscape is to balance these constraints in a manner that results in an acceptable end use and environmental performance.

Figure 16-1 Closure Planning Process



E16.2.3 Performance Assessment

The assessment of final landscape performance is based on a comparison of expected performance with baseline conditions, regulatory guidelines and end land use objectives. The performance assessment described herein is consistent with the detailed impact assessments for many of the components described in Section E of this EIA. The conclusions of the impacts that are related to closure performance are summarized in this plan.

Initial assessments are made in terms of a number of key issues which have developed during the course of this EIA. These issues include:

- geotechnical stability;
- landforms and aesthetics;

- changes in surface water hydrology;
- changes in groundwater hydrogeology;
- drainage on CT landforms;
- effects on the Muskeg River;
- end pit lake issues;
- soil/forest capability;
- habitat and wildlife use;
- biodiversity and self sustaining ecosystems;
- compatibility with nearby developments; and
- end land use potential.

Other issues, such as public health and safety are addressed in detail in the relevant impact assessment sections and are not repeated in this plan.

E16.3 CLOSURE PLANNING PROCESS

E16.3.1 Closure Goals and Policies

This section outlines the general goals and policies that have been used to guide the design of the Closure Plan. These goals have been developed based on current oil sands standards and practices, regulatory requirements, and recommendations from oil sands committees. Goals for the reclamation and closure of the Muskeg River Mine Project include:

- landforms will be geotechnically stable and conform as much as possible with the surrounding landforms;

- drainage systems will have to be designed to erosion rates and substance loadings;

- forest capability, including commercial forestry potential, will be equal or better than pre-development conditions;

- reclaimed areas will develop as self-sustaining ecosystems with an acceptable degree of biodiversity;

- on-site public health and safety will be protected;

- the final aesthetics will be acceptable; and

- reclamation certification will be achieved to allow transfer of the lands back to the Crown.

Corporate policies relevant to the ongoing closure process include:

- end land use objectives will be developed in consultation with stakeholders; and
- there will be an ongoing process with adjacent oil sands developers to ensure continuity of landforms and drainage systems across lease boundaries.

E16.3.2 The End Land Use Committee Goals

The End Land Use Committee (on which Shell Canada Limited participated) has published draft recommendations for closure planning goals (End Land Use Committee 1997). The final recommendations from the Committee will be used to provide guidance on end land use objectives for the Project. Based on the committee's draft guidelines, the end land use of the project will include consideration of the baseline information, closure plan coordination, and land use categories and allocation.

Baseline information has been collected to establish pre-development land capability and vegetation types. This information is described in Sections D7, D8, D9 and D10 of this EIA. The Closure Plan should be reviewed and coordinated with a regional body which considers input from regulatory agencies, industry, aboriginal peoples and other stakeholders. This input will be coordinated to ensure:

- continuity of landforms and watershed systems across lease boundaries;
- location of land uses in areas or on landforms that make physical, biological, social and economic sense; and
- forest productivity of the reclaimed landscape returned to the region to be equal or better than pre-development conditions.

The End Land Use Committee has indicated that planning should include considerations of natural conservation areas, forestry, and human use.

Natural Conservation Areas are an integral part of oil sands mining reclamation and are important to ensure that biodiversity is maintained. A portion of reclaimed land should be set aside for development of natural ecosystems, with no intention of land or vegetation re-disturbance. Reclamation in these areas will be undertaken to ensure evolution to a natural state, and will consider wildlife habitat, biodiversity, aesthetics, traditional aboriginal land uses, recreational uses, and general community hunting, trapping, fishing and gathering of plants.

One of the goals of the closure process is to have reclaimed land achieving a productivity equal to or better than pre-development lands, with an appropriate land area available for forestry. Additional end land use options may include forest research sites and orchards for tree seed production. Considerations in the process of reclamation for forestry use include:

- a similar species mix as occurred at pre-development to maintain biodiversity;
- contiguous blocks of forest as appropriate for efficient harvesting operations;
- wildlife habitat; and
- traditional land uses.

Establishment of acceptable end land uses will be completed with consideration of the pre-development conditions as well as with input from traditional land users, operators, regulators and other stakeholders. Fundamental considerations will include:

- establishing end land uses on a progressive basis with goals to minimize the amount of elapsed time from development to completion of reclamation;
- prioritizing re-establishment of land uses as defined by the regional body where the project has displaced pre-development land uses;
- assessing the impact of the loss of productive forest lands on annual allowable cut (AAC) and determining which mitigation measures can be taken to reduce the impact on the forest industry; and
- obtaining input from aboriginal peoples to develop reclamation guidelines for replacement of traditional land uses.

E16.3.3 Regulations and Guidelines

Closure regulations and guidelines exist in three sources which include:

- Fort McMurray-Athabasca Oil Sands Sub-regional Integrated Resource Plan (IRP) guidelines which are also focused on the oil sands area (AEP 1996a);
- Alberta Environmental Protection (AEP) additional guidelines that may be established as a result of their review of earlier oil sands mine applications (AEP/AHD/ADC 1997); and
- Conservation and Reclamation (C&R) Regulations which are specific to oil sands mining and which are addressed in the C&R Plan developed

for the Muskeg River Mine Project (as detailed in Section 16 of Volume 1 of the Application).

Integrated Resource Plan Guidelines

Recent guidelines contained in the IRP for the Fort McMurray-Athabasca Oil Sands Subregion have been incorporated into this reclamation plan (AEP 1996a). The overall intent of the IRP is to achieve development in a manner compatible with environmental and social considerations and to conserve land and natural resources.

Relevant IRP guidelines have been recommended to:

- minimize impacts;
- enable reclamation to an equivalent capability, optimizing the value of watershed, timber, wildlife, fish, recreation or other resources; and
- allow the development of alternative reclamation approaches where needed.

The Fort McMurray-Athabasca Oil Sands Subregion is divided into a series of Regional Management Areas (RMAs). The principal land area to be developed for the Muskeg River Mine Project (Lease 13 west) lies within the Mildred-Kearl Lakes Resource Management Area (RMA), with some mining activity in the Athabasca-Clearwater Resource Management Area (cf. Section D14).

The management intent of the Mildred-Kearl RMA is to promote the orderly planning, exploration and development of resources with emphasis on the area's oil sands reserves. The Mildred-Kearl RMA is also important to the aboriginal community's traditional activities and for supply requirements for the forest industry. In particular, the intent of the RMA for this area is to:

- encourage the orderly, efficient development and production of surface mineable oil sands reserves;
- restore post-developed lands to a state that will allow sustained levels of use equivalent to that which existed before development, including forest growth. Revegetation to a mixed wood boreal forest, using native species, will be the primary means by which the lands base is reclaimed;
- maintain moose habitat and to rebuild the wintering moose population to levels greater than the present population;

- consider the merits of agricultural development on reclaimed lands on a site-specific basis; and
- assure that future uses of reclaimed land are compatible with existing and planned uses for adjacent lands.

In view of their distinct character and ecological importance, the significant river valleys are considered a separate RMA: the Athabasca-Clearwater RMA. This area includes the nationally significant Athabasca River valley as well as provincially significant river valleys such as the Muskeg River. The IRP recognizes that river valleys in this region provide an important winter range for ungulates, fur bearers and bird game. For developments within this RMA, there must be a demonstration of impact mitigation on the following resources or values of the river valley:

- wildlife: valley vegetation, riparian habitat, habitat diversity;
- erosion: sensitive soils and drainage patterns;
- floodplain: setback to at least the 1:100 flood level and accommodation for natural evolution;
- water quality, including both surface water and groundwater;
- recreation and tourism: visual and acoustic, travel corridor, valley horizon;
- ecology: unique characteristics, rare flora and fauna, critical functions and processes;
- traditional use by aboriginal communities; and
- historic sites: scientific, educational and interpretive purposes.

E16.3.4 Regulatory Guidelines

The IRP indicates reclamation should achieve the replacement of the commercial conifer and deciduous forest land base and moose habitat to pre-disturbed levels. AEP's current guidance requires surplus capability be managed for sport fish or livestock. Moose are the most important wildlife species within the Local Study Area (LSA) from an economic and social viewpoint. They are the focal point of aboriginal subsistence hunting and the most sought after game species by sports hunters. In addition, moose have a very high social value as a wildlife viewing resource, contributing to recreation and tourism. The IRP places a strong emphasis on moose management and calls for an increased moose population and the restoration of moose habitat to be an objective of reclamation for oils sands mines. Therefore, AEP may recommend that the Project:

- maintain historic access to moose habitat in the reclaimed landscape;

- restore moose habitat capability and populations to at least pre-development levels; and

- monitor moose populations as a routine part of the Project's ongoing reclamation monitoring program.

Reclamation should establish self-sustaining ecosystems similar to pre-development ecosystems. Following surface development, the land should be reclaimed in a manner that re-establishes a watershed that resembles and functions as a natural system. The restructured soil profile shall be capable of supporting native vegetation. The ability of the land to support various end uses must be similar to what it was before surface development, but specific land uses will not necessarily be identical (i.e., the return of equivalent land capability), an approach that maintains future land use options.

AEP guidelines require that post-development lands be reclaimed to a capability equivalent to that existing before development. Where commercial forest is the reclamation objective, the capability will be measured in terms of meeting reforestation standards. Revegetation to a mixed wood boreal forest, using native species, will be the primary means by which the land base is reclaimed. An important aspect of this process is a commitment to continuing research by oil sands operators in land reclamation technology.

Biodiversity is an important issue and AEP may recommend:

- re-establishing biodiversity, in keeping with the Canadian Biodiversity Strategy;
- use of the "Native Species Strategy" as a general principle guiding reclamation;
- investigate reclamation strategies which will establish diverse native ecosystems; and
- monitor various aspects of biodiversity as an ongoing part of a commitment to protect and restore biodiversity.

E16.3.5 Summary of End Land Use Goals

Basic end land use goals for the Muskeg River Mine Project include:

- Maintain the amount of moose habitat;
- Provide equal or better commercial forest capability;

- Protect the aesthetic qualities of the landscape;
- Provide for traditional land uses (e.g., hunting and trapping);
- Leave open the opportunity for other end uses (e.g., recreational, agricultural); and
- Allow input from stakeholders regarding end use goals.

E16.4 Closure Plan

E16.4.1 Mine Schedule

The Closure Plan is based on the most recent mine plan and on the following schedule:

- Year 1999 - Clearing and Site Preparation
- Year 2002 - Commencement of open-pit mining and bitumen extraction.
- Year 2005 - Production with recycle water - without CT manufacture
- Year 2010 - Production of CT at 75% capacity
- Year 2014 - Production of CT at 95% capacity
- Year 2022 - End of Mining Operations
- Year 2030 - End of Reclamation
- Far Future - Equilibrium closure conditions

For the purposes of project closure planning, the year 2030 is taken as the final snapshot of the reclaimed landscape.

E16.4.2 Reclamation Units

There are approximately 20,200 ha in Lease 13, of which 10,298 ha are in the Project Development Area. Of this area, approximately 4,343 ha will be developed at this time. The major post-development landscape features include:

- 1039 ha for the reclaimed tailings settling pond (38 ha ponds and wetlands);
- 548 ha for above ground overburden disposal areas;
- 190 ha in the reclaimed reclamation material storage (RMS) areas;
- 1723 ha for backfilled mine cells (80 ha ponds and wetlands);
- 442 ha in the end pit lake (99 ha littoral zone);

- 95 ha in constructed ponds and wetlands outside the above noted reclamation units;
- 202 ha in the plant site;
- 87 ha for the utility corridor, and
- 17 ha for the product/solvent pipelines.

For the purposes of this plan, these features have been broken down into reclamation units which are shown on Figure E16-2. These units generally follow the post-development landscape features with the exceptions that the mine cells have been further broken down into overburden capped CT, sand capped CT, and sand capped overburden. In addition, the plant site and utility corridor have been lumped together into one reclamation unit. The following sections describe the reclamation units.

Tailings Settling Pond

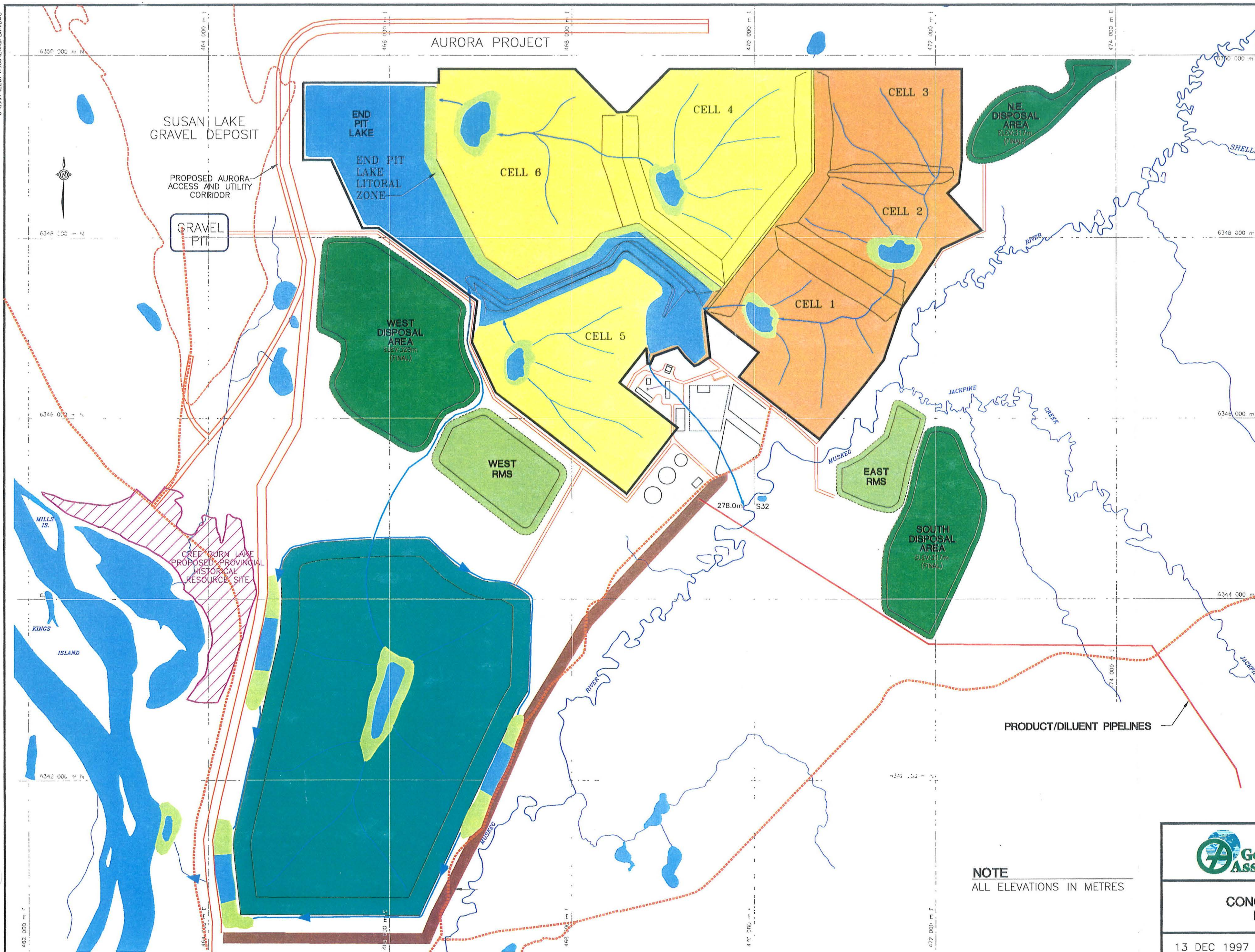
The tailings settling pond will be constructed to a maximum elevation of 337 metres above sea level (masl). During operations, it will be used to generate mature fine tails (MFT) and recycle water. MFT from the pond will be converted to CT as storage cells are constructed in the mine pit. The tailings settling pond will be contained within sand perimeter dykes. The external slopes of the tailings settling pond are currently planned to be constructed at an angle of 4H:1V. Further detailed geotechnical studies will be used to finalize designs for the slope angle. Seepage control will be provided by internal drains. During operations, discharges from these drains will be pumped back into the pond. At completion of the mine development, the remaining MFT will be pumped into the end pit lake, The centre of the tailings settling pond will be backfilled with tailings sand during a recontouring operation. The final elevation of the tailings settling pond will be 325 masl, a height reduction of 12 m. The predominant material in this reclamation unit will be tailings sand.

This structure will accentuate the Athabasca Escarpment at a height comparable to other areas along the river. It will also provide for a wildlife corridor between itself and the river.

Above Ground Disposal Areas

Storage for about 137 million m^3 of overburden and centre reject material will be required. This material will be stored in above ground disposal areas or in portions of the mine pit. In addition, muskeg not required for reclamation may be placed in these areas. The muskeg so disposed will be contained by overburden or centre rejects "dykes".

Above ground disposal areas will be engineered and constructed to ensure long-term geotechnical stability. Details of the disposal area designs are



REFERENCE
BASE PROVIDED BY NORWEST, DATED 22/10/97 TITLED MINE AND TAILINGS PLAN STATUS AT END OF YEAR 2022. 150000bbls/day SCENARIO

NOTE
ALL ELEVATIONS IN METRES

Golder Associates		SHELL CANADA LIMITED
CONCEPTUAL MINE CLOSURE PLAN LANDFORM AND DRAINAGE		
13 DEC 1997	Figure E16-2	DRAWN BY: KD

presented in Section 4 of Volume 1 of the Application. Three potential areas have been identified for the above ground overburden storage, including the:

- West Disposal Area
- South Disposal Area
- Northeast Disposal Area

Overburden and centre reject disposal areas will be constructed in lifts to achieve 3H:1V final slopes. Lift thickness will depend on the strength of the material being placed as well as the efficient control of surface drainage. To ensure stability, the disposal areas will be monitored and redesigned, if necessary. In accordance with Project planning objectives, including minimizing ore sterilization, the use of the Northeast Disposal Area will be delayed until 2007. This will allow sufficient time to continue geological and economic assessment of the ore in the area.

Since centre reject materials originate from within the oil sands ore body, they are likely to have chemical properties which are not conducive to revegetation. Overburden will be preferentially placed on the external slopes of the disposal areas to a minimum depth of 2 m. This handling practice may be reviewed once more information on the quality of the centre reject material is obtained.

Reclamation Materials Storage Areas

Muskeg will be removed during the winter and will be either salvaged for reclamation use or discarded. Muskeg salvaged for use as a soil amendment will be preferentially directed into reclamation areas or to the reclamation materials storage areas for future use. Reclamation materials storage areas will likely have an overburden shell around the perimeter with reclamation materials being confined within these shells. Sufficient reclamation materials are available for reclamation to allow discarding of some materials.

The storage of reclamation materials will be scheduled to minimize storage time, thereby maintaining the viability of the propagules within the reclamation materials. Current planning calls for two reclamation materials storage areas, including the East Reclamation Materials Storage Area (on the east side of the Muskeg River) and the West Reclamation Materials Storage Area.

Current material balances indicate that some muskeg must be discarded rather than stored for re-use. Muskeg to be discarded will be co-disposed in the above ground disposal areas with the overburden and the centre rejects.

As the reclamation progresses (and particularly after muskeg stripping has finished), muskeg will be hauled from the storage areas to areas undergoing reclamation. After the muskeg has been removed from the storage area, the overburden shells will be graded out and soil amendment will be placed over the area.

Backfilled Mine Cells

The tailings management plan meets the primary objective of placing consolidated tailings into the mine pits as soon as possible to minimize the size of the tailings settling pond and to allow for early reclamation of these areas. The pit will be divided up into six cells to facilitate this in-pit disposal process. The locations of these cells are shown on Figure E16-2.

The schedule and protocol for the disposal of tailings is given in Volume 1, Section 6 of the Application. In-pit CT placement begins into Cell 1 in 2006. The available in-pit space can support almost full CT production after 2014.

Consolidated Tails will be stored in Cells 1, 2, 3, 4 and 5. Overburden and centre rejects will be disposed in Cell 6. It is anticipated it will take 5 to 10 years for the CT to become trafficable, after which it will be capped. CT in Cells 1, 2 and 3 will be capped with 11 to 13 m of overburden and centre reject, while CT in Cell 4 and 5 will be capped with 12 to 13 m of tailings sand. The overburden in Cell 6 will be capped with 12 m of tailings sand. There will be no time lag required for overburden settlement and trafficability in this cell.

The backfilled mine cells will be a dominant landform after Project closure. Therefore the characteristics of its surface environment are crucial to accomplish many reclamation and closure goals (e.g., commercial forestry, wildlife habitat, aesthetics, traditional end land uses). Since the majority of this reclamation unit will be impacted by CT release water during the first few years, and, adequate drainage is a prerequisite for reclamation.

The designed drainage patterns for the reclaimed CT landform will provide a well-drained surface in comparison with a generally poorly drained pre-development landscape. However, both abiotic (e.g., siltation, consolidation and settling of CT deposits) as well as biotic (e.g., beaver dams, tree falls, dying vegetation) factors may alter drainage patterns such that a portion of the landscape may revert to a poorly drained condition. If this were to happen, an increase in soil salinity might result along with rising groundwater levels and a consequent decrease in forest production. For this reason, the degree of slope on CT landforms should be relatively high (e.g., 1%) so that processes creating poorly drained areas are localized in order to restrict their effects to as small an area as possible. The hummock areas on the reclaimed surface of a CT landform should also be elevated (e.g., > 3 m) relative to the wetlands surface since, for example, beaver dams in the area can approach 3 m in height.

For example, the existing elevation for the wetlands on the surface of Cell 6 is 282.5 masl compared with 285.7 masl on Cell 4. This approximate 3 m difference in elevation means that a beaver dam within the Cell 6 wetlands could back up water to form a much larger wetlands, potentially reaching back to Cell 4 and encompassing a wide swath of land on either side (since the existing design for topography shows relatively gentle slopes). Alternatively, the landscape could be arranged so that wetlands and/or drainage channels were contained within a steeper terrain which would act to limit the formation of undesirable large wetlands.

End Pit Lake

After mining is completed in Cell 7, the area will act as a collector for runoff and CT water that has expressed at the surface of the CT-filled cells. In addition, there will be groundwater inflow into the lake. MFT will be pumped from the tailings settling pond and will be discharged subsurface into the end pit lake. This transfer will reduce the risk associated with long term above ground storage of MFT. This transfer will be coordinated with sand removal from the tailings settling pond, as required for capping of Cells 4 and 5.

At the end of the transfer of MFT to the end pit lake, CT release water and other surface water (precipitation runoff) will continue to flow into the end pit lake. The MFT transfer operation will take several years to complete since MFT removal will be restricted by rapid draw down considerations of the tailings settling pond's interior beach slopes. The MFT transferred to the lake will settle to a volume of about 45 million m^3 within a few years after transfer and will consolidate slowly thereafter. Based on the estimated volume of MFT to be added to the end pit lake, it is expected that the end pit lake will have a water depth of about 20 m.

The end pit lake will have a surface area of about 442 ha and will store about 130 million m^3 of water. The shoreline area for the lake will be sculptured to allow for a littoral zone area of about 20 % of the lake volume to enhance its biological productivity. This littoral zone, which will be primarily located along the east side of the lake, as shown on Figure E16-2, will consist of gently sloping topography resulting in a water depth of between 0 and 1.5m. The other parts of the lake will be provided with erosion protection. The catchment area for the end pit lake will be about 17.2 km^2.

The end pit lake will provide remediation of CT porewater seepage, sand porewater seepage and MFT porewater release during consolidation. The lake will also reduce flood flows by providing storage for flow attenuation, but it will reduce annual water yield because lake evaporation exceeds precipitation. The lake has been designed to include the following functional goals:

- it will provide a valuable buffer for water flow effects on the Muskeg River;
- its littoral area will enhance its capability to treat CT release water; and
- it will increase the potential for enhanced wildlife diversity due to the large littoral and riparian areas.

Constructed Ponds/Wetlands

The extent of fens/bogs in the LSA is about 3,070 ha in the Project development area. These fens will be completely eliminated by the mine, but will be replaced by about 119 ha of marsh wetlands and 88 ha of associated ponds. Including the littoral zone for the end pit lake, which is included in the lake area, the total amount of wetlands area in the final closure landscape is 207 ha. The total pond and lake area is 448 ha, which is considerably more than the 57 ha of existing lakes, ponds and streams. This increase in the amount of open water will be a substantial benefit to many types of waterfowl, other waterbirds, amphibians and aquatic mammals.

The new ponds and wetlands will be constructed in three areas:

- on the surface of backfilled mine cells;
- in association with the drainage ditch around the reclaimed tailings settling pond; and
- within the internal slopes of the reclaimed tailings settling pond.

Ponded water within the wetlands will act to increase retention time and the supply of dissolved oxygen in the water column. The littoral zone of the end pit lake will be less than 1.5 m in water depth and will provide an environment conducive to biodegradation (e.g., plant surfaces for microbes, nutrient recycling).

The following table represents the size of the ponds and wetlands for the various reclamation units.

Table E16-1 Areas of Constructed Ponds and Wetlands

Location	Ponds (ha)	Wetlands (ha)
Tailings Settling Pond	11	27
Cells 1 and 2	14	13
Cells 4 and 6	16	25
Cell 5	5	7
End Pit Lake	354	88
Other Wetlands	48	47

Since these ponds and wetlands will be constructed after the CT has become trafficable (i.e., mostly dewatered), the ponded water will consist mostly of precipitation. However, CT release water will flow through these ponds, in ever diminishing quantities (i.e., as the CT finishes the consolidation process).

Plant Site and Utility Corridor

At the end of the plant site operations, the buildings and other man-made structures will be demolished and the area regraded to a topography that will support timely revegetation. It is anticipated that a muskeg amended soil will be used for this purpose.

Pipeline Corridor

It is anticipated that the pipeline corridor will have had significant and relatively undisturbed biological growth during operations. As such, closure will likely involve allowing continued invasion of trees and shrubs from the adjacent vegetation communities.

E16.5 Existing Conditions

E16.5.1 Soils

The spatial distribution and extent of each soil series found in the Muskeg River Mine Project LSA is described in detail in Section D8 of this EIA. Organic soils of the McLelland and Muskeg series currently comprise 41% of the soils by area, and are rated as class 5 or permanently non-productive for forestry. These fen and bog peat materials will be salvaged where practical for use in the reclamation soil amendment mix.

Only two of the mineral soils are recommended for salvage and possible placement as topsoil in the reclamation landscape, the Fort and Dover series which make up a total of 6% of the LSA. Further discussion of the qualities and characteristics of each soil series may be found in Section D8 of this EIA. The remainder of the LSA soils are mineral soils which are considered to be inappropriate for reclamation.

Based on this soils data and the existing drainage characteristics, forest capability ratings can be calculated using the system outlined by Leskiw (1996). This data is described in detail in Section D8 and is summarized on Table E16-2.

E16.5.2 Vegetation

Terrestrial vegetation has been subdivided into uplands (areas where soils are not saturated for extended periods) and wetlands. Detailed descriptions of upland vegetation and wetlands can be found in Sections D9 and D10 respectively of this EIA. Vegetation has been classified using the following classification systems:

Table E16-2 Summary of Forest Capability Classes

Capability Class	Pre-development Area (ha)	Post-Reclamation Area (ha)	% Gain(+) or Loss (-)
Class 1	0	0	0
Class 2	418	295	-70%
Class 3	998	4,033	+404%
Class 4	4,299	2,697	-63%
Class 5	4,515	2838	-63%
Open Water	185	802	+434%
Disturbed Land	539	289	-54%
Total	10,954	10,954	-

- Alberta Vegetation Inventory (AVI) mapping, which uses a forestry based vegetation classification;
- The Beckingham and Archibald (1996) field guide to ecosites in Northern Alberta, which uses and ecological land classification (ELC) based system; and
- The Alberta Wetland Inventory (Halsey and Vitt 1996) classification system.

Wetland vegetation covers 61% of the LSA, while upland community types cover 33%. The remaining areas were either disturbed, unvegetated, or open water.

E16.5.3 Wildlife

Details on wildlife species density and habitat are presented in Section D11 of this EIA. Wildlife has been grouped into ungulates, small mammals, terrestrial furbearers, semi-aquatic furbearers, waterfowl, upland game birds, and breeding birds.

Moose are considered to be the most important ungulate in the area. However, a shortage of preferred winter habitat has resulted in a low population density. There are numerous species of small mammals within the LSA. The snowshoe hare is the most common furbearer in the area followed by the red squirrel. The coyote is the most abundant large carnivore but it has a low population density. The most common carnivores are weasels and ermines. The black bear is relatively common with a stable population.

The beaver is the most common semi-aquatic furbearer whose population density has increased on the LSA as a result of the Alsands distribution. There is a low nesting density of waterfowl in the LSA. The spruce grouse is the most abundant upland gamebird followed by the ruffed grouse. The majority of the breeding birds who use the LSA are migratory.

E16.5.4 Existing land Use

Currently, 539 ha on the Muskeg River Mine Project site have been disturbed as a result of oil and gas exploration (seismic lines), the previous Alsands project (test pits, roads and an airstrip), gravel pit development and access roads to other oil sands leases. Other existing land uses include:

- forest resources development;
- traditional and non-traditional plant collecting;
- limited non-consumptive recreational use;
- hunting and trapping; and
- ceremonial use.

E16.6 Performance Assessment

E16.6.1 Framework For Assessment

The performance assessment is an evaluation of the conceptual snapshot for the proposed final landscape design as described in Section E16.4. The assessment described herein is based on data generated during this EIA process. Further refinement will be required with time. Where possible, quantitative measurement of anticipated performance has been made to demonstrate that the closure goals can be achieved with the proposed final landscape. Examples of these quantitative measurements include hydrological and water quality predictions and pre and post development soil/forestry capability. In other instances, judgment has been used to evaluate the potential of a factor meeting corporate goals. An example of the latter is geotechnical stability which is not considered to be a fatal flaw to the design in light of the low level of occurrence of Clearwater formation soils.

A discussion of the performance assessment is broken down by the key issues described in Section E16.2.3.

E16.6.2 Geotechnical Stability

The closure landscape is relatively flat with the only significant slopes being associated with the tailings settling pond and the disposal areas. At the current time, it is anticipated that there will not be deep seated stability concerns associated with these slopes, particularly in view of the relative absence of Clearwater soils on the site. Although the design of all soil structures must be confirmed by a site specific investigation, deep seated slope stability is not considered to be a significant issue related to the Closure Plan.

It is possible, however, that some shallow skin failures will be observed on the slopes of the tailings settling pond or, more likely, the disposal areas. These types of earth movements typically have a low consequence of failure and can be repaired by regular maintenance. For this plan, it is assumed that an observational approach will be appropriate and that specific design issues can be addressed as they arise.

Other geotechnical issues such as quick conditions and inadequate internal drainage are assumed to be addressed in the design of specific areas and thus are not considered to be a significant closure issue.

E16.6.3 Landforms and Aesthetics

Geotechnical stability is assumed; that is, landforms will be designed so that there is a very low risk of failure that would impact on the surface landscape either on-site or off-site. Therefore, the principal issues surrounding landforms are compatible with adjacent and pre-development structures in terms of their resulting ecological characteristics and suitability for a variety of potential end land uses.

Landforms

The percent of area for each landform has been calculated in Section E7 for the LSA. The principal issues surrounding landforms are that they are acceptable in terms of their resulting ecological characteristics and their suitability for a variety of potential end uses.

The Muskeg River Mine Project pre-development terrestrial LSA is dominated by two principal landform units - fens and glaciofluvial deposits. To a lesser extent, recent fluvial, glaciolacustrine, morainal, bog and eolian features are present. Except for the Athabasca River valley, relief in the terrestrial LSA is quite subdued, the topography best described as gently undulating (Section D8). In comparison, the post-development reclaimed landscape will have a number of topographic features that generally will provide for a better drained landscape with a variety of slopes and aspects. In general, the loss of fens will be offset by greater terrain diversity and improved habitat for some wildlife species.

Aesthetics

The aesthetics assessment is based on computer generated prospective views of the LSA at three different time periods. These time periods are pre-development (Figure E16-3), during development (Figure E16-4) and after reclamation and closure (Figure E16-5).

Each series of perspectives includes an aerial view looking towards the southeast and three "ground level" perspectives referred to as vantage points A, B, and C. Vantage point A is located on the west side of the Athabasca River just south of the Peter Lougheed Bridge. The elevation is comparable to the maximum height of the bridge span. During development (Figure E16-2), the tailings settling pond will be visible. In the far future (Figure E16-3) the top 10 to 15 m may still be visible. However, the forest cover close to the bridge may totally or partially block the line of site. In the far future all constructed landforms will be revegetated. This will also aid, in reducing the potential for visual impact.

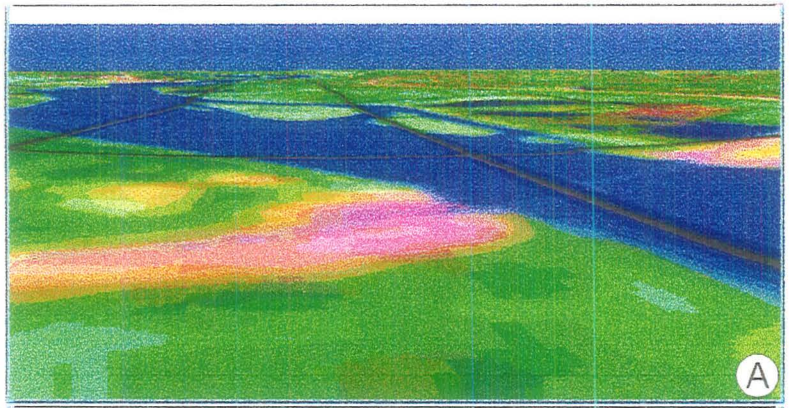
Vantage point B is taken from the Athabasca River. The visual impacts will be greatly mitigated by the recontouring of the reclaimed tailings settling pond, the revegetation of this structure and the blockage of the line of site by the forest cover.

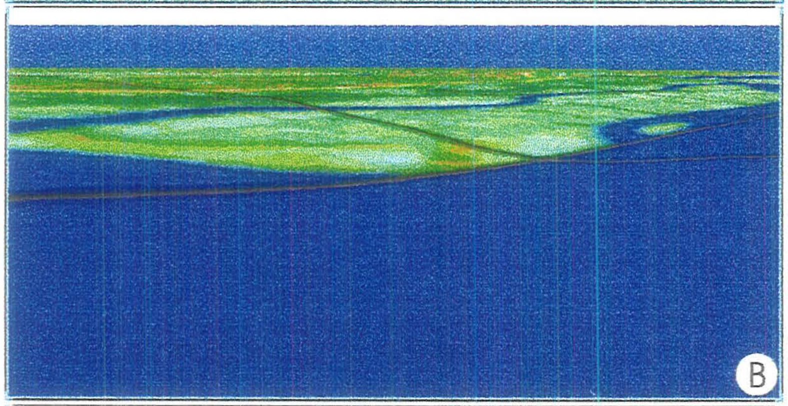
Vantage point C is taken east of the Athabasca River access road. The tailings settling pond will be a dominant factor from this view point.

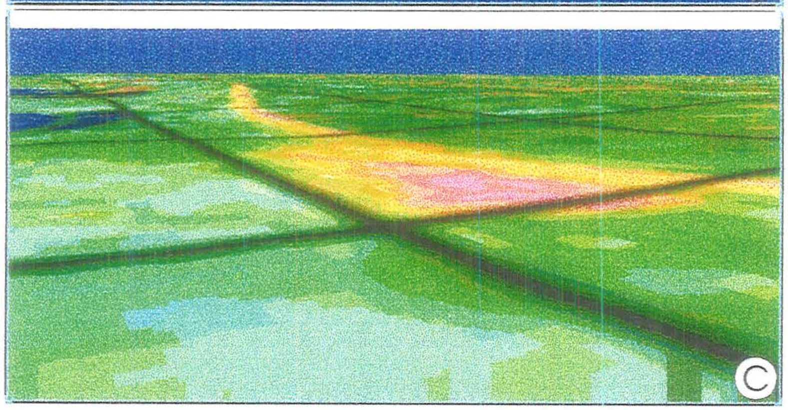
E16.6.4 Surface Water Hydrology

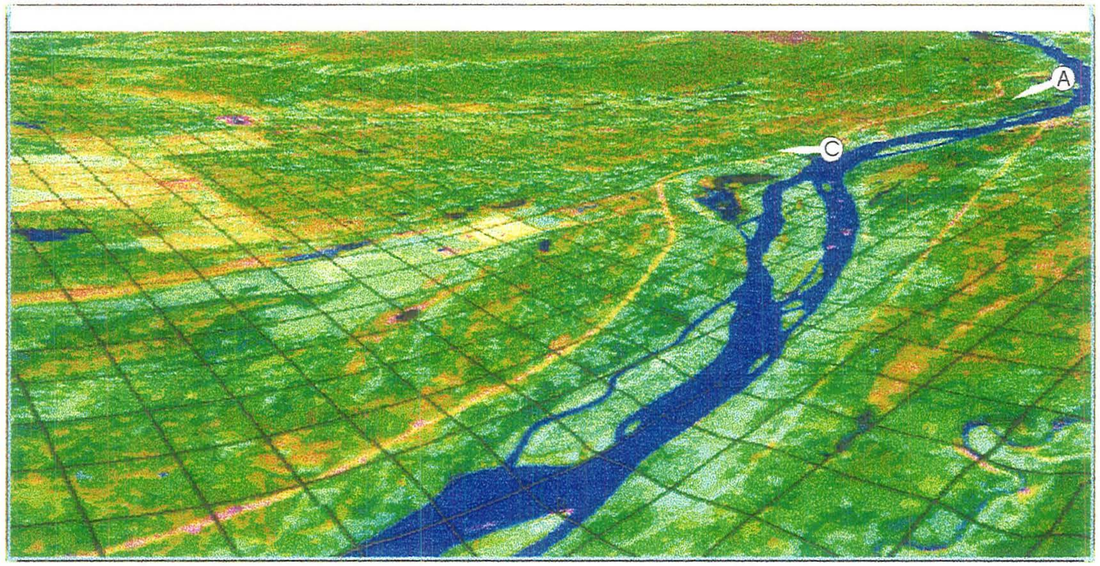
The assessment of the impact of the closure landscape on the surface water regimes in both the LSA and the RSA can be discussed in terms of the following factors:

- impacts of post-closure surface water flows and water levels;
- impacts on water balances on nearby waterbodies;
- impacts on sediment yield;
- impacts on channel regimes; and
- impacts of increased open water.









Three "ground level" perspective views show the landscape under current baseline condititions. The overview image (above) shows the entire site. The grid mesh has been added to help identify slopes. The "fish-eye" effect is an artifact of the visualization software. The colours are an approximation of real colours from false colour satellite imagery. The terrain surface model has been derived from elevation contours and mine plans.

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VIEWS OF MUSKEG RIVER MINE PROJECT PRE-DEVELOPMENT

05 DEC 97	Figure E16-3	DRAWN BY: JMCP/RFM

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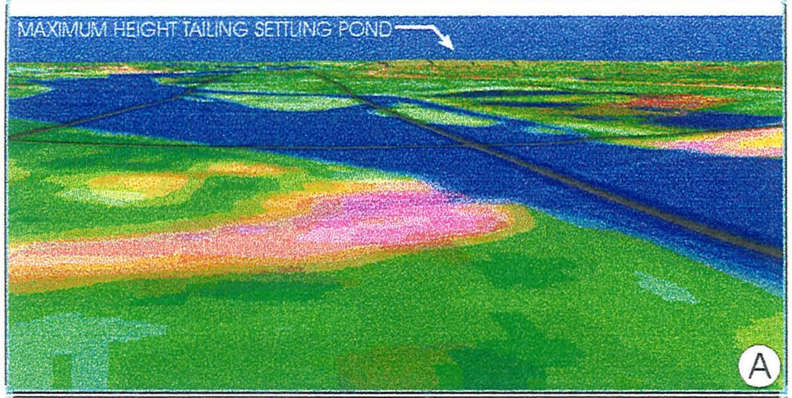

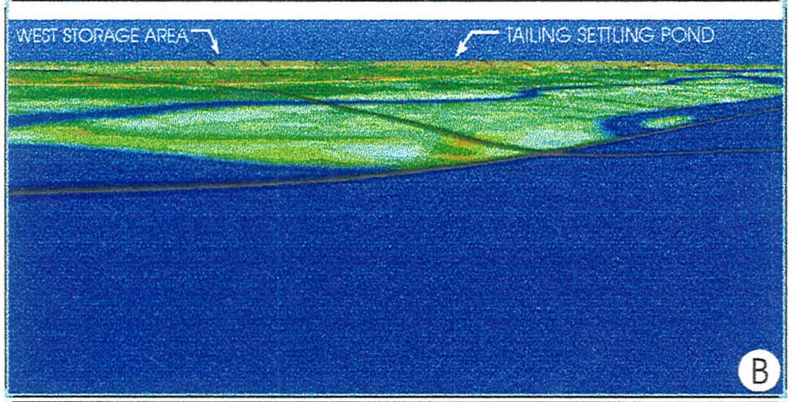

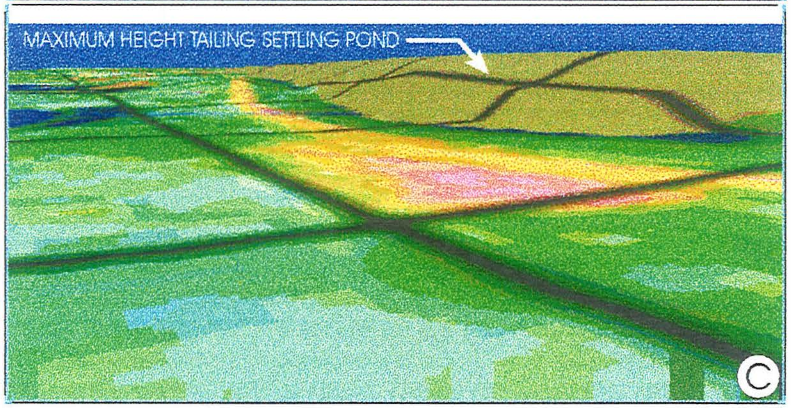

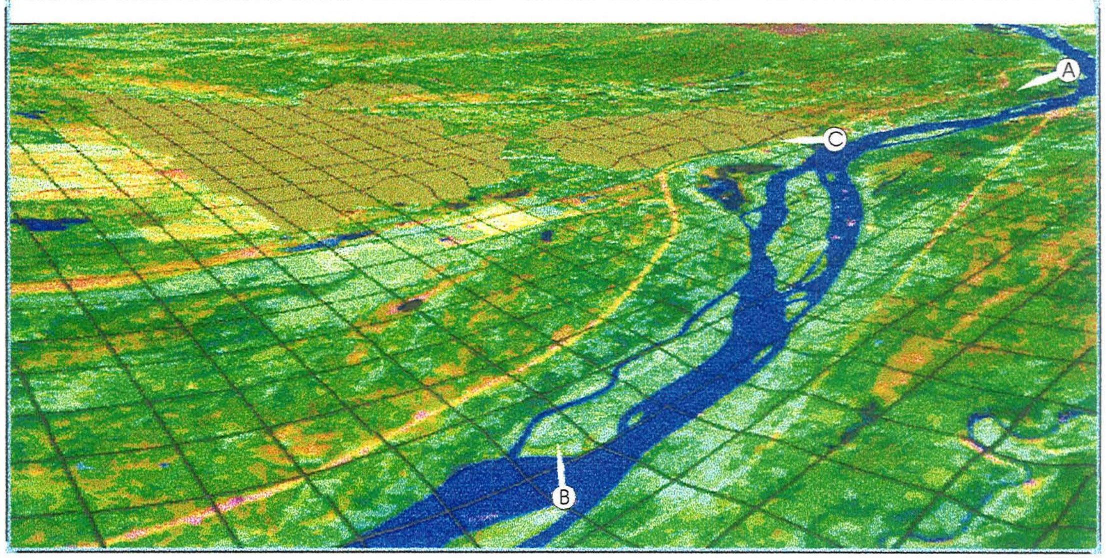

Three "ground level" perspective views illustrate various perspectives of the mine during operation. The overview image (above) shows the entire site. The grid mesh has been added to help identify slopes. The "fish-eye" effect is an artifact of the visualization software. The colours are an approximation of real colours from false colour satellite imagery. The terrain surface model has been derived from elevation contours and mine plans.

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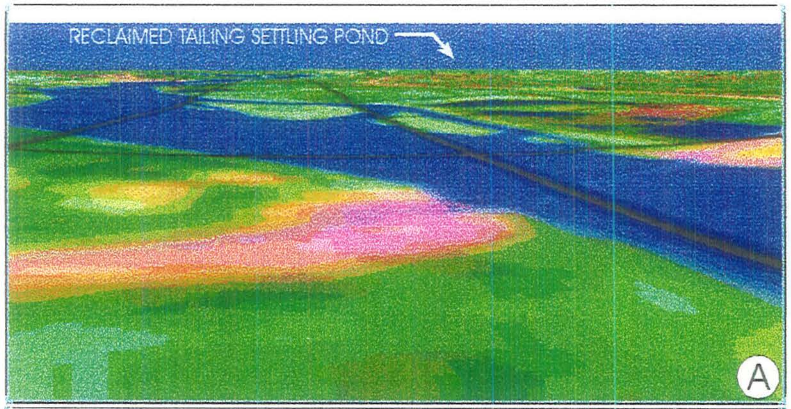
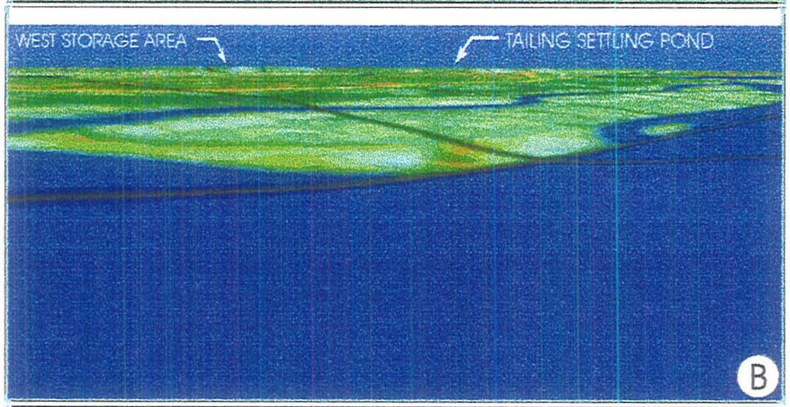
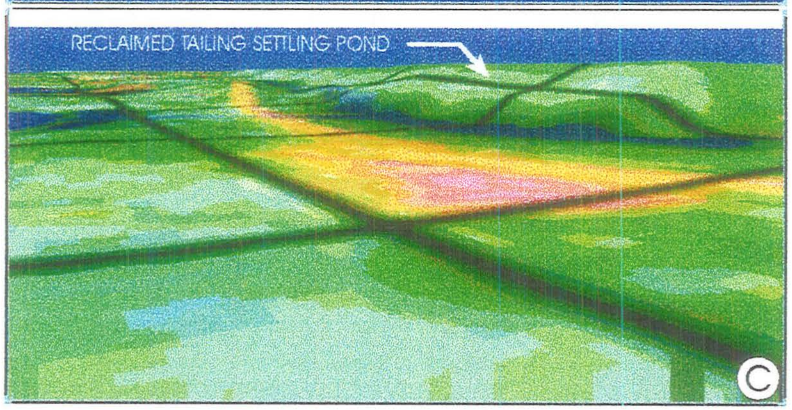
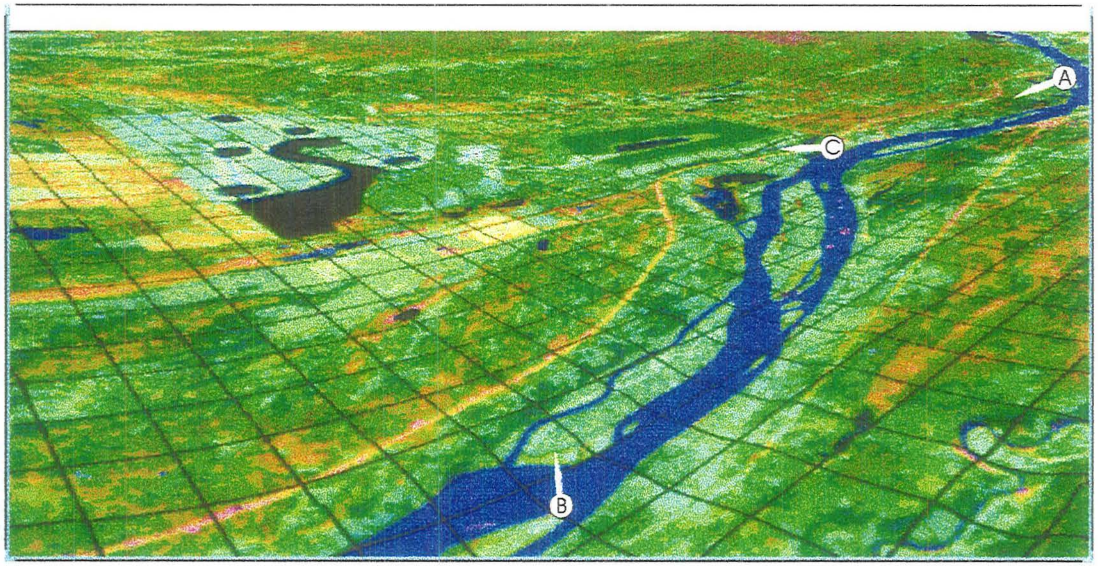
VIEWS OF MUSKEG RIVER MINE PROJECT DURING OPERATION

05 DEC 97	Figure E16-4	DRAWN BY: JMCP/RFM









Three "ground level" perspective views illustrate various perspectives of the post mine reclamation. The overview image (above) shows the entire site. The grid mesh has been added to help identify slopes. The "fish-eye" effect is an artifact of the visualization software. The colours are an approximation of real colours from false colour satellite imagery. The terrain surface model has been derived from elevation contours and mine plans.

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VIEWS OF MUSKEG RIVER MINE PROJECT FAR FUTURE

05 DEC 97	Figure E16-5	DRAWN BY: JMCP/RFM

A description of the existing hydrological conditions is contained in Section D4 of this EIA. Detailed impact analyses of the proposed development both during operations and after final reclamation are contained in Section E4.

Impacts on Flows and Water Levels After Closure

Runoff from the reclamation units will vary from the pre-development conditions. These differences detailed in terms of annual water yields (cf. Section E4, Table E4-16) as well as high and low flow conditions.

Surface water flow predictions from the reclaimed landscape are described in Section E4. In general, the reclaimed landscape will have a greater amount of surface runoff than the pre-development conditions due to the presence of slopes and the replacement of fens/bogs with better drained reclamation structures. This, however, is mitigated by the retention within the end pit lake.

The hydrological analyses described in Section E4 indicate that there will be no substantial changes in Athabasca River flows (cf. Table E4-19). Increases in mean open-water and ice-cover flows on the Alsands Drain are not of concern, since 10 year flood peak discharge will be about the same as existing conditions as a result of flood attenuation by the end pit lake (additionally, the Alsands Drain is a man-made structure).

The analyses similarly indicate that the Muskeg River mean annual discharge will increase by 16% in 2030 (i.e., second year after closure) but will only be 3% higher than existing conditions in the far future (i.e., equilibrium post-development conditions). Mean ice-cover discharge and open water 7Q10 discharge will increase by 60 and 251% in 2030, but will only be 3 and 4% higher than existing conditions in the far future.

Although there are some significant increases in Isadore's Lake inflows for 7Q10 flows (open water and under ice), other flows are about 20% below existing flows including mean annual peak flows. Similar data for other periods are:

- mean ice-cover discharge (-16%);
- open-water 7Q10 discharge (+20%);
- ice-cover 7Q10 discharge (+240%); and
- 10 year flood peak discharge (-16%).

However, lake level differences never exceed ±0.6% or 0.4 cm above mean open water depth and 1.4 cm below mean open water maximum depth (see Volumes 2, Section E4 -Table E4-21).

This predicted reduction in the mean open water level (and hence open water area) of Isadore's lake may represent a loss of nutrient inputs which may impact on both biotic and abiotic characteristics of this wetlands. Chemical and biological monitoring will be required to assess the significance of this loss.

Impacts on Water Balance on Nearby Waterbodies

Nearby waterbodies are those which do not directly receive surface runoff from the Project under the existing conditions. During operation dewatering/depressurization can affect the water balance in nearby water bodies (Section E3 - Hydrogeology Impact Analysis). Kearl Lake will be affected during operations; however, the increased loss to the Basal Aquifer only represents 0.8% of the mean annual lake inflow. Additionally, after closure and filling of end pit lake, depressurization will cease and the loss to the aquifer will decrease to pre development conditions.

Impacts on Sediment Yield

Although sediment yield from the reclaimed landscape will be higher than from the natural existing landscape (cf. Section E4, Table E4-27) impacts on the Muskeg River or Mills Creek will be negligible (cf. Section E4, Table E4-28). In the early closure years the Muskeg River will receive 8% (or increase from 9.5 to 10.3 mg/L) increase in total suspended sediment, while in the far future there will only be a 2% increase in total suspended solids load which is within the range of natural variation. However, there is potential for the shallow lakes/wetlands to infill before the need for biological treatment has expired. For example, a 1 m deep wetlands on the sand storage area may infill in about 125 years assuming all sediment is retained. The wetlands on overburden capped CT will take a much longer to fill (1,000 years), while wetlands on sand capped CT landforms may infill in about 150 years.

It is unlikely that water treatment will be required in 1,000 years. But it is possible that some treatment may be required in 100 years, when the wetlands storage (and therefore retention times and capacity for treatment) will likely be reduced due to sedimentation. For this reason the performance of the wetlands should be monitored. A potential mitigation if the wetlands are silting up at an unacceptable rate is to increase the depth of the open water (pond) section of these wetlands.

Channel Regimes

Channel regime defines the natural equilibrium geomorphic conditions of a stream channel, which may change with changes in flow. The Muskeg River channel regime will be negligibly affected after mine closure. Flows in Mills Creek will be reduced and therefore there will also be no affects on its channel regime.

E16.6.5 Hydrogeology

The types of potential hydrogeologic impacts from the Muskeg River Mine Project include impacts on groundwater resources, and changes in groundwater regimes that interact with surface water both in terms of quantity and surface flows, and effects on groundwater quality that are subsequently transmitted to receiving surface waters. Details with respect to each of these issues is provided in Volume 2, Section E3.

Impacts on Groundwater Levels and Groundwater Flows

Impacts of overburden dewatering include: 1) groundwater levels in surficial aquifers will be lowered within 1 to 2 km of the mine area; and 2) groundwater levels in the Basal Aquifer will be lowered within 30 to 40 km of the project. The level of these impacts are detailed in Volume 2, Section E3.

Increased downward seepage caused by dewatering will have some impact on Kearl, McClelland and Isadore's lakes during mine operations, as described in Section E3. However, when dewatering ceases upon completion of the project, groundwater levels in the Basal Aquifer will recover to near pre-development levels (at a rate similar to that of drawdown). Thus, the effects on the Basal Aquifer are largely reversible in the long term.

Re-establishment of Groundwater Systems After Mining and Reclamation

Groundwater levels and flow systems will be altered by project development, but will re-establish in the post-development landscape. With reduced groundwater recharge rates, and somewhat lower permeability materials than the natural setting, groundwater from the perimeter of the developed areas should be readily drained away from the reclaimed land by natural groundwater flow systems in the relatively permeable surficial sand. Generally, groundwater surface elevation in the reclaimed lands may be very shallow (less than 1 or 2 m below ground surface) in the centre of a reclaimed pit, while near the perimeter of the project the groundwater surface is likely to be in the 4 m range. Horizontal flow, directed outward from the project, will dominate in the relatively permeable overburden or tailings sand capping materials. In the underlying CT, downward-directed vertical flow will dominate, with vertical seepage into the underlying lean oil sands and/or Basal aquifer. This pattern is similar to the natural groundwater flow systems, in which horizontal flow dominates the surficial sand aquifers, with vertical, downward-directed flow through the oil sands, into the Basal Aquifer.

Direct Seepage to the Surface Water System

There will be seepage from many of the reclamation units. Seepage to the Muskeg River from the backfilled, below ground disposal cells is estimated to be 0.001 m^3/s, while seepage from the reclaimed tailings settling pond area is estimated to be 0.0035 m^3/s. These seepage rates will be significantly reduced during frozen ground periods when the annual low flows occur. Seepage from the reclaimed tailings settling pond area to Isadore's Lake is estimated to be 0.0024 m^3/s, but again will be significantly reduced during winter. Seepage flow into the Athabasca River is estimated to be 0.027 m^3/s, which is negligible when compared to the flow of the river. Upward flux from CT porewater is estimated to be 0.04 m^3/s in year 2030, decreasing to zero in the far future.

Impacts on Groundwater Quality

Potential impacts on groundwater quality include seepage of CT porewater from in-pit disposal areas to impact the groundwater quality in the Basal Aquifer, seepage of CT porewater from in-pit cells to impact groundwater areas beyond the mine pit, and seepage of tailings sand porewater from the tailings settling pond to impact groundwater quality.

The natural groundwater quality in the Basal Aquifer can be characterized as Na-Cl-HCO_3 or Na-HCO_3-Cl type water, whereas CT porewater seepage is a Na-SO_4 type water. Additionally, the CT porewater seepage will exceed maximum acceptable concentrations for drinking water for benzo(a)pyrene, cadmium, lead and mercury. However, the natural groundwater quality is also not considered potable because of the high salts content.

The natural groundwater quality in the McMurray Formation oil sands in the vicinity of the sand storage area can be characterized as Ca-Mg or C-Mg-Na-HCO_3 type water, whereas tailings sand seepage is expected to be Na-HCO_3 type water. Although none of the water quality parameters for tailings sand seepage exceed maximum acceptable concentrations for drinking water; a few parameters will exceed aesthetic objectives. Impacts to the Basal Aquifer are expected to be low, while they are moderate to high for surficial aquifers.

E16.6.6 Wetlands

Wetlands on CT Deposits

Wetlands will be located within the drainage areas of Cells 1, 2, 4, 5 and 6. The function of these wetlands include:

- surface water retention;
- CT release water treatment; and
- provision of a diverse and productive wildlife habitat.

The total area of both ponds and wetlands will be approximately 80 ha which is slightly less than 5% of the total catchment area for the backfilled mine cells. Collectively, these ponds and wetlands are estimated to store 760,000 m^3 of water. The total peak discharge from surface runoff (100 year return period) will be about 4.6 m^3/s or about 400,000 m^3/d. Therefore the estimated hydraulic retention time (HRT) for the collective wetlands at these peak flows will be about 2 days. Using average values for the mean annual discharge (0.18 m^3/s or about 15,000 m^3/d), the mean HRT will be about 50 days.

Wetlands Within the Tailings Settling Pond

The wetlands within the reclaimed tailings settling pond will be about 38 ha in size and will drain an area of about 7.6 km^2 , providing a wetlands-catchment ratio of about 5%. This wetlands will store about 296,000 m^3 of water and will have a mean annual discharge of 0.429 m^3/s (~4,000 m^3/d) and hence the mean HRT will be about 74 days. The peak discharge (100 year return period) will be about 16,000 m^3/d, with a peak HRT of about 19 days.

Wetlands Hydraulic Retention Times

The loss of pre-development wetlands will decrease the retention of water in the remaining reclaimed wetlands. Consequently, spring runoff will not be stored and the CT landform will be better drained than pre-development landforms. The released water will, however, be stored in the end pit lake and hence flows to the Muskeg River will be more evenly distributed over the summer compared with pre-development flows. This may reduce spring flows in the Muskeg River.

Low retention times for wetlands on CT deposits may also affect their capability to treat any CT release water during peak flows. Initial estimates of the retention time required to treat this water are in the order of about one month. In contrast, initial calculations show a hydraulic retention time of between 7 and 2 days for peak flows during 2 year and 100 year return periods respectively. This short retention time, however, may be offset by the greater degree of dilution during peak flow times. The effectiveness of the wetlands and end pit lake treatment for CT water will be monitored as the project progresses.

Finally, low retention times during the freshet may result in scouring and channelization in the reconstructed wetlands. This would reduce their size over time and hence further inhibit their ability to treat chemicals in CT release water. This is off-set by the reduction in chemical loading in the waters with time.

In contrast to the above retention times, wetlands at the toe of the sand storage area have retention times of 100 to 180 days even in peak flows and hence the water treatment capacity of these wetlands should be adequate to mitigate any adverse impacts of chemicals associated with these discharges.

Treatment Capability of CT Wetlands Associated with Backfilled Mine Cells

Immediately after project closure, there will be an estimated 1.3 x 10^6 m^3/yr (about 0.04 m^3/s) of CT release water being discharged through the reconstructed wetlands associated with the backfilled mine cells. This compares with an overall mean annual discharge of 5.3 x 10^6 m^3/yr (0.17 m^3/s); that is, CT release water will be about 24% of the total flow of surface water immediately following closure. As time progresses, this percentage will decrease to zero in the very long-term which may be greater than 100 years. However, for the purposes of project closure, and to reflect a conservative evaluation, a 1:5 dilution is considered most applicable.

The design of self-sustaining marsh-type wetlands on the surface of CT landforms and at the toe of the sand storage area has somewhat contradictory aspects since these type of wetlands typically evolve quickly (in terms of natural cycles) into meadows, grasslands, and eventually forest ecosystems. Therefore, there will be a dynamic (but unknown) conflict between the time required for treatment and the sustainability of these wetlands. The duration and quantity of discharge of CT release waters into these wetlands is currently uncertain at this time. As described earlier, the rate of infilling of these wetlands is predicted to be about 150 years. The design of the wetlands system will have to evolve as more information becomes available on issues such as CT water release (i.e., ongoing water quality monitoring) and wetlands sedimentation. A further complicating factor will be settlement of CT areas which could impact (both positively and negatively) overall drainage and wetland effectiveness.

This uncertainty between the required time for wetlands performance of a water treatment function and the life expectancy of the landform also may apply to wetlands at the toe of the sand storage area since drainage of process-affected water from these dykes will also occur over significant periods.

During peak flows on CT landforms, the estimated retention time for water in these wetlands is about 2 to 7 days. This time period would likely be too short to allow adequate treatment for undiluted CT release water. However, this retention time may be adequate after closure since the amount of CT release water will decrease substantially over time, and hence the degree of dilution with surface runoff will increase and the need for treatment will decrease. There is a concern, however, that peak flows after closure may have adverse impacts due to the flushing effects of chemicals from CT deposits and/or from overlying sand/overburden material which may accumulate CT-related compounds (e.g., salts, metals, naphthenic acids) during the initial consolidation and dewatering period. In that event, this retention time may be inadequate for treatment of this water. Flushes of untreated CT water, perhaps containing ammonia and naphthenic acids, may limit the productivity and capability of the aquatic ecosystem within these wetlands and drainage channels. However, more significant impact to the Muskeg River would be averted by dilution and residency within the end pit lake.

Treatment Capability of Wetlands Associated With the Reclaimed Tailings Settling Pond

There will be three constructed wetlands at the toe of the reclaimed tailings settling pond. Water collected from these ponds flows into an existing wetland prior to entering the Athabasca River. The total area of the three wetlands will be about 80 ha and will store an estimated volume of 1,200,000 m^3 of water (assuming the design mean depth of 1.5 m). The estimated mean annual discharge of process-affected water (i.e., from the sand dykes) through these wetlands is about 0.02 m^3/s or about 630,000 m^3/yr. Therefore, the estimated mean annual hydraulic retention time (HRT) is estimated to be about 1.9 years or 695 days. During peak flows for the 2 and 100 year return period, HRT values would decrease to about 180 and 100 days respectively. Therefore, the water treatment capability of these wetlands will likely be adequate.

E16.6.7 Impacts on the Muskeg River

Fish Habitat

The loss of large areas of pre-development wetlands and the creation of a deep end pit lake may reduce water temperatures in outflows to the Muskeg River. It is not clear at this time if this predicted decrease will be sufficient to impact adversely on the growth of fish and other biological components of this ecosystem. Alternatively, the survival of fish eggs may be enhanced at lower temperatures. Similarly, the attenuation of water flows to the Muskeg River (as a result of the end pit lake) may act to either enhance fish habitat (i.e., if low summer flows increase) or reduce fish habitat (i.e., if spring spawning areas are reduced). Further research is required to resolve these issues.

Water Quality

As detailed in Section E5 of this EIA, the discharge of CT release water to the end pit lake and its eventual release will have minimal impact on the Muskeg River. Monitoring programs have been identified to confirm these predictions.

E16.6.8 End Pit Lake Issues

The intended end use for the lake is a self-sustaining, biologically productive water body. It has not been designed with the requirement for Athabasca River water for initial filling.

Water quality of the end pit lake will be a function of several variables, including:

- rates and relative amounts of reclamation and natural waters flowing into the lake;
- depth and physical layout of the lake, as this affects mixing conditions;
- watershed design criteria, such as number and placement of wetlands, as this will affect water quality of the influent streams; and
- rate of filling and relative contribution of types of water used to fill the lake.

These design criteria can be optimized to ensure that water quality conditions in the lake will be suitable for end use purposes. The concept of a water capped, fine tails bottom lake has been evaluated and approved as a reclamation feature for Syncrude's Mildred Lake facility (Base Mine Lake). The EPL for the Project is similar to that lake with the following major differences:

- The Project extraction process is caustic-free and is expected to result in lower naphthenic acid levels and hence lower toxicity levels than those observed to date (Mikula and Kasperski 1997). Therefore, initial water quality of the end pit lake is expected to be better than those in other planned end pit lakes.
- The water is much deeper (20 m) than proposed for Base Mine Lake (5 m). This eliminates the possibility of mixing of MFT into surface waters, but creates the potential for a concentration of chemicals below a thermocline.
- It will consist of aged MFT, 30% water by volume, so consolidation rates will be very low, thus input from MFT consolidation to chemical loads will be very low.

These are positive design differences that should result in an end pit lake that is sustainable and safe for users. Even so, there are a number of potential issues that need resolution and further evaluation:

- stratification potential;
- nutrient status;
- H_2S generation;
- possibility of incomplete mixing of releases; and
- time frame over which lake water quality will improve so that it would be acceptable for discharge.

In the event that the performance of the lake is not as expected, the following mitigative measures should be considered:

- provide a larger littoral area where the degradation of constituents can be enhanced by the diffusion of oxygen into the water column;
- decrease the depth of the top water layer to 5 to 10 m to promote mixing of the water column so that any released gas/chemicals would be degraded by indigenous microbes on a continuous basis and thereby prevent any accumulation of certain constituents; and
- include a wetlands at the outflow of the lake or downstream from the outflow to act as a contingency water treatment system.

E16.6.9 Soil and Forest Capability

Protocol for Soil Reclamation

The protocols for identifying soil and forest capability are described in Sections E16.5.2 and D8 of this EIA. A class 3 soil, which can be made using a 20 cm layer of soil amendment over sand or overburden, is capable of supporting commercial timber harvesting. If needed, a higher class of soil (i.e., class 2) could be achieved by placing 50 cm of soil amendment on the CT deposits and/or overburden stockpiles.

The placement of overburden over CT deposits will enhance soil quality of the reclaimed landscape in terms of making available more clay and inorganic material compared with a sand cap. However, the likely increase in clay content may also make this soil more vulnerable to any impacts of salinity from the discharge of CT release water; that is, soil quality may decrease over time. To accommodate the drainage of CT release water from below the overburden cap, sand channels will be constructed as described in more detail in Section E4 of this EIA.

Capability Changes

IRP guidelines are to restore forest capability to a level of use equivalent to pre-development levels and corporate and End Land Use Committee goals are to achieve equal or better capability. AEP guidelines are to restore to a mixed wood boreal forest using native species.

Soil capability on the reclamation landscapes will be on average greater than or equal to pre-development conditions. This is primarily because the reclaimed landscape will be better drained than the pre-development landscape, an improvement that results in soils with greater capability. Alberta Environment has requested that areas of commercial forests on CT deposits be a minimum of 4 ha in size. The End Land Use Committee guidelines request that the cut blocks be planted with a similar species mix as occurred at pre-development and that the land be developed in contiguous blocks to facilitate efficient forest operations.

Table E16-2 summarized the gains and/or losses in soil and forestry capability classes for the post- versus pre-development scenario. The most significant result is the 404% increase in class 3 soils compared with pre-development conditions. Since this class encompasses the largest area (4,033 ha) within the LSA, the overall soil and forest capability will be substantially improved after mine closure.

E16.6.10 Habitat and Wildlife Use

During the construction and operational life of the Project, land development will result in a change of the Ecological Land Classification (ELCs) on the Project area. As a result of this development, wildlife displacement will occur. Sensory disturbance will compound this displacement for some wildlife species.

Following mine closure, new ELC units will be replacing those lost. Upland vegetation communities will predominate the new landscape replacing the previously existing wetlands. These wetland communities were selected to conform to the IRP guidelines regarding maintenance of moose habitat. In addition, the addition of open water and the end pit lake littoral zone will provide greater habitat for waterfowl. Increased upland and forest area will ultimately result in more habitat for terrestrial furbearers, upland game birds and breeding birds. Details of the changes in habitat for the key indicator resources (KIRs) is provided in Section E11 of this EIA.

E16.6.11 Biodiversity

Biodiversity issues will be considered as per the guidelines from the End Land Use Committee and AEP recommendations; however, its measurement and evaluation will be restricted to plant types, plant communities and ELC due to the inability of contemporary science to accurately assess other components of the natural landscape. The three principal issues that may act to decrease levels of biodiversity on the reclaimed landscape are the loss of fens, the uncertainty in the performance of the reclaimed terrestrial landscape and the impact of salinity from CT water.

The Permanent Loss of Fens

The loss of fen-type wetlands will be permanent since it likely will not be possible to recreate that exact environment (e.g., deep peat layers, inflows of groundwater, nutrient-poor regimes). Indeed, it would not be desirable to recreate poorly drained conditions given the goal of a creating an equal or better commercial forestry and given the above concerns regarding possible increases in salinity in both aquatic and terrestrial systems

These fen areas have been characterized in the EIA with respect to vegetation types and water quality. More detailed characterization has not been attempted and, given the nature of biological science, a complete listing of indigenous species is not practical. Therefore, there will likely be some loss of fen-related species in the reclaimed landscape. As a result, protection of these biological communities in adjacent, non-developed areas is important. For example, the mitigation of impacts from dewatering on non-mined fen areas should be monitored and evaluated further.

The Uncertainty in the Performance of the Reclaimed Terrestrial Landscape

The nature of the climax community on reclaimed lands cannot be completely predicted and therefore a comparison of biodiversity between pre-development and post-reclamation conditions is not possible. This is because of the complex interrelationships between all the biotic and abiotic factors in the environment and the lack of area-specific long term reclamation data. The latter is particularly important since the time required to achieve (and assess) the biodiversity of a stable, self-sustaining biological community (perhaps about 100 years) is significantly less than the current reclamation experience of approximately 20 years. For this reason, research and monitoring programs are needed to assess existing reclaimed sites in more detail and to provide innovative approaches to reclamation protocols if warranted by these surveys.

Salinity

The release of CT water through the consolidation of treated fine tails deposited within the CT landforms will result in the discharge of water with elevated levels of salinity and other chemicals from both surface and groundwater sources. It is possible that there may be other sources of salinity due to sodic materials in overburden and centre rejects but these sources are likely to be relatively minor compared to the CT landforms. This discharge will inevitably affect the characteristics of the biological community in aquatic ecosystems and also in those terrestrial systems exposed to this water (e.g., the fringes of wetlands, groundwater discharge locations, poorly drained areas), perhaps decreasing biodiversity. To minimize any (unknown) impacts, reclaimed landscapes on CT landforms are designed to be well drained to enhance the flushing of salts and/or other chemicals from both soil and aquatic ecosystems.

E16.6.12 Public Health and Safety

The protection of public health and safety is fundamental to the Closure Plan. This means that there will be no substantial risks in terms of both physical and chemical exposure. An analysis of the health implications of a hunter/trapper living on the reclaimed landscape is contained in Section

E12 of this EIA. It is not anticipated that there will be physical hazards associated with the reclaimed landscape with the possible exception of the end pit lake. The hazards associated with this lake should not be different compared to other lakes in the area.

E16.6.13 Self-Sustaining Ecosystems

The criterion for achieving this goal is a minimal and reasonable measure of management activity based on the desired end land use. For example, aquatic systems should require the same level of management as undertaken in pre-development areas (i.e., virtually none). However, areas of productive forests will need to be managed as would any other timber harvest area; but unusual efforts to maintain sustainability will not be required (e.g., soil fertilization and/or pH control). In terms of natural processes such as erosion, sediment yield rates and/or other measurement endpoints, the sustainability of the landscape will be similar to those on similar undeveloped terrain types.

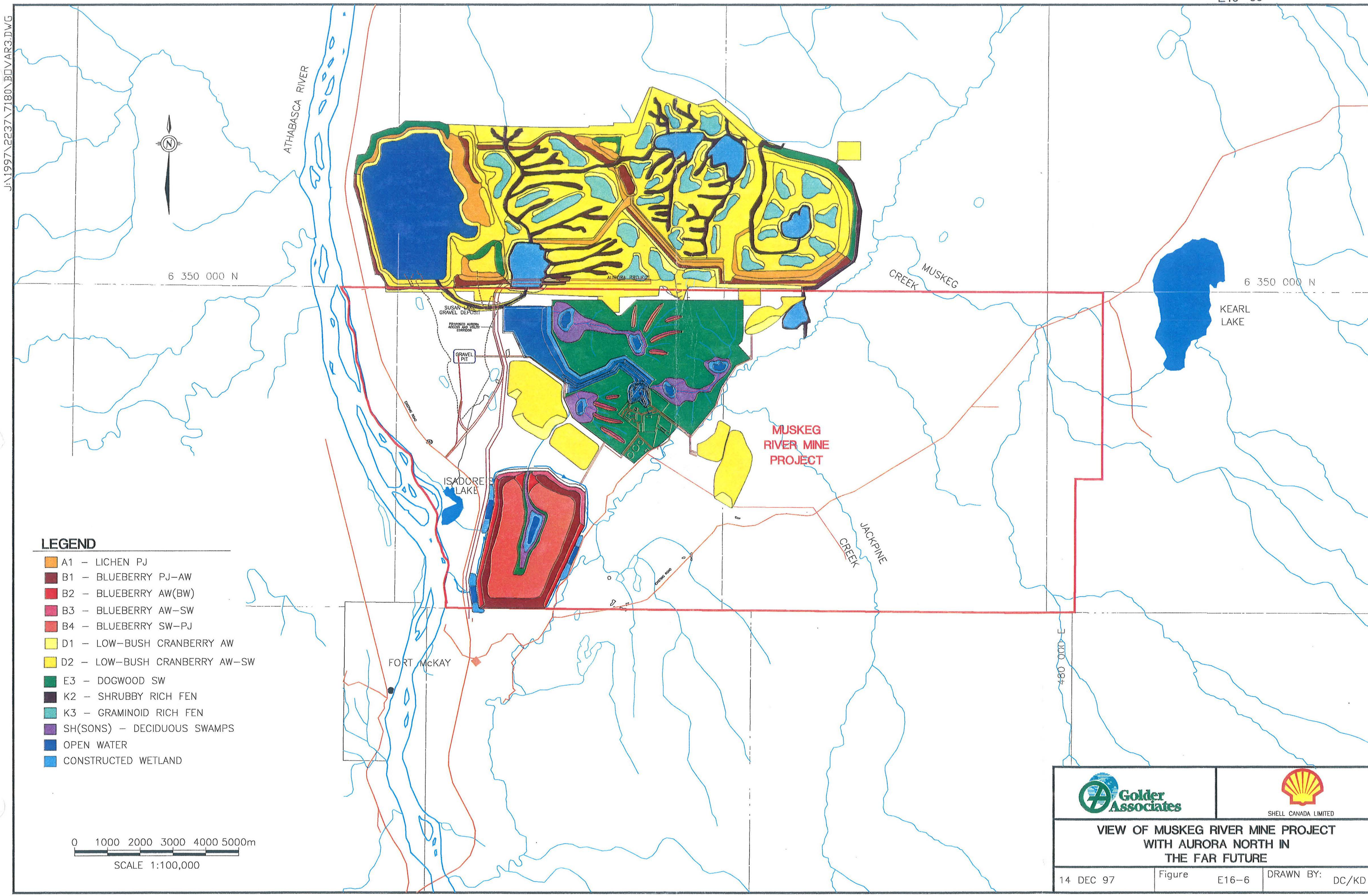
E16.6.14 Compatibility with Nearby Developments

The Project directly abuts the Aurora North mine project that has recently been approved for Syncrude Canada Ltd. A terrestrial vegetation map showing the proposed communities for both projects is shown on Figure E16-6.

The proposed revegetation plans for both projects are upland communities with wetlands dispersed throughout. The predominant vegetation community proposed for the Aurora North site is an aspen/white spruce dominated forest. White spruce communities will be established on north facing slopes while jack pine communities were selected for south-facing slopes.

The predominant landscape unit adjacent to the north lease boundary of the Project is the backfilled mine cells, the majority of which have CT deposits. A white spruce dominant, aspen subdominant community is anticipated to occupy the majority of these landforms. Exceptions are the constructed wetlands, riparian areas, and sand swales.

The second largest reclamation unit on the Project is the tailings settling pond. A series of jack pine/aspen, aspen, aspen/white spruce, and white spruce/jack pine is proposed for this area. On the northern slopes, an aspen/white spruce community is proposed. On the gently sloping interior of this reclamation unit, a community of white spruce/jack pine is proposed. As moisture conditions improve, a white spruce dominated forest will develop separating the drier areas from the riparian (deciduous swamp) and the constructed wetlands.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MUSKEG RIVER MINE PROJECT
ISADORE'S LAKE
JACKPINE CREEK
FORT McKAY
480 000 E
LEGEND
A1 – LICHEN PJ
B1 – BLUEBERRY PJ–AW
B2 – BLUEBERRY AW(BW)
B3 – BLUEBERRY AW–SW
B4 – BLUEBERRY SW–PJ
D1 – LOW-BUSH CRANBERRY AW
D2 – LOW-BUSH CRANBERRY AW–SW
E3 – DOGWOOD SW
K2 – SHRUBBY RICH FEN
K3 – GRAMINOID RICH FEN
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OPEN WATER
CONSTRUCTED WETLAND
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SCALE 1:100,000
Golder Associates
SHELL CANADA LIMITED
VIEW OF MUSKEG RIVER MINE PROJECT WITH AURORA NORTH IN THE FAR FUTURE
14 DEC 97
Figure E16-6
DRAWN BY: DC/KD

In general, the vegetation community proposals for both projects compliment each other quite well. However, detailed planning for drainage and community transitions will be necessary where the projects abut each other.

E16.7 End Land Use Potential

Maintenance of traditional land uses implies that the land is stable (in terms of erosion) and provides for a comparable diversity of wildlife usages (i.e., not just moose). Since wildlife diversity depends largely on access to riparian areas, a key issue here is the nature of the wetlands and drainage streams in the reclaimed landscape compared with the pre-development landscape. This comparison is favourable to an increase in wildlife numbers and wildlife diversity since the reclaimed wetlands will be more accessible to wildlife (i.e., better drainage). Land will be of the marsh-type rather than bog-type. Marsh wetlands are more nutrient-rich since they drain substantial catchment areas as compared with bog/fens which are fed primarily (if at all) from nutrient-poor groundwater. In addition, upland areas in the reclaimed landscape will be less isolated (i.e., less surrounding areas of poorly drained land) and this will likely enhance the terrestrial habitat. For these reason, it is likely that traditional land uses, most notably fur trapping but also berry picking and as others, will be enhanced in the reclaimed landscape.

E16.8 Monitoring and Research Programs

Ongoing monitoring and research is necessary to address issues have been identified in developing this Closure Plan and because it is recognized that closure planning is an iterative process responding to changes in regulatory guidelines, improved knowledge bases, further clarification of stakeholder goals, and other factors. Issues identified in this closure plan include:

- suitability of centre reject materials;
- CT release water characteristics;
- wetland retention;
- definition of the actual capability of amended soils;
- use of mineral soils as soil amendment;
- vegetation re-establishment and sustainability; and
- establishment and use of wildlife habitat.

Once active reclamation is complete and vegetation has been re-established, progress toward maturation of landscapes and ecosystems will be monitored to allow evaluation of the reclamation program, as well as to provide the basis for future submissions for reclamation certification. Practical criteria will be established which can serve as milestones in the maturation process (to determine whether long-term goals are likely to be achieved). The monitoring and research process will include continued refinement and application of the Oil Sands Reclamation Performance Assessment Framework as one method for evaluation of the success of reclamation plans and process.

Monitoring is the foundation of adaptive management, providing on-going feedback to adjust future plans and methods as well as establishing and directing the kinds of research required to mitigate unresolved issues. Vegetation and soil characteristics in reclaimed areas will be monitored each year. The monitoring program will consist of annual vegetation cover assessment and soil sampling on areas reclaimed within the past three to four years, followed by detailed assessment and sampling of all reclaimed areas every fifth year.

The proposed Closure Plan provides considerable flexibility and opportunities to address specific future land uses including wildlife habitat, traditional land use, recreation and possibilities for commercial forest production. It is anticipated that future large-scale demonstrations followed by monitoring of fully-reclaimed areas will establish the basis to determine the final end use of the reclaimed land. Shell has, and will, participate in existing reclamation research strategies conducted by the existing oil sands mines.

Suitability of Centre Rejects Material

Centre reject is contained within the ore body. The chemical properties of the centre reject may retard reclamation. Shell will work with other companies to address this concern.

CT Release Water

CT release water will contain both organic and inorganic (mostly salts) compounds. Wetlands will allow for the degradation of the organic compounds. The salts contained in the CT water may lead to a soil salinity problem. Joint industry efforts will address this potential concern.

Soils

Performance of reconstructed soils is a key element of erosion control and ecosystem sustainability. Shell will monitor trends by comparing key parameters with reference soils including:

- pH
- salt content (as indicated by electrical conductivity or EC)
- macronutrient levels
- organic carbon content

- nitrate-nitrogen
- phosphorus
- potassium
- sulphate-sulphur

This monitoring will allow evaluation and demonstration of the application of the Land Capability Classification for Forest Ecosystems in the Oil Sands Region (Leskiw 1996). It will also provide supporting scientific data for the capability rating system assigned to the reclamation soil types as discussed previously.

Vegetation

The reclamation monitoring program will include an annual program specifically to assess herbaceous vegetation growth as well as physical and chemical properties of soil. The reclamation program will include a routine maintenance component involving fertilization of revegetated areas, erosion repair and control, and planting of areas with poor performance. Annual assessments of tree and shrub survival and growth have been conducted in areas where known numbers of seedlings were planted. Results of these programs will be reported to AEP in annual Conservation and Reclamation Reports. These monitoring programs will be extended sequentially into newly reclaimed areas.

Wildlife

Assessment of the sustainability of wildlife in re-established ecosystems requires consideration of soil and vegetation development, forecasts on the evolution of revegetated areas to mature systems and re-entry of wildlife. Monitoring of wildlife use of reclaimed landscapes will provide feedback on the success of reclamation and revegetation techniques. Previous experience has shown that wildlife will begin using reclaimed areas as soon as a herbaceous vegetation cover is established. The diversity of wildlife using the reclamation sites will increase over time as more food and cover become available. Monitoring of wildlife species representative of the various successional stages will indicate the degree to which reclaimed areas are developing into productive sustainable ecosystems.