Shell Canada Limited

application for the approval of

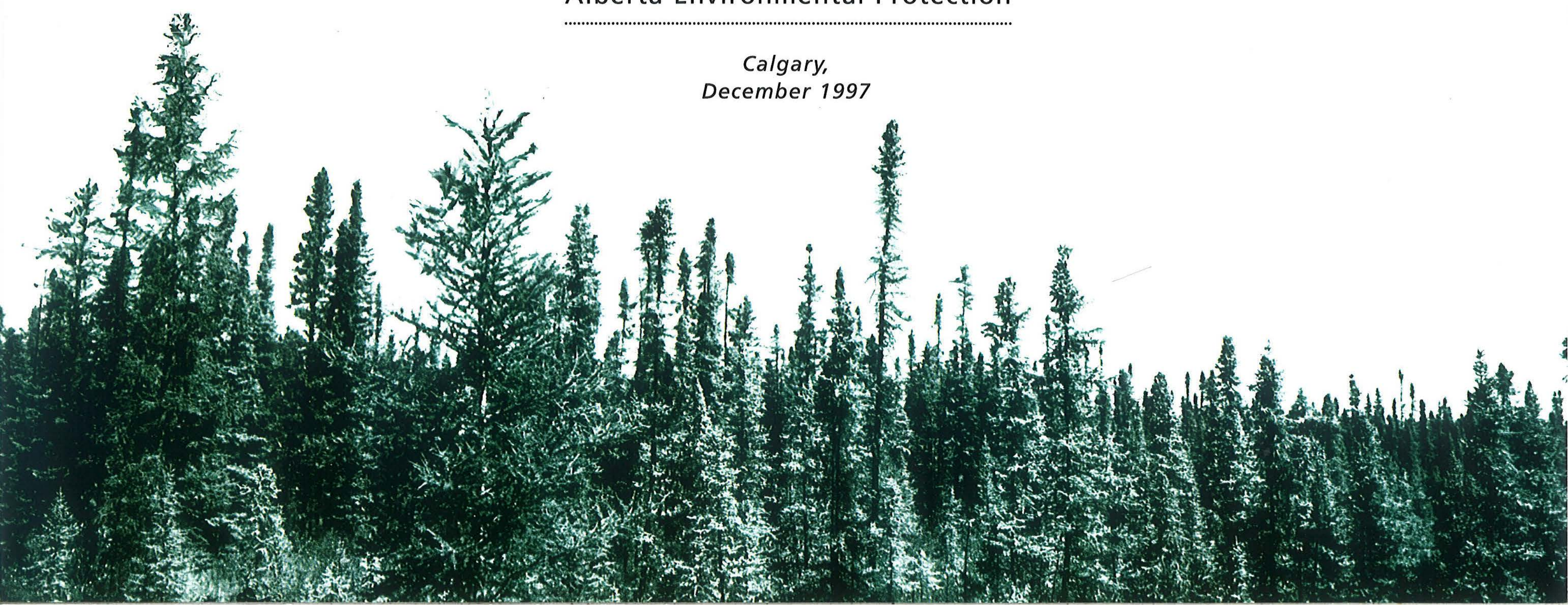
MUSKEG RIVER MINE PROJECT

Volume 2 • Environmental Impact Assessment

Biophysical and Historical Resources Baseline Conditions

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

Calgary,
December 1997



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

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

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

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

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

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

Volume 1 - EUB/AEP Joint Application
Volume 2 - Includes; Introduction (A), Project Description (B), Consultation (C) and Environmental Settings (D)
Volume 3 - Impact Assessments (E)
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

Volume 1 - EUB/AEP Joint Application
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Volume 5 - Socio-Economic Baseline, Impact Assessment and Cumulative Effects Assessment

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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A INTRODUCTION

A1 MUSKEG RIVER MINE PROJECT OVERVIEW

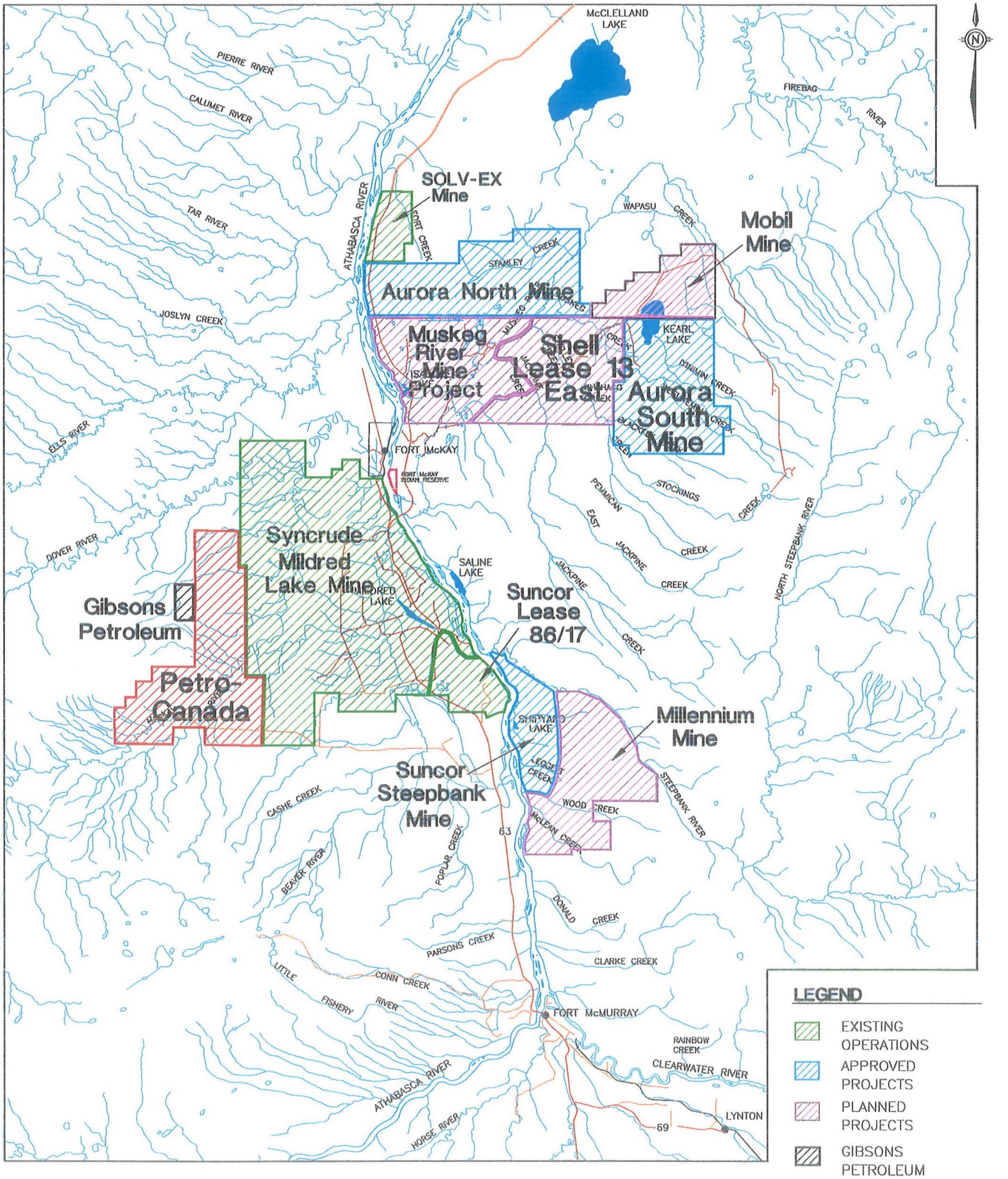
The Muskeg River Mine Project includes an oil sands mine, extraction operations and associated infrastructure on Lease 13, an oil sands lease on the east side of the Athabasca River. The project plant site will be approximately 70 km north of Fort McMurray, Alberta and approximately 12 km northeast of Fort McKay, a community located on the west side of the Athabasca River. Shell Canada Limited (Shell) and The Broken Hill Proprietary Company Limited (BHP) are parties to a Feasibility agreement for assessing and advancing the development of an oil sands project on Lease 13.

The location of the Muskeg River Mine Project (the Project) is shown relative to other existing or planned oil sands developments in Figure A-1. The Project facilities will be located in the portion of Lease 13 which is east of the Athabasca River and west of the Muskeg River, as shown in Figure A-2. Syncrude Canada Ltd.'s recently approved Aurora North Mine is located on the leases to the immediate north of the Muskeg River Mine.

A2 MUSKEG RIVER MINE PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Integral to the application for development of an oil sands mining and extraction development is the completion of an Environmental Impact Assessment (EIA). The Muskeg River Mine Project Application to Alberta Energy Utilities Board and Alberta Environmental Protection (the Application) includes five volumes, of which four comprise the EIA. Volume 1 of the Application provides a detailed review of the Project, the history of Lease 13 and information on Shell and BHP, as development proponents. The balance of the Application comprises the EIA volumes, including:

- Volume 2 - EIA - Biophysical and Historical Resources Baseline Conditions
- Volume 3 - EIA - Biophysical and Historical Resources Impact Assessment
- Volume 4 - EIA - Biophysical and Historical Resources Cumulative Effects Assessment
- Volume 5 - Socio-Economic Baseline and Impact Assessment and Cumulative Effects Assessment



0 5 10 15 20 25km

SCALE 1:500,000

REFERENCE

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

Golder Associates

SHELL CANADA LIMITED

EXISTING AND POTENTIAL OIL SANDS DEVELOPMENT IN REGIONAL STUDY AREA

13 DEC 97	Figure A–1	DRAWN BY: RFM

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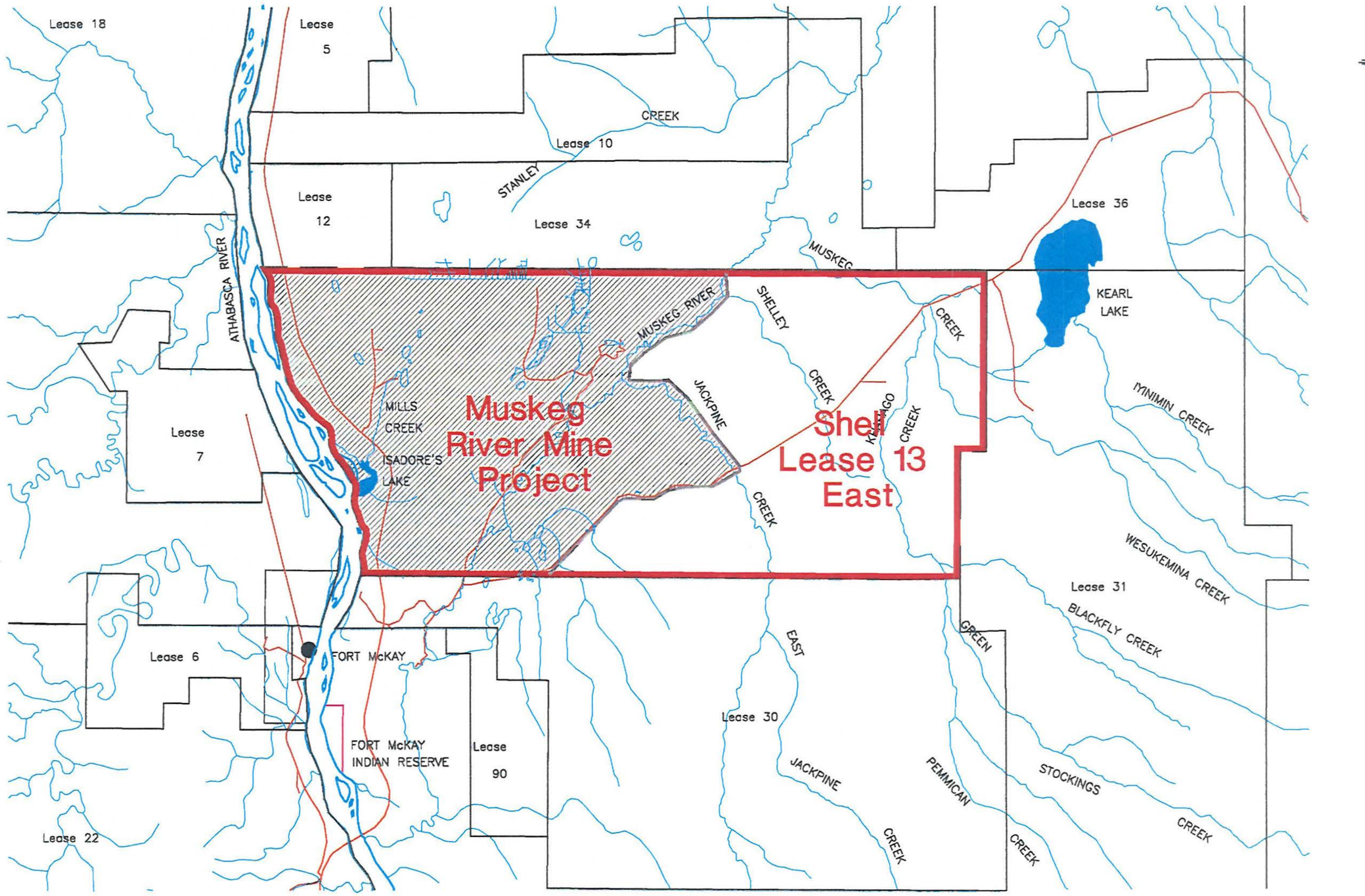

REFERENCE

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

0 2000 4000 6000 8000 10000(m)

SCALE 1:200,000

Golder Associates

SHELL CANADA LIMITED

PROJECT DEVELOPMENT AREA FOR MUSKEG RIVER MINE PROJECT EIA

13 DEC 97	Figure A-2	DRAWN BY: RFM

A3 REGIONAL COOPERATION

The Project has been planned with the goal of actively exploring opportunities for cooperation which will enhance economic return and mitigate any potentially adverse environmental, socio-economic and cultural impacts. This cooperative approach is focused on fostering resource conservation goals and promoting environmental protection.

The regional approach for the Project involved two main considerations:

- Developments associated with the Muskeg River and its watersheds. These developments include:
    - Muskeg River Mine Project
    - Syncrude Aurora North Mine
    - Mobil Kearl Mine
    - Syncrude Aurora South Mine
    - Shell Lease 13 East
- Developments associated with other projects in the Athabasca Oil Sands area, including:
    - Syncrude Mildred Lake
    - Suncor Lease 86/17 and Steepbank Mine
    - Suncor Project Millennium
    - Petro-Canada MacKay River
    - Gibsons Petroleum UTF
    - SOLV-EX

Also included in the regional cooperative is consideration of other developments in the area, including forestry and other mineral extraction operations.

Details on the regional cooperation approach integral to the Muskeg River Mine Project are provided in Section 1.7, Volume 1 of the Application.

A4 APPROVALS REQUIRED FOR THE MUSKEG RIVER MINE PROJECT

This EIA supports Shell's application to the Alberta Energy Utilities Board (EUB) for the proposed Project. This EIA meets obligations under the *Alberta Environmental Protection and Enhancement Act*, the *Oil Sands Conservation Act* and applicable federal regulations to provide information relating to the potential environmental effects of the development, operation and reclamation, and closure of the Project. It also discusses measures that will be employed to mitigate impacts, and provides an assessment of the importance of potential environmental changes.

A4.1 Terms of Reference

This EIA report was prepared in accordance with the Final Terms of Reference provided to Shell by Alberta Environmental Protection (AEP) on November 7, 1997 (AEP 1997a, Appendix I). The requirements in the EIA Terms of Reference have been cross-referenced to the information provided in the EIA and in Volume 1 of the Application. The Terms of Reference cross-reference list has been slotted after the Table of Contents and Abbreviations at the start of Volumes 2, 3 and 4.

A4.2 Approvals Requested

Shell is applying for approval for the construction, operation and reclamation, and closure of the Muskeg River Mine Project. The project includes site preparation, mining, extraction, bitumen transport and associated infrastructure, all of which are described in Volume 1 of the Application. Shell also seeks approval for the reclamation activities to be undertaken in association with the Project. Further details on required approvals for the Project are provided in Section 1.8, Volume 1 of the Application.

A4.2.1 Approvals Requested of the Energy and Utilities Board

In this application, Shell seeks Energy and Utilities Board (EUB) approval for the proposed scheme or operation for the recovery of bitumen from oil sands from the Project, including:

- Lease development, mining, on-site waste management and reclamation activities in respect of the Application Area, pursuant to Section 10 of the *Oil Sands Conservation Act*, (1983, c. O-5.5) and pursuant to the Oil Sands Conservation Regulation, (Alta. Reg. 76/88) including Sections 2, 23, 24, 25 and 26 thereof.
- Construction and operation of an extraction plant and associated utilities for the preparation of bitumen for transportation via a bitumen pipeline for processing at the Scotford refinery in Fort Saskatchewan.
- Shipment of bitumen equivalent from the Project to such approved processing facilities as may be authorized to accept oil sands or bitumen equivalent for processing, from time to time, pursuant to Section 10 of the *Oil Sands Conservation Act*.

A4.2.2 Approvals Requested of Alberta Environmental Protection

Shell hereby requests that an approval be issued pursuant to Section 63 of the *Environmental Protection and Enhancement Act,* (S.A. 1995, c.E-13.3) and the Approvals Procedure Regulation (Alta. Reg. 113/93), in respect of the following activities to be carried out in conjunction with the Project, as described in this Application:

- Opening up, operation and reclamation of the Muskeg River Mine Project oil sands site.
- Construction, operation and reclamation of an extraction treatment plant and associated utilities with a nominal capacity of 8.7 million m^3 per annum of bitumen equivalent.
- Oil sands site infrastructure, including but not limited to works, buildings, structures, facilities, equipment, apparatus, mechanism, instrument or machinery belonging to or used in connection with the proposed mine, extraction and utilities plant, industrial landfill, overburden disposal sites, reclamation materials storage, access roads, telecommunication lines and other infrastructure as detailed in Volume 1 of the Application.

Shell also requests of AEP, under Section 11.1 of the *Water Resources Act*, approval for the collection and diversion of surface waters as described in Section 16 of Volume 1 of the Application, including:

- impoundment of surface and groundwater for process water use;
- diversion of natural surface waters around or away from the lease area;
- muskeg dewatering;
- process water ditching;
- granular resource dewatering; and
- mine depressurization.

The legal description of the area to be covered by this approval is provided in Table A-1.

Table A-1 **Legal Description of the Project Area**

Township	Range	Section	Meridian (west of)
95	11	24, 25, 36	4th
95	10	1 - 36	4th
95	9	7, 8, 17 - 20, 29 - 32	4th

A4.2.3 Other Required Approvals

The Project will also require additional agreements, approvals or licences from the provincial government, which will be applied for in a timely manner as development proceeds. Additional approvals required are detailed in Volume 1, Section 1 (Table 1-2) of the Application.

A5 PURPOSE OF THE ENVIRONMENTAL IMPACT ASSESSMENT

This Environmental Impact Assessment (EIA) presents a summary of the environmental effects associated with construction, operation and reclamation, and closure of the Project. The EIA comprises Volumes 2 to 5 of the Application for approval of the Project, with Volumes 2, 3 and 4 focused on the biophysical and historical resources and Volume 5 focused on socio-economics. Volume 1 of the Application includes a detailed description of the Project as well as an application for the *Alberta Environmental Protection and Enhancement Act* 10-year environmental operating approval. Also included in Volume 1, Section 10 is a summary of the results of the EIA.

The purpose of the EIA is to present information and analyses that meet the requirements identified in EIA Terms of Reference for the Project, as provided by Alberta Environmental Protection (AEP 1997a). The final Terms of Reference is provided in Volume 2, Appendix I of the Application. The EIA focuses on oil sands development issues and specific concerns raised during the Project's extensive public consultation process.

The key information requirements for an Environmental Impact Assessment are: a comprehensive knowledge of the Project; an understanding of the issues and concerns raised by the public, regulators and other Project stakeholders; and an inventory of biophysical and historical resources. The Project EIA includes:

- A description of the Project activities that have the potential to affect the environment, detailed in Volume 1 of the Application and summarized in Section B, Volume 2 of the Application.

- A list of issues and concerns raised during Project consultation efforts, summarized in Section C, Volume 2 of the Application. Section 12, Volume 1 of the Application details the public consultation program completed as an integral part of preparing the Application for the Project.

- A summary of the existing (baseline) biophysical and historical conditions in the Project area, presented in Section D, Volume 2 of the Application.

- A discussion of the potential impacts of the Project on biophysical and historical conditions, presented in Section E, Volume 3 of the Application.

- A summary of the potential cumulative effects associated with the Project and with Regional Development, discussed in Sections F and G, Volume 4 of the Application.

- Details on the socio-economic baseline conditions for the Project, as well as the socio-economic impact assessment, including cumulative effects, presented in Volume 5 of the Application.

A5.1 Quality Assurance/Quality Control

A detailed quality assurance/quality control (QA/QC) plan was designed to ensure data quality for the collection, analysis and management of a range of information and samples for the Project EIA.

The QA/QC plan identified procedures that were implemented to ensure data were of sufficient quality to be used in support of the EIA.

A5.2 EIA Results

The results of the Project EIA have been summarized to provide information on the design features and mitigation activities that will be undertaken to reduce impacts related to the Project. Additionally, proposed monitoring programs that will be implemented to evaluate the effectiveness of design and mitigation efforts are described.

The residual impacts associated with the Project are summarized in Tables A-2 and A-3, including:

- the design features and mitigation measures, monitoring programs and planned participation in other regional initiatives that will be implemented by Shell to reduce potential impacts associated with construction and operation of the Project; and

- the Residual Impacts for environmental resources (biophysical and historical) and socio-economics.

The cumulative effects from development of the Muskeg River Mine Project are summarized for the environmental resources in the Introduction to Volume 4 of the Application and for socio-economics in Volume 5 of the Application.

Table A-2 Mitigation Measures and Residual Impacts for Biophysical and Historical Resources

Key Question/Environmental Issue	Mitigation/Monitoring	Residual Impact
AIR QUALITY ISSUES		
AQ-1 Will Muskeg River Mine Project Emissions Result in Exceedances of Ambient Air Quality Guidelines? AQ-2 Will Muskeg River Mine Project Emissions Result in Human Health Effects? AQ-3 Will Muskeg River Mine Project Emissions Result in the Deposition of Acid Forming Compounds That Exceed Target Loadings? AQ-4 Will Muskeg River Mine Project Emissions Result in the Formation of Ozone That Exceeds Air Quality Guidelines?	**Mitigation:** Fugitive PM Emissions: • Mitigation measures to reduce visible and other emissions associated with vegetation clearing will include: timber salvage to reduce required burning; burning when large fuel material has low moisture content; keeping burn piles free of dirt to minimize smoldering; and immediate cleanup of piles following the burn. Areas to be cleared will be minimized. • Mitigation to reduce particulate emissions associated with overburden removal include the selection of mine areas covered with shallow overburden. Shallow depths of overburden reduce fuel use and emissions from haul trucks. Overburden disposal areas will be revegetated to stabilize surfaces. • Roadways will be watered as required during warm, dry conditions to reduce particulate emissions. Water will not be used during winter for safety reasons. Occasionally, other dust suppression methods will be used on the roads. • The exterior surfaces of tailings settling ponds will be revegetated to stabilize sand surfaces.	**Construction / Operation:** • Fugitive PM emissions will result from vegetation clearing, overburden removal, road construction and use, mining activities and tailings management. The residual impacts will be **Negative** in direction, Low (overburden removal and mining activities) to Moderate (vegetation clearing, roads and tailings management) in magnitude, Long-Term in duration, Local in geographic extent (except for vegetation burning, which can be Regional) and Reversible. The degree of concern is **Low** to **Moderate**. • See Human Health Section E12 for analysis of human health effects. **Closure:** • No residual impacts are expected, therefore the degree of concern is Negligible.

Key Question/Environmental Issue	Mitigation/Monitoring	Residual Impact
Continuation of: **AQ-1** Will Muskeg River Mine Project Emissions Result in Exceedances of Ambient Air Quality Guidelines? **AQ-2** Will Muskeg River Mine Project Emissions Result in Human Health Effects? **AQ-3** Will Muskeg River Mine Project Emissions Result in the Deposition of Acid Forming Compounds That Exceed Target Loadings? **AQ-4** Will Muskeg River Mine Project Emissions Result in the Formation of Ozone That Exceeds Air Quality Guidelines?	NO_X Emissions: • Low NO_X burners will be installed on the stationary combustion sources at the plant site to reduce NO_X emissions. • Mine fleet vehicles with emission control technology will be selected to manage NO_X, VOC and PM emissions.	**Construction / Operation:** • Oxides of nitrogen emissions will result from combustion sources that are either stationary (e.g., boilers) or mobile (e.g., mine fleet). The residual impact will be **Negative** in direction, Low to Moderate in magnitude, Long-Term in duration, Local in geographic extent and Reversible. The degree of concern is **Low**. **Closure:** • No residual impacts are expected, therefore the degree of concern is Negligible.
	VOC Emissions: • Tailings solvent recovery (TSR) will reduce solvent loss to the pond and hence fugitive VOC emissions from the tailings settling pond. • Vapour control will reduce emission from the solvent and product storage tanks. **Monitoring:** • Periodic stack surveys for key sources to confirm NO_X emissions. • Ambient monitoring to confirm NO_X and PM_{10} in the vicinity of the mine. • Confirm fugitive VOC emissions from the mine and tailings settling pond. • Participate in the Southern Wood Buffalo Air Shed Management Zone for regional air quality and meteorology monitoring.	**Construction / Operation:** • Hydrocarbon and reduced sulphur emissions will result from volatilization associated with the tailings settling ponds, the extraction plant vents and from fugitive sources, such as exposed oil sands faces. The residual impact will be **Negative** in direction, Moderate (tailings settling pond and oil sands faces) and Low (vents) in magnitude, Long-Term (tailings settling pond and oil sands faces) to intermittent (deaerator vents) in duration, Local in regional extent and Reversible. The degree of concern is **Moderate**. **Closure:** • The presence of fugitive VOC emissions from a dry CT landscape is unknown. However, no residual impacts are expected, therefore the degree of concern is Negligible.
AQ-5 How Will Muskeg River Mine Project Greenhouse Gas Emissions (GHG) Compare to Those Associated With Conventional Production?	**Mitigation:** • The warm water extraction process will result in an energy efficient (low emissions) operation. An efficient mine operation will minimize ore truck haul distances. The selection of a high-grade/low overburden ore body, which minimizes the amount of material handled will minimize energy expenditure and GHG emissions.	**Construction / Operation:** • CO_2 emissions will result from combustion sources that are either stationary (e.g., boilers) or mobile (e.g., mine fleet). **Closure:** • Revegetation and reclamation will result in a carbon sink.

Key Question/Environmental Issue	Mitigation/Monitoring	Residual Impact
HYDROGEOLOGICAL ISSUES		
GW-1 Will the Muskeg River Mine Project Change Groundwater Levels and Groundwater Flow Patterns?	**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.	**Construction / Operation / Closure:** • The dewatering of overburden and depressurization of the Basal Aquifer will lower groundwater levels from their natural state. The residual impact will be **Negative** in direction, Low to Moderate in magnitude, Local in geographic extent, Medium to Long-Term in duration and the frequency is High. The degree of concern is **Low**.
GW-2 Will Groundwater Systems Re-establish After Mining and Reclamation?	**Monitoring:** • Monitoring of recovery of groundwater levels 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.	**Construction / Operation / Closure:** • 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. The residual impact will be **Neutral** in direction, Low to Moderate in magnitude, Local in geographic extent, Long-Term in duration and the frequency is High. The degree of concern is **Low**.
GW-3 Will the Muskeg River Mine Project Change Groundwater Quality?	**Mitigation:** • Potential mitigation of seepage impacts may be required if seepage was found to be flowing past the perimeter ditch through surficial aquifers to the Muskeg River. In this event, an appropriate method, such as an interceptor ditch between the river and the tailings settling pond, could be employed to collect tailings seepage before it reaches the Muskeg River. **Monitoring:** Monitoring of groundwater quality during operations and closure will be accomplished by installation of monitoring wells at selected	**Construction / Operation / Closure:** • 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 east of CT disposal pits, and on both sides of the tailings settling pond, will also be altered from its natural condition. The residual impact will be **Negative** in direction, Moderate to High in magnitude, Local in geographic extent, Long-Term in duration, Irreversible and of High frequency. The degree of concern is **Low** in the Basal Aquifer, and **Moderate** to **High** in unmined oil sands or surficial aquifers.

Key Question/Environmental Issue	Mitigation/Monitoring	Residual Impact
	sites. 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.	

Key Question/Environmental Issue	Mitigation/Monitoring	Residual Impact
SURFACE WATER ISSUES		
SW-1 Will the Muskeg River Mine Project Affect Flows and Water Levels in Receiving Streams, Lakes, Ponds and Wetlands?	**Mitigation:** • Maximize use of tailings and consolidated tailings porewater release, Basal Aquifer water, and site runoff for process water to minimize raw water withdrawal requirement from the Athabasca River. • 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 impacts of closed-circuit operations on the flows and water levels in Muskeg River and Mills Creek by maximizing diversion of natural runoff from undeveloped areas (no contact with oil sands) around the mining area to the receiving streams. • 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. **Monitoring:** • Monitor flows and water levels at selected sites. • participate in the Regional Hydrology and Climate Monitoring Program, including climate monitoring for correlating with, and interpreting of the results of streamflow monitoring.	**Construction:** • Alsands Drain: The degree of concern of the residual impacts is rated Negligible, although the flow changes in this man-made channel will be relatively High. • Muskeg River: The residual impacts will be **Negative** in direction, Low in magnitude, Local in geographic extent, Medium Term in duration, Reversible and of Intermittent frequency. The degree of concern is **Low**. • Mills Creek: The residual impacts will be **Negative** in direction, Low in magnitude, Local in geographic extent, Medium Term in duration, Reversible and of Continuous frequency. The degree of concern is **Low.** • Isadore's Lake: The changes in inflows to the lake will cause Negligible changes in lake water levels. • Athabasca River: The Project will have Negligible effects on the Athabasca River flows. **Operation:** • Alsands Drain: The degree of concern of the residual impacts is Negligible, although the flow changes in this man-made channel will be relatively High. • Muskeg River: Temporary release of the end pit lake water during the management period may moderately increase the river flows. The residual impacts will be **Negative** in direction, Low to High in magnitude, Local in geographic extent, Medium Term in duration, Reversible and of Continuous frequency. The degree of concern is **Low** to **Moderate**. • Mills Creek: Muskeg drainage and overburden dewatering will temporarily increase the streamflows. The residual impacts will be **Negative** in direction, Low to High in magnitude, Local in geographic extent, Medium Term in duration, Reversible and of Continuous frequency. The degree of concern is **Moderate**. • Isadore's Lake: The changes in inflows to the lake will cause Negligible changes in lake water levels. • Athabasca River: The Project will have Negligible effects on

Key Question/Environmental Issue	Mitigation/Monitoring	Residual Impact
		the Athabasca River flows. **Closure:** • Alsands Drain: The degree of concern of the residual impacts is Negligible, although the flow changes in this man-made channel will be Low to High. • Muskeg River: The residual impacts will be **Negative** in direction, Low in magnitude, Local in geographic extent, Long Term in duration, Irreversible and of Continuous frequency. The degree of concern is **Low**. • Mills Creek: Surface runoff to the creek will be reduced. The residual impacts will be **Negative** in direction, Moderate in magnitude, Local in geographic extent, Long Term in duration, Irreversible and of Continuous frequency. The degree of concern is **Moderate**. • Isadore's Lake: The changes in inflows to the lake will cause Negligible changes in lake water levels. • Athabasca River: The Project will have Negligible effects on the Athabasca River flows.
SW-2 Will the Muskeg River Mine Project Affect Water Balance of Nearby Lakes, Ponds, Wetlands and Streams?	**Monitoring:** • Monitor water levels and outflows at Kearl Lake as part of RAMP.	**Construction / Operation / Closure:** • The degree of concern of the Project residual impacts on the Kearl Lake water balance is Negligible, because the Basal Aquifer depressurization will cause Negligible changes to the lake outflows.
SW-3 Will the Muskeg River Mine Project Affect Basin Sediment Yields and Sediment Concentrations in Receiving Streams?	**Mitigation:** • Minimize incremental sediment loads to the Muskeg River by routing muskeg drainage, overburden dewatering and runoff from site clearing and overburden stripping operations to sedimentation ponds before releasing to the receiving streams. • Follow regulatory guidelines and best management practices to minimize erosion and sediment loading during site clearing and construction of pipeline crossings. • Provide a minimum of 100 m buffer zone between the mining footprint and the	**Construction:** • The degree of concern of the Project residual impacts on the streamflow sediment concentrations in Muskeg River and Mills Creek is Negligible. **Operation:** • Muskeg drainage and overburden dewatering during operation will increase channel erosion in Mills Creek. A temporary large increase of the Muskeg River flows during the end pit lake management period will increase channel erosion in Muskeg River. The residual impacts will be **Negative** in direction, Negligible to Low in magnitude, Local in geographic extent, Medium Term in duration, Reversible and of Continuous frequency.

Key Question/Environmental Issue	Mitigation/Monitoring	Residual Impact
	channels of Muskeg River and Jackpine Creek. • Provide erosion protection measures to minimize erosion of the facilities located in the 100-year flood risk limits. • Construct road ditches to collect and route surface runoff from disturbed areas to polishing ponds before release to receiving streams. • Revegetate areas disturbed during construction by seeding and mulching. • Provide erosion protection measures such as riprap at river crossing embankments. **Monitoring:** • Monitor streamflow sediment concentrations at selected sites.	The degree of concern is **Low**. **Closure:** • The increase of the Muskeg River flows after closure will be small. The residual impacts will be **Negative** in direction, Low in magnitude, Local in geographic extent, Long Term in duration, Irreversible and Continuous. The degree of concern is **Low**.
SW-4 Will the Muskeg River Mine Project Affect Channel Regimes of Receiving Streams?	**Mitigation:** • The measures to minimize increases of flows in receiving streams listed under Key Question SW-1 also help minimize channel erosion potential and thus minimize changes in channel regimes of receiving streams.	**Construction / Operation / Closure:** • Increased streamflows in Muskeg River and Mills Creek will cause small increases in the channel erosion rates. The degree of concern of the Project residual impacts on the channel regimes of Muskeg River and Mills Creek is Negligible.
SW-5 Will the Muskeg River Mine Project Change the Open-Water Areas Including Lakes and Streams?	**Mitigation:** • Create closure reclamation drainage systems consisting of drainage channels, shallow lakes/wetlands and an end pit lake.	**Construction / Operation:** • The Project will displace a small number of shallow lakes/ponds in the Project area. The residual impacts will be **Negative** in direction, Low in magnitude, Local in geographic extent, Medium Term in duration, Reversible and Continuous. The degree of concern is **Low**. **Closure:** • The reclaimed landscape and drainage systems will provide larger open-water areas of streams, wetlands and lakes in the Project area and thus replace the open-water areas lost during construction and operation. The

Key Question/Environmental Issue	Mitigation/Monitoring	Residual Impact
		degree of concern of this impact is Negligible.
SW-6 Will the Muskeg River Mine Project Affect Landscape and Drainage System Sustainability After Closure?	**Mitigation:** • All the reclaimed surfaces will be covered with reclamation material consisting of organic and mineral soils to support vegetation. Sand ridges will be constructed 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 built with drainage networks characteristic of natural systems. Drainage networks 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. 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.	**Closure:** • A reclamation drainage plan has been designed for the Project to develop a long term reclamation landscape and drainage systems on closure. The residual impacts will be **Negative** in direction, Low in magnitude, Local in geographic extent, Long Term in duration, Irreversible and Continuous. The degree of concern is **Low**.

Key Question/Environmental Issue	Mitigation/Monitoring	Residual Impact
	Monitoring: • A program will be designed for monitoring flows and water quality from the sedimentation ponds.	

Key Question/Environmental Issue	Design Feature/Mitigation/Monitoring	Residual Impact
WATER QUALITY ISSUES		
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?	**Mitigation:** • Perimeter ditches around the tailings settling pond will penetrate to an underlying low permeability layer. Seepages will be collected and pumped back into the pond during operation; this will effectively prevent seepages from progressing beyond this point. • CT deposited below grade to reduce seepage. • Water from CT will be recycled into the closed-circuit system during operation. • At closure, the perimeter ditch will drain to wetlands before discharging to the Athabasca River. • Wetlands will be developed on CT deposits and reclaimed tailings settling pond. • After operation, sand and CT seepage water will be channeled to the end pit lake for remediation. **Monitoring:** • A water quality monitoring program will be developed in conjunction with RAMP.	**Construction / Operation / Closure:** • Although background levels of several metals exceed water quality guidelines in the Athabasca and Muskeg rivers, no exceedances of water quality guidelines for aquatic life are predicted to occur as a result of the Project. The degree of concern is Negligible. • Exceedances of human health water quality guidelines for two PAH compounds were predicted to occur as a result of end pit lake discharges in the Muskeg River. The residual impact will be **Negative** in direction, Low in magnitude, Local in geographic extent, Medium-Term in duration, Reversible, and of Medium (several years) frequency. The degree of concern is **Low**. Further evaluation by Human Health Section E12 eliminated these compounds as a concern. • No acute or chronic toxicity guideline exceedances are predicted to occur in the Athabasca and Muskeg rivers. The degree of concern is Negligible. • Isadore's Lake water quality will not be affected.
WQ-3 Will Operational and Reclamation Water Releases From the Project Alter the Temperature Regime of the Muskeg River?	**Mitigation:** • Discontinue filling end pit lake during winter months to control rate of discharge to Muskeg River. • Control end pit lake discharges during critical fish life stages, if necessary. **Monitoring:** • Temperature regime of Muskeg River will be monitored in selected years as part of RAMP.	**Construction / Operation / Closure:** • Adjustment of timing of end pit lake water releases will result in no residual impacts on temperature in the Muskeg River, with the potential exception of reduced diurnal fluctuation. The degree of concern is Negligible for cooling in open water season and slower seasonal temperature changes. It is Undetermined for reduced diurnal fluctuation.
WQ-4 Will Muskeg Dewatering Activities Associated With the Project Reduce Dissolved Oxygen Concentrations to Unacceptable Levels in the Muskeg River?	**Mitigation:** • Sedimentation ponds will be constructed to collect muskeg and overburden (operational) waters.	**Construction / Operation:** • Waters will be controlled and treated if necessary to ensure no residual impacts on dissolved oxygen concentrations. Degree of concern is Negligible.

Key Question/Environmental Issue	Design Feature/Mitigation/Monitoring	Residual Impact
	• Aerate sedimentation pond, if necessary. **Monitoring:** • The BOD of these waters will be monitored before release.	**Closure:** • Operational waters will no longer be discharged at closure, hence no impact is predicted. The degree of concern is Negligible.
WQ-5 Will PAHs in Operational and Reclamation Waters Released From the Project Accumulate in Sediments and be Transported Downstream?	**Mitigation:** • Sedimentation ponds and wetlands will be constructed to intercept waters and allow settling of particulates. **Monitoring:** • Participation in regional aquatics monitoring program (RAMP).	**Construction / Operation / Closure:** • No accumulation and transport of PAHs in sediments is anticipated, however some uncertainty exists. The residual impact will be **Negative** in direction, Negligible to Low in magnitude, Local in geographic extent, Medium-Term in duration, Reversible and of Moderate frequency. The degree of concern is **Negligible** to **Low**.
WQ-6 Will End Pit Lake Water be Toxic Prior to Discharge to the Muskeg River?	**Mitigation:** • Filling of the end pit lake will be controlled at such a rate that lake discharges will be non-toxic. • 20% littoral zone to enhance biological productivity.	**Construction / Operation / Closure:** • Discharges from end pit lake will not be toxic. The degree of concern is Negligible.
WQ-7 Will Accidental Water Releases Occur That Could Affect Water Quality in the Athabasca and Muskeg Rivers?	**Mitigation:** • Emergency spill response manual. • Spill response training. • Best management practices.	**Construction / Operation / Closure:** • Degree of concern is rated as Negligible.
WQ-8 Will Changes in Water Quality Result From Acidifying Emissions?	**Monitoring:** • Shell will cooperate with other operators in the region to more fully understand acid deposition.	**Construction / Operation / Closure:** • Questions remain about spring runoff impact of acidification on water quality. The residual impact will be **Negative** in direction, Undetermined in magnitude, Local in geographic extent, Medium-Term in duration, Reversible and of Medium frequency. The degree of concern is **Undetermined**.

<table>
<tr><th>Key Question/Environmental Issue</th><th>Design Feature/Mitigation/Monitoring</th><th>Residual Impact</th></tr>
<tr><td colspan="3">AQUATIC RESOURCES ISSUES</td></tr>
<tr><td>AR-1 Will Muskeg River Mine Project Activities Change Fish Habitat?</td><td>Mitigation:
• Avoid critical sports fish habitat in the Muskeg River or Jackpine Creek.
• See design features for minimizing sediment loading (SW-3).
• See mitigation to prevent changes in temperature regime of Muskeg River (WQ-3).
• Aquatic habitat will be established in the reclaimed landscape including streams, wetlands and an end pit lake. Fish may be introduced into the end pit lake.

Mitigation:
• Habitat monitoring of Isadore's Lake and Muskeg River will be undertaken as part of RAMP.</td><td>Construction / Operation:
• No residual impacts on northern pike, Arctic grayling, longnose sucker, walleye or lake whitefish habitat are anticipated during the life of the Project. The degree of concern is Negligible.
• Several small ponds will be lost during construction. The Alsands drainage system, which covers 3.4 ha, will be removed in operation and replaced at closure when it will form the outlet channel from the end pit lake. Habitat of equivalent quality and quantity will be replaced during operation. The residual impact will be Negative in direction, Low in magnitude, Medium-Term in duration, Local in geographic extent, Reversible and once in frequency. The degree of concern is Low.

Closure:
• Positive impact through creation of sport and forage fish habitat in reclaimed landscape (wetlands, streams and end pit lake).</td></tr>
<tr><td>AR-2 Will Muskeg River Mine Project Activities Result in Acute or chronic Effects on Fish?</td><td>Mitigation:
• See mitigation features for WQ-1 and WQ-2.</td><td>Construction / Operation / Closure:
• No residual acute or chronic effects on fish are anticipated. The degree of concern is Negligible.</td></tr>
<tr><td>AR-3 Will Muskeg River Mine Project Activities Change Fish Tissue Quality?</td><td>Mitigation:
• No operational discharges of process-affected water.
• See features for WQ-1 and WQ-2.
Monitoring:
• Monitoring of fish tissue for bioaccumulation through RAMP.
• Only monitor for tainting if tainting studies indicate potential for tainting from CT water.</td><td>Construction / Operation / Closure:
• No residual acute or chronic effects on fish are anticipated. The degree of concern is Negligible.</td></tr>
</table>

Key Question/Environmental Issue	Design Feature/Mitigation/Monitoring	Residual Impact
AR-4 Will Muskeg River Mine Project Activities Change Fish Abundance?	**Monitoring:** • Monitoring of fish abundance as part of RAMP.	**Construction / Operation / Closure:** • No residual effects on fish abundance are anticipated. The degree of concern is Negligible.
AR-5 Will Muskeg River Mine Project End Pit Lake Support a Viable Ecosystem?	**Mitigation:** • See design features under WQ-6. • See mitigation under WQ-6. **Monitoring:** • Monitoring of fish health, tainting, bioaccumulation and fish populations. Monitoring plans will be finalized once end pit lake design is final.	**Construction / Operation:** • The end pit lake will start to discharge to the Muskeg River near the end of operation (2029). This rules out effects during these phases. The degree of concern is Negligible. **Closure:** • End pit lake is expected to support a viable aquatic ecosystem, however additional information is required to confirm this; the impact is Undetermined in direction and magnitude.

Key Question/Environmental Issue	Design Feature/Mitigation/Monitoring	Residual Impact
	ECOLOGICAL LAND CLASSIFICATION ISSUES	
ELC-1 Will the Activities From the Muskeg River Mine Project Result in a Loss or Alteration of ELC Units?	**Monitoring:** • Site clearing for the mine, tailings settling pond, overburden disposal areas, reclamation materials storage areas, roads, plant site, linear infrastructure (e.g., roads and pipelines) and other associated facilities (e.g., ponds and drainage structures) has been designed to minimize area disturbed. • Conduct a reclamation monitoring program to evaluate the re-establishment of ELC units.	**Construction / Operation:** • Some ELC units will be lost or altered due to site clearing and overburden stripping/disposal. The residual impact will be **Negative** in direction, Low in magnitude, Local in geographic extent, Medium-Term in duration, Reversible and of Low frequency. The degree of concern is **Low to High.** **Closure:** • Vegetation communities will be reclaimed using reclamation materials taken from the Project area. Plantings from intact native vegetation communities as well as supplemental planting with native species will be undertaken. Some ELC units can be reclaimed, while others (e.g., patterned fens) cannot be replaced with current technologies. The residual impact will be **Neutral** in direction, Low in magnitude, Long-Term in duration, Reversible and of Low Frequency. The degree of concern is **Low**.
ELC 2 Will the Activities From the Muskeg River Mine Project Change Biodiversity?	**Monitoring:** • Site clearing for tailings settling pond, overburden disposal sites, muskeg storage areas, end pit lake and linear infrastructure (i.e., roads and pipelines) has been designed to minimize area disturbed. • Reclaim disturbed areas sequentially as development proceeds. • Develop criteria and conduct a program to monitor the change in biodiversity at the landscape level.	**Construction / Operation:** • ELC units will be lost/altered as a result of site clearing and overburden stripping/disposal. The residual impact will be **Negative** in direction, Low in magnitude, Local in geographic extent, Medium-Term in duration, Reversible and of Low frequency. The degree of concern is **Low to High**. **Closure:** • Vegetation communities will be reclaimed with stored reclamation materials, using native seed mixes and cuttings from intact native vegetation communities. The residual impact will be **Neutral** in direction, Low in magnitude, Long-Term in duration, Reversible and of Low Frequency. The degree of concern is **Low**.

Key Question/Environmental Issue	Design Feature/Mitigation/Monitoring	Residual Impact
TERRAIN AND SOILS ISSUES		
TS-1 Will the Activities From the Muskeg River Mine Project Result in Loss or Alteration of Terrain and Soils ?	**Mitigation:** • Conduct phased reclamation over the life of the project. • If direct placement of salvaged reclamation material is not possible it will be stored in temporary reclamation material storage areas. • Naturally developed terrain units and soil cover will be removed during Project development and replaced with recontoured landforms and a reclamation soil mix. **Monitoring**: • Participation in RACQQ Environmental Effects Monitoring for evaluating acidification of sensitive soils from operation emissions.	**Construction / Operation:** • The degree of acidification is Undetermined. • The impact of construction and operations will be **Negative** in direction, High in magnitude, Local in extent, Long-Term in duration and Irreversible. The degree of concern is **Moderate** to **High**.
TS-2 Will Reclamation for the Muskeg River Mine Project Change the Distribution of Terrain and Soils ?	**Mitigation:** • Reconstructed landforms and reclamation materials soil cover will enhance landscape diversity.	**Closure:** • The closure landscape will have greater relief and a wider variety of landforms than the pre-development scenario. The residual impact will be **Positive** in direction. • The reclamation material soil mixes will not be naturally occurring soil types. The residual impact will be **Positive** in direction.
TS-3 Will the Reclamation of the Landscape for the Muskeg River Mine Project Change Soil Productivity ?	**Mitigation:** • Recontoured landforms and reclamation material soil mix will be designed to enhance the potential for forest ecosystem re-establishment.	**Closure:** • There will be more productive soils for forest ecosystems in the reclaimed landscape. The residual impact will be **Positive** in direction.

Key Question/Environmental Issue	Design Feature/Mitigation/Monitoring	Residual Impact
	TERRESTRIAL VEGETATION ISSUES	
VE-1 Will Muskeg River Mine Project Activities Result in a Loss or Alteration of Vegetation Communities?	**Mitigation:** • Site clearing for the mine, tailings settling pond, overburden disposal sites, reclamation material storage areas, roads, plant site, linear infrastructure (e.g., roads and pipelines) and other associated facilities (e.g., ponds and drainage structures) has been designed to be minimal. • Maintain adjacent areas of native vegetation to use for seed and cutting source during reclamation.	**Construction / Operation:** • Vegetation communities will be lost/altered as a result of site clearing. The greatest impact will occur within the wetland ecosite phases. The residual impact will be **Neutral** to **Negative** in direction, Negligible to Moderate in magnitude, Local in geographical extent, Medium to Long-Term in duration, Reversible and of Low frequency. The degree of concern is **Negligible** to **Low**. • Mine dewatering effects will be limited to the wetlands and lake margins and will not affect terrestrial or upland vegetation communities. The residual impact will be **Neutral** to **Negative** in direction, Negligible to Moderate in magnitude, Local in geographical extent, Medium to Long-Term in duration, Reversible on the east side and Non-Reversible on the west side of the mine footprint and of High frequency. The degree of concern is **Negligible** to **Moderate**.
VE-2 Will Muskeg River Mine Project Air Emissions or Water Releases Alter Vegetation Health?	**Mitigation:** • Direct effects may be minimized by ensuring that ambient concentration levels meet regulatory guidelines. **Monitoring:** • Shell will be a member of the Regional Air Quality Coordinating Committee (RAQCC), which includes an Environmental Effects Monitoring Program.	**Construction / Operation:** • The degree of acidification is Undetermined. • Air emissions associated with Project activities will likely not affect plants negatively. The degree of concern is Undetermined.
VE-3 Will the Muskeg River Mine Project Change Plant Diversity?	**Mitigation:** • Where technically feasible for the final development plan, avoid highly sensitive plant communities and areas with rare plants. • Maintain areas of native vegetation to allow for use during reclamation. These areas will	**Construction / Operation:** • Vegetation communities will be lost/altered as a result of site clearing and overburden stripping/disposal. The greatest impact will occur within the wetlands ecosite phases. The residual impact will be Neutral to **Negative** in direction, Moderate to High in magnitude, Local in

Key Question/Environmental Issue	Design Feature/Mitigation/Monitoring	Residual Impact
	provide native sources of seed and vegetation for replanting. • Reclaim disturbed areas sequentially to produce a variety of age classes in the revegetated communities. **Monitoring:** • Component of monitoring program will assess plant species diversity.	geographical extent, Medium to Long-Term in duration, Reversible and of Low frequency. The degree of concern is **Moderate** to **High**.
VE-4 Will Landscape Reclamation and Closure of the Muskeg River Mine Project Result in a Replacement of Plant Communities?	**Mitigation:** • Where technically feasible for the final development plan, avoid highly sensitive plant communities and areas with rare plants. • Maintain adjacent areas of native vegetation to allow for their use during reclamation. These areas will provide native sources of seed and vegetation for replanting. **Monitoring:** • Design a reclamation monitoring program that documents the re-establishment of plant community types.	**Closure:** • Vegetation communities will take time to evolve to pre-development condition. The residual impact will be **Positive** in direction.

Key Question/Environmental Issue	Design Feature/Mitigation/Monitoring	Residual Impact
	WETLANDS ISSUES	
WL-1 Will Muskeg River Mine Project Activities Result in a Loss or Alteration of Wetlands?	**Mitigation:** • Where technically feasible for the final development plan, avoid highly sensitive wetlands areas (e.g., patterned fens and riparian areas). • Minimize the extent of air emissions through design (e.g., low NO_x burner) and regulatory compliance. **Monitoring:** • Include wetlands vegetation in the local and regional monitoring programs of RAQCC. • Establish a wetlands monitoring site on Lease 13 west to evaluate changes to wetlands due to changes in water levels.	**Construction / Operation:** • Impact to bogs and marshes will be Negligible since they are mostly situated outside the mine development area and most are beyond the aquifer drawdown zone. Some wetlands areas cannot be avoided. The residual impact will be **Negative** in direction, Moderate in magnitude, Local in geographical extent, Long-Term in duration, Irreversible and of Low frequency. The degree of concern is **Moderate**.
WL-2 Will Landscape Reclamation and Closure of the Muskeg River Mine Project Result in a Replacement of Wetlands?	**Mitigation:** • Where technically feasible for the final development plan, avoid highly sensitive wetlands areas (e.g., patterned fens and riparian areas). Maintain areas of native wetlands vegetation to provide donor site for wetlands reclamation. These areas will provide native sources of seed and vegetation for replanting. • Development of wetlands systems in association with reclamation drainage systems, as well as reclaimed CT pits and the tailings settling pond. **Monitoring:** • Participate in the RAMP wetlands vegetation monitoring program to document the re-establishment of plant species and plant	**Closure:** • Wetlands types such as shallow open water and marshes will be reclaimed using native seed and plantings from undisturbed wetlands communities within the Project area. However, other wetland types (e.g., patterned fens) cannot be reclaimed with present technologies. Although some wetlands will be reclaimed, the distribution and composition of wetlands is expected to change over the life of the Project. The residual impact will be **Positive** in direction.

Key Question/Environmental Issue	Design Feature/Mitigation/Monitoring	Residual Impact
	WETLANDS ISSUES	
	community types. Expand to reclamation wetlands sites over time.	
WL-3 Will the Muskeg River Mine Project Change Wetlands Diversity?	**Mitigation:** • Successive revegetation over the course of mine development will allow for a variety of revegetated wetlands age classes to develop, promoting diversity of wetlands successional stages.	**Closure:** • Wetlands types such as shallow open water and marshes will be reclaimed using native seed and plantings from undisturbed wetlands communities within the Project area. However, other wetlands types (e.g., patterned fens) cannot be reclaimed with present technologies. Although some wetlands will be reclaimed, the distribution and composition of wetlands is expected to change. The residual impact will be **Negative** in direction, Low in magnitude, Local in geographic extent, and Long-Term in duration. The degree of concern is **Low**.

Key Question/Environmental Issue	Design Feature/Mitigation/Monitoring	Residual Impact
	WILDLIFE ISSUES	
W-1 Will Activities From the Muskeg River Mine Project Change Wildlife Habitat?	**Mitigation:** • Locate the development away from important wildlife habitat, where practical. • Phased reclamation of the development area. **Monitoring:** • Assess wildlife use of possible corridors.	**Construction / Operation:** • Wildlife habitat will be lost/altered due to site clearing and other Project activities. The residual impacts will be **Negative** in direction, High in magnitude for most KIRs (e.g., moose habitat units will be reduced by 54% in the LSA). The degree of concern is **Moderate**.
W-2 Will Water Releases From the Muskeg River Mine Project Change Wildlife Health?	**Mitigation / Monitoring:** • Refer to Section E5 for mitigation measures and monitoring for water quality and Section E6 for Aquatic Resources. • Water quality monitoring (component of RAMP).	**Construction / Operation / Closure:** • During operation and closure, no impacts were identified for all chemicals evaluated. However there is uncertainty regarding the potential chronic effects of naphthenic acids on animals. The residual impact will be **Negative** in direction, Low in magnitude, Local in geographic extent, Long-Term in duration, Reversible and of Medium frequency. The degree of concern is **Low**.
W-3 Will Consumption of Plants Affected by Muskeg River Mine Project Change Wildlife Health?	**Mitigation:** • Refer to Section E2 for mitigation measures for air emissions that may affect the quality of local plants. **Monitoring:** • Participation in the Environmental Effects Monitoring (EEM) Subcommittee of the Regional Air Quality Coordinating Committee for Southern Wood Buffalo Zone to undertake periodic monitoring of plant tissue concentrations and corresponding soil concentrations outside the development area.	**Construction / Operation:** • During operation, no impacts to wildlife health were identified based on consumption of plants in areas outside the development area where wildlife will be foraging. The Degree of Concern is Negligible. **Closure:** • Residual impacts to health foraging of wildlife on the reclaimed landscape following closure are discussed under key question W-7.
W-4 Will the Combined Exposure to Water, Aquatic Invertebrates and Plants Affected by the Muskeg River Mine Project Change Wildlife Health?	**Mitigation:** • Refer to Section E5 for mitigation measures for water quality and Section E2 for mitigation measures for air emissions that	**Construction / Operation / Closure:** • During operation and closure, no impacts were identified for all chemicals evaluated. However, there is some uncertainty regarding the potential chronic effects

Key Question/Environmental Issue	Design Feature/Mitigation/Monitoring	Residual Impact
	may affect the quality of local plants. **Monitoring:** The monitoring programs outlined for key questions W-2 and W-3 also apply here.	of naphthenic acids. The residual impact will be **Negative** in direction, Low in magnitude, Local in geographic extent, Long-Term in duration, Reversible and of Medium frequency. The degree of concern is **Low**.
W-5 Will the Muskeg River Mine Project Change Wildlife Abundance or Diversity?	**Mitigation:** • Implement a nuisance wildlife management plan in cooperation with Fish and Wildlife Service, AEP. • Where feasible, design straight roads with long lines-of-site • Maintain vegetation free shoreline in tailings pond. • Use bird deterrence devices, particularly during the spring and fall migration periods, such as human effigies and propane-fuelled cannons. • Participate in the Oil Sands Bird Protection Committee to discuss mitigation results and strategies. **Monitoring:** • Wildlife-tailings pond mortality. • Wildlife-traffic mortalities.	**Construction / Operation / Closure:** • Changes in wildlife abundance and diversity will result in the LSA primarily due to changes in wildlife habitat. The extent of these changes depends on the amount of habitat lost or altered (Golder 1998b). The residual impact will be **Negative** in direction, High in magnitude, Local in geographic extent, Medium-Term in duration, Reversible and of Low frequency. The degree of concern is **Moderate**.
W-6 Will the Reclaimed Landscape From the Muskeg River Mine Project Change Wildlife Habitat?	**Mitigation:** • Mitigation will be reclamation of the development area to vegetation communities that will support the desired end land uses. **Monitoring:** • Monitoring of wildlife habitat variables on reclaimed lands to closure.	**Closure:** • There will be gains in some wildlife habitats (e.g., upland habitats) and losses in others (e.g., wetlands). Some habitats are more difficult to reclaim than others (e.g., patterned fens). Moose habitat is projected to increase by 10% over baseline, beaver habitat will decrease by 6% and western tanager habitat will increase by 189%. Most impacts will be **Positive** in direction.
W-7 Will the Reclaimed Landscape From the Muskeg River Mine Project Change Wildlife Health?	**Mitigation:** • Refer to Section E16 for mitigation measures considered for closure planning and	**Closure:** • During operation, no impacts to wildlife health were identified based on consumption of plants in areas

Key Question/Environmental Issue	Design Feature/Mitigation/Monitoring	Residual Impact
	reclamation of the development site. **Monitoring:** • Periodic monitoring of plant tissue concentrations and soil concentrations on the reclaimed landscape. • Participation of Shell in the Environmental Effects Monitoring (EEM) Subcommittee of the Regional Air Quality Coordinating Committee for Southern Wood Buffalo Zone.	outside the development area where wildlife will be foraging. However, there is a lack of toxicity data respecting naphthenic acids. The residual impact will be **Negative** in direction, Low in magnitude, Local in geographic extent, Long-Term in duration, Reversible and of Medium frequency. The degree of concern is **Low.**
W-8 Will the Reclaimed Landscape and Post-disturbance Activities From the Muskeg River Mine Project Change Wildlife Abundance or Diversity?	**Monitoring:** • Monitoring of wildlife populations on reclaimed lands to closure.	**Closure:** • There will be a gain in abundance for some wildlife species (e.g., moose, western tanager) and a loss in abundance for other wildlife species (e.g., wetlands species) due to changes in habitat. Most impacts will be **Positive** in direction.

Key Question/Environmental Issue	Design Feature/Mitigation/Monitoring	Residual Impact
HUMAN HEALTH ISSUES		
HH-1 Will Water Releases From the Muskeg River Mine Project Change Human Health?	**Mitigation:** • Refer to Section E5 for mitigation measures for water quality. **Monitoring:** • Refer to Section E5 for water quality monitoring and integration with RAMP. In addition, consideration will be given to resolve data gaps in toxicity data for naphthenic acids as part of CONRAD.	**Construction / Operation / Closure:** • During operation and closure no significant health impacts were identified for human health; however, there is some uncertainty regarding the chronic toxicity of naphthenic acids. The residual impact will be **Negative** in direction, Low in magnitude, Local in geographic extent, Long-Term in duration, Reversible and of Medium frequency. The degree of concern is **Low**.
HH-2 Will Air Emissions From the Muskeg River Mine Project Change Human Health?	**Mitigation:** • Refer to Section E2 for mitigation measures for air quality. **Monitoring:** • Refer to Section E2 for air quality monitoring.	**Construction / Operation:** • During construction and operation, no significant health impacts were identified as a result of air emissions. Therefore, the degree of concern was Negligible. **Closure:** • No particulate or volatile air emissions are anticipated following closure.
HH-3 Will Consumption of Local Plants and Game Animals Affected by the Muskeg River Mine Project Change Human Health?	**Mitigation:** • Refer to Section E2 for mitigation measures for air quality which may also mitigate deposition of air contaminants on plant and soils that ultimately may be consumed by humans. **Monitoring:** • Periodic monitoring of plant and animal tissue from local and regional locations to better characterize spatial and temporal trends, and to improve exposure analysis, should be conducted on a regional basis.	**Construction / Operation / Closure:** • During operation and closure no significant impacts were identified for human health as a result of consumption of native plants or wild game; therefore the concern is Negligible.

Key Question/Environmental Issue	Design Feature/Mitigation/Monitoring	Residual Impact
HH-4 Will the Combined Exposure to Water, Air, Plants and Game Animals Affected by the Muskeg River Mine Project Change Human Health?	**Mitigation:** • Refer to Section E5 for mitigation measures for water quality. **Monitoring:** • Refer to Section E5 for water quality monitoring and integration with RAMP. In addition, consideration should be given to resolve data gaps in toxicity data for naphthenic acids as part of CONRAD.	**Construction / Operation / Closure:** • During operation and closure no significant impacts were identified for human health through this multimedia exposure pathway. However, there is some uncertainty regarding the chronic toxicity of naphthenic acids. The residual impact will be **Negative** in direction, Low in magnitude, Local in geographic extent, Long-Term in duration, Reversible and of Medium frequency. The degree of concern is **Low**.
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)*	**Mitigation:** • Corporate training programs in place to enhance worker knowledge of safe and emergency response training and procedures.	**Construction / Operation / Closure:** • Qualitative evaluation of the corporate policies and procedures respecting worker health and safety indicated the necessary resources and know-how were in place to ensure worker health and safety and emergency response planning. The impact is Negligible.
HH-6 Will noise from Muskeg River Mine Project Activities during Construction and Operation Unduly Affect People who Reside in the Local Area?	**Mitigation:** • Manage the location of equipment based on monitoring results. Possible sound attenuating barriers if needed. **Monitoring:** • Ambient noise monitoring with multiple octaves, at various nodes.	**Construction / Operation:** • Truck and shovel operation may cause periodic exceedances of permissible sound level in Fort McKay. This may arise from unique additive circumstances of the Project plus the Aurora Mine. The residual impact will be **Negative** in direction, Low in magnitude, local in geographic extent, Long-Term in duration, Reversible and of Medium Frequency. The degree of concern is **Low**. **Closure:** • Work related noise will cease at closure.
HH-7 Will the Release of Chemicals From the Reclaimed Landscape Change Human Health?	**Mitigation:** • Refer to Section E5 for mitigation measures for water quality. **Monitoring:** • Refer to Section E5 for water quality monitoring and integration with RAMP.	**Closure:** • Following closure in the far future when equilibrium conditions have been established, the multimedia exposure risk assessment indicated no significant impacts to human health through this multimedia exposure pathway. However, there is some uncertainty regarding the chronic toxicity of naphthenic acids. The

Key Question/Environmental Issue	Design Feature/Mitigation/Monitoring	Residual Impact
		residual impact will be **Negative** in direction, Low in magnitude, Local in geographic extent, Long-Term in duration, Reversible and of Low frequency. The degree of concern is **Low**.

Key Question/Environmental Issue	Design Feature/Mitigation/Monitoring	Residual Impact
HISTORICAL RESOURCES ISSUES		
HR-1 Will Development Activities Associated With the Muskeg River Mine Project Change Sites, Warranting Avoidance or Further Information Recovery? **HR-2** Will the Mitigation Program Designed for Muskeg River Mine Project Effectively Offset Project Effects?	**Mitigation:** • Avoidance: No historical resources identified within the development area require permanent avoidance. • Pre-development mitigation: completion of existing mitigation requirements previously established by Alberta Community • Development for sites within impact zones, including the Bezya site (HhOv 73). • Completion of mitigation requirements set by Alberta Community Development for sites of Moderate value situated in impact zones. Studies would focus on sites that represent unusual sources of information and on representative sampling from typical sites. **Monitoring:** • Surface inspection of recently cleared areas to record exposed sites. Sample recovery from unique sites or representative sites if no comparable samples exist for the area in question. • Palaeoenvironmental sampling: recovery of bone and other relevant materials exposed during muskeg removal.	**Construction / Operation:** • During construction and operation stages, sites within impact zones will be completely removed. Residual impacts will occur in the form of destruction of those historical resources not recovered during mitigation programming. Samples recovered for permanent preservation, along with their analysis and interpretation, will adequately offset these effects. Because low value resources would be affected, residual impacts will be **Negative** in direction, Low in magnitude, Localized to development zones, Short-Term in duration and Irreversible. Degree of concern is **acceptable**.

Key Question/Environmental Issue	Design Feature/Mitigation/Monitoring	Residual Impact
RESOURCE USE ISSUES		
RU-1 Will There be a Change in Surface and Mineral Materials ?	**Mitigation:** • Salvage materials (e.g., gravel) during site clearing, where possible.	**Construction / Operation:** • During construction and operation, restricted access will reduce potential for other extraction purposes. The residual impact will be **Negative** in direction, of Moderate magnitude, of Local geographic extent, Medium-Term duration and Reversible. The degree of concern is **Low**. **Closure:** • Following closure, surface and other mineral extraction may occur and may be enhanced due to improved access.
RU-2 Will There be a Change in Environmentally Significant Areas (ESAs) ?	**Mitigation:** • Minimize clearing as much as possible. Re-vegetation will enhance cover for wildlife. • Reclaim areas to the extent possible with by reseeding and planting with native vegetation.	**Construction / Operation:** • Minor changes to Kearl Lake moose habitat. The degree of concern is Negligible.
RU-3 Will There be a Change in Forestry ?	**Mitigation:** • Salvage merchantable timber during site clearing. Keep site clearing to the smallest possible area. • Develop a forest management plan in conjunction with the FMA quota holder and the government for closure planning. Reclaim forest to equivalent or greater capability. **Monitoring:** • A monitoring program will be designed to document the establishment of regeneration for commercial forestry purposes.	**Construction / Operation:** • Site clearing will remove productive forest and regeneration during the life of the Project. The residual impact will be **Negative** in direction, Low in magnitude, Local in geographic extent, Long-Term in duration, Reversible and of Low frequency. The degree of concern is **Low**. **Closure:** • The forest resource will be reclaimed to equivalent or greater capability. As well, access should be enhanced following closure. Thus, impact on forestry is expected to be **Positive** in the long term.

Key Question/Environmental Issue	Design Feature/Mitigation/Monitoring	Residual Impact
	RESOURCE USE ISSUES	
RU-4 Will There be a Change in Berry Picking ?	**Mitigation:** • Revegetation schemes should include berry-producing shrubs where possible.	**Construction / Operation:** • Loss of vegetation due to site clearing and restricted access will affect berry picking activities. The residual impact will be **Negative** in direction, Low in magnitude, Local in geographic extent, Moderate in duration, Reversible and of Low frequency. The degree of concern is **Low**. **Closure:** • Opportunities for berry picking are expected to increase due to careful reclamation and improved access.
RU-5 Will There be a Change in Non-consumptive Recreational Use ?	**Mitigation:** • Leave buffers of native vegetation between disturbance and watercourses and highways to reduce visual impact.	**Construction / Operation:** • Loss of vegetation due to site clearing and restricted access will affect recreational activities. The residual impact will be **Negative** in direction, Low in magnitude, Local in geographic extent, Moderate in duration, Reversible and of High frequency. The degree of concern is **Low**. **Closure:** • Opportunities for recreation are expected to increase due to careful reclamation and improved access.
RU-6 Will There be a Change in Hunting ?	**Mitigation:** • Reclaim site to equivalent or greater capability for wildlife.	**Construction / Operation:** • Loss of wildlife due to construction and operations and restricted access will affect hunting opportunities. The residual impact will be **Negative** in direction, Low in magnitude, Local in geographic extent, Moderate in duration, Reversible and of Moderate frequency. The degree of concern is **Low**. **Closure:** • Opportunities for hunting are expected to increase due to careful reclamation and improved access. The impact is **Positive**.

Key Question/Environmental Issue	Design Feature/Mitigation/Monitoring	Residual Impact
RESOURCE USE ISSUES		
RU-7 Will There be a Change in Trapping ?	**Mitigation:** • Reclaim site to equivalent or greater capability for wildlife. Reimburse trappers for lost revenue.	**Construction / Operation:** • Loss of wildlife due to construction and operations and restricted access will affect trapping opportunities. The residual impact will be **Negative** in direction, Low in magnitude, Local in geographic extent, Moderate in duration, Reversible and of Moderate frequency. The degree of concern is **Low**. **Closure:** • Opportunities for trapping are expected to increase due to careful reclamation and improved access. The impact is **Positive**.
RU-8 Will There be a Change in Fishing ?	**Monitoring:** • Monitor water quality to ensure that fish abundance and health are not affected.	**Construction / Operation:** • No changes will occur to sport fishing as a result of the Project. **Closure:** • Opportunities for fishing may increase due to improved access and the creation of the end pit lake.

Table A-3 Mitigation Measures and Residual Impacts for Socio-Economics

Key Question/Socio-Economic Issue	Mitigation/Monitoring	Residual Impact
SOCIO-ECONOMIC ISSUES		
What is the impact on local employment and training?	• Local hiring, but always on merit. Shell will use and encourage local businesses - including First nations and Metis businesses - where they are competitive and can meet Shell's requirements. **Mitigation:** • Provide local educational institutions with population forecast to aid planning. • Participate in career days and similar events, consideration given to aboriginal scholarship fund.	• Enhanced local employment and business opportunities.
What are the impacts on local services and infrastructure?	**Mitigation:** • Active cooperation with the municipality and other levels of government to identify impacts and explore solutions. The Athabasca Oil Sands Facilitation Committee and the Regional Infrastructure Working Group on Training and Education are examples of collaborative initiatives. • Use of construction camp, that may be kept open partially during operations phase. • Participation in the Career Preparation and other education programs; Employee orientation programs and EAP. • Development of corporate charitable donation policy; encouragement of volunteer efforts of staff. • Provision of basic medical services to workers on site; disaster planning. • Mutual aid agreements with other emergency services.	• Temporary housing shortage; remaining concern about the availability of rental accommodations. • Increased demand on social and emergency service providers. • Increased traffic on Highway 63, especially north of the urban service area.

Key Question/Socio-Economic Issue	Mitigation/Monitoring	Residual Impact
	• Traffic scheduling to avoid peak hours; bussing services for commuting workers.	
What are the impacts on the procurement of local, Alberta and Canadian goods?	**Mitigation:** • Procurement of local, Albertan and Canadian goods and services, where competitive and able to meet the project needs.	• Increased opportunity for local, Albertan and Canadian suppliers.

B PROJECT DESCRIPTION

B1 HISTORY OF PROJECT

B1.1 Early Development Activities on Lease 13

The proposed Muskeg River Mine Project (the Project) focuses on the development of the western portion of Bituminous Oil Sands Lease No. 7277080T13 (Lease 13). Shell Canada Limited (Shell) began work to evaluate development on Lease 13 in 1955 when testing of production methods was initially conducted on the lease. An application for approval of an in-situ project was made to, but subsequently withdrawn from, the Alberta government in 1962.

In 1974, following completion of a four-year drilling program, Shell applied for a 100,000 barrels per day (bpd) mining project. This was pursued for two years although it did not proceed to a commercial project development. Shell continued work on development options, culminating in 1979 with the application for the Alsands Project, a 137,000 bpd development for production of synthetic crude oil from oil sands on Lease 13 and some neighbouring leases. This project received regulatory approval but was canceled in 1982 due to escalating costs, falling crude oil prices and uncertain fiscal considerations.

Further details on the history of development activities on Lease 13 are provided in Section 1.2, Volume 1 of the Application.

B1.2 Current Project Development Plans

The Project development area is located on the east side of the Athabasca River in the area approximately 70 km north of Fort McMurray, Alberta. The project was officially launched through a Public Disclosure on March 14, 1997 (Shell 1997a).

The project will be developed on the western portion of Lease 13, which covers approximately 20,182 ha of surface area and has a potentially mineable resource of approximately 800 million m^3 of bitumen. The reserves in the area of the Project are assessed at 200 million m^3 (1.3 billion bbl). The targeted production rate for the project is 8.7 million m^3 (55 million bbl) of bitumen per year, or 23,850 m^3 per day (150,000 bpd) of bitumen, resulting in an expected mine life of about 20 years. If the economic environment remains favourable, the intent is to also develop the eastern portion of Lease 13 in the future.

The scope of the Muskeg River Mine Project includes:

- Mine - truck and shovel mining.

- Extraction - a warm (45 - 50°C) water-based, caustic free ore conditioning and extraction process coupled with a conventional centrifuge froth treatment process, and a paraffinic solvent-based product cleanup unit to meet the low solids and water specification for the bitumen.

- Tailings - use of a tailings settling pond for initial tailings storage, converting to consolidated tailings production and the initiation of in-pit storage after four years.

- Utilities - basic utilities including:
  - raw water supply through a dedicated Athabasca River intake station and water supply line,
  - natural gas-fired process water heating, and
  - electrical power via connections to the Alberta electrical grid.

- Utilities corridor that runs southwest from the plant site to the lease boundary, then west for connections to:
  - the Alberta electrical grid, via two 144 kV tie-in lines,
  - natural gas supply pipelines,
  - communications network and links, and
  - Highway 963.

Details on the proposed Project development are provided in Volume 1 of the Application.

B1.3 Project Needs and Alternatives

The project needs and alternatives are discussed in Section 1.1 of Volume I of the Application. In support of Shell's planning efforts and its Application for approval of the proposed Project, a number of options or alternatives were considered for many of the major project features.

Environmental, engineering and economic criteria appropriate to the components under consideration were evaluated to select the preferred options for each of the Project features. Where the preferred option for the process or component is still under development, a contingency option is considered. This EIA does not specifically address the potential environmental impacts of the contingency options. Options considered and discussed in Volume 1 of the Application include:

- mine operating location
- plant site selection

- tailings site selection
- tailings deposition plan
- extraction process
- corridor route selection
- water intake and supply

B2 GEOLOGY AND RESERVES

Geology and reserves for the Project have been evaluated in detail over a number of years. Detailed geological understanding of the project area has been achieved through:

- Geological Block Model - 1996, which included a review of all available core and geological information for Lease 13 (over 500 core holes for the Project area) and establishment of a new geological block model.

- Core Drilling Program - 1997, which included a field program to drill 40 core holes. The objective for this program was correlation with, and validation of the historical information base, as well as to define mine boundaries and potential external disposal sites.

- Geological Facies Model - 1997, which included establishment of a facies geology model to enhance understanding of the resource and improve predictive capability.

- Geological Field Project - 1997/1998, which is a planned program to drill an additional 130 core holes, 200 overburden wells, two pumping test wells for the basal aquifer and two piezometer wells. In addition, a shallow seismic program will be conducted. These additional activities will provide the necessary definition for detailed design and mine operating plans.

B3 PROJECT DEVELOPMENT PLANS

The Project involves the mining and processing of oil sands from the western portion of Lease 13 to produce a diluted bitumen product. After initial site preparation including clearing, draining and pre-stripping of overburden materials, the Lease 13 oil sands deposit will be mined using conventional truck and shovel methods. The ore will be crushed into relatively small pieces using an in-pit crusher, then transported to the extraction facility via conveyer systems.

Oil sands will be subjected to a primary extraction process followed by froth treatment. Following the froth treatment, the product will be transported via pipeline to an upgrading facility near Edmonton.

Additional details on the components of the Project can be found below or in Volume 1 of the Application.

B3.1 Mine Sequence

A screening analysis of three conceptual mining sequences was performed to optimize the balance of overburden stripping, oil sand mining, ore grade and tailings disposal. The mine plan for the Project assumes that tailings from the process will be transported by pipeline initially to an out-of-pit tailings settling pond. Once sufficient space is available in-pit, internal dykes will be constructed to allow placement of consolidated tails (CT) in-pit.

The mine plans must meet normal mining objectives, as well as allow logical development of CT containment cells within the mine pit area. The mine schedule also has to provide a consistent feed grade (average grade 11.4%), particularly in the early years to facilitate effective start-up and operation of the extraction plant.

The life of mine composite plan, as shown in Figure B-1, was the one that best balanced feed quality and tailings management. Continuing refinement to the mine sequencing will be performed during ongoing mine feasibility and planning activities.

Additional details on the mine sequencing can be found in Section 4, Volume 1 of the Application.

B3.2 Infrastructure

The Muskeg River Mine Project will initially require all source process water to be provided through a combination of surface and mine drainage water and a supply from the Athabasca River. Within approximately two years, water will be recycled from the tailings settling pond and the Athabasca River makeup volumes will be reduced. A project water intake facility and supply pipeline will be required to transfer water from the Athabasca River to the plant.

The plant site selection for the Project is described in Section 4.2, Volume 1 of the Application. The plant site is centrally located to facilitate relatively short distances between the mining areas and the processing facilities.

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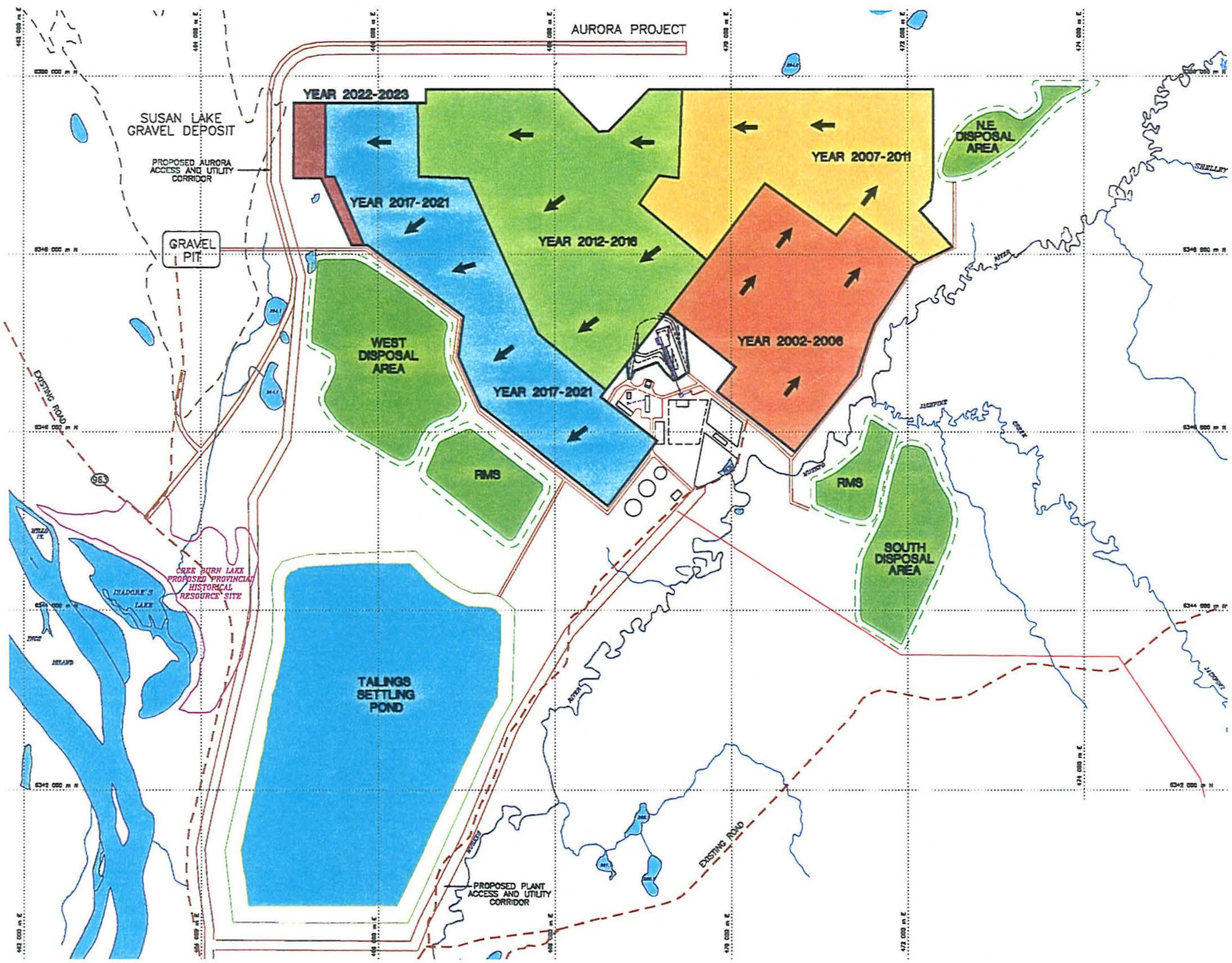


REFERENCE

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 STORAGE
COORDINATE SYSTEM: NAD27

B-5

Golder Associates

SHELL CANADA LIMITED

LIFE OF MINE COMPOSITE PLAN

13 DEC 97	Figure B–1	DRAWN BY: RFM

Screened and crushed pit run gravel for all mine haul and service roads will be obtained from the existing Susan Lake gravel deposit, operated by a contractor under the supervision of AEP, Land and Forest Services. The gravel, which will be screened and crushed by contractors, will be hauled and placed with mine equipment.

Positioning of reclamation material storage areas and overburden disposal areas in areas to minimize ore sterilizations means that two such areas will be developed in the area south of the Muskeg River and west of Jackpine Creek (Figure B-1). A structure will be built to allow crossing of the Muskeg River without causing disturbance to the river.

Further details on the infrastructure associated with the Project can be found in Section 4.2, Volume 1 of the Application.

B3.3 Mine Preparation

The Muskeg River Mine Project land surface must be cleared and grubbed before mining begins, with these activities typically scheduled between two and five years in advance of the mining faces. This preparation also enables drainage ditches and basal aquifer depressurization wells to be constructed or installed ahead of the mining activities.

Muskeg soil resources (reclamation materials) will be removed from the cleared and drained areas. Sufficient reclamation materials will be stored to ensure adequate supplies are available for future reclamation activities. As soon as sites are available for reclamation activities, reclamation materials will be placed directly on the reclamation areas rather than hauled to storage areas.

Overburden, centre rejects and oil sands will be loaded using large cable shovels and hydraulic shovels where selectivity is required. The loaded oil sands will be hauled by large dump trucks to the crushers. The overburden and centre reject materials will be hauled by truck to either external disposal areas or to in-pit locations.

Overburden disposal areas typically will be constructed in 10 m lifts to achieve three horizontal to one vertical (3H:1V) final slope configurations. The thickness of the lifts will depend on the strength of the materials being placed as well as the considerations for efficient control of surface drainage.

The construction of tailings dykes with overburden will require on-site engineering and supervision control. Dyke construction will include truck haulage, placing fill material by bulldozers and graders, and compaction.

Dewatering and Drainage

The drainage plan for the Muskeg River Mine Project will include surface drainage and basal aquifer dewatering. The mining area is relatively flat, ranging in elevation from about 285 to 300 m above sea level (masl). The area is characterized by gentle slopes, wet muskeg, shallow ponds and a poorly defined drainage system. The eastern mining areas of the Project development area slope toward the Muskeg River, which in turns flows into the Athabasca River. The western mining areas of the Project development area generally slope southwest toward the Athabasca River.

Underlying the oil sands deposit are basal aquifers ranging in thickness from 0 to 50 m. The aquifers will require dewatering before mining activity begins.

Surface water will be handled by diversion ditches and mine water ditches. Before mining begins, diversion ditches will be constructed to divert clean surface waters around the mining area and into the existing drainage courses of the Muskeg or Athabasca rivers. The diversion ditches will be designed to take advantage of drainage systems constructed for the Alsands Project. Finger ditches will be constructed annually to divert surface water from wet areas into the main diversion ditches.

Process-affected waters, those from collection systems or those which contact active oil sands mining areas, will be taken from the active mining areas into sumps via constructed drainage systems.

Additional details on project dewatering activities can be found in Section 4.5, Volume 1 of the Application.

Prestripping

Prestripping activities will be carried out as soon as the initial mine area has been cleared and drained, and had the reclamation materials removed. The early start results from the need to send material to the external tailings settling pond starter dyke to be used in preloading muskeg materials. The overburden materials for this will come from the crusher excavation or from that obtained from the first mining block.

A total of 12.3 million bank cubic metres (bcm) will be required to construct the starter dyke. This will consume all the crusher excavation overburden and much of the prestrip overburden removed to develop working faces in the first mining block. Any surplus materials will be sent to the south overburden stockpile.

Developing the crusher excavation will release 1.7 million tonnes of oil sands, which will be placed on a temporary stockpile and used for plant commissioning (scheduled for January 2002).

Mine Advance

The mine will advance in a number of steps between 2002 and 2022. The life of mine composite plan is shown in Figure B-1.

Status at End of 2005

Two adjacent mining areas will be developed east of the crusher and head northeast, parallel to the Muskeg River. Overburden and centre reject material will be taken to the south disposal area. Before 2005 some in-pit dykes will be constructed.

Status at End of 2010

From 2006 to 2010, the mining faces will have reached the north and east final pit limits, and the mine will advance westward along the north lease boundary. The dykes for in-pit CT disposal cells 1a, 1b and 2 will be completed.

By the end of 2010, most of the high grade, low strip ratio ore will be exhausted and higher sustained production volumes will be necessary. That is, overburden and centre reject volumes will increase to over 20 million bcm annually. The northeast disposal area will be completed as the mining faces progress to the west.

Status at End of 2020

From 2010 to 2020, the mine will continue advancing to the west and southwest. A new truck haul route will be established to haul oil sands from the west areas to the crushers. By the end of 2020, dykes 4, 5 and 6 will have been completed.

Beginning in 2012, some of the in-pit overburden and centre rejects will be deposited in Cell 1, which by then will be a mature, consolidated tailings deposit. There will be sufficient room in-pit to allow overburden and centre reject material to be hauled and dumped in mined-out areas.

Status at End of 2022

The mine approaches completion in 2022. Final dykes will be constructed and a void will be left at the western limit of the pit. This area will be reclaimed to form an end pit lake as part of the final mine closure plan.

Details on the mining operations, including detailed drawings of the mine progression, are provided in Section 4.4 of Volume 1 of the Application.

B3.4 Extraction and Tailings

Extraction Process

The oil sands ore, which will be sized to less than 400 mm using an in-pit crusher, will be conveyed approximately 600 m to the extraction processing facility. A schematic of the extraction process is shown in Figure 5-1 (Section 5.2, Volume 1 of the Application).

The start of the extraction processing facility will involve addition of water to the oil sands to create a warm water slurry at approximately 45 - 50°C. The oil sands slurry advances through a rotary breaker where the ore is sized to less than 50 mm.

The slurry will be pumped from the rotary breaker to the first of several agitated conditioning tanks, where the bitumen froth is generated and subsequently separated in a conventional primary bitumen extraction unit. The coarse sand is removed at that stage. The primary extraction process for the Project does not include the addition of sodium hydroxide (caustic) as a bitumen separation aid.

The bitumen froth will be processed in a froth treatment plant which has a conventional dilution centrifuging froth treatment process followed by a product clean-up processing unit to provide final removal of ultra-fine solids and residual water. This product clean up step involves the recently developed paraffinic solvent demulsification process.

The bitumen material from the froth treatment will be taken to a solvent recovery unit where the bulk of the paraffinic solvent is removed. Roughly 30% by volume of the solvent is left with the bitumen to reduce the viscosity to a level necessary for effective pipeline transport.

Additional details on the extraction process to be employed for the Project are provided in Section 5.2 ,Volume 1 of the Application.

Tailings Management

Volumetric schedules for the tailings settling pond and in-pit consolidated tailings (CT) cells have been developed in association with the mining plans.

Tailings deposition using conventional methods will begin in 2002 in the external tailings settling pond southwest of the extraction plant (Figure B-1). This pond will be used at full production rates until 2006, after which the rate of deposition will be reduced as in-pit CT deposition is initiated.

The tailings materials will be pumped to the out-of-pit tailings settling pond designed to function as a tailings disposal site until adequate in-pit cells are ready for CT disposal. Therefore, the tailings settling pond will be operated as the only receptor of tailings for the initial four years of plant operation. For the next five to seven years, most of the tailings will go into CT, with mature fine tailings (MFT) from the tailings settling pond used in the process. After this, all tailings production will be into CT, with volumes of MFT drawn from the tailings settling pond to combine with the fresh primary extraction tailings.

Further details on tailings management for the Project can be found in Section 6, Volume 1 of the Application.

B3.5 Utilities

Electrical Power and Natural Gas

The Project will produce heat and steam through import of natural gas.

Electric power is to be supplied from the Alberta grid, with power requirements equalling approximately 81 megawatts (MW). Two 144 kV electrical power lines to the site will be required to provide a reliable power supply. An electrical substation will be built at the entrance to the site facilities. This substation will contain the 144 kV breakers and 144 kV to 25 kV transformers.

Natural gas will be supplied through a new line to the Lease 13 site. Natural gas demands will range between 2,085 gigajoules per hour (GJ/h) during the winter to 1,470 GJ/h in the summer for an annual average of 1,828 GJ/h. The incoming gas line will be designed for 2,500 GJ/h.

Auxiliary Utilities

Auxiliary utilities for the Project include diesel fuel, nitrogen, plant air and steam. The average annual diesel fuel consumption is estimated at 66 million litres over the mine life. Various supply options are being evaluated for the Project.

Nitrogen is required for inert gas blanketing of tanks and equipment in the extraction and froth treatment plants, as well as for solvent stripping in the tailings solvent recovery unit. Nitrogen will be supplied by a conventional air separation unit at the plant site. Produced nitrogen will be distributed through a low-pressure piping network.

Instrument and utility air requirements will be produced through a conventional industrial air plan. Air will distributed through a separate low-pressure piping network.

About 100,000 kg/h of 1,000 kPa(g) steam is required for froth dearation, solvent recovery, heat racing and utility steam. Steam will be supplied using two conventional natural gas-fired utility boilers.

Additional details on the utilities and associated off-site requirements for the Project are provided in Section 7, Volume 1 of the Application.

B3.6 Reclamation and Closure

A comprehensive conservation and development (C&R) plan has been developed as a part of the integrated EUB/AEP Application for the Muskeg River Mine Project. The C&R plan is provided in Section 16, Volume 1 of the Application.

Closure planning has been initiated as an integral component of mine planning. The closure planning process is described in Section E16, Volume 3 of the Application.

B4 ECONOMIC CONTRIBUTION AND WORKFORCE

The Muskeg River Mine Project economics and workforce requirements have been assessed based on the estimated initial capital cost of $1.2 billion (1997$). These costs are estimated based on consideration of lease evaluations, engineering, environmental and project management, mine development, and construction of extraction and utilities facilities.

The socio-economic evaluation for the Project, including consideration of the direct and indirect labour associated with the Project, is presented in Volume 5 of the Application, with a summary provided in Section 11, Volume 1 of the Application.

Additional details on the business plan for the Muskeg River Mine Project are presented in Section 14, Volume 1 of the Application.

C CONSULTATION

Consultation specific to the Environmental Impact Assessment (EIA) for the Muskeg River Mine Project began in March 1997 with the release of the Lease 13 Public Disclosure document (Shell 1997a).

The formal consultation process began on May 14, 1997 when the Proposed Terms of Reference - Environmental Impact Assessment (EIA) Report for the Proposed Shell Canada Limited Lease 13 Project, Fort McMurray, Alberta (Shell 1997b) was issued to Alberta Environmental Protection (AEP), Canadian Environmental Assessment Agency (CEAA) and key project stakeholders.

Consultation for the EIA comprises only part of the consultation completed for the Muskeg River Mine Project. Section 12, Volume 1 of the Application details the public consultation program activities and initiatives completed up to filing of the project application. Table 12-1 details the non-regulatory stakeholder consultation sessions. Table 12-2 details the consultation sessions with regulatory stakeholders.

Issues identified as part of the Project consultation program were tracked using a database, described in Section 12.4, Volume 1 of the Application. The key issues raised through Project stakeholder consultation, as well as Shell's response to those issues, are detailed in Table 12-3, Volume 1 of the Application. Key issues raised through the public consultation program for the Muskeg River Mine Project, as well as through consultation activities associated with other oil sands development applications, were incorporated in the EIA where appropriate.

Discussions on where changes were made to the Project or additions were made to the EIA as a result of Public and Regulatory Consultation are provided within each of the component areas in the impact assessment section of the EIA (Volume 3 of the Application). Specific examples include:

- incorporation of micro-topographic design into the overburden disposal areas to ensure landforms mesh with the surrounding area,
- addition of thermal regime analysis for the Muskeg River,
- addition of three key indicator resources (KIRs), lake whitefish, pileated woodpecker and western tanager,
- carry-through of some chemicals within human health risk assessment, although they were not related to Project activities, and
- evaluating the closure plan for the Muskeg River Mine Project with consideration of the closure plan proposed for the Syncrude Aurora North Mine project.

D ENVIRONMENTAL SETTING

This section of the EIA contains information describing baseline conditions for each EIA component and its relationship to the Muskeg River Mine Project EIA terms of reference. Included are descriptions of the baseline conditions for environmental, historical resources and land use components of the Muskeg River Mine Project EIA. Regional and Local Study Area selection criteria are defined. Section D is followed by the Impact Assessment Section E in Volume 3 of the Application, which describes the potential incremental effect of the Muskeg River Mine Project on the baseline conditions described here.

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

D1 INTRODUCTION

D1.1 Overview

The environmental and historical baseline settings for the Muskeg River Mine Project (the Project) are provided in this section of the EIA. Included are descriptions of the baseline conditions for environmental, historic and land use components of the Project EIA. Socio-economics are discussed in detail in Volume 5 of the Application. The Muskeg River Mine Project EIA baseline setting is divided into the following subsections:

- Air Quality (D2)
- Hydrogeology-Groundwater (D3)
- Surface Water Hydrology (D4)
- Surface Water Quality (D5)
- Aquatic Resources (D6)
- Ecological Land Classification (D7)
- Terrain and Soils (D8)
- Terrestrial Vegetation (D9)
- Wetlands (D10)
- Wildlife (D11)
- Human Health (D12)
- Historical Resources (D13)
- Traditional Land Use (D14)
- Resource Use (D15)

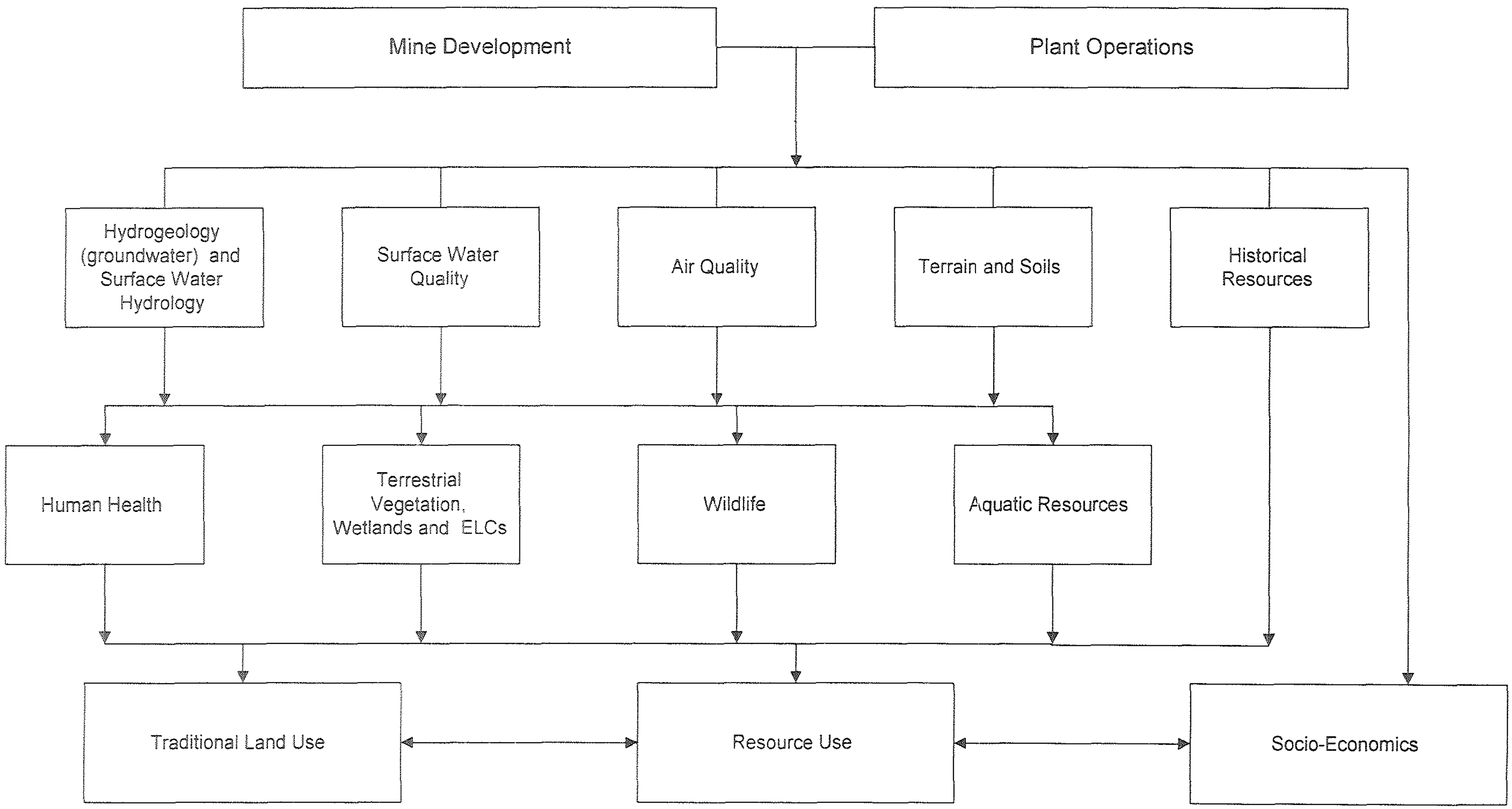
Each of these subsections includes a discussion on:

- the relationship of the subsection to requirements listed in the Muskeg River Mine Project EIA terms of reference (AEP 1997a); and

- the relevant baseline environmental, historical or resource use information.

Although the baseline conditions for each of the EIA components are described in a stand-alone fashion, it is recognized that there are significant interdependencies among them. This interdependency is shown schematically in Figure D1-1. This figure shows the confluence of the outputs from the mine development and plant operations in terms of physical parameters (e.g., groundwater, surface water, air quality) that impact on the components that constitute the viability or productivity of the natural ecosystem (as measured in terms of human health, fish and wildlife habitat and health, and plant communities). These ecosystem components combined with socio-economic factors, as discussed in Volume 5 of the Application, may impact the resource and land use both in the Project area and in the region.

Figure D1-1 Linkages Between EIA Components



Baseline conditions for the Project EIA are defined as those that exist in the region as of 1997. Baseline and historical information is summarized in this section of the EIA, as well as additional information collected in 1997 specifically for the Muskeg River Mine Project. Background information that is important for understanding issues and potential impacts is also included. For example, some sections describe the relevant regulatory guidelines (e.g., air quality guidelines), while other sections provide information on sensitivity to disturbance (e.g., sensitivity of vegetation to air emissions).

D1.2 Project Area

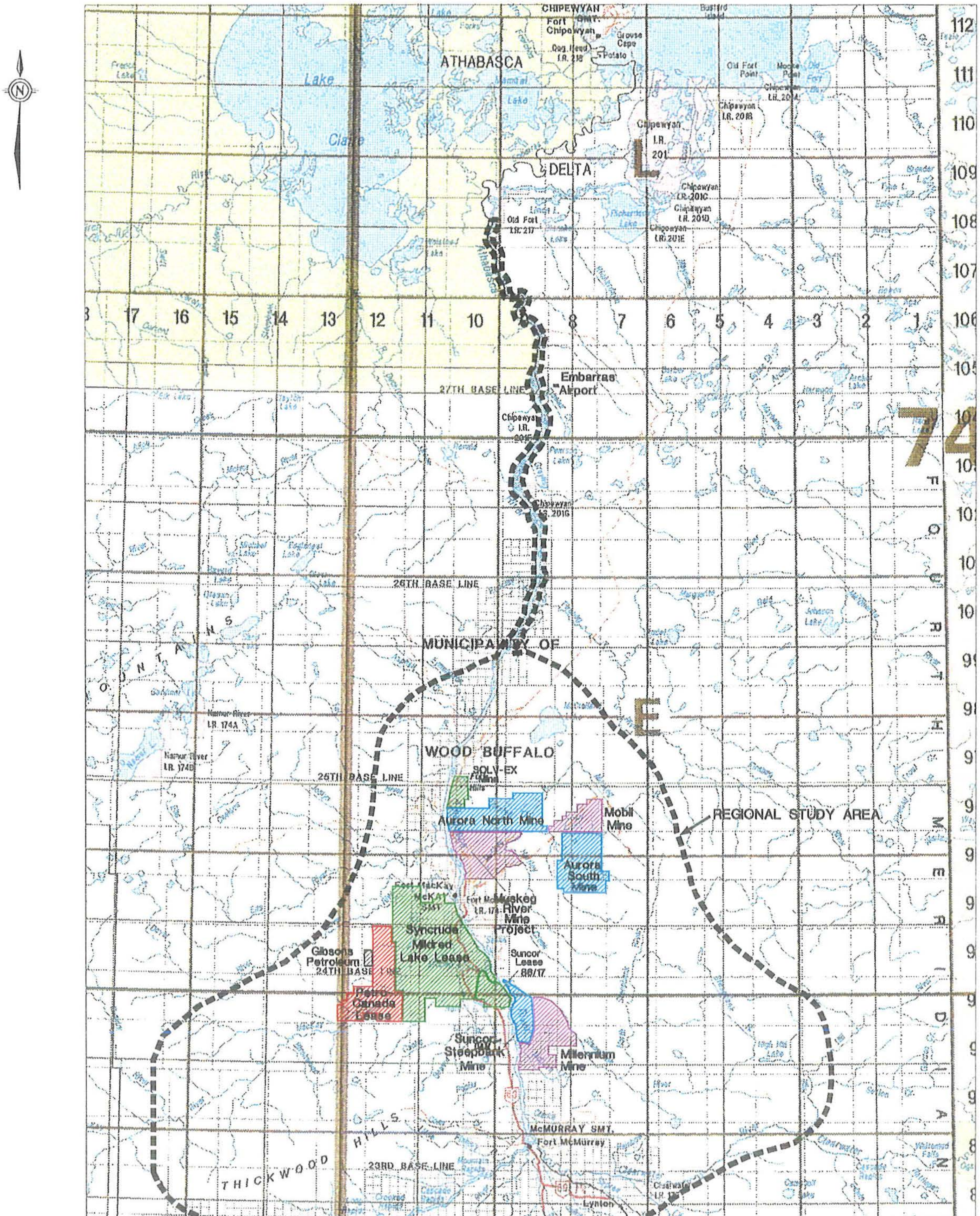
The Muskeg River Mine Project includes an open pit oil sands mine, an extraction plant and associated infrastructure. The Project is being proposed for development on the western portion of Shell Canada Limited's Lease 13 in the Athabasca Oil Sands region of northeastern Alberta. Details on the proposed Project are provided in Volume 1 as well as in Section B of Volume 2 of the Application.

Two major study area levels have been defined for the assessment of the potential impacts from the Muskeg River Mine Project. The study areas include a regional study area and local study areas. As described below, the spatial distribution of the study areas may vary for different EIA components.

A secondary study area level is also used in discussions on the Project. The Project area refers to the western portion of Lease 13, while the Project Development area refers to those parts of the western portion of Lease 13 where Project-specific development activities will take place.

D1.2.1 Regional Study Area (RSA)

The Regional Study Area (RSA) for the environmental, historic and land use components of the Muskeg River Mine Project EIA is based on the RSA used for the Suncor Energy Inc. Steepbank Mine and Syncrude Canada Ltd. Aurora Mine EIAs (Suncor 1996, BOVAR 1996a). This study area, shown in Figure D1-2, provides the basis for addressing cumulative effects resulting from the Project and from regional development. Through maintenance of the same RSA, results are directly comparable among project EIAs and consistency is maintained. In addition, there has been no significant additions to water or air emissions from existing or recently approved developments between the time the boundaries of the RSA were established in 1996 and the announcement of the Muskeg River Mine Project in 1997. Therefore, retaining the RSA boundary is justified.



0 10 20 30 40 50km

SCALE (Approx.)

REFERENCE

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

SHELL CANADA LIMITED

Golder Associates

OIL SANDS REGIONAL STUDY AREA (RSA)

04 DEC 97	Figure D1-2	DRAWN BY: TM

One slight difference between the Project RSA and that for the Steepbank and Aurora EIAs is the inclusion of a longer, downstream portion of the Athabasca River, ending at the confluence with the Embarras River. This extension was added for the purpose of ensuring potential regional effects on surface water quality were adequately addressed.

Some other variations to the base RSA for this Project were made depending on the specific EIA component being addressed. For example the RSA for human health cumulative effects encompasses a region of up to 100 km radius from the oil sands development area and includes the communities of Fort McMurray, Fort McKay and Fort Chipewyan. Changes to the base RSA are discussed in the specific component section of the EIA.

The environmental RSA boundaries were originally selected using an ecosystem-based approach, as defined by BOVAR Environmental (1996a). In summary, this approach included consideration of three criteria, airshed, watershed and landscape (ecological land classification), all of which are discussed briefly below.

Airshed Criterion

The production of acidifying emissions by the Muskeg River Mine Project will be very low. Although low from the Project, the production of these emissions on a regional basis is of concern for the oil sands development area. Therefore, the cumulative effects of emissions from the Project need to be addressed in the context of emissions from existing or planned oil sands facilities in the region. Air quality modelling of concentrations and depositions was used to set the geographic extent of the potential and direct or indirect impacts of air emissions on water, soil and vegetation (BOVAR 1996a).

Watershed Criterion

Watersheds provide an ecological basis for defining a boundary for water-related impacts to aquatic resources, vegetation, soil and wildlife habitat utilization (BOVAR 1996a). The Project RSA includes watersheds of rivers and streams in the vicinity of the current and planned projects. The major rivers included in the watershed criterion were the Muskeg River, Steepbank River, MacKay River and the Athabasca River, from a point in the south where the Clearwater River enters the Athabasca River near Fort McMurray, to the confluence with the Embarras River in the north.

Landscape (Ecological Land Classification) Criterion

Ecological land classification (ELC) considerations used to delineate the RSA were described in BOVAR Environmental (1996a). In summary, the ELC considerations involved focus on ecodistricts, or subdivisions of the mid-boreal mixedwood ecoregion, as described by Strong (1992). The outer boundaries of those ecodistricts aligned with the oil sands development area were used to set the RSA boundary from a landscape perspective.

D1.2.2 Local Study Areas (LSA)

The Local Study Areas (LSAs) have been defined to include the spatial extent of all resources directly or indirectly affected by the Project. Therefore, the LSAs encompass the Project development area or a larger area depending on the environmental component (Figure D1-3).

There are seven different LSAs for the project:

- Air Quality;
- Hydrogeology - Groundwater;
- Aquatics (Surface Water Hydrology, Surface Water Quality and Aquatic Resources);
- Terrestrial (Terrain and Soils, Terrestrial Vegetation, Wetlands, Wildlife and Ecological Land Classification);
- Human Health (combination of Air and Aquatic LSAs);
- Historical Resources; and
- Traditional Land Use and Resource Use (same as for Terrestrial and Aquatics).

Air Quality

The Air Quality LSA (or local airshed) is defined by a 41 by 41 km area centred on the Project. It is within this region where air quality changes due to the Project are expected to be greatest. This study area includes the community of Fort McKay.

Hydrogeology - Groundwater

The LSA established for the Hydrogeologic-Groundwater impact assessment is defined as the entire Muskeg River Mine Project area, plus an area extending approximately 2 km north into the Syncrude Aurora North Mine area. Within the Project area, the groundwater LSA focuses on the area between the Athabasca and Muskeg rivers. These rivers represent the base of subsurface drainage for regional and local groundwater flow systems and therefore form natural hydrogeologic boundaries. Consequently, overburden dewatering effects and tailings or consolidated tailings seepage will not extend across these hydrogeologic boundaries. To the north of the Project boundary, the drawdown of surficial aquifers due to overburden dewatering is expected to be limited to less than 2 km from the edge of the mine pit development. This extension crosses the north boundary of the lease and extends into the Syncrude Aurora Mine area.

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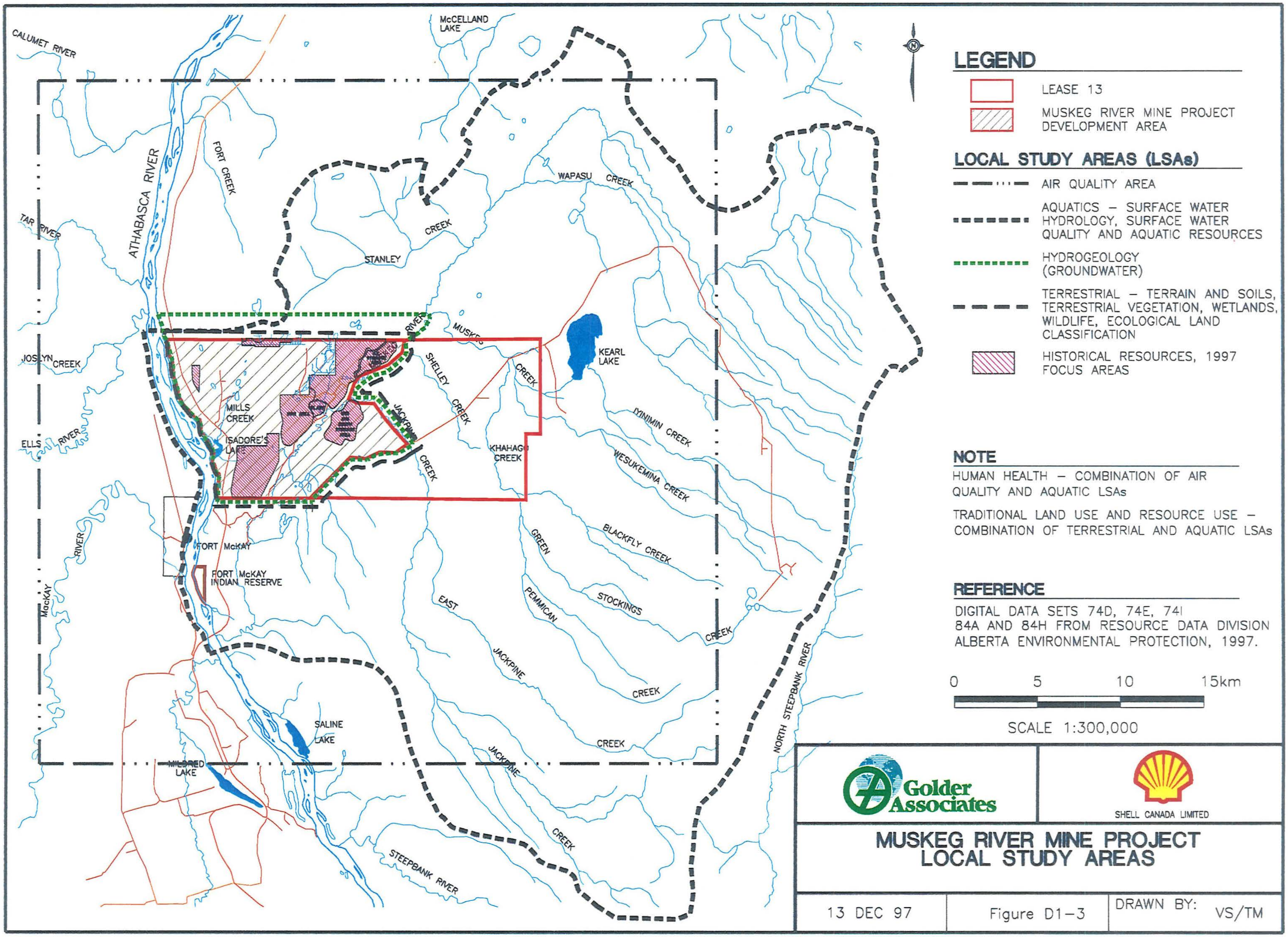


The Hydrogeology-Groundwater boundary is therefore bounded by the Athabasca River on the west and a combination of the Muskeg River, Jackpine Creek and the Lease Traverse Road on the east. The southern boundary is the Lease Traverse Road or the Lease 13 border.

Aquatics

The Aquatics LSA includes the Surface Water Hydrology, Surface Water Quality and Aquatic Resources components of the EIA. The LSA includes both the Muskeg River watershed and the Isadore's Lake watershed. It focuses on watercourses and waterbodies in the Project development area. The study area extends along the Athabasca River from the confluence of the Muskeg and Athabasca rivers to the northern boundary of Lease 13.

Terrestrial

The Terrestrial LSA has been designed to encompass potential direct effects to ecological land classification units (ELC), terrain and soils, terrestrial vegetation, wetlands and wildlife components. The Terrestrial LSA is defined by the Project development area with the exception of the south and east boundaries. Along these two borders, the LSA extends 500 m past the Project development area. The 500 m buffer is based on previous studies in the area and is designed to ensure inclusion of the potential disturbance to wildlife species.

Human Health

The local study area (LSA) for the human health component was selected based on the areas identified for evaluation of changes in air and water quality and the location of the nearest residential communities. The LSA includes the Muskeg River watershed, the Athabasca River up to the north boundary of Lease 13, and a 41 km radius from air emission sources on the Muskeg River Mine Project. The community of Fort McKay is included within the LSA. Worker health and safety considerations were confined to the construction and operation activities associated with the Muskeg River Mine Project. Evaluation of the reclaimed landscape was also confined to the Muskeg River Mine Project area.

Historical Resources

The Historical Resources LSA is within the Project area and includes only areas directly affected by the mine footprint and associated infrastructure. Additional areas within the Project development area have previously been assessed. These are discussed within the Historical Resources baseline.

Traditional Land Use and Resource Use

The Traditional Land Use and Resource Use LSA is generally the same as the Terrestrial LSA, as most aspects of these components are related to the terrestrial resources (e.g., forestry, environmentally significant areas, non-consumptive resource use, hunting and trapping). For aspects of traditional land use and resource use related to the aquatic environment (e.g., fishing, hunting and trapping), the LSA includes consideration of the waterbodies and watercourses within the Aquatics LSA.

D2 AIR QUALITY

D2.1 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:

- Baseline climate and air quality conditions in the area (TofR, Section 4.2).

Project-specific impacts on air quality are addressed in Section E2 of this EIA. Cumulative effects on air quality are addressed in Section F2. This section (Section D2) describes the air quality baseline in terms of available information and current monitoring activities for the following:

- existing sources and emissions
- meteorology; and
- background air quality.

Four baseline air quality reports were prepared in 1996 for the Suncor Steepbank Mine and the Syncrude Aurora Mine environmental assessments. The reports are:

- **Report 1: Source Characterization.** This report identifies and quantifies anthropogenic air emissions in the Fort McMurray-Fort McKay corridor. These emission sources include industrial point, fugitive, traffic and residential combustion sources (BOVAR 1996b).

- **Report 2: Ambient Air Quality Observations.** This report summarizes ambient air quality monitoring undertaken in the Fort McMurray-Fort McKay airshed. The sources include continuous data from the Suncor, Syncrude and Alberta Environmental Protection (AEP) networks as well as periodic data associated with other monitoring programs (BOVAR 1996c).

- **Report 3: Meteorology Observations.** This report summarizes meteorological data that describe the transport, dispersion and deposition of emissions in the area. A review of the terrain in the region and its effect on meteorology is provided (BOVAR 1996d).

- **Report 4: Air Quality Modelling.** Concurrent source, air quality and meteorological data are used to select an optimum dispersion modelling approach resulting in predictions that compare favourably with observations. The modelling complements the ambient monitoring by providing local and regional short- and long-term air quality changes associated with the current oil sands operations (BOVAR 1996e).

These reports summarize information collected to mid-1995. The air quality setting for the Muskeg River Mine Project presented in this subsection is based on these baseline reports and is supplemented with data collected after mid-1995. The air quality setting discussion is organized as follows:

- **Section D2.2** identifies existing sources and emissions in the regional study area (RSA).
- **Section D2.3** identifies sources of air quality and meteorological data in the region.
- **Section D2.4** characterizes the meteorological parameters that control the transport and dispersion of these emissions.
- **Section D2.5** provides a summary of background air quality information on an individual parameter basis.
- **Section D2.6** provides dispersion model predictions to complement the ambient monitoring results presented.
- **Section D2.7** provides a summary on greenhouse gases.
- **Section D2.8** provides a summary statement of baseline air quality in the context of the Muskeg River Mine Project area.

Study Area Boundaries

For the purposes of assessing air quality, two study areas were defined. These areas, which were described previously in Section D1, include:

- The Local Study Area, or local airshed (LSA) is defined by a 41 by 41 km area centred on the Project. It is within this region where air quality changes due to the Project are expected to be the greatest. This study area includes the community of Fort McKay.
- The Regional Study Area, or regional airshed (RSA) is defined by an area approximately 160 by 140 km centred over the location of the current Suncor and Syncrude facilities. This area has been used in previous assessments to depict the overlap of current and proposed oil sands operations. This study area includes the community of Fort McMurray.

The LSA is shown in D1-3 while the RSA is shown in Figure D1-2.

Ambient monitoring data from both the local and regional airsheds are discussed in this section and dispersion model predictions are provided for the (LSA) in this section (D2.6) for the current sources and in Section E2 for the Muskeg River Mine Project. Dispersion model predictions for the regional airshed are provided in Section F2.

D2.2 Existing Sources and Emissions

Major sources of air emissions in the Project area include the two existing oil sands operations. These facilities have AEP approvals for air emissions, and have both controlled and fugitive emission sources. The facilities are:

- **Suncor Energy Inc., Oil Sands (Suncor).** The Suncor Lease 86/17 facilities are located about 30 km south of the Project site. The facilities are serviced by numerous stacks that vent combustion products to the atmosphere. The Suncor utilities plant is serviced by a flue gas desulphurization (FGD) plant, which was commissioned in July 1996. Emission parameters for this stack are detailed in the Steepbank Mine Assessment (BOVAR and Golder 1996) and more recent information is also provided in the Suncor 1996 Annual Air Report (Suncor 1997).

- **Syncrude Canada Ltd. (Syncrude).** The Syncrude Mildred Lake facilities are located about 25 km to the south of the Project site. Like Suncor, the Syncrude facilities are serviced by numerous stacks. Recent information is detailed in the Syncrude 1996 Annual Air Report (Syncrude 1997).

Other currently operating industrial facilities with quantifiable air emissions include the Northlands Forest Products conical burner and the Gibson Petroleum in situ oil sands operation. Non-industrial sources include the traffic and residential emissions in the communities of Fort McMurray and Fort McKay.

The emission sources associated with these operations are summarized in Table D2-1. The results in Table D2-1 confirm the two existing oil sands operations as the major sources of regional emissions (i.e., Suncor and Syncrude). The other sources, while smaller, can affect air quality adjacent to the respective source zones. It should be noted that fugitive emission

Table D2-1 Summary of Anthropogenic Emissions From Current Emission Sources in the Region

	Emission						
Source	**SO_2 (t/d)**	**NO_x (t/d)**	**CO_2 (t/d)**	**CO (t/d)**	**PM (t/d)**	**THC (t/d)**	**TRS (t/d)**
Suncor	(a)	(a)	(b)	(b)	(b)	(b)	(b)
FGD Stack	27.2[c]	21.9	5665	14.1	1.3[c]		
SRU Incinerator	18.2	-	93	5.5	0.003	0.001	0.6
Secondary Sources	-	13.9	3451	0.9	0.3	0.04	-
Intermittent Flaring	15.6	0.1	19	0.06	0.001	0.02	-
Continuous Flaring	11.5	0.1	12	0.04	0.001	0.01	-
Mine Fleet	-	3.3	201	0.9	0.2	0.2	-
Upgrading (Fugitive)	-	-	-	-	-	6.3	0.04
Tailings Ponds	-	-	-	-	-	3.5	0.07
Subtotal	*72.5*	*39.3*	*9440*	*21.4*	*1.8*	*23.0*	*0.7*
Syncrude	(a)	(a)	(b)	(b)	(b)	(b)	(b)
Main Stack	197.4	13.2	6647	47.2	7.7	-	-
Secondary Sources	-	12.2	13475	2.6	0.9	0.3	-
Diverter Stacks	0.2	-	30	6.0	0.5	0.6	0.7
Flare Stacks	1.9	0.2	141	0.2	0.01	0.1	-
Mine Fleet	-	11.1	540	2.5	0.5	0.7	-
Settling Basin (Fugitive)	-	-	-	-	-	2.1	0.05
Other (Fugitive)	-	-	-	-	-	11.7	0.04
Subtotal	*199.5*	*36.7*	*20 833*	*58.6*	*9.6*	*15.5*	*0.8*
Other[e]	(b)	(b)	(b)	(b)	(b)	(b)	(b)
Gibsons Petroleum UTF	0.06	0.23	183	0.05	-	0.009	-
Northlands Forest Products	0.03	0.27	918	35	-	3.0	-
Highway 63	0.01	0.46	81	1.6	-	0.3	-
Fort McMurray/Fort McKay	0.2	0.88	129	3.9	-	2.1	-
Subtotal	*0.3*	*1.8*	*1311*	*40.6*	-	*5.4*	-
Total	272.3	77.8	31 584	120.6	11.4	43.9	1.6

(a) From Suncor 1997 and Syncrude 1997.
(b) From BOVAR 1996b.
(c) Combined FGD and Powerhouse average value - see note in text.
(d) Value included in FGD stack value.
(e) No values for SOLV-EX as operation currently suspended.

SO_2 = sulphur dioxide
NO_x = oxides of nitrogen
CO_2 = carbon dioxide
CO = carbon monoxide
PM = particulate matter
THC = total hydrocarbons
TRS = total reduced sulphur
FGD = flue gas desulphurization
SRU = sulphur recovery unit

estimates (e.g., for particulate matter [PM] and hydrocarbons [HC]) have not been estimated from these smaller sources. Detailed source parameters used for the dispersion model assessment are taken from the previously referenced documents (Section D2.1).

Before commissioning the FGD system at Suncor, all the utilities plant effluent was vented up the powerhouse stack. When the FGD unit is fully operating, the effluent from the three coke-fired boilers is vented up the FGD stack. The emissions provided in the table assume the FGD stack is operational and the overall average SO_2 and PM emission rates are weighted according to an FGD uptime of 95%. Overall, the average combined SO_2 emissions for the Suncor powerhouse stack (5% uptime) and the FGD stack (95% uptime) are expected to be 27.2 t/d. Similarly, PM emissions are expected to be 1.3 t/d. This compares with average Powerhouse stack SO_2 and PM emissions of 214.1 t/d and 6.3 t/d, respectively. The emission rates for the other gaseous compounds in the table are assumed to be the same for the Powerhouse and FGD stacks.

In 1996, the total Syncrude and Suncor SO_2 emissions were about 463 t/d. The effect of the FGD is to reduce this amount to 272.3 t/d.

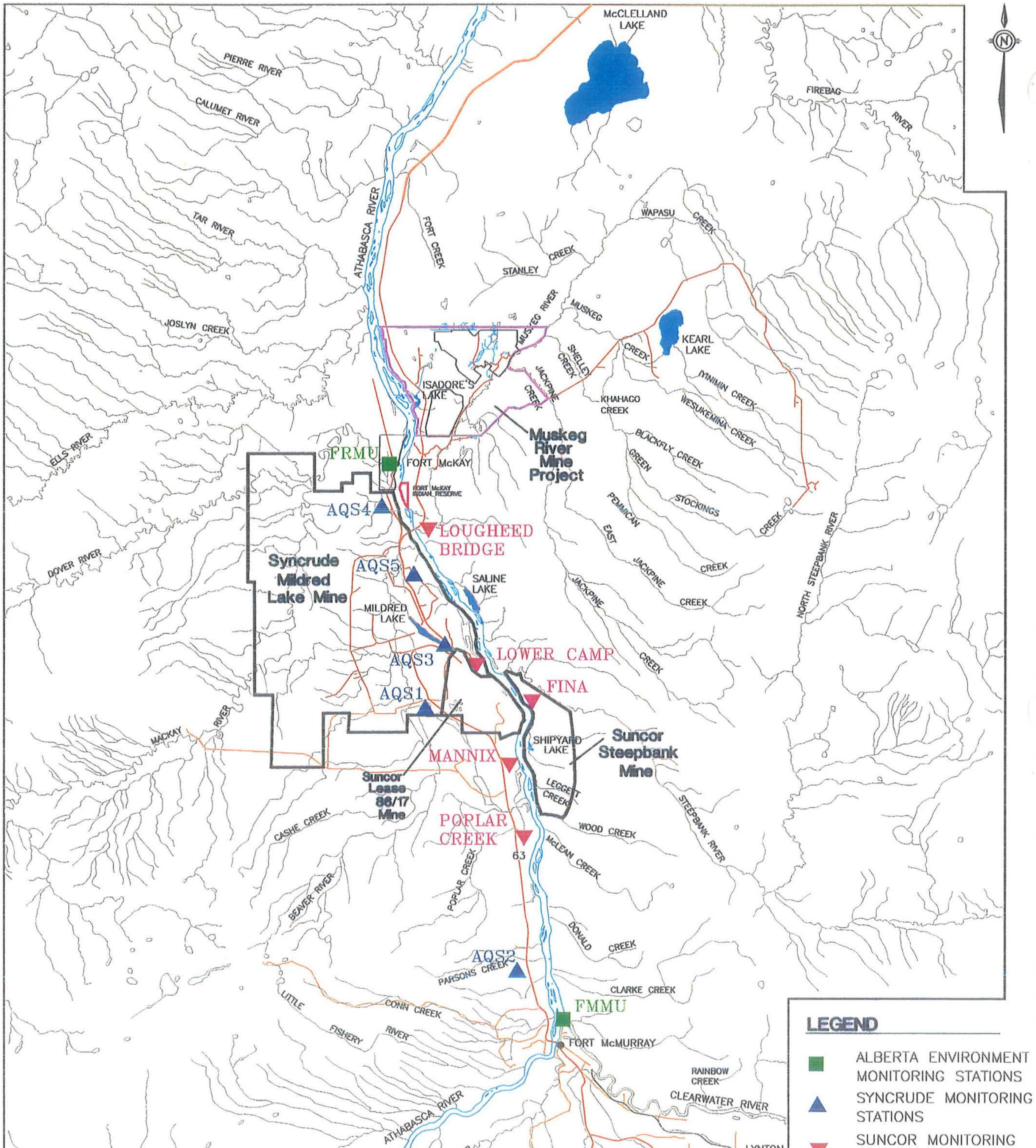
D2.3 Sources of Air Quality and Meteorological Data

D2.3.1 Ambient Air Quality

Suncor, Syncrude and AEP collectively maintain 12 continuous ambient air quality stations to monitor air quality and associated meteorology (Figure D2-1). AEP and Environment Canada collectively maintain nine precipitation quality monitoring stations in the vicinity of northern Alberta (within 600 km of the oil sands area). These monitoring programs have been further supplemented by baseline air quality monitoring conducted for the SOLV-EX, OSLO and SandAlta projects and supplemental meteorological monitoring conducted by Suncor at the Mannix and Lower Camp air quality station sites.

Table D2-2 provides a summary of the parameters measured at the 12 continuous monitoring stations. While data from all stations can be used to describe regional air quality, the following stations are used to define local air quality:

- The SOLV-EX Lease 5 background air quality station. Data are available for the 10-month period September 1996 to June 1997. This station is 15 km northwest of the Muskeg River Mine Project area.



0 5 10 15 20 25km

SCALE 1:500,000

REFERENCE

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

Golder Associates

SHELL CANADA LIMITED

**FORT McMURRAY - FORT McKAY
AMBIENT AIR QUALITY MONITORING NETWORK**

28 NOV 1997	Figure D2–1	DRAWN BY: CG

- The OSLO background air quality station. Data are available for the 22 month period March 1988 to December 1989. This station is 7 km east of the Muskeg River Mine Project area.

- The SandAlta background air quality station. Data are available from AEP for the 24-month period April 1984 to March 1986 (Hansen 1985, 1986). This station was 13 km southeast of the Muskeg River Mine Project area.

- The AEP Fort McKay station. This station is 12 km southwest of the Muskeg River Mine Project area.

- The Suncor Lougheed Bridge compliance monitoring station. This station is 14 km south-southwest of the Muskeg River Mine Project area. Data collection at the site began in October 1991.

These stations are all located within the LSA and provide an indication of the existing source effects on air quality. They do not provide an indication of background air quality associated with air flow into the LSA or the RSA. There are three background air quality stations in western Canada that can provide this type of information. These stations include the Acid Deposition Research Project (ADRP) Fortress Mountain (1985 - 1987) site located in southern Alberta (Legge and Krupa 1990), the West Central Airshed Society (1996) Hightower site located north of Hinton (West Central Airshed Society 1997) and the Environment Canada station located near Cree Lake, Saskatchewan (1988 to 1995). These three locations have instruments to measure low background concentration values, in contrast to the other stations, which have a compliance monitoring functionality and are instrumented to measure higher concentration values.

D2.3.2 Precipitation Quality

Table D2-3 identifies the location of the seven precipitation monitoring stations operated by AEP and the two stations operated by Environment Canada within 600 km of the RSA. Fort McMurray and Fort Chipewyan are the closest stations to the RSA. The Fort Vermilion, High Prairie and Beaverlodge stations are located in northwestern Alberta. The Cold Lake and Vegreville stations are located to the south of the oil sands area while Cree Lake station is to the east in Saskatchewan. Snare Rapids is located to the north in central N.W.T. The data from these stations were reviewed to provide an understanding of the precipitation quality associated with air flow into the RSA and LSA.

Table D2-2 Summary of Parameters Currently Monitored Continuously

Operation	Station	U	θ	SO_2	H_2S	NO_x	THC	O_3	CO	PM_{10}
Suncor	Mannix (#2)	✓	✓	✓	✓	×	✓	×	×	×
	Lower Camp (#4)	✓	✓	✓	✓	×	✓	×	×	×
	Fina Airstrip (#5)	✓	✓	✓	✓	×	×	×	×	×
	Poplar Creek (#9)	✓	✓	✓	✓	×	✓	×	×	×
	Lougheed Bridge (#10)	✓	✓	✓	✓	×	✓	×	×	×
Syncrude	AQS1 (Mine South)	✓	✓	✓	✓	×	×	×	×	×
	AQS2 (Fort McMurray)	✓	✓	✓	✓	×	✓	×	×	×
	AQS3 (Mildred Lake)	✓	✓	✓	✓	×	×	×	×	×
	AQS4 (Tailings North)	✓	✓	✓	✓	✓	✓	×	×	×
	AQS5 (Tailings East)	✓	✓	✓	✓	×	×	×	×	×
Alberta Environmental Protection	FMMU (Fort McMurray)	✓	✓	✓	✓	✓	✓	✓	✓	✓
	FRMU (Fort McKay)	✓	✓	✓	✓	×	✓	×	×	×

✓ = currently being monitored
× = not being monitored
U = wind speed
θ = wind direction
SO_2 = sulphur dioxide
H_2S = hydrogen sulphide
NO_x = oxides of nitrogen
THC = total hydrocarbons
O_3 = ozone
CO = carbon monoxide
PM_{10} = particulate matter less than 10 μm in diameter

Table D2-3 Precipitation Quality Monitoring Locations

Location	Distance[a] (km)	Direction[a]
Fort McMurray	36	SSE
Fort Chipewyan	190	N
Fort Vermilion	310	WNW
High Prairie	360	SW
Beaver Lodge	530	SW
Cold Lake	300	SSE
Vegreville	395	S
Cree Lake (Saskatchewan)	285	ENE
Snare Rapids (N.W.T.)	450	NNE

[a] From Muskeg River Mine Project area.

D2.3.3 Meteorology

Meteorological data collected at the OSLO and the Suncor Mannix sites are summarized and are used to assess local and regional air quality changes. The OSLO wind data were collected by instruments at a height of 15.8 m. The Mannix wind data are collected at three levels (20, 45 and 75 m above sea level (masl)) of a tower located above the valley (base elevation = 334 masl). The Mannix tower is about 30 km south of the Muskeg River Mine Project area. Validated data are available for the period November 1993 to June 1995.

The OSLO data are more representative of air flow in the immediate vicinity of the Project due to proximity and the lower emission heights associated with the Project operations. The Mannix data are more representative of regional air flows that affect emissions from the taller sources (i.e., Syncrude and Suncor).

D2.4 Meteorology

Meteorology controls the transport and dispersion of gaseous emissions that are vented into the atmosphere. Specific meteorological parameters of concern include: wind direction, wind speed, mixing height and atmospheric turbulence. These elements are required by dispersion models used to predict ground-level air quality concentrations. Precipitation quantity information is required to predict the wet deposition or removal of contaminants.

D2.4.1 Wind Direction

Wind direction data can be displayed by plotting the frequency distribution as a "windrose." The windrose is comprised of bars whose length indicates the frequency the wind blows from a given direction. Wind information is displayed for the 16 points of a compass (e.g., N, NNE, NE, ENE, etc.).

Figure D2-2 presents windrose from the OSLO (March 1988 to December 1989) and Mannix sites (November 1993 to June 1995). Both sites indicate two prevailing wind direction quadrants: winds from the south (S) and south-southeast (SSE); and winds from the north (N) and north-northeast (NNE). These directions coincide with the north-south orientation of the Athabasca River Valley and the location of other elevated terrain landforms (e.g., Birch Mountain and Muskeg Mountain).

Although differences in wind direction observed at various locations in the oil sands area occur due to differing site characteristics, elevations and time periods, the windrose depicted in Figure D2-2 are typical of other oil sands sites. Specifically, the wind direction observations reflect the channelling due to topography (e.g., the Athabasca River valley).

D2.4.2 Wind Speed

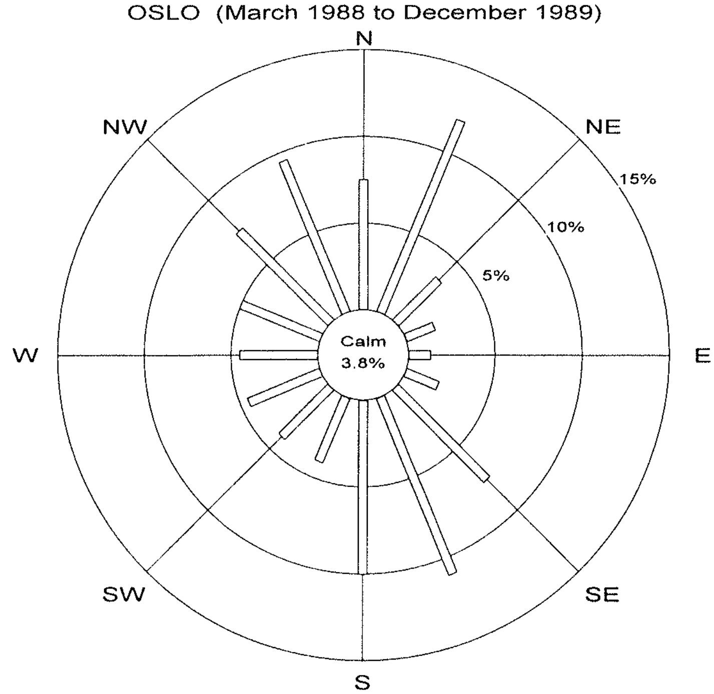
Wind speed information can be displayed in a histogram format. Wind speed can vary from site to site due to differences in site elevation, observation height and site characteristics.

Figure D2-3 compares the wind speeds observed at OSLO (15.8 m above ground level) and Mannix (75 m above ground level). At the OSLO site, the most frequent winds are in the 1 to 11 km/h range; at the Mannix site, the most frequent winds are greater than 12 km/h. In reviewing other regional wind data, this difference can be attributed to the difference in the respective measurement heights.

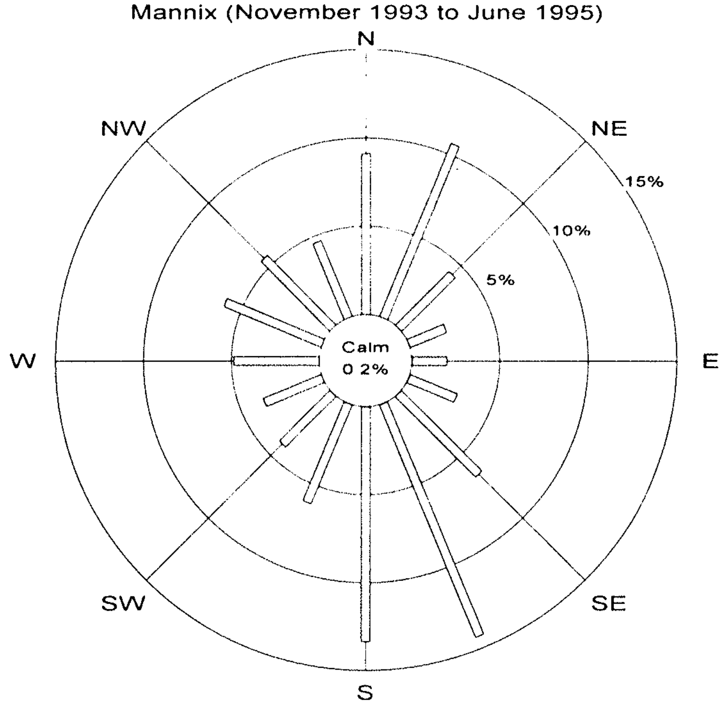
Table D2-4 summarizes the mean wind speeds (km/h) observed at the two sites. These mean wind speeds compare to a value of 9.6 km/h observed at Fort McMurray Airport (13 m above ground level). Due to the expanse of flat, cleared areas the wind speeds recorded at airports tend to be higher than those observed above a forest canopy (i.e., OSLO). Winds in northern Alberta are generally lower than those observed in southern Alberta (e.g., Calgary has a mean wind speed of 16.2 km/h) (Environment Canada 1983).

Figure D2-2 Annual Windrose for OSLO and Mannix Monitoring Sites

OSLO (March 1988 to December 1989)



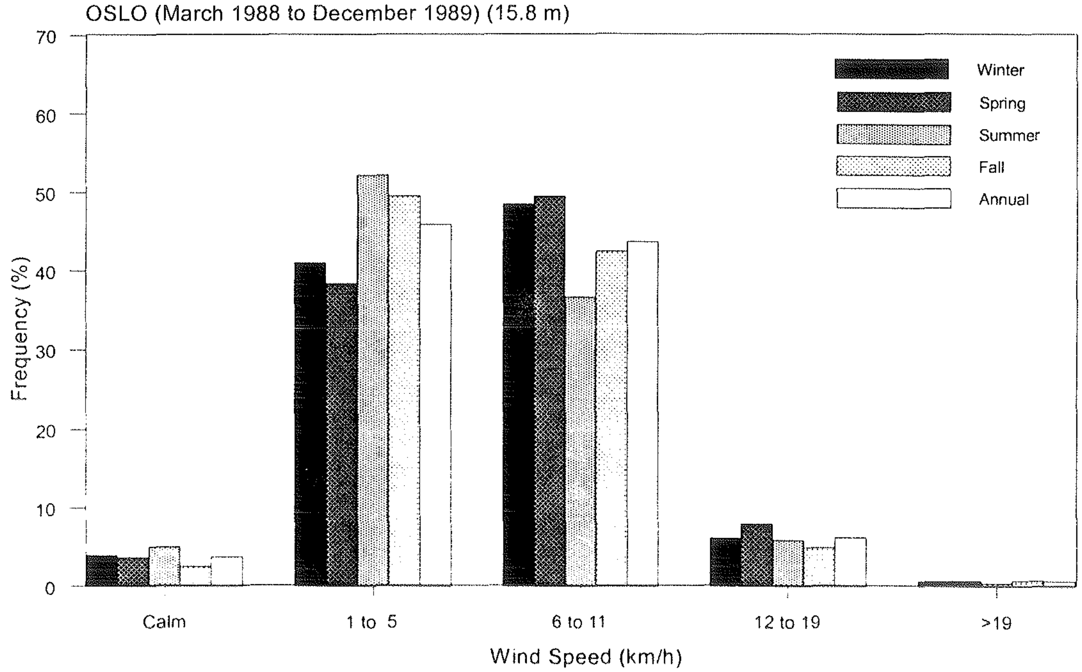
Mannix (November 1993 to June 1995)



*OSLO recorded 15.8 m above ground level; Mannix recorded 75 m above ground level.

Figure D2-3 Annual Wind Speed Frequency Distribution for OSLO and Mannix Monitoring Sites

OSLO (March 1988 to December 1989) (15.8 m)



Mannix (November 1993 to June 1995) (75 m)

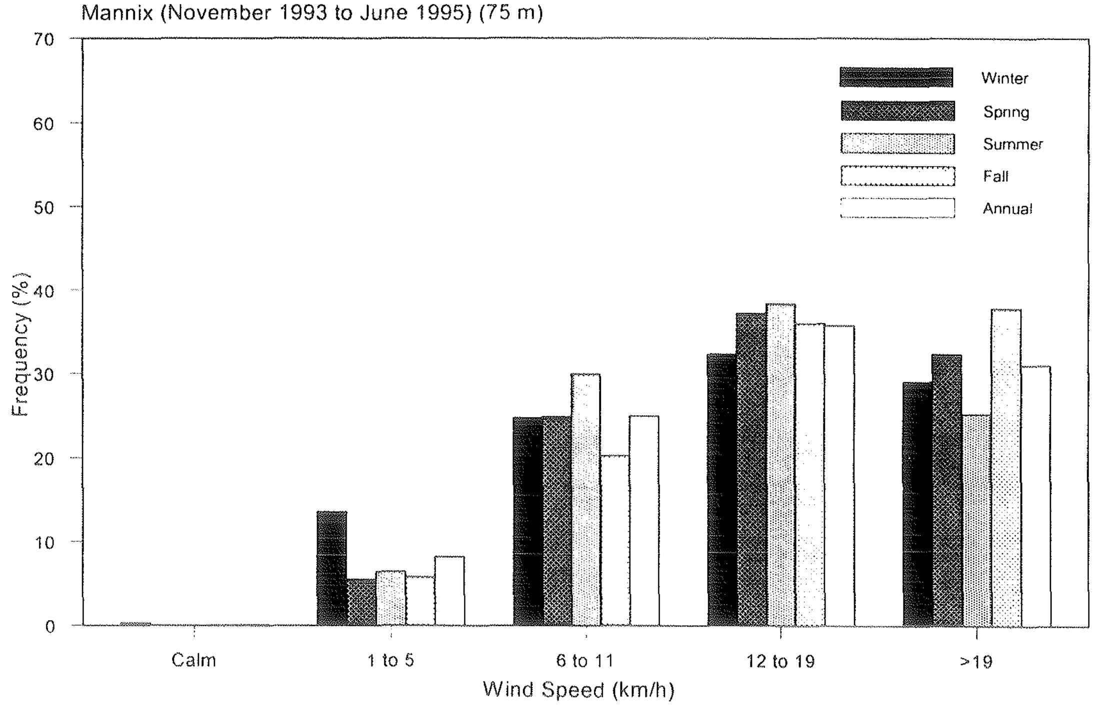


Table D2-4 Comparison of Mean Wind Speeds Observed at the OSLO and Mannix Sites

Season	OSLO (15.8 m)	Mannix (75 m)
Winter (Dec., Jan., Feb.)	6.1	14.3
Spring (Mar., Apr., May)	6.5	15.8
Summer (Jun., Jul., Aug.)	5.8	14.5
Fall (Sep., Oct., Nov.)	6.1	16.6
Annual	6.1	15.2

D2.4.3 Mixing Height

In a well-mixed atmosphere, the temperature tends to decrease 1°C for every 100 m increase in height above the ground. During the nighttime when the ground cools due to radiation heat loss, the temperature may increase with increasing height. This is referred to as a temperature inversion. The base of an inversion can be ground-based or elevated.

In the case of an elevated inversion layer, a two-layer atmosphere is created. The lower layer tends to be well-mixed and is characterized by neutral or unstable conditions. The depth of this lower layer is referred to as the mixing height. The upper layer tends to be characterized by stable conditions. The vertical transfer of mass between these two layers is suppressed by temperature gradient differences.

Because mixing heights are not routinely measured hourly, they have to be inferred from other collected data. The estimation of mixing heights should include mechanical and convective mechanisms that produce limited mixing layers.

Mixing layer heights have been calculated for the OSLO site from climatological relationships (Concord 1992a) based on time of day and season. Mixing layer heights have been calculated for the Mannix site based on net radiation observations (BOVAR 1996d).

Figures D2-4 and D2-5 show the diurnal and seasonal mixing height values observed at the OSLO and Mannix sites. During the winter, the mixing heights do not show much diurnal variation due to lower solar radiation values. During the other seasons, the mixing heights tend to increase after sunrise to a maximum value by mid-afternoon then decrease at sunset.

Table D2-5 compares these median afternoon values to the median values reported for the oil sands area by Davison et al., (1981) and the mean maximum values reported by Portelli (1977). While these comparisons are not completely independent, they confirm the smallest afternoon mixing heights tend to occur in winter (~ 300 to 500 m) and the largest in spring/summer (~ 1000 to 1800 m).

Table D2-5 Comparison of Maximum Afternoon Mixing Height Values Reported for the Oil Sands Area

	OSLO (m)	Mannix (m)	Davison et al. (1981) (m)	Portelli (1977) (m)
Winter	490	500	270	260
Spring	1390	1000	1000	1230
Summer	1780	1000	1000	1725
Fall	850	800	800	760

All values in m above ground level

D2.4.4 Atmospheric Turbulence

Atmospheric turbulence determines the dilution of a plume as it is transported by the wind. The turbulence may be generated by either thermal or mechanical mechanisms. Surface heating or cooling by radiation contributes to the generation or suppression of thermal turbulence, while high wind speeds contribute to the generation of mechanical turbulence.

Meteorologists frequently use the Pasquill-Gifford (PG) stability classification scheme when describing the amount of turbulence present in the atmosphere. These classes range from Unstable (Stability Classes A, B and C) through Neutral (Stability Class D) to Stable (Stability Classes E and F). Unstable conditions are primarily associated with daytime heating conditions, which result in enhanced turbulence levels. Stable conditions are associated primarily with nighttime cooling conditions, which result in suppressed turbulence levels. Neutral conditions are primarily associated with high wind speed conditions or with overcast conditions.

Atmospheric stability can be either measured directly from wind fluctuation observations or inferred from indirect measurements. For the OSLO site, the estimation of the PG stability class was based on standard deviations of the wind direction (σ_θ) while the PG estimates for the Mannix site were based on standard deviations of the vertical wind angle (σ_ϕ). For both sites, the stability classes were limited from A to D for daytime conditions and from D to F for nighttime conditions.

Figure D2-4 Diurnal and Seasonal Mixing Height Values Based on OSLO Data

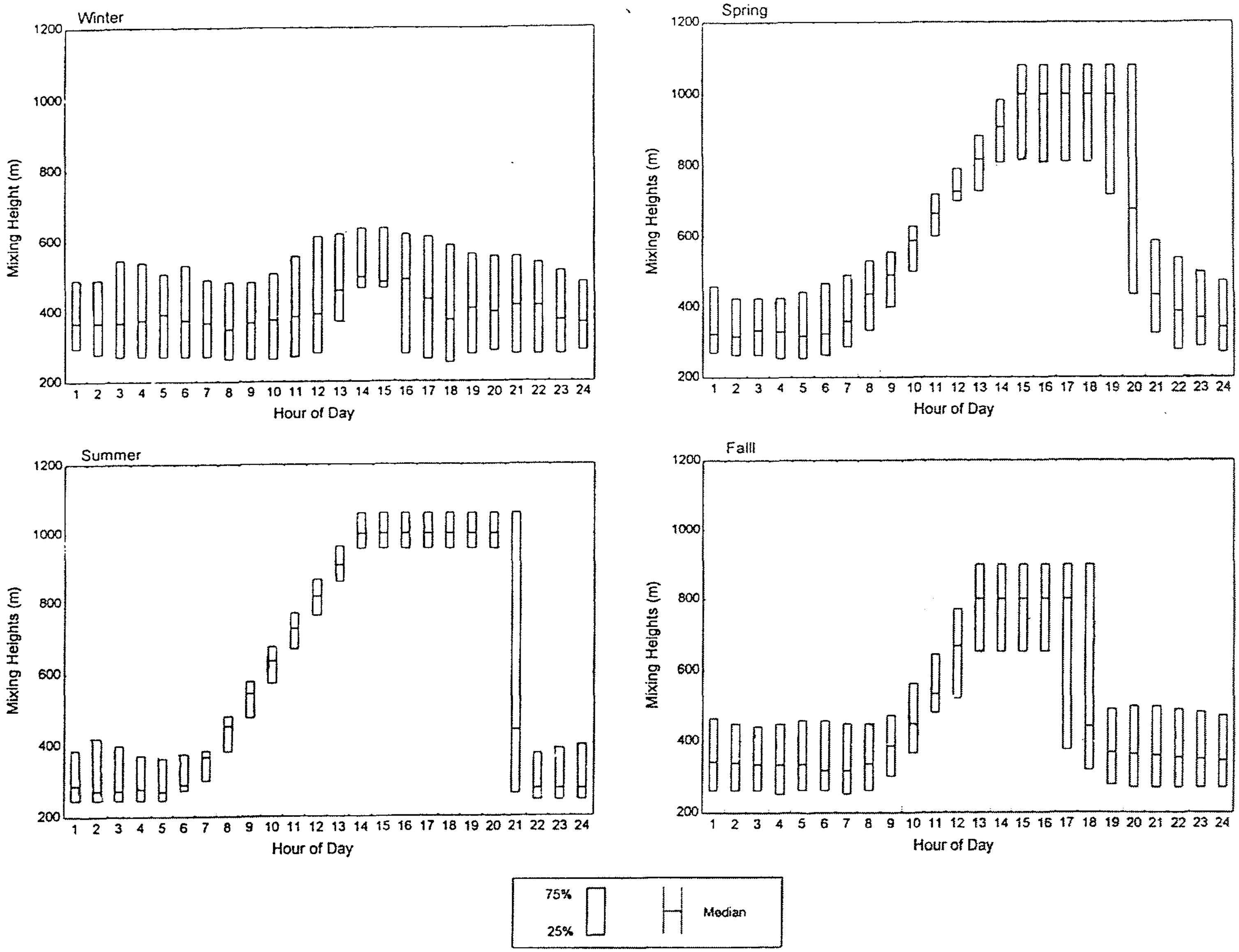
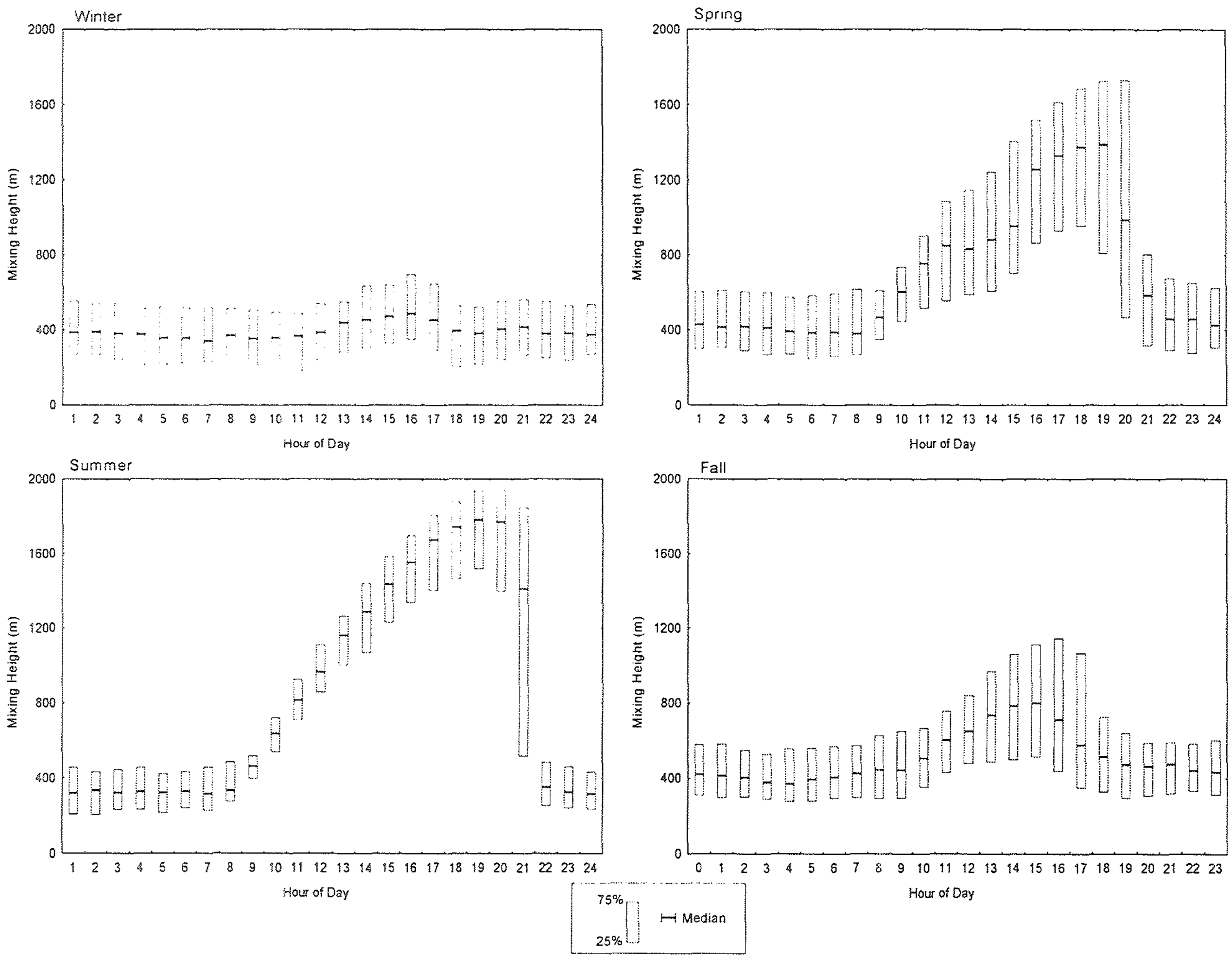


Figure D2-5 Diurnal and Seasonal Mixing Height Values Based on Mannix Data



Figures D2-6 and D2-7 show the diurnal and seasonal variation of PG stability classes. The figure confirms PG classes A to C being limited to the day, PG classes E and F being limited to the night and the greater frequency of unstable conditions (A to C) during the summer. The neutral PG class D can occur day or night.

Table D2-6 summarizes the frequency of unstable, neutral and stable conditions for the OSLO and Mannix sites. The difference between the two sites reflect the subjectivity involved in estimating the PG stability class rather than actual site-to-site variation.

Table D2-6 Comparison of PG Stability Class Frequency for the OSLO and Mannix Sites

Season	Site	Frequency (%)		
		Unstable (A, B, C)	Neutral (D)	Stable (E, F)
Winter	OSLO	18	47	36
	Mannix	4	61	35
Spring	OSLO	43	35	21
	Mannix	22	61	17
Summer	OSLO	45	31	24
	Mannix	32	53	15
Fall	OSLO	28	38	33
	Mannix	8	66	26
Year	OSLO	36	37	28
	Mannix	16	61	23

D2.4.5 Precipitation Quantity

The presence of precipitation, the precipitation rate and the type (e.g., liquid or frozen), control the wet removal of compounds vented into the atmosphere. For the period associated with the Mannix meteorological data, hourly precipitation rates (mm/h) were obtained from the Fort McMurray airport. Figure D2-8 compares monthly total precipitation observed at the Mannix site for the period November 1993 to January 1995 to the long-term climatological values observed in Fort McMurray (Environment Canada 1983b). In comparison, February, March and June were wetter for the period than the longer-term norms, and August and September were dryer for the period than the longer-term norms.

Figure D2-6 Diurnal and Seasonal Stability Class Values Based on OSLO Data

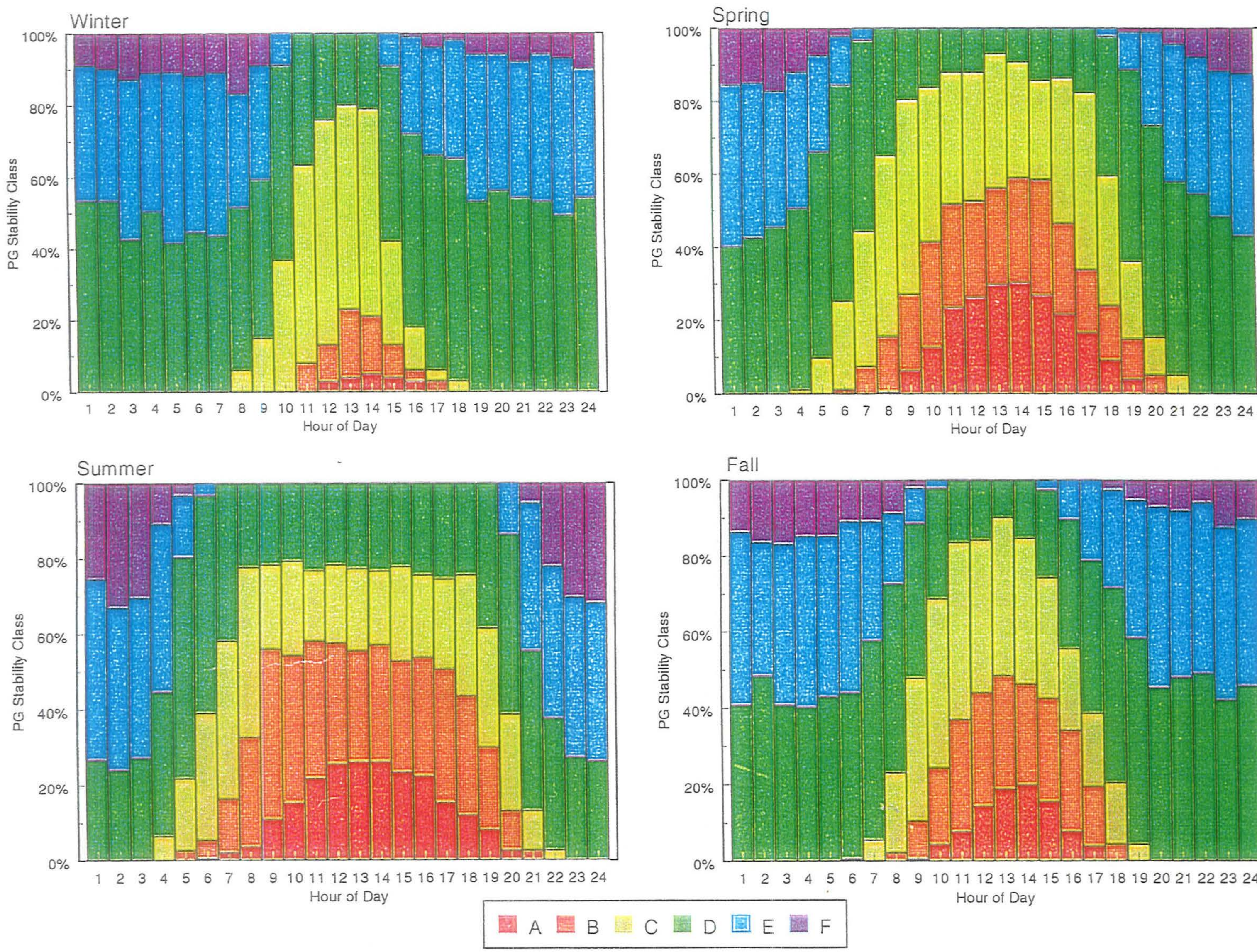


Figure D2-7 Diurnal and Seasonal Stability Class Values Based on Mannix Data

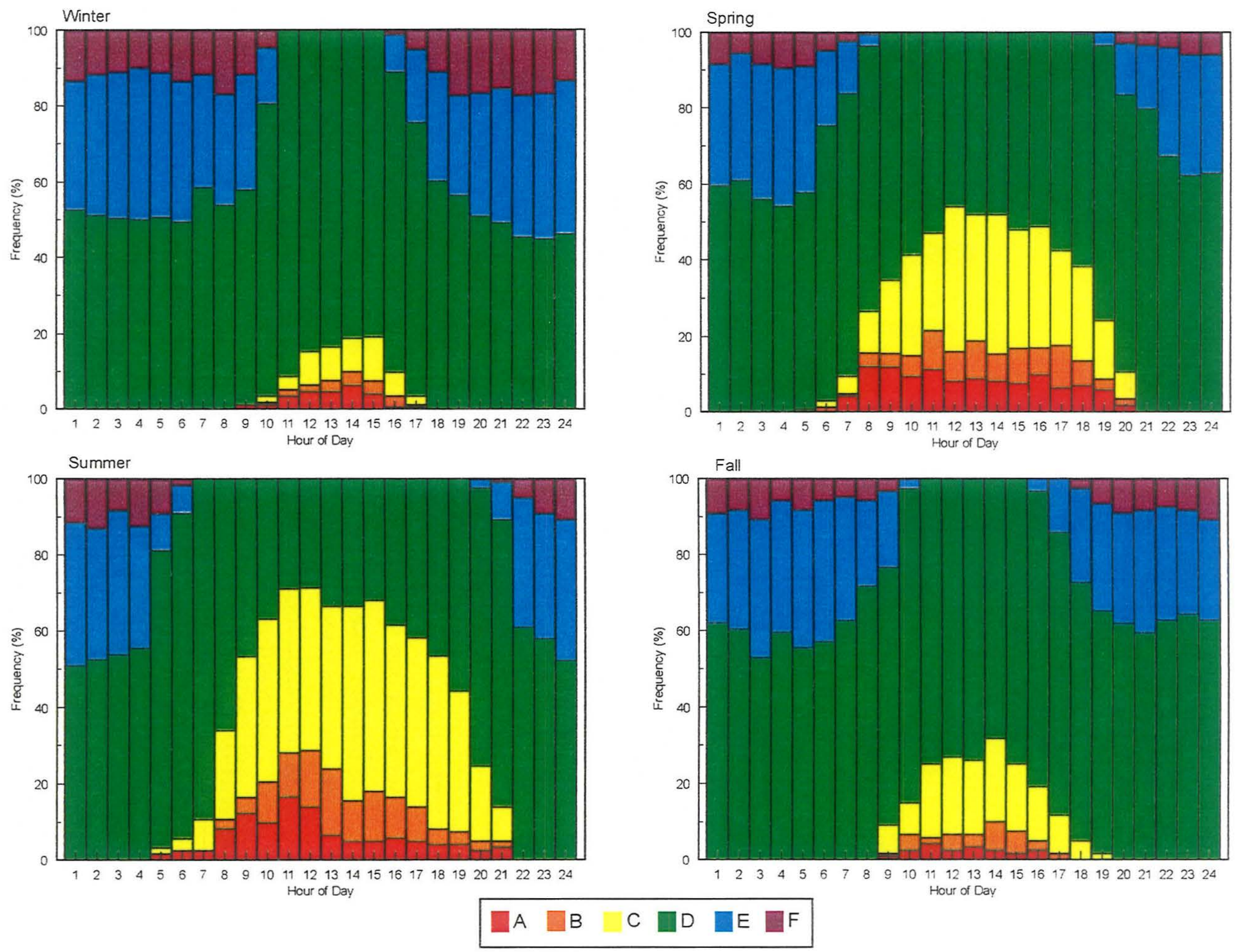
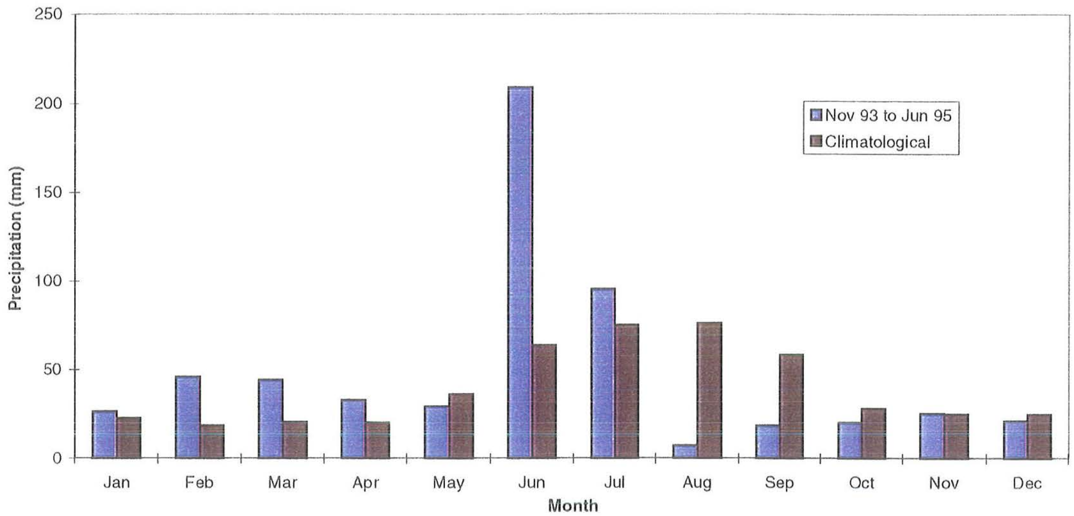


Figure D2-8 Comparison of Long-Term Monthly Precipitation With Precipitation From November 1993 to June 1995



D2.5 Background Air Quality Information

The background air quality information is presented on an individual parameter basis in the following sections. Where appropriate, the observations are compared to ambient air quality criteria that exist as guidelines or target loadings.

D2.5.1 Air Quality Guidelines

The impact of air emissions introduced into the atmosphere by industrial activities can be broad. The emissions can have direct and indirect effects on humans, other animals, vegetation, soil, water and visibility. It is for this reason that environmental regulatory agencies have established maximum concentration limits in the atmosphere.

Ambient Concentration Criteria

Table D2-7 presents the Alberta provincial guidelines and the Canadian federal government air quality objectives for regulated compounds. The compounds include: sulphur dioxide (SO_2), hydrogen sulphide (H_2S), nitrogen dioxide (NO_2), carbon monoxide (CO), oxidants expressed as ozone (O_3) and suspended particulates. These guidelines and objectives refer to averaging periods ranging from one hour to one year. In addition,

Table D2-7 Federal, Alberta and Other Government Ambient Air Quality Guidelines and Objectives

	Alberta Guidelines		Federal Objectives[a]		
			Desirable	Acceptable	Tolerable
SO_2 (µg/m³)					
Annual	30	(0.01 ppm)	30	60	n/a[b]
24-Hour	150	(0.06 ppm)	150	300	800
1-Hour	450	(0.17 ppm)	450	900	n/a
H_2S (µg/m³)					
24-Hour	4	(0.003 ppm)	n/a	5[c]	n/a
1-Hour	14	(0.01 ppm)	1[c]	15[c]	n/a
NO_2 (µg/m³)					
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
CO (mg/m³)					
8-Hour	6	(5 ppm)	6	15	20
1-Hour	15	(13 ppm)	15	35	n/a
Oxidants (µg/m³)[d]					
Annual	n/a		n/a	30	n/a
24-Hour	50	(0.025 ppm)	30	50	n/a
1-Hour	160	(0.082 ppm)	100	160	300
Suspended Particulates (µg/m³)					
Annual[e]	60	n/a	60	70	n/a
24-Hour	100	n/a	n/a	120	400
PM_{10}[f]					
24-Hour	50[g]	n/a	n/a	n/a	n/a
24-Hour	150[h]	n/a	n/a	n/a	n/a
Annual	50[h]	n/a	n/a	120	400
$PM_{2.5}$[i]					
24-Hour	65[h]	n/a	n/a	n/a	n/a
Annual	15[h]	n/a	n/a	n/a	n/a

(a) At a temperature of 25°C and pressure of 101.3 kPa, respectively.
(b) n/a = not applicable.
(c) Proposed.
(d) As ozone (O_3).
(e) As a geometric mean.
(f) PM_{10} - particulate matter emissions with particle diameter less than 10µm.
(g) Based on B.C. and Ontario.
(h) Based on US EPA.
(i) $PM_{2.5}$ - particulate matter emissions with particle diameter less than 2.5 µm

the federal government has established three levels of objectives (Environment Canada 1981). The levels are as follows:

- The maximum **desirable** level defines the long-term goal for air quality and provides a basis for an anti-degradation policy for the unpolluted parts of the country and for the continuing development of control technology.

- The maximum **acceptable** level is intended to provide adequate protection against adverse effects on soil, water, vegetation, materials, animals, visibility, personal comfort and well-being.

- The maximum **tolerable** level denotes a concentration of an air contaminant that requires abatement without delay to avoid further deterioration to an air quality that endangers the prevailing Canadian lifestyle or ultimately, to an air quality that poses a substantial risk to public health.

In Alberta, the maximum concentrations in ambient air are currently specified as guidelines for SO_2, H_2S, NO_2, CO, oxidants expressed as O_3 (ozone) and total suspended particulate matter (Government of Alberta 1993).

With the exception of oxidants and the proposed federal one-hour average objective for H_2S, the Alberta Environment guidelines are equal to the most stringent of the federal objectives. The Alberta guidelines for oxidants are less strict when compared with the Federal Air Quality objectives since rural ozone concentrations in Alberta have been observed to exceed the Federal Desirable Level (Angle and Sandhu 1986, 1989).

The primary focus on Particulate Matter (PM) emissions is the inhalable fraction, with diameters less than 10 μm (referred to as PM_{10}) and the respirable fraction, with diameters less than 2.5 μm (referred to as $PM_{2.5}$), not Total Suspended Particulate (TSP) matter. Neither Alberta nor the federal government have adopted PM_{10} or $PM_{2.5}$ guidelines; the values provided in Table D2-8 reflect those adopted by B.C., Ontario and the U.S. EPA.

Deposition Criteria

Deposition includes both wet and dry processes and can result in the long-term accumulation of emissions in aquatic and terrestrial ecosystems. Wet processes involve the removal of emissions vented into the atmosphere by precipitation. Dry processes involve the removal by direct contact with surface features (e.g., vegetation). Both wet and dry deposition are expressed as a flux in units of "kg/ha/a." Where more than one chemical species is considered, the flux is often expressed in "keq/ha/a" where "keq" refers to hydrogen ion equivalents (1 keq = 1 kmol H^+). The deposition of

Table D2-8 Deposition Target Loadings for Acid Forming Emissions

Form	Loading[a]	Comments	Reference
Wet Sulphate Deposition	20 kg/ha/a (Target)	SO_4^{2-} not strongly correlated with H^+ in western Canada. Does not include dry deposition or NO_x precursors.	US-Canada Memorandum of Intent (1983)
Acidifying Potential (AP)	0.12 to 0.31 keq/ha/a (Critical)	Does not include dry deposition or NO_x precursors. $AP = [SO_4^{2-}]-([Ca^{2+}]+[Mg^{2+}])$	Interim Acid Deposition Target Loadings Task Group (1990)
Effective Acidity (EA)	0.1 to 0.7 keq/ha/a depending on soil sensitivity (Critical)	Various forms account for wet and dry deposition and NO_x precursors. Accounts for soil response to deposition. $EA = [H^+] + 1.15\ [NH_4^+] - 0.7\ [NO_3^-] + [SO_2] + [SO_4^{2-}]$	Alberta Environment (1990) and Peake and Fong (1992)
Acid Neutralizing Capacity (ANC)	0.25 to 1.5 keq/ha/a depending on ecosystem (Critical)	Includes wet and dry deposition of all components. e.g., $ANC = ([Ca^{2+}] + [Mg^{2+}] + [K^+] + [Na^+]) - ([SO_4^{2-}] + [NO_3^-] + [NH_4^+] + [Cl^-])$	World Health Organization (1994)
Potential Acid Input (PAI)	0.25 keq/ha/a (Critical)	For sensitive areas. Includes SO_x and NO_x, wet and dry deposition and baseline precipitation. $PAI = ([SO_4^{2-}] + [NO_3^-] + [NH_4^+]) - ([Ca^{2+}] + [Mg^+] + [K^+])$	Target Loading Subgroup (1996)

[a] Target Load: Maximum level of atmospheric deposition, which provides long-term protection from adverse ecological consequences, and is practically and politically achievable.

Critical Load: Highest load that will not cause chemical changes leading to long-term harmful effects on the most sensitive ecological systems.

sulphur and nitrogen compounds to these systems has been associated with changes in water and soil chemistry and with the acidification of water and soil.

Table D2-8 presents target loading values that have been considered for application to the deposition of acidic compounds in Alberta. The preferred AEP method is based on the Potential Acid Input (PAI) that is similar to the acid neutralizing capacity (ANC) except the oceanic salt contribution has been removed (i.e., [Na^+] and [Cl^-]). The calculation of the PAI is based on sulphur compounds (e.g., SO_2 (gas), SO_4^{2-} [particle]), nitrogen compounds (e.g., NO, NO_2 and HNO_3 (gas), NO_3^- (particle)) and base cations (e.g., Ca^{2+}, Mg^+ and K^+ (particle)).

The critical target loading recommended by the Target Loading Subgroup (1996) is for sensitive systems and is based on the European Approach outlined in the World Health Organization document (WHO 1994). This approach specifies critical target loads of 0.25, 0.5, 1.0 and 1.5 keq/ha/a that range from the most sensitive to least sensitive ecosystems. The terrestrial sensitivities depend on the geology of the parent material and the surface water sensitivities depend on the base cation concentration and runoff amounts.

D2.5.2 Sulphur Dioxide Concentrations

Table D2-9 summarizes the number of times sulphur dioxide (SO_2) concentrations have been observed above the 0.17 ppm (450 $\mu g/m^3$) hourly ambient air quality guideline. While exceedances have been observed at all sites, the frequency of exceedances in the LSA is typically 0 to 2 events per year (as defined by the Lougheed Bridge and Fort McKay stations). Figure D2-9 shows the maximum hourly average SO_2 concentrations observed at the SOLV-EX, SandAlta, OSLO and Fort McKay stations. Specific to the LSA stations, the following are noted:

- **SOLV-EX Lease 5.** The maximum SO_2 concentrations for each of the 10 months of monitoring ranged from 0.013 to 0.114 ppm (34 to 296 $\mu g/m^3$).

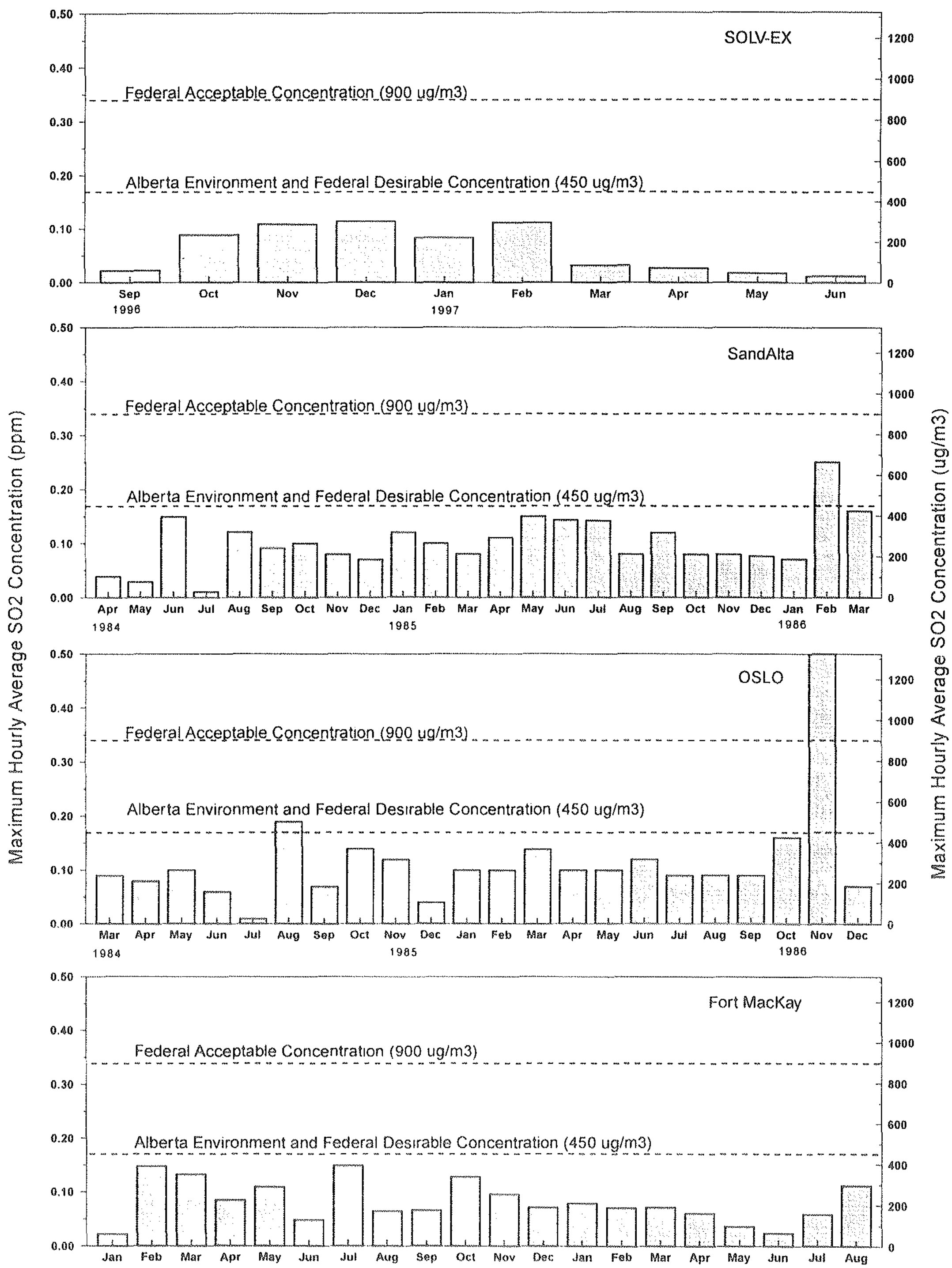
- **SandAlta.** The maximum SO_2 concentrations for each of the 24 months of monitoring ranged from 0.02 to 0.25 ppm (50 to 660 $\mu g/m^3$). On average, the maximum hourly values for each month tend to be about 0.10 ppm (260 $\mu g/m^3$).

- **OSLO.** An extreme event of 0.5 ppm (1300 $\mu g/m^3$) was observed in November 1986. This may have been due to an abnormal emission (e.g., flaring) event. For the most part, the average maximum hourly values tend to be about 0.10 ppm (260 $\mu g/m^3$).

Table D2-9 Number of Hourly SO_2 Concentrations Greater Than 0.17 ppm (450 μg/m^3)

Station	1990	1991	1992	1993	1994	1995	1996	Total	Average
Mannix (#2)	21	7	5	9	21	20	10	93	16
Lower Camp (#4)	18	11	1	3	6	5	3	49	8
Fina (#5)	41	20	9	14	16	21	11	132	22
Poplar Creek (#9)	0	0	2	0	4	4	3	13	2
Lougheed Bridge (#10)	0	0	2	2	6	2	0	12	2
AQSI (Mine South)	6	2	0	3	7	3	1	22	4
AQS2 (Fort McMurray)	1	2	0	0	5	6	0	14	2
AQS3 (Mildred Lake)	4	3	5	4	8	5	2	31	5
AQS4 (Tailings North)	4	2	1	0	3	3	2	15	3
AQS5 (Tailings East)	0	0	0	0	1	0	2	3	0.5
FMMU (Fort McMurray)	0	0	0	0	0	1	0	1	0.2
FRMU (Fort McKay)	0	2	1	1	2	2	0	8	2
Total	95	49	26	36	79	72	34		

Figure D2-9 Maximum Hourly Average SO_2 Concentrations Observed at the SOLV-EX, SandAlta, OSLO and Fort McKay Monitoring Stations



- **Fort McKay.** Maximum hourly SO_2 concentrations since 1996 have typically been in the 0.072 to 0.231 ppm (188 to 611 µg/m^3) range. The period January 1996 to August 1997 is shown.

Once in the atmosphere, SO_2 (gas) can be converted into sulphate (SO_4^{2-}, a particle). Background SO_2 and SO_4^{2-} values representative of the air flow into the region are useful in defining a regional background deposition. Table D2-10 summarizes values from the previously indicated background sites. Although the SO_2 concentrations are similar at the three sites, the SO_4^{2-} concentrations recorded at Cree Lake are larger. This may be due to the 2.5 µm size limitation associated with the observations at Hightower Ridge and Fortress Mountain.

In summary, historical monitoring has indicated exceedances of the hourly air quality guideline for SO_2 in the LSA. These exceedances typically occur up to two hours per year. "Pristine" SO_2 and SO_4^{2-} concentrations are typically 1.2 and 0.7 µg/m^3 respectively.

Table D2-10 Background SO_2 and SO_4^{2-} Concentrations for "Pristine" Continental Areas

Site	SO_2		SO_4^{2-}
	ppm	µg/m^3	µg/m^3
Hightower Ridge (1996)	0.41	1.1	0.58
Fortress Mountain (1985 to 1987)	0.51	1.4	0.51
Cree Lake (Saskatchewan) (1988 to 1995)	0.45	1.2	0.99
Average	0.46	1.2	0.69

D2.5.3 Hydrogen Sulphide Concentrations

Table D2-11 summarizes the number of hourly hydrogen sulphide (H_2S) concentrations in excess of the 0.01 ppm (14 µg/m^3) ambient air quality guideline. While exceedances have been observed at all sites, the frequency in the local area is typically about once per year (as defined by the Lougheed Bridge and Fort McKay stations). Specific to the LSA stations, the following are noted:

- **SOLV-EX Lease 5.** The maximum H_2S concentrations for each of the 10 months of monitoring ranged from 0.001 to 0.010 ppm (1.4 to 14 µg/m^3).

Table D2-11 Number of Hourly H_2S Concentrations Greater Than 0.01 ppm (10 ppb or 14 µg/m^3)

Station	1990	1991	1992	1993	1994	1995	1996	Total	Average
Mannix (#2)	44	37	5	24	42	10	16	162	27
Lower Camp (#4)	100	7	0	2	2	4	12	115	19
Fina (#5)	-	-	-	-	2	-	-	2	2
Poplar Creek (#9)	0	15	1	0	0	4	0	20	3
Lougheed Bridge (#10)	1	0	0	1	2	2	2	6	1
AQSI (Mine South)	10	2	0	4	10	0	1	26	4.7
AQS2 (Fort McMurray)	3	0	0	3	13	0	0	19	3.5
AQS3 (Mildred Lake)	80	4	1	3	1	0	3	89	16
AQS4 (Tailings North)	2	1	0	5	6	2	0	16	2.9
AQS5 (Tailings East)	0	1	0	0	0	2	0	3	0.5
FMMU (Fort McMurray)	1	5	0	0	5	0	0	11	2.0
FRMU (Fort McKay)	1	0	0	0	0	2	1	4	0.6
Total	242	72	7	42	83	72	35		

- **Lougheed Bridge.** The maximum hourly H_2S concentration of 0.10 ppm (140 μg/m^3) was observed at this location.

- **Fort McKay.** Maximum hourly H_2S concentrations since 1995 have typically been in the 0.002 to 0.071 ppm (3.8 to 135 μg/m^3) range.

In summary, historical monitoring has indicated exceedances of the hourly air quality guidelines for H_2S in the local airshed. These exceedances can be expected about once per year and when they occur, they can be several times the guideline value. These peak values will result in odours.

D2.5.4 Nitrogen Dioxide Concentrations

Figure D2-10 shows the maximum hourly nitrogen dioxide (NO_2) concentrations observed at the SOLV-EX, OSLO and SandAlta monitoring sites compared to the guideline of 0.21 ppm (400 μg/m^3). The monitoring results indicate:

- **SOLV-EX Lease 5.** The maximum NO_2 concentrations for each of the 10 months of monitoring ranged from 0.010 to 0.058 ppm (20 to 110 μg/m^3).

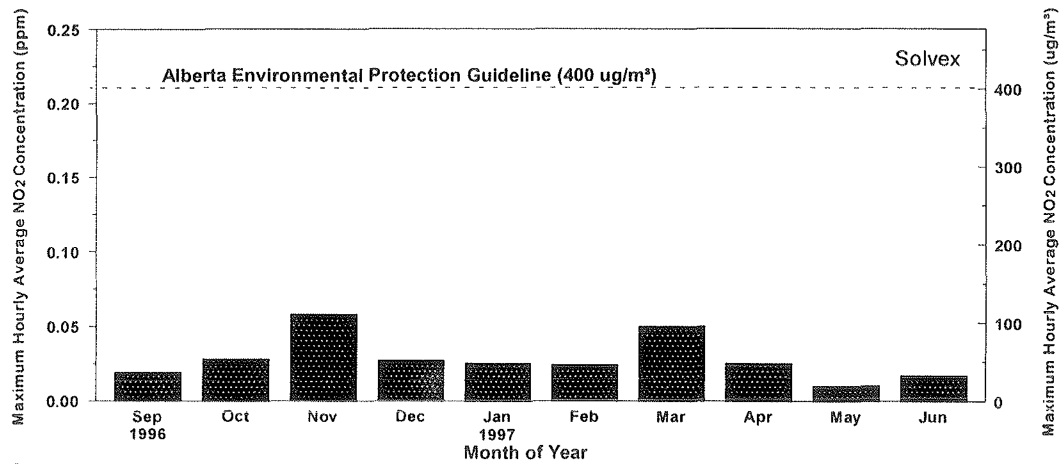
- **OSLO.** The maximum NO_2 concentrations for each of the 22 months of monitoring range from 0 to 0.17 ppm (0 to 324 μg/m^3). The majority of the NO_x observations were likely due to local traffic or emissions from the monitoring station electrical generator.

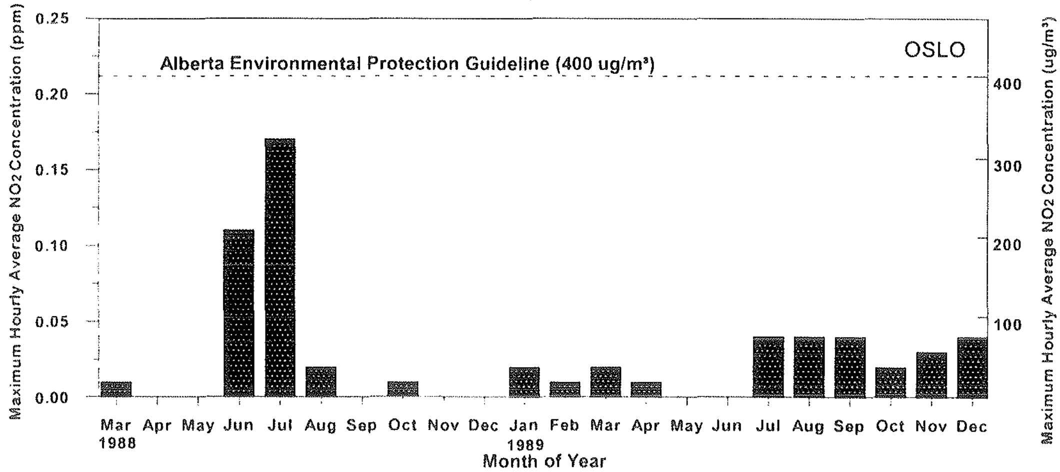
- **SandAlta.** The maximum NO_2 concentrations for each of 24 months of monitoring range from 0 to 0.04 ppm (0 to 76 μg/m^3).

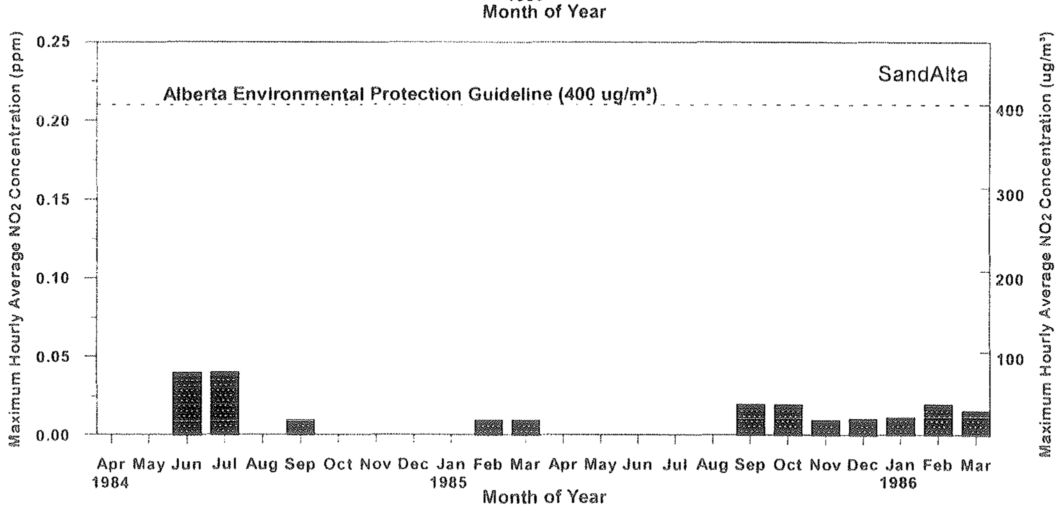
No exceedances of the hourly NO_2 guideline have been recorded.

Once in the atmosphere, NO is rapidly oxidized to form NO_2. These gases can then be transformed into nitric acid (HNO_3; a gas), ammonium (NH_4^+; a particle) or nitrate (NO_3^-; a particle). Pristine background levels of NO_2 and NO are low as these compounds are readily transformed into HNO_3 through reactions with ambient O_3 and methane. Background levels of NO_x (NO + NO_2) tend to range from 10 to 15% of the total nitrogen compounds in remote areas to 60% in areas where nearby sources are present (Ridley 1991). Table D2-12 summarizes values from the previously identified background sites. Observed values of HNO_3 and NO_3^- at Cree Lake are about one-half the values observed at the other two locations. Background NH_4^+ values are similar at both Cree Lake and Hightower Ridge.

Figure D2-10 Maximum Hourly Average NO_2 Concentrations as Observed at the SOLV-EX, OSLO and SandAlta Monitoring Stations







In summary, the maximum NO_2 concentrations are relatively low in the local area and are within the air quality guideline. "Pristine" HNO_3, NH_4^+ and NO_3^- are about 0.23, 0.19 and 0.09 μg/m³, respectively.

Table D2-12 Background HNO_3, NH_4^+ and NO_3^- for "Pristine" Continental Areas

Site	HNO_3		NH_4^+	NO_3^-
	(ppb)	(μg/m³)	(μg/m³)	(μg/m³)
Hightower Ridge (1996)	0.10	0.27	0.18	0.09
Fortress Mountain (1985 to 1987)	0.11	0.31	-	0.13
Cree Lake (1988 to 1995)	0.06	0.15	0.20	0.05
Average	0.10	0.23	0.19	0.09

D2.5.5 Ozone Concentrations

Ozone has been monitored continuously at Fort McMurray for the longest period and monitored for limited periods at the SOLV-EX, OSLO and SandAlta stations.

Table D2-13 summarizes the monthly ozone statistics at Fort McMurray for the period January 1990 to August 1997. The last hourly exceedance of 0.082 ppm (82 ppb) occurred in June, 1993. Since that time the maximum hourly values have typically been in the 58 to 77 ppb range. While exceedances of the hourly guidelines are relatively infrequent, exceedances of the daily guideline (25 ppb or 50 μg/m³) can occur on average about 135 days per year. Exceedances of the daily guidelines have been observed 50 to 90% of the time in rural Alberta areas compared to 10 to 40% of the time in urban areas (Angle and Sandhu 1989).

Figure D2-11 shows the maximum hourly ozone values observed at the SOLV-EX, OSLO and SandAlta monitoring sites:

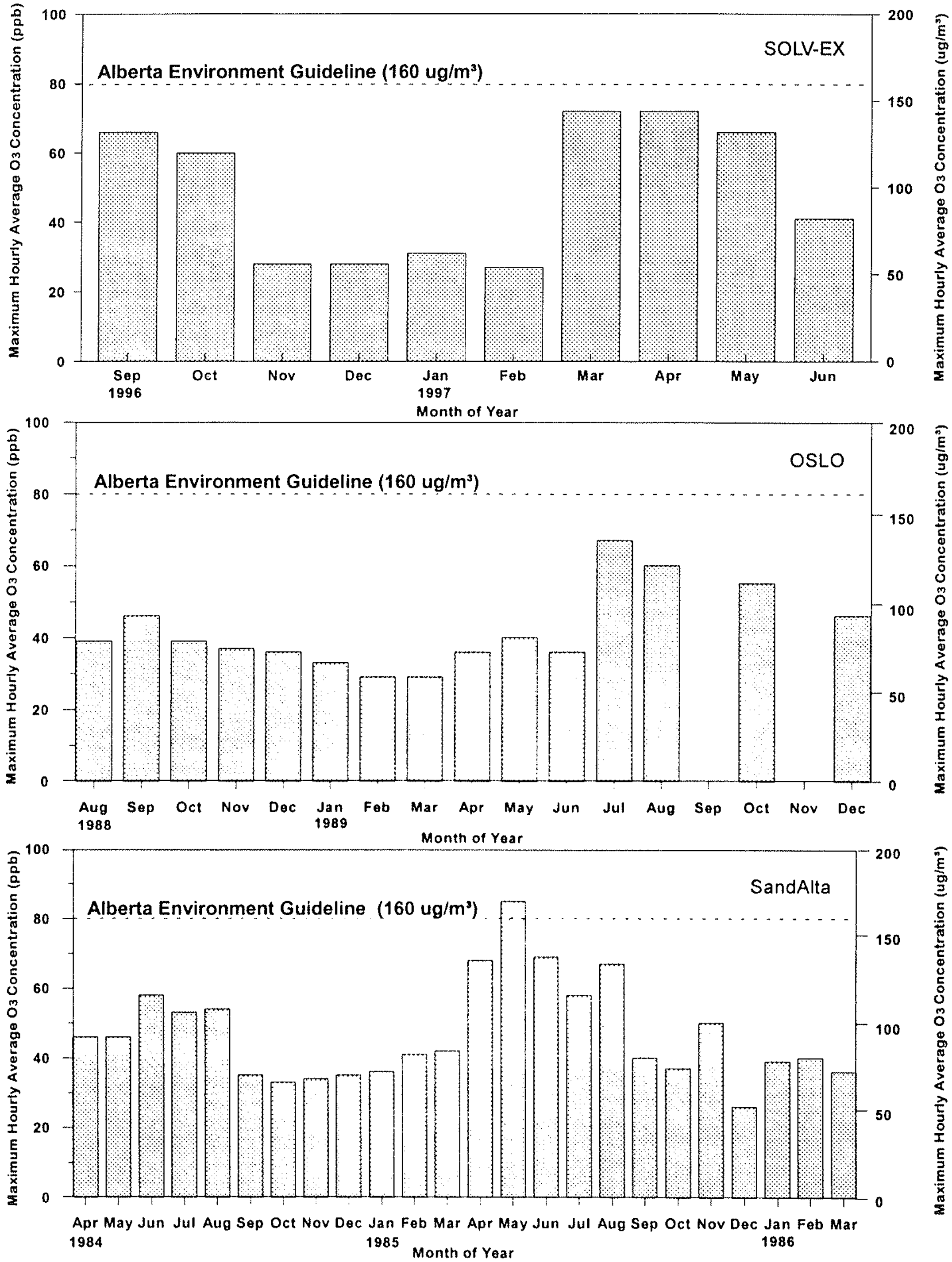
- **SOLV-EX Lease 5.** The maximum O_3 concentration was 72 ppb (140 μg/m³) which occurred in March and April 1997.
- **OSLO.** The maximum O_3 concentration of 69 ppb (134 μg/m³) occurred in July 1989.
- **SandAlta.** The maximum O_3 concentration of 87 ppb (170 μg/m³) occurred in May 1985.

Table D2-13 Ozone Statistics Observed at Fort McMurray

Station	1990	1991	1992	1993	1994	1995	1996	1997[a]	1990 - 1997
Hourly Statistics									
Mean (ppb)	25	22	21	22	24	25	18	21	23
Median (ppb)	22	21	20	21	22	23	17	20	21
Maximum (ppb)	89	65	59	91	77	71	58	61	91
N ≥ 82 ppb (h/a)	16	0	0	4	0	0	0	0	2.5
Daily Statistics									
Mean (ppb)	25	22	21	22	24	25	18	21	23
Median (ppb)	23	22	21	21	23	25	17	21	22
Maximum (ppb)	68	43	43	54	58	50	44	44	68
N ≥ 25 ppb (d/a)	156	131	91	127	153	86	98	86	135

(a) From January 1 to August 30, 1997.

Figure D2-11 Maximum Hourly Average O_3 Concentrations as Observed at the SOLV-EX, OSLO and SandAlta Monitoring Stations



Over the period March 1977 to April 1980, ozone was measured by the Alberta Oil Sands Environmental Research Program (AOSERP) at Birch Mountain and Bitumount. The Birch Mountain site is located about 45 km northwest of the Muskeg River Mine Project area and was selected as a background site. The Bitumount site is located at the forestry lookout tower about 12 km north of the Project area. Table D2-14 provides a summary of the ozone values observed at these two areas. These monitoring results indicate higher values than those from 1990 to 1997, as depicted in Table D2-13. The higher values occur during periods when the NO_x/VOC emissions (ozone precursors) were lower. The higher values may be attributable to natural background values and the higher elevation locations.

For the purpose of comparison, the maximum ozone concentrations observed at remote sites in Alberta have been 122 ppb [Fortress Mountain (1985 to 1987)] and 68 ppb [Hightower Ridge (1996)]. The average ozone concentrations at these two sites were 43 and 38 ppb, respectively.

The values observed in Fort McMurray are consistent with observations from northern latitudes. For example, maximum hourly average O_3 concentrations that have been observed are as follows: Norway, 0.055 to 115 ppb (Pederson and Lefohn 1994); Finland, 59 to 79 ppb (Laurila and Lattila 1994); northern UK, 55 to 107 ppb (Bower et al., 1994).

In summary, maximum hourly and daily ozone concentrations in excess of the guidelines have been observed in the region. The maximum values are consistent with background observations at other areas in Alberta. Various reasons have been proposed for the high rural ozone values, ranging from troposphere/stratosphere interactions (Angle and Sandhu 1986, Davies and Schuepbach 1994) to long range transport of photochemical ozone precursors (Legge and Krupa 1990, Pederson and Lefohn 1994).

Table D2-14 O_3 Values Observed at Birch Mountain and Bitumount

(1997 to 1980)	Birch Mountain	Bitumount
Hourly Statistics		
Mean (ppb)	37	28
Maximum (ppb)	120	130
N > 82 ppb	3	13
Daily Statistics		
Mean (ppb)	37	28
Maximum (ppb)	66	83
N > 25 ppb	325	212

D2.5.6 Carbon Monoxide Concentrations

Carbon monoxide (CO) is monitored only at the Fort McMurray location. Since 1995, maximum values tend to be in the 1.2 to 4.1 ppm (1380 to 4730 $\mu g/m^3$) range. This compares to the corresponding hourly air quality guideline of 13 ppm (15,000 $\mu g/m^3$). Local Fort McMurray sources are likely the most significant contributor to the observed CO values.

D2.5.7 Total Hydrocarbon and Non-Methane Hydrocarbon Concentrations

Table D2-15 summarizes median and maximum total hydrocarbon (THC) concentrations measured at selected sites. Median values are in the 1.5 to 2.2 ppm range while individual values of up to 35 ppm have been observed at the Lougheed Bridge site.

Non-methane hydrocarbons (NMHC) were measured at the SOLV-EX background site. On a monthly basis, the maximum values ranged from 5.3 to 13.3 ppm. However, in February and March 1997, the peak values were 73 and 22 ppm, respectively.

Most of the THC value is expected to be methane. For the purposes of comparison, the average and maximum methane concentrations observed in the West Central Alberta Airshed area in 1996 were 2.0 and 4.5 ppm, respectively. These values were observed at Violet Grove, near Drayton Valley. Methane concentrations in the atmosphere are typically 1.7 ppm (e.g., Ahrens 1994). The average and maximum NMHC measured at Violet Grove were 0.02 and 4.6 ppm, respectively.

In summary, relatively high THC and NMHC have been periodically measured in the LSA, although there are no ambient guidelines for these parameters.

D2.5.8 Particulate Matter Concentrations

Total Suspended Particulate Matter

A high-volume sampler was used to collect filter samples of total suspended particulate (TSP) matter at the OSLO site from March to December 1988 (Figure D2-12). The overall maximum TSP was 62.7 $\mu g/m^3$ observed in May 1988. This is within the Alberta 24-hour guideline of 100 $\mu g/m^3$.

TSP is also measured by Syncrude at the AQS4 (Tailings North) site. Since 1991, two exceedances of TSP guidelines have been observed at AQS4. One was attributed to a truck engine that was left running near the station during station servicing. Figure D2-12 also shows the maximum 24-hour value observed at this site in 1996. The maximum value of 53 $\mu g/m^3$ was within the Alberta guideline of 100 $\mu g/m^3$.

Table D2-15 Median and Maximum THC Concentrations (ppm)

	Lougheed Bridge (#10)	AQS4 (Tailings North)	Fort McMurray (FMMU)	Fort McKay (FRMU)
Median 1990	2.1	1.8	1.6	1.8
1991	1.7	1.8	1.6	1.6
1992	2.0	2.0	1.8	1.7
1993	1.9	1.8	2.0	1.8
1994	1.6	1.5	2.2	1.7
1995	-	1.7	2.0	1.7
1996	-	-	2.2	1.8
Maximum 1990	30.9	5.9	3.5	4.1
1991	13.5	6.1	8.6	3.5
1992	12.7	7.0	3.8	3.9
1993	35.0	5.7	3.2	3.6
1994	13.7	4.3	3.7	3.3
1995	-	14.6	2.7	3.5
1996	-	-	3.8	3.9

(a) No data collected.

For the purposes of comparison, limited TSP data are also available from AOSERP Birch Mountain and Bitumount (Strosher 1978). The maximum values observed in May 1997 at Birch Mountain and Bitumount were 29 and 55 $\mu g/m^3$, respectively.

The review of the OSLO, Syncrude AQS4 and the two AOSERP sites indicate that TSP values can be as high as 50 to 60 $\mu g/m^3$ in the local airshed.

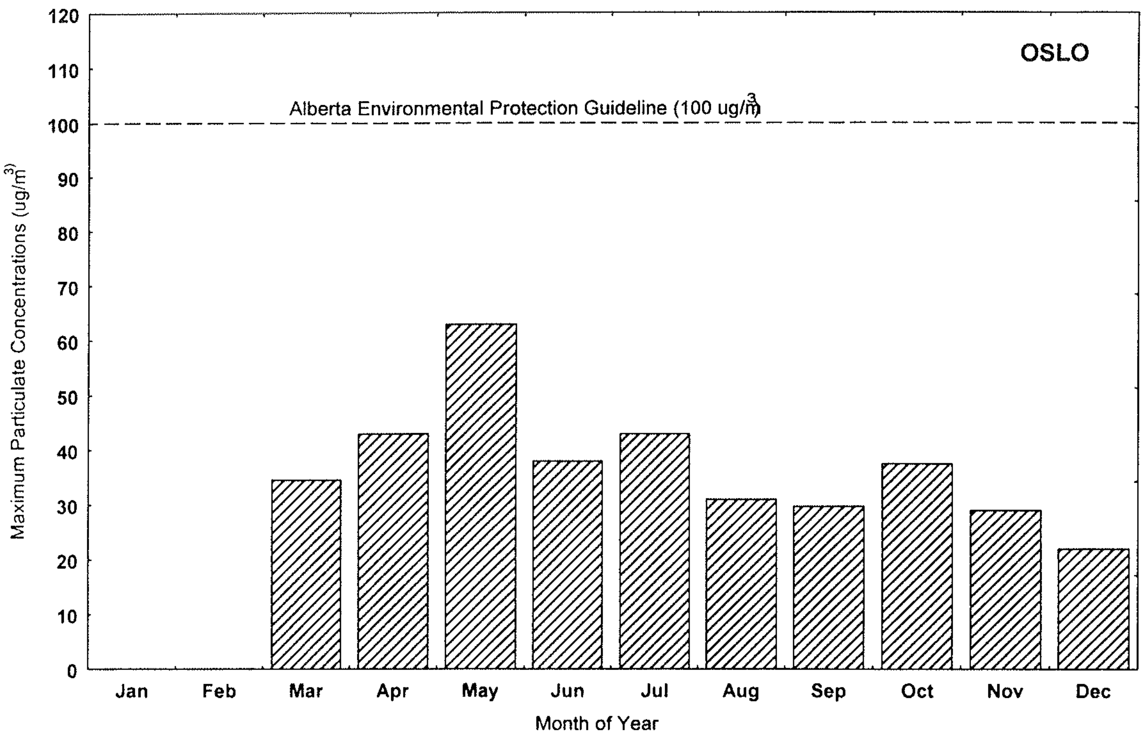
PM_{10}

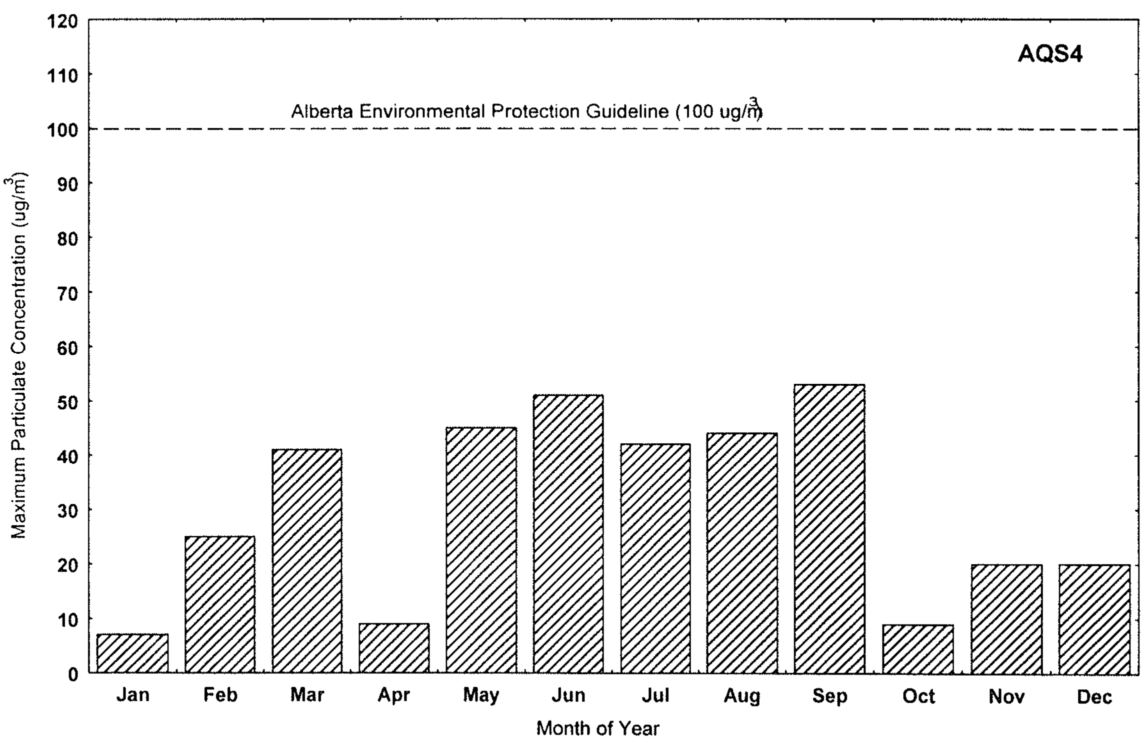
Since January 1997, AEP has measured PM_{10} on a continuous basis (hourly average) at Fort McMurray. Based on the six-month period January to June, the maximum hourly values for each month have ranged from 11.8 to 105.5 $\mu g/m^3$, with the latter value occurred in March. These values are within the US EPA 24-hour guidelines.

Acidifying PM

In addition to potential health effects, particulates play an important role in the acidification process. Background levels of sulphate (SO_4^{2-}), nitrate (NO_3^-) and ammonium (NH_4^+) were given in the sections on SO_2 and NO_2 concentration. Base cations such as Ca^{2+}, Mg^{+2} and K^+ have the ability to neutralize acid inputs, and are also important nutrient elements for ecosystems.

Figure D2-12 Maximum Particulate Concentrations as Observed at the OSLO Monitoring Station (March to December 1988) and the Syncrude AQS4 (Tailings North) Station (1996)





Ambient concentrations of these base cations can be inferred from precipitation concentration measurements (e.g., Draaijers et al., 1997). This approach was used to estimate concentrations based on precipitation observations at Cree Lake (1983 to 1992), Snare Rapids (1989 to 1996), Fort Chipewyan (1992 to 1996) and Fort McMurray (1992 to 1996) (Table D2-16). The median diameters of these cations are expected to be in the 4 to 7 μm range.

The inferred concentrations for Cree Lake and Snare Rapids are similar to each other and are consistent with those measured on Birch Mountain during the winter of 1976 (Legge and Krupa 1990). These values would be typical of a pristine continental area. The Fort Chipewyan and Fort McMurray values tend to be greater than those measured at Cree Lake or Snare Rapids. The range and median Ca^{2+} concentrations observed at Fortress Mountain were 0.001 to 0.89 μg/m^3 and 0.10 μg/m^3, respectively. Corresponding Fortress Mountain values for K^+ were 0.001 to 0.28 μg/m^3 and 0.04 μg/m^3, respectively.

Cree Lake and Snare Rapids are located within the Canadian Shield area, distant from expected sources of Ca^{2+}. Fort McMurray is likely to be influenced by local activities, but the data collection is much better than that at Fort Chipewyan. However, since the inferred concentrations are not that dissimilar between these two sites; the regional background Ca^{2+}, Mg^{2+} and K^+ concentrations for air flow into the RSA were taken as 0.36, 0.09 and 0.15 μg/m^3, respectively. These are the average of the Fort McMurray and Fort Chipewyan stations.

Table D2-16 Observed Concentrations in Precipitation and Inferred Ambient Air Concentrations of Selected Cations

		Cree Lake	Snare Rapids	Fort Chipewyan	Fort McMurray
Ca^{2+}	precipitation concentration (mg/L)	0.068	0.047	0.258	0.237
Ca^{2+}	air concentration (μg/m^3)	0.10	0.071	0.38	0.35
Mg^{2+}	precipitation concentration (mg/L)	0.015	0.010	0.036	0.058
Mg^{2+}	air concentration (μg/m^3)	0.026	0.017	0.07	0.12
K^+	precipitation concentration (mg/L)	0.028	0.022	0.082	0.034
K^+	air concentration (μg/m^3)	0.069	0.057	0.21	0.09

D2.5.9 Precipitation Quality

Acid-forming substances released into the atmosphere will eventually be deposited on the earth's surface in the form of precipitation (wet deposition) or as particles or gases (dry deposition). The effects of deposition will depend on the amount being deposited and the buffering capacity of the receptor. Alberta Environmental Protection conducts precipitation quality measurements at selected locations in Alberta with the following objectives:

- to monitor the quality of precipitation;
- to detect any significant trends in precipitation; and
- to determine long-range transport of pollutants into the province.

This provincial monitoring program has been supplemented by a similar program conducted by Environment Canada. The Environment Canada program includes two sites in the Alberta and Saskatchewan region.

Precipitation is collected by a sampler that opens automatically whenever it is raining or snowing. Samples are retrieved monthly, weekly or daily and are analyzed for acidity (pH), cation concentrations (positively charged ions) and anion concentrations (negatively charged ions). By also collecting total precipitation values, the wet deposition can be calculated from the concentration measurements. Tables in this section are based on computer databases provided by AEP.

Precipitation pH

The term pH is used as a direct indication of acidity and is defined on a logarithmic scale from the following relationship:

$$pH = -\log_{10} [H^+]$$

where $[H^+]$ = hydrogen ion concentration expressed in moles per litre. pH values less than 7 are associated with acidic solutions, while those greater than 7 are associated with alkaline (or basic) solutions. A pH of 7 is regarded as neutral; a pure water solution would have a pH of 7. Clean water in equilibrium with "unpolluted" air would be slightly acidic with a pH of 5.6, which is a result of the water being in equilibrium with CO_2 in the atmosphere. However, measurements of precipitation at remote locations have shown that the pH of uncontaminated rain can be near 5.0 (Galloway et al., 1982, Sequeria 1981).

Table D2-17 provides the annual average pH values at the stations identified in Table D2-3 for the period 1990 to 1996. On average, it appears that the pH of the precipitation in locations closest to the oil sands area (i.e., Fort McMurray) is more acidic (pH ~ 4.8) than other regions in northern Alberta. Other, more distant, regions in northern Alberta tend to have pH values between 5.0 and 5.3. This compares with the average value in northern Saskatchewan and central N.W.T. (i.e., Cree Lake and Snare Rapids) of about 5.0.

Wet Sulphate and Nitrate Deposition

Anions such as sulphate (SO_4^{2-}) and nitrate (NO_3^-) result from sources venting products of combustion such as SO_2 and NO_2 into the atmosphere. Industrial sources venting these compounds include oil sands plants, gas processing plants, oil refineries and coal-fired power plants. Table D2-18 shows the annual variation of SO_4^{2-} deposition and Table D2-19 shows the annual variation of NO_3^- deposition at the identified precipitation monitoring sites.

Sulphate (SO_4^{2-}) deposition ranges from a low of 0.9 kg/ha/a at Snare Rapids to a maximum of 4.6 kg/ha/a in Fort McMurray. At other northern Alberta vicinity sites, deposition ranges from 1.9 to 3.9 kg/ha/a. There is considerable year-to-year as well as spatial variability. The larger Fort McMurray sulphate values (4.6 kg SO_4^{2-}/ha/a) likely represent contributions from the existing sources identified in Table D2-1. In the absence of these sources, the "pristine" northern Alberta values would likely be about 1.7 kg SO_4^{2-}/ha/a. From this, it is estimated that the existing sources could therefore be contributing as much as 3.2 kg SO_4^{2-}/ha/a in Fort McMurray.

Nitrate (NO_3^-) deposition ranges from 0.7 kg/ha/a at Snare Rapids to 3.0 kg/ha/a at Vegreville. The average value observed in Fort McMurray is 2.2 kg/ha/a. There is also considerable year-to-year as well as spatial variability. Similar to sulphate, the Fort McMurray nitrate value (2.2 kg NO_2^{-3}/ha/a) represents contributions from existing sources. In the absence of these sources, the "pristine" northern Alberta values are about 1.1 kg NO_3^{-3}/ha/a. The existing sources could therefore be contributing about 1.1 kg NO_3^{2-}/ha/a in Fort McMurray.

Wet Potential Acidifying Input (PAI) From Wet Deposition

The degree of acidification generally depends on the balance of acid-forming compounds (such as SO_4^{2-}, NO_3^- and NH_4^+) and cations (positively charged ions such as Ca^{2+}, Mg^{2+} and K^+) in the precipitation. The Potential Acid Input (PAI) as a composite measure of acidification is expressed as:

$$PAI\ (wet) = ([SO_4^{2-}] + [NO_3^-] + [NH_4^+]) - ([Ca^{2+}] + [Mg^{2+}] + [K^+])$$

The PAI takes into account sulphur and nitrogen species and all values are in units of "keq/ha/a."

Table D2-20 summarizes the PAI values that have been observed in northern Alberta area. The average PAI observed in Fort McMurray is 0.09 keq/ha/a; this compares to 0.02 keq/ha/a value observed in Fort Vermilion and Fort Chipewyan. The central N.W.T. (Snare Rapids) value is 0.04 keq/ha/a. Based on an average of Fort Chipewyan, Fort Vermilion, Cree Lake and Snare Rapids, the average background wet PAI is about 0.038 keq/ha/a. This suggests that the existing sources could be contributing 0.05 kmol H^+/ha/a in Fort McMurray.

Table D2-17 Precipitation Acidity (pH) Observed at Selected Precipitation Stations

	Year									
	1990[a]	1991	1992			1993	1994	1995	1996	Average[d]
Fort McMurray	4.9	4.9	4.7	4.7	4.7	4.7	4.8	4.8	4.9	4.8
Fort Chipewyan	5.1	5.0	5.4	5.2	5.3	5.0	5.4[e]	5.3[e]	5.3[e]	5.2
Fort Vermilion	5.3	5.3	5.2	5.3	5.2	5.2	5.0[f]	5.5[e]	-	5.2
High Prairie	5.6	5.3	5.1	5.2	5.1	5.1	5.2	5.2[e]	5.3[e]	5.3
Beaverlodge	5.1	5.2	5.0	5.1	5.1	5.0	5.0	4.9	5.0	5.0
Cold Lake	5.6	5.1	5.2	5.1	5.2	5.3	5.2	5.3	5.5	5.3
Vegreville	n/a	n/a	5.3	-	5.3	5.3	5.1	5.4	5.5	5.3
Cree Lake (Sask)	5.0	5.0	-	5.0	-	4.9[b]	-	-	-	5.0
Snare Rapids (N.W.T.)	5.1	-		5.0		5.0	4.9	5.1	5.0	5.0

(a) Values in AEP report were calculated improperly (these are corrected).
(b) Only first quarter values, then station closed.
(c) Not operational.
(d) Averages include monthly values 1990, 1991, then weekly values 1992 through 1996 and are logarithmically averaged.
(e) Less than 50% of data available.
(f) > 50 to < 75% of data available.

Table D2-18 Annual Average Sulphate (SO_4^{2-}) Deposition (kg SO_4^{2-}/ha/a) Observed at Selected Precipitation Stations

	Year							
	1990[a]	1991	1992	1993	1994	1995	1996	Average
Fort McMurray	5.2[a]	6.0	4.5	5.3	3.0	4.5	3.9	4.6
Fort Chipewyan	1.5[a]	1.6[c]	4.8[d]	4.3	-[f]	-[f]	-[f]	2.6
Fort Vermilion	2.5[b]	2.9[a]	1.6[e]	1.2	1.4	-[f]	-	1.9
High Prairie	4.2	4.4	2.0	2.0	1.5	-[f]	-[f]	2.8
Beaverlodge	2.4	2.2[b]	1.9	2.3	3.2	3.0	2.5	2.5
Cold Lake	3.4	2.8	2.0	3.4	2.7	1.5	2.7	2.6
Vegreville	-	n/o	3.1	6.8	3.2	3.3	2.9	3.9
Cree Lake	1.9	2.3	2.3	-	-	-	-	2.2
Snare Rapids	0.6	-	1.0	0.9	0.8	0.9	1.4	0.9

(a) 10 months
(b) 11 months
(c) 8 months
(d) 6 of 8 monthly values
(e) 7 of 8 monthly values
(f) Less than 50% of data available

Table D2-19 Annual Average Nitrate (NO_3^-) Deposition (kg NO_3^-/ha/a) Observed at Selected Precipitation Stations

	Year							
	1990[a]	1991	1992	1993	1994	1995	1996	Average
Fort McMurray	2.8[a]	3.7	1.7	1.7	1.5	1.9	2.3	2.2
Fort Chipewyan	1.0[a]	0.8[c]	0.8[d]	0.7	-[f]	-[f]	-[f]	0.8
Fort Vermilion	2.0[b]	2.6[a]	0.9[e]	0.7	0.8	-[f]	-	1.4
High Prairie	2.6	2.5	1.2	1.1	1.0	-[f]	-[f]	1.7
Beaverlodge	1.7	1.8[b]	1.1	1.1	1.9	2.2	1.7	1.6
Cold Lake	2.7	2.9	1.9	2.4	2.5	1.8	3.1	2.5
Vegreville	-	-	2.3	4.6	2.5	3.2	2.8	3.0
Cree Lake	1.4	1.6	1.4	-	-	-	-	1.5
Snare Rapids	0.4	-	0.5	1.0	0.7	0.8	1.1	0.7

* 1992 data were monthly until August, then weekly
(a) 10 months
(b) 11 months
(c) 8 months
(d) 6 of 8 monthly values
(e) 7 of 8 monthly values
(f) Less than 50% of data available

D2.5.10 Dry Deposition

The values in the previous tables reflect the contribution by wet deposition. For the purposes of calculating dry deposition, a single annual deposition velocity is often used. This is not strictly correct as the deposition velocities change with time of day and season to reflect the variability of meteorological and receptor uptake processes. The dry component of the PAI (in equivalents) can be given by:

$$\text{PAI (dry)} = ([SO_2] + [SO_4^{2-}] + [HNO_3] + [NO_3^{+}] + [NH_4^{+}]) - ([Ca^{2+}] + [Mg^{2+}] + [K^{+}])$$

where SO_2 and HNO_3 are in a gaseous form and the remaining species are in particulate form.

Table D2-21 shows the estimation of the regional dry component of the PAI based on the background sulphur, nitrogen and base cation concentrations. The deposition velocities are based on calculations from Royal Park, which is located 15 km northwest of Vegreville (Bates 1996). The estimated dry PAI contribution is 0.045 keq/ha/a. This estimate is subject to significant uncertainty since the base cation contribution is inferred from precipitation measurements. Also, there is some uncertainty in the application of the deposition velocities used.

In a recent study, the dry deposition of base cations was found to be 4.4 times that of sulphate due to the size differences. Most of the sulphate particles are in the fine fraction with a median diameter of 0.5 μm, while the median diameter for base cations can range from 3 to 7 μm (Ruigrok et al., 1997). In contrast, Bates (1996) assumed the deposition velocity for base cations to be the same as that for sulphate. The latter, more conservative assumption was used for the calculation of PAI reported here.

Table D2-20 Annual Average Potential Acid Input (PAI) (keq/ha/a) Observed at Selected Precipitation Stations

	Year							
	1990	1991	1992	1993	1994	1995	1996	Average
Fort McMurray	0.05	0.11	0.11	0.08	0.06	0.10	0.09	0.09
Fort Chipewyan	0.02	0.02	0.01[c]	0.00	-[a]	0.01	-[a]	0.02
Fort Vermilion	0.05	0.01	0.00	0.02	0.03	0.00	-[b]	0.02
High Prairie	-0.15	0.01	0.04[c]	0.03	-[a]	-[a]	-[a]	0.03[d]
Beaverlodge	0.05	0.04	0.05	0.05	0.09	0.07	0.06	0.06
Cold Lake	0.11	0.07	0.08	-[a]	0.07	0.05	0.09	0.06
Vegreville	-[b]	-[b]	0.05[c]	-[b]	0.09	0.05	-[b]	0.08
Cree Lake	0.06	0.07	0.07	-	-	-	-	0.07
Snare Rapids	0.02	-	0.02	0.04	0.03	0.10	0.05	0.04

(a) Less than 50% of data available.
(b) >50 to <75% of data available.
(c) Value represents monthly samples from January to August; weekly values were sampled from September to December where < 75% of the data were available, therefore no value is given for this period.
(d) Excludes the 1990 value, which appears anomalous.

D2.5.11 Total Potential Acidifying Input

The total background PAI for air masses entering the region is the sum of the wet and dry deposition values, and total contributions are estimated as:

PAI (wet)	0.038 keq/ha/a
PAI (dry)	0.045 keq/ha/a
PAI (total)	0.083 keq/ha/a

This value was estimated from data to represent the PAI associated with air flow into the regional airshed. This compares to the target loading value of 0.25 keq/ha/a for sensitive ecosystems.

Table D2-21 Estimation of Background Dry Component of the Potential Acid Input (PAI)

Parameter	Concentration ($\mu g/m^3$)	Deposition Velocity (cm/s)	Deposition (kg/ha/a)	Deposition keq/ha/a
Sulphur Compounds				
SO_2 (gas)	1.2	0.37	1.40	0.044
SO_4^{2-}(particle)	0.7	0.14	0.31	0.006
			1.71	0.050
Nitrogen Compounds				
NH_4^+ (particle)	0.19	0.14	0.08	0.004
HNO_3 (gas)	0.23	1.33	0.96	0.015
NO_3^- (particle)	0.09	0.26	0.07	0.001
			1.11	0.020
Base Cations				
Ca^{2+} (particle)	0.036	0.14	0.20	0.003
Mg^{2+} (particle)	0.09	0.14	0.04	0.020
K^+ (particle)	0.15	0.14	0.07	0.002
			0.31	0.025
$PAI = \Sigma(S) + \Sigma(N) - \Sigma(Base)$				0.045

D2.6 Model Predictions

Dispersion model predictions were used to complement the ambient monitoring in terms of defining baseline air quality. Dispersion modelling has the advantage of providing a better indication of spatial variability than the monitoring programs offer. Specifically, the models were used to predict maximum hourly SO_2 and NO_2 concentrations and associated deposition that could occur in the local airshed due to the existing sources. Further discussion on the model approach is provided in Appendix I2.

D2.6.1 SO_2 Predictions

Maximum hourly average SO_2 concentrations from the Suncor and Syncrude sources as detailed in Table D2-1 were predicted using the ISC3BE model and the meteorological measurements from the Mannix station. For Syncrude, no flaring or use of the diverter stack was assumed. Therefore, total Syncrude SO_2 emissions were 197.4 t/d. The predictions were undertaken for two cases:

- Case 1 assumes the Suncor utilities plant emissions are vented up the Powerhouse stack (i.e., the FGD system is down). This case would therefore represent conditions prior to July 1996 (i.e., powerhouse stack SO_2 emissions = 214.1 t/d). No intermittent flaring was assumed, therefore total Suncor SO_2 emissions are: 214.1 (Powerhouse) + 18.2 (SRU) + 11.5 (Continuous flaring) = 244 t/d.

- Case 2 assumes the Suncor utilities plant emissions are vented up the FGD stack (i.e., the FGD system is operating). The case conservatively assumes a weighted SO_2 emission based on 95% FGD uptime (i.e., FGD SO_2 emission = 27.2 t/d). No intermittent flaring was assumed, therefore the total Suncor SO_2 emissions are: 27.2 (FGD) + 18.2 (SRU) + 11.5 (Continuous flaring) = 56.9 t/d.

Maximum predicted hourly SO_2 concentrations are presented in Figure D2-13 for Case 1 and Figure D2-14 for Case 2. The results in the figures indicate:

- Maximum values are associated with the elevated Muskeg Mountain terrain near the southeast portion of the area depicted. The effect of the FGD system is to reduce the maximum hourly SO_2 value from 1500 $\mu g/m^3$ (0.57 ppm) to 500 $\mu g/m^3$ (0.19 ppm).

- Maximum values on the Fort Hills (near the northern portion of the area depicted) are predicted to be about 300 $\mu g/m^3$ (0.11 ppm) and 100 $\mu g/m^3$ (0.04 ppm) for Cases 1 and 2, respectively.

- The elevated concentrations over the proposed Muskeg River Mine Project tailings settling pond are also shown in the figure. The maximum values on the pond are 400 $\mu g/m^3$ (0.15 ppm) and 150 $\mu g/m^3$ (0.06 ppm) for Cases 1 and 2, respectively.

The maximum predicted values can be compared to the observed maximum presented in Table D2-8. While the model tends to under predict the extreme maximum observed at the LSA monitoring sites, the model predictions are in agreement with the typical maximum values that have been observed. In summary, maximum hourly SO_2 concentrations in the vicinity of the Muskeg River Mine Project should be within the air quality guideline value of 450 $\mu g/m^3$ (0.17 ppm) when the Suncor FGD is operating.

D2.6.2 NO_x/NO_2 Predictions

Maximum hourly average NO_2 concentrations from the Suncor and Syncrude sources were predicted using the ISC3BE model and the meteorology measurements from the Mannix station. The maximum predicted values presented in Figure D2-15 indicate:

- The maximum value in the area depicted is 200 $\mu g/m^3$ (0.11 ppm), which occurs in the southwest corner of the LSA.
- In the Muskeg River Mine Project area, the maximum hourly NO_2 concentration ranges from about 75 to 100 $\mu g/m^3$ (0.04 to 0.05 ppm).

The ISC3BE model enhances predicted concentration values in the Athabasca River valley by reducing the lateral spread of a plume. Due to the lower stack heights associated with the NO_x sources, this effect is more pronounced for predicted NO_x concentrations than for predicted SO_2 concentrations.

These predictions are consistent with those observed in the LSA which range from 50 to 100 $\mu g/m^3$ (0.03 to 0.05 ppm). In summary, NO_2 concentrations in the vicinity of the Muskeg River Mine Project are expected to be within the air quality guideline value of 400 $\mu g/m^3$ (0.21 ppm).

D2.6.3 Deposition Predictions

The CALPUFF model was used to predict maximum annual average deposition patterns in the area using the same SO_2 and NO_2 emissions. The results are presented in the following figures:

- Figure D2-16 shows the total annual sulphate equivalent deposition based on predicted SO_2 and SO_4^{2-} deposition (wet and dry) due to SO_2 emissions from the Syncrude and Suncor sources (Case 2 SO_2 emissions were assumed). No background values have been added. The maximum predicted value of 13 kg SO_4^{2-}/ha/a is predicted to occur on the southern boundary of the LSA. The 13 kg SO_4^{2-}/ha/a value is equivalent to 0.27 keq/ha/a.

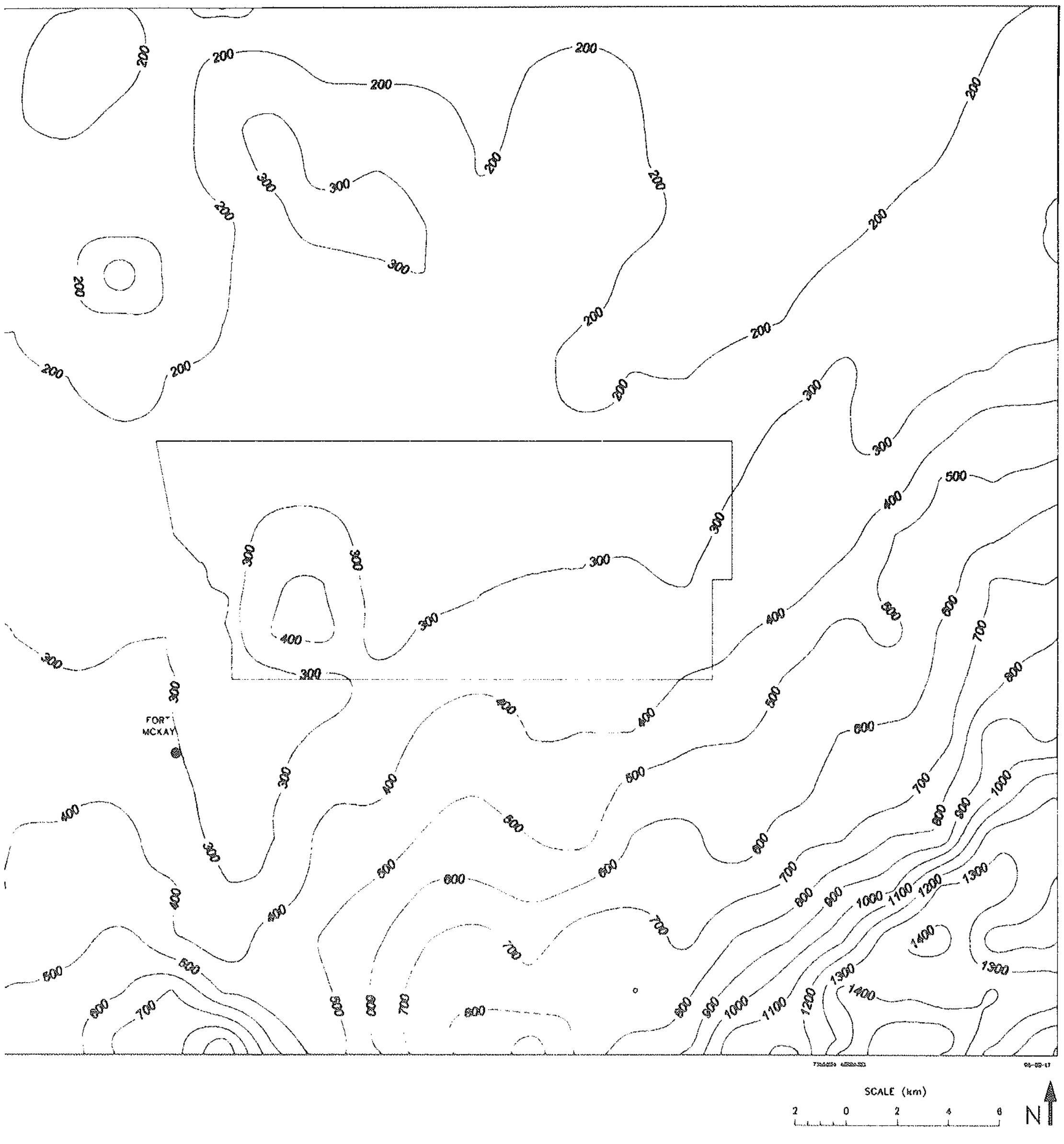
- Figure D2-17 shows the total annual nitrate equivalent deposition based on predicted NO_2, HNO_3 and NO_3^- deposition (wet and dry) due to NO_x emissions from the Syncrude and Suncor sources. No background values have been added. The maximum predicted value of 18 kg/ha/a is predicted to occur on the southern boundary of the LSA. The 18 kg NO_3^-/ha/a is equivalent to 0.27 keq/ha/a.

- Figure D2-18 total PAI based on expressing the total sulphate and nitrate deposition from Figures D2-16 and D2-17 and expressed in keq/ha/a. The maximum predicted value of 0.55 keq/ha/a (which includes a background value of 0.083 keq/ha/a) is predicted to occur on the southern boundary of the LSA. Table D2-22 summarizes the maximum predicted values in the LSA due to current sources. The maximum PAI exceeds the 0.25 keq/ha/a interim guideline for sensitive ecosystems.

Table D2-22 Summary of Maximum Total Sulphate, Nitrate and PAI in the Local Study Area

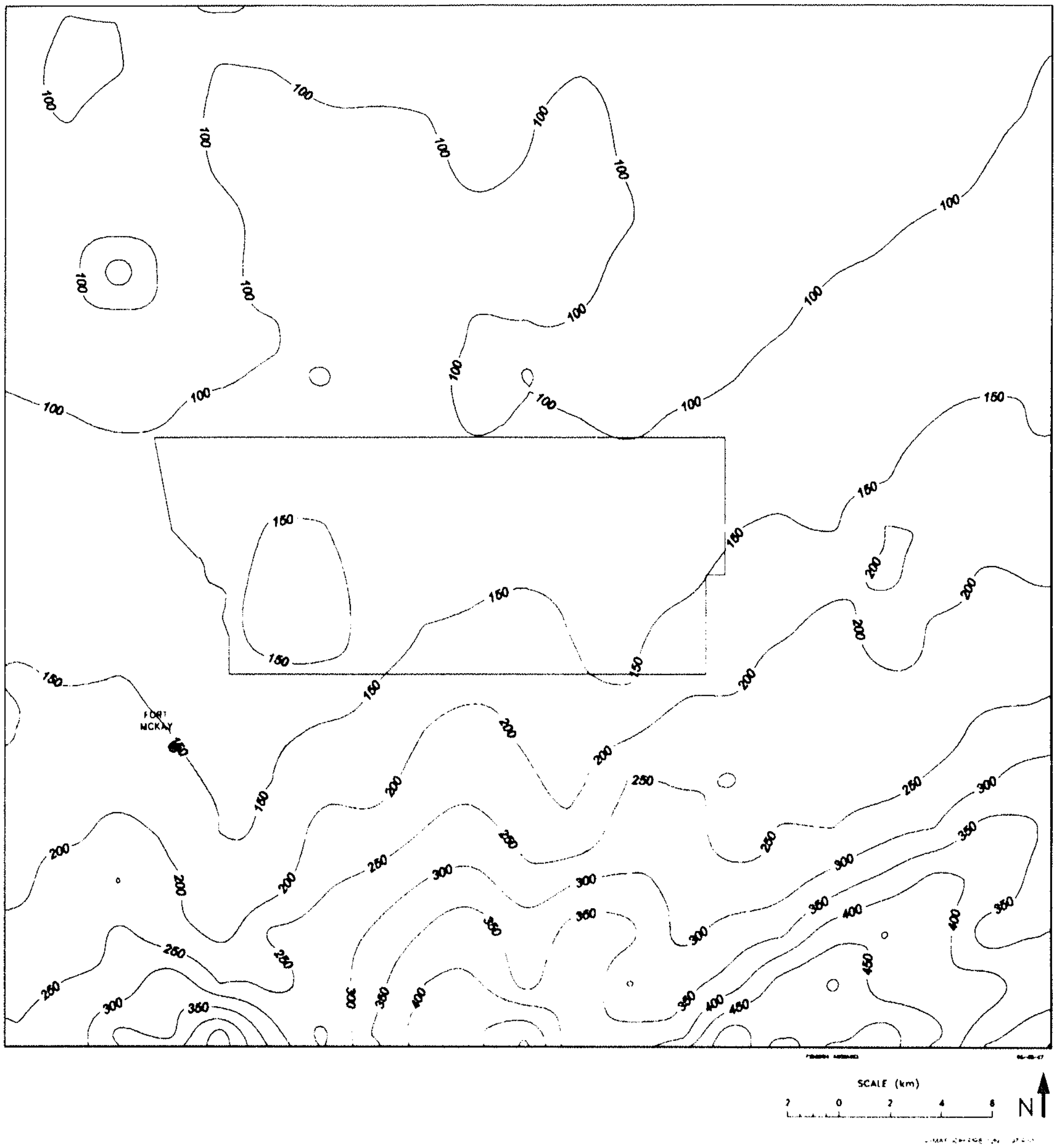
Total Sulphate (kg/ha/a)	
From Suncor and Syncrude	13.0
Pristine background	3.4
Combined	16.4
Total Nitrate Equivalent (kg/ha/a)	
From Suncor and Syncrude	18.0
Pristine background	2.2
Combined	20.2
Total PAI (keq/ha/a)	
From Suncor and Syncrude (with background)	0.55

Figure D2-13 Maximum Predicted Hourly Average SO_2 Concentrations ($\mu g/m^3$) From Existing Sources (Assumes Suncor FGD Is not Operating)



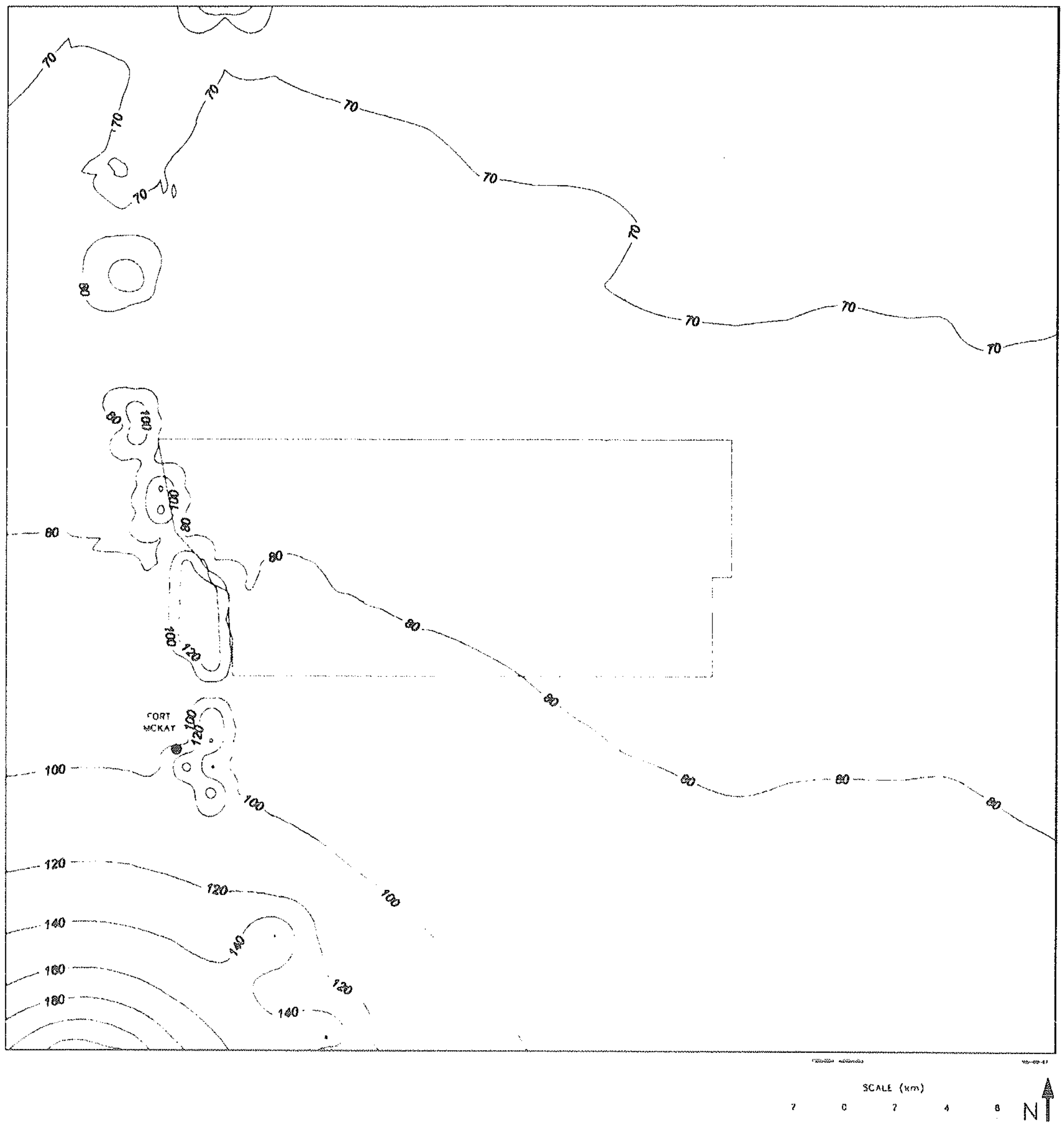
Model:	ISC3BE
Meteorology:	Mannix
Sources:	Suncor SO_2 = 244 t/d
	Syncrude SO_2 = 197 t/d
Hourly SO_2 Guideline = 450 $\mu g/m^3$	

Figure D2-14 Maximum Predicted Hourly Average SO_2 Concentrations (µg/m^3) from Existing Sources (Assumes Suncor FGD Is Operating)



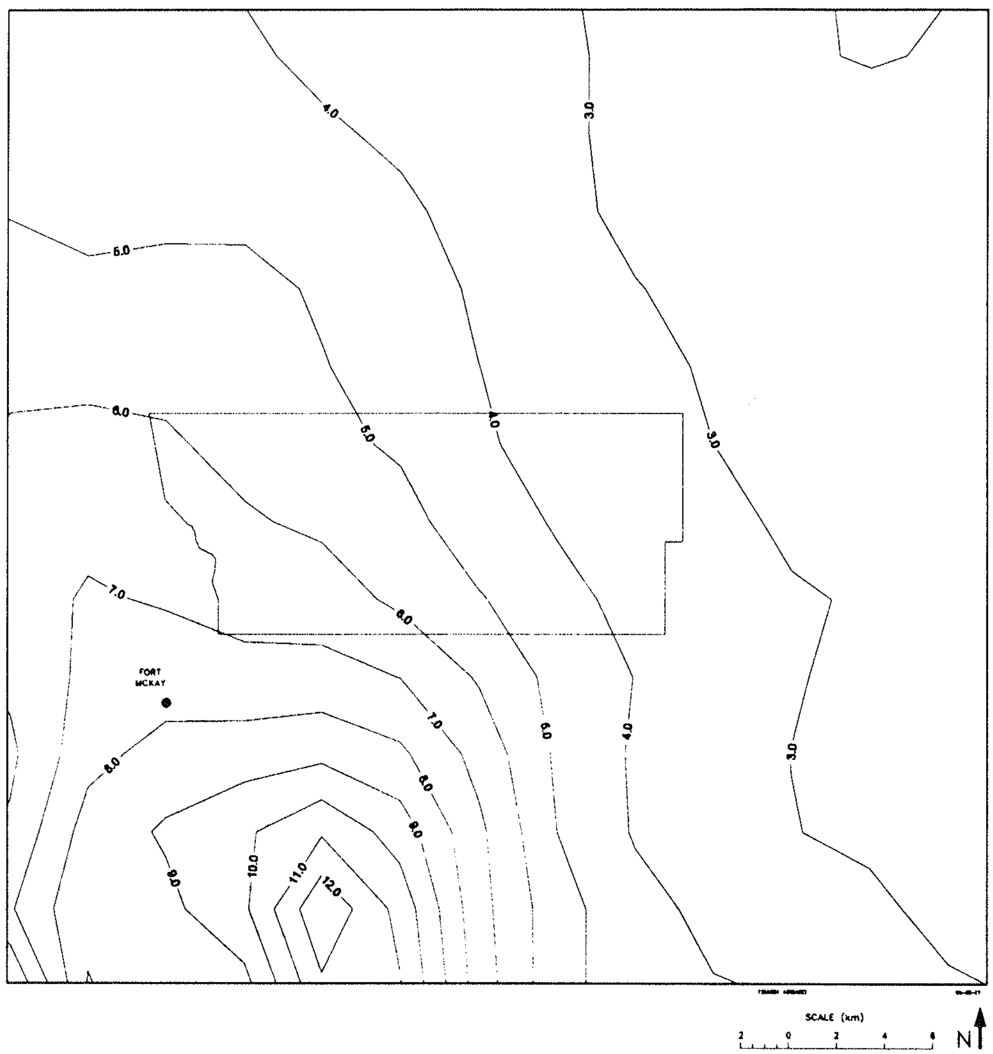
Model:	ISC3BE
Meteorology:	Mannix
Sources:	Suncor SO_2 = 57 t/d
	Syncrude SO_2 = 197 t/d
Hourly SO_2 Guideline = 450 µg/m^3	

Figure D2-15 Maximum Predicted Hourly Average NO_2 Concentrations ($\mu g/m^3$) From Existing Sources



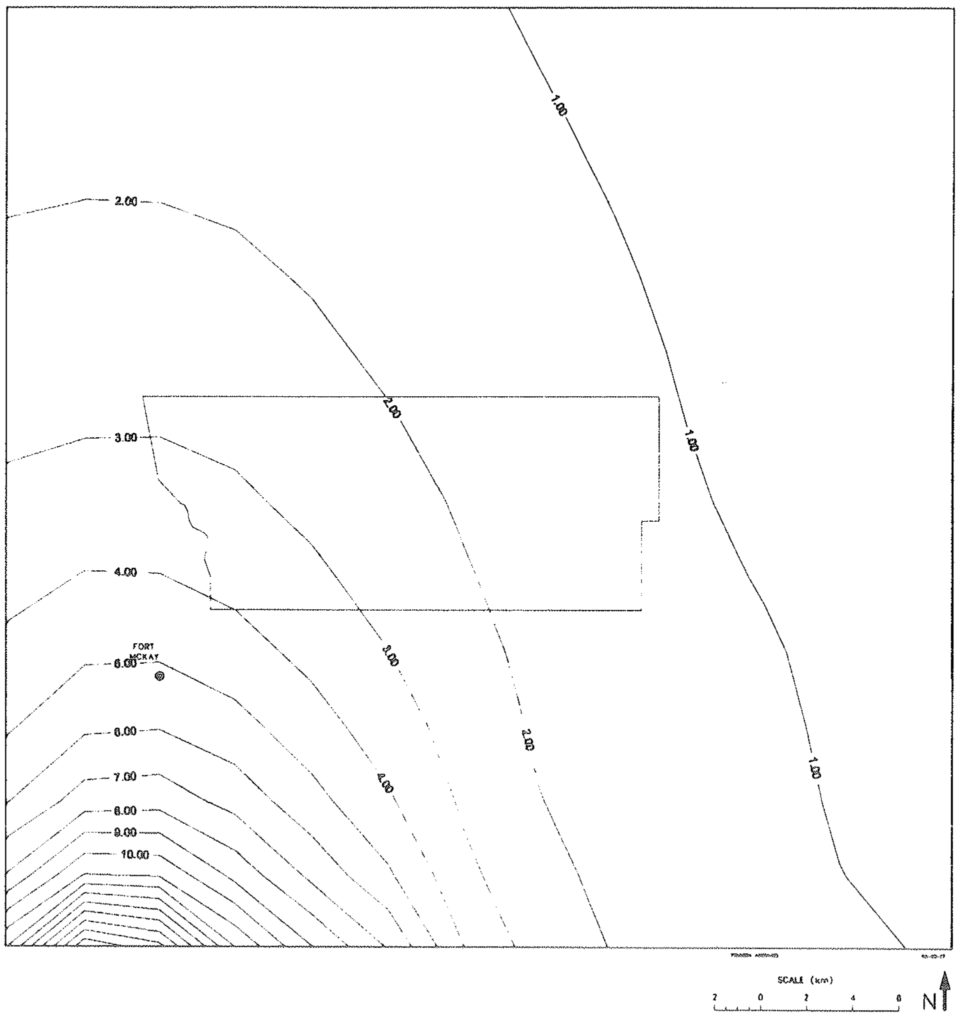
Model:	ISC3BE
Meteorology:	OSLO
Sources:	Suncor NO_x = 39 t/d
	Syncrude NO_x = 37 t/d
Hourly NO_2 Guideline = 400 $\mu g/m^3$	

Figure D2-16 Predicted Sulphate Equivalent Deposition (kg SO_4^{2-}/ha/a) from Existing Sources in the Region (Assumes Suncor FGD Is Operating)



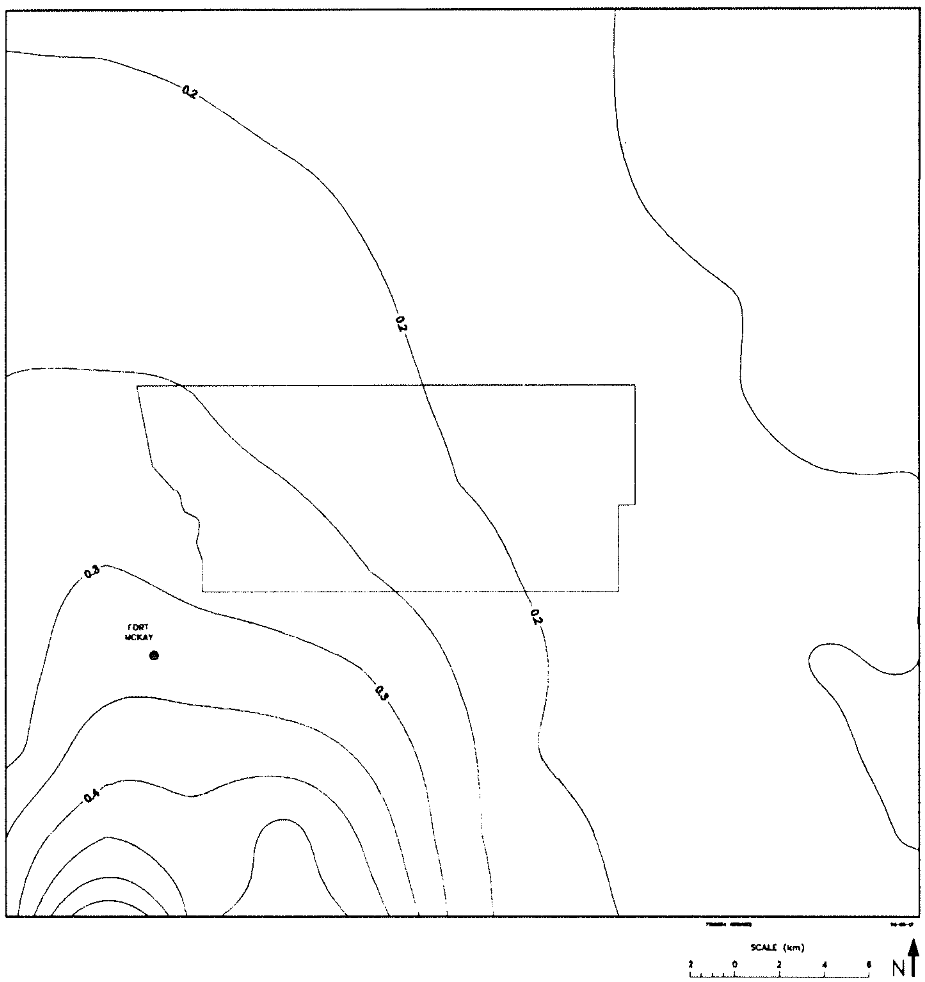
Model:	CALPUFF
Meteorology:	Mannix
Sources:	Suncor SO_2 = 57 t/d
	Syncrude SO_2 = 197 t/d

Figure D2-17 Predicted Nitrate Equivalent Deposition (kg NO_3^-/ha/a) From Existing Sources in the Region (Predicted Values do not Include a Background Value)



Model:	CALPUFF
Meteorology:	Mannix
Sources:	Suncor NO_x = 39 t/d
	Syncrude NO_x = 37 t/d

Figure D2-18 Predicted Potential Acid Input (keq/ha/a) From Existing Sources in the Region (Includes a Background Value of 0.083 keq/ha/a)



Model:	CALPUFF		
Meteorology:	Mannix		
Sources:	Suncor	SO_2	= 57 t/d
	Suncor	NO_x	= 39 t/d
	Syncrude	SO_2	= 197 t/d
	Syncrude	NO_x	= 37 t/d
Critical Load:	0.25 keq/ha/a (sensitive system)		

D2.6.4 Provincial Scale Modelling

Alberta Environmental Protection and Environment Canada have applied a long-range transport and dispersion model to estimate total potential acid input (PAI) in Alberta (Cheng et al. 1997). This application is based on the Regional Lagrangian Acid Deposition (RELAD) model that addresses wet and dry deposition of sulphur and nitrogen compounds. The model was applied to B.C., Alberta and Saskatchewan and the results are based on 1990 NO_x and SO_2 emission data, which do not reflect the lower Suncor SO_2 emissions related to the FGD.

The provincial scale modelling results indicate:

- The maximum sulphur compound loading is in the 4.8 to 7.2 kg SO_4^{2-}/ha/a range, which is less than the peak value of 13 kg SO_4^{2-}/ha/a shown in Figure D2-16.
- The maximum nitrogen compound loading is in the 0 to 3.1 kg NO_3^-/ha/a range, which is less than the peak value of 18 kg NO_3^-/ha/a shown in Figure D2-17.
- The overall PAI is in the 0.05 to 0.10 keq/ha range which compares with the peak value of 0.59 keq/ha/a shown in Figure D2-18.

The RELAD model predictions are presented as averages over a 60 x 110 km grid system. As such, these predictions are less than the finer scale predictions using the CALPUFF model. This is because the present scale modelling focuses on the LSA, which is smaller and can account for these finer scale features.

Table D2-23 Maximum Values in the Fort McMurray Area Predicted by the AEP and EC Provincial Scale Modelling

Fort McMurray	kg/ha/a	keq/ha/a
Sulphur loading (SO_2 and SO_4^{2-})	4.8 to 7.2	0.10 to 0.15
Nitrogen loading (NO_x, HNO_3, NO_3^-, and NH_4^+)	0 to 3.1	0.00 to 0.05
Total sulphur and nitrogen loading	-	0.10 to 0.15
Base cation (Na^+, Mg^{2+}, Ca^{2+} and K^+)	-	0.05 to 0.10
PAI	-	0.05 to 0.10

D2.7 Greenhouse Gases

It is generally well understood that the production and burning of fossil fuels generates CO_2 and other greenhouse gases. The effect of these gases on our global climate is still under investigation, as further research and evidence is necessary to determine the effects and their significance. In the near term, a voluntary challenge program is in place in Canada to stabilize the amount of CO_2 emissions at the level produced in 1990.

Canadian and Alberta Emissions

Canada's greenhouse gas emissions for 1995 are summarized as follows:

Emissions	Amount (kt/a)	CO_2 Equivalent (kt/a)
CO_2	499,600	499,600
CH_4	3,780	78,600
N_2O	104	32,300
Other	-	9,000
Total CO_2 Equivalent (kt/a)		619,000

The breakdown of the Canadian emissions in CO_2 equivalent (kt/a), by sector is as follows:

- Industrial process - 93,400
- Stationary fuel combustion - 313,000
- Mobile fuel combustion - 165,000
- Municipal waste incineration - 796
- Agriculture - 27,600
- Miscellaneous - 20,100

Alberta contributes about 189,000 CO_2 equivalent kt/a, which represents about 30% of the Canadian total. Of the Alberta amount, the oil sands region contributes about 11,500 kt/a or about 6% of the Alberta total.

D2.8 Summary

Air quality and meteorological data are available from a number of different locations in the vicinity of the proposed Muskeg River Mine Project area. A summary review of this information follows.

D2.8.1 Emissions

The existing Suncor and Syncrude facilities are the major emission sources in the region with a minor contribution by other sources. In summary, the current regional airshed emissions, based on 1996 information, including the Suncor FGD operation, are:

Parameter	t/d
SO_2	272
NO_x	78
CO_2	31,584
CO	121
PM_{10}	11
HC	44
TRS	1.5

The 1997 SO_2 emissions are expected to be much lower with greater utilization of the Suncor FGD system (e.g., total of 272 t/d based on 95% utilization of FGD). The PM_{10} emissions given in the table only reflect combustion sources and do not include fugitive sources from mining and other activities. Similarly, the CO_2 emissions only reflect site-based combustion sources and do not include those associated with electrical energy usage.

D2.8.2 Meteorology

A review of the meteorological data collected in the region was undertaken to provide information required for dispersion modelling. The meteorological data indicates:

- Wind directions are predominantly form the north and south, reflecting the orientation of the Athabasca River valley and other terrain features.

- Compared with the southerly portion of the province, wind speeds are relatively light. Mean wind speeds are 6.1 and 15.2 km/h at 15.8 and 75 m above ground level, respectively.

- Limited mixing conditions range from 300 to 500 m above ground level during the night and during the winter. During the spring and summer, the afternoon mixing heights range from 1,000 to 2,000 m above ground level.

- Atmospheric turbulence is enhanced during the day (unstable conditions) and is more frequent during the spring and summer. Turbulence is reduced during the night.

D2.8.3 Observed Air Quality

A review of air quality conditions recorded in the vicinity of the Muskeg River Mine Project area indicates the following:

- The hourly average SO_2 concentration in the area has exceeded the hourly air quality guideline of 450 $\mu g/m^3$ (0.17 ppm) for up to two hours per year. Based on observations at OSLO and SandAlta stations (1984 to 1989 period), maximum hourly SO_2 values on a monthly basis range from 130 to 400 $\mu g/m^3$ (0.05 to 0.15 ppm). Based on Fort McKay and SOLV-EX observations (1996 to 1997 period) maximum hourly SO_2 values on a monthly basis range from 130 to 260 $\mu g/m^3$ (0.05 to 0.10 ppm).

- The hourly average H_2S concentrations in the area can be expected to exceed the guideline of 14 $\mu g/m^3$ (0.01 ppm) about once per year. The H_2S exceedance value, however, can be several times the guideline for H_2S. On a monthly basis, the maximum hourly H_2S concentration ranges from 1.4 to 7 $\mu g/m^3$ (1 to 5 ppb).

- The maximum hourly average NO_2 values on a monthly basis range from 50 to 100 $\mu g/m^3$ (0.03 to 0.05 ppm).

- Maximum hourly average O_3 concentrations range from about 60 $\mu g/m^3$ (30 ppb) during the winter to 120 to 150 $\mu g/m^3$ (60 to 70 ppb) during the summer. Exceedances of the hourly guideline of 160 $\mu g/m^3$ (82 ppb) occurred in 1990 and 1993.

- PM_{10} values are monitored only in Fort McMurray. The maximum hourly value for the months January to June 1997 have ranged from 12 to 105 $\mu g/m^3$.

- While average THC concentrations range from 1.4 to 2.1 ppm, peak values of up to 31 ppm have been observed.

The precipitation quality data were reviewed to determine current deposition values in Fort McMurray and those associated with air flow into the RSA:

- The mean pH of precipitation in Fort McMurray is 4.8; this compares with other areas in northern Alberta that range from 5.0 to 5.3.

- The mean wet sulphate deposition is about 4.6 kg SO_4^{2-}/ha/a in Fort McMurray; this compares to a background wet value of 1.7 kg SO_4^{2-}/ha/a. With dry deposition, the estimated background total sulphate deposition is 3.4 kg SO_4^{2-}/ha/a.

- The mean wet nitrate deposition is about 2.2 kg NO_3^-/ha/a in Fort McMurray; this compares to a background wet value of 1.1 kg NO_3^-/ha/a. With dry deposition, the estimated total nitrate deposition is 2.2 kg NO_3^-/ha/a.

- The wet Potential Acid Input (PAI) in Fort McMurray is about 0.09 keq/ha/a, this compares to a background value of 0.038 keq/ha/a. The estimated background dry component of PAI is 0.045 keq/ha/a. Therefore the total background PAI (wet + dry) is about 0.083 keq ha/a. This compares to the target loading for sensitive, moderately sensitive and buffered ecosystems of 0.25 keq/ha/a, 0.5 keq/ha/a and 1.0 keq/ha/a, respectively.

D2.8.4 Model Predictions

Dispersion model predictions were used to provide an indication of the spatial variability of SO_2 and NO_2 in the vicinity of Muskeg River Mine Project area from the following existing sources:

- The maximum predicted SO_2 concentrations on the Project area are in the 200 to 300 $\mu g/m^3$ (~ 0.08 to 0.11 ppm) range, when the Suncor FGD system is down.

- The maximum predicted SO_2 concentrations when the FGD is operating are in the 75 to 150 $\mu g/m^3$ (0.03 to 0.06 ppm) range.

- The maximum predicted NO_2 concentrations are in the 75 to 90 $\mu g/m^3$ range (0.039 to 0.097 ppm).

The model predictions are consistent with the observations in the region. Additional model predictions of deposition in the LSA due to existing sources are as follows:

- The maximum sulphate deposition is 16 kg SO_4^{2-}/ha/a.
- The maximum nitrate deposition is 20 kg NO_3^- /ha/a.
- The PAI is 0.55 keq/ha/a.

These include background values associated with airflow into the region. The maximum PAI exceeds the interim guideline value for sensitive and moderately sensitive ecosystems, but is within the guideline for buffered ecosystems.

D2.8.5 Conclusion

The air quality in the vicinity of the Muskeg River Mine Project area is affected by emissions from local sources. Episodic upset events are likely the source of elevated THC/NMHC and H_2S observations. While ambient SO_2 concentrations are within the guidelines, exceedances can be expected up to two hours per year. Ambient NO_x values are within the guidelines. Naturally occurring high ozone levels tend to occur in the spring and have exceeded the guidelines (4 hours in 1993). The maximum PAI in the region exceeds the interim guideline for sensitive and moderately sensitive systems but is within the guideline for buffered ecosystems.

D3 HYDROGEOLOGIC (GROUNDWATER) SETTING

D3.1 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:

- discussion on the groundwater regime of the Study Area through summarization of the existing regional databases including flow patterns, groundwater quality and interactions with regional groundwater flows;

- discussion on the relationship between groundwater and surface water in the Study Area; and

- description of the surficial and upper bedrock groundwater regimes in the Project area (TofR, Section 4.7).

Project-specific impacts on groundwater are addressed in Section E3 of this EIA. Cumulative effects on groundwater are addressed in Section F3.

The following information is abstracted and summarized from a detailed hydrogeology baseline study for the Muskeg River Mine Project (the Project) conducted by Komex (1997). The Hydrogeology Baseline Study - Oil Sands Lease 13 West report (Komex 1997) provides additional information on the hydrogeologic setting of the Project area.

The following five groundwater-bearing intervals (listed in ascending order) are of regional significance in the Athabasca oil sands area:

1. La Loche Formation;
2. Methy Formation;
3. Water sand at the base of the McMurray Formation (Basal Aquifer);
4. Water-bearing lenses within the oil sands (Intra-orebody aquifers); and
5. Quaternary deposits (Surficial aquifers).

These water-bearing zones, as they occur in the Project area, are discussed in the following subsections.

Hydrogeological investigations within the Project area span a period between 1971 and 1997, with work undertaken by Shell Canada Limited (Shell) and a number of consultants. Most of these programs are discussed and referenced by Komex (1997).

According to archival records, within the Project area are:

- seven monitoring wells that intercept the Middle Devonian Methy Formation, with seven chemical analyses of groundwater;
- 35 monitoring wells installed in the Lower Cretaceous Basal Aquifer, with 60 chemical analyses of groundwater;
- 31 monitoring wells installed in the Lower Cretaceous Intra-orebody and near the contact with Quaternary deposits, with 14 chemical analyses of groundwater; and
- 39 monitoring wells installed in Quaternary deposits, with 18 chemical analyses of groundwater.

The following is a discussion of the study area boundaries for the Project area and a summary of hydrogeological conditions in the main groundwater-bearing units. The units are in ascending order from the oldest (La Loche Formation) to the youngest (Quaternary sediments).

D3.2 Study Area Boundaries

The Local Study Area (LSA) for hydrogeologic impact assessment is defined as the entire Muskeg River Mine Project area, plus an area extending approximately 2 km north into the Syncrude Aurora lease. The hydrogeology LSA was defined in Section D1 (Figure D3-1).

The Regional Study Area (RSA) for groundwater is the area bounded by the Athabasca River on the west, and the outcrop or subcrop of the McMurray Formation to the north, the Firebag River to the northeast and the Steepbank River to the east and south. The hydrogeology RSA was also defined in Section D1. These rivers are the base of surface drainage for regional groundwater flow systems, and therefore form natural hydrogeologic boundaries for the RSA. As the hydraulic conductivity of Devonian rocks below the McMurray Formation is very low (Komex 1997), hydrogeologic effects of mining on the McMurray Formation will be restricted to areas where the McMurray Formation is present, so the RSA for groundwater is limited by the subcrop of this formation. Note that the RSA for groundwater is a subset of the RSA for the overall EIA.

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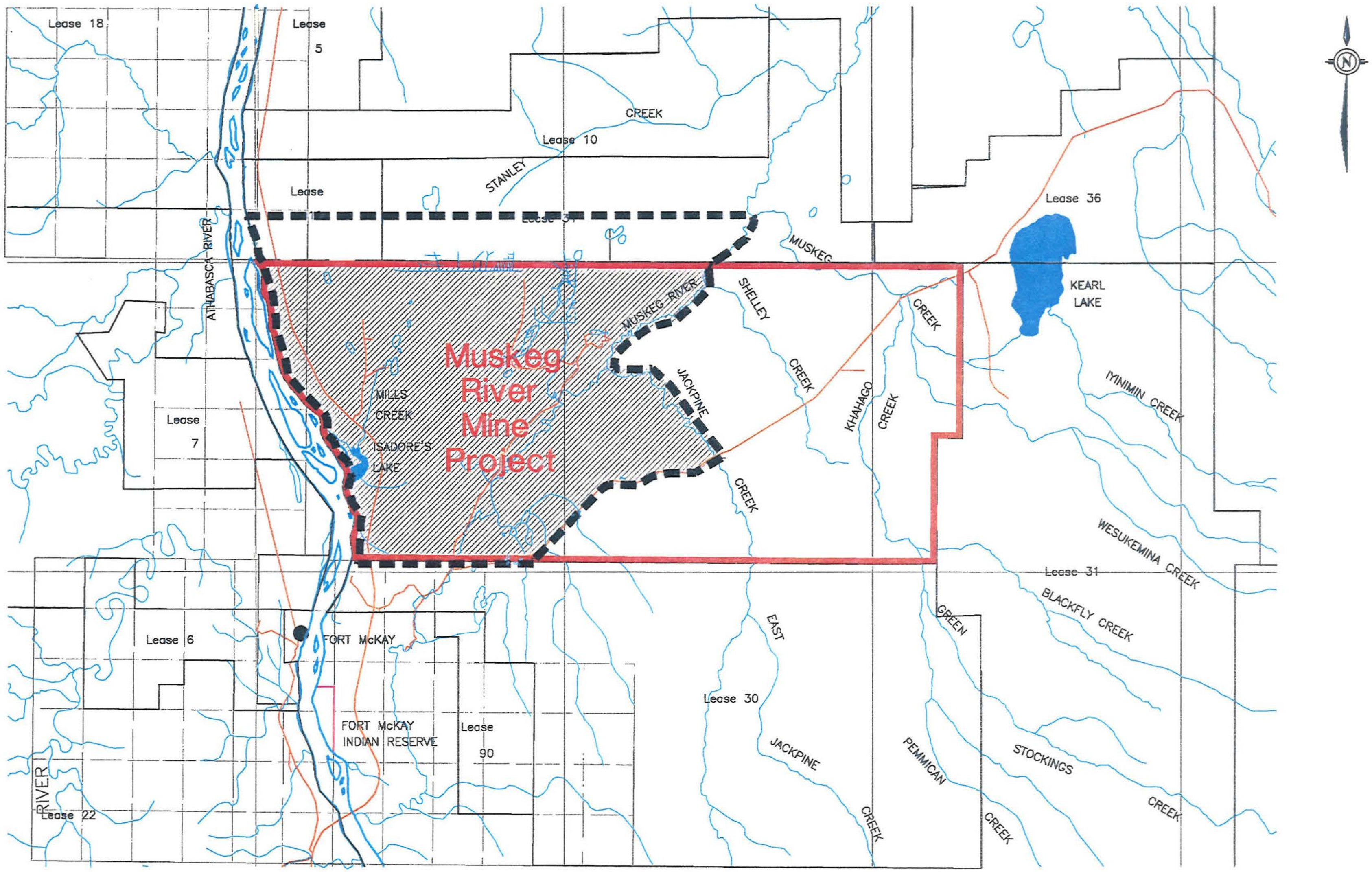


D3 - 3

REFERENCE

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

0 2000 4000 6000 8000 10000(m)

SCALE 1:200,000

Golder Associates

SHELL CANADA LIMITED

LOCAL STUDY AREA FOR GROUNDWATER MUSKEG RIVER MINE PROJECT

03 DEC 97	Figure D3-1	DRAWN BY: RFM

D3.3 Groundwater-Bearing Intervals of Regional Significance

D3.3.1 La Loche Formation

The La Loche Formation is located beyond the zone potentially affected by the proposed mining operation, thus no piezometers were installed in this unit.

Drill stem tests (DST) conducted in hole W805021 (now outside of the Project area within Aurora North leases) and W805027, indicate the presence of groundwater-bearing zones with highly variable thickness and hydraulic properties. The potentiometric surface (converted to equivalent freshwater) stabilizes approximately 25 m below ground surface (W805021) and approximately 12 m above the Methy Aquifer (Alsands Energy Ltd. 1981). The drill stem tests conducted within high porosity intervals indicate hydraulic conductivity ranging from practically zero to $2x10^{-5}$ m/s. Due to the insufficient number of observation wells, groundwater flow direction and velocities cannot be readily defined within this stratigraphic unit.

Only one groundwater sample was collected from this formation (W805021). Groundwater pH was 8.0, mineralization approximately 172,000 mg/L total dissolved solids (TDS) and chloride concentration 102,206 mg/L. This brine represents a Na-Cl hydrochemical type (Alsands Energy Ltd. 1981).

D3.3.2 Methy Formation

The Methy Formation is underlain by an 18 to 48 m thick layer of low hydraulic conductivity McLean River Formation. Observed differences in piezometric elevations between the La Loche and Methy formations indicate that these units are hydraulically separated by intervening McLean River sediments.

Groundwater surface elevations in this confined groundwater-bearing zone, as measured in March 1981, range between 256 m above sea level (masl) (W8015039) and 267.8 masl (W731489). Some of these elevations may represent resultant groundwater surface elevations originating from relatively long sand pack and/or screen interval completions. The hydrographs presented in Alsands Energy Ltd. (1981) indicate that very small temporal changes (<0.5 m) occur in groundwater surface elevations. This indicates hydraulic isolation of this groundwater-bearing zone.

The Methy Formation includes zones of highly variable hydraulic conductivity. Based on two DST tests, Alsands Energy Ltd. (1981) reports hydraulic conductivities ranging from unmeasurably small to $3x10^{-6}$ m/s, and from $7x10^{-10}$ to $3x10^{-9}$ m/s based on analysis from two cores.

Piezometers completed in this formation indicate hydraulic conductivities ranging from $2x10^{-9}$ m/s to $>1x10^{-4}$ m/s. Zones of high hydraulic conductivity, and associated high yields encountered during piezometer development, are most likely limited to reefal buildups.

Distribution of hydrochemical types and groundwater mineralization within this stratigraphic unit are shown in Figure D3-2. Groundwater in this unit represents a chloride-sodium hydrochemical type, with mineralization ranging from 9,824 to 78,666 mg/L TDS. This variability is most likely related to either inadequate piezometer development and/or piezometer designs. Sampling during the winter 1997/98 program, more than 15 years after piezometer reconstruction, should clarify the issue of groundwater mineralization.

An issue of potential hydraulic connection between the Methy Formation and Basal Aquifer, and its impact on proposed Project development, has been raised in the past. Hydrogeological information available to date indicates that such a hydraulic connection does not exist. The factors leading to this conclusion are as follows:

- piezometric pressures in the Basal Aquifer and Methy Formation are different (Komex 1997; Tables 1A and 1B; Figures 10 and 11);

- during long-term Basal Aquifer dewatering, associated with the test pit excavation, no drawdown was observed in the Methy Formation (Alsands Energy Ltd. 1981);

- low seasonal groundwater surface fluctuations in the Methy Formation indicate hydraulic isolation from shallower units (including the Basal Aquifer);

- groundwater chemistry and mineralization are significantly different in both zones (Komex 1997; Tables 3A and 3B) and Alsands Energy Ltd. (1981). Environmental isotopes further confirm isolation of these two groundwater-bearing zones (Wallick and Dabrowski 1982); and

- the Prairie Evaporite Formation, Watt Mountain Formation and Beaverhill Lake Group, representing in excess of 100 m of low hydraulic conductivity sediments, are acting as an aquiclude, effectively separating the Methy Formation and Basal Aquifer.

In the unlikely event that a hydrogeological "window" is opened between the Methy Formation and Basal Aquifer, saline groundwater inflows could be controlled using a conventional engineering approach. Grouting of groundwater circulation routes may be the best approach in achieving separation between those two aquifers. This should be feasible because of the:

- relatively small differences (10 to 20 m) that exist in piezometric levels between the two zones of concern;
- presence of thick sequence (>100 m) of low permeability sediments that separate both geological units;
- relatively small storage of saline water within reefal buildups in Methy Formation; and
- possible lack of hydraulic connection between reefal buildups.

D3.3.3 Basal Aquifer

The Basal Aquifer is a confined aquifer underlain by low hydraulic conductivity basal clay (if present) and Beaverhill Lake Group sediments (Alsands Energy Ltd. 1981). Locally, groundwater may occur within the Upper Devonian fractured zones and/or the weathered uppermost part of this stratigraphic unit. In this case, it is expected that the upper zone would remain in hydraulic communication with the overlying Basal Aquifer.

The Basal Aquifer is represented by fine- to coarse-grained sand (0 to 40 m thick) deposited on the erosional surface of Upper Devonian sediments. Several monitoring wells were installed in this major aquifer (Komex 1997; Figure 6). Piezometer completion details, groundwater surface elevations and hydraulic conductivity test results are summarized in Table 1B (Komex 1997).

Groundwater surface elevations range from 230.9 to 289.9 masl. Depth to groundwater surface varies from less than 2 m to more than 60 m below ground surface. The vertical hydraulic gradient between the Basal Aquifer and Methy Formation is downward in the Project area and upward in the area adjacent to the Athabasca River. Hydrographs obtained from Basal Aquifer piezometer measurements indicate that very small seasonal changes occur in groundwater surface elevations. In most cases, these fluctuations do not exceed 1 m (Alsands Energy Ltd. 1981). Small amplitude and lack of a distinct seasonal trend in the groundwater surface elevation fluctuations indicate that direct recharge to the Basal Aquifer occurs far beyond the LSA.

Significant recharge will occur where McMurray Formation basal sands subcrop below permeable Quaternary sediments or outcrop at the surface. The presence of tritium in porewater obtained from oil sands, indicates that groundwater in the Basal Aquifer is also recharged through the oil sands. In some areas (e.g., lean oil sands and higher permeability sediments), such recharge may occur within a timeframe of 5 to 10 years (Wallick and

Dabrowski 1982). Where thick layers of high grade oil sands are present, recharge rates will be much slower.

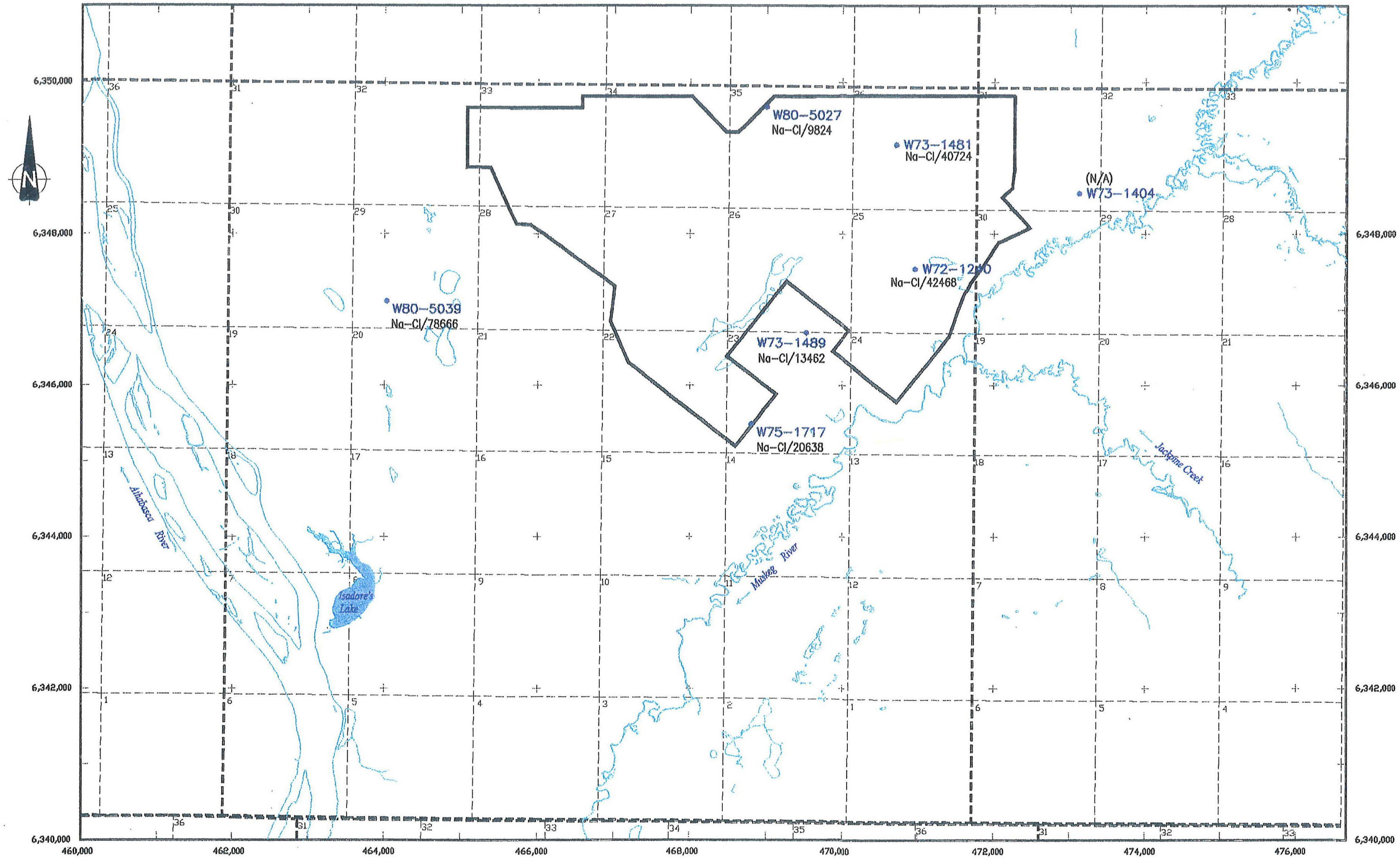
A peizometric surface contour map for the Basal Aquifer is shown in Figure D3-3. It shows that in the proposed mine pit area, groundwater surface elevations range from approximately 275 masl to 289.9 masl.

Although not confirmed, the change in hydraulic gradient west of the proposed mine may reflect a constriction of groundwater flow in the Basal Aquifer. This may be due to relief variations on the Devonian surface (e.g., bedrock highs), which in turn would directly impinge on Basal Aquifer thickness. This may also reflect an overall increase in the hydraulic conductivity of the Basal Aquifer adjacent to the Athabasca River. For example, hydraulic connection between the Basal Aquifer and the Athabasca River is inferred to occur in the vicinity of piezometers W805053, W805054 and MW97-42, where groundwater surface elevations (230 - 235 masl) are comparable with elevations in the Athabasca River (230 - 235 masl).

Groundwater flow is generally toward the west with hydraulic gradients ranging between approximately 0.002 (in the proposed mine area) to 0.025 (in the zone of steep hydraulic gradients west of the Project area).

Aquifer tests in the Project area between 1972 and 1974 were interpreted to give a range of hydraulic conductivity of $2x10^{-5}$ to $3x10^{-4}$ m/s, with a geometric mean of $5x10^{-5}$ m/s (Alsands Energy Ltd. 1981). In addition, 26 single well tests were performed during development of wells in 1981. Sixteen of the wells gave a range of hydraulic conductivity from $1x10^{-5}$ to $>1x10^{-4}$ m/s (Komex 1997; Table 1B), which is similar to the range found from the aquifer test referred to above. Ten of the wells gave lower values, in a range of $5x10^{-8}$ to $7x10^{-6}$ m/s (Alsands Energy Ltd. 1981 and 1982). These lower values may be related to the piezometer screen being plugged with heavy oil, or placing the screen within oil sands, where the Basal Aquifer is absent.

Other measurements of hydraulic conductivity based on pumping tests in the Basal Aquifer are also available. Golder Associates Ltd. (1996a) refers to the analysis of a pumping test on Lease 34 (Aurora Mine North) that was analyzed to give a transmissivity ranging from 21 to 61 m^2/d. If a Basal Aquifer thickness of 25 m is assumed, based on isopach maps in Golder 1996a, then a range in hydraulic conductivity values of $1x10^{-5}$ to $3x10^{-5}$ m/s may be calculated.



LEGEND

• W80-5039	PIEZOMETER LOCATION – METHY FORMATION
Na-Cl/78666	HYDROCHEMICAL TYPE AND MINERALIZATION (TDS), IN mg/L
N/A	DENOTES INFORMATION NOT AVAILABLE

NOTES:
1. SAMPLES COLLECTED IN MARCH 1981.
2. SAMPLES W73-1481 AND W80-5039 MAY REPRESENT A COMPOSITE CHLORIDE CONCENTRATION RESULTING FROM MIXING OF GROUNDWATER ORIGINATING FROM DIFFERENT DEVONIAN FORMATIONS.

0 1.5 3.0 km
SCALE 1 : 60,000

Source: Shell Canada Limited
OBPIEZO.DXF – Surficial Piezometers
WSPIEZO.DXF – Basal Aquifer Piezometers
Date: 22-JUL-97

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DISTRIBUTION OF HYDROCHEMICAL TYPES AND MINERALIZATION IN GROUNDWATER DEVONIAN: METHY FORMATION

DRAWN BY:	EDITED BY:	DATE:
M.T.	J.P.	DEC.03/97
APPROVED:	FIGURE: D3-2	

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Based on the results of these aquifer tests, it appears that the Basal Aquifer (clean sand) in the Project area has a hydraulic conductivity in the range of $1x10^{-5}$ to $>1x10^{-4}$ m/s. Lower values are associated with oil-saturated sands.

Storativity for the Basal Aquifer was calculated from each of four aquifer tests (1972 - 1974) referred to in Alsands Energy Ltd. Energy Ltd. (1981). A total of 14 values were evaluated, 11 of which were within a $1x10^{-5}$ to $1x10^{-4}$ m/s. The two tests conducted in 1974 yielded higher values up to $2x10^{-2}$/s, which would be considered unusual for a confined aquifer, and one value of $1x10^{-3}$ m/s. Analysis of aquifer tests at OSLO Lease 31 yielded storativity values between $2.2x10^{-5}$ and $1.3x10^{-4}$ m/s. Analysis of the 1996 aquifer test at Lease 34 (Aurora Mine North) gave values ranging from $4x10^{-5}$ to $3x10^{-4}$ m/s (Golder 1996a).

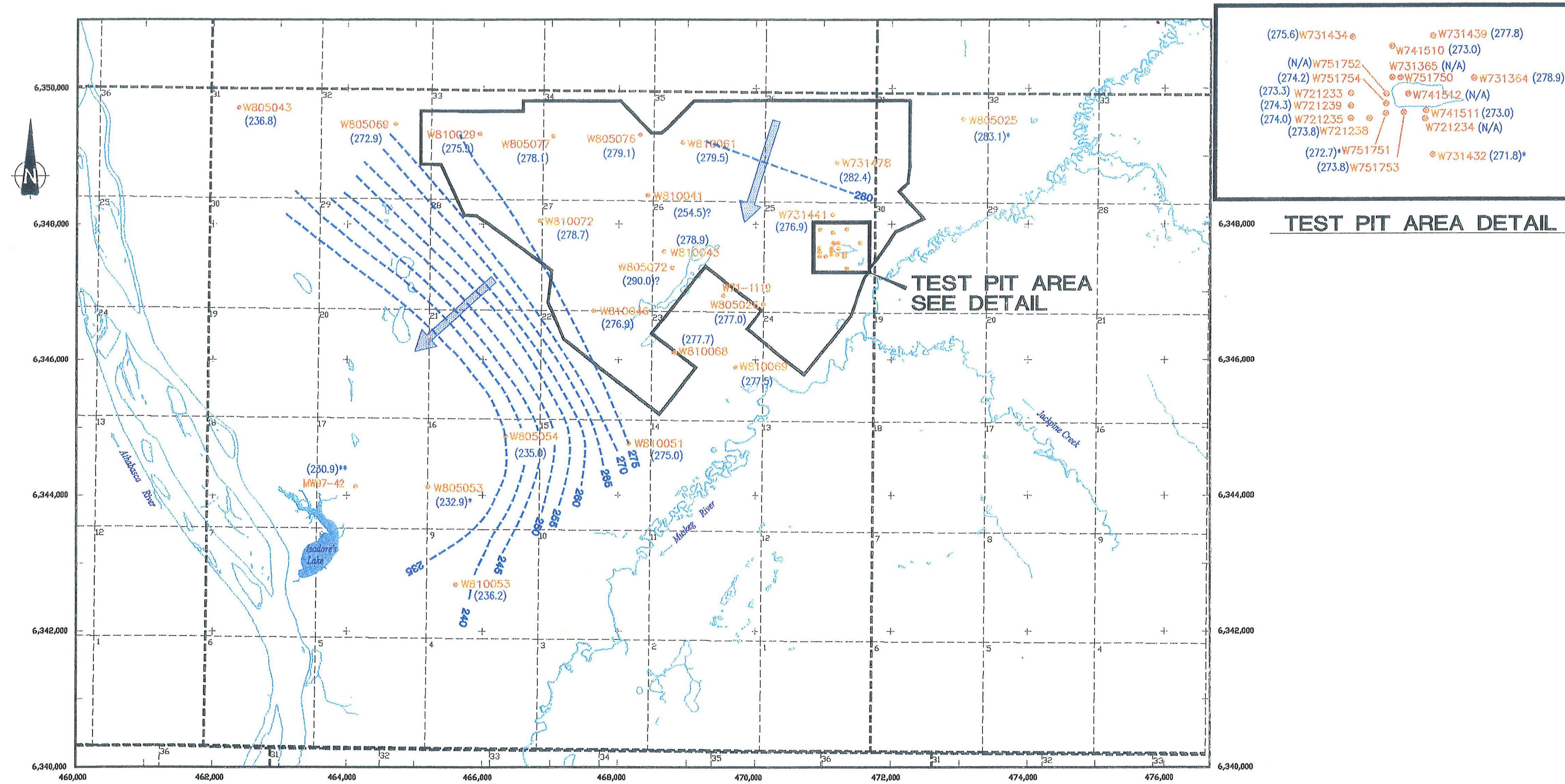
Based on these aquifer tests, it would appear that the Basal Aquifer in the Aurora leases and the Muskeg River Mine Project area has a storativity in the range $1x10^{-5}$ to $4x10^{-4}$ m/s, typical of a confined aquifer.

Distribution of hydrochemical types is shown in Figure D3-3. Groundwater represents mostly Cl-HCO_3-Na and HCO_3-Cl-Na hydrochemical types, with mineralization ranging between 1,430 and 7,407 mg/L TDS. An anomalous hydrochemical type was encountered in piezometer W810061, where HCO_3-Na type water with a relatively low mineralization of 1,430 mg/L TDS was found.

Chloride distribution is shown in Figure D3-4. Concentrations range from 81 mg/L (W810061) to 2,793 mg/L (W810068). The anomalous hydrochemical type combined with low TDS and chloride concentrations in W810061 suggest the presence of a hydrogeological "window" in the area adjacent to this monitoring well.

D3.3.4 Cretaceous Intra-Orebody and Near Contact With Quaternary

Intra-orebody groundwater-bearing zones are represented by generally thin and locally discontinuous layers of silty sands and/or sands with low bitumen content. Such aquifers may be present within the McMurray Formation profile extending from the contact with Quaternary deposits and the top of the Basal Aquifer. Groundwater may be under confined conditions, especially in the lower parts of the McMurray Formation. Due to restricted recharge and low storage capacity, the groundwater reserves in the intra-orebody aquifers are expected to be relatively small.



LEGEND

W810053	PIEZOMETER LOCATION – BASAL AQUIFER
(236.2)	GROUNDWATER SURFACE ELEVATION m.a.s.l. (MEASURED FEBRUARY/MARCH, 1981)
(283.1)*	GROUNDWATER SURFACE ELEVATION m.a.s.l. (MEASURED SEPTEMBER/NOVEMBER, 1980)
(230.9)**	GROUNDWATER SURFACE ELEVATION m.a.s.l. (MEASURED APRIL, 1997)
(290.0)?	ANOMALOUS GROUNDWATER SURFACE ELEVATION (not included in the interpretation)
N/A	DENOTES INFORMATION NOT AVAILABLE
- - - - - -	APPROXIMATE PIEZOMETRIC SURFACE CONTOUR LINE (m.a.s.l.)
⟸	GENERAL GROUNDWATER FLOW DIRECTION

0 1.5 3.0 km

SCALE 1 : 60,000

Source: Shell Canada Limited
OBPIEZO.DXF – Surficial Piezometers
WSPIEZO.DXF – Basal Aquifer Piezometers
Date: 22–JUL–97

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PIEZOMETRIC SURFACE CONTOUR MAP
CRETACEOUS: BASAL AQUIFER

DRAWN BY:	EDITED BY:	DATE:
M.T.	J.P.	DEC.03/97
APPROVED:	FIGURE:	
	D3-3	

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A relatively small number of observation wells have been installed in this zone. Groundwater surface elevations range from approximately 230 masl to 300 masl. Seasonal changes in groundwater surface elevations are within a range of 1.5. It is expected that a downward hydraulic gradient dominates within the McMurray Formation.

The bitumen content of the oil sands results in a low hydraulic conductivity, which is often difficult to measure in well tests. Analysis of a Syncrude 1996 pumping test using the Neuman and Witherspoon (1972) method gave an estimate of $2x10^{-10}$ m/s for the vertical hydraulic conductivity of the oil sands (Golder 1996a). Clark (1960) estimated a range of $3.2x10^{-8}$ to $1x10^{-5}$ m/s based on laboratory studies. Wallick and Dabrowski (1982) estimate a vertical hydraulic conductivity of $4x10^{-8}$ m/s based on a study of tritium concentrations in porewater.

Golder Associates Ltd. (1997a) measured hydraulic conductivity in piezometer MW97-42A within an interval 20.7 to 24.5 m below ground surface. The result, $7x10^{-8}$ m/s, is consistent with results obtained from the literature.

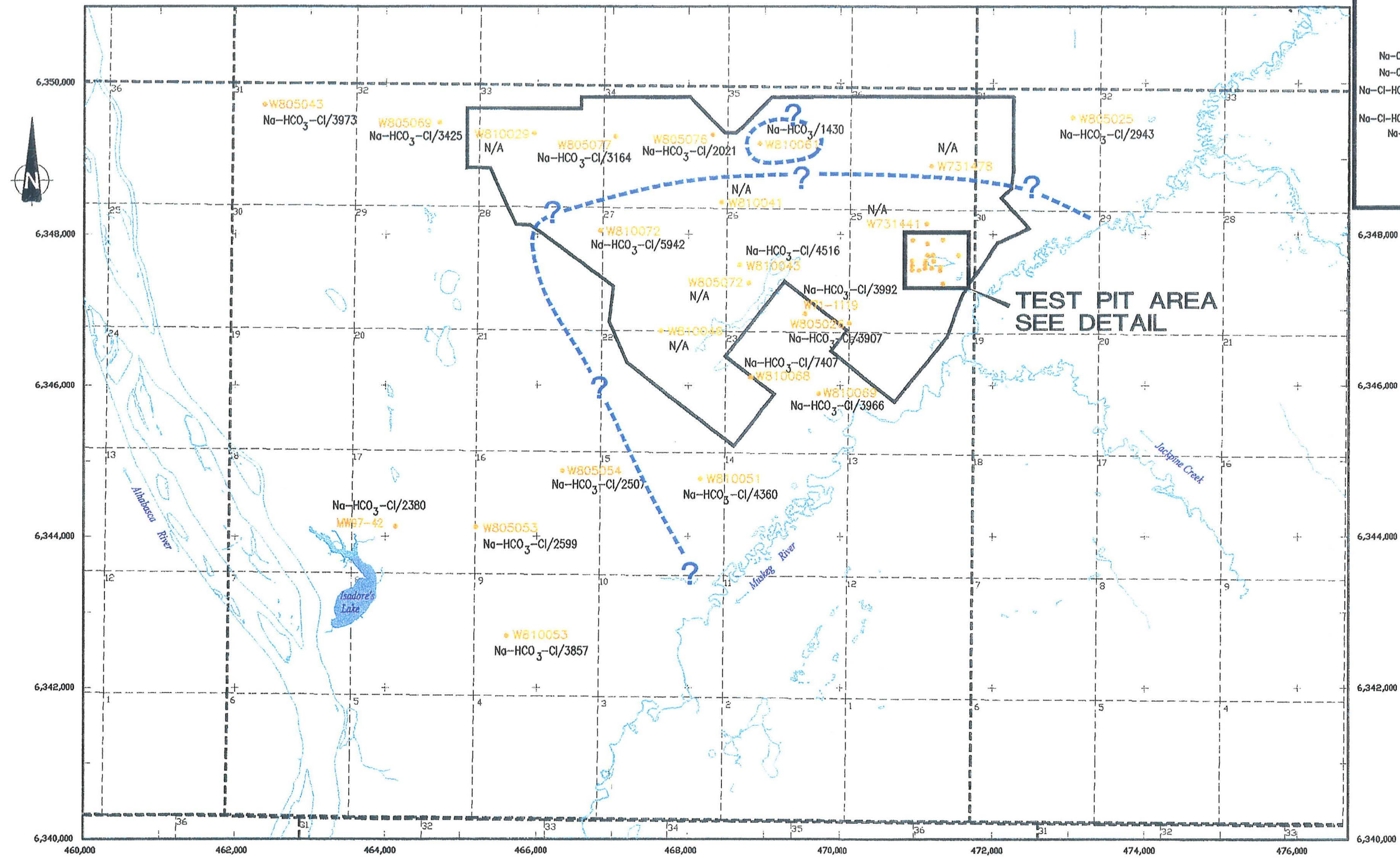
Six different hydrochemical types of groundwater were encountered within the McMurray Formation. Associated with this variability is a wide range of mineralization 239 to 846 mg/L TDS. Chloride concentrations are relatively low and do not exceed 122 mg/L (Golder 1997a).

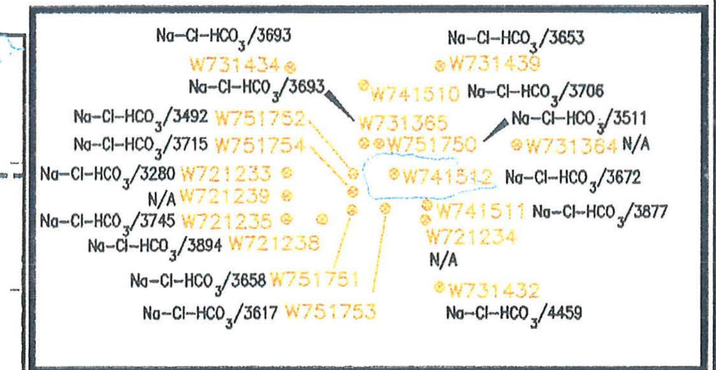
D3.3.5 Quaternary

The surficial aquifers are represented by relatively thin (<20 m) fluvioglacial and alluvial sands and gravels of Quaternary age. These aquifers are usually unconfined. Within the Project area, depth to the phreatic surface varies from 0 to 7 m below ground surface.

A buried tributary valley was identified in the western part of Lease 13, extending north from Isadore's Lake. Groundwater reserves associated with such channels are highly variable, depending on the extent and thickness of water-bearing granular deposits.

Depth to the groundwater surface within the Project area was measured periodically to define seasonal groundwater surface fluctuations and direction of groundwater flow. The direction of groundwater flow in surficial sediments is not well defined. However, the aquifers drain toward local topographical depressions and surface drainage systems. A downward vertical hydraulic gradient exists between the surficial aquifers and the Basal Aquifer.





TEST PIT AREA DETAIL

NOTE: HYDROCHEMICAL DATA WAS COLLECTED DURING DIFFERENT EXPLORATION PROGRAMS (1971, 1975, 1980, 1981 AND 1997).

LEGEND

• W810053	PIEZOMETER LOCATION – BASAL AQUIFER
Na-HCO3-Cl/3857	HYDROCHEMICAL TYPE AND MINERALIZATION (TDS), IN mg/L
N/A	DENOTES INFORMATION NOT AVAILABLE
- - - -	APPROXIMATE BOUNDARY BETWEEN GROUNDWATER HYDROCHEMICAL TYPES

0 1.5 3.0 km

SCALE 1 : 60,000

Source: Shell Canada Limited
OBPIEZO.DXF – Surficial Piezometers
WSPIEZO.DXF – Basal Aquifer Piezometers
Date: 22-JUL-97

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DISTRIBUTION OF HYDROCHEMICAL TYPES AND MINERALIZATION IN GROUNDWATER CRETACEOUS: BASAL AQUIFER

DRAWN BY:	EDITED BY:	DATE:
M.T.	J.P.	DEC.03/97
APPROVED:	FIGURE:	D3-4

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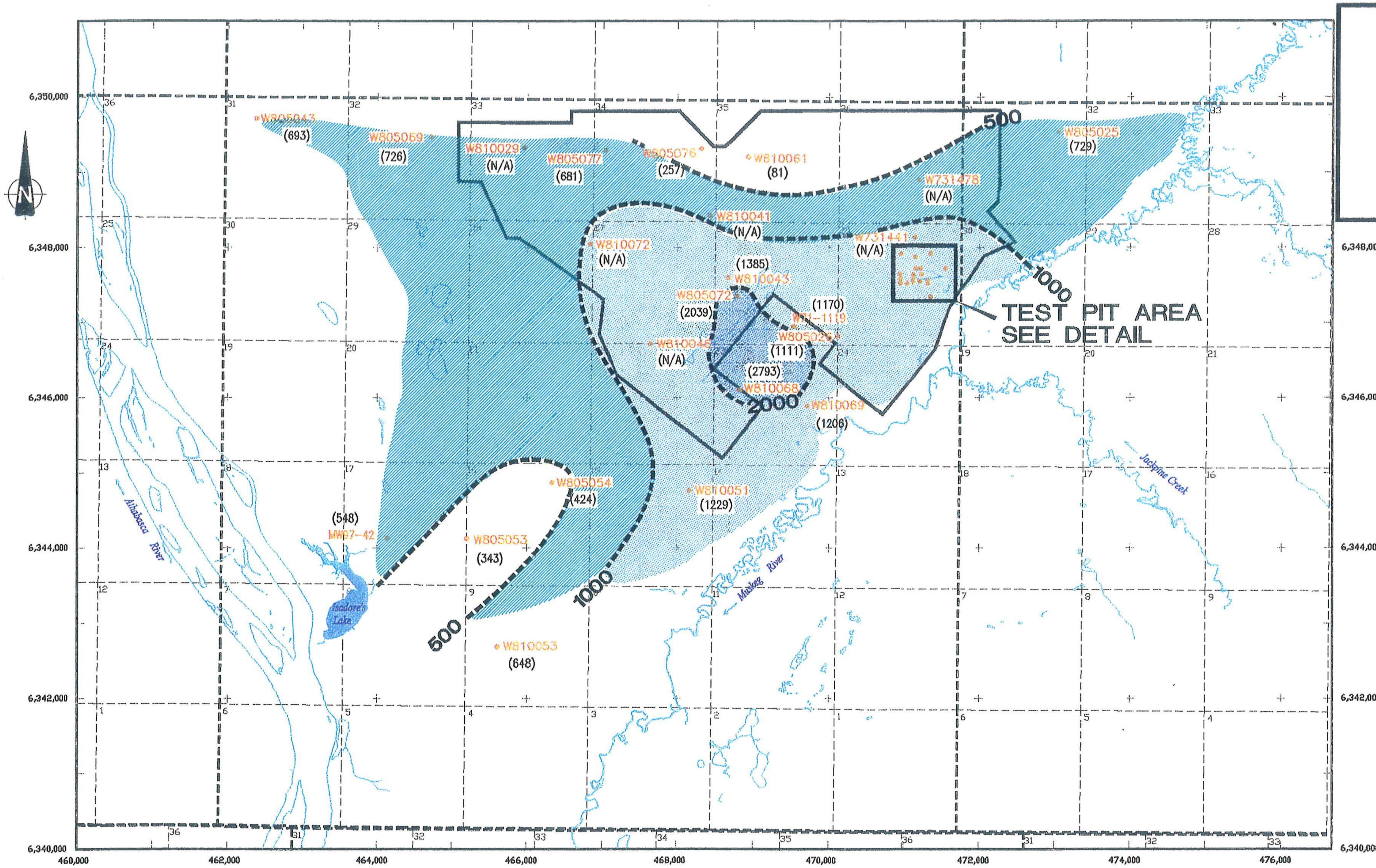

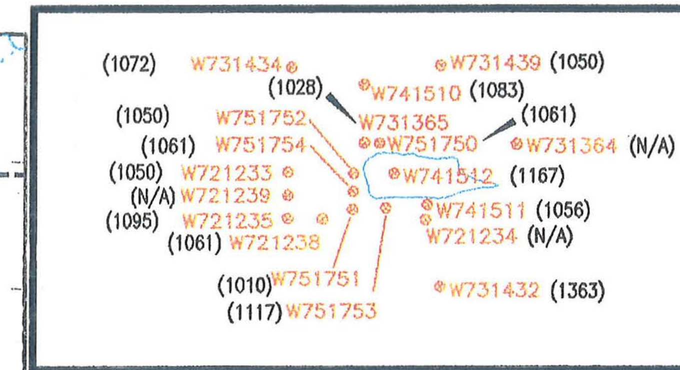

TEST PIT AREA DETAIL

NOTE: CHLORIDE CONCENTRATIONS ORIGINATE FROM DIFFERENT EXPLORATION PROGRAMS (1971, 1975, 1976, 1980 AND 1997).

LEGEND

W810053	PIEZOMETER LOCATION – BASAL AQUIFER
(7)	CHLORIDE CONCENTRATIONS IN mg/L
(N/A)	DENOTES INFORMATION NOT AVAILABLE
	CHLORIDE CONCENTRATION <500 mg/L
	CHLORIDE CONCENTRATION 500 – 1000 mg/L
	CHLORIDE CONCENTRATION 1000 – 2000 mg/L
	CHLORIDE CONCENTRATION >2000 mg/L

0 1.5 3.0 km

SCALE 1 : 60,000

Source: Shell Canada Limited
OBPIEZO.DXF – Surficial Piezometers
WSPIEZO.DXF – Basal Aquifer Piezometers
Date: 22-JUL-97

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CHLORIDE DISTRIBUTION IN GROUNDWATER
CRETACEOUS: BASAL AQUIFER

DRAWN BY:	EDITED BY:	DATE:
M.T.	J.P.	DEC.03/97
APPROVED:		FIGURE: D3-5

FILE: J:\4577B\13-BASE.DWG

Hydrographs obtained from surficial aquifer piezometers indicate a relatively slow response of the groundwater surface to extended periods of rain. In general, seasonal fluctuations in the groundwater surface do not exceed 1.5 m. This is due mostly to the significant storage capacity of the Quaternary sediments. Most surficial piezometers are frozen from December until the end of May.

Hydraulic conductivity of surficial aquifers is highly variable and ranges from approximately $1x10^{-8}$ to $1x10^{-3}$ m/s.

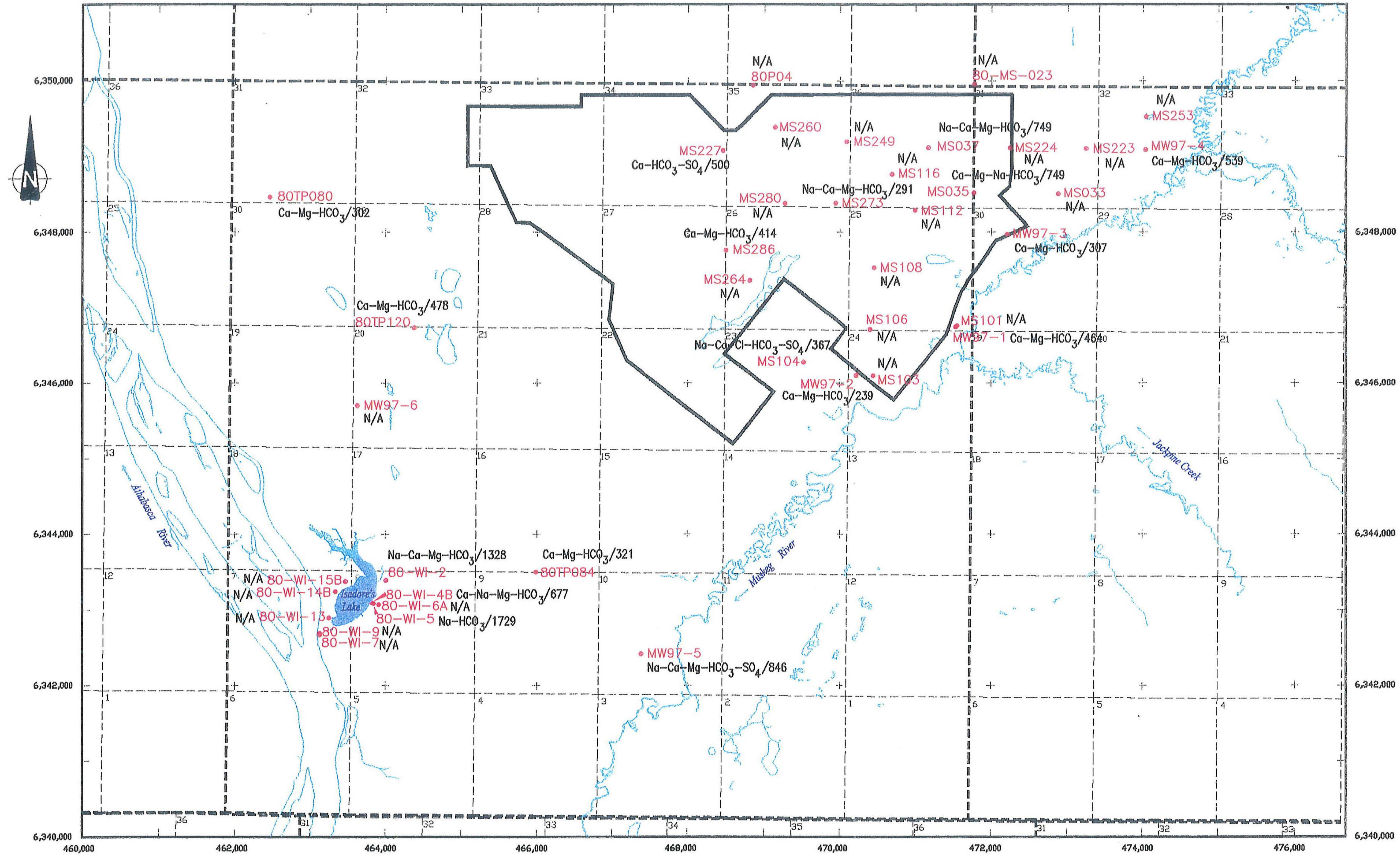
Golder (1996a) noted a range of $1x10^{-9}$ to $1x10^{-3}$ m/s for the hydraulic conductivity of surficial deposits in the Aurora Mine areas, while Alsands Energy Ltd. (1981) indicate a range of $1x10^{-6}$ to $1x10^{-3}$ m/s for the Project area. The large range is due to the variation in surficial materials from highly permeable sands and gravels to low permeability lacustrine clays. Golder (1996a) also give a vertical hydraulic conductivity of $5x10^{-10}$ m/s for lacustrine clay, a vertical hydraulic conductivity range of $6x10^{-11}$ to $4x10^{-8}$ m/s for till, and a horizontal hydraulic conductivity range of $6x10^{-8}$ to $2x10^{-7}$ m/s for till.

A pumping test performed in the main Pleistocene channel in the Aurora Mine South area gave a transmissivity of $3.6x10^{-3}$ m^2/s, which was reported to correspond to a hydraulic conductivity of $1.9x10^{-3}$ m/s (Golder 1996a).

Groundwater in Quaternary aquifers consists mostly of the HCO_3-Ca-Mg and HCO_3-Ca-Mg-Na hydrochemical types. Distribution of groundwater hydrochemical types is shown in Figure D3-6.

The majority of the samples collected from the zone encompassing the Quaternary sediments indicate the presence of fresh water in these aquifers. In general, mineralization varies from 239 to 1,729 mg/L TDS, while chloride concentrations are below 135 mg/L (Komex 1997; Table 3D).

Local hydrochemical anomalies were found in the Isadore's Lake area, where relatively high mineralization was encountered in holes 80-W1-2 and 80-W1-5. In these holes, mineral content exceeded 1,300 mg/L TDS (Komex 1997; Table 3D). These holes may be in hydraulic contact with Cretaceous deposits.



LEGEND

• MW97-5 — PIEZOMETER LOCATION – QUATERNARY DEPOSITS

Na-Ca-Mg-HCO_3-SO_4/846 — HYDROCHEMICAL TYPE AND MINERALIZATION (TDS), IN mg/L

N/A — DENOTES INFORMATION NOT AVAILABLE

NOTES:
1. HYDROCHEMICAL DATA WAS COLLECTED DURING THE 1980 AND 1997 EXPLORATION PROGRAMS.
2. PIEZOMETERS WERE COMPLETED IN DIFFERENT LITHOLOGICAL UNITS AND AT DIFFERENT DEPTHS (1.89 – 11.87 m), THUS, DELINEATION OF HYDROCHEMICAL ZONES WAS NOT POSSIBLE.

0 1.5 3.0 km
SCALE 1 : 60,000

Source: Shell Canada Limited
OBPIEZO.DXF – Surficial Piezometers
WSPIEZO.DXF – Basal Aquifer Piezometers
Date: 22-JUL-97

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DISTRIBUTION OF HYDROCHEMICAL TYPES AND MINERALIZATION IN GROUNDWATER QUATERNARY DEPOSITS

DRAWN BY:	EDITED BY:	DATE:
M.T.	J.P.	DEC.03/97
APPROVED:		FIGURE: D3-6

FILE: J:\4577B\13-BASE.DWG

D4 SURFACE WATER HYDROLOGY

D4.1 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:

- discussion on the surface water hydrology in the Study Area; and
- discussion on the probable maximum flood or probable maximum precipitation events (TofR, Section 4.6).

Project-specific impacts on surface water hydrology are addressed in Section E4 of this EIA. Cumulative effects on surface water hydrology are addressed in Section F4.

This section presents a summary of the surface water hydrology baseline data and relevant climate information for the Regional Study Area (RSA), as shown in Figure D1-2, and the Local Study Area (LSA), as shown in Figure D4-1.

Previous surface water hydrologic studies in the region were conducted for the existing Syncrude and Suncor oil sands facilities west of the Athabasca River: the Syncrude Aurora Mine Project in the Muskeg River basin and the Suncor Steepbank Mine Project east of the Athabasca River. The most recent baseline hydrology study conducted for the Aurora project EIA (AGRA 1996a) contains a portion of the baseline hydrology and climate data applicable to the Shell Muskeg River Mine Project (the Project) EIA.

Shell Canada Limited (Shell) commissioned Golder Associates to collect additional hydrology baseline data in the LSA during the winter and summer of 1997 to expand the hydrologic baseline database developed for the Aurora Project. The expanded database fills data gaps and provides a good basis for conducting the Muskeg River Mine Project EIA. Jointly, Shell and Syncrude will continue to operate the existing climate and hydrology monitoring networks in the Muskeg River basin to provide the data for hydrological modelling. Continuing monitoring is important for collecting data for future design of water management systems and for monitoring the effects of the Project on surface water hydrology.

A hydrologic modelling analysis was conducted during this baseline study, to calibrate a continuous hydrologic simulation model based on the short-term streamflow data collected in the LSA. This modelling study improved the definition of the streamflow characteristics of the small streams in the LSA, beyond that available for the Aurora Mine Project and has provided a sound basis for the EIA.

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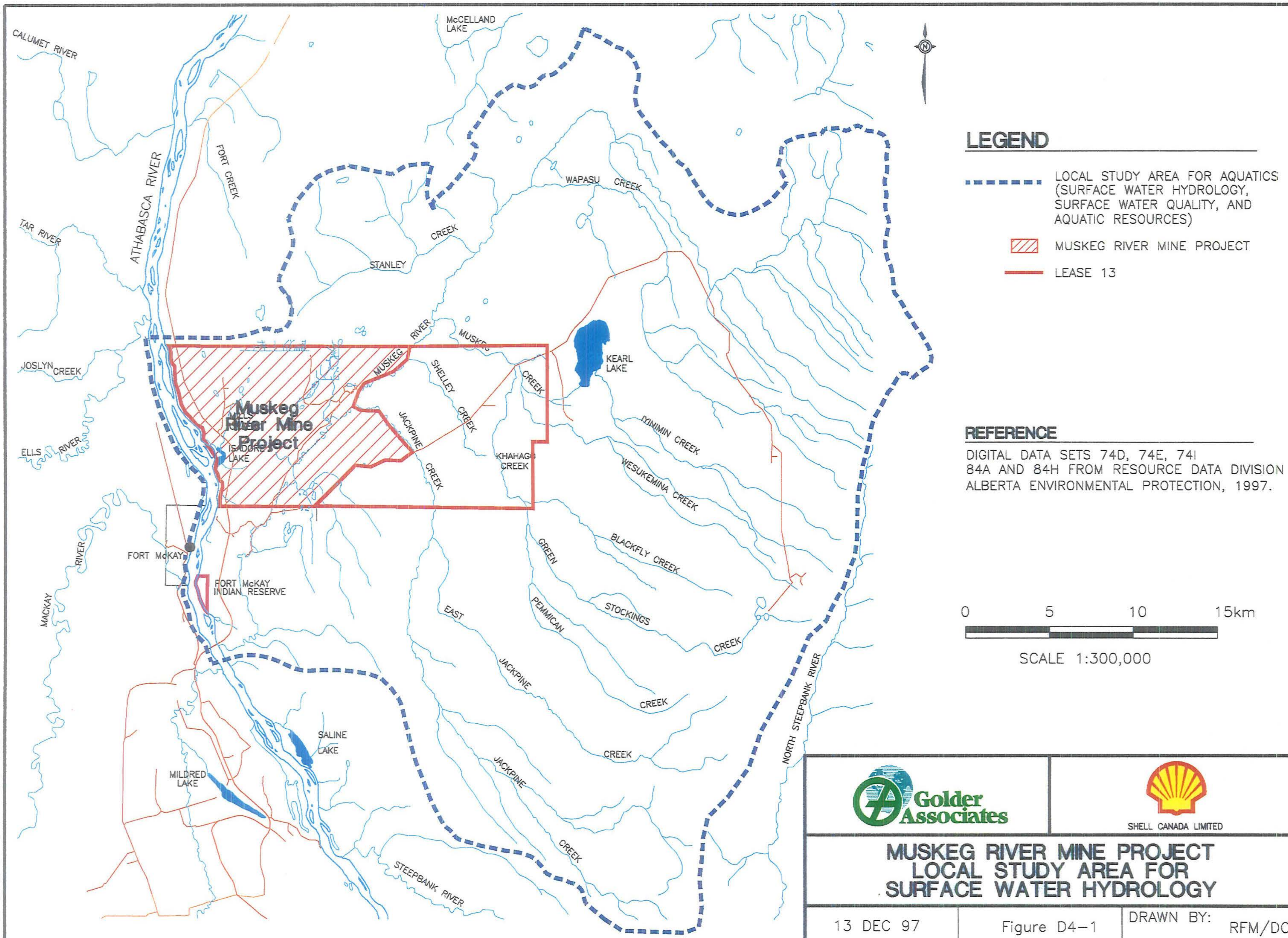

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MUSKEG RIVER MINE PROJECT LOCAL STUDY AREA FOR SURFACE WATER HYDROLOGY

13 DEC 97	Figure D4-1	DRAWN BY: RFM/DC

This section synthesizes all available hydrology information and data, as well as relevant climate data. Additional data collected during the 1997 winter and summer programs are presented in two Golder Associates reports entitled "Lease 13 Surface Water Hydrology - 1997 Winter Data Collection Program" (Golder 1997b) and "1997 Summer Data Collection Program and Baseline Hydrologic and Hydraulic Studies for the Muskeg River Mine Project, December 1997" (Golder 1997c). The latter report also presents the detailed modelling methodology and results of the baseline hydrologic and hydraulic modelling studies.

D4.1.1 Physical Setting

The Muskeg River Mine Project LSA is situated on the east side of the Athabasca River with the majority of the development within the lower watershed of the Muskeg River. The remainder of the Project development is situated within the Isadore's Lake watershed, which drains directly into the Athabasca River.

The RSA has a continental climate with significant seasonal variations in temperature and precipitation. Daily mean temperatures typically dip below freezing in mid-October and remain below zero until the beginning of April.

The terrain in the Project area is nearly flat with elevations ranging from 276 to 300 masl (metres above sea level) with an average elevation of about 290 masl. The Muskeg River basin is generally flat, except for Muskeg Mountain on the east side of the watershed. Ground slopes of less than 0.5% are typical of the poorly drained lowland in the LSA. Slopes of 1 to 3% are typical of the better drained upland areas at elevations above 340 masl. Details on the terrain of the Project area are provided in Section D8.

The dominant surficial soils in the LSA are fen soils, which are highly absorbent, generally poorly drained and characterized by a high water table, at or near the ground surface, following spring snowmelt. The fen soils of the study area are typically 0.5 to 4.5 m thick and overlie relatively impervious lacustrine deposits. Details on the soils of the Project area are provided in Section D8.

Vegetation in the LSA consists primarily of willow brush, shrubs, black spruce and sphagnum moss. A mixed forest cover of coniferous and deciduous trees occurs in upland areas. Details on the Project area vegetation and wetlands are provided in Sections D9 and D10.

There is a great deal of beaver activity in the LSA, especially in lowland areas. Most of the well-defined streams are blocked by beaver dams at numerous locations. Beaver lodges are also present in permanently inundated lowland areas. Details on the Project area wildlife are provided in Section D11.

D4.2 Climate

Climate considerations are important for surface water hydrology because of the significant impact of precipitation, wind and temperature on hydrology.

D4.2.1 Data Sources

Published Data

There is a significant quantity of climate data available for the RSA. Data are principally gathered by Atmospheric Environment Services of Environment Canada (AES) and Alberta Forestry at a regional network of seasonally and continuously operated climate monitoring stations. The regional AES stations generally have 20 or more years of records. Additional short-term data are available from other baseline studies conducted for the study area and from stations operated by Syncrude and Suncor at their respective oil sands operations.

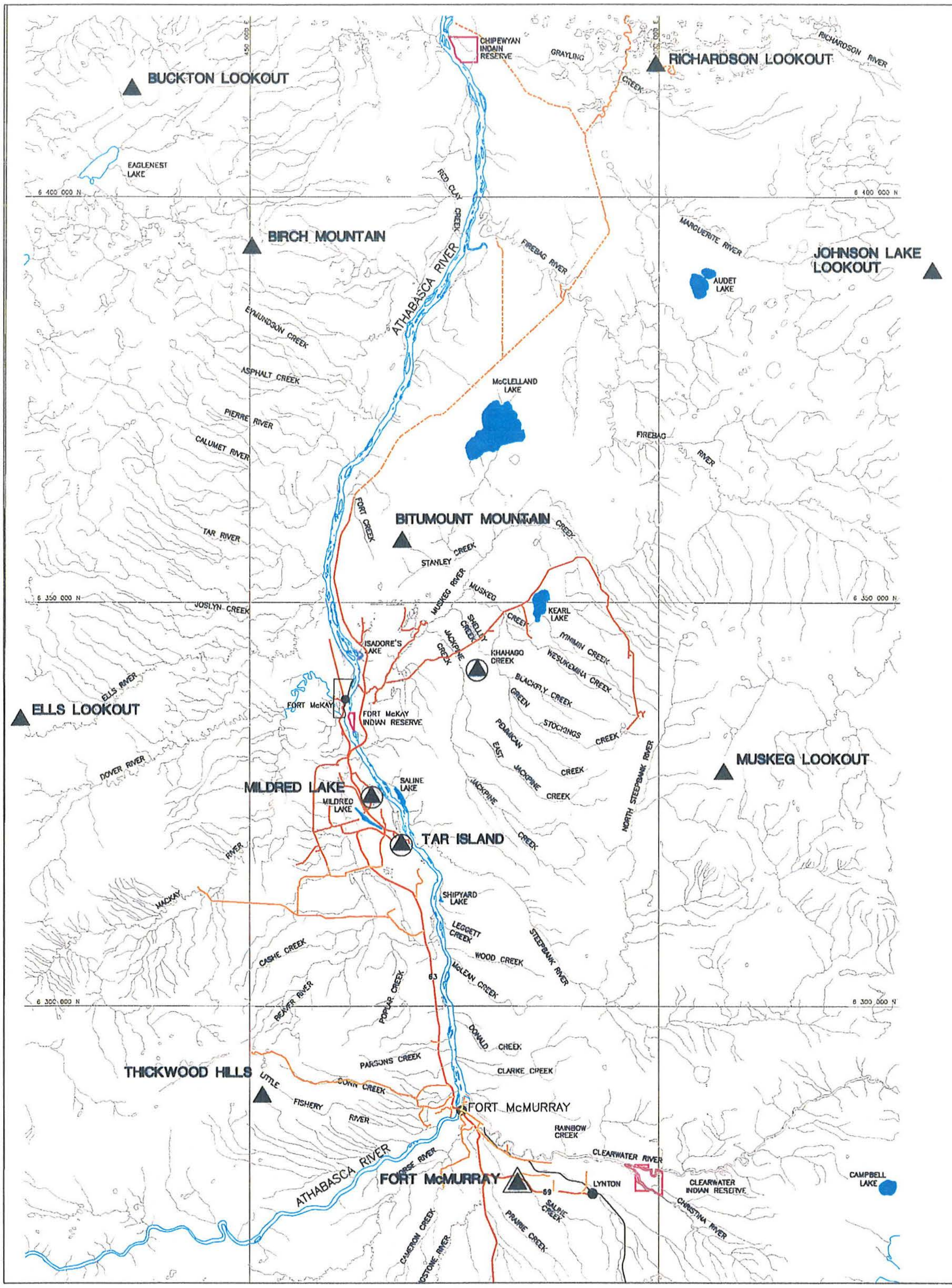
A substantial amount of summer rainfall and temperature data are available from the AES stations. Snowfall data have been recorded at only three stations, but two of these have been discontinued. The only year-round climate station in the RSA with a long period of record is located at the Fort McMurray airport. Climate stations at Mildred Lake and Fort McMurray airport are the only climate stations in the RSA that collect wind, solar radiation and evaporation data. Figure D4-2 shows the locations of the regional climate stations, which include:

- Alberta Forestry seasonal precipitation monitoring stations;
- Atmospheric Environment Services of Environment Canada long-term, year-round monitoring stations; and
- oil sands industry year-round climate monitoring stations.

Aurora Mine Climate Monitoring Station

Syncrude has operated a climate station for the Aurora Mine project since May 1995. Climatic variables monitored at the station include the following at hourly intervals:

- air temperature;
- rainfall;
- snowfall;
- global solar radiation;
- relative humidity; and
- wind speed and direction.



0 10 20 30 40km

SCALE 1:750,000

LEGEND

▲ ALBERTA FORESTRY SEASONAL PRECIPITATION MONITORING STATION

▲ AES YEAR-ROUND LONG-TERM PRECIPITATION MONITORING STATION

(▲) YEAR ROUND INDUSTRY CLIMATE MONITORING STATION

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LOCATION OF LOCAL AND REGIONAL CLIMATE MONITORING STATIONS

13 DEC 1997	Figure D4–2	DRAWN BY: BGM/DC

Air Temperature

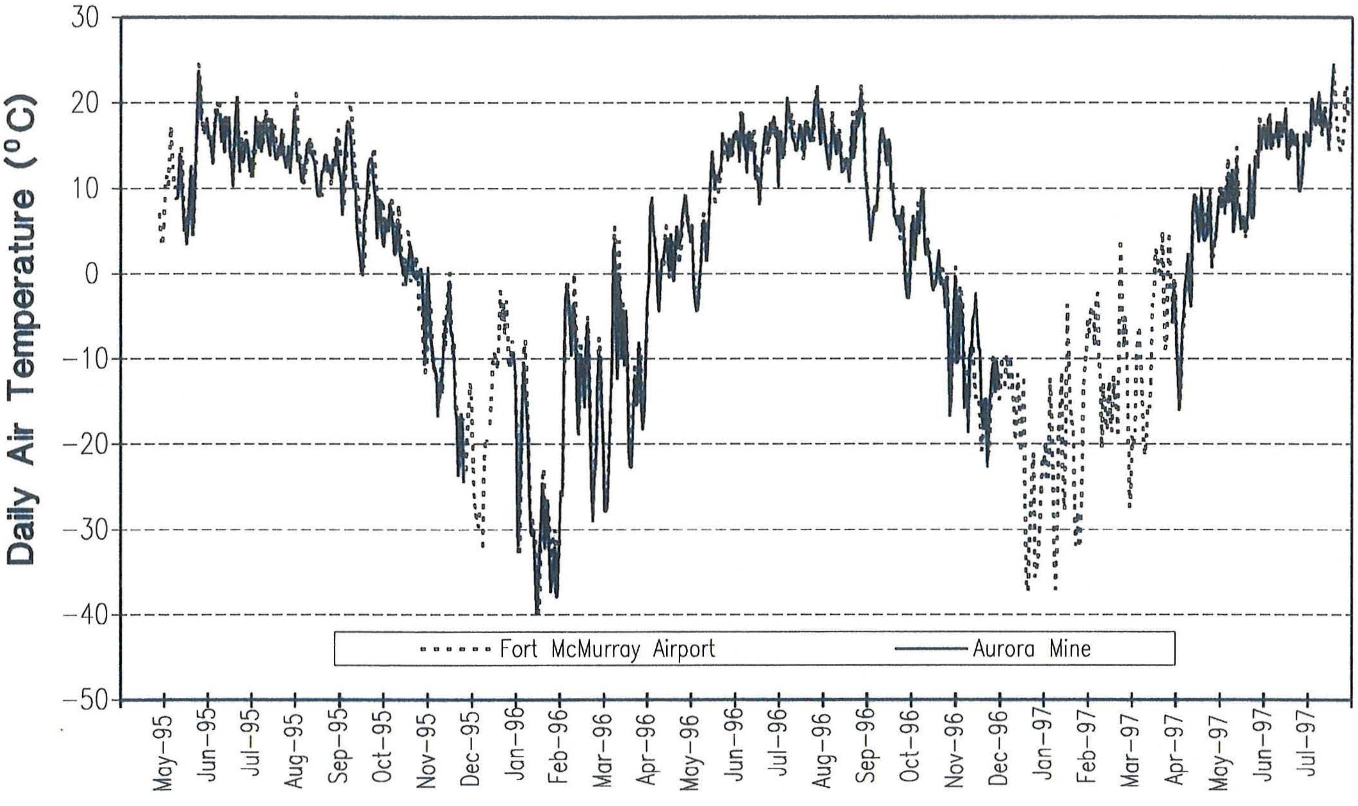
Figure D4-3 shows a comparison between the recorded daily air temperatures at the Fort McMurray airport and Aurora Mine stations for the period May 1995 to July 1997. The similarity of daily temperature variations at these two stations suggests that the long-term temperature statistics at the Fort McMurray airport are representative of the conditions in the LSA. Table D4-1 shows hourly and daily air temperature statistics for the LSA. Table D4-2 shows monthly statistics. These statistics were derived from recorded data at the Fort McMurray airport for the period 1953 to 1995.

Mean monthly air temperatures in the LSA typically range from -20°C in January to 16.5°C in July. The maximum hourly air temperature was 36.5°C recorded in August, and the minimum hourly air temperature was -47.8°C recorded in January. Figure D4-4 shows the temporal distribution of monthly air temperatures for the LSA.

Table D4-1 Derived Hourly and Daily Air Temperature Statistics for the LSA[a]

Month	Hourly Extreme (°C)		Daily Mean and Daily Extreme (°C)		
	Maximum	Minimum	Maximum	Mean	Minimum
January	12.5	-47.8	8.4	-20.0	-41.1
February	13.4	-44.4	9.2	-15.0	-36.9
March	17.8	-43.9	9.2	-7.8	-32.0
April	29.8	-34.4	20.9	2.4	-26.4
May	34.8	-13.3	24.6	9.8	-5.9
June	35.0	-3.9	25.0	14.2	3.6
July	35.6	0.6	26.5	16.5	8.2
August	36.5	-2.9	26.7	15.0	2.5
September	31.9	-13.9	21.4	9.0	-5.0
October	28.4	-24.4	18.3	2.9	-19.9
November	15.5	-37.2	9.4	-8.6	-35.2
December	15.6	-42.7	6.6	-16.5	-39.8

[a] Based on data recorded at the Fort McMurray airport between 1953 and 1996.



NOTE: BASED ON DATA RECORDED BETWEEN MAY, 1995 AND JULY, 1997.

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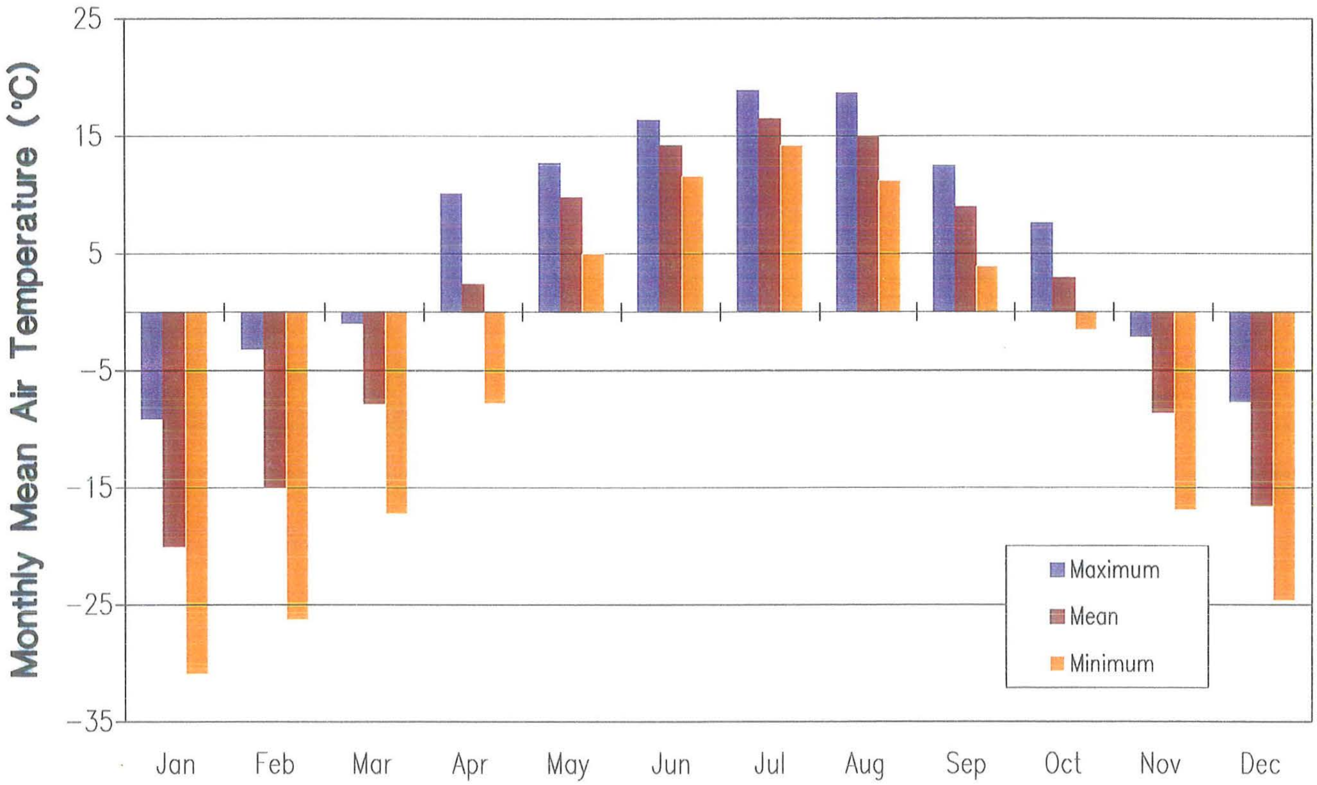
COMPARISON OF DAILY AIR TEMPERATURES RECORDED AT FORT McMURRAY AIRPORT AND AURORA CLIMATE STATION (Period of Record: May 1995 to July 1997)

03 DEC 97	Figure D4-3	DRAWN BY: RFM/TM



NOTE: BASED ON DATA RECORDED AT THE FORT McMURRAY AIRPORT DURING 1953 TO 1996.

Golder Associates

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MONTHLY MEAN AIR TEMPERATURES FOR THE MUSKEG RIVER MINE PROJECT AREA

03 DEC 97	Figure D4-4	DRAWN BY: RFM

Table D4-2 Derived Monthly Air Temperature Statistics for the LSA[(a)]

Month	Monthly Mean and Extreme (°C)		
	Maximum	Mean	Minimum
January	-9.1	-20.0	-30.9
February	-3.2	-15.0	-26.3
March	-1.0	-7.8	-17.2
April	10.1	2.4	-7.8
May	12.7	9.8	5.0
June	16.4	14.2	11.6
July	18.9	16.5	14.2
August	18.7	15.0	11.2
September	12.5	9.0	3.9
October	7.6	2.9	-1.5
November	-2.1	-8.6	-16.9
December	-7.7	-16.5	-24.6

(a) Based on data recorded at the Fort McMurray airport between 1953 and 1996.

Precipitation

Precipitation statistics were derived for the LSA from long-term records at the Fort McMurray airport, which were adjusted for known changes in precipitation with elevation, as determined by a regional analysis. Table D4-3 shows the resulting mean and extreme monthly and annual precipitation estimates for the Project area.

Table D4-3 Derived Monthly and Annual Precipitation Statistics for the LSA[(a)]

Month	Total Precipitation (mm)				
	100 Year Dry	10 Year Dry	Average Year	10 Year Wet	100 Year Wet
January	3.9	7.5	19.4	34.8	56.1
February	1.1	3.7	15.4	31.3	53.6
March	2.3	4.8	16.6	32.9	55.7
April	0.0	4.4	20.2	38.7	64.2
May	1.8	9.5	34.1	65.9	110.1
June	16.6	25.9	62.3	111.1	178.6
July	12.5	33.7	72.6	118.0	179.6
August	17.9	28.1	69.2	111.1	176.6
September	10.9	19.1	47.6	84.6	135.9
October	1.5	7.0	26.5	52.2	87.7
November	0.0	7.4	22.9	41.3	66.6
December	5.7	9.4	21.1	36.1	56.8
Annual	269	319	423	545	712

(a) Mean elevation at the Muskeg River Mine Project site = 290 masl; based on precipitation data recorded at the Fort McMurray airport during 1966 to 1995, with adjustment for lower elevation of Muskeg River Mine Project area.

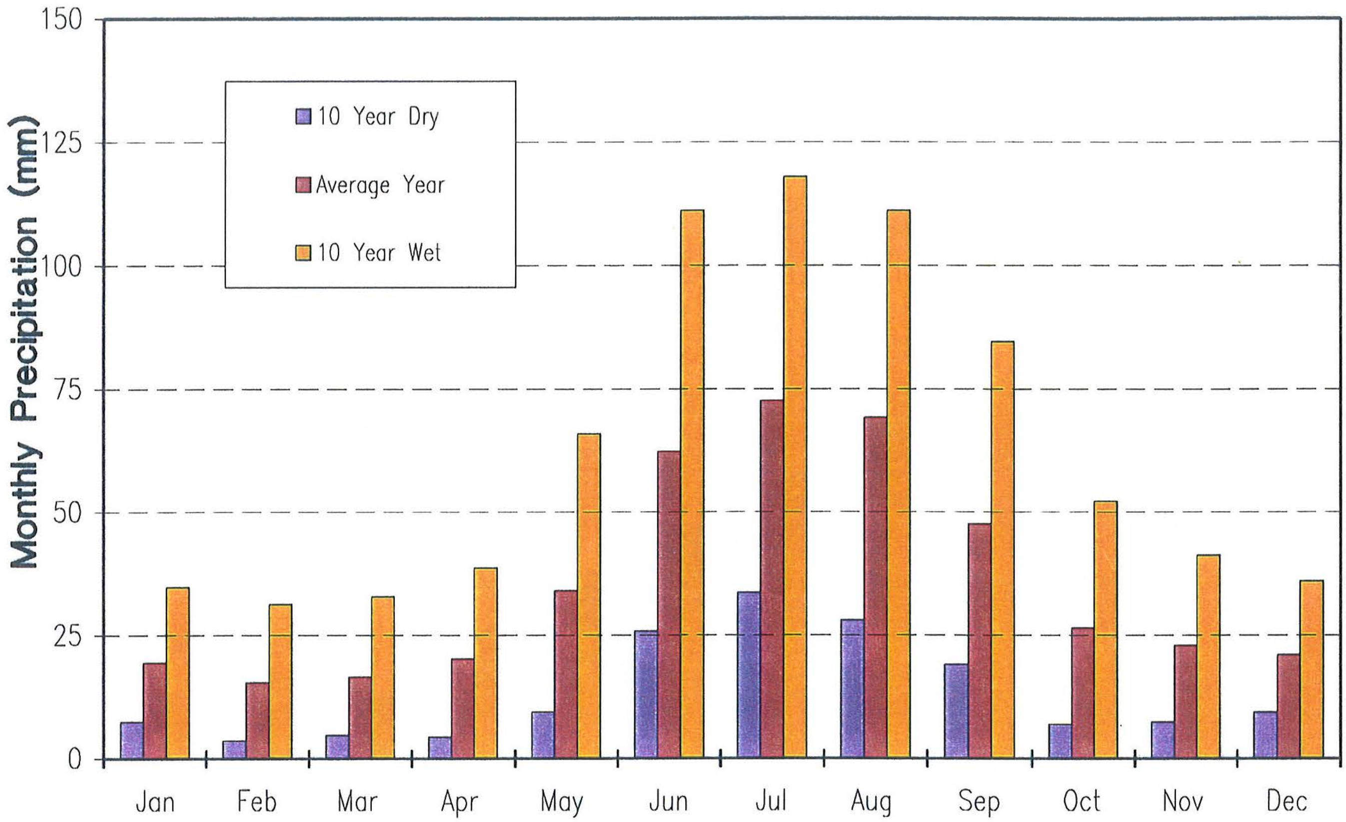
Average annual precipitation in the Project area is estimated to be 423 mm. Approximately 70% (296 mm) of the average annual precipitation occurs as rainfall, with approximately 30% (127 mm) occurring as snowfall. The 10-year wet annual precipitation is estimated to be 319 mm, and the 10-year dry annual precipitation is 319 mm. Figure D4-5 shows the temporal distribution of monthly precipitation derived for the Project area.

Table D4-4 and Figure D4-6 present rainfall Intensity-Duration-Frequency (IDF) curves derived for the Project area. The 24-hour rain with 10-year return period is estimated to be 61.9 mm, and the 24-hour rain with 100-year return period is estimated to be 94.5 mm. These compare with the 24-hour probable maximum precipitation (PMP) of 391 mm derived for the Project area.

Table D4-4 Derived Rainfall Intensity-Duration-Frequency (IDF) Data for the LSA

	Total Rainfall (mm/h)					
Duration	**2 Year**	**5 Year**	**10 Year**	**20 Year**	**50 Year**	**100 Year**
5 minutes	52.8	76.8	92.4	108.0	127.2	141.6
10 minutes	37.8	52.8	63.0	72.6	85.2	94.8
15 minutes	30.0	42.4	50.4	58.4	68.4	86.0
30 minutes	19.4	28.8	35.0	35.0	48.8	54.8
1 hour	11.6	16.5	19.7	19.7	26.8	29.7
2 hours	7.6	10.7	12.8	12.8	17.3	19.2
6 hours	3.9	5.6	6.8	6.8	9.4	10.5
12 hours	2.4	3.6	4.4	4.4	6.1	6.8
24 hours	1.5	2.1	2.6	2.6	3.5	3.9
2 days	0.85	1.2	1.4	1.4	2.0	2.2
5 days	0.40	0.55	0.65	0.65	0.88	0.93
10 days	0.25	0.34	0.40	0.40	0.52	0.58

(a) Mean Elevation at the Muskeg River Mine Project area = 290 m.
(b) Based on recorded precipitation at Fort McMurray airport from 1966 to 1995, adjusted for lower elevations at the Muskeg River Mine Project area.



NOTE: BASED ON DATA RECORDED AT THE FORT McMURRAY AIRPORT DURING 1966 TO 1995.

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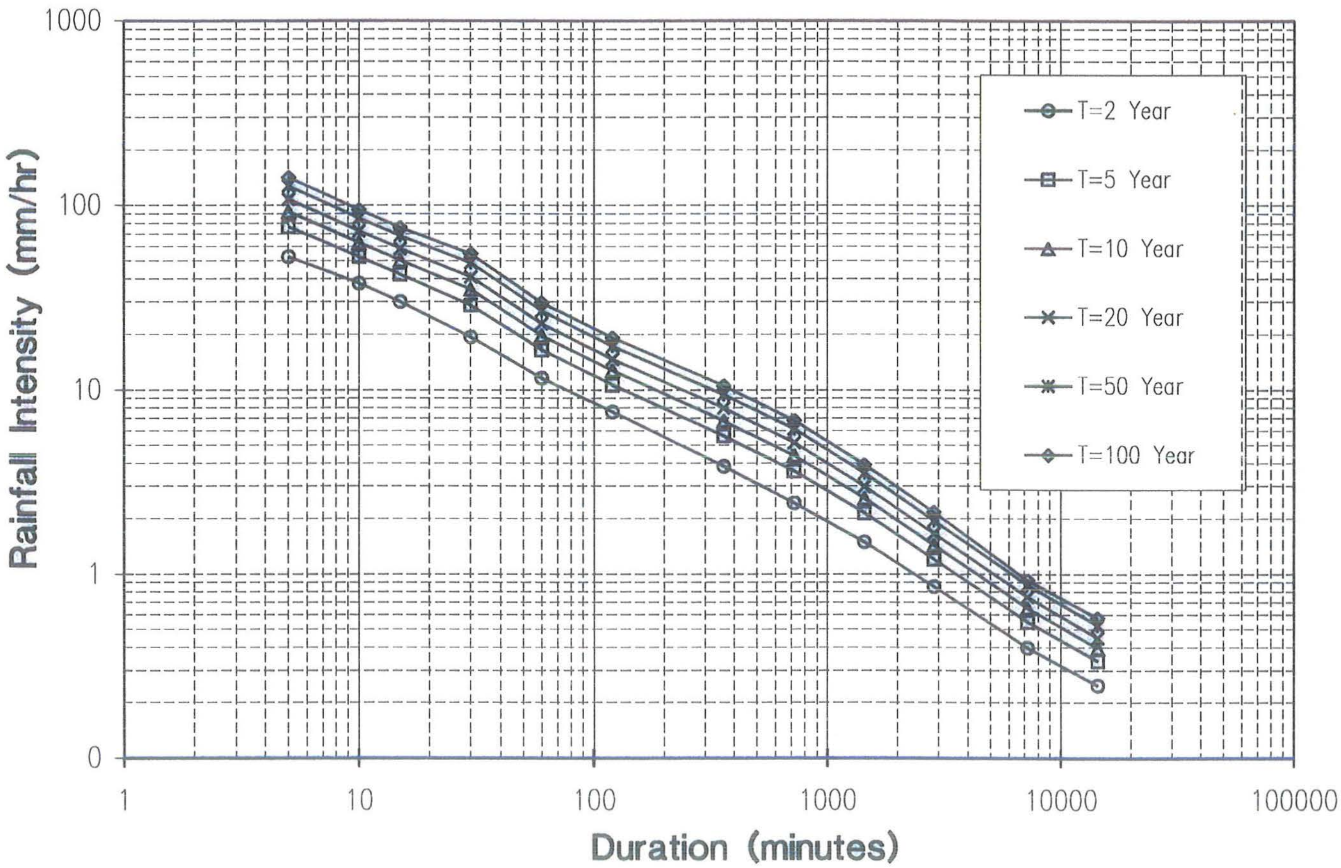
MONTHLY PRECIPITATION DERIVED FOR THE MUSKEG RIVER MINE PROJECT AREA

02 DEC 97	Figure D4-5	DRAWN BY: RFM



NOTES: 1. BASED ON THE DATA RECORDED AT THE FORT McMURRAY AIRPORT DURING 1966 TO 1995.

2. T IS THE RETURN PERIOD FOR A RAINFALL EVENT

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RAINFALL INTENSITY-DURATION-FREQUENCY CURVES DERIVED FOR THE MUSKEG RIVER MINE PROJECT AREA		
01 DEC 97	Figure D4-6	DRAWN BY: RFM

Evaporation and Evapotranspiration

Evaporation is the process by which water is transferred from open water surfaces to the atmosphere. Transpiration is the process by which water is transferred from soil and plant surfaces to the atmosphere. Evapotranspiration is the combined losses of water from the earth's surface to the atmosphere through evaporation and transpiration. Potential evaporation is the evaporation that occurs from a small water surface. Lake evaporation is the evaporation that occurs from a large water surface. Potential evapotranspiration is the evapotranspiration that occurs in a moist environment from a small area. Areal evapotranspiration is the evapotranspiration that occurs from a large area.

Table D4-5 shows evaporation and evapotranspiration statistics including potential evaporation and evapotranspiration for the Muskeg River Mine Project area. These statistics were derived using the CLRE model from Alberta Environmental Protection (AEP), based on climate data recorded at the Fort McMurray Airport for the period 1953 to 1993.

Table D4-5 Derived Evaporation and Evapotranspiration Statistics for the LSA

Month	Evaporation (mm)				Evapotranspiration (mm)	
	Potential	Lake			Potential	Areal
		1 m Depth	2 m Depth	5 m Depth		
January	-3	-3	-4	-3	-3	-3
February	-2	-2	-3	-3	-1	-1
March	14	12	7	0	22	13
April	85	56	45	19	92	31
May	151	101	95	66	153	43
June	163	120	118	105	161	68
July	168	131	131	128	161	81
August	135	105	111	121	125	56
September	76	54	63	85	62	19
October	25	20	26	48	18	11
November	-1	-1	1	20	-3	-1
December	-5	-5	-4	-1	-4	-4
Annual	806	588	588	584	782	512

Note: Negative values denote condensation by which water vapour changes to the liquid or solid state.

Mean annual potential evaporation is estimated to be 806 mm for the Muskeg River Mine Project area. Lake evaporation is estimated to be 588 mm, and is much lower than potential evaporation because blowing air has a cooling effect over a large lake surface area. Most lake evaporation occurs in summer with a peak monthly evaporation of approximately 130 mm occurring in July. The seasonal occurrence of the maximum lake evaporation is a function of lake depth. The greater heat capacity of a deep lake delays seasonal warming and cooling, resulting in higher evaporation rates at later dates.

Mean annual potential evapotranspiration is estimated to be 782 mm, which is almost as great as potential evaporation. Actual areal evapotranspiration averages 312 mm per year, because of the limited water supply in a basin and the cooling effect of moving air. Peak mean monthly evapotranspiration is estimated to be 81 mm, occurring in July.

Figure D4-7 shows the temporal distribution of monthly lake evaporation and areal evapotranspiration derived for the Muskeg River Mine Project area.

There is relatively little variation in lake evaporation and areal evapotranspiration from year to year, as indicated by the results of the frequency analysis in Table D4-6.

Table D4-6 Frequency Analysis of Extreme Annual Evaporation and Evapotranspiration for the Muskeg River Mine Project Area

Return Period (years)	Annual Lake Evaporation (mm)	Annual Areal Evapotranspiration (mm)
2	588	312
5	623	325
10	640	340
20	653	349
50	668	360
100	677	367

Relative Humidity

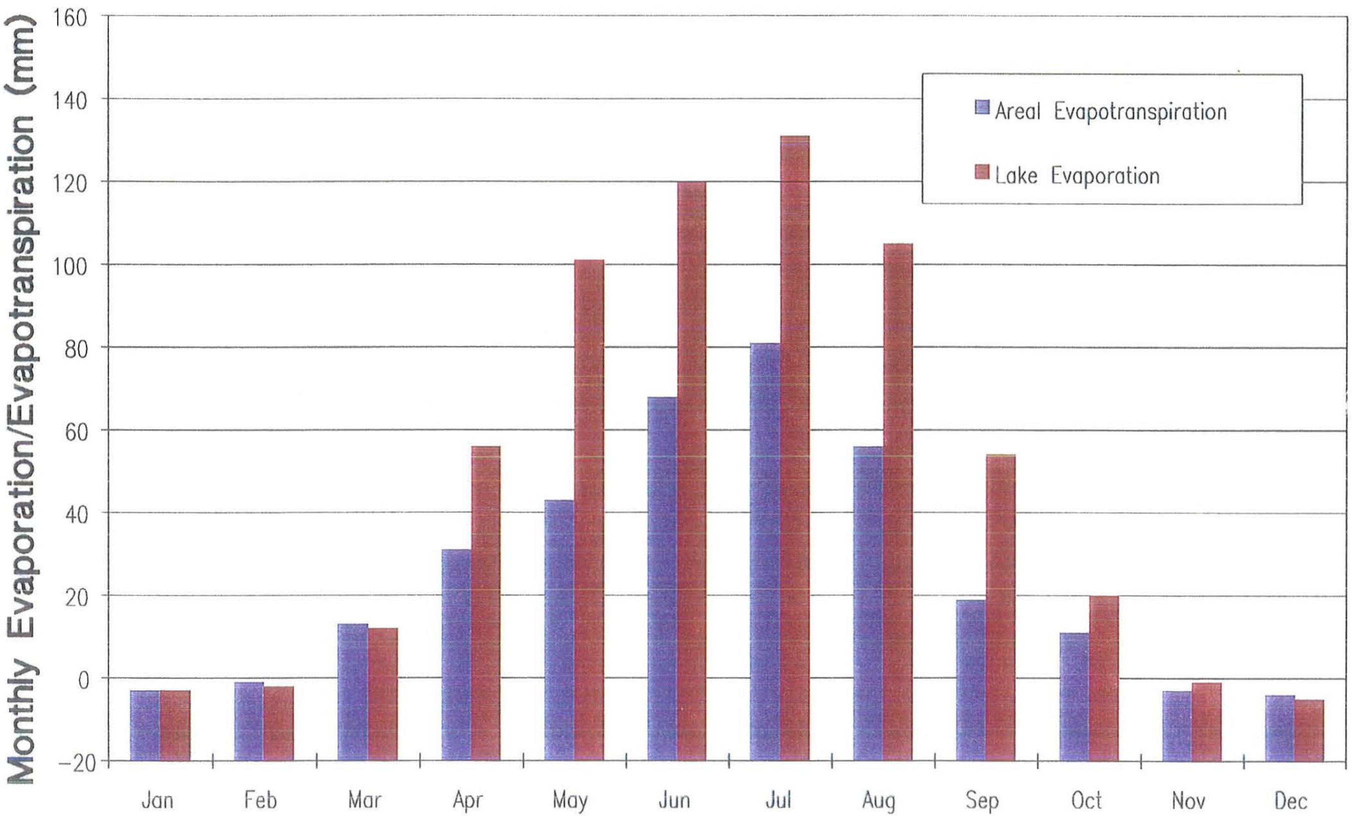
Relative humidity statistics for the Muskeg River Mine Project area were derived from the long-term record at the Fort McMurray airport for the period 1953 to 1995. Table D4-7 presents hourly and daily relative humidity statistics. Table D4-8 and Figure D4-8 present the monthly relative humidity statistics. Mean daily relative humidity is usually in the range of 55 to 80%. Winter months typically have higher relative humidity than summer months.

Table D4-7 Derived Hourly and Daily Relative Humidity Statistics for the LSA

Month	Hourly Humidity (%)		Daily Humidity (%)		
	Maximum	Minimum	Maximum	Mean	Minimum
January	100	64	100	76	39
February	100	57	99	73	34
March	100	42	97	69	33
April	100	28	98	61	27
May	100	23	99	57	25
June	100	29	97	64	31
July	100	32	98	69	32
August	100	40	98	72	37
September	100	37	100	74	41
October	100	41	100	73	41
November	100	63	98	79	40
December	100	71	96	78	30

Table D4-8 Derived Statistics of Monthly Relative Humidity Statistics for the LSA

Month	Monthly Relative Humidity (%)		
	Maximum	Mean	Minimum
January	95	76	65
February	88	73	60
March	78	69	52
April	73	61	46
May	68	57	47
June	76	64	52
July	76	69	62
August	82	72	62
September	84	74	66
October	82	73	65
November	88	79	70
December	86	78	66



NOTE: BASED ON DATA RECORDED AT THE FORT McMURRAY AIRPORT DURING 1953 TO 1995.

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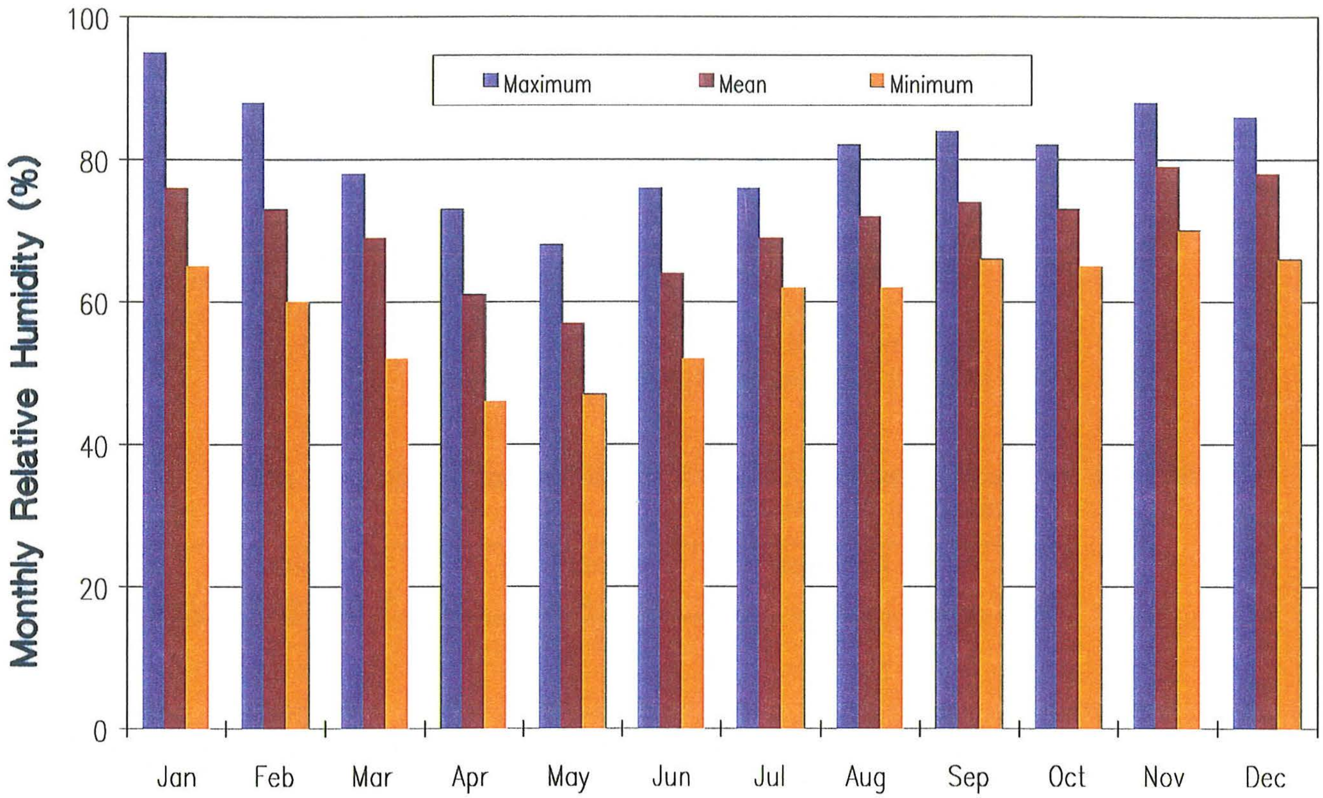
MEAN MONTHLY LAKE EVAPORATION AND AREAL EVAPOTRANSPIRATION DERIVED FOR THE MUSKEG RIVER MINE PROJECT AREA

01 DEC 97	Figure D4-7	DRAWN BY: RFM



NOTE: BASED ON THE DATA COLLECTED AT THE FORT McMURRAY AIRPORT DURING THE PERIOD 1953 TO 1997.

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MONTHLY RELATIVE HUMIDITY DERIVED FOR THE MUSKEG RIVER MINE PROJECT AREA

03 DEC 97	Figure D4-8	DRAWN BY: RFM

Wind

The wind statistics for the LSA are presented in Section D2-4. These statistics were derived from the short-term wind data available at the OSLO (March 1988 to December 1989) and Mannix (November 1993 to June 1995) stations. These data are enhanced with other regional data collected over longer periods or from areas closer to the Project LSA.

The recorded wind data at the Fort McMurray airport, Mildred Lake and Aurora climate stations were compared for the same period of record, since May 1995. The comparison showed that Fort McMurray and Mildred Lake had similar wind statistics. However, the Aurora Mine climate station wind data exhibited differences from the other two climate stations, possibly due to the influence of tall forest surrounding the Aurora Station.

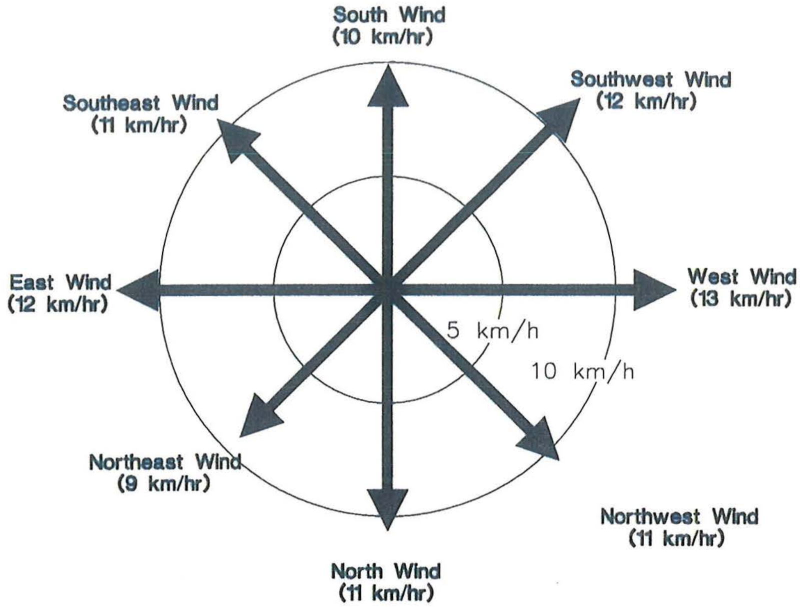
To illustrate the regional variation of wind statistics, Table D4-9 and Figure D4-9 present mean wind speed statistics and probability of occurrence based on the long-term records (1959 to 1996) at the Fort McMurray airport. Table D4-10 and Figure D4-10 present the frequency analysis and wind rose plot of the extreme hourly wind speeds.

Table D4-9 Mean Wind Speeds and Probabilities of Occurrence at Fort McMurray Airport [a]

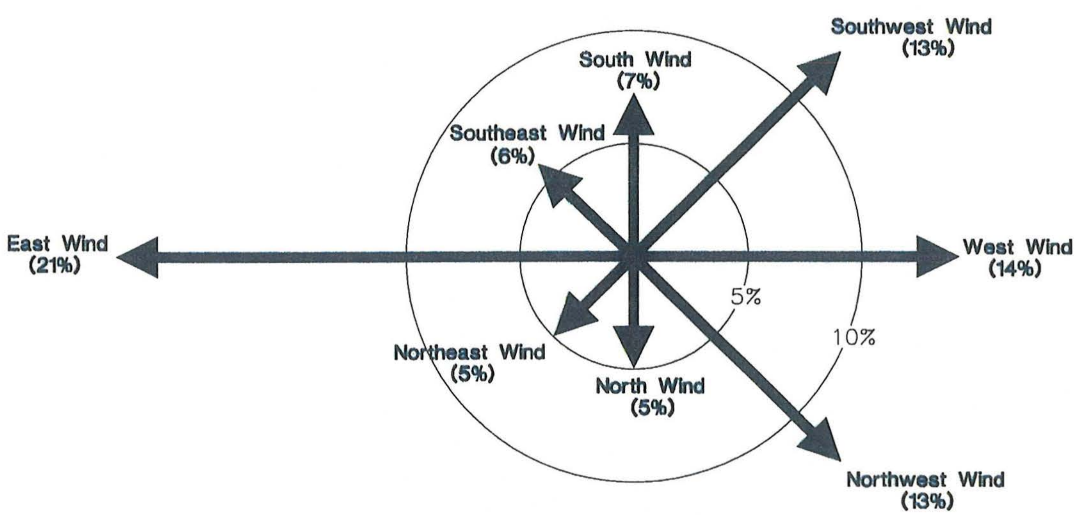
Wind Direction	Mean Speed (km/h)	Probability of Occurrence (%)
N	11	5.4
NE	9	4.9
E	12	20.9
SE	11	6.2
S	10	6.7
SW	12	12.8
W	13	14.1
NW	11	12.8
CALM	0	16.2
ALL	9.6	100

[a] Based on data recorded at the Fort McMurray Airport between 1959 and 1996.

(a) MEAN WIND SPEED (JANUARY TO DECEMBER)



(b) FREQUENCY OF OCCURRENCE (JANUARY TO DECEMBER)



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WIND CHARACTERISTICS RECORDED AT THE FORT McMURRAY AIRPORT

03 DEC 1997	Figure D4-9	DRAWN BY: BGM

NOTES:
1. BASED ON DATA RECORDED AT FORT McMURRAY AIRPORT FROM 1959 TO 1996.
2. FREQUENCY OF CALM CONDITIONS IS 16%.

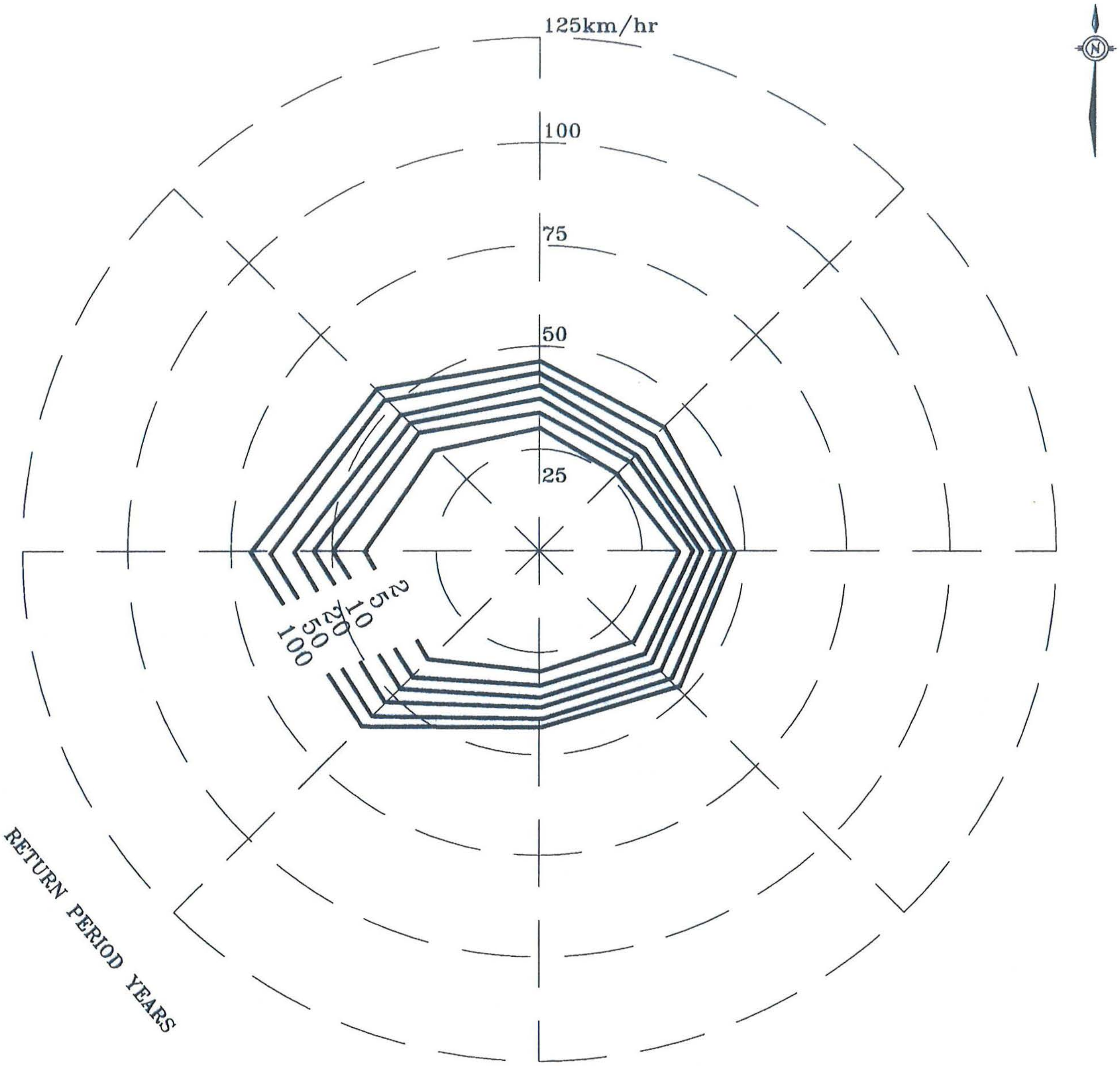
Table D4-10 Frequency Analysis of Extreme Hourly Wind Speeds at Fort McMurray Airport [a]

Wind Direction	Extreme Hourly Wind Speeds for Various Return Periods (km/hr)		
	2 Year	10 Year	100 Year
N	30	37	47
NE	26	33	42
E	33	40	47
SE	32	39	47
S	29	36	44
SW	37	48	61
W	43	55	70
NW	36	44	56

[a] Based on data recorded at the Fort McMurray airport between 1959 and 1996.

The dominant wind at Fort McMurray Airport is an easterly wind with the highest probability of occurrence (21%). This compares with the dominant wind directions in the LSA from south to southeast or north to northeast based on data from OSLO and Mannix stations (Figure D2-2), due to the effects of the Athabasca River valley and local landforms.

The mean wind speed at Fort McMurray Airport is about 9.6 km/h. This compares with the mean wind speeds of 6.1 km/h at OSLO (Table D2-4) because of the effect of the local forest canopy. The westerly wind at Fort McMurray Airport typically has the highest speed with a mean value of about 13 km/h, and the 100-year return period of extreme hourly wind speed is about 70 km/h also from the west.



NOTES: 1. BASED ON DATA AT THE FORT McMURRAY AIRPORT FROM 1959 TO 1996.
2. DO NOT INTERPOLATE BETWEEN MAIN DIRECTIONS.

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WIND ROSE PLOT FOR THE FORT McMURRAY AIRPORT (JANUARY - DECEMBER)

02 DEC 97	Figure D4-10	DRAWN BY:	RFM

D4.3 Surface Water Hydrology

D4.3.1 Data Sources

Regional Monitoring

There are more than 30 streamflow monitoring stations in the region. However, most of these stations have short-term or discontinuous periods of record and are therefore of little value in defining the regional hydrologic characteristics. Long-term data from 10 streamflow monitoring stations operated by Water Survey of Canada (WSC) were used in defining the regional hydrology. Of these 10 stations, the Muskeg River and Jackpine (formerly Hartley) Creek stations have recorded streamflow data within the LSA. Figure D4-11 shows these long-term regional hydrologic monitoring stations. Some of these stations also record sediment data.

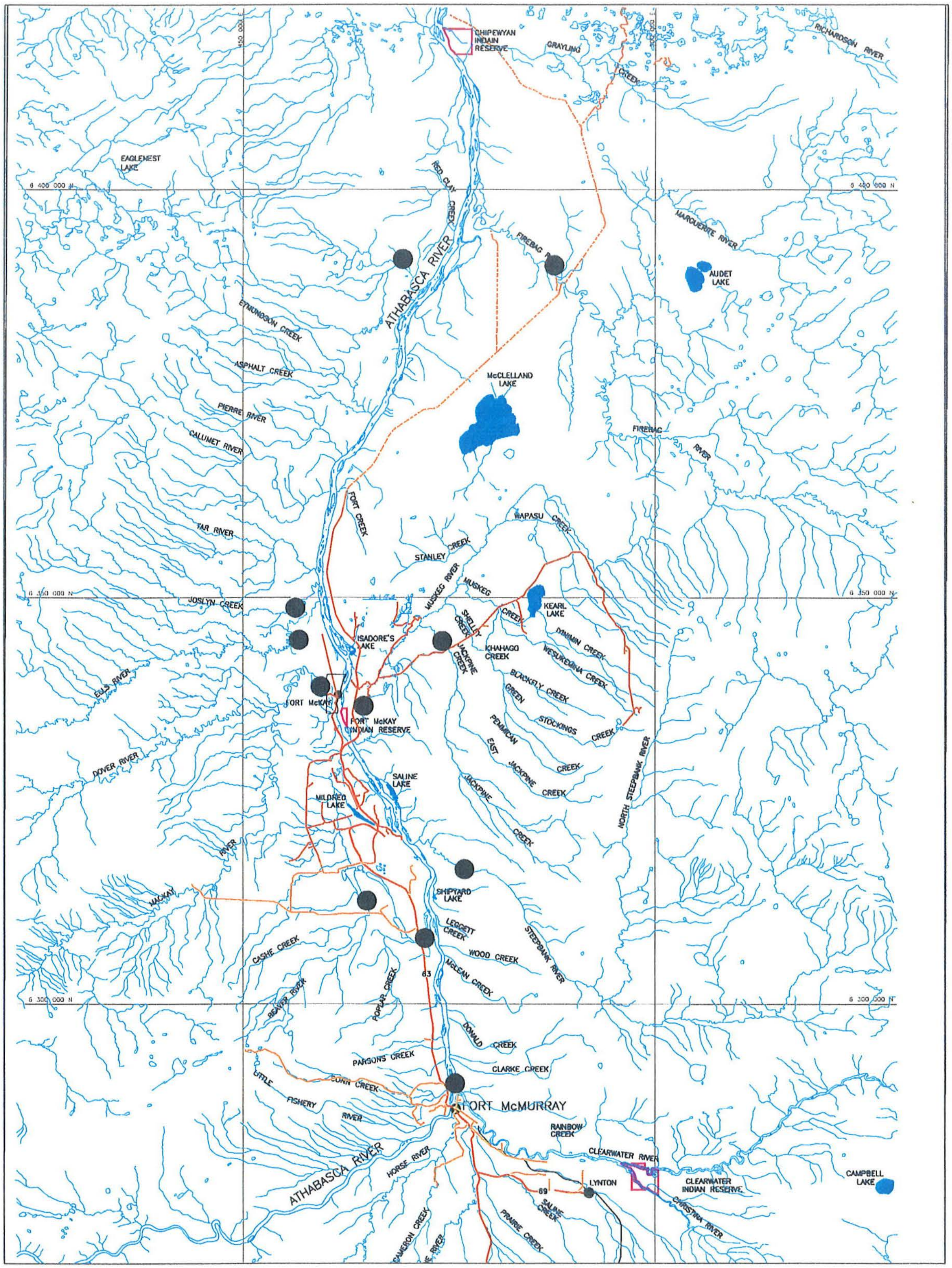
Local Monitoring

Syncrude installed five hydrologic (streamflow and sediment) monitoring stations for the Aurora Mine in the spring of 1995 (S1, S2, S3, S4 and S5 in Figure D4-12). Shell recognized the need for additional site-specific, hydrologic data for the Muskeg River Mine Project area. One additional hydrologic monitoring station was established on Mills Creek to monitor inflows to Isadore's Lake (S6 in Figure D4-12). A temporary weir was installed at the station in the spring of 1997, and a permanent flow measurement structure is planned for late fall 1997 or early spring 1998.

Figure D4-12 shows the locations of the LSA hydrologic monitoring stations. Local, short-term monitoring stations include:

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

Syncrude and Shell jointly conducted the hydrologic and climatic monitoring during the 1997 data collection program in the LSA and plan to continue this cooperative program.



LEGEND

● WSC HYDROLOGIC MONITORING STATION

REFERENCE

MONITORING STATION LOCATIONS PROVIDED BY AGRA EARTH AND ENVIRONMENTAL LIMITED FIGURE No. 3 (JULY 1995).

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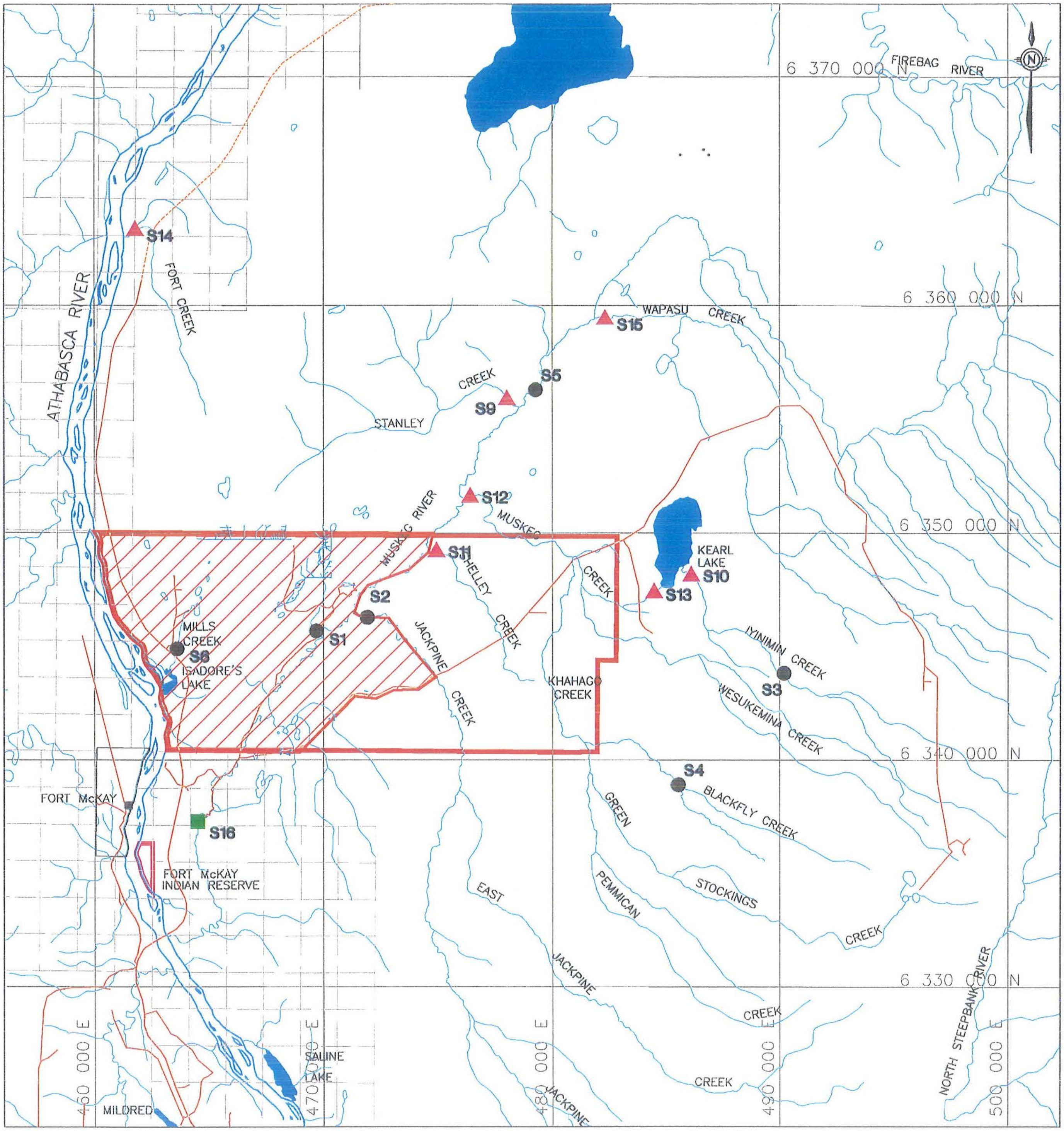
LOCATIONS OF REGIONAL WSC HYDROLOGIC MONITORING STATIONS

02 DEC 97	Figure D4–11	DRAWN BY: BGM/DC



LEGEND

- ● LOCAL, SHORT-TERM HYDROLOGIC MONITORING STATION
- ▲ IMPACT ANALYSIS NODES
- ■ WSC HYDROLOGIC MONITORING STATION
- MUSKEG RIVER MINE PROJECT
- LEASE 13

0 2.5 5 7.5 10 12.5 km

SCALE 1:250,000

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LOCATIONS OF HYDROLOGIC MONITORING STATIONS IN THE LOCAL STUDY AREA

02 DEC 1997	Figure D4-12	DRAWN BY: BGM

D4.3.2 Regional Analysis and Hydrologic Modelling

The hydrologic characteristics of the large basins in the RSA were determined based on a regional analysis of the 10 gauged watersheds with drainage areas ranging from 151 km^2 (Poplar Creek) to 5,990 km^2 (Firebag River). The hydrologic characteristics of the Athabasca River were defined based on the records at the WSC gauging station on the Athabasca River below Fort McMurray.

Data collection at the streamflow monitoring stations in the LSA began in May 1995. These data are valuable for calibrating hydrologic models. However, the data are insufficient for defining reliable statistics without extension of the database by modelling. The continuous (dynamic) Hydrologic Simulation Program Fortran (HSPF) model developed by the US Environmental Protection Agency (USEPA) was previously calibrated based on the Beaver River Basin (AGRA 1996a). During the current baseline study, the HSPF model was also calibrated based on long-term data recorded at the Muskeg River Basin and short-term data collected at the local S1 to S6 stations (Figure D4-12). The calibrated model was used to derive the streamflow statistics for the small basins in the LSA.

D4.3.3 Streamflow Characteristics of the Athabasca River

The drainage area of the Athabasca River in the RSA increases by about 17% from immediately downstream of its confluence with the Clearwater River near Fort McMurray to the downstream boundary near Embarras. The mean annual flow of the Athabasca River below the Clearwater River confluence is about 640 m^3/s. Daily low flows occur in winter, with the 10-year return period daily low flow is about 107 m^3/s at this location.

Streamflow characteristics of the Athabasca River along the study reach in the RSA were derived from the WSC gauging station located downstream of its confluence with the Clearwater River and the WSC gauging station at the Embarras airport, which is located at the very northern edge of the RSA, as shown in Figure D1-2. Table D4-11 and Figures D4-13 and D4-14 present the temporal distribution of monthly flows recorded at the WSC stations below Fort McMurray and at the Embarras airport. Monthly river flow typically peaks in July and reaches the lowest flow in February. Table D4-12 presents the mean and flood flow statistics for four locations in the RSA. Table D4-13 presents the low flow statistics for the four locations.

Table D4-11 Athabasca River Monthly Flows Recorded at the WSC Stations Below Fort McMurray and at the Embarras Airport [a]

Month	Monthly Discharge (m^3/s)					
	WSC Station below Fort McMurray			WSC Station at Embarras Airport		
	Maximum	Mean	Minimum	Maximum	Mean	Minimum
January	242	179	101	269	224	143
February	213	163	105	240	198	134
March	271	171	107	220	208	181
April	1030	510	213	1050	627	436
May	2080	1060	487	1970	1190	626
June	2050	1330	671	2060	1500	823
July	2740	1410	731	2790	1660	948
August	1740	991	557	1360	1130	845
September	1510	766	435	1760	943	530
October	864	570	329	1210	711	376
November	490	333	211	590	482	325
December	293	203	107	322	250	197

[a] Periods of Record: 1957-1995 below Fort McMurray and 1971-1984 at the Embarras Airport.

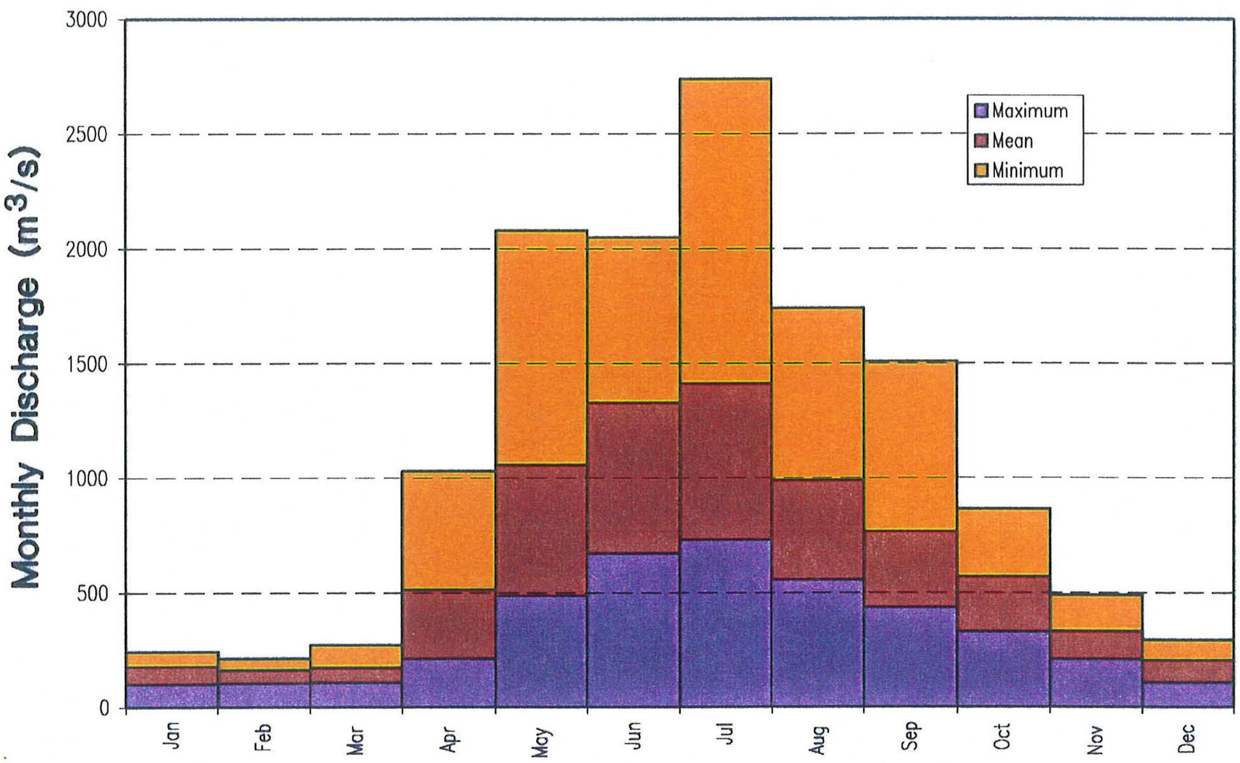
Table D4-12 Mean and Flood Flow Statistics of the Athabasca River in the RSA

Location along Athabasca River	Drainage Area	Mean Annual Discharge	Annual Flood Peak Discharge for Specified Return Period (m^3/s)		
	(km^2)	(m^3/s)	2 Years	10 Years	100 Years
Below Fort McMurray[a]	133,000	640	2450	3900	5950
Below Confluence with Muskeg River[b]	135,200	650	2489	3962	6045
Below Confluence with MacKay River[b]	141,600	681	2608	4152	6334
Near the Embarras Airport[c]	155,000	745	2854	4543	6931

[a] Discharges estimated based on statistical analysis of WSC gauging station.

[b] Mean and annual flood peak discharges are estimated based on the ratios of drainage areas.

[c] Mean and annual flood peak discharges are estimated based on the ratios of drainage areas. The records of concurrent period at the WSC stations (below Fort McMurray and at the Embarras Airport) were compared to verify the discharge estimates based on the area ratio.



NOTE: BASED ON THE WSC DATA COLLECTED FOR THE ATHABASCA RIVER BELOW FORT McMURRAY DURING 1957 TO 1995.

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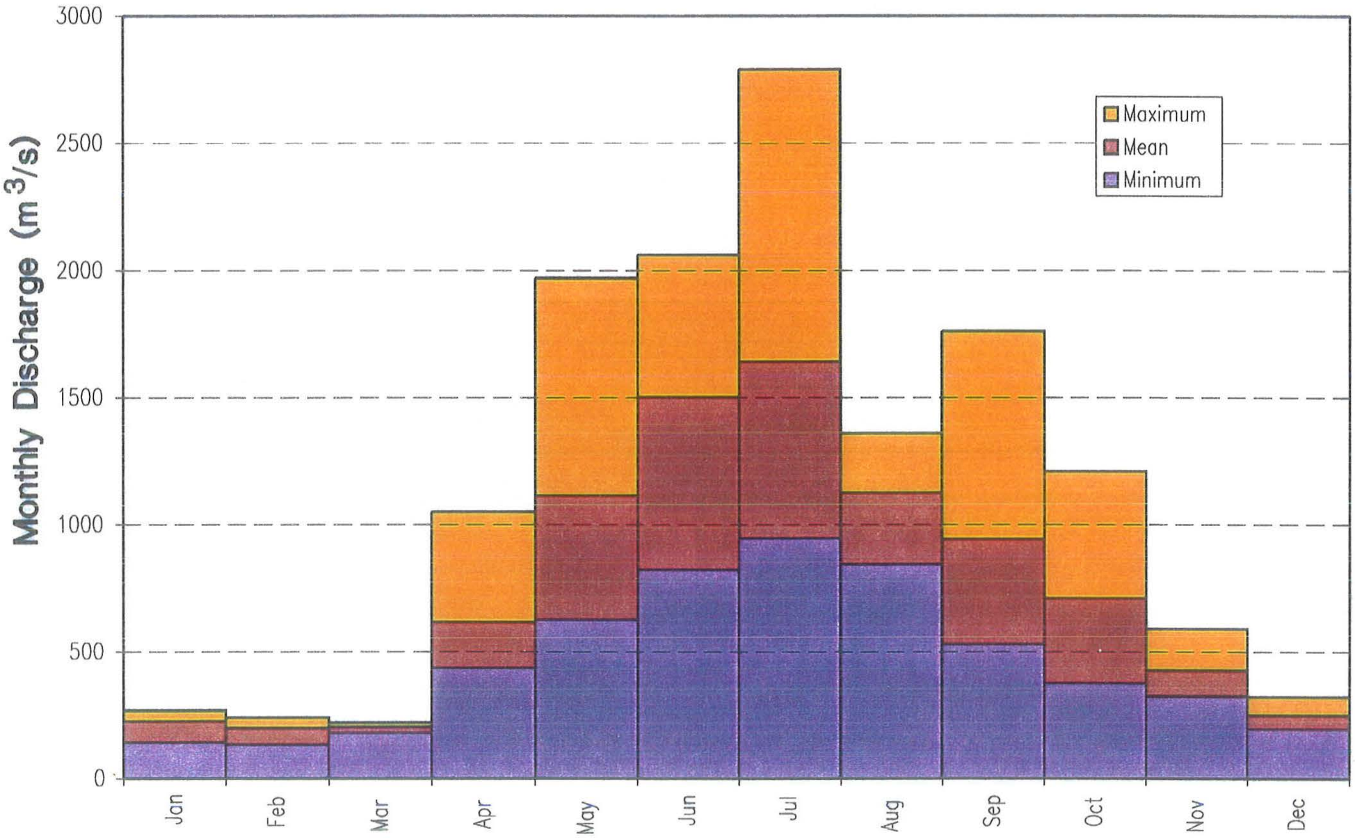
MEAN MONTHLY FLOWS - ATHABASCA RIVER BELOW FORT McMURRAY

02 DEC 97	Figure D4-13	DRAWN BY: RFM



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MEAN MONTHLY FLOWS - ATHABASCA RIVER AT THE EMBARRAS AIRPORT

NOTE: BASED ON THE WSC DATA COLLECTED FOR THE ATHABASCA RIVER AT THE EMBARRAS AIRPORT DURING 1971 TO 1984.

01 DEC 97	Figure D4-14	DRAWN BY: RFM

Table D4-13 Low Flow Statistics of the Athabasca River in the RSA

Low Flow Parameter			Locations Along the Athabasca River: Below Fort McMurray	Below Confluence with Muskeg River[a]	Below Confluence with MacKay River[a]	At the Embarras Airport[a]
Daily Low Flow (m^3/s)	Open-Water Season (mid April to mid November)	2 Years	451	458	480	526
		10 Years	300	305	319	350
		100 Years	181	184	193	211
	Ice-Cover Season (mid November to mid April)	2 Years	143	145	152	167
		10 Years	107	109	114	125
		100 Years	75	76	80	88
7-Day Low Flow (m^3/s)	Open-Water Season (mid April to mid November)	2 Years	453	460	482	528
		10 Years	306	311	326	357
		100 Years	203	206	216	237
	Ice-Cover Season (mid November to mid April)	2 Years	147	149	157	171
		10 Years	111	113	118	129
		100 Years	77	78	82	90

[a] Low flow statistics are estimated from the ratios of drainage areas.

D4.3.4 Streamflow Characteristics of Large Gauged Basins in the RSA

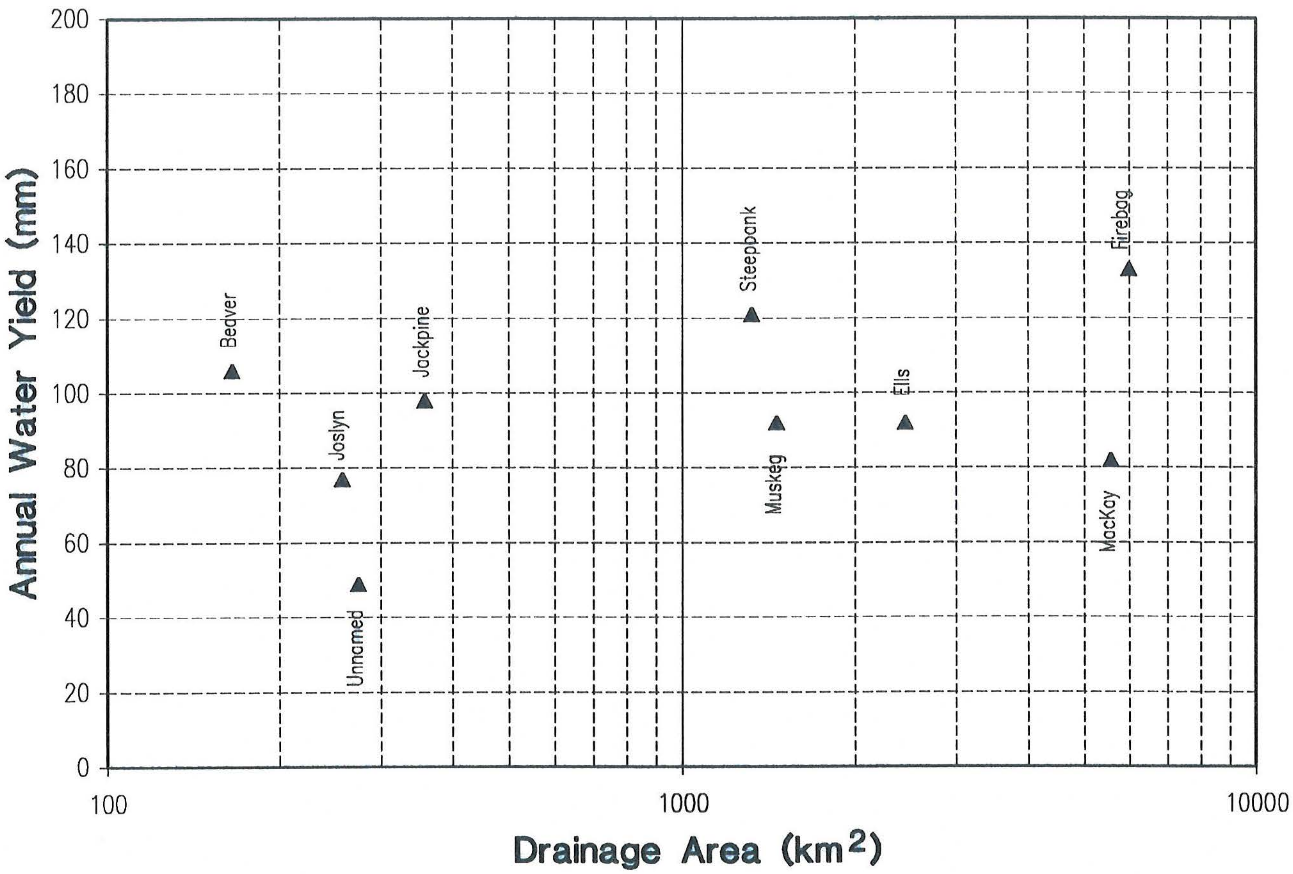
Annual Water Yield

Analysis of annual water yields of large gauged basins in the RSA show no distinct correlation between annual water yield and basin area. The results of the analysis of annual water yields at 10 major gauged basins are given in Table D4-14 and Figure D4-15. Other basin characteristics, such as slope and elevation, affect water yield. Mean annual water yields of the large gauged basins in the RSA range from 49 to 133 mm. The Muskeg River basin has a large percentage of lowland area (about 45%), and its mean annual water yield is 86 mm. Figure D4-16 shows the temporal distribution of recorded monthly flows at the WSC station for the Muskeg River. The highest monthly flow on the Muskeg River occurs in May and the lowest in February.

Table D4-14 Regional Mean Annual Water Yield for Large Gauged Basins

Gauged River Basin Name	Drainage Area (km^2)	Annual Water Yield (mm)	Period of Record
Poplar Creek	151	200[a]	1972-1986
Beaver River	165	106	1975-1995
Joslyn Creek	257	77	1975-1993
Unnamed Creek	274	49	1975-1993
Jackpine Creek	358	98	1975-1993
Steepbank River	1320	121	1972-1995
Muskeg River	1460	86	1974-1995
Ells Creek	2450	92	1975-1986
MacKay River	5570	82	1972-1995
Firebag River	5990	133	1971-1995

(a) Recorded flow at Poplar Creek included diverted flow from the Beaver River basin. Therefore, this value does not represent the natural Poplar Creek basin water yield.



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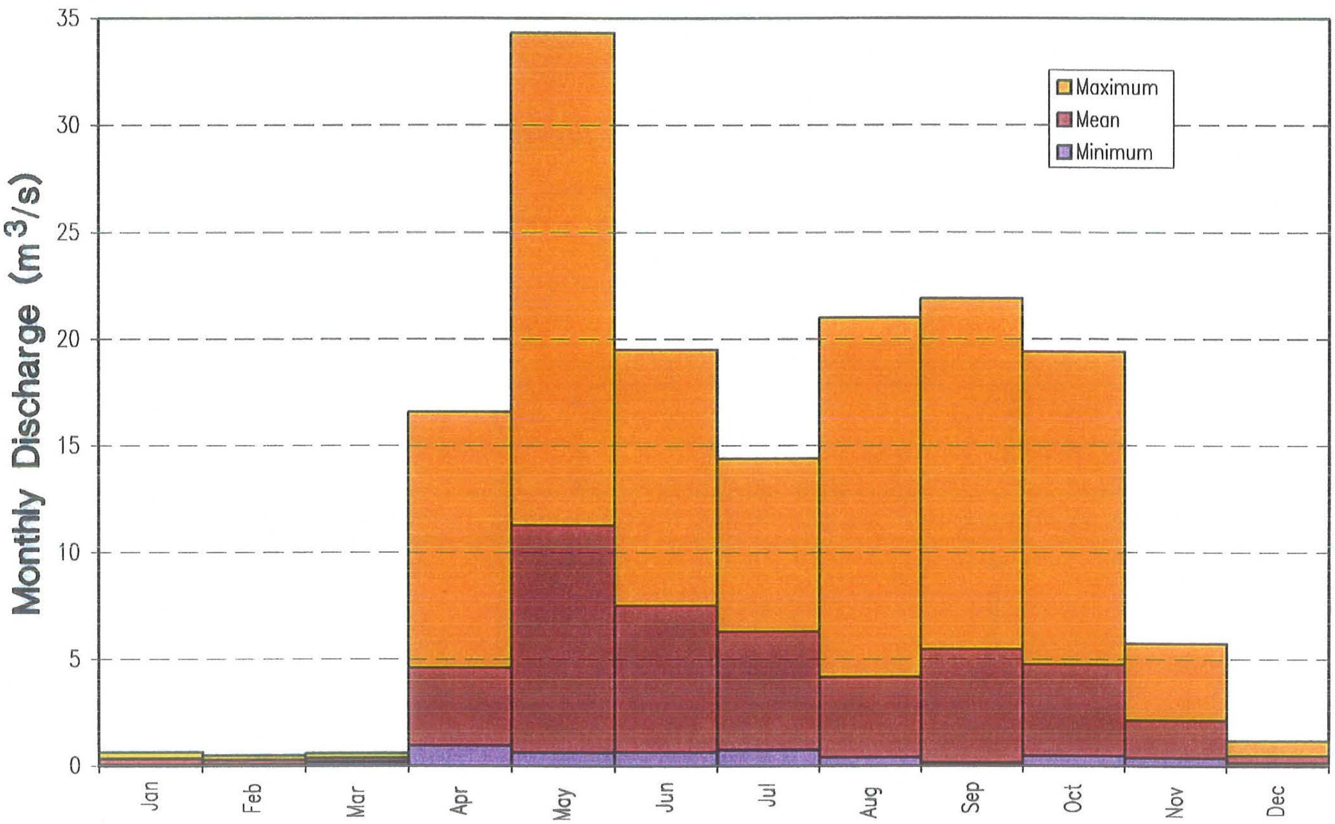
MEAN ANNUAL WATER YIELD FOR LARGE REGIONAL GAUGED BASINS

01 DEC 97	Figure D4-15	DRAWN BY: RFM



NOTE: BASED ON THE WSC DATA COLLECTED FOR THE MUSKEG RIVER NEAR FORT McKAY DURING 1974 TO 1995.

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MEAN MONTHLY FLOWS
MUSKEG RIVER NEAR FORT McKAY

01 DEC 97	Figure D4-16	DRAWN BY: RFM

Flood Peak Discharge

Frequency analyses of flood peak discharge on gauged basins are presented in Table D4-15. Flood peak discharge was recorded at the WSC stations. Rainfall runoff events produce higher peak flow than the snowmelt runoff events for most of the gauged basins. Snowmelt events in the Muskeg River basin typically produce higher peak flow than the rainfall events, because of the relatively large percentage of lowland area and relatively high storage capacity in the Muskeg River basin.

Table D4-15 Flood Peak Discharge of Large Gauged Basins by WSC

Gauged River Basin Name	Drainage Area (km^2)	Flood Peak Discharge for Various Return Periods (m^3/s)					
		Snowmelt Runoff			Rainfall Runoff[(a)]		
		2 Years	10 Years	100 Years	2 Years	10 Years	100 Years
Poplar Creek	151	4.26	14.1	29.3	5.75	15.9	28.6
Beaver River	165	3.13	7.45	13.9	10.1	28.3	51.0
Joslyn Creek	257	7.97	16.1	28.5	6.13	18.2	77.5
Unnamed Creek	274	3.07	6.49	10.8	3.74	12.3	33.3
Jackpine Creek	358	3.49	10.6	21.1	5.43	13.9	24.5
Steepbank River	1320	25.7	71.0	128	21.7	56.6	120
Muskeg River	1460	17.7	53.8	91.5	16.6	34.2	56.2
Ells River	2450	29.7	68.8	118	32.2	150	324
MacKay River	5570	72.7	292	638	74.5	203	427
Firebag River	5990	86.8	158	264	66.1	127	370

[(a)] Note: Adds 0.015 $m^3/s/km^2$ to rainfall flood peak discharge to account for rain-on-snow conditions.

Low Flow

Daily low flow of the large gauged streams occurs in winter. Summer daily low flow is usually one to two orders of magnitude higher than the winter daily low flow. Low flow statistics of the large gauged basins are shown in Table D4-16. Data are provided in litres/second because of very low numbers for smaller streams.

Table D4-16 Low Flow Frequency Analyses for Large Gauged Basins

Gauged River Basin	Daily Low Flow (L/s)						Monthly Low Flow (L/s)					
	Spring/Summer Season (May - Sep)			Fall/Winter Season (Oct - Apr)			Spring/Summer Season (May - Sep)			Fall/Winter Season (Oct - Apr)		
Name	2 Yr	10 Yr	100 Yr	2 Yr	10 Yr	100 Yr	2 Yr	10 Yr	100 Yr	2 Yr	10 Yr	100 Yr
Beaver River	124	17.6	0.0	6.7	0.16	0.0	204	52.0	0.0	12.1	0.55	0.0
Joslyn Creek	52.5	2.9	0.0	2.5	0.00	0.0	149	9.5	0.0	6.6	2.14	0.0
Unnamed Creek	67.3	6.7	0.0	n/a[(a)]	n/a[(a)]	n/a[(a)]	170	67.5	55.5	n/a[(a)]	n/a[(a)]	n/a[(a)]
Jackpine Creek	152	9.6	0.0	3.26	0.0	0.0	261	16.8	0.0	4.00	0.000	0.0
Steepbank River	1270	117	0.0	242	74.2	0.0	2310	358	56.1	310	151	50.8
Muskeg River	666	142	61.4	182	68.8	20.2	1190	268	99.4	235	109	44.2
Ells River	2790	609	81.7	689	180	0.000	3560	940	505	798	242	0.0
MacKay River	2120	232	0.0	234	75.3	0.000	4180	480	0.0	328	136	19.5
Firebag River	14,700	9590	7500	7340	5490	3590	18,900	10,900	7630	8130	6330	4990
Athabasca River	521,000	383,000	335,000	139,000	103,000	76,900	697,000	500,000	409,000	158,000	118,000	87,200

(a) Seasonal monitoring; limited winter discharge records are available.

D4.3.5 Streamflow Characteristics of Small Basins in the LSA

Streamflow Derivation

The small gauged basins in the LSA have short periods of record (less than two years), except for Station S2 on Jackpine Creek, which has a longer period of record from WSC. The locations of these stations (S1 to S6) are shown in Figure D4-12. Other reference locations (nodes) shown in Figure D4-12 (S9 to S15) are not gauged. The streamflow characteristics of these small streams (S1, S3 to S6, and S9 to S15) were based on hydrologic simulations. Streamflow characteristics of Jackpine Creek (Station S2) were derived from the recorded data at the long-term WSC station.

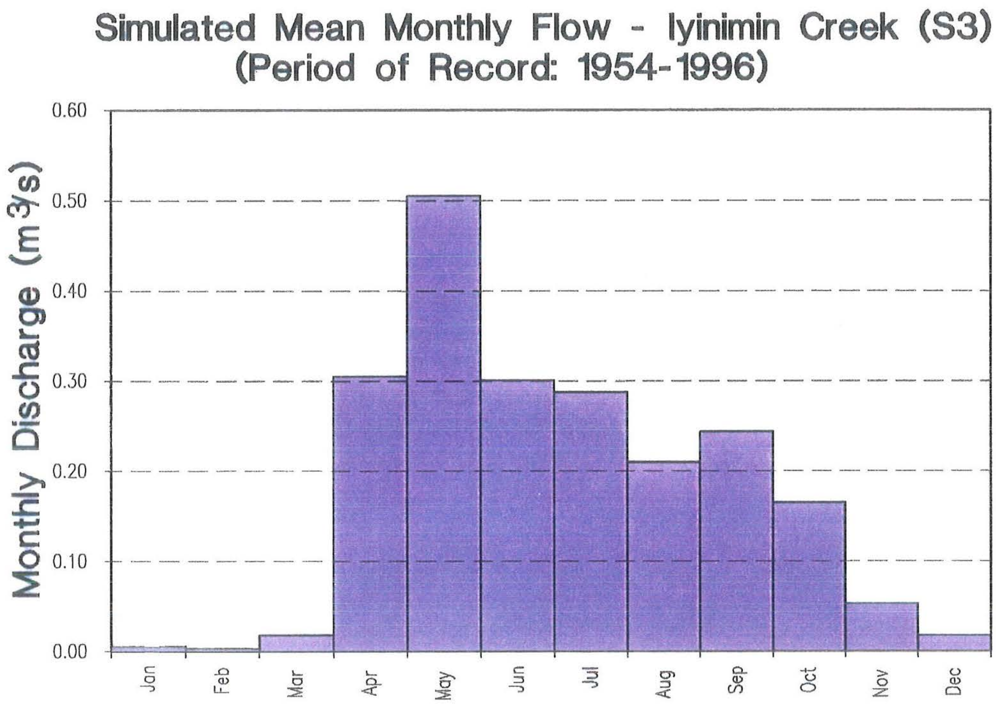
Annual Water Yield

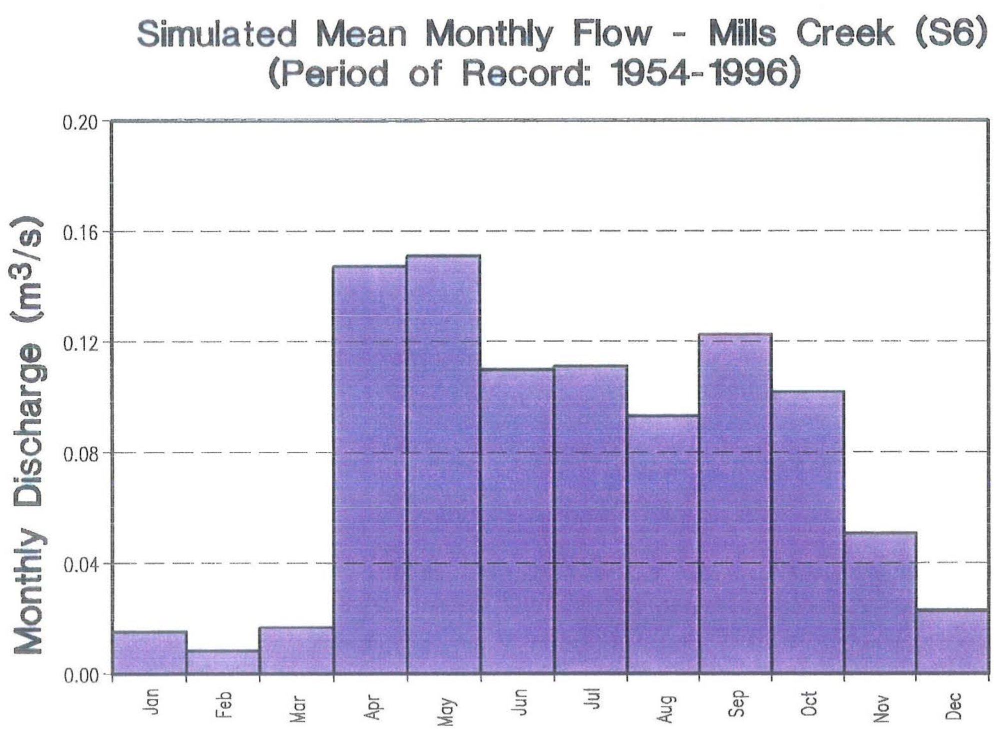
Percentage of upland and lowland areas is an important factor affecting the annual water yield of a small basin. The simulated mean annual discharge of the small streams in the LSA are presented in Table D4-17. Figure D4-17 shows the temporal distribution of the simulated monthly flows for the Stations S3 and S6. Station S3 is located on Iyinimin Creek, which is a typical small upland basin. Station S6 is located on Mills Creek, which is a typical lowland basin.

Table D4-17 Simulated Mean Annual Discharge of Small Streams in the LSA (period of record: 1954 to 1996)

Station or Node No.	Stream Name	Basin Area (km^2)			Mean Annual Discharge	
		Upland	Lowland	Total	(m^3/s)	mm/yr
S1	Alsands Drain	0.0	15.8	15.8	0.05	92
S2	Jackpine Creek[a]	203.0	155.0	358.0	1.39	122
S3	Iyinimin Creek	39.5	0.0	39.5	0.18	143
S4	Blackfly Creek	38.2	0.0	38.2	0.16	143
S5	Muskeg River	218.0	172.0	390.0	1.56	126
S6	Mills Creek	0.0	23.8	23.8	0.07	91
S9	Stanley Creek	36.9	27.3	64.2	0.24	117
S10	Iyinimin Creek	58.4	9.6	68.0	0.33	154
S11	Shelley Creek	18.4	0.0	18.4	0.05	81
S12	Muskeg Creek	270.0	97.2	367.2	1.55	133
S13	Muskeg Creek	58.4	15.2	73.6	0.31	134
S15	Wapasu Creek	81.6	44.7	126.3	0.51	124

[a] Mean annual discharge was estimated from recorded data at Jackpine Creek WSC station between 1975 and 1993.





NOTE: BASED ON SIMULATED FLOWS FOR THE PERIOD 1954 TO 1996.

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SIMULATED MEAN MONTHLY FLOWS
IYINIMIN CREEK (S3) and MILLS CREEK (S6)

01 DEC 97	Figure D4-17	DRAWN BY: RFM

Flood Peak Discharge

Table D4-18 shows flood peak discharge of local streams derived from the hydrologic simulations and frequency analyses of simulated flood peak discharges.

Table D4-18 Simulated Flood Peak Discharge of Small Streams in the LSA

Station or Node No.	Stream Name	Drainage Area (km^2)	Flood Peak Discharge for Specified Return Period (m^3/s)		
			2 Years	10 Years	100 Years
S1	Alsands Drain	15.8	0.3	0.7	1.6
S2	Jackpine Creek	358.0	9.5	18.9	33.8
S3	Iyinimin Creek	39.5	1.7	3.3	5.8
S4	Blackfly Creek	38.2	1.5	2.9	5.1
S5	Muskeg River	390.0	10.4	20.6	35.7
S6	Mills Creek	23.8	0.5	1.2	2.5
S9	Stanley Creek	64.2	2.0	4.1	8.1
S10	Iyinimin Creek	68.0	3.0	6.2	11.1
S11	Shelley Creek	18.4	0.3	0.8	2.1
S12	Muskeg Creek	367.0	10.6	20.3	33.7
S13	Muskeg Creek	73.6	1.1	1.5	1.8
S15	Wapasu Creek	126.0	3.4	6.5	10.6

Low Flow

Daily low flow of the small streams in the LSA occurs in winter. Low flow characteristics of these streams are represented by the 7Q10 parameter, which denotes mean low flow of a 7-day duration with 10-year return period. Table D4-19 presents these low flow statistics for both the open-water (mid-April to mid-November) and ice-cover (mid-November to mid-April) periods.

Table D4-19 Low Flow Statistics of Small Streams in the LSA

Station or Node No.	Stream Name	Low Flow Parameter 7Q10 ($10^{-3}m^3/s$ or L/s)	
		Open-Water Period (mid April to mid November)	Ice-Cover Period (mid November to mid April)
S1	Alsands Drain[(a)]	3	1
S2	Jackpine Creek	73	12
S3	Iyinimin Creek	0	0
S4	Blackfly Creek	0	0
S5	Muskeg River	83	16
S6	Mills Creek[(a)]	5	1
S9	Stanley Creek[(a)]	6	1
S10	Iyinimin Creek[(a)]	4	1
S11	Shelley Creek	0	0
S12	Muskeg Creek	53	4
S13	Muskeg Creek	27	1
S15	Wapasu Creek	32	4

(a) Low flow statistics at this station (or node) were estimated from the ratio of the natural lowland area at the WSC hydrologic monitoring station (or node) for the Muskeg River area at Node 16 (Figure D4-12).

D4.3.6 Mapping of Muskeg River and Jackpine Creek Floodplains

A flood risk map for the 13 km reach of the Muskeg River and the 8 km reach of Jackpine Creek in the LSA is shown in Figure D4-18. This analysis of flood levels was conducted to show the natural flood risk limits and to provide a basis for evaluating the effect of any potential encroachment onto the river floodplain by the Project. Open-water flood water surface profiles were calculated using the HEC-RAS program developed by the Hydrologic Engineering Centre (US Army Corps of Engineers 1995). The following input data were used in the hydraulic modelling:

- Channel and floodplain cross-sectional data were surveyed along the study reaches of the Muskeg River and Jackpine Creek. The surveyed data included 17 selected cross-sections to represent the channel and floodplain geometry of the study reaches.

- The Manning's roughness coefficient is a hydraulic parameter used to model energy losses in a hydraulic conveyance system. The Manning's roughness coefficient for the main channel is the most important hydraulic parameter governing flood levels. It was calibrated using the recorded water levels along the study reaches. The methodology was to use the HEC-RAS model to reproduce measured high water levels by adjusting coefficient for the Manning's roughness.

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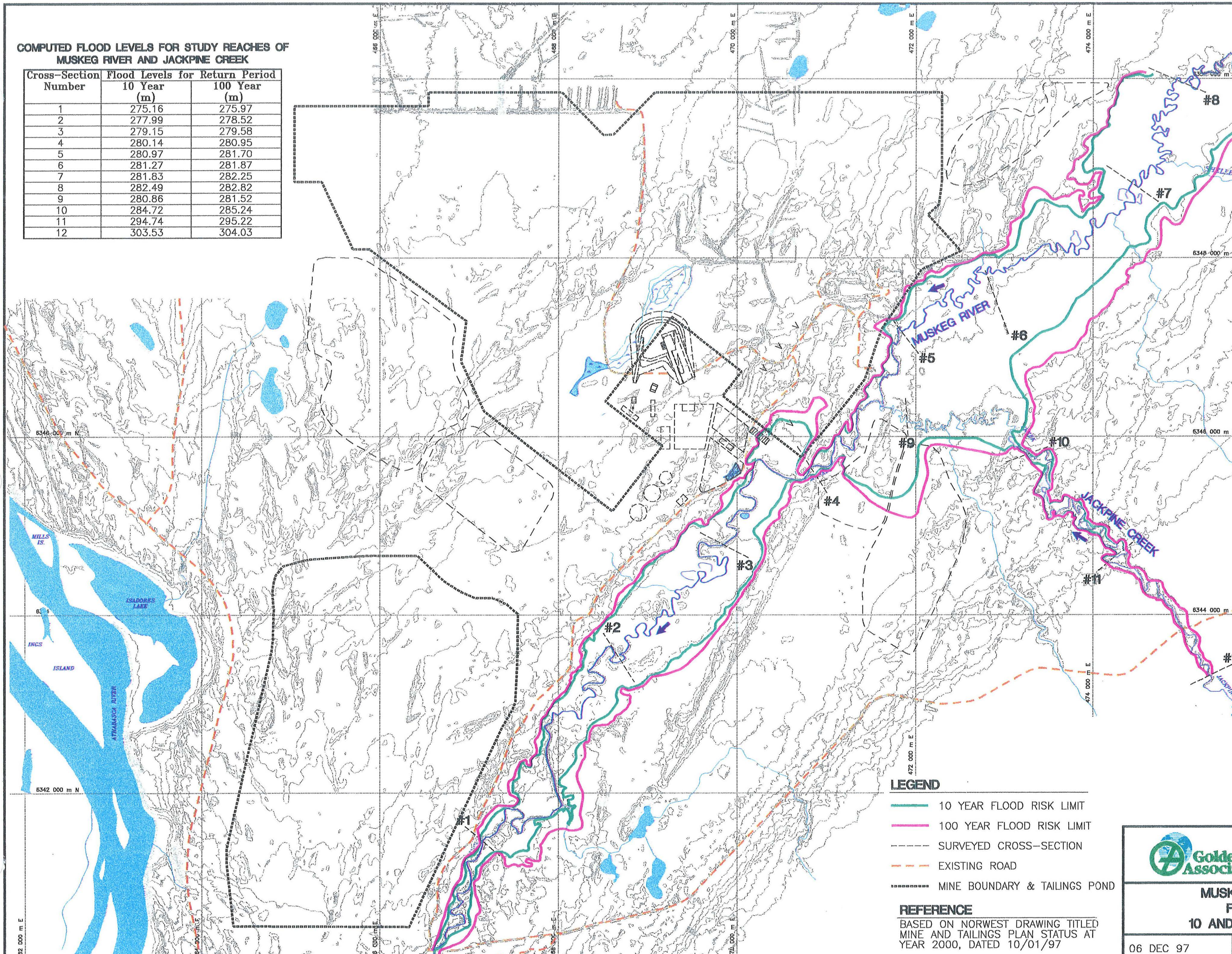
COMPUTED FLOOD LEVELS FOR STUDY REACHES OF MUSKEG RIVER AND JACKPINE CREEK

Cross-Section Number	Flood Levels for Return Period 10 Year (m)	100 Year (m)
1	275.16	275.97
2	277.99	278.52
3	279.15	279.58
4	280.14	280.95
5	280.97	281.70
6	281.27	281.87
7	281.83	282.25
8	282.49	282.82
9	280.86	281.52
10	284.72	285.24
11	294.74	295.22
12	303.53	304.03



LEGEND

- 10 YEAR FLOOD RISK LIMIT
- 100 YEAR FLOOD RISK LIMIT
- SURVEYED CROSS-SECTION
- EXISTING ROAD
- MINE BOUNDARY & TAILINGS POND

REFERENCE

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

COORDINATE SYSTEM: NAD27

Golder Associates

SHELL CANADA LIMITED

MUSKEG RIVER MINE PROJECT FLOOD RISK MAP FOR 10 AND 100 YEAR FLOOD EVENTS

06 DEC 97	Figure D4-18	DRAWN BY: TM/DC

The Muskeg River and Jackpine Creek floodplain was mapped for both the 10 and 100 year flood events. The flood risk areas were delineated on a 1:20,000 scale map as shown in Figure D4-18.

D4.4 Stream Sediment Transport

D4.4.1 Regional Basin Sediment Yields

Climatic, hydrologic and geomorphic conditions of a drainage basin jointly influence basin sediment yield. The sediment yield characteristics of the large basins in the region were analyzed based on available stream sediment measurements (Golder 1996). Analysis results are presented in Table D4-20 and in Figure D4-19. The mean annual sediment yield (ranging from about 0.0016 to 0.16 mm yield per unit area) does not exhibit any strong correlation with the drainage area. The mean annual sediment yield for the Muskeg River is about 0.0016 mm, the lowest in the region. This contrasts with the mean annual sediment yield of 0.16 mm for the Athabasca River.

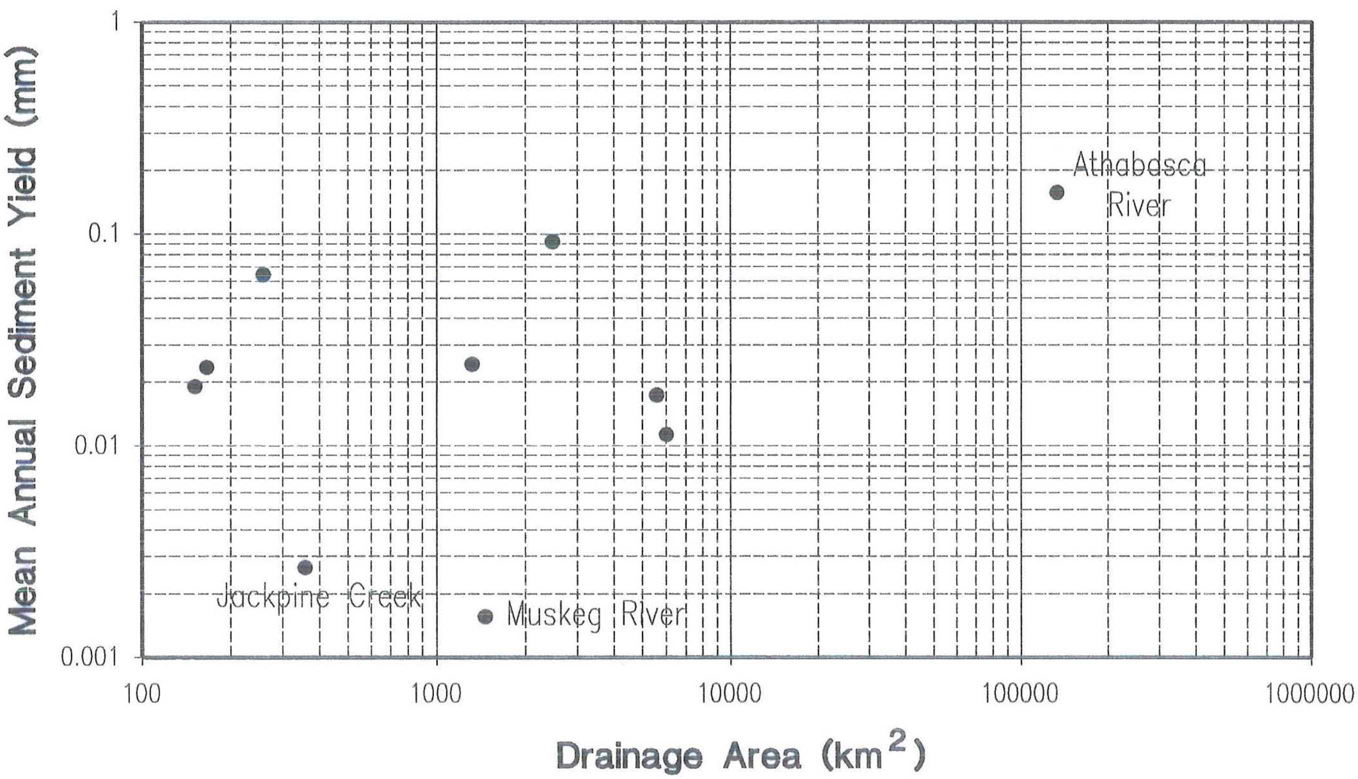
Table D4-20 Mean Annual Sediment Yields of Large Basins Gauged by WSC

Basin Name	Drainage Area (km^2)	Mean Annual Sediment Yield (mm)
Poplar Creek (07DA007)	151	0.0193
Beaver River (07DA018)	165	0.0236
Joslyn Creek (07DA016)	257	0.0647
Jackpine Creek (07DA009)	358	0.0027
Steepbank River (07DA006)	1,320	0.0246
Muskeg River (07DA008)	1,460	0.0016
Ells River (07DA017)	2,450	0.0928
MacKay River (07DB001)	5,570	0.0175
Firebag River (07DC001)	5,990	0.0114
Athabasca River (07DA001)	133,000	0.159

Note: Drainage areas are for the full basin for the listed rivers and creeks.

D4.4.2 Muskeg River Sediment Transport

The available total suspended sediment (TSS) measurements from 1976 to 1983 at the WSC hydrometric station on the Muskeg River were analyzed to determine the relationship of sediment transport and stream discharge. The results are shown in Figure D4-20. The sediment concentrations during the snowmelt period (April 1 to May 15) were relatively high, with values up to 40 mg/L. The sediment concentrations measured during the spring/summer period (May 15 to October 31) were much less than the sediment concentrations measured during the snowmelt period.



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MEAN ANNUAL SEDIMENT YIELD OF LARGE REGIONAL BASINS GAUGED BY WSC

01 DEC 97	Figure D4–19	DRAWN BY: RFM

D4.4.3 Small Stream Sediment Transport

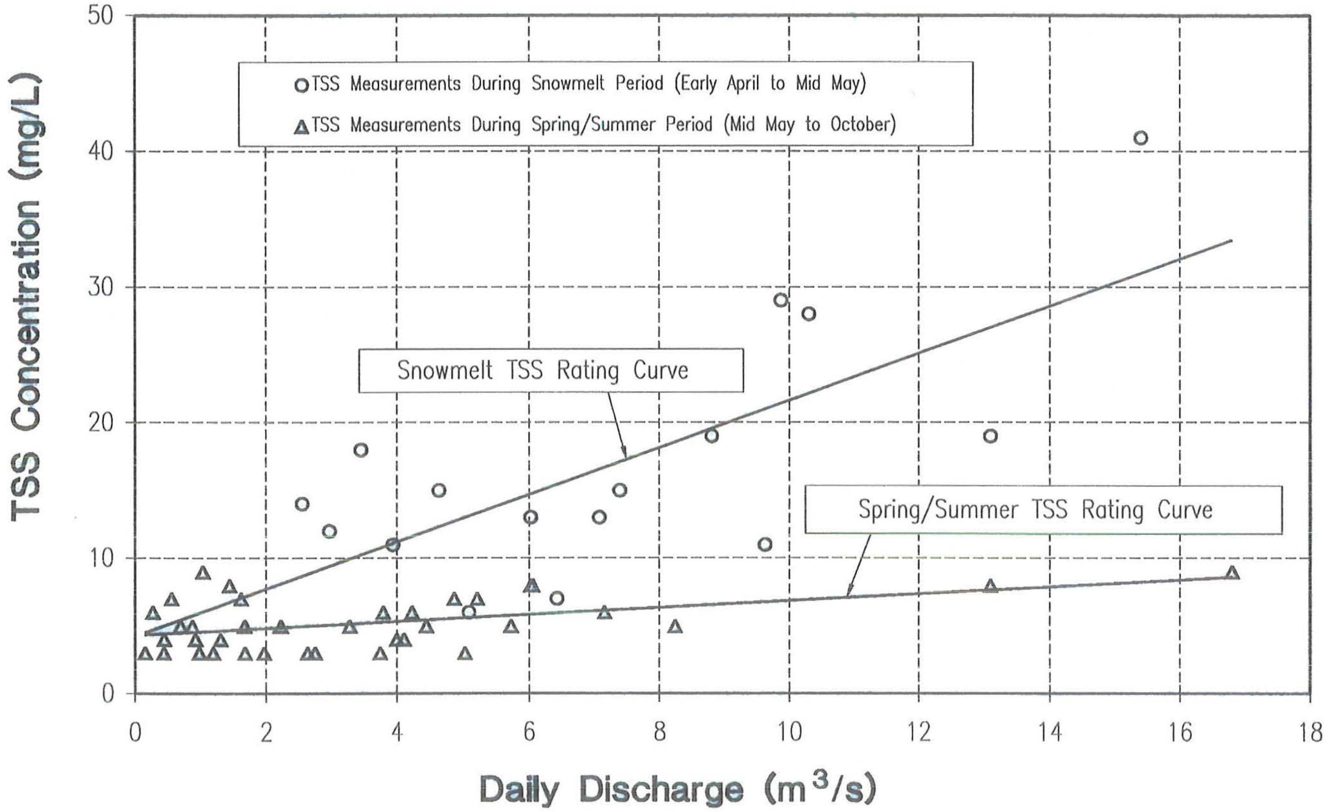
TSS concentration was monitored at the small gauged basins (S1 to S6) in the LSA between April and October 1997. This sediment monitoring program will be extended to develop a database for accurate quantification of small basin sediment yield and the small stream sediment transport characteristics. The collected TSS data during this short period were analyzed and the results are shown in Figure D4-21. The available measurements indicate that the smaller streams (such as S3) have higher concentrations of TSS (up to 130 mg/L) than the larger streams (such as S5).

D4.5 Stream Geomorphic Conditions

Previous geomorphic studies in the region included the study of the headwater streams in the Muskeg River basin conducted for the OSLO Project (W-E-R Engineering 1989) and the study of the streams in the Beaver River basin conducted for Syncrude (AGRA 1995b). A supplemental geomorphic study for the Muskeg River Mine Project was conducted to provide site-specific information and data for defining the geomorphic characteristics of the local streams in and adjacent to the Muskeg River Mine Project area.

The site locations where geomorphic surveys were conducted in the LSA are shown in Figure D4-22. Table D4-21 presents a summary of the stream geomorphic data including basin area, channel bed slope, valley slope, channel depth, channel width, entrenchment ratio and bed material size.

The survey data and information for the local streams in and adjacent to the LSA were used to classify each stream using the Rosgen classification system (Rosgen 1996). This system indicates the degree of stream channel stability and the degree of its resistance to disturbance or change in flow regime. Most of these surveyed streams are classified as E5 or E6 in the Rosgen classification, and are characterized by pronounced meandering, wide floodplains, and low to moderate width-to-depth ratios. They are typically found in broad alluvial-type valleys. The channel banks are typically stable and well vegetated. They are highly stable if the floodplain and the width-to-depth ratio are maintained. However, if these two characteristic features are disrupted, the streams are subject to rapid de-stabilization.



NOTE: BASED ON THE WSC DATA COLLECTED FOR THE MUSKEG RIVER NEAR FORT McKAY DURING 1976 TO 1983.

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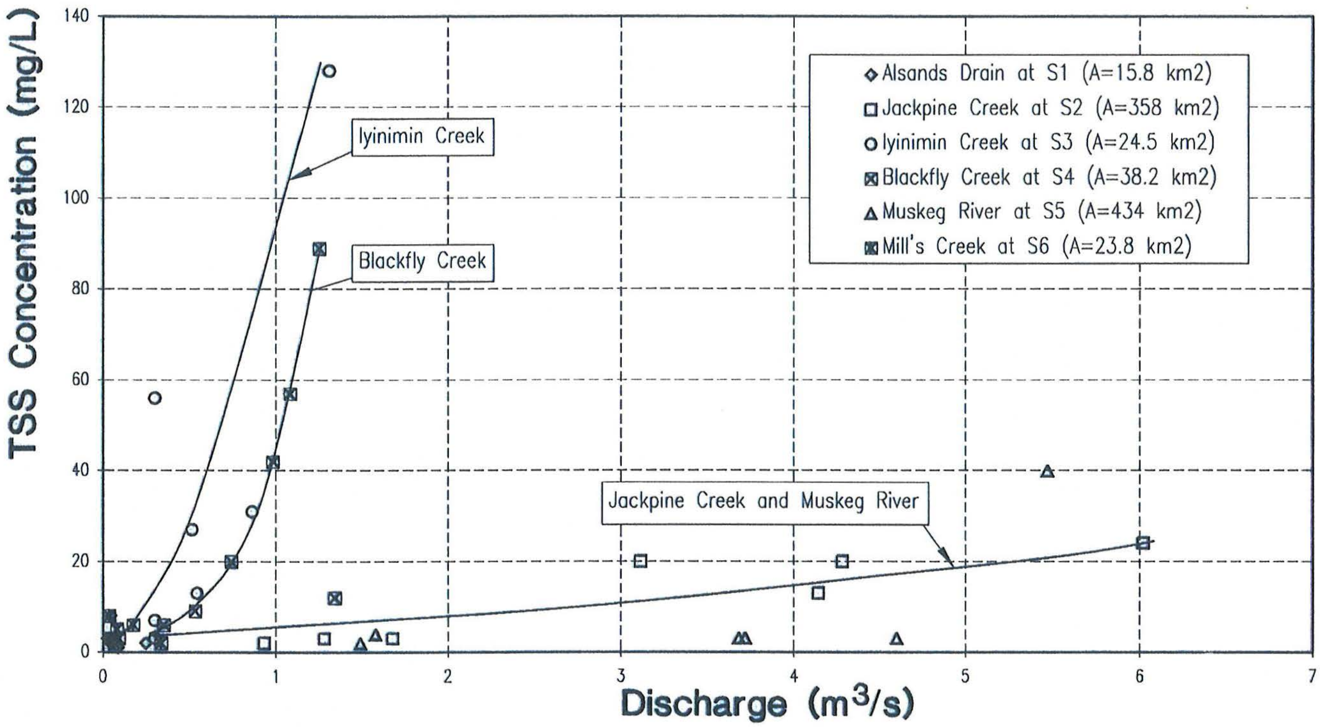
TSS RATING CURVES AT THE WSC STATION ON THE MUSKEG RIVER

01 DEC 97	Figure D4–20	DRAWN BY: RFM



NOTE: BASED ON THE DATA COLLECTED AT THE LOCAL HYDROLOGIC STATIONS OPERATED BY SHELL AND SYNCRUDE FROM APRIL TO OCTOBER, 1997.

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TSS CONCENTRATIONS FOR SMALL STREAMS IN THE LOCAL STUDY AREA (Period of Record: April to October 1997)

29 NOV 97	Figure D4-21	DRAWN BY: RFM

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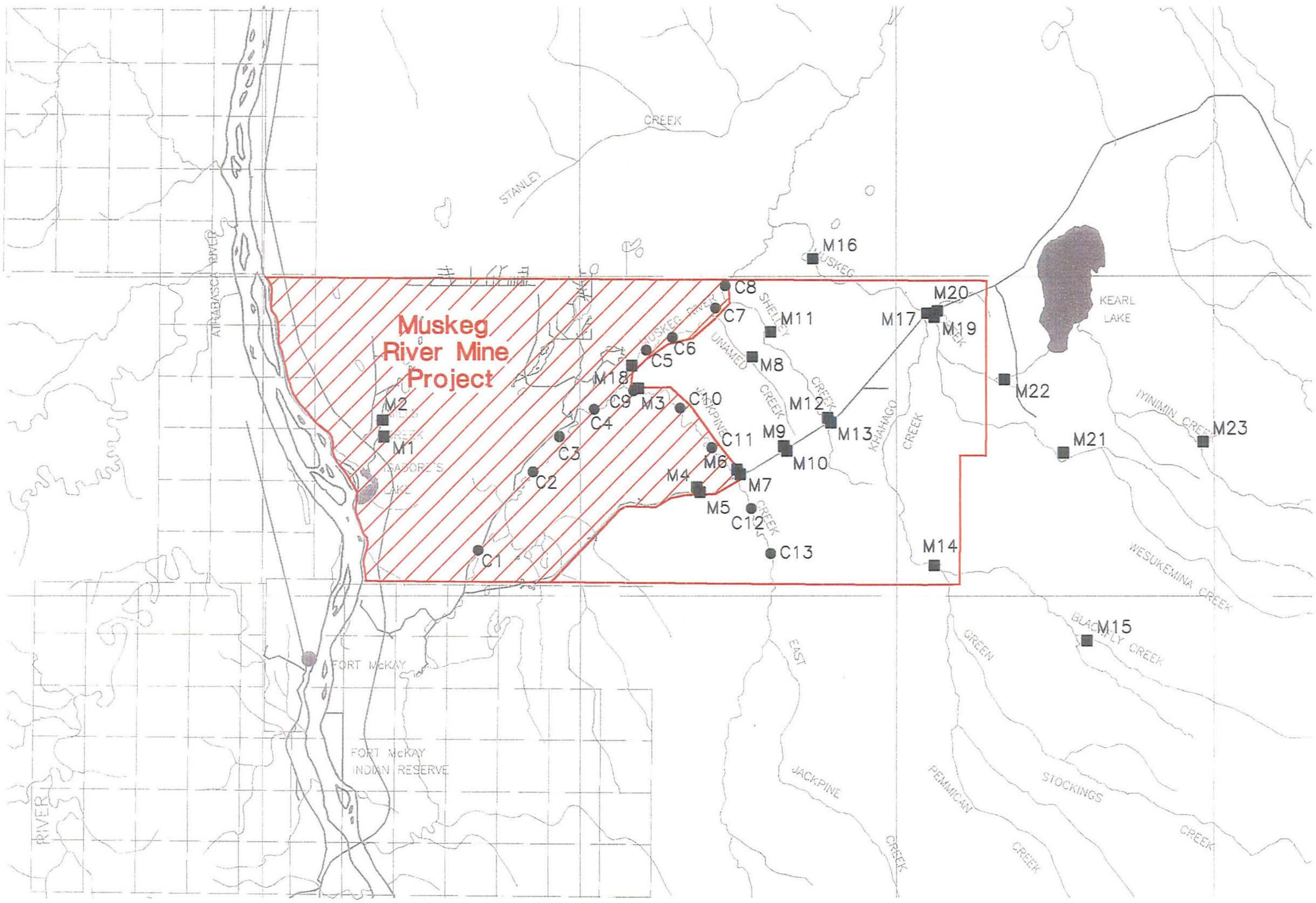

LEGEND

■ M1 GEOMORPHIC ASSESSMENT SITES

● C1 DETAILED CROSS-SECTIONAL SURVEY SITES

LEASE 13 BOUNDARY

0 2000 4000 6000 8000 10000(m)

SCALE 1:200,000

REFERENCE

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

Golder Associates

SHELL CANADA LIMITED

MUSKEG RIVER MINE PROJECT
GEOMORPHIC ASSESSMENT SITE MAP

29 NOV 97	Figure D4–22	DRAWN BM

Table D4-21 Summary of Stream Geomorphic Data

Site No.	Stream Name	Basin Area (km^2)	Bed Slope	Valley Slope	Mean Depth[a] (m)	Bankfull Width[b] (m)	Sinuosity[c]	Entrenchment Ratio[d]	Width/ Depth[e]	D_{50}[f] (mm)	D_{100}[g] (mm)
M1	Lower Mills Creek	23.8	0.0190	0.0286	0.28	4.9	1.5	1.5	17	0.22	1.25
M2	Upper Mills Creek	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a		
M3	Jackpine Creek	358	0.0033	0.0083	1.1	8.6	2.5	> 2.2	7.6	0.15	0.63
M4	Unnamed Creek	6.75	0.0102	0.0143	0.4	1.05	1.4	n/a	7.6		
M5	Unnamed Creek	6.75	0.0095	0.0143	0.26	2.4	1.5	n/a	7.6		
M6	Jackpine Creek	342	0.0029	0.0034	0.31	11.3	1.2	1.6	35		
M7	Jackpine Creek	342	n/a	n/a	0.55	13	n/a	2.1	23	0.07	0.63
M9	Unnamed Creek 2	8.8	0.0044	0.0053	0.26	1.9	1.2	> 2.2	7.3		
M10	Unnamed Creek 2	8.8	0.0044	0.0053	n/a	n/a	1.2	n/a	n/a		
M12	Shelley Creek	7.6	0.0051	0.0077	0.45	4	1.5	> 2.2	8.8		
M13	Shelley Creek	7.6	0.0055	0.0077	0.24	3.2	1.4	> 2.2	13	0.29	2
M14	Khahago Creek	156.5	0.0020	0.0029	1.5	12	1.5	> 2.2	8.0		
M15	Blackfly Creek	27	0.0048	0.0071	0.44	4.7	1.5	1.3	10		
M16	Muskeg Creek	331	0.0018	0.0045	1.3	7.8	2.5	> 2.2	6.0	0.24	0.63
M17	Muskeg Creek	329	0.0031	0.0040	1	8.1	1.3	> 2.2	6.9		
M18	Muskeg River	938	0.0006	n/a	n/a	n/a	n/a	n/a	n/a	0.35	2
M19	Unnamed Creek 3	187.8	0.0024	0.0041	2	5	1.7	> 2.2	12		
M20	Unnamed Creek 4	131.5	0.0047	0.0061	0.36	4.4	1.3	1.3	12		
M21	Wesukemina Creek	> 2	0.0035	0.0043	0.26	1	1.2	> 2.2	3.8		
M22	Kearl Lake Outlet	72.5	0.0039	0.0042	0.57	4.6	1.1	> 2.2	8.0		
M23	Iyinimin Creek	24.5	0.0148	0.0222	0.57	3.7	1.5	1.2	6.5		
C1	Muskeg River	1351	0.0006	0.0007	1.63	40	1.2	> 2.2	24		
C2	Muskeg River	1323	0.0004	0.0005	0.94	12.5	1.3	> 2.2	13		
C3	Muskeg River	1306	0.0004	0.0006	1.88	24	1.5	> 2.2	13		
C4	Muskeg River	1272	0.0006	0.0008	1.94	33	1.3	> 2.2	17		
C5	Muskeg River	1233	0.0004	0.0006	1.0	15	1.5	> 2.2	15		
C6	Muskeg River	1224	0.0002	0.0004	0.69	20	2.4	> 2.2	29		
C7	Muskeg River	1202	0.0002	0.0005	0.69	15	2.9	> 2.2	22		
C8	Muskeg River	1177	0.0003	0.0008	0.63	10.5	3.1	> 2.2	17		
C9	Jackpine Creek	350	0.0015	0.0025	0.9	12.8	2.2	> 2.2	23		
C10	Jackpine Creek	344	0.0021	0.0035	0.7	22.4	1.7	> 2.2	29		

Site No.	Stream Name	Basin Area (km^2)	Bed Slope	Valley Slope	Mean Depth[a] (m)	Bankfull Width[b] (m)	Sinuosity[c]	Entrenchment Ratio[d]	Width/ Depth[e]	D_{50}[f] (mm)	D_{100}[g] (mm)
C11	Jackpine Creek	342	0.0030	0.0048	0.9	17.5	1.6	> 2.2	20		
C12	Jackpine Creek	340	0.0028	0.0037	0.74	8.6	1.3	> 2.2	24		
C13	Jackpine Creek	337	0.0027	0.0029	0.70	15.5	1.1	> 2.2	25		

(a) Mean depth: mean bankfull depth across a stream channel.
(b) Bankfull width: width of channel measured at bankfull stage.
(c) Sinuosity: ratio of stream length to valley length.
(d) Entrenchment ratio: (width of the flood-prone area at an elevation twice the maximum bankfull depth) / (bankfull width).
(e) Width/depth ratio: bankfull width / mean bankfull depth.
(f) D_{50} = median particle size of channel bed soil.
(g) D_{100} = maximum particle size of channel bed soil.

D5 SURFACE WATER QUALITY

D5.1 Introduction

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

- description of the baseline water quality conditions in the Study Area;
- discussion of seasonal variation and effects; and
- comparison of the existing water quality with the Alberta Ambient Surface Water Quality Interim Guidelines, relevant United States Environmental Protection Agency Guidelines and the Canadian Water Quality Guidelines (TofR, Section 4.8).

Project-specific impacts on water quality are addressed in Section E5 of this EIA. Cumulative effects on water quality are addressed in Section F5.

Surface water, sediment and porewater quality data were summarized from a variety of information sources, including the Project field programs (Golder 1997b in part), routine monitoring by AEP (Hamilton et al., 1985, Noton and Shaw 1989, Noton and Saffran 1995), the Northern River Basins Study (Crosley 1996, Brownlee et al., 1997), baseline programs for various oil sands developments (R.L.&L. 1989, Golder 1996b) and the Oil Sands Regional Aquatic Monitoring Program established for the oil sands area (Golder 1998a). The complete data set is presented in the Aquatic Resources Baseline Study for the Muskeg River Mine Project (Golder 1997d) and is summarized in this section.

Water quality of rivers and lakes in the study area is described in terms of chemical characteristics and toxicity. Descriptions of water chemistry are focused on parameters that are considered indicators of certain aspects of water quality. These groups and toxicity are briefly described below:

- pH is an indication of the acidic or basic (alkaline) nature of water. Neutral waters have a pH near 7. The pH of natural surface waters usually falls between 6 and 9 in Alberta. Acidification causes a decline in pH.

- Dissolved salts can occur in a variety of forms in surface waters (e.g., sodium chloride, calcium sulphate). Total dissolved solids is a frequently used indicator of total salt level in water. As a general rule, salt levels in excess of 2,000 mg/L total dissolved solids are usually considered deleterious to aquatic life.

- Suspended sediments includes all solid particles suspended in the water column. An increase in suspended sediment level usually results in a corresponding increase in stress to aquatic animals. Total suspended sediment levels below 25 mg/L are usually not considered harmful to aquatic life, but much higher levels may be tolerated for short periods.

- Nutrients include a variety of nitrogen and phosphorus compounds that are required for plant growth in very small quantities. Biological productivity of lakes and rivers is usually limited by one nutrient (frequently phosphorus), referred to as the limiting nutrient. Total phosphorus level typically ranges between 0.001 mg/L in unproductive waters such as alpine lakes, to >0.1 mg/L in highly productive waters.

- Metals usually occur in small quantities (<1 mg/L) in surface waters, since they are usually associated with suspended sediments and tend to settle out. Exceptions include metals forming water-soluble salts (e.g., calcium, magnesium, sodium, potassium), which may occur in excess of 100 mg/L in dissolved form, as positively charged ions (cations). These are frequently referred to as "major ions," along with the negative ions (anions) that balance them in surface waters. Elevated levels of metals are usually harmful to aquatic organisms. The level causing toxicity varies by metal.

- Organic compounds include chemicals consisting of chains or rings of carbon atoms, such as hydrocarbons, phenols, polycyclic aromatic hydrocarbons (PAHs) and naphthenic acids. These may originate from natural sources (e.g., oil sands deposits, forest fires), or may be released from industrial sources. Elevated levels of organic compounds may be harmful to aquatic organisms. The level causing toxicity varies widely by chemical. In the oil sands area, naturally occurring hydrocarbons and PAHs have been reported at elevated (but not toxic) levels in natural surface waters.

- Toxicity refers to harmful effects on organisms caused by chemicals. The Microtox® test is a standard rapid test that provides an indication of the level of toxicity of the water tested. It measures the degree of light inhibition in a bioluminescent bacterium caused by exposure to the test water. Microtox® IC50 and IC25 values between 90 and 100% and Microtox® screen values >75% of the control value indicate the lack of toxicity to bacteria.

To provide an indication of the "level" of water quality in the waterbodies discussed, concentrations of individual chemicals (parameters) were compared with water and sediment quality guidelines for the protection of aquatic life. Whenever possible, winter water chemistry data were used for these comparisons, because concentrations of the majority of chemicals are usually at their annual maximum in surface waters in this season. This is due to the lowest annual dilution capacity in rivers during the winter low-flow period. In the absence of winter data, fall data were used for guideline comparisons. Since sediment chemistry does not vary greatly by season, all available sediment data were compared with guidelines.

Guidelines developed by regulatory agencies based on toxicity data were used for these comparisons (Table D5-1), as recommended by AEP (1996c). Compliance with acute guidelines in surface waters protects aquatic organisms from short-term, lethal effects; meeting chronic guidelines provides protection from longer-term, lethal or sublethal effects (e.g., reduced growth or reproduction). Sediment chemistry was compared with values of the threshold effect level (TEL) and the probable effect level (PEL), using the interim freshwater Canadian sediment quality guidelines (Smith et al., 1996).

D5.2 Athabasca River

D5.2.1 Surface Water

Water quality of the Athabasca River has not changed measurably over the last two decades (Table D5-2). Typically, pH remains between 7 and 8, dissolved salt and nutrient concentrations are moderate, and levels of metals are low. The Microtox® test has not provided an indication of potential toxicity in river water. Much of the variation in water quality within a typical year is the result of seasonal changes in the river's discharge; summer high flows usually cause a large increase in suspended sediment load, which is reflected in the concentrations of a number of parameters (e.g., total phosphorus and some metals).

Concentrations of naturally occurring hydrocarbons have been consistently low in the Athabasca River throughout the period of record. Based on the relatively large amount of data available for this river, oil sands-related discharges have not had a discernible effect on water quality (Noton and Saffran 1995).

In general terms, water quality of the Athabasca River is good, though periods of high suspended sediments may cause stress to aquatic organisms. Exceedances of water quality guidelines for the protection of aquatic life were found for a number of metals and total phosphorus (Table D5-3). These exceedances were typically minor and were largely by metals that tend to be elevated due to increased suspended sediment levels. These exceedances are of no concern regarding potential adverse effects on aquatic organisms.

D5.2.2 Bottom Sediments

Bottom sediments have not been extensively sampled in the Athabasca River. Recent studies found elevated levels of naturally occurring hydrocarbons above and adjacent to existing oil sands operations (Table D5-4). Although metal levels were typical of sediments in large rivers in Alberta, as documented in the North Saskatchewan River by Shaw et al., (1994), occasional exceedances of TELs for cadmium and nickel were found near Tar Island Dyke (TID) and at Fort Creek (Table D5-3). Levels of certain PAHs also exceeded the applicable TELs above TID in 1994 (Table D5-3).

Bottom sediment surveys conducted during the Northern River Basins Study (NRBS) found detectable but low PAH levels along the entire length of the Athabasca River (Crosley 1996, Brownlee et al., 1997). Total PAH concentration nearly doubled upstream of Fort McMurray relative to the upper river sites, but declined slightly below existing oil sands operations. Compared with levels for the Peace and Wapiti rivers, levels of individual PAHs were lower at all sites sampled in the Athabasca River. The limited data available do not reveal spatial trends consistent with input of PAHs from oil sands operations, but suggest there is an increase in natural input of PAHs near the upstream limit of the oil sands area.

D5.2.3 Porewater

Porewater samples collected in 1995 at three sites in the Athabasca River contained variable amounts of dissolved salts and naphthenic acids, most likely reflecting the presence of varying amounts of oil sands at the sampling sites (Table D5-5, Golder 1994a, 1995). Low levels of naturally occurring PAHs were detected at one of the sampling sites. Overall, the amount of oil sands in bottom sediments is a major determinant of porewater chemistry.

D5.3 Muskeg River Basin

D5.3.1 Surface Water

Surface waters of the Muskeg River basin were characterized by pH of 7 to 8, low to moderate dissolved salt concentrations and moderate levels of nutrients (Tables D5-6 to D5-8). Dissolved organic carbon was elevated in all streams, indicating the influence of muskeg drainage. Concentrations of metals were generally low. Levels of organic chemicals were not markedly affected by naturally occurring deposits of oil sands, though hydrocarbons were detected at low concentrations at a few sites sampled during 1995 (Golder 1996f). Microtox® test results did not indicate any toxicity in the basin from natural sources.

Table D5-1 Water and Sediment Quality Guidelines for the Protection of Aquatic Life

Parameter	Units	Water Quality Guidelines		
		Acute	Chronic	Reference
Surface Water				
Chloride	mg/L	860	230	USEPA
Nitrate	mg/L	-	10	CCME
Nitrite	mg/L	-	0.06	CCME
Total Suspended Solids	mg/L	-	10	ASWQG
Total Phenolics	mg/L	-	0.005	ASWQG
Total Ammonia (low winter flow)	mg/L	16	2.1	USEPA
Total Ammonia (open water flow)	mg/L	10	1.9	USEPA
Total Phosphorus	mg/L	-	0.05	ASWQG
Aluminum (Al)	mg/L	-	0.1	CCME
Arsenic (As)	mg/L	0.36	0.01	USEPA, ASWQG
Barium (Ba)	mg/L	-	1	ASWQG
Beryllium (Be)	mg/L	0.13	0.0053	USEPA
Boron (B)	mg/L	-	0.5	ASWQG
Cadmium (Cd)	mg/L	0.0074*	0.0018*	USEPA
Chromium (Cr)	mg/L	0.016	0.011	USEPA
Cobalt (Co)	mg/L	-	0.05	CCME
Copper (Cu)	mg/L	0.027*	0.007*	ASWQG
Iron (Fe)	mg/L	-	0.3	ASWQG
Lead (Pb)	mg/L	0.17*	0.007*	USEPA
Lithium (Li)	mg/L	-	2.5	CCME
Manganese (Mn)	mg/L	-	0.05	ASWQG
Mercury (Hg)	mg/L	0.0024	0.000012	USEPA
Molybdenum (Mo)	mg/L	-	1	BCMOE
Nickel (Ni)	mg/L	2.3*	0.25*	USEPA
Selenium (Se)	mg/L	-	0.01	ASWQG
Silver (Ag)	mg/L	0.01*	0.05	USEPA, ASWQG
Uranium (U)	mg/L	-	0.01	CCME
Vanadium (V)	mg/L	-	10	BCMOE
Zinc (Zn)	mg/L	0.19*	0.17*	USEPA
Sediment		TEL	PEL	
Arsenic	µg/g	5.9	17	Smith et al. 1996
Cadmium	µg/g	0.596	3.53	Smith et al. 1996
Chromium	µg/g	37.3	90	Smith et al. 1996
Copper	µg/g	35.7	197	Smith et al. 1996
Lead	µg/g	35	91.3	Smith et al. 1996
Mercury	µg/g	0.174	0.486	Smith et al. 1996
Nickel	µg/g	18	35.9	Smith et al. 1996
Zinc	µg/g	123	315	Smith et al. 1996
Phenanthrene	µg/g	0.0419	0.515	Smith et al. 1996
Benz(a)anthracene	µg/g	0.0317	0.385	Smith et al. 1996
Benzo(a)pyrene	µg/g	0.0319	0.782	Smith et al. 1996
Chrysene	µg/g	0.0571	0.862	Smith et al. 1996
Fluoranthene	µg/g	0.111	2.355	Smith et al. 1996
Pyrene	µg/g	0.053	0.875	Smith et al. 1996

NOTES: - = no guideline; * guideline specified for hardness of 175 mg/L $CaCO_3$
ASWQG = Alberta Surface Water Quality Guidelines
BCMOE = British Columbia Ministry of the Environment
CCME = Canadian Council of Ministers of the Environment
USEPA = United States Environmental Protection Agency
TEL = Threshold effect level
PEL = Probable effect level

Table D5-2 Water Quality of the Lower Athabasca River (1976-1997)

Parameter	Units	Upstream Fort McMurray				Near Donald Creek			Below Existing Oil Sands Operations			Below Fort Creek			
		Winter	Spring	Summer	Fall	Spring	Summer	Fall	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Conventional Parameters and Nutrients															
pH	-	7.88	8.01	7.98	7.90	7 81 - 8 1	7 63	7 82-8 0	7 94	7 63 - 8	-	7 92	8.2	7.95	8.3
Total Alkalinity	mg/L	169	102	98	110	76 - 97 4	88 2	92-94 8	104	90 3 - 94	-	144	99	90.1	104
Total Dissolved Solids	mg/L	243	159	144	158	140 - 141	120	146-200	146 - 240	123 - 158	-	-	46	182	140-160
Total Suspended Solids	mg/L	2.45	82	126.5	19 2	19 - 181	624	4 0-57	30 - 190	624 - 676	-	2 5	215	265.5	36
Total Hardness	mg/L	190	114	105	124	<1 - 111	114	100-104	121	101 - 118	-	158	103	92	105.7
Dissolved Organic Carbon	mg/L	8	10	8	8	7 1 - 11	16.7	9-9 2	7 6	13 - 16 1	-	6 8	11	12.7	8.8
Total Kjeldahl Nitrogen	mg/L	0.54	0.87	0.81	0.62	1 2	-	<0.02	-	<0 2	-	0 33	1 2	1 01	0.5
Total Ammonia	mg/L	0.03	0.02	0.01	0.01	<0.01 - <0.05	0 04	<0 01-<0 05	<0 01	0 04 - <0 05	-	0 055	0.05	0.03	<0.05
Total Phosphorus	mg/L	0.022	0.110	0.128	0.033	0.14 - 0.144	1 17	0 084-0 087	0 12	0 298 - 1 32	0 08	0 0285	0 082	0.2895	0.058
Dissolved Phosphorus	mg/L	0.012	0.013	0.013	0.007	0.02	-	0 022	-	0 019	0 01	0.0195	0 015	0 018	0.013
Metals (Total)															
Aluminum (Al)	mg/L	0.055	0.844	0.908	0.23	0.17 - 5.18	8 64	0.11-2 23	0 15 - 4 05	10 1 - 14 1	3 89	0 0155	3 66	6 13	2.38
Arsenic (As)	mg/L	0.0004	0.0012	0.0012	0.001	0.0006 - 0.002	0.007	0 0005-0 0013	0 0008 - 0 002	0 0057 - 0 007	0 0015	0.0004	0.0011	0.0045	0.0008
Cadmium (Cd)	mg/L	0.001	0.001	<0.001	<0.001	<0.0002 - <0.003	<0 003	<0 002-<0 003	<2E-04 - <0	0 0002 - <0 003	<0.0002	0 001	<0.001	0.001	0.001
Chromium (Cr)	mg/L	0.003	0.0045	0.004	0.0025	<0.002 - 0.0051	0.003	<0 002-0 0026	<0 002 - 0 005	<0 002 - 0 0197	0 0043	0 0025	0.005	0.00995	0.003
Copper (Cu)	mg/L	0.001	0.004	0.005	0.0015	<0.001 - 0.007	-	0 049	0 004 - 0 006	0 0181	0 0041	0.0015	0.002	0 008	0.002
Iron (Fe)	mg/L	0.174	3.21	3.115	0.352	0.43 - 5.24	17 9	0 91-2 19	0 43 - 3 76	17 6 - 19 4	2 98	0 4625	5 04	16.1	2.41
Mercury (Hg)	mg/L	0.0001	0.0001	<0.0001	<0.0001	<0.0002 - <0 05	<0 05	<0 0001-<0 05	<2E-04 - <0 05	<0 0001 - <0 05	<0 0001	0 0001	<0.0001	<0 0001	<0.0001
Vanadium (V)	mg/L	<0.002	0.002	0.0045	-	<0.002 - 0.0125	0 009	<0 0001	0 004 - 0 011	0 015 - 0 0379	0 0097	<0 002	0 009	0 023	0.0061
Zinc (Zn)	mg/L	0.007	0.0145	0.013	0.007	-	-	0 014	-	-	0 034	-	-	-	0.005
Metals (Dissolved)															
Aluminum (Al)	mg/L	0.01	0.0675	<0.002-0.02	0.02	0.241	0 0159	0 0443	0 0572	0 0499	0 0729	-	0 415	0 026	0 036
Arsenic (As)	mg/L	0.0005	0 0009	0 0009	0.0006	0 001	<0 0004	0 0005	0 0006	0 0006	0 0006	-	0 0012	0 0005	0.0005
Cadmium (Cd)	mg/L	<0.001	<0 001-0.006	<0.001	-	<0.0001	0.0028	0.0001	<0 0001	0 0002	0 0001	-	0 0001	0 0002	0.0001
Chromium (Cr)	mg/L	0.003	0.003	0.003	0.003	<0 0004	<0.0004	<0.0004	<0 0004	<0 0004	<0 0004	-	0.0007	<0 0004	<0.0004
Copper (Cu)	mg/L	<0.001	<0 001-0 003	0.002	-	0 0043	0 0022	0.0022	0 0024	0 006	0 0042	-	0 0049	0 003	0 002
Iron (Fe)	mg/L	0.11	0 1	0 07	0.12	1.14	0.1	0 14	0 32	0 08	<0 01	-	1 93	0 43	0 14
Mercury (Hg)	mg/L	-	-	-	-	<0 0002	<0.0002	<0.0002	<0 0002	<0 0002	<0.0002	-	<0.0002	<0 0002	<0 0002
Vanadium (V)	mg/L	<0.001	<0.001-<0.002	<0.001	-	0.0012	<0.0001	<0.0001	0 0002	<0.0001	0.0002	-	0.002	0.0001	<0 0001
Zinc (Zn)	mg/L	0.002	<0.001	<0.001	-	-	0.038	0.014	0 006	0.027	0 023	-	0.015	0 016	0.019
Organics															
Naphthenic Acids	mg/L	-	-	-	-	<1 - 2	<1	<1	<1	<1	ND	-	1	-	-
Recoverable Hydrocarbons	mg/L	-	-	-	-	<0 5 - <1	1	<1	<0 5 - <1	<0.5 - <1	-	-	<0.5	-	-
PAHs and Alkylated PAHs	µg/L	-	-	-	-	ND	ND	ND	ND - 0 03	ND	-	-	-	-	-
Target PANHs	µg/L	-	-	-	-	ND	ND	ND	ND	ND	-	-	-	-	-
Phenolics	µg/L	-	-	-	-	ND	ND	-	ND	ND	-	-	-	-	-
Volatile organics	µg/L	-	-	-	-	ND	-	-	ND	-	-	-	-	-	-
Toxicity															
Microtox IC50	%	-	-	-	-	100	100	>100	91 - 100	100	-	-	-	-	-
Microtox IC25	%	-	-	-	-	100	100	>100	91 - 100	100	-	-	-	-	-

NOTES: - = No data; ND = Not detected; PAH = Polycyclic aromatic hydrocarbon; PANH = Polycyclic aromatic nitrogen heterocycle
Median concentrations (n>2), ranges (n=2), or measured concentrations (n=1) are presented; data sources are listed by Golder (1997e)

Table D5-3 Summary of Water and Sediment Quality Guideline Exceedances

Parameter	Athabasca R. upstream Fort McMurray (Winter)	Athabasca R. near Donald Creek (Fall)	Athabasca R. upstream Muskeg River (Fall)	Athabasca R. below Fort Creek (Winter)	Athabasca River above TID, West Bank (sediment)	Athabasca River at TID, East Bank, 1994 (sediment)	Athabasca River at TID, East Bank, 1995 (sediment)	Athabasca River at TID, West Bank, 1994 (sediment)	Athabasca River at Fort Creek (sediment)	Mouth of Muskeg River (Water in Winter, Sediment in Fall)	Lower Muskeg River (Winter)	Muskeg River upstream Jackpine Creek (sediment)	Upper Muskeg River (Winter)	Mouth of Jackpine Creek (Water in Winter, Sediment in Fall)	Lower Jackpine Creek (Fall)	Upper Jackpine Creek (Winter)	Shelley Creek (Winter)	Muskeg Creek (Winter)	Upper Muskeg Cr. Drainage (Winter)	Isadore's Lake (Winter)	Muskeg Drainage Water
Water Quality Guideline Exceedances																					
Total Phosphorus		C	C										C	C			C		C	C	
Total Aluminum		C	C																	C	C
Total Copper		A,C													ND						
Total Iron		C	C	C						C	C		C	C	ND	C	C	C	C	C	C
Total Manganese	ND	C	C	ND						C	C		C		ND	C	C	C	C	C	C
Total Mercury	C			C						C	C		C		C	C		C			ND
Total Phenolics										C	ND		ND		ND	ND	ND	ND	ND	ND	
Sediment Quality Guideline Exceedances																					
Cadmium							TEL														
Nickel						TEL		TEL	TEL												
Benz(a)anthracene					TEL*					TEL*		TEL*		TEL*							
Chrysene					TEL*					TEL*		TEL*		TEL*							
Fluoranthene					TEL																
Pyrene					TEL																

NOTES:
C = chronic guideline exceeded
A = acute guideline exceeded
ND = no data
TEL = threshold effect level
TID = Tar Island Dyke
*concentrations of benz(a)anthracene and chrysene were reported as one number, which exceeded the TEL for both of these compounds

Concentrations of total phosphorus, total phenolics and a number of metals occasionally exceeded chronic water quality guidelines (Table D5-3). Overall, water quality in the Muskeg River basin can be classified as good, and occasional guideline exceedances are of no concern to aquatic life.

D5.3.2 Bottom Sediments

Bottom sediment samples were collected in fall 1997 from the Muskeg River and Jackpine Creek as part of the Regional Aquatic Monitoring Program (RAMP) for the oil sands area. Levels of metals were typically lower than in the Athabasca River (Table D5-4) or the North Saskatchewan River (Shaw et al., 1994), and no guideline exceedances were found (Table D5-3). Concentrations of PAHs were also below those in the Athabasca River. Potential exceedances of the TEL value for benz(a)anthracene and chrysene occurred at all three sites sampled in the Muskeg River basin (Table D5-9); however, since concentrations of these compounds were reported together, exceedances cannot be evaluated with certainty.

D5.3.3 Porewater

Porewater data are limited to two sites in the Muskeg River basin (Muskeg River and Jackpine Creek), sampled in 1995 (Table D5-5). Dissolved salt concentrations were low at these sites and naturally occurring hydrocarbons, PAHs and naphthenic acids were not detected. Samples were not toxic to bacteria. Compared with samples from the Athabasca and Steepbank rivers, all measured parameters were less concentrated in porewater from the Muskeg River and Jackpine Creek.

D5.4 Isadore's Lake and Mills Creek

D5.4.1 Surface Water

Water quality of Isadore's Lake and Mills Creek was assessed during the Muskeg River Mine Project baseline surveys in 1997 (Golder 1997d). The data suggest that, in terms of water quality, these waterbodies are generally similar to others in the Muskeg River basin (Table D5-10). Differences from other surface waters in the basin include higher dissolved salts in Mills Creek in the fall only and slightly lower dissolved organic carbon and nutrient levels in both Isadore's Lake and Mills Creek. However, these differences may simply represent the limited data available at the present for Isadore's Lake and Mills Creek.

Table D5-4 Sediment Quality of the Athabasca River in 1994, 1995 and 1997

Parameter	Units	1994[1]			1995[2]			1997[3]	
		1 km Above TID West Bank	At TID East Bank	At TID West Bank	1 km Above TID West Bank	At TID East Bank	At TID West Bank	At Donald Creek	At Fort Creek
Total Organic Carbon	Weight %	1.07	1.31	0.49-1.61	1.39	0.49	1.02	0.67	2.32
Recoverable Hydrocarbons	µg/g	-	-	-	2160	450	703	423	1190
Metals									
Aluminum	µg/g	6420	7670	4250-7740	3910	3730	4890	10700	7790
Arsenic	µg/g	1.7	2.1	1.3-2	0.6	0.9	1	5.6	5.1
Cadmium	µg/g	<0.3	<0.3	<0.3	<.3	0.6	0.5	<0.5	<0.5
Chromium	µg/g	15.3	17.3	13.4-17.2	13.9	11.1	12.4	19	20.2
Copper	µg/g	5.1	7.9	3.6-8.6	4.6	3.6	6.5	15	15
Iron	µg/g	13600	16400	10200-14800	11000	9820	13100	15000	15500
Lead	µg/g	3	6	6.0-8.0	4	5	5	9	8
Mercury	µg/g	0.023	0.03	<0.02-0.03	0.03	0.04	0.03	0.05	0.06
Nickel	µg/g	15	18	14-19	13.8	11.8	15.6	16	19
Molybdenum	µg/g	1	1.2	0.9-1.4	<0.3	0.4	0.5	<1	<1
Vanadium	µg/g	18.8	19.4	14-19.8	14.7	12.8	14.5	28	18.5
Zinc	µg/g	35.6	43.6	26.3-46.1	29.9	27.6	39.6	53	57.4
PAHS and Alkylated PAHS									
Phenanthrene	µg/g	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	0.01	0.01
Benz(a)anthracene/Chrysene	µg/g	2.1	<0.01	<0.01-0.02	0.03	<0.01	0.01	0.02	0.025
Benzo(a)pyrene	µg/g	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.006
Fluoranthene	µg/g	0.4	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.006
Pyrene	µg/g	1.5	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01
Total PAHs	µg/g	4.3	-	0.5	0.66	0.07	0.13	0.48	1.203
Toxicity									
Microtox Screen	% Control	73-99	118	91-120	-	-	-	-	-

NOTES:
[1]Golder (1994a)
[2]Golder (1996b)
[3]Samples collected in fall 1997 for RAMP
TID = Tar Island Dyke
\- = no data or not applicable

Table D5-5 Porewater Chemistry and Toxicity in the Athabasca, Steepbank and Muskeg Rivers and Jackpine Creek in 1994 and 1995

Site	Sodium (mg/L)	Total Dissolved Solids (mg/L)	Naphthenic Acids (mg/L)	Total Ammonia (mg/L)	Total PAHs (µg/L)	Microtox IC50 (%)
Athabasca R. 1 km above TID, West Bank	1210	3220	17	0.78	0.04	>100
Athabasca River at TID, West Bank	12.8	259	<1	0.58	ND	>100
Athabasca River at TID, East Bank	423	1730	<1	0.59	ND	>100
Steepbank River at the mouth	12.6-26.5	240-374	2-4	0.47-0.62	ND-0.84	>100
Steepbank River, 15 km from the mouth	380-5120	1370-14500	3-16	0.5-3.01	1.21-33.75	>100
Steepbank River, 25 km from the mouth	11.5-26.1	125-228	<1-5	0.03-0.06	ND-0.03	>100
Muskeg River at the mouth	11	130	<1	<0.01	ND	>100
Jackpine Creek at the mouth	10.5	168	<1	0.01	ND	>100

TID = Tar Island Dyke

ND = Not detected

PAH = Polycyclic aromatic hydrocarbon

Data from Golder (1996a)

Table D5-6 Water Quality of the Muskeg River (1972-1997)

Parameter	Units	At Mouth				Lower Muskeg River				Upper Muskeg River			
		Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Conventional Parameters and Nutrients													
pH	-	7.5	7.7	8.0	8-9.2	7.4	7.5	7.8	7.7	7.4	7.5	7.6	7.7
Total Alkalinity	mg/L	257	113	148	153	259	101	170	136	301	128	196	171
Total Dissolved Solids	mg/L	331	143	202	184	303	138	195	162	327	135	211	23
Total Suspended Solids	mg/L	4	1	3	6	6	5	3	3	10	3	4	-
Total Hardness	mg/L	253	111	153	148	253	74	156	141	291	125	177	168
Dissolved Organic Carbon	mg/L	21.4	15.8	24	24.0	20	17.3	22.5	25.3	21.5	16.8	24.5	24.5
Total Kjeldahl Nitrogen	mg/L	1.11	0.60-0.76	1.05	0.7	1.30	0.86	1.04	0.90	1.50	0.81	1.04	0.85
Total Ammonia	mg/L	0.23	<0.03	0.04	0.05	0.59-1.63	<0.05	-	-	0.82	0.05	0.14	0.07
Total Phosphorus	mg/L	0.027	0.034	0.029	0.045	0.038	0.031	0.025	0.028	0.099	0.031	0.055	0.037
Dissolved Phosphorus	mg/L	0.008	<0.02	0.015	0.014	<0.02	0.60	-	-	-	-	-	-
Metals (Total)													
Aluminum (Al)	mg/L	0.01	0.01	0.05	0.06	0.04	0.07	0.05	0.04	0.03	0.03	0.04	0.02
Arsenic (As)	mg/L	0.0002	0.0003	<0.0004	0.001	<0.0004	<0.0004	<0.005	0.001-<0.005	0.0004	0.0004	0.0002	0.0005
Cadmium (Cd)	mg/L	0.001	<0.002	<0.001	0.003	<0.0002-0.001	<0.0002	-	-	<0.001	<0.001	<0.001	<0.001
Chromium (Cr)	mg/L	0.003	0.002	0.002	0.006	<0.0004-0.01	<0.0004	-	-	<0.001	0.001	0.001	0.001
Copper (Cu)	mg/L	0.001	0.001	0.004	0.001	0.002	0.0008	-	-	<0.001	<0.001	<0.001	<0.001
Iron (Fe)	mg/L	1.37	0.56	0.84	1.14	2.42	0.79	-	-	6.2	1.06	2.71	1.17
Mercury (Hg)	mg/L	0.0001	<0.0002	<0.0002	<0.05	0.0001	0.0001	<0.0001	0.0001	0.0001	0.0001	<0.0001	0.0001
Vanadium (V)	mg/L	<0.002	0.0015	0.002	0.002	0.0005	0.0004	-	-	<0.001	0.001	<0.001	0.001
Zinc (Zn)	mg/L	0.003	0.0065	0.015	0.0205	0.013-0.03	0.011	-	-	0.0055	0.0015	0.001	0.011
Metals (Dissolved)													
Aluminum (Al)	mg/L	-	0.0315	0.0094	0.0269	-	0.0315	-	-	-	-	-	-
Arsenic (As)	mg/L	<0.00075	<0.0004	<0.0004-<0.0005	<0.001	0.0004	0.0005	0.00035	0.0004	0.0005	0.0005	0.00025	<0.0002-0.0003
Cadmium (Cd)	mg/L	<0.001	<0.0001	0.0001-<0.001	<0.0001	-	<0.0001	-	-	-	-	-	-
Chromium (Cr)	mg/L	0.004	<0.0004	<0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.005	0.003	<0.003
Copper (Cu)	mg/L	0.001	0.0013	0.0009-<0.001	0.0011	-	0.0013	-	-	-	-	-	-
Iron (Fe)	mg/L	0.48	1.03	0.12-0.41	0.25	-	1.03	-	-	-	-	-	-
Mercury (Hg)	mg/L	-	<0.0002	<0.0002	0.0002	-	<0.0002	-	-	-	-	-	-
Vanadium (V)	mg/L	<0.001	0.0001	<0.0001-<0.001	-	-	0.0001	-	-	-	-	-	-
Zinc (Zn)	mg/L	<0.001	0.008	0.001-0.017	-	-	0.008	-	-	-	-	-	-
Organics													
Naphthenic Acids	mg/L	-	1	<1	<1	<1	4	-	-	-	<1	<1	-
Recoverable Hydrocarbons	mg/L	-	0.5	<0.75	<1	2	<0.5	-	-	0.4	<0.1	0.15	0.25
PAHs and Alkylated PAHs	µg/L	-	-	ND	ND	ND	-	-	-	-	-	-	-
Target PANHs	µg/L	-	ND	ND	ND	ND	-	-	-	-	-	-	-
Phenolics	µg/L	-	ND	ND	ND	ND	-	-	-	-	-	-	-
Volatile Organics	µg/L	-	-	-	-	-	-	-	-	-	-	-	-
Toxicity													
Microtox IC50	%	-	>100	>100	100	>99	>91	-	-	-	>100	>100	-
Microtox IC25	%	-	>100	100	100	-	>91	-	-	-	>100	>100	-

NOTES: - = No data; ND = Not detected; PAH = Polycyclic aromatic hydrocarbon; PANH = Polycyclic aromatic nitrogen heterocycle
Median concentrations (n>2), ranges (n=2), or measured concentrations (n=1) are presented; data sources are listed by Golder (1997e)

Table D5-7 Water Quality of Jackpine Creek (1976-1997)

Parameter	Units	At Mouth				Lower Jackpine Creek				Upper Jackpine Creek			
		Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Conventional Parameters and Nutrients													
pH	-	7.1	7.6	7.6	7.8	7.5-8.0	7.3-8.3	7.7	7.5	7.75	7.62	7.7	7.6
Total Alkalinity	mg/L	134	74	126	101	141-303	56-99	136	182	272.7	79.2	127.6	110.0
Total Dissolved Solids	mg/L	136	84	142	124	147-385	74-117	168	202	330	108	145	125
Total Suspended Solids	mg/L	13.0	5.3	2.0	3	12.0	1.9	2.8	6.8	6	4.8	2.6	4.4
Total Hardness	mg/L	121.1	57.0	98.75	84.6	130.2-275.9	51.0-74.6	109.9	170.5	259.3	57.8	104.0	101.9
Dissolved Organic Carbon	mg/L	28	17	23	19	13-34	12.0-28.0	11.5-27.0	12.5-27.0	23.0	14.3	24.3	25.6
Total Kjeldahl Nitrogen	mg/L	0.45	0.82	1.29	0.80	0.5-1.23	0.86-1.02	0.91	0.64	0.86	0.80	1.04	0.82
Total Ammonia	mg/L	-	0.03	0.065	<0.05	-	-	0.12-0.22	-	1.60	0.05	<0.05	0.01-0.03
Total Phosphorus	mg/L	0.140	0.020	0.025	0.020	0.071	0.030	0.026	0.030	0.044	0.022	0.030	0.024
Dissolved Phosphorus	mg/L	-	-	-	0.013-0.014	-	-	-	-	<0.02	<0.02	-	-
Metals (Total)													
Aluminum (Al)	mg/L	0.07	0.09	0.05	0.04	0.03-0.07	0.08-0.34	<0.01	0.06	0.0475	0.07	0.055	0.04
Arsenic (As)	mg/L	-	0.0004	0.0050	0.0004	-	-	0.0080	0.0080-0.0200	<0.0004	0.0004	0.0004	0.0006
Cadmium (Cd)	mg/L	-	<0.001	<0.0055	<0.001	-	-	<0.01	-	<0.001	<0.0002	<0.001	<0.001-0.004
Chromium (Cr)	mg/L	-	<0.001	0.008	<0.0016	-	-	<0.01	-	<0.01	<0.0004	<0.001-0.004	<0.001-0.012
Copper (Cu)	mg/L	-	<0.001	0.003	0.0024	-	-	<0.005	-	0.0009	0.001	<0.001	<0.001
Iron (Fe)	mg/L	-	0.26-0.47	0.96	1.12	-	-	0.51-0.52	-	2.25-2.40	0.47	0.87-0.93	0.57-0.58
Mercury (Hg)	mg/L	<0.0001	<0.0001	<0.0001	<0.00005	<0.0001-0.0003	<0.0001	<0.0001	0.0002	0.0001	<0.0002	<0.0001	<0.0001
Vanadium (V)	mg/L	-	<0.001	<0.006	0.0014	-	-	<0.1	-	0.0004	0.0002	0.002-0.005	<0.002
Zinc (Zn)	mg/L	-	0.001-0.003	0.02	0.027	-	-	0.03-0.1	-	0.011-0.025	0.008	0.001-0.433	0.002-0.186
Metals (Dissolved)													
Aluminum (Al)	mg/L	-	-	-	0.058-0.092	-	-	-	-	-	-	-	-
Arsenic (As)	mg/L	0.0010	0.0007	0.0004	0.0010	<0.0001-0.0200	0.0011	0.0014-0.0040	< 0.0010	0.0003	0.001	0.0005	0.0003
Cadmium (Cd)	mg/L	-	-	-	<0.001	-	-	-	-	-	-	-	-
Chromium (Cr)	mg/L	0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.003	0.003	0.003	0.003	0.003
Copper (Cu)	mg/L	-	-	-	0.0022-0.0027	-	-	-	-	-	-	-	-
Iron (Pb)	mg/L	-	-	-	0.32-0.34	-	-	-	-	-	-	-	-
Mercury (Hg)	mg/L	-	-	-	<0.0002	-	-	-	-	-	-	-	-
Vanadium (V)	mg/L	-	-	-	0.0002-0.0003	-	-	-	-	-	-	-	-
Zinc (Zn)	mg/L	-	-	-	0.016-0.02	-	-	-	-	-	-	-	-
Organics													
Naphthenic Acids	mg/L	-	-	-	1	-	-	-	-	<1	<1	<1	<1
Recoverable Hydrocarbons	mg/L	-	<0.1	0.3	0.5	-	-	0.6-1.5	-	<1	<0.5	<0.5	<1
PAHs and Alkylated PAHs	µg/L	-	-	-	-	-	-	-	-	-	ND	ND	ND
PANHs	µg/L	-	-	-	-	-	-	-	-	-	ND	ND	ND
Phenolics	µg/L	-	-	-	-	-	-	-	-	-	ND	ND	ND
Volatile Organics	µg/L	-	-	-	-	-	-	-	-	-	ND	-	-
Toxicity													
Microtox IC50	%	-	-	-	-	-	-	-	-	>99	>91	100	>100
Microtox IC25	%	-	-	-	-	-	-	-	-	-	>100	>100	>100

NOTES: - = No data; ND = Not detected; PAH = Polycyclic aromatic hydrocarbon; PANH = Polycyclic aromatic nitrogen heterocycle
Median concentrations (n>2), ranges (n=2), or measured concentrations (n=1) are presented; data sources are listed by Golder (1997e)

Table D5-8 Water Quality of Other Muskeg River Tributaries (1976-1997)

Parameter	Units	Muskeg Creek				Shelley Creek			Upper Muskeg Creek Drainage			
		Winter	Spring	Summer	Fall	Winter	Spring	Summer	Winter	Spring	Summer	Fall
Conventional Parameters and Nutrients												
pH	-	7.2	7.2	7.7	7.4	7.2	7.3	7.8	7.8	7.8	7.7	7.6
Total Alkalinity	mg/L	168	79	115	109	284	60	106	233	84	140	112
Total Dissolved Solids	mg/L	196	87	123	125	290	70	129	260	93	146	125
Total Suspended Solids	mg/L	5	5	4	1	14	3	2	11	1	3	3
Total Hardness	mg/L	146	60	95	83	243	45	89	188	65	114	87
Dissolved Organic Carbon	mg/L	33.5	16.5	28.0	26.5	32.0	14.0	24.8	-	-	33.2	29.6
Total Kjeldahl Nitrogen	mg/L	1.71	1.13	1.22	0.82	2.33	0.92	0.20	1.48	0.67	0.84	0.87
Total Ammonia	mg/L	0.46	0.05	0.05	0.04	0.51	0.05	0.05	1.04	0.04	0.08	0.03
Total Phosphorus	mg/L	0.052	0.030	0.034	0.033	0.200	0.020	0.025	0.135	0.019	0.032	0.019
Dissolved Phosphorus	mg/L	< 0.02	< 0.02	< 0.02	-	< 0.02	< 0.02	< 0.02	-	-	-	-
Metals (Total)												
Aluminum (Al)	mg/L	0.04	0.07	0.03	0.02	0.05	0.04	0.038-0.043	0.04	0.02	0.06	0.02
Arsenic (As)	mg/L	0.0004	0.0003	<0.0005	0.0003	0.0011	0.0004	<0.0004	0.0011	0.0004	0.0009	0.0004
Cadmium (Cd)	mg/L	<0.001	<0.001	<0.001	<0.001	<0.0002	<0.0002	0.0002	<0.001	<0.001	<0.002	0.001
Chromium (Cr)	mg/L	<0.001	0.001	0.002	0.001	<0.0004	<0.0004	<0.0004-0.0018	<0.001	<0.001	< 0.0055	0.001
Copper (Cu)	mg/L	<0.001	<0.001	0.001	<0.001	0.0012	0.0012	0.0009-0.001	<0.001	0.001	<0.001	<0.001
Iron (Fe)	mg/L	1.15	0.47	0.61	0.39	7.92	0.09	0.39-0.61	3.30	0.43	0.64	0.46
Mercury (Hg)	mg/L	0.0001	<0.0001	<0.0001	0.0001	<0.0001	<0.0001	0.0001	<0.0001	<0.00005	0.00005	<0.000075
Vanadium (V)	mg/L	<0.001	<0.001	>0.002	<0.001	0.001	<0.0002	<0.0002-0.0007	<0.001	<0.001	<0.005	0.001
Zinc (Zn)	mg/L	0.0045	0.0065	0.0105	0.004	0.027	0.005	0.028-0.103	0.006	0.002	0.02	0.003
Metals (Dissolved)												
Arsenic (As)	mg/L	0.001	<0.0005	0.0004	0.0002	0.001	0.0005	0.0002-0.0005	-	-	-	-
Chromium (Cr)	mg/L	0.003	0.003	<0.003	<0.003	<0.003	0.003	-	-	-	-	-
Organics												
Naphthenic Acids	mg/L	1	<1	<1	<1	1	<1	<1	-	-	<1	<1
Recoverable Hydrocarbons	mg/L	1.1	<0.3	<0.3	0.4	<1	<0.5	<0.5	0.6	<0.1	0.7	<0.4
Toxicity												
Microtox IC50 @ 15 min	%	>99	91-100	>100	<100	>99	>91	-	-	-	>100	>100
Microtox IC25 @ 15 min	%	-	>100	>100	<100	-	-	-	-	-	>100	>100

NOTES: - = No data; ND = Not detected; median concentrations (n>2), ranges (n=2), or measured concentrations (n=1) are presented; data sources are listed by Golder (1997e)

Concentrations of total phosphorus and a number of metals exceeded chronic water quality guidelines in Isadore's Lake (Table D5-3). No guideline exceedances were found in Mills Creek. Overall, water quality in Isadore's Lake and Mills Creek can also be classified as good, and the guideline exceedances noted are of no concern to aquatic life.

D5.5 Relationship Between Total and Dissolved Metal Levels in Surface Waters

The available data were examined to see if there are general relationships between total and dissolved metal concentrations on a seasonal basis. In rivers with seasonally varying levels of suspended sediments, total metal levels tend to also fluctuate seasonally. However, because typically only a small fraction of the total metals is in the dissolved form, total metal measurements reveal little about the potential for biological effects during periods of high suspended sediment levels. Therefore, seasonal estimates of the proportions of dissolved and particulate forms of metals may advance our understanding of the potential effects of elevated levels of metals on aquatic biota.

Only limited data are available at the present regarding dissolved metal concentrations in the study area. However, some patterns are beginning to emerge (Table D5-11). In all rivers sampled, dissolved aluminum, cobalt, titanium and vanadium tend to form a small percentage of total metals. In contrast, antimony, calcium, sodium and strontium were mostly in the dissolved form. Other metals were either in the intermediate range (e.g., molybdenum), or the percentage of the dissolved form varied widely by season (e.g., iron).

Overall, percentages of dissolved metals were lower in the Athabasca River than in the Muskeg River basin, which reflects the generally higher suspended sediment levels in the Athabasca River. As well, seasonal variation in the percentage of dissolved metals was greater in the Athabasca River, as may be expected, since this river carries a seasonally variable sediment load, whereas suspended sediment level is relatively constant in the Muskeg River basin.

Table D5-9 Sediment Quality in the Muskeg River and Jackpine Creek in 1997

Parameter	Units	Muskeg River at Mouth	Muskeg River upstream Jackpine Creek	Jackpine Creek at Mouth
Total Organic Carbon	%	2.98	4.5	2.0
Recoverable Hydrocarbons	µg/g	3440	3690	5660
Metals				
Aluminum (Al)	µg/g	2970	5820	3060
Arsenic (As)	µg/g	1.0	2.4	1.2
Cadmium (Cd)	µg/g	<0.5	<0.5	<0.5
Chromium (Cr)	µg/g	6.9	12.3	7.8
Copper (Cu)	µg/g	7	10	7
Iron (Fe)	µg/g	11200	23000	5430
Lead (Pb)	µg/g	<5	<5	<5
Mercury (Hg)	µg/g	0.04	0.04	0.03
Molybdenum (Mo)	µg/g	<1	<1	<1
Nickel (Ni)	µg/g	6	9	6
Vanadium (V)	µg/g	9	16	11
Zinc (Zn)	µg/g	26.4	37.9	22.2
PAHs				
Phenanthrene	µg/g	0.007	0.009	<0.003
Fluoranthene	µg/g	0.003	0.006	0.004
Pyrene	µg/g	0.012	0.015	0.006
Benz(a)anthracene/Chrysene	µg/g	0.035	0.057	0.034
Benzo(a)pyrene	µg/g	0.013	0.016	0.015
Total PAHs	µg/g	1.712	3.888	2.027

NOTES: PAH = Polycyclic aromatic hydrocarbon

Table D5-10 Water Quality of Isadore's Lake and Mills Creek in 1997

Parameter	Units	Isadore's Lake			Mills Creek	
		Winter	Summer	Fall	Spring	Fall
Conventional Parameters and Nutrients						
pH	-	7.2	8.4	8	8	8
Total Alkalinity	mg/L	287	129	136	237	237
Dissolved Organic Carbon	mg/L	15	11	9	5	7
Total Dissolved Solids	mg/L	290	236	220	390	894
Total Suspended Solids	mg/L	24	2	6	7	<2
Total Hardness	mg/L	277	154	164	345	319
Total Kjeldahl Nitrogen	mg/L	0.8	0.4	0.4	<0.2	<0.2
Total Ammonia	mg/L	0.51	<0.05	0.11	<0.05	<0.05
Total Phosphorus	mg/L	0.14	0.016	0.012	0.042	<0.002
Dissolved Phosphorus	mg/L	<0.02	0.008	0.012	0.05	<0.002
Metals (Total)						
Aluminum (Al)	mg/L	0.368	0.018	0.062	0.055	0.031
Arsenic (As)	mg/L	0.0011	<0.0004	0.0018	<0.0004	<0.0004
Cadmium (Cd)	mg/L	<0.0002	<0.0002	0.0003	<0.0002	<0.0002
Chromium (Cr)	mg/L	<0.0004	0.0014	<0.0004	<0.0004	<0.0004
Copper (Cu)	mg/L	0.0012	0.0009	0.0066	0.0008	0.0008
Iron (Fe)	mg/L	7.92	0.21	<0.01	0.82	0.05
Mercury (Hg)	mg/L	<0.0002	0.0001	<0.0001	<0.0002	<0.0001
Vanadium (V)	mg/L	0.0009	0.0004	<0.0002	<0.0002	<0.0001
Zinc (Zn)	mg/L	0.027	0.013	0.012	0.009	0.008
Metals (Dissolved)						
Aluminum (Al)	mg/L	-	-	0.0346	-	0.023
Arsenic (As)	mg/L	-	-	0.0016	-	<0.0004
Cadmium (Cd)	mg/L	-	-	0.0003	-	<0.0001
Chromium (Cr)	mg/L	-	-	<0.0004	-	<0.0004
Copper (Cu)	mg/L	-	-	0.0015	-	0.0013
Iron (Fe)	mg/L	-	-	0.02	-	0.03
Mercury (Hg)	mg/L	-	-	<0.0002	-	<0.0002
Vanadium (V)	mg/L	-	-	0.0001	-	<0.0001
Zinc (Zn)	mg/L	-	-	0.017	-	0.01
Organics						
Naphthenic Acids	mg/L	1	<1	1	<1	<1
Recoverable Hydrocarbons	mg/L	<1	<0.5	<0.5	<0.5	<0.5
Phenolics	mg/L	-	<0.001	<0.001	<0.001	<0.001
Volatile Organics	µg/L	-	-	-	-	-
Toxicity						
Microtox IC50	%	>99	-	-	>91	-
Microtox IC25	%	-	-	-	>91	-

NOTES: - = no data; measured values (n = 1) are presented
Data sources are listed by Golder (1997e)

D5.6 Muskeg Drainage Water

Muskeg drainage water refers to the water released from muskeg, which covers large areas in the Muskeg River basin. It constitutes a large proportion of stream flow during the open-water season. Large volumes of muskeg drainage water are expected to enter surface waters during muskeg dewatering, which occurs during the initial phase of oil sands mine development. The available information on muskeg water was summarized to provide background information on the characteristics of these waters.

In the Muskeg River and Jackpine Creek, the proportions of total flow contributed by muskeg drainage water, groundwater and precipitation vary considerably by season under natural conditions (Schwartz 1980). Baseflow in winter is contributed almost exclusively by groundwater. The makeup of spring flows is highly variable, and includes precipitation (snowmelt), groundwater and muskeg water in rapidly changing proportions. From late spring to freeze up, muskeg drainage contributes an average of 80% of stream flow in Jackpine Creek and about 60% of the flow in the Muskeg River.

The quality of muskeg drainage waters has not been characterized in detail, with the exception of major ion concentrations (Schwartz 1980). A few samples of muskeg drainage water were collected by Syncrude in the Aurora Mine area and were analyzed for a wider variety of parameters.

Most pH measurements were between 6 and 8, but pH exhibited a wide range (1.98 to 9.15) in samples collected by Schwartz (1980). Calcium was the dominant cation in muskeg waters, with lower concentrations of sodium and magnesium, while bicarbonate dominated the anions (Table D5-12). Concentrations of most ions varied seasonally in 1978, but within a relatively narrow range (Schwartz 1980).

Table D5-11 Dissolved Metals Expressed as the Percentage of Total Metals in Surface Waters

Metal	Athabasca River			Muskeg River Basin		
	Spring (n=3)	Summer (n=1)	Fall (n=1)	Spring (n=1)	Summer (n=1)	Fall (n=3)
Aluminum (Al)	6	<1	2	14	13	7
Antimony (Sb)	-	83	100	-	100	-
Arsenic (As)	52	11	40	-	-	-
Barium (Ba)	59	22	52	75	87	68
Boron (B)	70	55	79	87	100	99
Cadmium (Cd)	-	100	-	-	-	-
Calcium (Ca)	89	54	92	-	89	-
Chromium (Cr)	19	-	-	-	-	-
Cobalt (Co)	42	3	25	-	-	15
Copper (Cu)	57	33	100	100	12	50
Iron (Fe)	23	<1	-	100	59	24
Lead (Pb)	40	9	92	93	-	46
Lithium (Li)	66	28	64	83	91	88
Manganese (Mn)	57	2	14	92	49	49
Molybdenum (Mo)	49	50	83	65	45	16
Nickel (Ni)	70	22	32	-	50	28
Potassium (K)	59	80	53	-	84	-
Silicon (Si)	24	8	-	62	87	94
Sodium (Na)	100	100	93	-	87	-
Strontium (Sr)	84	68	91	89	89	89
Titanium (Ti)	4	1	1	22	29	4
Uranium (U)	58	34	73	-	-	-
Vanadium (V)	11	-	2	25	-	11
Zinc (Zn)	28	42	68	73	100	73

NOTE:
Data from 1997 RAMP field program
- = no data

Comparison of the Syncrude data with seasonal medians for streams in the Muskeg River basin indicates that muskeg drainage waters are similar to surface waters sampled during the winter (Table D5-12). Major ion composition of muskeg water was very similar to that in stream samples, but nutrient levels were generally lower in muskeg water. Levels of metals in muskeg water were similar to those in surface waters, or in some cases higher in muskeg water, but total metal measurements likely reflect the higher suspended sediment level in the Syncrude samples.

Concentrations of aluminum, iron and manganese in muskeg water exceeded chronic water quality guidelines (Table D5-3). These exceedances were likely caused by the elevated suspended sediment level in Syncrude's muskeg water samples.

In summary, the limited data available on the quality of muskeg drainage waters suggest that these waters are not substantially different from stream water in the Muskeg River basin during the winter.

Table D5-12 Water Quality of Muskeg Drainage Waters Compared with Stream Water in the Muskeg River Basin

Parameter	Units	Muskeg Drainage Water[1]	Muskeg Drainage Water[2]	Muskeg River, Jackpine Creek, Shelley Creek and Muskeg Creek (Seasonal Median Values)			
				Winter	Spring	Summer	Fall
Conventional Parameters and Major Ions							
pH	-	7.13	-	7.45	7.60	7.80	7.60
Conductance	µS/cm	481	137	480	167	255	226
Total Dissolved Solids	mg/L	263	-	300	111	174	156
Total Suspended Solids	mg/L	29	-	6	5	3	3
Calcium	mg/L	85.0	17.0	69.0	20.0	33.1	30.0
Magnesium	mg/L	12	4.9	17.1	6.0	9.0	8.5
Potassium	mg/L	0.9	0.6	1.5	1.3	0.5	0.8
Sodium	mg/L	4.4	4.1	15.1	8.2	11.8	12.3
Bicarbonate	mg/L	317	81	349	100	171	183
Chloride	mg/L	<0.05-<0.5	2.4	4.75	1.7	2.1	2.0
Sulphate	mg/L	<0.1-3.1	5.9	5.1	4.1	4.5	3.3
Total Hardness	mg/L	261	-	242	72	116	111
Total Alkalinity	mg/L	260	-	256	85	141	119
Total Organic Carbon	mg/L	10.2	-	25.0	18.0	25.5	25.5
Dissolved Organic Carbon	mg/L	9.8	-	23.0	15.8	24.0	24.0
Biochemical Oxygen Demand	mg/L	6.4	-	1.5	1.0	0.8	1.7
Total Phenolics	mg/L	<0.001	-	0.007	0.009	<0.001	0.002
Nutrients							
Nitrate + Nitrite	mg/L	<0.03-0.016	-	0.100	<0.003	<0.1	<0.05
Total Ammonia	mg/L	0.17	-	0.53	<0.05	<0.05	0.04
Total Kjeldahl Nitrogen	mg/L	0.34	-	1.30	0.83	<0.20	0.82
Total Phosphorus	mg/L	<0.1	-	0.052	0.030	<0.005	0.031
Metals (Totals)							
Aluminum (Al)	mg/L	0.33	-	0.04	<0.01	<0.005	<0.01
Cadmium (Cd)	mg/L	<0.0002	-	<0.001	<0.001	<0.001	<0.001
Chromium (Cr)	mg/L	0.011	-	<0.001	<0.001	<0.001	<0.001
Copper (Cu)	mg/L	0.0035	-	<0.001	<0.001	<0.001	<0.001
Iron (Fe)	mg/L	4.44	-	1.41	0.56	0.84	0.925
Lead (Pb)	mg/L	<0.0003	-	0.002	<0.02	<0.02	<0.002
Manganese (Mn)	mg/L	0.357	-	0.487	0.024	0.041	0.053
Vanadium (V)	mg/L	<0.002-0.005	-	<0.001	<0.001	<0.001	<0.001
Zinc (Zn)	mg/L	0.020	-	0.008	0.006	<0.001	0.016

NOTES: - = no data

[1]Median values or range (n=4); data from Syncrude, Aurora Mine, February and March, 1997.

[2]Means for 144 samples of standing water in muskeg (Schwartz 1980).

D6 AQUATIC RESOURCES

D6.1 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 fish resources in the Study Area, including identification of the species composition, distribution, relative abundance, movements and general life history parameters;
- discussions of the relevance of the fish resources to existing or potential domestic, sport or commercial fisheries;
- description and mapping, as appropriate, of the fish habitat of the Athabasca River, Muskeg River and other tributaries likely to be affected by the Project; and
- identification of critical or sensitive habitats such as spawning, rearing, overwintering and migration areas (TofR, Section 4.9).

Project-specific impacts on aquatic resources are addressed in Section E6 of this EIA. Cumulative effects on aquatic resources are addressed in Section F6.

Studies of aquatic ecosystems routinely include investigations of benthic invertebrates (i.e., bottom-dwelling organisms), fish habitat and fish communities. This type of information is summarized in this section from a variety of historical and recent sources (Bond 1980, R.L.& L. 1989, Golder 1996b, 1996c, 1997d and 1998a). For more details on aquatic resources in the LSA see the Aquatic Resources Baseline Study for the Muskeg River Mine Project (Golder 1997d).

This section presents information on aquatic resources for waterbodies within the Local Study Area (LSA). These include the Athabasca River, the Muskeg River and its tributaries, ponds within the Muskeg River basin, the Alsands Drain and Isadore's Lake (Figure D6-1).

D6.2 Athabasca River

D6.2.1 Benthic Invertebrates

The Athabasca River in the oil sands area is wide and carries a considerable silt load during the summer months. It provides relatively low quality, largely depositional habitat for benthic invertebrates.

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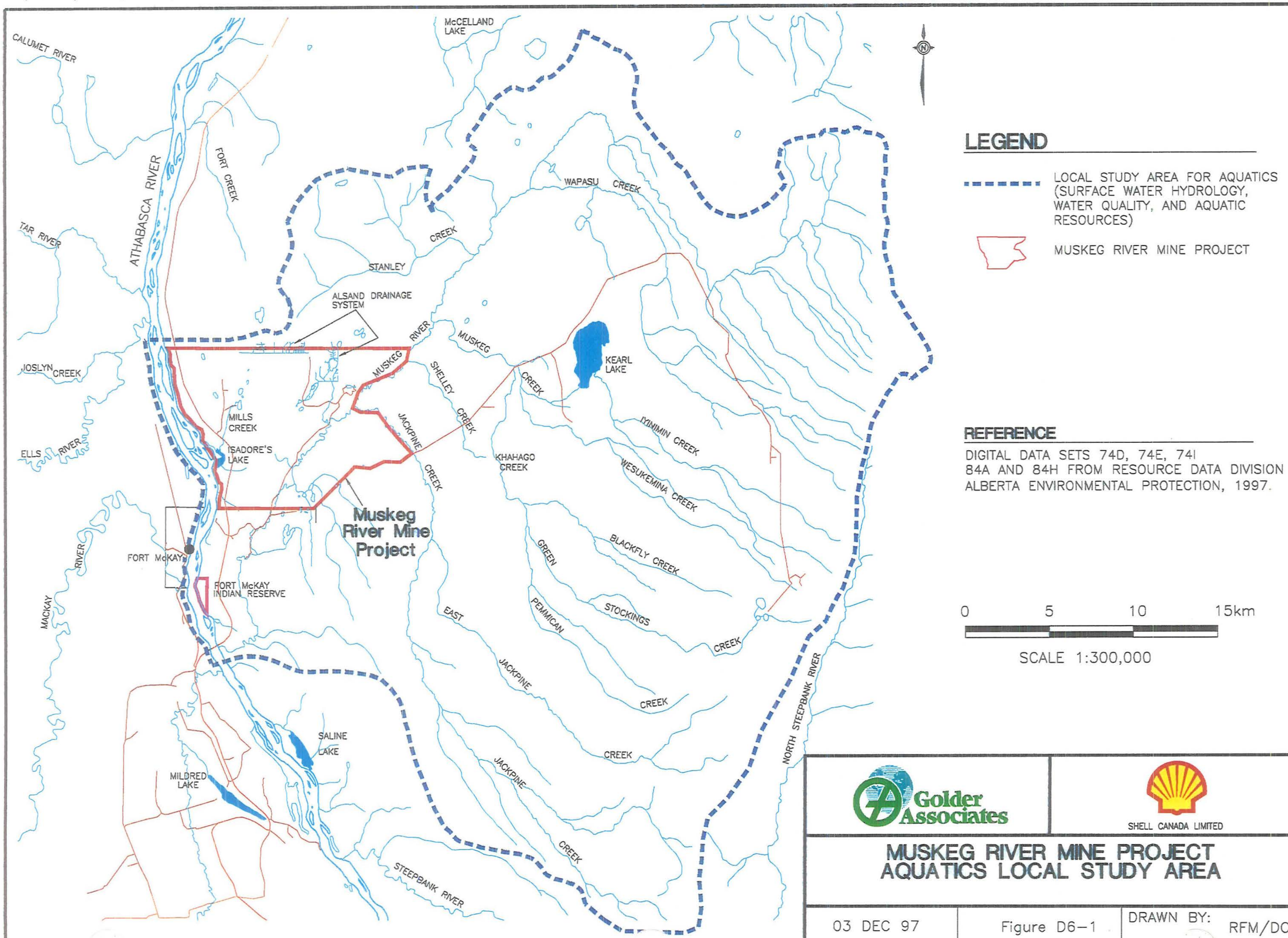

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MUSKEG RIVER MINE PROJECT AQUATICS LOCAL STUDY AREA

03 DEC 97	Figure D6-1	DRAWN BY: RFM/DC

Bottom sediments of the lower Athabasca River support a relatively homogeneous benthic fauna, characterized by low density and number of species, consisting largely of chironomid midge larvae, oligochaete worms and nematode worms (Anderson 1991). More diverse communities were documented on artificial substrate (AS) samplers used for monitoring oil sands-related discharges. Since AS provides ideal colonization habitat for invertebrates, this finding is consistent with expectations. These samplers were colonized by representatives of several pollution-sensitive invertebrate groups (e.g., Ephemeroptera, Plecoptera and Trichoptera), in addition to invertebrates found in bottom sediments (McCart et al. 1977, Noton 1979, Noton and Anderson 1982, Golder 1996b).

Studies have documented minor, localized effects of water release from oil sands operations. Reductions in invertebrate density and taxonomic richness below Suncor's Tar Island Dyke refinery wastewater and sewage outfalls were reported by Noton (1979), Noton and Anderson (1982) and Boerger (1983). Results of recent benthic surveys suggest that such effects are absent below areas of discharge from oil sands operations (Golder 1994a, 1996b). However, these studies did not sample immediately below discharge areas, so localized effects cannot be ruled out.

D6.2.2 Fish Habitat

Fish habitat in the Athabasca River near the Muskeg River Mine Project was mapped in 1996 and 1997 (Golder 1996b, 1998a). The most recent habitat maps of this reach of the river are presented in the Regional Aquatics Monitoring Program (RAMP) report (Golder 1998a).

The Athabasca River has turbid cool-water habitat and dynamic shifting-sand channels (Golder 1996b). In the LSA, single channels are the major channel type, but near islands and sand bars, multiple channels are present (Golder 1998a). Major habitat features include backwaters and snyes associated with islands and sandbars. The substrate is almost entirely sand. Instream cover is minimal except for that provided by depth and turbidity. River banks are mainly armoured or erosional with some depositional areas and cliffs.

Fish habitat in the Athabasca River is relatively poor due to the homogeneous habitat and shifting-sand bottom. Fish are usually associated with distinct habitat features such as backwaters, snyes and tributary mouths (Golder 1996b, 1998a). The Athabasca River is an important migratory corridor for fish that move from overwintering and feeding areas to spawning areas in tributaries or rapids (e.g., lake whitefish, longnose sucker) (Golder 1996b).

D6.2.3 Fish Communities

Several fish surveys of the Athabasca River have been conducted within the LSA. These include:

- The Regional Aquatics Monitoring Program (RAMP) of 1997 (Golder 1998a);
- Inventories conducted by Syncrude in 1996 and from 1989 to 1991 (Golder 1996c, Syncrude unpublished data);
- The Northern River Basins Study (NRBS) fish inventories (R.L.&L. 1994); and
- The Alberta Oil Sands Environmental Research Program (AOSERP) (McCart et al. 1977, Bond 1980, Tripp and McCart 1979, Tripp and Tsui 1980).

Fish species occurrence and habitat use of the Athabasca River is presented in Table D6-1 and shown in Figure D6-2. Twenty-seven species have been reported historically from the Athabasca River in the LSA (Bond 1980). In the 1997 RAMP fisheries inventories, a total of 14 species were captured in the reach of river from the mouth of the Muskeg River to approximately the northern boundary of Lease 13 (Table D6-1). Similar species composition was also found in 1996 (Golder 1996b). Species abundance and distribution patterns are similar to those reported by the AOSERP studies of the late 1970s (McCart et al. 1977, Bond 1980, Tripp and McCart 1979, Tripp and Tsui 1980) and the recent NRBS fish inventories (R.L.&L. 1994).

Fish species that use the Athabasca River near the LSA fall into two categories: migratory populations and resident fish species. Most of the large fish species are migratory. The resident populations are those which overwinter in the system (Table D6-1).

Recent and historical studies indicate that goldeye, walleye, white sucker and longnose sucker are the most abundant large fish species in the Athabasca River near the LSA (Bond 1980, Golder 1996c, 1998a).

Historical studies report that immature goldeye migrate from Lake Athabasca to feed in the lower reaches of the Athabasca River in the spring. In 1995, 1996 and 1997, a small proportion of goldeye captured in the Athabasca River in the oil sands area were found in spawning condition (Golder 1996b, 1996c, 1998a).

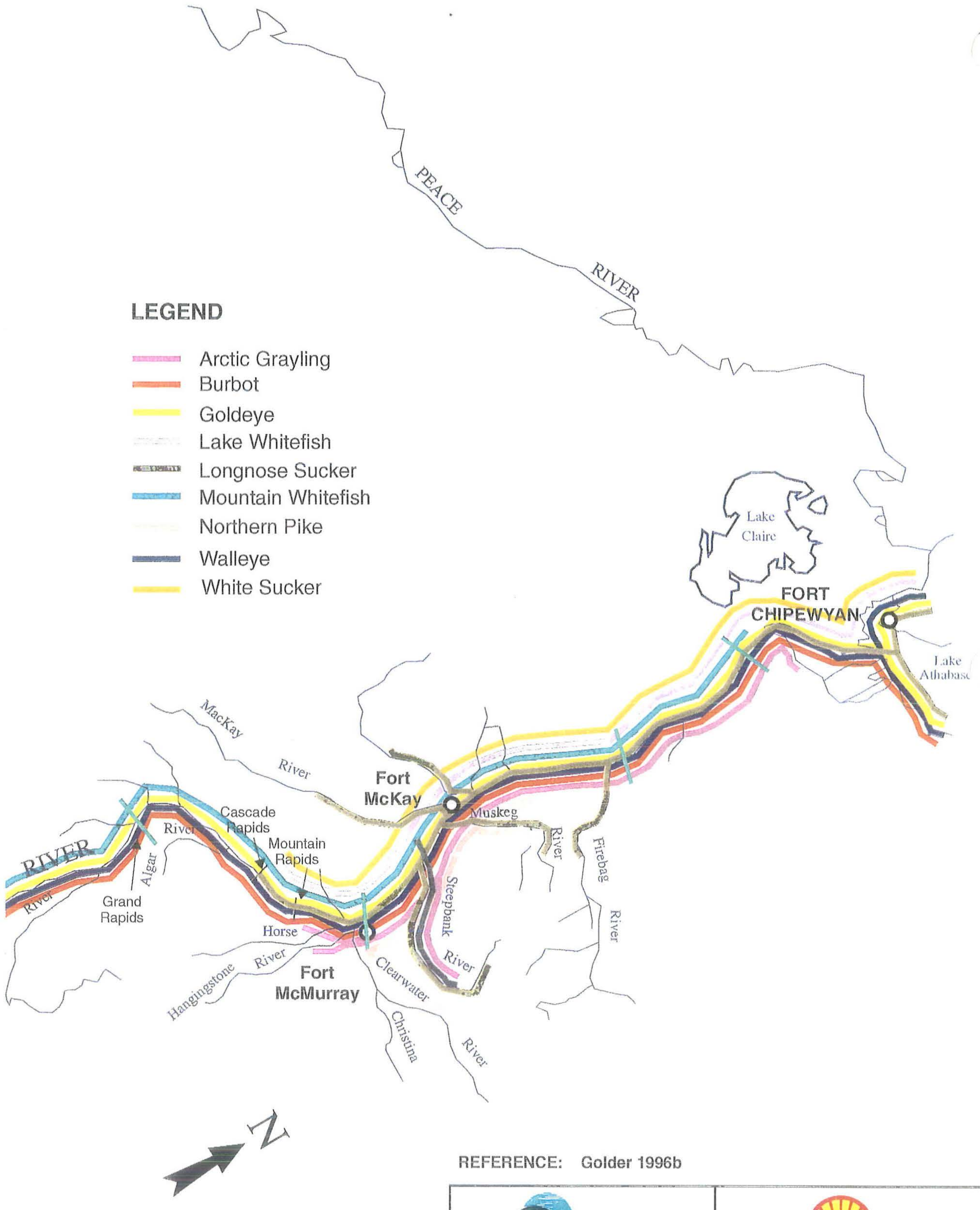
Table D6-1 Fish Species Use of the Athabasca River in the LSA

Species	1997 Study[b]	1996 Study[c]	Past Studies[d]	Spawning	Rearing	Feeding	Overwintering	Migrating
Arctic Grayling [a]			●			✓	✓	✓
Burbot [a]	●	●	●	✓	✓	✓		✓
Emerald Shiner [a]	●	●	●	✓	✓	✓	✓?	✓
Flathead Chub [a]	●	●	●	✓	✓	✓	✓?	
Goldeye [a]	●	●	●	✓?	✓	✓		✓
Lake Chub [a]	●	●	●	✓	✓	✓	✓	
Lake Whitefish [a]	●	●	●			✓		✓
Longnose Sucker [a]	●	●	●		✓	✓		✓
Northern Pike [a]	●	●	●			✓	✓	
Spottail Shiner [a]	●	●	●	✓	✓	✓	✓	
Trout Perch [a]	●	●	●		✓	✓	✓	
Walleye [a]	●	●	●		✓	✓		✓
White Sucker [a]	●	●	●		✓	✓		✓
Brassy Minnow			●			✓		
Brook Stickleback			●			✓		
Bull Trout			●			✓		
Fathead Minnow			●			✓		
Finescale Dace			●			✓		
Iowa Darter			●			✓		
Longnose Dace			●			✓		
Mountain Whitefish	●	●	●			✓		
Ninespine Stickleback			●			✓		
Northern Redbelly Dace			●			✓		
Pearl Dace			●			✓		
River Shiner	●							
Slimy Sculpin			●	✓	✓	✓	✓	
Spoonhead Sculpin			●			✓		
Yellow Perch		●	●			✓		

(a) Common, widespread species in the Athabasca River. Note that Arctic grayling are mainly found in the tributaries during the open-water season.
(b) Golder 1998a.
(c) Golder 1996b.
(d) Data from Bond 1980, McCart et al. 1977, Tripp and McCart 1979, Tripp and Tsui, 1980, R.L. & L. 1994, Syncrude's unpublished fish inventories 1989-91, Golder 1996b, 1996c and 1998a.
● present in study area
✓kind of habitat use
? may use habitat but use not confirmed

Walleye also move upstream in the spring to spawn. The Athabasca River near the Muskeg River Mine Project area provides important rearing and summer feeding habitat for walleye. Walleye spawning locations have not been located with certainty but there is evidence that they spawn at the rapids upstream of Fort McMurray (Tripp and McCart 1979). A radiotelemetry study, currently under way as part of the RAMP program, may provide information on walleye spawning areas (Golder 1998a).

Longnose sucker and white sucker migrate upstream in the spring and move into the tributaries to spawn (Tripp and McCart 1979, McCart et al. 1977). Shortly after spawning, they move back into the Athabasca River, and remain there to feed for the rest of the open-water season (Golder 1996b).



REFERENCE: Golder 1996b

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Fish Use of the Athabasca River

3 December 1997	Figure D6-2	DRAWN BY: RPunzalan

I:\1997\2237\AQUATICS\FISHUSE2.CDR project# 972-2237.6070

Other game and commercial fish species captured in the Athabasca River include lake whitefish, mountain whitefish, burbot, northern pike, Arctic grayling and yellow perch (Golder 1996b, 1996c, 1998a).

Lake whitefish spawn in the rapids upstream of Fort McMurray in the fall. The LSA, particularly the mouths of tributaries, is an important feeding and resting area for lake whitefish moving upstream to spawn (Golder 1998a).

Mountain whitefish also migrate within the Athabasca River system. They are found in low abundance in the Athabasca River near the LSA. Feeding migrations of mountain whitefish often occur in the tributaries, but spawning and overwintering locations are unknown (Bond 1980).

Burbot are found in the mainstream Athabasca River in low abundance throughout the open-water season, although in the summer some burbot are thought to migrate back to Lake Athabasca to avoid warm-water temperatures (Bond 1980). Burbot spend part of the winter in Lake Athabasca but migrate into the river to spawn during late winter (January or February). Burbot spawning has been documented in the Athabasca River near Suncor (Bond 1980).

Northern pike do not move as far afield as other large fish species in the Athabasca River (Tripp and McCart 1979). They spawn in the tributaries and in a few areas of the Athabasca River that have flooded vegetation. Northern pike are thought to overwinter in the Athabasca River (Tripp and McCart 1979).

Similarly, Arctic grayling spawn in the tributaries and remain there until late fall when most return to the Athabasca River (Machniak and Bond 1979, Golder 1996b).

Yellow perch are uncommon in the Athabasca River but reside in some of the tributaries (Tripp and Tsui 1980).

The major small fish species in the Athabasca River near the LSA are fathead chub, spottail shiner, lake chub, trout-perch, slimy sculpin and emerald shiner. Most of these species are found in the Athabasca River year-round, except for emerald shiner, which are thought to overwinter in the Athabasca Delta and then migrate into the Athabasca River to spawn (Bond 1980). Fathead chub is one of the most common small fish species (McCart et al. 1977). They are generally confined to the mainstem and rarely enter the tributaries. Spottail shiner also reside primarily in the mainstem Athabasca River. In contrast, lake chub are common in both the mainstem Athabasca River and in the tributaries. They likely spawn in the lower reaches of the tributaries and overwinter in both the tributaries and the Athabasca River. Trout-perch also spawn in the tributaries but feed and overwinter in the Athabasca River (McCart et al. 1977). Slimy sculpin are found in both the tributaries and the Athabasca River.

D6.3 Muskeg River Basin

D6.3.1 Benthic Invertebrates

Benthic communities in the Muskeg River and several of its tributaries were characterized during the 1980s (Beak 1986, R.L.&L. 1989) and in 1995 (Golder 1996b).

In 1985 and 1988, stream sites were classified as pool, riffle or run habitat. Pool sites supported slightly fewer taxa and lower numbers of invertebrates than other habitats. All habitats were dominated by chironomid midges and other dipterans, followed by non-insect taxa and the aquatic insect groups Ephemeroptera, Trichoptera and Plecoptera. The percentage of insects was slightly higher at riffle sites than at pool or run sites, and the benthic invertebrate community was dominated by detritivores at all sites.

In 1995, benthic communities also reflected the habitats sampled. Stream sites were classified as depositional or erosional habitat. Depositional sites typically supported invertebrate communities with moderate density and low taxonomic richness, consisting almost exclusively of oligochaete worms, nematode worms and chironomid midge larvae. Erosional sites supported less dense invertebrate communities, but a greater variety of invertebrates. The structure of benthic communities, in terms of relative proportions of functional feeding groups, was consistent with habitat type; i.e., detritivores in depositional habitat and mostly scrapers in erosional habitat.

Qualitative examination of a subset of the available data for stream sites in the Muskeg River basin and Kearl Lake revealed that invertebrate density may vary considerably among years. Large year-to-year variability was found in density in the Muskeg River, Iyinimin Creek and Kearl Lake. In contrast, numbers remained similar in three other streams. Taxonomic richness was low and variable in fall samples in all three years, with lowest values in Kearl Lake.

Taxonomic composition has varied little during the last decade. All stream sites, with the exception of Iyinimin Creek, were numerically dominated by chironomid midges and non-insect taxa. This is typical of the Muskeg River basin, where the predominant lotic habitat is depositional and is characterized by slow current velocity and large amounts of organic material in the sediments. The Iyinimin Creek site supported a relatively large proportion of stonefly nymphs (Plecoptera), which is consistent with the erosional habitat reported for this site by all three surveys. The fauna of the Jackpine Creek site was unique, since it included a relatively constant proportion of mayfly nymphs (Ephemeroptera), which were nearly absent from other stream sites selected for this comparison. Kearl Lake supported the simplest community, which consisted largely of chironomid midges and oligochaete worms.

D6.3.2 Fish Habitat

Muskeg River

Fish habitat in the Muskeg River has been characterized by Machniak and Bond (1979) and Walder et al. (1980). They classified the river into six reaches based on stream gradient, flow characteristics, substrate and channel form (e.g., straight, irregular, meander). Habitat mapping of representative areas within these reaches has been conducted by O'Neil et al. (1982), Beak (1986), R.L. & L. (1989) and Golder (1996b, 1997d).

Reach 1, in the area of the river mouth, is a fairly straight reach that extends for 0.5 km (O'Neil et al. 1982, 1989, Golder Associates 1996a). The next 8.5 km comprise Reach 2, which has irregular meanders. Both reaches have a high gradient and are characterized by runs, riffles and pools. Fast, low-quality, shallow runs are predominant at the mouth, with the occasional riffle and pool. Farther upstream in Reach 2, pools are more common. Substrate composition in these reaches is mainly gravel and cobble with very little evidence of sedimentation. Near the mouth, banks are less than 1 to 3 m high, while farther upstream in Reach 2, there are cliffs that range from 10 m to 20 m.

Reach 3 is about 7.5 km (Walder et al. 1980). Characteristics of Reach 3 are intermediate between Reaches 2 and 4. It has a lower gradient than Reach 2, but still has gravel substrate and runs interspersed with riffles and pools (R.L.&L. 1989). However, the runs are deep and slow, a characteristic that is representative of Reach 4.

Reach 4 is very long (over 60 km) and represents the most common type of habitat in the Muskeg River. Here the river has slow, deep runs and tortuous meanders. Substrate in the runs consists mainly of organic debris and silt with a few large boulders. Riffles are uncommon but there are a few associated with cobble substrate. Beaver activity is common and there are many dams causing ponding.

Reaches 5 and 6 encompass the headwaters of the Muskeg River and although exhibiting a relatively high gradient, contain large numbers of beaver impoundments, debris, pools and fine/silted substrates.

The Project is within Reach 4 of the Muskeg River. Habitat maps from fall 1995 and 1997 for a portion of the river within the Project area are shown in Figures D6-3 and D6-4. Table D6-2 shows the relative proportions of habitat features in the two years, which differed significantly in flow conditions. In 1995, flow was low (discharge 1.8 m^3/s). Several beaver dams were present and there was a small proportion of riffles. Under high flow conditions in fall 1997 (discharge 21 m^3/s), no riffles or beaver dams were present and some deep pools were noted.

Table D6-2 Habitat Features in the Muskeg River in 1995 and 1997

Habitat Feature	Percent Composition	
	Fall 1995 (Discharge 1.8 m^3/s)	Fall 1997 (Discharge 21 m^3/s)
Run	83.6%	81.4%
Riffle	1.8%	0 %
Pool	0%	4.0%
Backwater	14.6%	14.6%
Number of Beaver Dams	3	0

Jackpine Creek

Jackpine Creek has five fairly distinct reaches that differ mainly in stream gradient (Bond and Machniak 1979, O'Neil et al. 1982). The lower 3.4 km have a low gradient that results primarily in slow runs and tortuous meanders. Beaver activity is abundant in this area (R.L.&L. 1989, Golder 1996b). The second reach (from 3.4 to 7.4 km) has a slightly higher gradient, more habitat diversity and fewer meanders than the lower reach. Beaver dams are also common in this stretch of river, resulting in flat flow characteristics interspersed with run-riffle-pool sequences. In the third reach, the stream gradient is higher and cobble/gravel substrate is common. Riffle/run/pool sequences are predominant. Habitat in Reach 3 is high quality, particularly for Arctic grayling (O'Neil et al. 1982). Reach 4 (from 9.4 to 14.9 km) has a moderate gradient and similar flow and meander pattern to Reach 2. The upper reach of Jackpine Creek is similar to the lower reach; low gradient with meanders.

Other Muskeg River Tributaries

The Muskeg Creek subwatershed is located east of Jackpine Creek (Figure D6-5). Muskeg Creek drains Kearl Lake. These watercourses have mainly moderate quality run/pool habitat, except for a high-gradient section in the middle of Muskeg Creek that contains riffles. Khahago and Blackfly creeks constitute the southwest drainage into Muskeg Creek. The low-quality habitat in Khahago Creek is characterized by deep, slow or flat runs and organic/silt substrate. Blackfly Creek, which discharges into Khahago Creek, has a higher-quality habitat with a higher gradient. It flows through an area where white spruce provide overhead cover and in-stream cover from dead snags is abundant. Iyinimin Creek drains the southeast part of the Muskeg Creek watershed into Kearl Lake. The upper reach of this creek has a high gradient and flows through similar terrain as Blackfly Creek, while the lower reach offers low-quality habitat with meanders.

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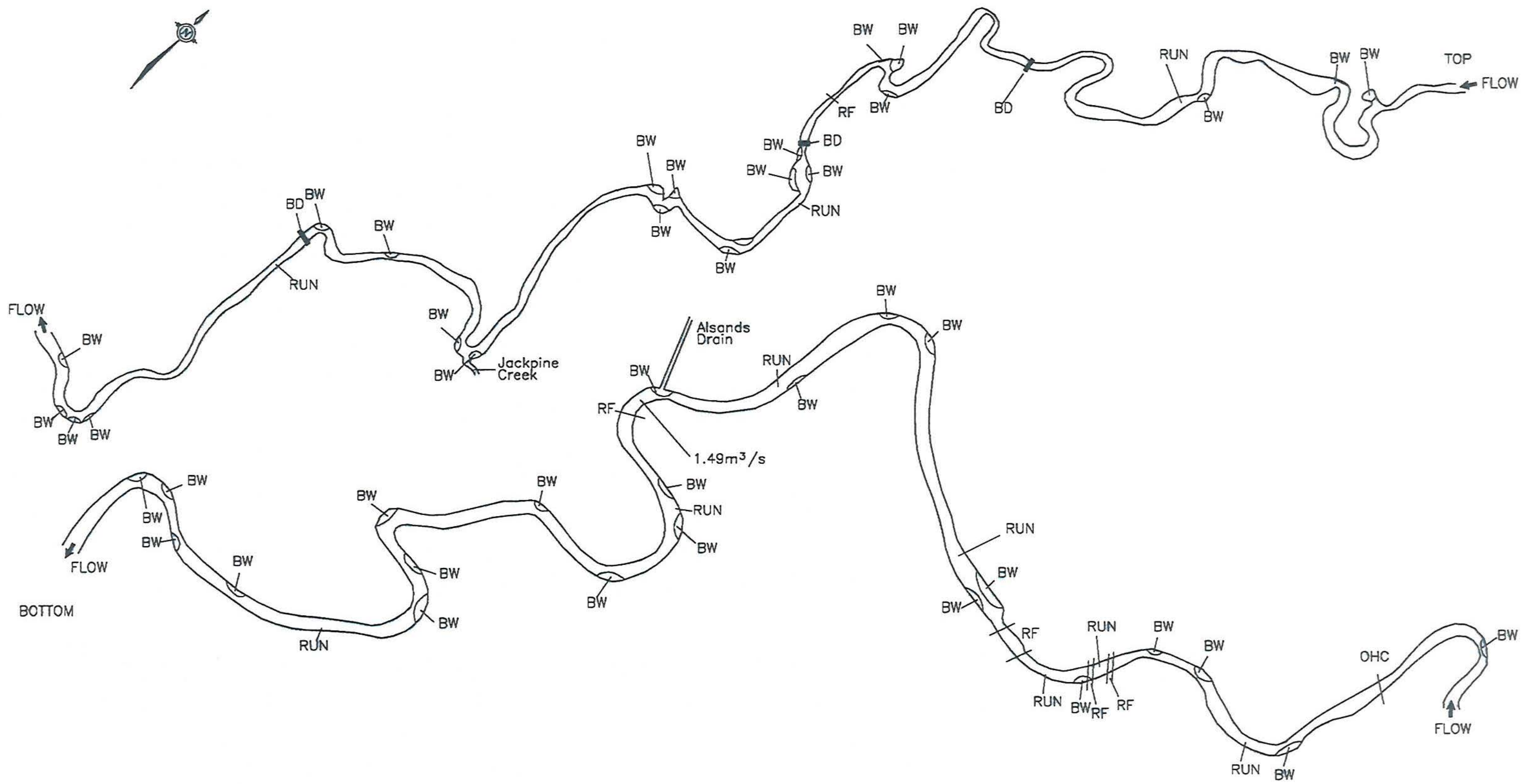

LEGEND

RF – Riffle
BW – Backwater
BD – Beaver dam
OHC – Overhead cover

0 100 200 300 400 500m
SCALE 1:10,000

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HABITAT MAP OF THE MUSKEG RIVER, SPRING 1995

01 DEC 1997	Figure D6–3	DRAWN BY: VS/TM

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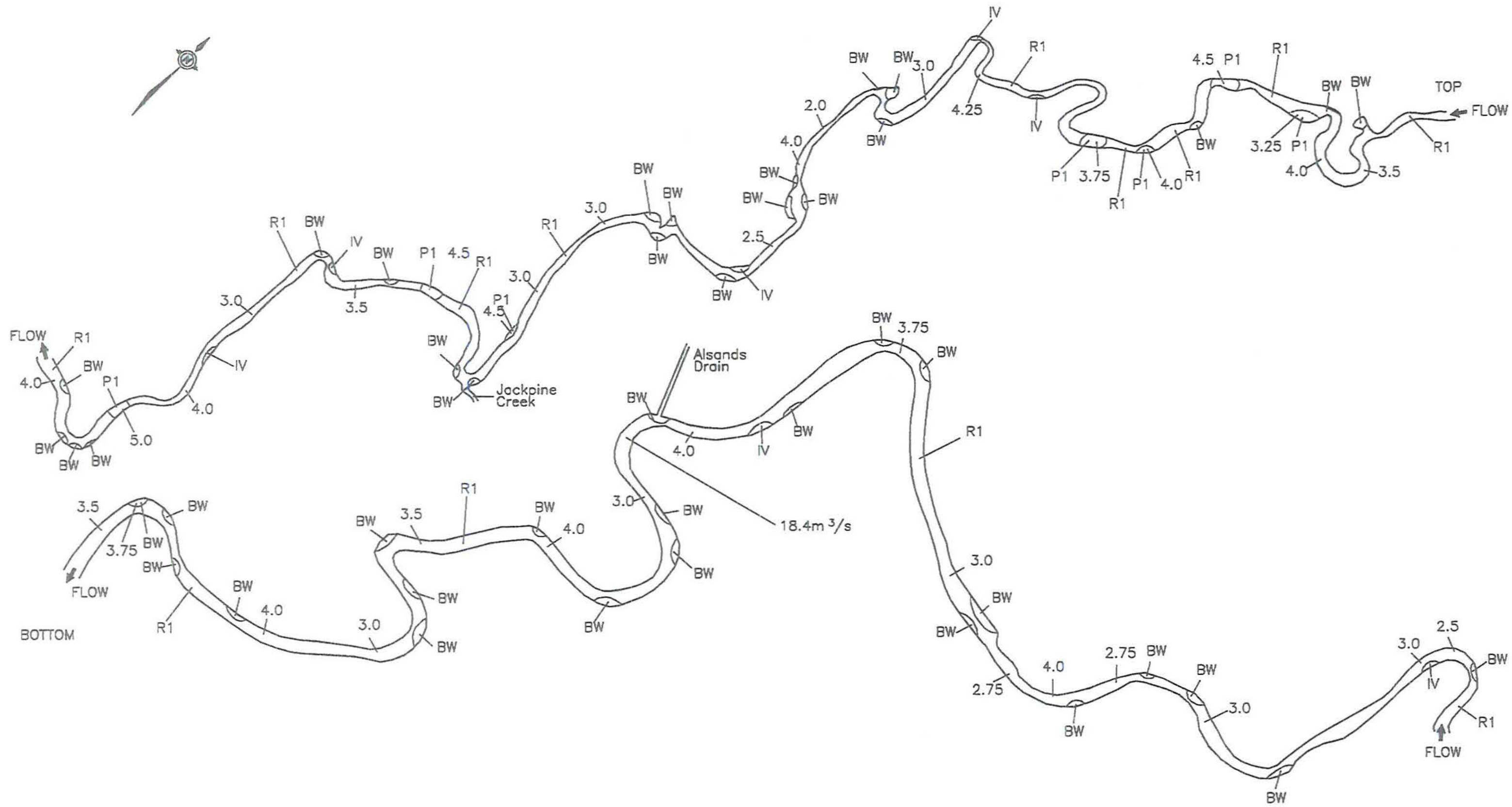

LEGEND

R1 – Run
BW – Backwater
IV – Inundated vegetation
4.0 – Depth in metres

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HABITAT MAP OF THE MUSKEG RIVER, FALL 1997

01 DEC 1997	Figure D6–4	DRAWN BY VS/TM

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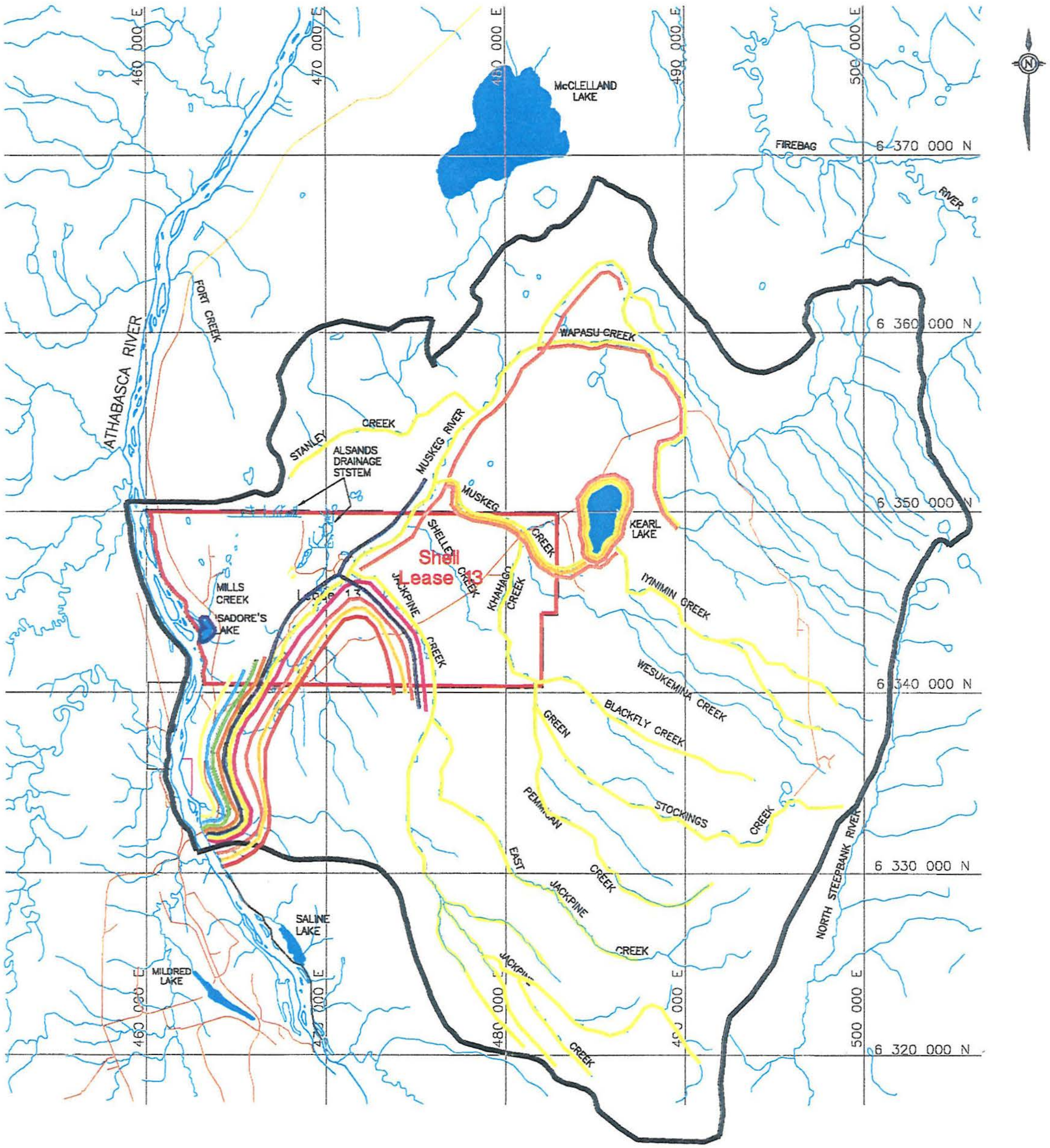

LEGEND

- BURBOT[1]
- LAKE WHITEFISH[1]
- WALLEYE[1]
- GOLDEYE[1]
- FORAGE FISH[2]
- ARCTIC GRAYLING
- NORTHERN PIKE
- WHITE SUCKER
- LONGNOSE SUCKER
- MOUNTAIN WHITEFISH
- LOCAL STUDY AREA FOR MUSKEG RIVER MINE PROJECT HYDROLOGY, AQUATICS EIA COMPONENTS

1 Occasional migrants to the lower reaches of the Muskeg River.

2 Stream may contain some or all of the folliwing fish species: pearl dace, brook stickleback, slimy sculpin, fathead minnow, lake chub.

REFERENCE

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

THE DATA IS FROM O'NEIL AND JANTZIE 1974, BOND AND MACHNIAK 1979, WALDER ET AL. 1980, WEBB 1980, O'NEIL ET AL. 1982, BEAK 1986, R.L. & L. 1989, GOLDER 1996b AND GOLDER 1997d

0 2.5 5 7.5 10 12.5km

SCALE IN METERS

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FISH USE IN THE MUSKEG RIVER SYSTEM

03 DEC 1997	Figure D6–5	DRAWN BY: TM

Alsands Drain

The Alsands Drain is a drainage system that was developed for the Alsands project (Figure D6-1). Water from the drain enters the Muskeg River. There is no previously documented fish habitat in the area of the drainage system. The drainage system is fairly uniform in its physical characteristics. However, aquatic macrophytes are present in some areas. Fisheries surveys in fall 1997 reported forage fish species present in these drainage ditches (Golder 1997d).

Ponds

Ponds within the lease were examined as part of the Alsands study. Webb (1980) sampled eight shallow muskeg ponds (<1.5 m) north of the Muskeg River and four deep upland lakes (13.4 m to 22.3 m) south of the Muskeg River. Webb (1980) found that about half the ponds in the area were shallow (less than 1 m) with no inlet or outlet. Winter water quality sampling in these lakes indicated that oxygen levels would likely be too low for fish to overwinter.

A June 1997 orthophoto of the area indicates that only two of the shallow muskeg ponds previously sampled by Webb (1980) remain. Changes in numbers of shallow ponds are likely due to natural fluctuations in precipitation and water table (Golder 1997d). The four upland lakes to the south of the Muskeg River are similar in morphology to the findings of Webb (1980).

D6.3.3 Fish Communities

Muskeg River, Jackpine Creek and Tributaries

Seventeen fish species have been documented in the Muskeg River drainage basin. The occurrence of fish species in the Muskeg River and its tributaries is shown in Table D6-3 and Figure D6-5. Fish species in the Muskeg River basin can be classified into three main groups: resident species; species that use the river basin for part of their life cycle; and occasional migrants from the Athabasca River (Bond and Machniak 1979, R.L.& L. 1989).

Species known to use the Muskeg River and its tributaries for part of their life cycle include Arctic grayling, longnose sucker, white sucker, northern pike, lake chub and mountain whitefish (Bond and Machniak 1979, O'Neil et al. 1982, Golder 1997d). Spawning migrations of Arctic grayling, longnose and white sucker and northern pike in the Muskeg River occurred in the spring of 1995 (Golder 1996b). These species were also captured in the river during 1997 (Golder 1997d). As well, a few lake chub in spawning condition were documented in the spring. Previous investigators have also reported spawning migrations of these species into the lower reaches of this river, although in the past substantial numbers of fish also spawned in Jackpine Creek (Bond and Machniak 1979, O'Neil et al. 1982).

Table D6-3 Fish Species Utilization of the Muskeg River and Tributaries

Species	Muskeg River below Jackpine Creek	Muskeg River above Jackpine Creek	Jackpine Creek
Arctic Grayling	■ ● ○	○	■ ○
Northern Pike	■ ● ○	■ ● ○	■
Mountain Whitefish	■		■ ○
Walleye	■ ●	○	
Lake Whitefish	■		
Burbot	■ ●		
Longnose Sucker	■ ● ○	■ ○	■ ● ○
White Sucker	■ ● ○	■ ○	■ ●
Lake Chub	■ ● ○	■ ○	■ ○
Pearl Dace	■ ●	■ ○	■ ●
Slimy Sculpin	■ ●		■ ●
Trout-perch	■ ●		
Longnose Dace	■ ●		■ ○
Fathead Minnow	■ ●		■ ●
Brook Stickleback	■ ○	■	■ ● ○
Spoonhead Sucker			○
Northern Red Belly Dace			■

Data obtained from O'Neil et al. 1982, Beak 1986, Bond and Machniak 1979, R.L & L. 1989 and Golder 1996b, 1997d.

■ - occurrence of species documented in historical studies only.

● - occurrence of species documented in 1995 (Golder 1996b).

○ - occurrence of species documented in 1997 (Golder 1997d).

Fish access to Jackpine Creek is variable due to extensive beaver activity near the mouth of the creek, which may explain why none of these species was captured in this creek in 1995. Mountain whitefish have also been known to migrate into the Muskeg River for summer feeding, but were not recorded in 1995 or 1997 (Golder 1996b, 1997d).

Spring migrations into the Muskeg River vary in length depending on the species. Most longnose sucker and white sucker leave the river shortly after spawning, while northern pike and Arctic grayling remain to feed until fall. In the fall of 1995, northern pike and Arctic grayling were captured heading downstream on the Muskeg River, indicating that they were leaving the river (Golder 1996b).

Resident fish species documented in the Muskeg River and its tributaries in 1995 include slimy sculpin, pearl dace, brook stickleback, fathead minnow, longnose sucker and white sucker and northern pike (Golder 1996b).

In 1995, burbot, walleye and trout-perch were recorded in the lower part of the Muskeg River. These three species, as well as lake whitefish and spottail shiner are known to be only occasional migrants into the lower reaches of the river (R.L.&L. 1989).

The potential for large fish to overwinter in the Muskeg River system has been described as poor by R.L.&L. (1989) who assessed winter water quality in the Muskeg River and several tributaries. Data from winter 1997 (water quality and fish habitat assessments) generally support these conclusions as most of the small watercourses sampled in the Muskeg River system were frozen to near the bottom, and oxygen levels were low (Golder 1997e). Pools sampled in the Muskeg River and Jackpine Creek could potentially be used as overwintering areas as oxygen levels and depths were acceptable for large fish species. However, it is believed that most large fish species vacate these watercourses in fall, since observations at a fish fence installed in the lower portion of the Muskeg River in fall 1995 indicated that a large number of fish were moving downstream at that time (Golder 1996b).

Ponds

Results from the Alsands studies indicate that most ponds in the area do not support fish (Webb 1980). Two small ponds north of the Muskeg River support forage fish species and two of the upland lakes to the south of the Muskeg River also support forage fish (Webb 1980).

D6.4 Isadore's Lake and Mills Creek Watersheds

D6.4.1 Benthic Invertebrates

Benthic invertebrates have not been surveyed in Isadore's Lake or Mills Creek.

D6.4.2 Fish Habitat

Mills Creek Watershed

Mills Creek is a small stream that drains into Isadore's Lake (Figure D6-1). Mills Creek has a well-defined meandering channel where it intersects Highway 63. It becomes interspersed with flooded areas a few hundred metres above and below Highway 63 (Golder 1997d). The average channel width in the area near the road was 3.3 m and the average wetted width was 2.4 m. The habitat is primarily low-quality runs. Shallow riffles are found occasionally. The substrate is primarily sand, with small areas dominated by boulders and cobbles.

The largest of three pothole ponds that form the headwaters of Mills Creek was sampled in fall 1996 (Golder 1997d). The area surrounding this pond was dominated by black spruce and river alder. The pond is shallow and eutrophic with approximately 0.20 m of organics and algae present on the bottom. Average depth of the pond in fall 1996 was 0.86 m and maximum depth was 1.40 m (Golder 1997d).

Isadore's Lake

Isadore's Lake (also called Cree Burn Lake) is an oxbow lake of the Athabasca River located on the west boundary of the Muskeg River Mine Project area. The lowland areas around the lake are dominated by black spruce and the upland areas are dominated by aspen and white spruce. Three beaver lodges are present and beaver activity is evident throughout the lake (Golder 1997d).

Isadore's Lake is approximately 1.2 km long and 0.5 km wide. The lake is shallow and clear with a few deep pools present. The edges of the lake are 0.5 m deep. Emergent vegetation, such as common cattail and sedge is present. Measured depths ranged from 2.10 to 4.25 m in fall of 1996 (Golder 1997d). The bottom substrate was primarily organic material and sand/silt with a variety of aquatic vegetation present. Dominant submergent and floating species included northern water milfoil, Richardson pondweed, common bladderwort and yellow water lily.

D6.4.3 Fish Communities

Mills Creek Watershed

In fall 1996 fisheries surveys, no fish were captured or observed in Mills Creek (Golder 1997d). The presence of shallow, low-quality habitat, is likely the reason for the absence of fish in Mills Creek.

No fish were captured or observed in the headwater pond of Mills Creek during fisheries surveys in fall 1996. It is likely that the pond does not support fish because it is a shallow system that would likely result in anoxic conditions during the winter, leading to winter kill. If this were the case, downstream barriers to migration would prevent the pond from being colonized again in the summer.

Isadore's Lake

A fisheries survey of Isadore's Lake was conducted as part of the Alsands studies in the 1980s. Webb (1980) captured 19 adult northern pike from the lake. As well, several young-of-the-year were observed, indicating that pike spawned in the lake. One northern pike was captured by gill net in Isadore's Lake in fall 1996 (Golder 1997d). At this time, the outlet to the Athabasca River was impassable to fish from the Athabasca River due to low water levels and beaver dam blockages. It is not clear if the northern pike captured in Isadore's Lake is a resident fish, or if it originated from the Athabasca River before 1996.

It is likely that northern pike from the Athabasca River use Isadore's Lake for spawning when flow and passage conditions in the outlet allows access to Isadore's Lake. Spawning habitat for northern pike species is limited in the mainstream Athabasca River, and northern pike would be expected to use for spawning any suitable waterbodies, tributaries or side channels in the Athabasca River floodplain. The lake would also be used for rearing and then adults would leave it they could to gain access to prey.

D7 ECOLOGICAL LAND CLASSIFICATION

D7.1 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 and mapping of the Ecological Land Classification (ELC) units in the Study Area, including consideration of terrain and soils, terrestrial vegetation and wetlands; and
- collection of all baseline biophysical information in a manner that enables a detailed ecological land classification of the Project area to be completed (TofR, Sections 4.3 and 4.4).

Project-specific impacts on ELCs are addressed in Section E7 of this EIA. Cumulative effects on ELC are addressed in Section F7.

An ecological land classification (ELC) provides an integrated, holistic means of defining the landscape and potential impacts arising from the development and reclamation of an area. ELC refers to the identification and delineation of distinct land units, each with relative homogeneous biophysical characteristics within a hierarchical classification system. This process has been used to develop general ecoregions and ecodistricts of Alberta at 1:1,000,000 scale (Strong 1992), and has been further employed at the more detailed level of the ecosection (scale 1:50,000).

Air photo interpretation, ELC field surveys and a review of existing databases, including the Canadian Soil Classification System, Ecosites of Northern Alberta, Alberta Vegetation Inventory and Alberta Wetland Inventory, provided information on terrain and soils, vegetation, forestry and wetlands resources used to define the land units. The Field Guide to Ecosites of Northern Alberta (Beckingham and Archibald 1996) was used as the guideline to identify ecological land classes.

The objective of the ELC was to provide an integrated and comprehensive land classification scheme of the Project area so that the landscape, soil, vegetation and drainage conditions could be evaluated at a variety of scales and levels of complexity. By comparing similar ELC types or map units within the context of the LSA and RSA, the potential impacts on the terrestrial resources of the Project area can be more easily understood. ELC mapping is particularly useful in examining such issues as cumulative effects and biodiversity.

An ELC approach to mapping and describing an area has been recognized by Noss and Cooperider (1994) as important for assessing biodiversity at the "landscape level". Alberta Environmental Protection (AEP 1995c) recognized the importance of biodiversity and has identified it as one of the Terms of Reference to be addressed in this EIA. A detailed assessment of biodiversity is provided in the Ecological Land Classification (ELC) Baseline for the Muskeg River Mine Project (Golder 1997l).

D7.2 Study Areas for ELC

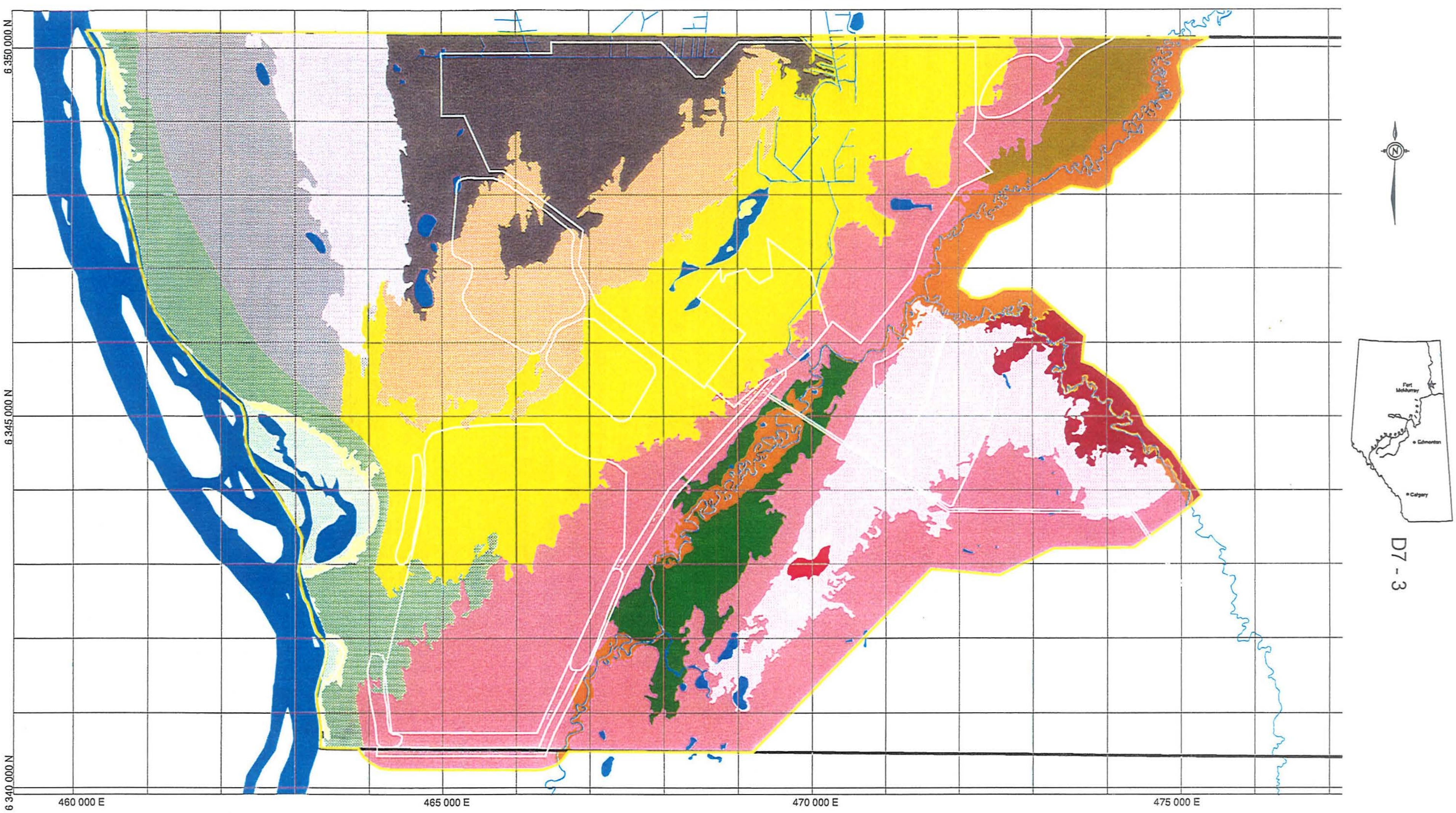
The ecological land units were classified in two study areas, the Regional Study Area (RSA) and Local Study Area (LSA). The ELC units within the LSA are directly comparable to those within the RSA, using the hierarchical ELC scheme developed for the Muskeg River Mine Project. These areas are described in detail in Section D1 and shown in Figures D1-2 and D1-3. Further details on the ELC within the LSA is provided below.

The LSA is located in the Central Mixedwood Natural Subregion (AEP 1984). The terrain is a complex mosaic of glaciofluvial, organic and lucustrine plains. The vegetation is characterized by rapid transitions between dry upland coniferous and deciduous communities to treed, shrub and graminoid wetlands. In an effort to simplify the ecological complexity of the LSA, a total of 30 ecological land classes were identified in the ELC baseline report (Golder 1997l).

D7.3 Methods

D7.3.1 Ecological Land Classification

The ecological land classification was developed from existing maps on terrain, soil, vegetation, forestry and wetland resources, complemented by field surveys. The LSA was pre-stratified according to the Alberta Vegetation Inventory (AVI) (AEP 1997b), which represents the most detailed level of forest mapping. All the thematic layers were overlain through ARCINFO, a Geographic Information System (GIS). Due to the complexity of the LSA, broad terrain or physiographic units were delineated first. These units form the coarsest level of detail and were further refined by delineating soil units and finally, vegetation and wetlands polygons within each physiographic unit. This integration process is highlighted in Figure D7-1. In addition, Global Positioning System (GPS) was employed in the field by Terrestrial component teams so that groundtruthing information on abiotic and biotic resources could be used to verify the ELC map units.



LEGEND

- Local Terrestrial Study Area
- Lease 13
- Open water

TERRAIN UNITS

- Athabasca Upland
- Boucher Organic Plain
- Creeburn Organic Plain
- Escarpment
- Susan Lake Outwash Plain
- Jackpine Creek Bog
- Jackpine Creek Lowland
- Jackpine Creek Organic Plain
- Muskeg River Organic Lowland
- Muskeg River / Jackpine Riparian Zone
- Muskeg River Lacustrine Plain
- Muskeg River Midland
- Mackay Upland
- Riparian Floodplain
- Riparian Terrace

SOURCE: The Forestry Corp., CanAg Enterprises Ltd., Golder Associates

1 0 1 2
Kilometers

MAP PROJECTION: Universal Transverse Mercator Zone 12   DATUM: NAD 83

Golder Associates
SHELL CANADA LIMITED

MUSKEG RIVER MINE PROJECT MACROTERRAIN CLASSIFICATION

5 Dec. 1997	Figure D7-1	PRODUCED BY: J. Shaw REVIEWED BY:

/data6/oilsands/972-2237/9700/9701/final/arcview/macroterr50fin.apr

The methodology employed to develop each of the biophysical maps is summarized below, and presented in detail in Section D8 (Terrain and Soils), D9 (Terrestrial Vegetation) and D10 (Wetlands).

D7.3.2 Terrain or Physiographic Units

Terrain classification was based on integrating data from the surficial geology map sources, soil map units, Alberta Vegetation Inventory (AVI) map units and a digital elevation model of the LSA with a contour interval of 2 m. The initial terrain amalgamation was derived by combining soil units with similar soil parent materials. For example, all the soil units developed on glaciofluvial deposits were merged to produce larger units with similar biophysical characteristics.

Due to the complexity of the LSA, broad physiographic units were developed. These were delineated based on the predominant type of terrain unit, elevation, slope and modifying processes. Physiographic units were named after known geographic or cultural features, typical of the region.

D7.4 Soils

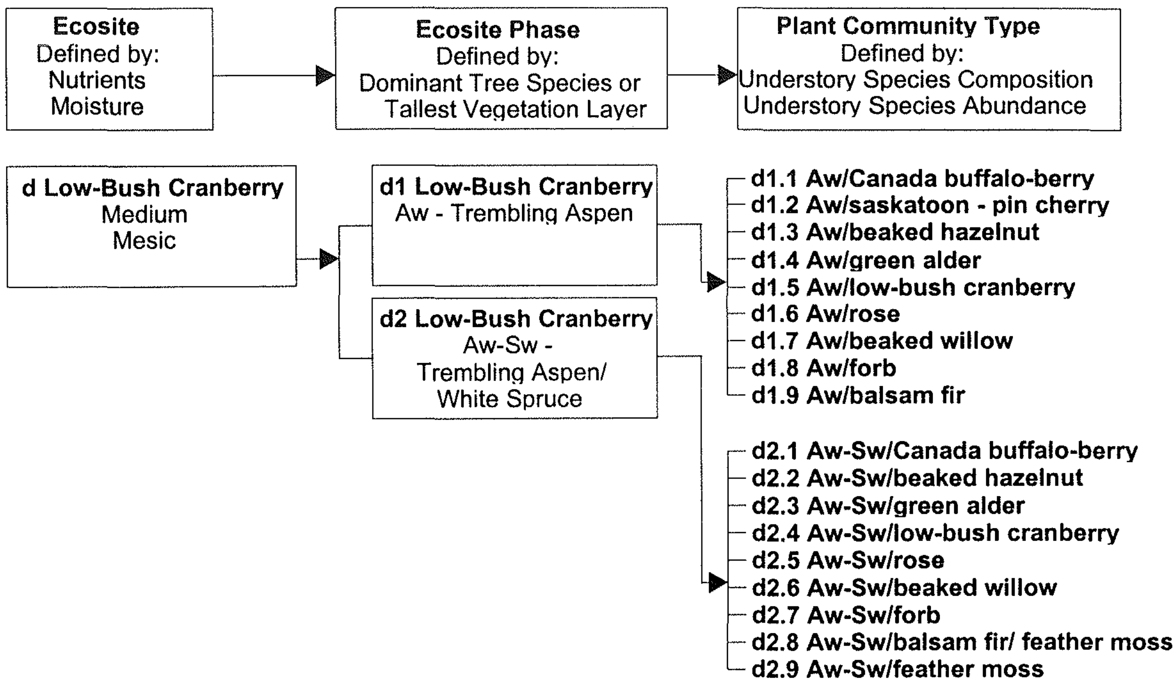
The soil sampling program was designed to meet the requirements of Alberta Environmental Protection Terms of Reference for this EIA. Soil sampling locations were selected from an AVI pre-stratification map of the LSA on 1997, 1:10,000 black and white aerial photographs. Information from soil sampling was extrapolated to representative soil map units using the principles of geomorphology and surficial geology, in combination with the vegetation patterns and interpretation of aerial photographs. Soil types naturally grade into one another so that the map units identified within the LSA are in fact a complex of soil units.

D7.5 Vegetation

The preliminary delineation of the vegetation communities was based on the AVI polygons that were reclassified to Beckingham and Archibald system, as described in the 1996 Field Guide to Ecosites of Northern Alberta. Beckingham and Archibald Classification is presented in Figure D7-2. The classification is based on a hierarchical system where each ecosite is identified from the nutrient and moisture regimes, while ecosite phases are identified by the dominant tree species, or the tallest vegetation layer. The next layer, plant community types, is defined by the understory species composition and abundance.

There are 12 terrestrial ecosites (a to l) in the boreal mixedwood forest of Alberta. In addition, wetlands ecosites (i to l) are identified in this classification and were used for the vegetation field investigations and in subsequent impact analysis.

Figure D7-2 Ecosite Classification Steps



EXAMPLE:

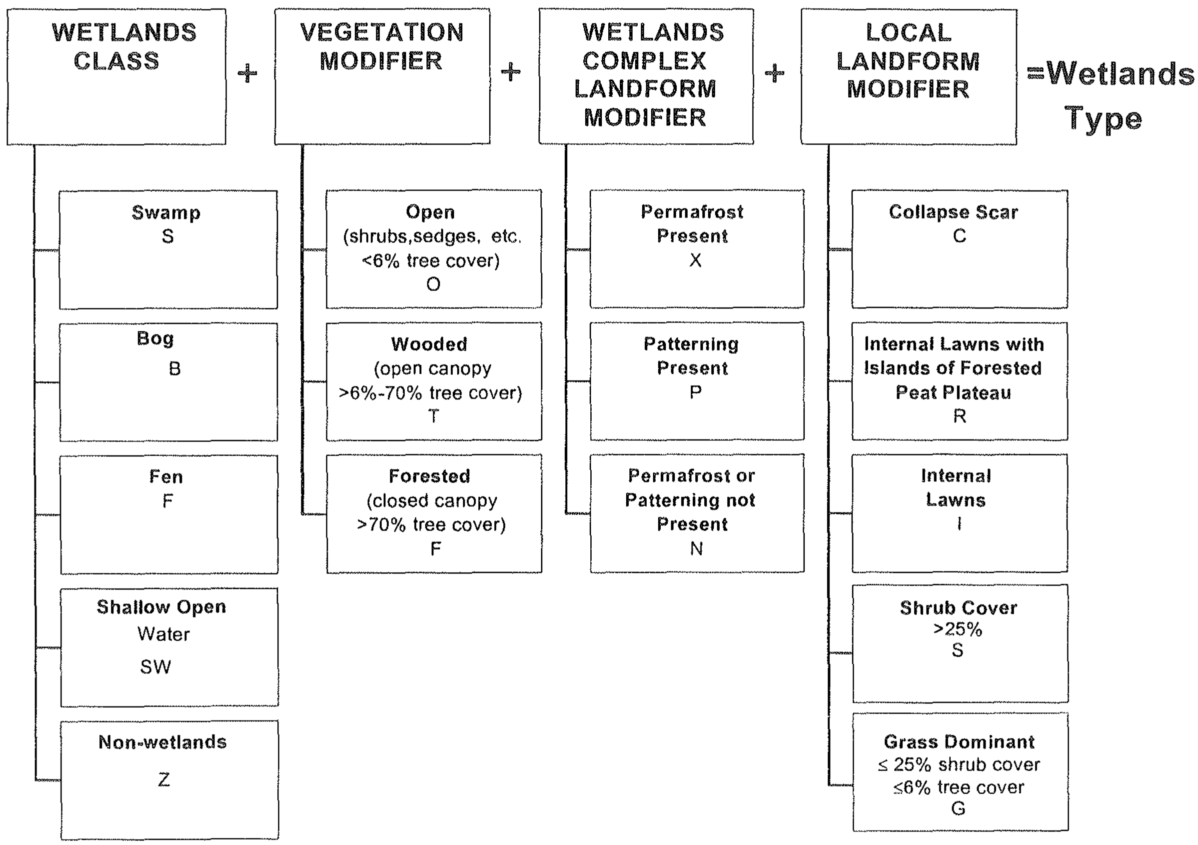
Ecosite		Ecosite Phase		Plant Community Type
d Low-Bush Cranberry	+	**d1 Trembling Aspen**	+	**d1.6 Trembling Aspen/rose (Aw/rose)**

D7.6 Wetlands

The Alberta Wetlands Inventory (AWI) classification system (Halsey and Vitt 1996) uses variables that are distinguishable on aerial photographs to classify wetlands. The wetlands classes were assigned to pre-stratified AVI polygons. Following field surveys, wetlands classes were defined as required.

The AWI classification system uses similar classes to those developed by the National Wetlands Working Group (NWWG 1988). However, the subdivision of the AWI classes follows a more simplified scheme than that of NWWG (1988). The classification system contains four levels: the wetlands class, the vegetation modifier, the wetlands complex landform modifier and the local landform modifier (Figure D7-3). This classification allows more detailed definition of the wetlands in the Project area and in the LSA.

Figure D7-3 Flow Chart Representation of Wetlands Classification Process



D7.7 ELC Results

In total, 16 ecological classes are defined for the study areas based on the integration of terrain, soil, vegetation and wetlands units. (Table D7-1). ELC units are shown in Figure D7-4.

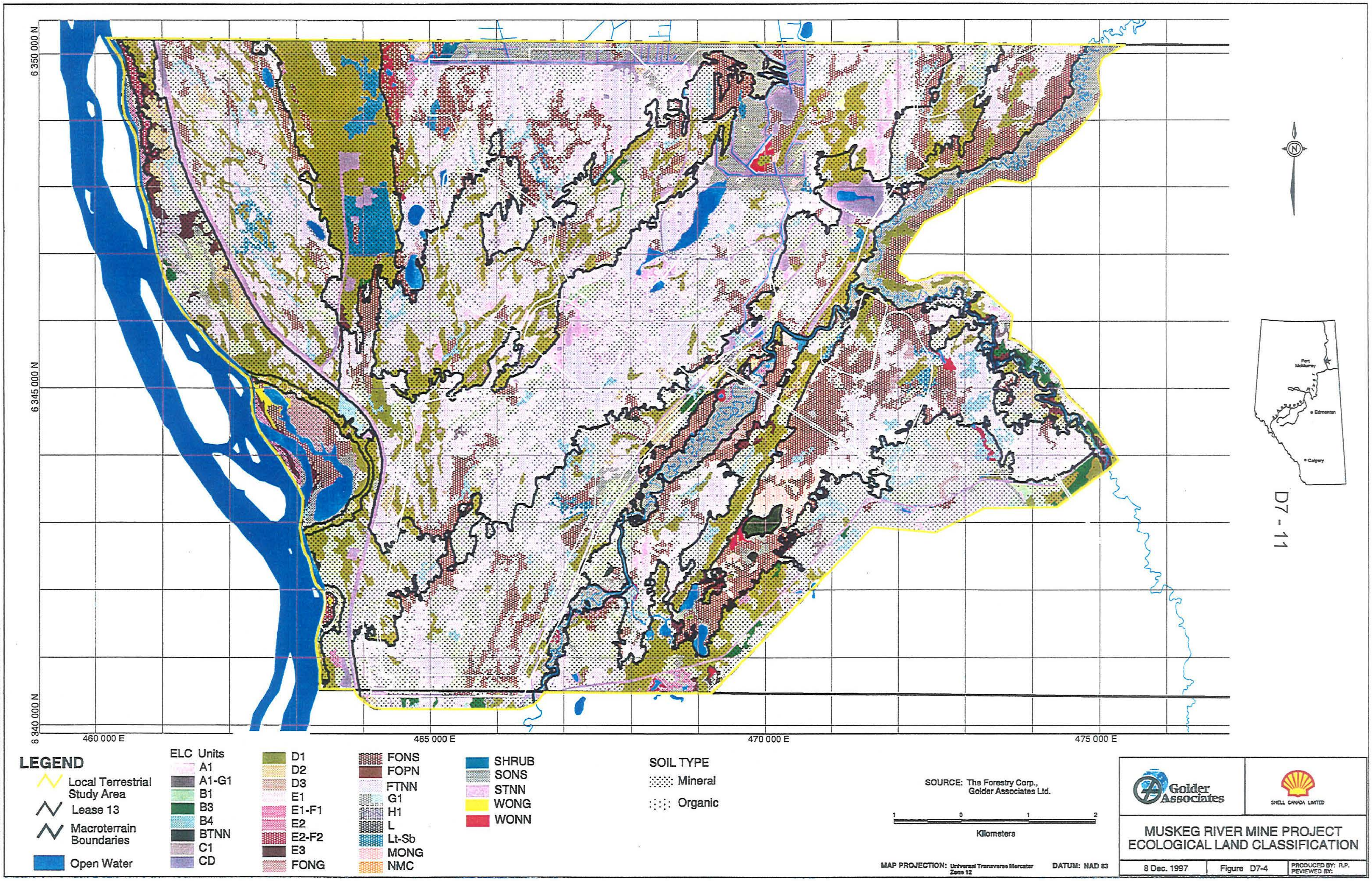
Table D7-1 Ecological Land Classes

Macroterrain	Area (ha)	% of LSA	Terrain Unit	Soil Unit	Vegetation Unit	% Cover	Wetlands Unit	% Cover
Athabasca Upland	770	7	Glaciofluvial	Mineral	B1	5.24	FTNN	21.87
					B4	3.82	FTNN(H1)	4.42
					D1	14.83	SB-LT	2.78
					SB-LT	2.78	STNN-(SB-LT)	3.08
				Organic			FONS	7.73
							FTNN	23.03
Athabasca Escarpment	95	1	Rough Broken	Mineral	D1	35.86	none	-
					D2	23.23		
					E1	1.47		
					E3	21.90		
Athabasca Riparian Floodplain	251	2	Glaciofluvial	Mineral	E1	1.26	FONG	13.42
					E1-F1	13.54	FONS	2.10
					E2-F2	2.40	FTNN	1.74
					E3	4.77	SONS(SHRUB)	8.61
							FONS	14.68
				Organic	D1	3.80	SONS(SHRUB)	5.70
							WONG	5.90
Athabasca Riparian Terrace	711	6	Glaciofluvial Fen	Mineral	B1	21.14	FTNN	11.77
					B4	2.02	STNN(B4)	1.52
					D1	23.07	STNN(G1)	1.04
					D2	5.66	STNN(H1)	2.62
					E1	1.75	STNN(SB-LT)	7.72
					E3	5.39		
					H1	3.02		
				Organic	B4	1.59	FTNN	1.93
							SONS(SHRUB)	2.39
Susan Lake Outwash Plain	517	5	Glaciofluvial	Mineral	B1	1.31	FONS	1.60
					B4	1.28	FTNN	3.54
					D1	64.11	STNN(H1)	1.34
					SHRUB	17.94		

Macroterrain	Area (ha)	% of LSA	Terrain Unit	Soil Unit	Vegetation Unit	% Cover	Wetlands Unit	% Cover
Boucher Organic Plain	1057	10	Shallow fens	Mineral	B1	1.59	FONS	17.18
			Fens		B4	1.62	FTNN	10.22
			Bogs		D1	2.15	SONS(SHRUB)	3.25
			Glaciofluvial				STNN(SB-LT)	2.57
							WONN	1.12
				Organic			FTNN	35.41
							SONS(SHRUB)	8.67
Creeburn Organic Plain	2,064	19	Fen	Mineral	A1	1.22	FTNN	11.38
			Shallow Fen		B1	5.28	STNN(LT)	2.14
			Bog		B4	1.21	STNN(SL-LT)	3.27
			Glaciofluvial		D1	6.44		
				Organic			FONS	9.04
							FTNN	38.79
							SONS(SHRUB)	3.67
							STNN(SB-LT)	2.00
Jackpine Creek Organic Plain	843	8	Fen	Mineral	B1	1.24	FTNN	2.49
			Shallow Fens		B4	3.18		
			Glaciofluvial		D1	3.62		
					Lt-Sb	1.37		
				Organic			FONS	37.11
							FTNN	36.78
							MONG	7.18
							SONS(SHRUB)	1.92
							WONN	1.03
Jackpine Creek Bog	15	<1	Bog	Organic			BTNN	100.0
Jackpine Creek Lowland	171	2	Glaciofluvial	Mineral	A1	1.01	FTNN	16.05
			Fen		B1	10.53		
					B3	5.49		
					B4	5.62		
					D1	5.77		
					D2	11.16		
					E1	1.50		
					D3	7.77		
					H1	4.67		
				Organic	A1-G1	1.95	FTNN	11.07

Macroterrain	Area (ha)	% of LSA	Terrain Unit	Soil Unit	Vegetation Unit	% Cover	Wetlands Unit	% Cover
					B3 B4 D1	4.20 1.70 3.61	STNN(H1)	2.88
Jackpine Creek Upland	75	1	Glaciofluvial Fen	Mineral Organic	A1/G1 complex B1 B3 B4 D1 D2 E3 Shrub	3.33 1.07 16.56 4.54 7.23 1.62 10.74 1.2	 FTNN STNN	 20.18 6.76
MacKay Upland	815	7	Glaciofluvial Fen Shallow Fens	Mineral Organic	B1 B4 D1 D2 H1	7.14 1.75 24.25 2.10 5.02	FTNN STNN(B4) STNN(H1) STNN(SB-LT) FONS FTNN SONS(SHRUB)	22.17 1.24 8.57 2.26 6.56 12.10 0.17
Muskeg River/Jackpine Creek Riparian	488	4	Stream Channel Fen Glaciofluvial	Mineral Organic	E1-F1 D1 D2	1.25 4.99 1.39	SONS(SHRUB) FONS FTNN SONS(SHRUB)	9.98 16.57 1.56 56.85
Muskeg River Lacustrine Plain	212	2	Fen Shallow Fen Glaciolacustrine	Mineral Organic	D1	16.88	FTNN STNN(SB-LT) FONS FTNN	6.23 3.48 44.63 28.08
Muskeg River Midland	2,511	23	Glaciofluvial Fen Shallow Fen	Mineral	A1 B1 B3 B4 D1	2.50 16.30 1.46 4.69 14.83	FONS FTNN SONS(SHRUB) STNN-SB-LT)	6.83 32.27 1.26 2.61

Macroterrain	Area (ha)	% of LSA	Terrain Unit	Soil Unit	Vegetation Unit	% Cover	Wetlands Unit	% Cover
Muskeg River Organic Lowland	359	3	Shallow Fen Stream Channel	Mineral	B1 B4 D1	11.56 3.46 2.22	FONG FONS FTNN	1.31 29.53 37.32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465 000 E
470 000 E
475 000 E
Fort McMurray
Edmonton
Calgary
LEGEND
Local Terrestrial Study Area
Lease 13
Macroterrain Boundaries
Open Water
ELC Units
A1
A1-G1
B1
B3
B4
BTNN
C1
CD
D1
D2
D3
E1
E1-F1
E2
E2-F2
E3
FONG
FONS
FOPN
FTNN
G1
H1
L
Lt-Sb
MONG
NMC
SHRUB
SONS
STNN
WONG
WONN
SOIL TYPE
Mineral
Organic
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
ECOLOGICAL LAND CLASSIFICATION
8 Dec. 1997
Figure D7-4
PRODUCED BY: R.P.
REVIEWED BY:
/data8/oilsands/972-2237/8700/9701/final/arcview/elc50fin.apr

D7.7.1 Athabasca Upland

The Athabasca Upland is northeast of Susan Lake. The terrain is predominantly Glaciofluvial with a mix of organic and mineral soils. The dominant vegetation type is wooded fens (FTNN, >40%), with upland vegetation dominated by low-bush cranberry-aspen communities (D1).

D7.7.2 Athabasca Escarpment

This area corresponds to the Rough Broken terrain unit and represents the typical steep eroding slopes of the Athabasca River valley. Soil development is poor and the existing vegetation is a mosaic of upland communities ranging from low-bush cranberry-aspen (D1), low-bush cranberry aspen-white spruce (D2), to low-bush cranberry white spruce (D3). Dogwood balsam poplar-aspen (E1)/horsetail balsam poplar (F1) dominate in the northern portion of the LSA.

D7.7.3 Athabasca Riparian Floodplain

The Athabasca Riparian Floodplain forms part of the Athabasca River valley, over which the river flows during of flood. Characterized by low relief and gentle slope gradients, this area is dominated by Glaciofluvial terrain units with Fen and Shallow Fen units adjacent to Isadore's Lake. Mineral soils are deposited on glaciofluvial terrain with vegetation communities varying from dogwood balsam poplar-aspen (E1)/horsetail balsam poplar (F1). Dogwood complexes with scattered islands of blueberry jack pine white spruce. Ruth Lake soils overlie the Fen terrain associated with Isadore's Lake. The wetlands vegetation is composed of non-patterned open, shrub and graminoid fens and marsh surrounding Isadore's Lake.

D7.7.4 Athabasca Riparian Terrace

Riparian terraces are at a slightly elevated topographical position on top of escarpment slopes just west of Highway 63. The terrain is Glaciofluvial with scattered shallow bogs and shallow fens. Soil units are predominantly organic. The vegetation associated with the Mildred soils are low-bush cranberry (D1), B1 blueberry jack pine-aspen and blueberry white spruce-jack pine (B4). Non-patterned open, shrubby and treed fens are dominant on organic soils.

D7.7.5 Susan Lake Outwash Plain

This area is a broad outwash plain located in the northern portion of the LSA, between the highway in the west and Susan Lake in the east. The terrain is Glaciofluvial with mineral comprising the dominant soils. The vegetation is predominantly treed fen with scattered upland vegetation phases that include blueberry jack pine - aspen (B1) and low-bush cranberry. One isolated Labrador tea/horsetail white spruce-black spruce (H1) associated with Fen and McLelland Lake soils is situated in this area.

D7.7.6 Boucher Organic Plain

The Boucher Organic Plain is northeast of Susan Lake. The unit is composed of Shallow Fens, Fens and Small Bog terrain with less than 10% Glaciofluvial deposits. The soils are a complex mosaic of Steepbank, Muskeg, Dover and McMurray. The complexity of soils is reflected in the vegetation ecosite phases, which consist of fen and bog wetlands that grade to Labrador tea/horsetail white spruce-black spruce phases. Better-drained mineral soils support low-bush cranberry aspen (D1), blueberry jack pine-aspen and blueberry white spruce-jack pine phases. Marshes are prevalent around the perimeters of lakes.

D7.7.7 Creeburn Organic Plain

The Creeburn Organic Plain, named after a prominent archaeological site in the area, is centrally located in the LSA and forms a broad band extending from Highway 63 to the northeast LSA boundary. The terrain is made up of predominantly Fen and Bog units with scattered Glaciofluvial veneers. The soils consist of McLelland, Bitumount, Mildred, Muskeg and Steepbank. The wetlands are non-patterned open treed, shrub and graminoid fens. Isolated upland vegetation phases are composed of lichen jack pine (A1), blueberry jack pine-aspen (B1), blueberry white spruce-jack pine (B4) and low-bush cranberry aspen (D1).

D7.7.8 Jackpine Creek Organic Plain

The Jackpine Creek Organic Plain occurs just west of the Jackpine Creek Lowland, and extends south and west toward the southern boundary of the LSA. Soils are dominantly organic, with scattered mineral soils. Vegetation is dominated by a mosaic of wetland communities, dominated by shrubby (FONS) and wooded fens (FTNN). Other wetland types include shallow open water (WONN), marshes (MONG) and shrubby/deciduous swamps (SONS). Upland communities are scattered and include low-bush cranberry, aspen (D1) and blueberry-white spruce, jack pine (B4).

D7.7.9 Jackpine Creek Bog

The Jackpine Creek Bog is a small area, occurring at the southeast corner of the LSA. This terrain unit is completely surrounded by the Jackpine Creek Organic Plain. Organic soils support a wooded bog (BTNN).

D7.7.10 Jackpine Creek Lowland

The Jackpine Creek Lowland occurs in a narrow strip adjacent to the south bank of the Jackpine Creek. In a number of places this terrain unit extends west into the Jackpine Organic Plain terrain unit. Soils are dominantly mineral, with scattered organics. Vegetation is dominated by a mosaic of upland communities, including: low-bush cranberry, aspen, white spruce (D1 and D2), blueberry - jack pine/ aspen/ white spruce (B1, B2 and B3) and dogwood-white spruce communities (E3). Wetland communities are scattered and dominated by wooded fens (FTNN).

D7.7.11 Jackpine Creek Upland

Jackpine Creek Upland is situated adjacent to Jackpine Creek. The upland is composed of fen and scattered glaciofluvial deposits. Both organic and mineral soils are present. The vegetation is composed of treed and shrubby fens, upland aspen and white spruce communities.

D7.7.12 MacKay Upland

MacKay Upland is centrally located in the LSA and is predominantly Glaciofluvial with small inclusions of Fen and Shallow Fen terrain units. The soil is a complex of Mildred, McLelland, Steepbank and Bitumount soil units. The tamarack fens with scattered black spruce bogs are associated with the McLelland, Steepbank and Bitumount soils. Isolated upland vegetation phases are composed of lichen jack pine (A1), blueberry jack pine-aspen (B1), blueberry white spruce-jack pine (B4) and low-bush cranberry aspen (D1). Transition areas between upland and wetlands support Labrador tea horsetail white spruce-black spruce (H1).

D7.7.13 Muskeg River/Jackpine Creek Riparian

This riparian zone aligns the Muskeg River and Jackpine Creek. The terrain is composed of Fen, Glaciofluvial and Stream Channel. The soils are predominantly McLelland soils with pockets of Fort mineral soils. Shrubby deciduous and black spruce and tamarack swamps and fens are the predominant vegetation communities. Some upland communities are also represented, including aspen and balsam poplar.

D7.7.14 Muskeg River Lacustrine Plain

The Muskeg River Lacustrine Plain terrain unit is found over a wide area of the LSA. This terrain unit occurs on either side of the Muskeg River, and extends from the southwest to the northeast of the LSA. In addition, this terrain unit extends east along the southern LSA boundary, and on the east bank of the Jackpine Creek. Soils are predominantly mineral. Vegetation is a mosaic of upland and wetland community types. Wetland communities are dominated by wooded fens (FTNN), but also include shrubby fens (FONS), coniferous (STNN) and deciduous (SONS) swamps. Upland communities are dominated by low-bush cranberry-aspen communities (D1) and blueberry - jack pine/aspen communities (B1).

D7.7.15 Muskeg River Midland

The Muskeg River Midland terrain unit is found over a wide area of the LSA. This terrain unit occurs on either side of the Muskeg River, and extends from the southwest to the northeast of the LSA. In addition, this terrain unit extends east along the southern LSA boundary, and on the east bank of the Jackpine Creek. Soils are predominantly mineral. Vegetation is a mosaic of upland and wetland community types. Wetland communities are dominated by wooded fens (FTNN), but also include shrubby fens (FONS), coniferous (STNN) and deciduous (SONS) swamps. Upland communities are dominated by low-bush cranberry-aspen communities (D1) and blueberry - jack pine/aspen communities (B1).

D7.7.16 Muskeg River Organic Lowland

The Muskeg River Organic Lowland is located east of the Muskeg River where there is relatively low topographical relief and gentle slopes. The terrain units are predominately Fen and Shallow Fens with some Glaciofluvial. The soils are dominantly mineral. Upland vegetation consists of blueberry jack pine aspen (B1) low-bush cranberry aspen (D1) and dogwood balsam poplar-aspen (E1). Wetlands vegetation is composed of non-patterned open, shrub and graminoid fens and marshes.

D8 TERRAIN AND SOILS

D8.1 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 and mapping of the topography of the Study Area; and
- description and mapping of the soil types and their distribution in the Project area (TofR, Section 4.3).

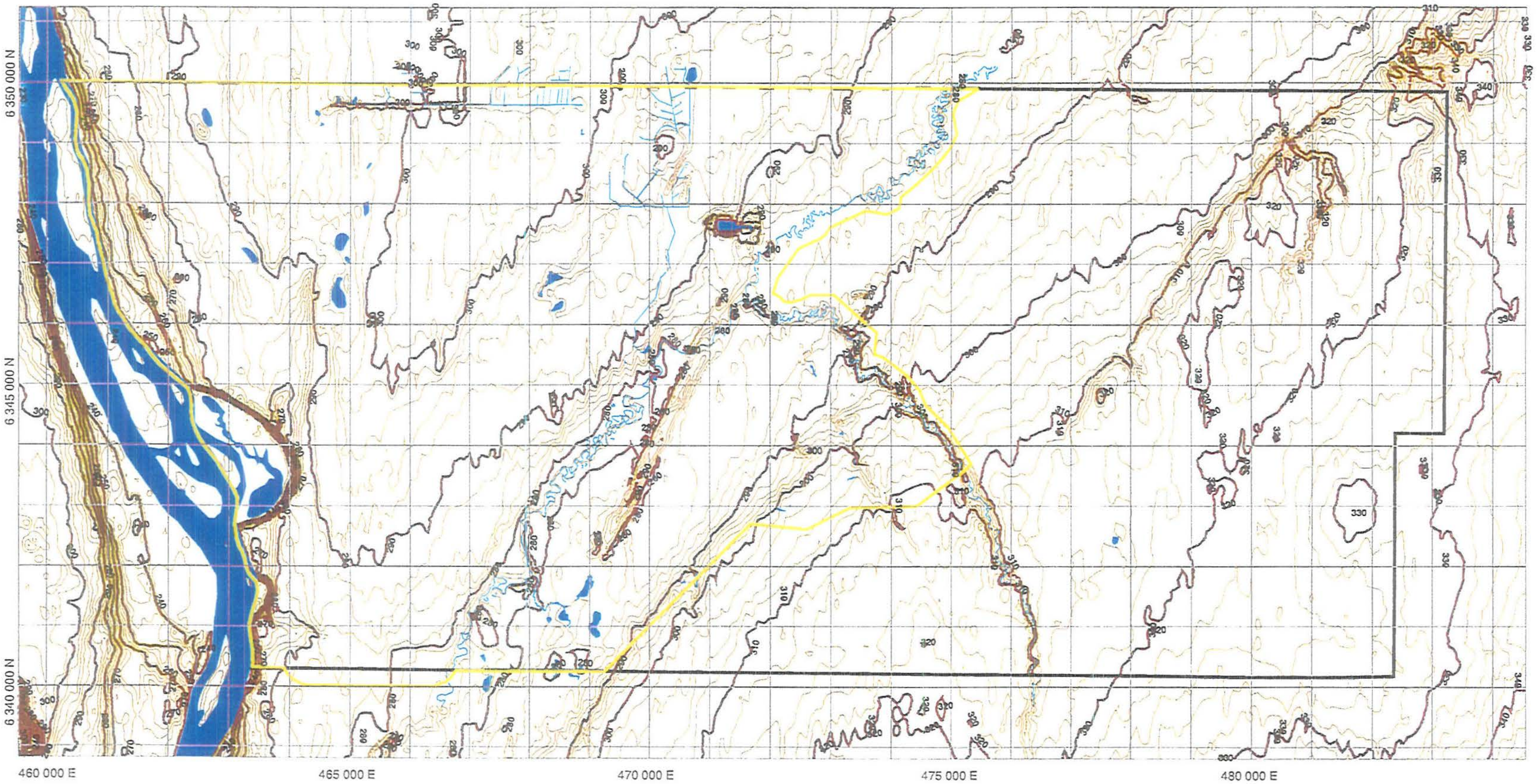
Project-specific impacts on terrain and soils are addressed in Section E8 of this EIA. Cumulative effects on terrain and soils are addressed in Section F8. Bedrock and surficial geology of the Project LSA are discussed in Section 2, Volume 1 of the Application.

The Project LSA is dominated by two principal terrain 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 LSA is quite subdued, the topography best described as gently undulating.

D8.1.1 Physiography and Surficial Geology

The physiography of the LSA is one of subdued relief and undulating topography. A maximum elevation of 300 m above sea level (masl) occurs approximately mid-way between the Athabasca and Muskeg rivers, declining to 280 masl along the west bank of the Muskeg River and to 240 masl at the top of the east bank escarpment of the Athabasca River. From north to south the elevation drops from 300 to 260 masl. Slopes in the LSA are typically less than 0.5% (Figure D8-1).

Pettapiece (1986) placed the majority of the LSA within the Northern Plains physiographic region. However, the extreme southeast corner of Twp 95 Rge 10 W4M and all of the eastern section of Lease 13 are part of the McMurray Lowland Section. Table D8-1 provides a more detailed description of the surface characteristics of the LSA.



LEGEND

- Local Terrestrial Study Area
- Lease13
- 2 Metre Contours
- 10 Metre Contours

SOURCE: Contours Derived from Digital Elevation Model, Alberta Environmental Protection

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

2 METRE CONTOURS

5 Dec. 1997	Figure D8-1	PRODUCED BY: J. Shaw REVIEWED BY:

/data8/oilsands/972-2237/9700/9701/working/arcview/contours.apr

Table D8-1 Physiographic Setting of the Muskeg River Mine Project LSA

Region[a]	Section	District	Surface Expression	Surficial Materials	Elevation (m)
Northern Plains	Great Slave Plain	Embarras Plain	Level - Undulating	Glaciofluvial, Eolian[b]	200 - 350
Northern Alberta Lowlands	McMurray Lowland	Kearl Lake Plain	Undulating	Glaciolacustrine	300 - 450

[a] After Pettapiece 1986.

[b] Eolian - windblown deposits are extremely small and widely scattered throughout the LSA. They do not form sizeable contiguous units.

Bayrock (1971) mapped the surficial geology of the LSA as primarily glaciofluvial outwash sands, medium to coarse in texture with pebbles and gravel lenses, and varying from less than 1 m to more than 6 m in thickness. Relief is classified as level to gently undulating. Two relatively small inclusions of different material occur within the LSA but outside the development footprint. Both are found along the east bank of the Athabasca River valley. The first is a small deposit of meltwater channel sediments described as 3 to 6 m of medium- to coarse-grained sand overlying 1 to 3 m of lag gravel containing many large boulders. The second is a pocket of recent alluvial stream sediment, mainly sand, which coincides with bedrock outcrops of the Waterways Formation.

D8.1.2 Bedrock Geology

The bedrock geology is principally the oil-impregnated sandstone and siltstone of the McMurray Formation. These are Cretaceous deltaic deposits with some interbedding of Clearwater Formation shales (Green 1972, Ozoray et al. 1980, RCA 1970). A small area of the Waterways shale and limestone complex is exposed along the eastern bank of the Athabasca River. More detailed discussions of various aspects of the geology in the area are provided in Carrigy and Kramers (1973).

D8.2 Description of Terrain Classification Units

Terrain analysis was based on integrating data from the soil map units, Alberta Vegetation Inventory (AVI) map units, a digital elevation model of the LSA with a 2-m contour interval and the composition of the surficial deposits. Once these components were reviewed and analyzed, the initial terrain amalgamation was derived by combining soil units with similar parent materials. For example, all the soil units developed on glaciofluvial deposits were merged to produce larger units with similar morphological and mechanical properties.

Bogs (B Units)

Bogs are wet, poorly drained peatlands occupying level or depressional areas in the landscape. Accumulations of poor to moderately decomposed organic material, mainly sphagnum mosses, are acidic in nature due to the stagnant water regime, and are generally nutrient-poor (Beckingham and Archibald 1996). The depth of organics over the underlying mineral contact varies considerably from less than 50 cm to over 2 m. Landcare (1996) noted the possible presence of permafrost in some of the bog units.

Fens (N Units)

Fens are a form of peatland characterized by water at or near the surface for part of the year. As opposed to the stagnant moisture conditions of the bog units, fens have varying degrees of surface or subsurface lateral flow, which produces a relatively nutrient-rich, oxygenated environment (Beckingham and Archibald 1996). These are accumulations of poorly to moderately decomposed organics, primarily mosses and sedges. Halsey et al. (1995) indicated the presence of paleopermafrost features in fen areas of the southeastern portion of the LSA.

Fluvial (F Units)

Fluvial units in the LSA are of relatively recent origin and located entirely along the present floodplain of the Athabasca River. The deposits are medium- to coarse-textured, poorly sorted and characterized by riparian vegetation.

Glaciofluvial (GF Units)

Quaternary glaciofluvial deposits are the principal terrain unit in areal extent within the LSA. The composition varies, but is generally coarse-textured, ranging from sandy loams through sands to gravels and in some instances may include boulders. Smith and Fisher (1993) and Smith (pers. comm. 1996) indicate that this area may have been a major spillway for the catastrophic release of water from glacial Lake Agassiz. This would explain the coarseness of the materials. Although the relief is mostly low with gentle slopes, some locally higher areas exist that are very well-drained. Conversely, there are expanses of level terrain where drainage is impeded and organic materials have accumulated. Small, isolated areas of eolian (windblown) sands and silts, in the form of thin surface veneers or minor dunes, are found in scattered locations throughout the LSA in association with the glaciofluvial deposits.

Lacustrine (L Units)

Lacustrine units combine features that in other studies, (e.g., Landcare 1996) were subdivided into "recent lacustrine" and "glaciolacustrine" units. These deposits are fine-textured, mostly silts and clays, and form a mantle less than 2 m thick over glacial till. Surface expression tends to be gently undulating and, combined with the fine textures, may impede drainage to the point where organic deposits have accumulated. Lacustrine units in the LSA are found exclusively in the extreme northeast corner.

Rough Broken (RB Units)

Rough Broken units are found on the steep slopes of the Athabasca River escarpment. They are composed of undifferentiated materials that, due to slope instability, have not had time to develop into classifiable soil types. The precise composition and depth of these materials is variable.

Other Features

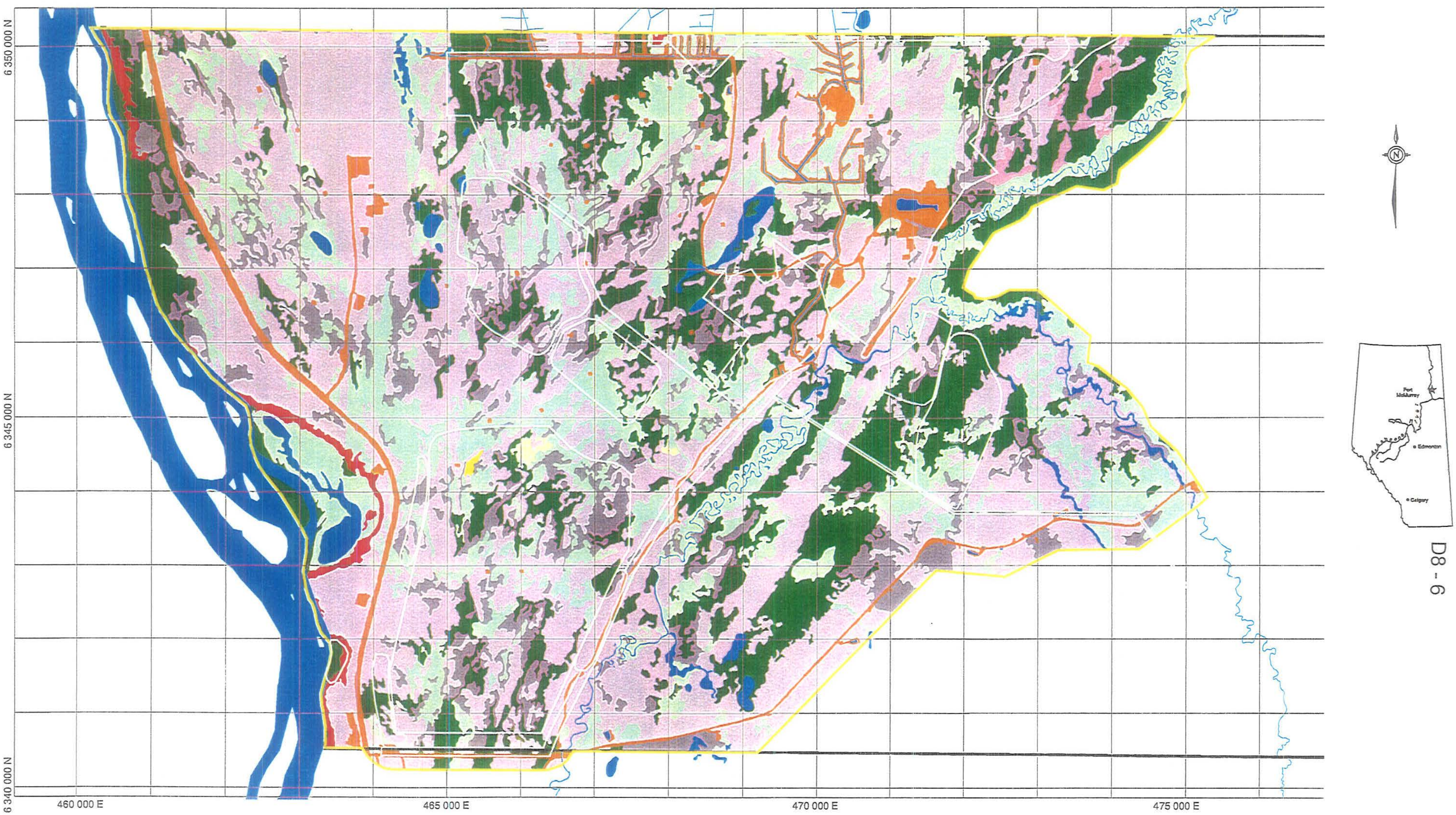
Areas of the LSA that did not meet criteria for inclusion in the above terrain units were classified as: cultural features, disturbed lands or water. Table D8-2 outlines the distribution of the terrain units in the LSA that are shown in Figure D8-2.

Table D8-2 Extent of Terrain Units in the Muskeg River Mine Project LSA

Terrain Unit	Area (ha)	% of LSA
Bog (B)	4	0.04
Shallow Bog, (Bs)	16	0.2
(Bogs - subtotal)	20	0.24
Fen (N)	2,155	19.6
Shallow Fen (Ns)	2,300	21.0
(Fens - subtotal)	4,155	40.6
Fluvial (F)	88	0.8
Glaciofluvial (Fg)	5,526	50.4
Glaciolacustrine (Lg)	42	0.4
Rough Broken (RB)	98	0.9
Total Area - Terrain Units	10,299	93.6
Disturbed Lands	540	4.9
Water	185	1.7
Total Area - Other Features	725	6.6
Total Area of LSA	10,954	100.0

D8.3 Soils

Two major classes of soils are found in the LSA: those developed in organic deposits, and those that have formed from mineral parent materials. Organic order soils include the McLelland and Muskeg series of the Mesisolic great group. Mineral soils include Bitumount and Steepbank series of the Gleysolic order; Dover and Fort series of the Luvisolic order; Mildred and Ruth Lake series of the Brunisolic order and McMurray series of the Regosolic order. The distribution of the soil series is shown in Table D8-3 and Figure D8-3.



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

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
TERRAIN CLASSIFICATION

5 Dec. 1997	Figure D8-2	PRODUCED BY: J.S./R.P. REVIEWED BY:

/data8/oilsands/972-2237/9700/9701/final/arcview/mrcroterr60fin.apr

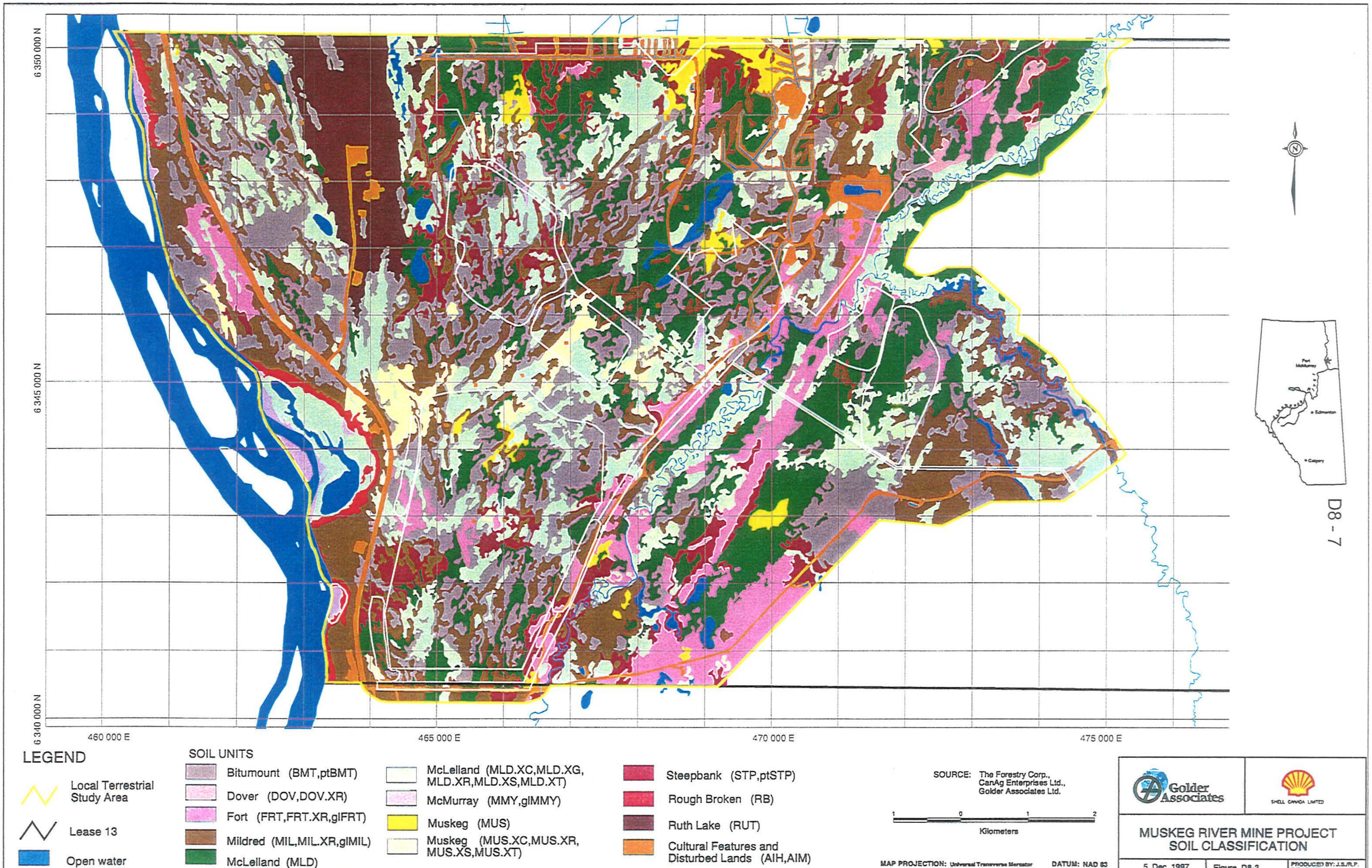


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Table D8-3 Extent of Soil Series in the Muskeg River Mine Project LSA

Series	Area (ha)	% of LSA
McLelland	4,144	37.8
Muskeg	340	3.1
McMurray	88	0.8
Bitumount	1,915	17.5
Fort	652	6.0
Mildred	1,895	17.3
Ruth Lake	445	4.1
Steepbank	610	5.6
Dover	42	0.4
Rough Broken	98	0.9
Total, Soil Units	10,229	93.4
Non-soil Features	725	6.6
Total in LSA	10,954	100

D8.3.1 Organic-Based Parent Materials and Soil Series

Organic soils, commonly referred to as peat, have formed accumulations in poorly drained, depressional locations. Two main types are distinguished within the LSA; fen soils and bog soils.

Fen Soils

One soil series in the LSA has developed on fen deposits. The McLelland series is Terric and Typic Mesisols formed in organic materials overlying glacial till. Slopes are less than 0.5% or depressional and very poorly drained. Fens were mapped where the depth of organic material is deeper than 120 cm, and where the mineral contact occurs between 40 and 120 cm below the surface (shallow fens).

Bog Soils

Terric and Typic Mesisols of the Muskeg series occupy a very small part of the LSA. These are generally less well-drained organic deposits than the fens and hence are more acidic in nature. Bogs, with organic materials deeper than 120 cm, and shallow bogs, where the mineral contact occurs between 40 and 120 cm below the surface, were mapped.

D8.3.2 Mineral-Based Parent Materials and Soil Series

Within the Muskeg River Mine Project LSA, three mineral parent materials were identified (fluvial, glaciofluvial and lacustrine), producing nine soil series, as discussed below.

Soil Series Formed on Fluvial Parent Materials

Recent fluvial deposits have given rise to one soil series characteristic of this environment within the LSA. McMurray series Cumulic Regosols are relatively young soils developed along the floodplain of the Athabasca River. Due to their medium to coarse textures, they are well-drained.

Soil Series Developed on Glaciofluvial Deposits

Glaciofluvial parent materials have given rise to five soil series, which in total occupy 50% of the LSA:

1. Bitumount series Peaty Orthic and Orthic Humic Gleysols have developed on very coarse but poorly drained deposits.

2. Fort series Orthic Grey Luvisols have formed on stratified medium over very coarse deposits found on gentle, 2 to 6%, slopes.

3. Mildred series Eluviated Dystric Brunisols have formed in coarse sandy loam to sandy materials.

4. Ruth Lake series Eluviated Eutric and Eluviated Dystric Brunisols have developed on very coarse-textured material overlying gravelly deposits. They are very rapidly drained with slopes ranging from 2 to 9%.

5. Steepbank series peaty Rego Gleysols have formed on loam or finer textured deposits with impeded drainage.

Soil Series Formed on Lacustrine Deposits

Lacustrine parent materials have produced a single soil series in the LSA. Dover series Orthic Grey Luvisols are found on fine-textured lacustrine sediments with 0.5 to 5% slopes. These moderately well-drained soils are very limited in extent in the LSA.

Unclassified Soils

One unit of surface materials occupies a small part of the LSA. It is not a soil in the strictest sense but is soil-like in composition. Rough Broken deposits are found along the steep escarpment of the Athabasca River valley where instability and downslope movement prevents the development of a diagnostic soil horizon.

Non-Soil Features

This category includes non-soil features such as open water, disturbed lands and cultural features.

D8.4 Capability Classification for Forest Ecosystems

Assessments were made of the pre-development soil unit capabilities for forest ecosystems, following the methodology of Leskiw (1996). The system has 5 classes: Class 1 or high capability; Class 2 or moderate capability; Class 3 or low capability; Class 4 or currently non-productive; and Class 5 or permanently non-productive. These classes correspond approximately to Classes 3 to 7, respectively, in the Canada Land Inventory Forestry Capability rating scheme. Tables D8-4 and D8-5 list the results of this evaluation and the distribution shown in Figure D8-4.

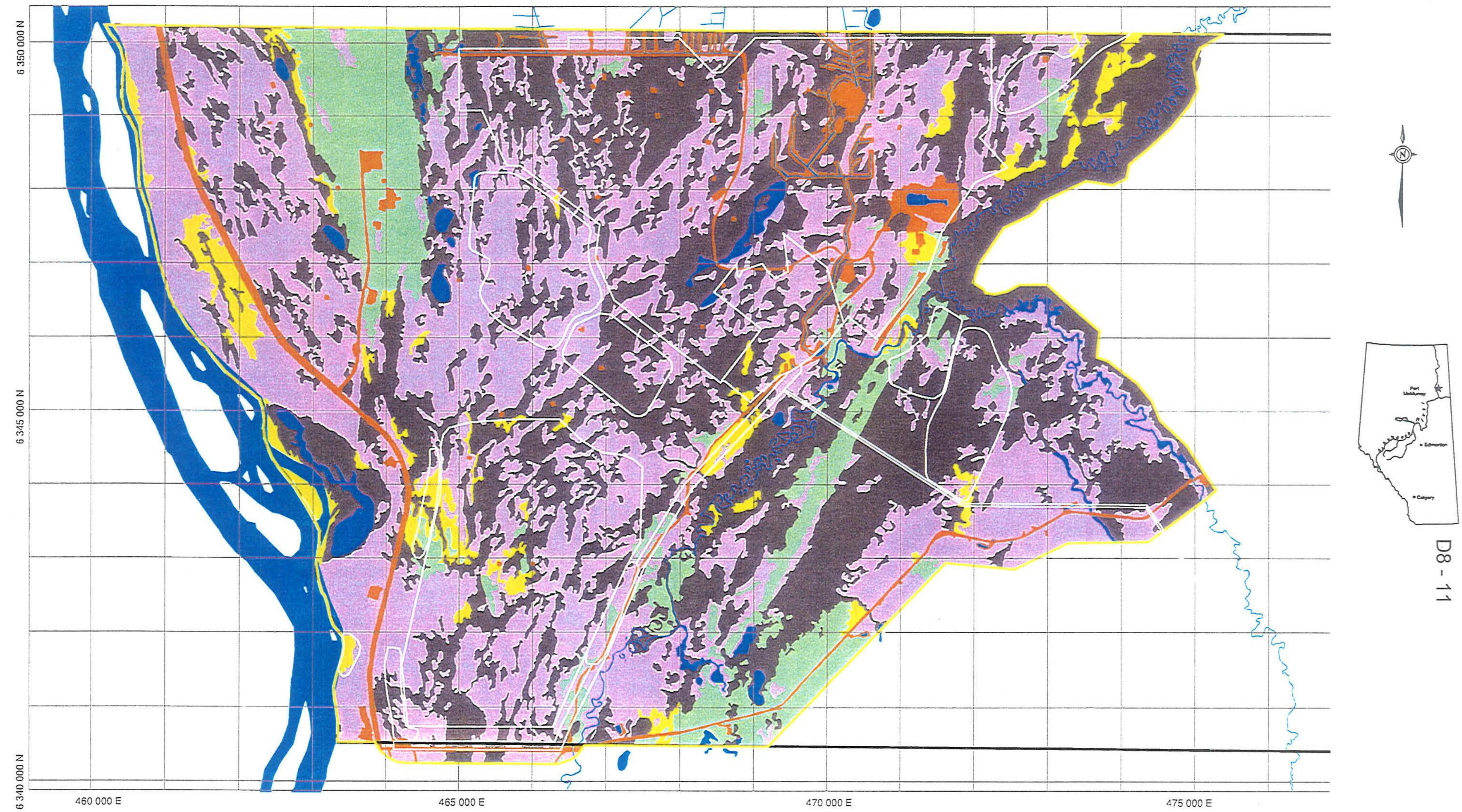
Table D8-4 Capability for Forest Ecosystems in the Muskeg River Mine Project LSA

Soil Series	Area (ha)	Capability Rating[a]
McLelland	4,144	5
Muskeg	340	5
McMurray	88	2 (5)
Bitumount	1,915	4 (2)
Fort	652	3 (2)
Mildred	1,895	3 (4)
Ruth Lake	445	3
Steepbank	610	4 (2)
Dover	42	2
Rough Broken	98	4
Disturbed Lands	540	n/a
Open Water and Stream Channels	185	n/a
Total	10,954	

[a] After Leskiw (1996)

Table D8-5 Summary of Areas for Each Forest Capability Class in the Muskeg River Mine Project LSA

Capability Class	Area (ha)	% of LSA
Class 1	0	0
Class 2	417.5	3.8
Class 3	997.5	9.1
Class 4	4,299	39.2
Class 5	4,515	41.2
Total	10,954	100



LEGEND

Local Terrestrial Study Area

Lease 13

Open water

CAPABILITY CLASSES

High (1)

Moderate (2)

Low (3)

Currently Non-Productive (4)

Permanently Non-Productive (5)

Cultural Features and Disturbed Lands

SOURCE: The Forestry Corp., CanAg Enterprises Ltd., Golder Associates 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
LAND CAPABILITY CLASSIFICATION
FOR FOREST ECOSYSTEM

5 Dec. 1997	Figure D8-4	PRODUCED BY: J.S./R.P. REVIEWED BY:

/data8/oilsands/972-2237/9700/9701/final/arcview/landcap50fin.apr

D8.5 Evaluation of Soils in the Muskeg River Mine Project LSA for Salvage and Suggested Placement for Reclamation

The soils of the Project LSA fall into two genetic classes, those derived from organic material and those based on mineral parent material. Both have potential value for placement as reclamation materials in the closure landscape but some discussion of their relative merits is warranted.

Organic Soils

The soils of the McLelland and Muskeg series make excellent materials for incorporation in the reclamation soil mix. Organic matter has the capacity to hold moisture and nutrient cations while reducing the bulk density, which enhances root penetration and moisture percolation. Approximate amounts of these soils present in the LSA, not just the development footprint, follow in Table D8-6. Note that these figures do not take into account potential shrinkage of the materials as water content decreases.

Table D8-6 Approximate Volumes of Salvageable Organic Materials in the Muskeg River Mine Project LSA

Soil Series	Area (ha)	Average Depth (m)	Volume (m^3)
McLelland 1	2,155	1.8	38,790,000
McLelland 2	2,300	0.7	18,400,000
Muskeg 1	156	1.8	2,808,000
Muskeg 2	182	0.6	1,092,000
Total	4,793	n\a	61,090,000

Mineral Soils

A very small percentage of the mineral soil cover in the LSA is suitable for direct use as reclamation material, the A horizons of the Dover and Fort series. These are relatively shallow horizons even when the overlying thin organic cover is included and the practicality of attempting to salvage them is questionable.

Mildred soils are generally coarser in texture, i.e., sandy soils, lack an A horizon and are best salvaged for mixing with peat (from the organic soils discussed above) to form the reclamation soil mix.

Approximate amounts of the available mineral soils suggested as being viable reclamation materials in the LSA, not just the development footprint, are in Table D8-7.

Table D8-7 Approximate Volumes of Salvageable Mineral Materials in the Muskeg River Mine Project LSA

Soil Series	Area (ha)	Average Depth (m)	Volume (m^3)
Dover	42	LFH = 0.05 m Ae/Ahe = 0.25 m	126,000
Fort	652	LFH = 0.03 m Ae = 0.11 m	912,800
Total			1,038,000
Mildred	1,895	Bm = 0.2 m	379,000

D9 TERRESTRIAL VEGETATION

D9.1 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:

- describe and map vegetation communities in the Study Area and identify any rare, threatened or endangered plant species; and
- evaluate forest resources according to the standards outlined in the Alberta Vegetation Inventory Standards Manual (AVI) Version 2.2 (TofR, Section 4.4).

Project-specific impacts on terrestrial vegetation are addressed in Section E9 of this EIA. Cumulative effects on terrestrial vegetation are addressed in Section F9.

Terrestrial vegetation, as defined here, corresponds to upland vegetation. Uplands are defined as areas where the soil is not saturated for extended periods, and in the study area are vegetated almost exclusively by forest stands. Wetlands vegetation is discussed in a separate section, D10.

The main objective of the study was to describe the terrestrial vegetation of the Local and Regional Study Areas at different levels of generalization in terms of:

- species composition and coverage;
- physical structure;
- age structure;
- diversity;
- rare plants; and
- plants with traditional uses.

These descriptions provided input to the ecological land classification (Section D7) and were used in impact assessment.

The Local Study Area (LSA) and Regional Study Area (RSA) for terrestrial vegetation were as described in Section D7.1.

D9.2 Methods

D9.2.1 Terrestrial Vegetation Classification

The terrestrial vegetation classification process was based on the following sources of information:

- Alberta Vegetation Inventory (AVI) mapping, which uses a forestry-based vegetation classification system:
- the Field Guide to Ecosites of Northern Alberta (Beckingham and Archibald 1996), which uses a vegetation classification system based on the principles of ecological land classification (ELC):
- field data reported in the Aurora EIA (BOVAR 1996a): and
- field data collected for the current study.

There were four steps in the terrestrial vegetation classification process:

1. AVI polygons were selected as mapping units.
2. AVI polygons were classified using Beckingham and Archibald's system to provide an initial delineation of ecosite phase.
3. Ground-truthing data were collected from plots located on the basis of the preliminary delineation.
4. The preliminary delineation was finalized as necessary using field data. Polygons and plots that did not fit Beckingham and Archibald's system were defined either as complexes of Beckingham units or as new vegetation units.

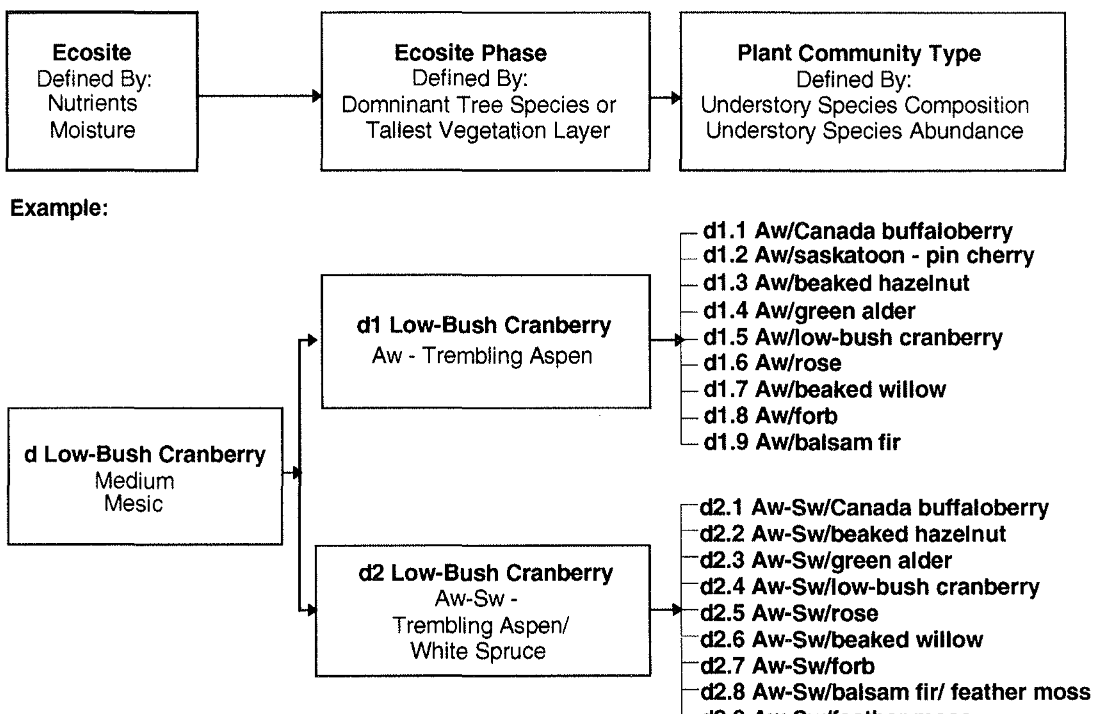
D9.2.2 Beckingham and Archibald's Classification System

Beckingham and Archibald's system, as expressed in their Field Guide to Ecosites of Northern Alberta (1996), uses a mixture of biotic and abiotic variables to create a hierarchical, or nested, ecological classification structure. At the coarsest level of classification, ecological areas and subregions are defined on the basis of broad ecoclimatic factors. At this level of generalization the entire study area is within the boreal mixedwood forest. Differences in soil nutrient and moisture regimes are then used to differentiate ecosites. Beckingham and Archibald recognized 8 upland ecosites in the boreal mixedwood forest. Ecosites are subdivided into ecosite phases according to the dominant species in the forest canopy or tallest vegetation layer. At the finest level of classification, ecosite phases are in turn subdivided into plant community types on the basis of differences in species composition within the understory vegetation (typically the shrub layer). Figure D9-1 summarizes the classification process, starting at the ecosite level, and works through an example for one ecosite.

Only polygons that were field visited so understories could be identified can be classified to the plant community level. Therefore, the vegetation classification for the LSA was completed only to the ecosite phase level.

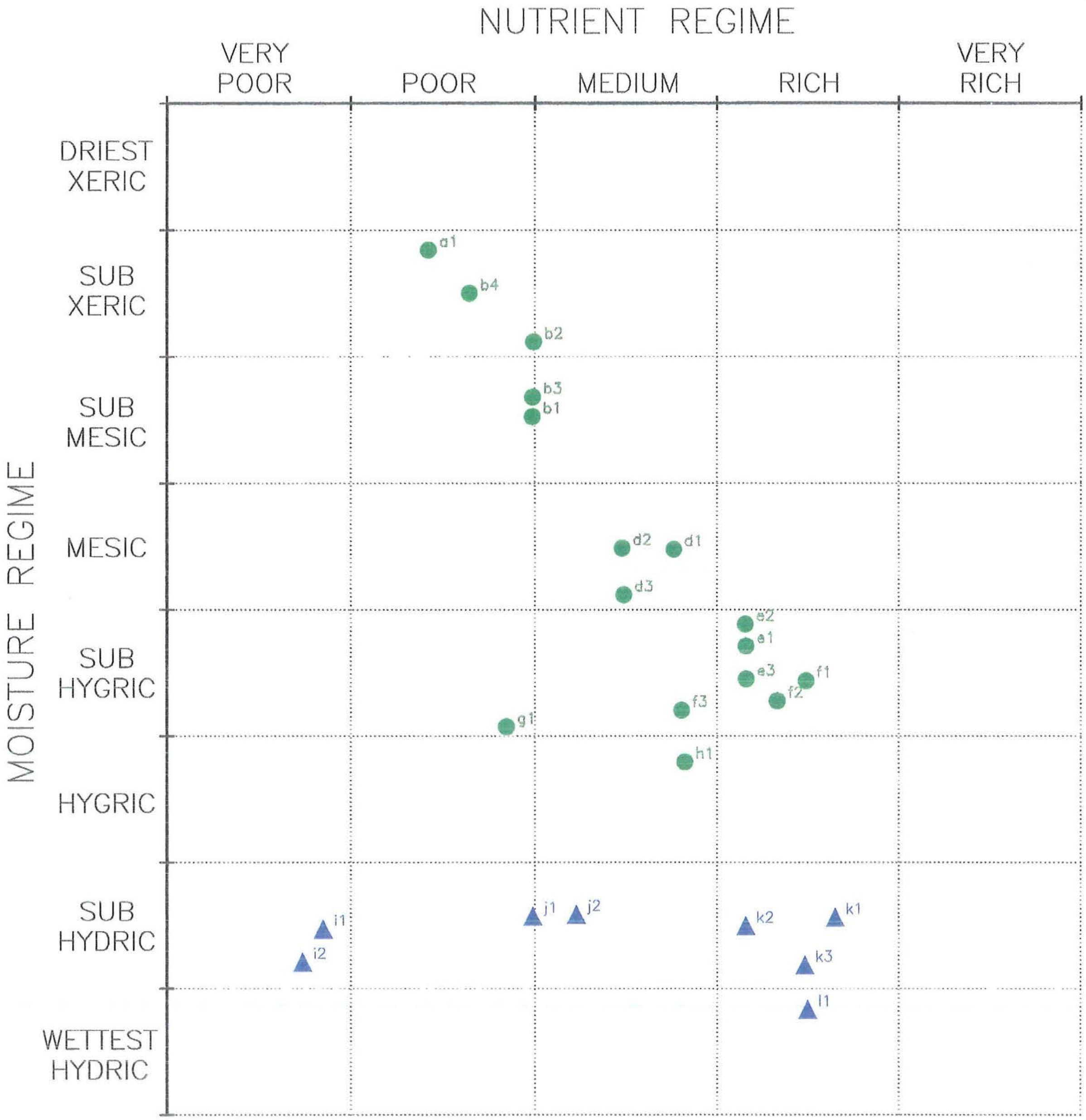
Figure D9-2 is an edatropic grid showing the ecological relationships, as defined by gradients of moisture and nutrient supply, of the 17 upland ecosite phases described by Beckingham and Archibald (1996). The eight wetlands ecosite phases are included for comparison. Moisture conditions, on the vertical (y) axis, range from hydric (wettest) to xeric (driest). Nutrient conditions, on the horizontal (x) axis, range from very poor to very rich. The positions of the ecosite phases shown in Figure D9-2 represent the mid-points of the ranges of moisture and nutrient regime reported by Beckingham and Archibald.

Figure D9-1 Ecosite Classification Steps for Upland Areas



Example:

d Low-Bush Cranberry + **d1 Aw - Trembling Aspen** + **d1.6 Aw/Rose** = **d1.6 Low-Bush Cranberry/ Trembling Aspen/ Rose**



LEGEND

- ● TERRESTRIAL ECOSITE PHASES
- ▲ WETLAND ECOSITE PHASES

Golder Associates

SHELL CANADA LIMITED

MOISTURE: NUTRIENT RELATIONSHIPS OF ECOSITE PHASES

03 DEC 1997	Figure D9–2	DRAWN BY: R.R.

D9.2.3 Plant Community Assessment Field Methods

Plot locations for the upland plant community assessment were determined using the initial delineation of plant communities (Section D9.2.1). Plots of 20 x 20 m were randomly located in five separate map polygons representative of each ELC unit (Section D7.3.7). Species composition and structural data were collected within each plot as follows:

- tree layer (>5 m high) - entire 20 x 20 m plot
  - % coverage for each species
  - average tree height
  - dbh (diameter at breast height) for all living, dead and downed trees
  - age of 3 largest trees
- shrub layer (0.5-5 m high) - 10 x 10 m subplot in one corner of 20 x 20 m plot
  - % coverage for each species
  - height of shrubs
- herb layer (<0.5 m high) - 7. 1 x 1 m plots within 10 x 10 m subplot
  - % cover for each herb, moss and lichen species.

Standard field techniques were used throughout. Field taxonomy followed *Flora of Alberta* Moss (1983) and Packer and Bradley (1984). Specimens of plants that could not be identified in the field were collected for herbarium identification.

D9.2.4 Rare Plants

A list of rare plant species potentially present in the study area was prepared from existing literature sources. The known habitat associations of these species were considered in selecting the field plot locations. During the field studies, each rare plant occurrence was documented using the rare native plant survey form provided by the AHNIC. Rare plants were photographed twice and specimens were collected if necessary.

D9.2.5 Plants With Traditional Uses

Plants traditionally used by local aboriginal people for food, medicine or spiritual purposes were identified using published literature and past interviews with community members (Fort McKay Environmental Services 1997).

D9.2.6 Species Richness and Diversity

Species richness and diversity indices were not calculated for the field data because only a few of the ecosite phases were represented by a sufficient number of plots to allow meaningful statistical comparisons. Instead, the mean and range of numbers of species for the ecosite phases with plots have been presented, both for the unit as a whole and for each of the tree, shrub and herb layers.

D9.3 Results

D9.3.1 Vegetation Communities

Areas of Ecosite Phases

Beckingham and Archibald (1996) defined eight upland ecosites and 17 associated ecosite phases within the boreal mixedwood forest. All of the ecosite phases except b2 and f3 are represented within the LSA. Table D9-1 gives the baseline areas of the upland ecosite phases and complexes of ecosite phases mapped within the LSA. Included are two upland vegetation types that do not fit into Beckingham and Archibald's classification, shrublands and black spruce-tamarack forest. In total, upland forest vegetation units comprise 33.1% of the LSA.

The ecosites and ecosite phases are described below. The characteristic species of the ecosite phases are summarized in Table D9-2. No floristic data are available for the shrubland and black spruce-tamarack vegetation types.

Lichen Ecosite (a)

The soils of the lichen ecosite are well-to rapidly-drained, with submesic to xeric moisture regimes. The nutrient regime is typically poor. This ecosite has only one phase, the lichen-jack pine.

The canopy of the lichen-jack pine (a1) ecosite phase is dominated by jack pine. The shrub understory typically consists of blueberry, bearberry, green alder, bog cranberry, Labrador tea, twin-flower, jack pine and sand heather.

Wild lily-of-the-valley is the only common forb. On the forest floor, reindeer lichen is dominant, while Schreber's moss, awned hair-cap moss and brown-foot cladonia are also found.

Blueberry Ecosite (b)

The soils of the blueberry ecosite are moderately well-to rapidly-drained. The moisture regime is usually submesic to subxeric, and the nutrient regime is poor to medium. Three of the four ecosite phases identified by Beckingham and Archibald (1996) occur in the LSA.

The canopy of the blueberry jack pine-trembling aspen (b1) ecosite phase is dominated by jack pine and aspen (Figure D9-3). White birch, white spruce and black spruce may also be found in the canopy. The shrub layer is diverse, typically consisting of bog cranberry, blueberry, green alder, bearberry, Labrador tea, twin-flower, Canada buffaloberry, aspen, white spruce and prickly rose. Herbs may include bunchberry, fireweed and cream-colored vetchling. Hairy wild rye is also present. Schreber's moss, stair-step moss and reindeer lichen are the characteristic non-vascular species.

Aspen and white spruce dominate the canopy of the blueberry aspen-white spruce (b3) ecosite phase. White birch and jack pine may also be present in the canopy. The shrub layer is denser than in b1 but species composition differs only in that Canada buffaloberry is not common in b3. Bunchberry, fireweed, wild lily-of-the-valley, wild strawberry and cream-colored vetchling are characteristic of the herb layer. The dominant grasses, mosses and lichens are the same as in b1 and percent coverages are similar.

The canopy of the blueberry white spruce-jack pine (b4) ecosite phase is dominated by white spruce and jack pine, although white birch and aspen are usually present as well. The shrub layer is similar to that of b3, with slightly lower average per cent cover.

Figure D9-3 Blueberry Ecosite With Jack Pine - Trembling Aspen Canopy

The herb layer is characterized by bunchberry, wild lily-of-the-valley and bastard toad-flax. Hairy wild rye and reindeer lichen also are characteristic. The moss layer is better developed than in the other blueberry ecosite phases, with >30% coverage, but the species are the same.

Table D9-1 Baseline Areas of Ecosite Phases Within the LSA

Ecosite Phase	Code	Area (ha)	Percent Cover
lichen jack pine	a1	106	1.0
lichen + Labrador tea	a1/g1	21	0.2
blueberry Pj-Aw	b1	878	8.0
blueberry Aw-Sw	b3	67	0.6
blueberry Sw-Pj	b4	286	2.6
Labrador Tea-mesic Pj-Sb	c1	20	0.2
low-bush cranberry Aw	d1	1,525	13.9
low-bush cranberry Aw-Sw	d2	169	1.5
low-bush cranberry Sw	d3	15	0.1
dogwood Pb-Aw	e1	61	0.6
dogwood + horsetail Pb-Aw	e1/f1	66	0.6
dogwood Pb-Sw	e2	4	0.0
dogwood + horsetail Pb-Sw	e2/f2	9	0.1
dogwood Sw	e3	93	0.8
Labrador tea - subhygric Sb-Pj	g1	8	0.1
Labrador tea/horsetail Sw-Sb	h1	123	1.1
shrubland	-	119	1.1
black spruce-tamarack	-	61	0.6
total, upland ecosite phases		3,631	33.1
total, wetlands vegetation units		6,719	61.4
disturbed, unvegetated, water		604	5.5
TOTAL LSA		10,954	100.0

Table D9-2 Average % Cover of Characteristic Species (Presence >70% of Plots)

Species	a1	b1	b3	b4	c1	d1	d2	d3	e1	e2	e3	f1	f2	g1	h1
Tree Layer															
aspen		14	27			50	28		30	15		24	8		
balsam poplar						5	3		22	8		23	8		
balsam fir							3	6		2	10				
black spruce					13		2							31	13
jack pine	27	26		14	27									12	
white birch		3	2	3		2	3		2	5		6	13		
white spruce			20	25			22	39		26	41		36		34
Shrub Layer															
aspen		3	3			3	3								
balsam fir								6			8		3		
bearberry	10	6	14	11											
black spruce					6									8	
blueberry	11	9	18	16	6									4	
bog cranberry	7	10	6	6	10									7	7
honeysuckle									8	7	5				
buffaloberry		3				6	3								
currant									3	3	4				
dogwood									11	12		5	4		
alder		6	4	6					7		7	6			
jack pine	3														
Labrador tea		6			10									16	14
low bush cranberry						8	10	6	9	8	8	4	7		
prickly rose		3	6	3		15	9	6	14	8	8	8	4		4
saskatoon				2		3									
twin-flower		4	4	4	3	5	6	8		5	6		3		
white spruce		3	5	6			3						4		
wild raspberry												4			
willow						4			4			8	5		5
Forbs															
bishop's-cap										3	5		4		
bunchberry		4	5	4	4	6	8	7		6	4		4		
common horsetail												16	12		12
cream-coloured vetchling						3									
dewberry						4	3	3	4	6	5	4	3		
fireweed			2			5	3		4						
wild lily-of-the-valley	2		3												
meadow horsetail												13	18		6
tall lungwort								2			3		2		
wild sarsaparilla						6	5	4	8	9	6	4	7		
wild strawberry			1	2											
woodland horsetail											7				
Grasses															
hairy wild rye		3	5	1		5	4								
marsh reed grass						7	5		5	9	9	11			
Mosses															
knight's plume moss					5		3	8		4			10	9	4
Schreber's moss	8	13	10	29	42		9	15		5			15	30	24
stair-step moss		8	5	5	13		15	48		12			25	31	48
Lichen															
reindeer lichen	31	6	2	6	6									8	

Labrador Tea-Mesic Ecosite (c)

The soils of the Labrador tea ecosite are usually moderately well-to well-drained. The moisture regime is subhygric to submesic, and the nutrient regime is typically poor. Labrador tea-mesic jack pine-black spruce (c1) (Figure D9-4) is the only ecosite phase.

Figure D9-4 Jack Pine-Black Spruce Forest With Labrador Tea Understory

The canopy of the Labrador tea-mesic jack pine-black spruce ecosite phase is dominated by jack pine and black spruce. The shrub layer typically consists of Labrador tea, bog cranberry, black spruce, blueberry, green alder, and twin-flower. Bunchberry is the only characteristic species in the poorly developed herb layer. The forest floor is dominated by Schreber's moss, with average ground coverage exceeding 40%. Stair-step moss, knight's plume moss and reindeer lichen also are characteristic.

Low-Bush Cranberry Ecosite (d)

The central moisture-nutrient concept of this ecosite is mesic-medium, although moisture regimes may vary from submesic to subhygric and nutrient regimes from poor to rich. There are three ecosite phases.

The tree layer of the low-bush cranberry aspen (d1) ecosite phase is usually dominated by a closed canopy of aspen (Figure D9-5), although white birch may be locally dominant.

Balsam poplar and white spruce are the other characteristic tree species. Prickly rose and low-bush cranberry are dominant in the shrub layer. Other typical shrubs are beaked hazelnut, green alder, Canada buffaloberry, saskatoon, willow, twin-flower and aspen. The herb layer is well-developed and is characterized by wild sarsaparilla, fireweed, bunchberry, dewberry, cream-colored vetchling and northern bedstraw. Marsh reed grass and hairy wild rye are abundant and characteristic. Stair-step moss and knight's plume moss may also be present.

Figure D9-5 Trembling Aspen Canopy With Low-Bush Cranberry Understory

The canopy of the low-bush cranberry aspen-white spruce (d2) ecosite phase is typically dominated by aspen and white spruce; however, balsam fir, black spruce, white birch and balsam poplar may all be locally dominant. The species composition of the shrub layer is the same as that of d1, except for the addition of pin cherry and choke cherry. The herb layer is less diverse than in d1, but grass coverage is essentially the same. Unlike d1, a moss layer is present. It is characterized by stair-step moss, Schreber's moss and knight's plume moss.

The canopy of the low-bush cranberry white spruce (d3) ecosite phase is dominated by white spruce. Balsam fir, aspen, black spruce, white birch and balsam poplar and black spruce also are characteristic. The shrub layer typically contains balsam fir, low-bush cranberry, twin-flower prickly rose, green alder and Canada buffaloberry. Sarsaparilla, bunchberry, dewberry and tall lungwort characterize the herb layer, along with hairy wild rye. Ground coverage by moss is usually >50%. The species are as in d2, with stair-step moss dominant.

Dogwood Ecosite (e)

Drainage conditions in the soils of the dogwood ecosite vary widely. Moisture regimes range from mesic to hygric and nutrient regimes from medium to rich, although the central concept of the ecosite is subhygric-rich. All three dogwood ecosite phases occur in the study area.

The tree canopy of the dogwood balsam poplar-aspen (e1) ecosite phase is usually dominated by aspen and balsam poplar, although white spruce may be locally dominant. White birch may also be present. Prickly rose, dogwood and low-bush cranberry are the most abundant shrub species. Other characteristic shrubs are bracted honeysuckle, green and river alder, willow and currant. In the herb layer, wild sarsaparilla, dewberry, marsh reed grass and fireweed are the most abundant of the characteristic species. Ferns are also characteristic but typically have cover values <1%.

White spruce, aspen and balsam poplar dominate the tree canopy of the dogwood balsam poplar-white spruce (e2) ecosite phase. White birch is usually present in the canopy as well. The dominant shrub species are the same as in e1 and the other characteristic shrub species differ only slightly. The herb layer is also the same except that bunchberry and bishop's-cap replace fireweed. There is a moss layer with approximately 20% ground coverage. It is dominated by stair-step moss.

The dogwood balsam poplar-white spruce (e3) ecosite phase usually occurs on wetter sites than e1 and e2. The dominant tree species is white spruce, with canopy coverage averaging about 40%. Balsam fir is typically present and all three deciduous species are occasionally present. Balsam fir, low-bush cranberry, prickly rose, green and river alder, twin-flower, bracted honeysuckle and currant are the characteristic shrub species. Woodland horsetail, wild sarsaparilla, bishop's-cap, dewberry, bunchberry and tall lungwort are the most characteristic forbs. Marsh reed grass is abundant. The well-developed moss layer consists of stair-step moss, Schreber's moss and knight's plume moss.

Horsetail Ecosite (f)

Soils in the horsetail ecosite are well-to poorly-drained, with mesic to hygric moisture regimes. The nutrient supply is commonly enhanced by flooding or seepage, giving characteristically rich nutrient regimes. Typically, the forest floor is blanketed by horsetail. Two horsetail ecosite phases were documented in the LSA, but only in small patches complexed with dogwood ecosite phases.

Balsam and aspen poplar co-dominate the tree canopy of the horsetail balsam poplar-aspen (f1) ecosite phase. White birch is also characteristic, and white spruce is often present at low cover values. Willow, prickly rose, green and river alder, dogwood, wild red raspberry and low-bush cranberry characterize the shrub layer. The herb layer is dominated by common horsetail, meadow horsetail and marsh reed grass. Wild sarsaparilla and dewberry are the only other characteristic constituents. Within the LSA, this ecosite phase was typically complexed with e1.

With an average canopy coverage of 36%, white spruce is the dominant tree species in the horsetail balsam poplar-white spruce (f2) ecosite phase. White birch, balsam poplar, aspen and balsam fir also are typically present. The shrub layer is characterized by low-bush cranberry, willow, white spruce, prickly rose, dogwood, balsam fir, twin-flower and white birch. Common horsetail and meadow horsetail dominate the forb layer although wild sarsaparilla, bishop's-cap, bunchberry, dewberry, tall lungwort and palmate-leaved coltsfoot also are characteristically present. There is a well-developed moss layer consisting of stair-step moss, Schreber's moss and knight's plume moss. Within the LSA, this ecosite phase was complexed with e2.

Labrador Tea-Subhygric Ecosite (g)

The soils of the Labrador tea-subhygric ecosite are imperfectly to very poorly drained, with subhygric to hydric moisture regimes. The nutrient regime is typically poor. There is only one ecosite phase, the Labrador tea black spruce-jack pine (g1) (Figure D9-6).

Figure D9-6 Jack Pine-Black Spruce Forest With Labrador Tea Understory

The canopy of the Labrador tea black spruce-jack pine ecosite phase is usually dominated by black spruce. Jack pine, the other characteristic tree species, may be locally dominant. Labrador tea is the dominant shrub. The other characteristic species in the shrub layer are bog cranberry, black spruce, blueberry, prickly rose and twin-flower. Only one species, bunchberry, is characteristic of the poorly expressed herb layer. Moss cover is quite high, usually >50%. Stair-step moss and Schreber's moss dominate, but knight's plume moss, peat moss and tufted moss also are typically present. Reindeer lichen is usually present as well.

Labrador Tea/Horsetail Ecosite (h)

The soils of the Labrador tea/horsetail ecosite are imperfectly to very poorly drained. Moisture regimes vary widely, from mesic to hydric, although most sites are in the subhygric-hygric range. Nutrient regimes range from rich to poor. There is one ecosite phase, the Labrador tea/horsetail white spruce-black spruce (h1) (Figure D9-7).

The canopy of the Labrador tea/horsetail white spruce-black spruce ecosite phase is dominated by white spruce, with black spruce typically being subdominant. White birch is usually present. Labrador tea is the most abundant shrub. The other species characteristic of the shrub layer are bog cranberry, willow, prickly rose and twin-flower. Common horsetail, meadow horsetail, woodland horsetail, bunchberry and dwarf scouring rush are the only common forbs. Marsh reed grass and sedges are typically present at low cover values. The moss layer is very well-developed, with cover values averaging 70% or more. Stair-step moss and Schreber's moss dominate; tufted moss and knight's plume moss also are characteristic.

Figure D9-7 White Spruce Canopy With Labrador Tea and Horsetail Understory

Species Richness and Diversity

Table D9-3 provides an indication of relative species richness among ecosite phases, as indicated by the mean and range of numbers of species. Of the ecosite phases for which data are available, species richness appears to be highest in h1.

Table D9-3 Species Richness by Ecosite Phase

Ecosite Phase	No. of Plots	Number of Species		
		Mean	Minimum	Maximum
a1	5	19	8	31
b1	4	26	23	27
c1	1	16	16	16
d1	4	23	20	27
d2	5	27	24	30
g1	6	24	11	30
h1	1	33	33	33

Table D9-4 shows the mean and range of numbers of species in each of the tree, shrub and herb layers in each of the ecosite phases for which data are available. In each case, the mean, minimum and maximum number of species are highest in the herb layer and lowest in the tree layer.

Rare Plants

Previous studies (BOVAR 1996a) documented the existence of 17 species of vascular plants listed as rare within the LSA. Within the RSA, 25 species have previously been documented. During the 1997 field studies, nine species of rare plants were documented, including three wetlands species -- *Sparganium fluctuans, Nymphaea tetragona leibergii* and *Carex hystricina* -- not previously found within the LSA or RSA. None of the rare plants occurring within the LSA or RSA is considered to be rare nationally.

Table D9-4 Species Richness by Structural Layer

Ecosite Phase	Number of Species, by Structural Layer					
	Tree		Shrub		Herb	
	Mean	Range	Mean	Range	Mean	Range
a1	1.8	1-4	4.6	2-11	15.6	7-23
b1	2.8	2-4	7.3	3-11	20.5	18-22
c1	2	2-2	4	4-4	14	14-14
d1	1.7	1-2	8.8	6-12	17.8	15-20
d2	2.8	2-4	6.6	6-8	21.8	19-26
g1	2.5	2-3	7.2	4-10	19.5	8-25
h1	2	2-2	10	10-10	26	26-26

Neither the 1995 nor the 1997 studies generated enough data to find statistically significant relationships between rare plants and vegetation units. During the 1997 field studies, four species of rare plants were observed in three different upland vegetation units, as shown below in Table D9-5.

Table D9-5 Rare Plant Species

Species	Community Type
Barbarea orthoceras	b1
Carex hystricina	b1
Carex lacustris	b1, e1/f1, shrub
Coptis trifolia	g1.1, b1.2
Rhamnus alnifolia	g1.1
Scirpus cyperinus	d2.3
Lycopus uniflorus	d2

Plants With Traditional Uses

The baseline report (BOVAR 1996a) lists plants documented as having traditional uses in the RSA. In all, 30 species or species groups are used either for food, medicine or spiritual purposes by First Nations people. A majority of these occur in upland vegetation types.

D10 WETLANDS

D10.1 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:

- evaluate peatlands/wetlands resources according to the standard outlined in the Alberta Vegetation Inventory Standards Manual (AVI) Version 2.2 (TofR, Section 4.4).

Project-specific impacts on wetlands are addressed in Section E10 of this EIA. Cumulative effects on wetlands are addressed in Section F10.

The National Wetlands Working Group (NWWG 1988) definition of wetlands "... land that is saturated with water long enough to promote wetlands or aquatic processes as indicated by hydric soil, hydrophytic vegetation and various kinds of biological activity which are adapted to the wet environment" has been adopted as a working definition for the purposes of the current study.

The objective of the wetlands component of the ecological landscape classification study was to describe the lowland or wetlands ecosite types in the Local Study Area (LSA) and Regional Study Area (RSA). The LSA and RSA for wetlands corresponded with the terrestrial LSA and RSA described in Section D1.

The wetlands descriptions and classification were guided by Project Terms of Reference (TofR) issued on November 7, 1997 by AEP. Specifically, Section 4.4 of the TofR directs that the wetlands section is to:

evaluate peatlands/wetlands resources according to the standard outlined in the Alberta Vegetation Inventory Standards Manual (AVI) Version 2.2.

Study area wetlands were described and classified using the wetlands classifications in the Field Guide to Ecosites of Northern Alberta (Beckingham and Archibald 1996) and the Alberta Wetlands Inventory (AWI) (Halsey and Vitt 1996). Beckingham and Archibald's system was used as the basis for the floristic analysis and initial classification of wetlands types, but the AWI was used for the final wetlands classification presented in the ELC (Section D7).

D10.2 Methods

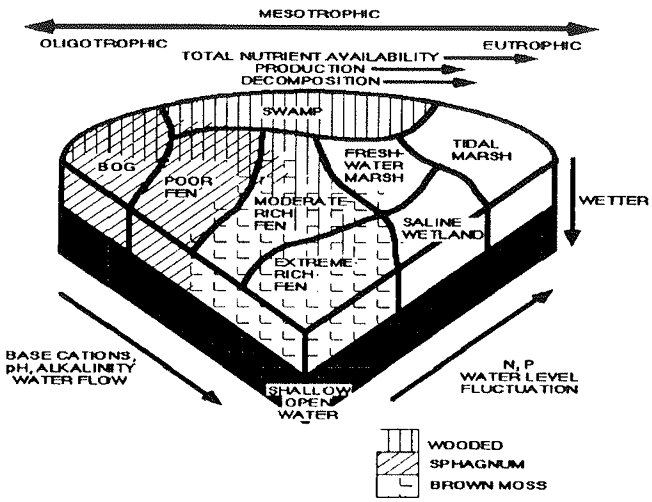
There were five steps in the wetlands vegetation classification process:

1. Alberta Vegetation Inventory (AVI) polygons were selected as mapping units.
2. AVI polygons were classified using Beckingham and Archibald's system to provide an initial delineation of vegetation communities.
3. Ground truthing data were collected from plots located on the basis of the preliminary delineation.
4. The preliminary delineation was finalized as necessary using field data.
5. Wetlands were reclassified and mapped using the AWI classification system.

Beckingham and Archibald's (1996) system uses a mixture of biotic and abiotic variables to create a hierarchical, or nested, ecological classification structure. At the coarsest level of classification, ecological areas and subregions are defined on the basis of broad ecoclimatic factors. At this level of generalization, the entire study area is within the boreal mixedwood forest. Differences in soil nutrient and moisture regimes are then used to differentiate ecosites. Beckingham and Archibald recognized four wetlands ecosites-bog, poor fen, rich fen and marsh-in the boreal mixedwood forest. The four wetlands ecosites are subdivided into eight ecosite phases according to the gross physiognomy of the vegetation (i.e., tree, shrub or graminoid). At the finest level of classification, ecosite phases are in turn subdivided into plant community types on the basis of differences in plant species composition. A summary of the classification process and an example are presented in Figure D9-1 (Section D9). The ecological relationships among the eight wetlands ecosite phases, as defined by gradients of moisture and nutrient supply, are shown in Figure D9-2 (Section D9).

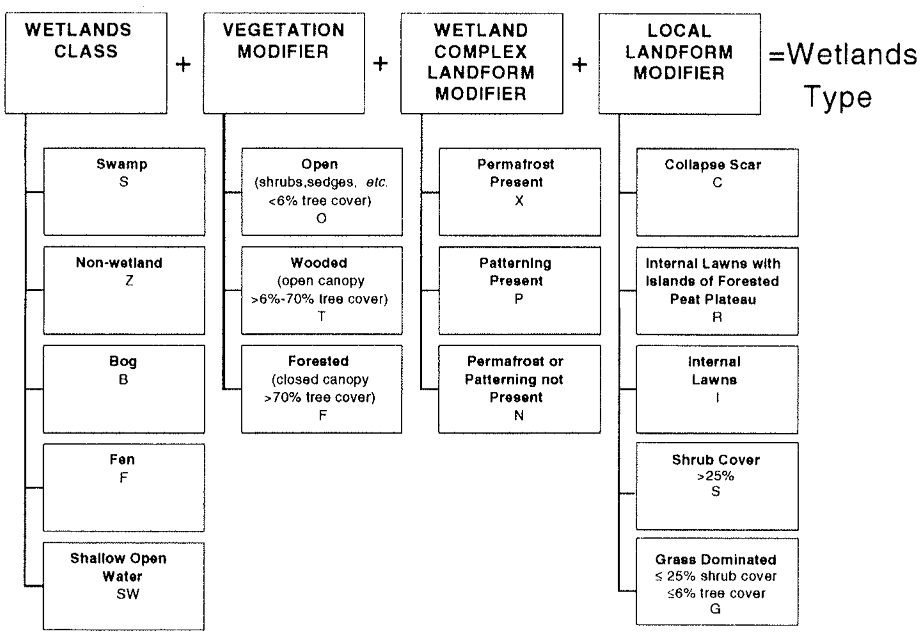
In the AWI system, five primary wetlands types-bog, fen, marsh, swamp and shallow open-water are defined in terms of interrelationships among the hydrologic, chemical and biotic processes that control wetlands development (Figure D10-1). Vegetation and landform modifiers are then applied to subdivide the primary wetlands types (Figure D10-2). The modifiers have been defined in such a way that the subdivided wetlands classes can readily be discriminated on air photos.

Figure D10-1 Primary Wetlands Classification Based on Hydrologic, Chemical and Biotic Gradients



Source: Halsey and Vitt 1996

Figure D10-2 AWI Wetlands Classification Process



Example:

Bog (B) + Wooded (T) + Permafrost not Present (N) + Internal Lawns (I) = Wooded Bog with Internal Lawns (Btni)

Source: Nesby 1997

An important consequence of the different ways in which wetlands units are defined in the Beckingham and Archibald (1996) and AWI systems is that AWI wetlands units are often easier to identify on air photos. At the same time, the AWI system provides a finer subdivision of units. Table D10-1 compares the two systems.

Table D10-1 Comparison of AWI and Field Guide to Ecosites of Northern Alberta Wetlands Classification Systems

Alberta Wetlands Inventory[a]			Field Guide to Ecosites[b]
Class	Subclasses		
Shallow open-water (SW)	n/a	n/a	n/a
Marsh (M)	n/a	n/a	Marsh (l1)
Swamp (S)	n/a	Coniferous swamp (St)	Wetter end of horsetail (f)
	n/a	Shrubby swamp (Sa)	n/a
Fen (F)	Open fen (≤10% tree cover)	Patterned fen (Fop)	n/a
		Non-patterned shrubby fen (Fons)	Shrubby poor fen (j2) and shrubby rich fen (k2)
		Non-patterned graminoid fen (Fong)	Graminoid rich fen (k3)
	Wooded fen (>10% - ≤70% tree cover)	No internal lawns (Ft)	Treed poor fen (j1) and treed rich fen (k1)
		Forested peat plateau and open internal lawns as islands in treed fens (Ftxi)	n/a
		Internal lawns as islands in treed fens (Fti)	n/a
Bog (B)	Open bog (<6% tree cover)	Veneer bogs (Box)	n/a
	Forested bog (>70% tree cover)	Peat plateau (Bfx)	n/a
	Wooded bog (>10%, ≤70% tree cover)	No internal lawns (Bt)	n/a
		Peat plateau and internal lawns as islands in treed bog (Btxi)	Treed bog (i1) and shrubby bog (i2)
		Internal lawns as islands in treed bog (Bti)	n/a

n/a= not applicable
(a) Halsey and Vitt (1996)
(b) Beckingham and Archibald (1996)

D10.3 Results

D10.3.1 Wetlands Ecosite Phases

Beckingham and Archibald (1996) defined four wetlands ecosites-bog, poor fen, rich fen and marsh-and eight associated ecosite phases within the boreal mixedwood forest. All of the ecosite phases except i1, treed bog, are represented within the LSA. Table D10-2 gives the baseline areas of the wetlands ecosite phases and complexes of ecosite phases mapped within the LSA. Included are two wetlands units that do not fit into Beckingham and Archibald's classification-swamp and shallow open-water. These are categories in the AWI classification system. In total, wetlands vegetation units comprise 61.4% of the LSA.

Table D10-2 Baseline Areas of Ecosite Phases Within the LSA

Ecosite Phase or Wetlands Unit	Symbol	Baseline Area	
		Hectares	% of LSA
Shrubby bog	i2	20	0.2
Treed poor fen	j1	356	3.3
Treed fen-subhygric Labrador tea complex	j1/g1	27	0.2
Treed fen-Labrador tea/horsetail complex	j1/h1	74	0.7
Shrubby poor fen	j2	1,182	10.8
Shrubby fen- Labrador tea/horsetail complex	j2/h1	2	<0.1
Treed rich fen	k1	1,370	12.5
Shrubby rich fen	k2	2,136	19.5
Graminoid rich fen	k3	51	0.5
Marsh	l1	85	0.8
Swamp	Stnn, Sfnn	1,359	12.4
Shallow open-water		57	0.5
Total, wetlands vegetation		**6,719**	**61.4**

The wetlands ecosites and ecosite phases that occur in the LSA are described in the subsections below. The floristic characteristics of the ecosite phases are summarized in Table D10-3. No floristic data are available for the swamp and shallow open-water wetlands types.

Table D10-3 Average % Cover of Characteristic Species (Presence >70% of Plots)

Species	i2	j1	j2	k1	k2	k3	l1
Trees							
black spruce		21					
tamarack		10		18			
Shrubs							
bog cranberry	10	7	9				
bog rosemary				3			
black spruce	35	16	20				
dwarf birch		4	12	21	7		
Labrador tea	37	26	23	6			
leatherleaf	7						
river alder					5		
small bog cranberry	4		3				
tamarack		5	3	12			
willow		5	7	6	37		
Forbs							
cattail							11
cloudberry	10		4				
common horsetail		8					
marsh cinquefoil				2			
northern willowherb							6
3-leaved Solomon's seal		3		3			
Graminoids							
bulrush							3
creeping spike-rush							5
marsh reed grass				7	20	5	5
northern reed grass						4	
reed grass							11
sedge		10	10	15	23	59	26
Mosses							
brown moss				4	9	8	6
golden moss		9	13	20			
peat moss	66	34	60	14			
ragged moss						9	
Schreber's moss	6	7		4			
slender hair-cap	3						
stair-step moss		8					
tufted moss		5	6	23			
Lichen							
Reindeer lichen	12	5	4				

Bog Ecosite

The bog ecosite has organic soils consisting of materials derived from peat moss. Drainage is poor to very poor, yielding hygric to hydric moisture regimes. Nutrient regimes are poor to very poor. Bogs occur in depressions or in level areas where water is stagnant and there is a high accumulation of peat and organic matter. One bog ecosite phase occurs in the LSA.

The shrubby bog ecosite phase (I2) lacks a tree layer but typically has a well-developed shrub layer dominated by Labrador tea and white spruce. Cranberries and leatherleaf are the other characteristic shrub species. Cloudberry is the only characteristic forb. The ground vegetation is dominated by peat moss. Schreber's moss, slender hair-cap and reindeer lichen are usually present as well.

Poor Fen Ecosite

Poor fens are midway between bogs and rich fens in terms of nutrients and species composition. Drainage is poor to very poor, although some water flows slowly through the soil/organic layers. The moisture regime is subhygric to hydric. The nutrient regime is very poor to medium or rich. Poor fens occur in depressions or on level surfaces. There is an accumulation of peat moss and other organic matter such as sedges. There are two ecosite phases, treed poor fens and shrubby poor fens.

An open canopy of stunted black spruce and tamarack typifies the treed poor fen (j1) ecosite phase. Labrador tea and black spruce are dominant in the shrub layer, which also includes cranberries, willow, tamarack and dwarf birch. The herb layer, which is not very well-developed, consists mainly of common horsetail and sedges. The characteristic mosses are peat moss, golden moss, stair-step moss, Schreber's moss, tufted moss and slender hair-cap. Reindeer lichen is also characteristic.

Shrubby poor fens (j2) lack a tree canopy. The species composition of the shrub layer is essentially the same as that of j1, although dwarf birch assumes more prominence in j2. The herb layer is also similar except that horsetail is not characteristic of j2. The ground vegetation is dominated by peat moss. Golden moss, tufted moss, slender hair-cap and reindeer moss are also present.

Rich Fen Ecosite

Rich fens typically have very poor internal drainage with hygric to hydric moisture regimes. They are characterized by flowing water, nutrient-rich regimes. Rich fens occur in level areas or depressions. Water is near or at the surface of the fen for part of the year. There are three ecosite phases-treed rich fens, shrubby rich fens and graminoid rich fens.

Treed rich fens (k1) have an open tree canopy mainly composed of stunted tamarack. Scattered black spruce are typically present as well. Dwarf birch and tamarack dominate the shrub layer, while willow, Labrador tea, bog rosemary and black spruce are also present. The herb layer is dominated by sedges and marsh reed grass. Three-leaved Solomon's seal, buck-bean, marsh cinquefoil and marsh marigold are also characteristic with low cover values in the 2-3% range. The well-developed moss layer typically includes tufted moss, golden moss and peat moss, brown moss and Schreber's moss.

The tree layer is lacking in the shrubby rich fen (k2) and the shrub layer is dominated by willow. Dwarf birch, river alder and tamarack are the other characteristic species in the shrub layer. The herb layer consists mainly of sedges and marsh reed grass. Forbs are not well-represented. Coverage by mosses is typically in the 10% range, with brown moss dominant.

Graminoid rich fens (k3) are dominated by sedges, which typically have about 60% coverage. Marsh reed grass and northern reed grass are the characteristic grasses. As in k2, there are few forbs. The moss layer is dominated by ragged moss and brown moss.

Marsh Ecosite

Marshes have poor to very poor drainage with subhydric to hydric moisture regimes. The nutrient regime is medium to very rich due to occasional inputs from slow-moving water. Marshes occur in level areas, especially around the edges of lakes or rivers. Water is above the level of the rooting zone of the plants for part or all of the year. There is only one ecosite phase.

Marshes (l1) are dominated by sedges, cattail and other emergent vegetation. Also characteristic are northern willowherb, wild mint, reed grass, marsh reed grass, spike-rush and bulrush. The moss layer is not well- developed, although brown moss is typically present.

D10.3.2 Alberta Wetlands Inventory Classification System

The following subsections describe the AWI wetlands types that occur in the LSA.

Bogs (Btnn)

Bogs are peatlands that have low surface water flow. The only water available for bogs is from precipitation; consequently, bogs are generally acidic, with a pH of less than 4.5. Bogs are dominated by acid-loving plant species such as peat moss, feathermoss and lichens. They are subdivided into categories based on the percentage and type of forest cover, and on the presence of permafrost and internal lawns following Vitt et al. 1994.

Examples of bog locations include drainage divides, stagnation zones of peatland areas and small isolated basins (Figure D10-3).

Wooded bogs without internal lawns (Btnn), the only bogs identifed in the study area, have a flat, uniformly wooded, homogeneous surface. Typically they occur as islands or peninsulas within large fens or are confined to small basins associated with hummocky terrain. Peat moss and lichens dominate the ground cover (Halsey and Vitt 1996). Within the LSA, these bogs are found in a broad, poorly defined depression near a drainage divide.

Figure D10-3 Wooded Bog With a Variety of Understory Species

Fens (Fopn, Ftnn, Ffn, Fons, Fong)

Fens are peatlands or wetlands where peat accumulates because the rate of plant decomposition is slower than plant production. Fens are also characterized by water flow (i.e., they may have inflow and outflow). Fens can be open and dominated by sedges, rushes and cotton grasses; shrubby and dominated by willow or birch; or wooded and dominated by black spruce, tamarack or willow (Figure D10-4).

The water level of typical fens is at or near the surface. Fens are relatively rich in mineral elements and, thus, vegetation. The number of indicator vegetation species present can be used to subdivide fens based on acidity: poor fens are acidic (pH of 4.5 to 5.5) with few indicators; moderately rich fens are slightly acid to neutral (pH of 5.5 to 7.0) and have more indicator species; and extremely rich fens are basic (pH >7.0), with a high number of indicator species. As rich and poor nutrient levels cannot be differentiated by air photo interpretation, the AWI classification uses vegetation and patterning to distinguish between treed, patterned, shrubby and open fens (Halsey and Vitt 1996).

Figure D10-4 Fen With Black Spruce and Shrubby Understory

Open Fens (Fopn)

Only three patterned fens have been idenitified in the LSA. The surface of patterned fens alternates between open, wet areas (flarks), and drier shrubby to wooded areas (strings). The pattern of flarks and strings results from the perpendicular orientation of the direction of water flow to the landforms. Depending on whether flarks or strings dominate, a patterned fen can be considered wooded or open. The vegetation cover on the strings may be any combination of tamarack, black spruce, birch and willow. Potential ground cover varies, ranging from peat moss in poor fens; to golden moss and associated brown mosses, which require mid-levels of nutrients, in moderately rich fens; to scorpion feathermoss and associated brown mosses in extremely rich fens.

Non-patterned fens represent the highest proportion of wetlands types in the LSA. They can be dominated by either shrubs or grasses. In shrub-dominated fens, shorter birch and willow are common, with >25% cover. Conifers may have ≤6% cover. Shrub-dominated fens are located in small isolated basins and in areas sloping gently in the direction of drainage. The equivalent ecosite in the Beckingham and Archibald (1996) classification system encompasses both the shrubby poor fen and shrubby rich fen.

Open, non-patterned, grass and grass-like dominated peatlands may be poor, moderately rich or extremely rich in nutrients (Vitt and Chee 1990; Nicholson and Gignac 1995). They are characterized by a continuous sedge layer. Tree cover in these fens is ≤6% and shrub cover is <25%. Open, grass and grass-like dominated poor fens occur as collapse scars (low, wet areas) in association with peat plateaus (Halsey and Vitt 1996). They also have ground cover characterized by drier species of peat moss that can withstand nutrient-poor conditions. Open, graminoid-dominated fens are also found in small isolated basins, and in areas that slope gently in the direction of drainage.

Wooded Fens (Ftnn, Fons, Ffnn)

Wooded fens have greater than 10% tree cover and are classified into three categories, based on the presence of permafrost. Non-patterned, wooded fens with no internal lawns, or lower wet areas, vary in nutrients from poor, to moderately rich, to extremely rich. The overstory is composed of >6% black spruce and/or tamarack, and birch and willow may be found in the understory. The ground cover of wooded fens can be dominated by peat moss or brown moss. Wooded fens are found only in level areas of land, distinguishing them from upland wooded regions, which may be found in sloped areas. Only nonpatterned fens without internal lawns were identified in the LSA.

Marshes (Mong)

Marshes have relatively high water flow and seasonally fluctuating water levels (Halsey and Vitt 1996). While elevated concentrations of nitrogen and phosphorus allow for high plant productivity in marshes, decomposition rates are also high. For this reason, little peat accumulates in these wetlands, and mosses and lichens are uncommon. They are dominated instead by sedges, rushes (*Juncus* sp., *Luzula* sp.) and cattails (Figure D10-5). Marshes are often associated with the margins of streams and lakes. Only 18 marsh polygons were identified in the LSA, covering an area of 85 ha or 0.8%.

Figure D10-5 Marsh Dominated by Sedges, Rushes and Cattails

Swamps (Stnn, Sfnn, Sons)

Swamps often occur where there are bodies of water that flood frequently or where water levels fluctuate (e.g., along peatland margins). They are non-peaty wetlands that can be forested, wooded or shrubby. Few mosses and lichens grow in swamps due to the fluctuating water levels and peat accumulation is low due to high decomposition rates. Common species within swamps include tamarack, birch, willow, alder and black spruce. Two types of swamps, coniferous and deciduous, are recognized by the AWI classification system. Swamps represent 1,359 ha or 12.4% of the LSA.

Coniferous swamps exist near floodplains and streams associated with peatland areas. They have a dense (>70%) tree cover of black spruce and tamarack. Deciduous swamps, which are dominated by willow, are associated with floodplains, stream terraces and peatland ridges. Shrub cover is >25%, with few bryophytes (e.g., liverworts, mosses) due to fluctuating water levels.

Shallow Open-Water (Wonn)

Shallow open-waters are areas where water up to 2 m deep occurs during midsummer, but which do not function as typical aquatic (pond or lake) systems. Submergent and/or floating vegetation is present, representing the middle ground between terrestrial and aquatic systems. This wetlands class is often associated with other wetlands types such as marshes in the south, or thermokarst basins associated with peat plateaus in the north. Only a relatively small amount of open shallow water (57 ha or 0.5%) is represented in the LSA.

D10.3.3 Species Richness and Diversity

Table D10-4 provides an indication of relative species richness among wetlands ecosite phases, as indicated by the mean and range of numbers of species.

Table D10-4 Species Richness by Ecosite Phase

Ecosite Phase	No. of Plots	Number of Species		
		Mean	Minimum	Maximum
i2	4	24	19	27
j1	5	22	21	23
l1	2	12	10	14

Table D10-5 shows the mean and range of numbers of species in each of the tree, shrub and herb layers in each of the wetlands ecosite phases for which data are available. In each case, the mean, minimum and maximum number of species are highest in the herb layer and lowest in the tree layer.

Table D10-5 Species Richness by Structural Layer

Ecosite Phase	Number of Species, by Structural Layer					
	Tree		Shrub		Herb	
	Mean	Range	Mean	Range	Mean	Range
i2	1.5	1-2	5.8	4-8	21.5	19-24
j1	2	2-2	7.4	6-8	19.4	17-21
l1	0	-	6.5	6-7	9	8-10

D10.3.4 Rare Plants

Rare plants often require unique habitat types, a number of which were observed in the Muskeg River Mine Project LSA by BOVAR (1996a) and Golder (1997n). Within the LSA, 10 rare plants have been identified in wetlands, which include bogs, fens, swamps and marches (Table D10-6). 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.

Table D10-6 Rare Plants Observed in Wetlands in the LSA During 1995 and 1997 Field Surveys

Botanical Name	Common Name	Ecosite Phase	AWI	Location Plot	
				1995 (BOVAR)	1997 (Golder)
Carex lacustris	lakeshore sedge	e2, i1	Btnn	217	18, 22, 30
Clintonia uniflora	corn lily	j2	Ftnn	223	
Barbarea orthoceras	American winter cress	r1	Stnn		18
Drosera anglica	Oblong-leaved sundew	k2	Ftnn	214	
Kalmia polifolia	northern laurel	k3	Fong	186	
Rhamnus alnifolia	alder-leaved buckthorn	i2, g1	Btnn		10, 33
Carex tenuiflora	thin flowered sedge	j2	Ftnn	180	
Sparganium fluctuans		i2	Btnn		30
Nymphaea tetragona leibergii	small water-lily	i1	Mong		30
Carex hystricina	porcupine sedge	r1	Stnn		18

D11 WILDLIFE

D11.1 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 wildlife habitat types and use of the Study Area by wildlife;
- identification of any rare or endangered species and their habitat requirements;
- identification of seasonal habitat use in significant areas; and
- description and mapping of moose and other key indicator species, significant local habitat, seasonal habitat use patterns, extent of wintering and summer range and seasonal movement corridors (TofR, Section 4.5).

Project-specific impacts on wildlife are addressed in Section E11 of this EIA. Cumulative effects on wildlife are addressed in Section F11.

During the past two decades, the following baseline studies have been carried out on or near the Muskeg River Mine Project area, including:

- the wildlife component of the Alsands EIA (Alsands Project Group 1978);
- the Alberta Oil Sands Environmental Research Program (AOSERP) from 1975 to 1984;
- the Other Six Leases Operations (OSLO) baseline inventory (Salter et al. 1986, Salter and Duncan 1986, Eccles and Duncan 1988);
- wildlife surveys conducted by Westworth (1996), Fort McKay Environment Services Ltd. (1996a), and wildlife habitat modelling conducted by AXYS (1996) in support of an EIA for the Aurora Mine (BOVAR 1996a);
- winter track counts and owl surveys (Golder 1997f); and
- spring ungulate fecal pellet group count and browse use/availability surveys, spring and summer waterfowl and raptor nest surveys, spring songbird surveys, and a late summer small mammal survey conducted by Golder (1997g).

For this EIA, an ecosystem-based management approach was used for assessing the impact of the Muskeg River Mine Project on wildlife in the

Lease 13 area. Species, and the communities formed by species assemblages, are tightly coupled with the characteristics of particular habitats (plant communities and physical attributes). The interaction among habitat types and wildlife communities produces the type of ecosystem present in the environment. Consequently, linking habitat type with species associations is fundamental to forming an ecosystem-based management plan.

Key Indicator Resources (KIRs) were selected for the EIA based on the selection process used for the Suncor Steepbank Mine EIA (Suncor 1996a) and the Syncrude Aurora Mine EIA (BOVAR 1996a) and input from Alberta Environmental Protection (AEP) (Table D11-1). Details on the KIR selection process are provided in Section D1.

Table D11-1 Wildlife Key Indicator Resources and the Selection Rationale

Key Indicator Resource (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[a]	use of open forest mixedwood, 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 to those used for the Steepbank and Aurora mines; based on input from AEP.

D11.2 Wildlife Species of the Project Area

Investigations of wildlife species found in the Project Local Study Area (LSA) and Regional Study Area (RSA) are reviewed below.

The Project LSA and RSA are discussed in Section D1.

D11.2.1 Ungulates

Introduction

Ungulates (moose, mule deer, white-tailed deer, woodland caribou, elk) are important to the public from both a consumptive and non-consumptive viewpoint. These large herbivores also play important roles in the boreal ecosystem.

Abundance

Moose

A number of aerial and winter track count surveys have been conducted in the oil sands area of northeastern Alberta in the last 25 years. Early estimates of moose density were 0.09/km^2 for the Lease 13 area (Shell 1975), and 0.31/km^2 for the larger Alsands area (Bibaud and Archer 1973). Current estimates for the Lease 12, 13 and 34 study area are approximately 0.10/km^2 (Westworth 1996), indicating that moose populations in the Lease 13 study area have remained low and relatively stable. Low moose densities may reflect the shortage of preferred winter habitat (deciduous and mixedwood forest) in the area (BOVAR 1996a). Prime moose habitat, with minimal hunting mortality, such as that of the Peace Athabasca Delta, can support moose populations of 0.1 to 1.0 moose/km^2 (Telfer 1984).

Mule and White-Tailed Deer

Mule deer are traditional residents of the western boreal forest, most frequently associated with cleared or disturbed habitat. Populations are generally small and localized. White-tailed deer were at one time not found in the oil sands area. Recent changes to access and the creation of open habitat for these species has resulted in a northern range expansion (BOVAR 1996f). Mule deer (Alsands Project Group 1978) and white-tailed deer (Westworth 1980) have been observed during aerial surveys. Westworth (1996) estimated white-tailed deer populations in the Lease 12, 13 and 34 study area at 0.08/km^2.

Woodland caribou and elk were at one time residents of the oil sands area. Caribou exist at low densities 60 km northwest of the Aurora Mine site, while elk are restricted to the Athabasca River valley south of Fort McMurray (BOVAR 1996a). The Steepbank woodland caribou zone is located 20 km east of the Muskeg River Mine Project area (NSERC 1997).

Habitat

Moose

Moose within the oil sands area preferentially use deciduous forest, mixedwood forest and riparian areas. Alsands Project Group (1978) and Westworth (1979, 1980, 1996) found that moose were most often associated with aspen and mixedwood forests during the winter. During aerial surveys, Westworth (1978) found that 67% of moose observations occurred in deciduous and mixedwood habitat. A later study by Skinner and Westworth (1981), using both aerial and winter track count surveys, also showed that moose preferred riparian shrub areas. Golder (1997g) confirmed that moose prefer deciduous and mixed forests and riparian areas on Lease 13.

Mule and White-Tailed Deer

Westworth (1996) recorded track count data for deer in the Lease 12, 13 and 34 study area. The majority of tracks were found in cleared peatlands and aspen forest. Westworth (1980) also noted the presence of deer in regenerating areas. It is expected, therefore, that any deer present in the study area should be found primarily in early regenerating or open stands with abundant deciduous browse.

D11.2.2 Small Mammals

Introduction

Small mammals (shrews, voles, mice) are important as they form a large basis of the food chain. They are also one of the more diverse mammal groups in the LSA, making them good indicators of biodiversity.

Abundance

Numerous species of small mammals are likely to occur in the LSA (Table D11-2). Food items for small mammals include insects, plant shoots and roots, seeds, nuts and fruits. Most species, except the porcupine and woodchuck, have home ranges of less than 1 ha. They occupy a wide array of habitat types, and while some can persist in many habitats, others have more specific habitat requirements.

Small mammal trapping conducted by Golder Associates (1997g) indicated that the masked shrew was the most common small mammal in the vegetation communities sampled. Red-backed voles and meadow voles were the second and third most common small mammals. The red-backed vole is a diurnal species that remains active throughout the year with regular cyclic fluctuations in population numbers occurring every four to five years (Green 1979). Summer 1977 population density estimates for the red-backed vole in mixedwood habitat ranged from 9.3 to 19.1 animals/ha (Westworth 1979). In 1980, Westworth and Skinner estimated red-backed vole populations to vary between 8.6 and 19.7 animals/ha within the Syncrude Mildred Lake leases (AXYS 1996).

Habitat

Red-backed voles were selected as a KIR for the EIA. The presence of aspen and mixed white spruce jack pine communities in the Project area provides prime habitat for red-backed voles (AXYS 1996). Green (1980) also described balsam poplar, aspen and jack pine communities as providing high-quality habitats for the red-backed vole. In the Project study area, abundance of red-backed voles was greatest in wetland, riparian and coniferous habitats. These habitats were associated with moderate to high

Table D11-2 Small Mammal Feeding and Habitat Preference, and Home Range Size [(a)]

Species[(b)]	Feeding Preference	Habitat	Home Range (ha)
Arctic shrew[(b)]	Insectivore	Forested and non-forested areas; bogs, marshes and grassy clearings. Tree climbers can tolerate drier conditions than most other shrews.	0.04
Masked shrew[(b)]	Insectivore; also eats small mammals	Margins of moist fields, bogs and marshes. Moist or dry woods, requires litter and high humidity.	0.04-0.1
Pygmy shrew[(b)]	Insectivore	Wooded areas, bogs and wet meadows. Prefers clearings within forests. Uncommon.	--
Short-tailed shrew[(b)]	Insectivore; also eats worms and small vertebrates	Hardwood forests, areas of high humidity. Requires loose humus.	0.5
Water shrew	Insectivore; also fish and larval amphibians	Streams, lakes and ponds with adequate bank cover. Favours fast-flowing streams in dense climax conifer forests.	within 20-60 m of shoreline
Red-backed vole[(b)]	Herbivore; mycorrhizal fungi important in diet	Coniferous and mixed hardwoods. Moist areas. Low tolerance for dry conditions.	0.01-0.5
Bog lemming[(b)]	Herbivore, mainly grass and sedges; mycorrhizal fungi	Wet forested areas, bogs and wetlands. Uncommon.	0.08-0.2
Heather vole	Herbivore	Dry, open pine/spruce stands. Shrubs near forest edge or open grassy areas.	0.08
Meadow vole[(b)]	Herbivore; grasses and sedges	Clearings and wet meadows. Grass cover essential. Avoids deep forests and dry grasslands.	0.1-0.3
Deer mouse	Granivore; also herbs and insects	Broad habitat tolerance; disturbed areas, dry land habitat. Not usually found in wet areas.	0.5-2.0
Meadow jumping mouse[(b)]	Granivore; also herbs and insects	Grasslands, meadows, clearings and forest edges. Damp meadows favoured. Uncommon.	0.2-1.1
Least chipmunk[(b)]	Granivore; also herbs and invertebrates	Prefers clearings, forest edges and disturbed areas.	0.1
Woodchuck	Herbivore	Mixedwood, pastures. Rare in climax forests and glades.	2.4
Northern flying squirrel	Omnivore; lichens, seeds, fruits, nuts, insects and eggs	Coniferous forests, not found in disturbed areas.	0.8-1.2
Porcupine	Herbivore; winter diet of bark and tree buds	Deciduous and mixedwood forests. Uncommon in conifer stands.	13.0-14.5

[(a)] From Adler 1988, Banfield 1987, Forsyth 1985, Peles and Barrett 1996, Wrigley 1986.
[(b)] Species recorded in the Project LSA.

levels of structural and compositional variation on the ground. Such habitats generally have abundant food and cover, and a relatively stable microclimate, which provides prime habitat for small mammals, including red-backed voles (Carey and Johnson 1995).

The relative abundance of masked shrews in the Project area is greatest in mixedwood and riparian habitats (Golder 1997g). Arctic shrews were captured in wetlands and two pygmy shrews were captured in mixedwood habitat.

D11.2.3 Terrestrial Furbearers

Abundance

Snowshoe Hares

Snowshoe hares are common throughout the oil sands area, and usually account for most of the observations during track count surveys. Populations of snowshoe hares generally fluctuate on a 9- to 11-year cycle, leading to large variations in track count data from year to year (Boutin et al. 1995). Figures from years near the trough of the population cycle display track densities of 2.9 tracks/km-track-day (Syncrude 1973) and 3.5 tracks/km-track-day. In years of peak populations, densities can be 8 to 10 times higher. For example, Westworth (1981) estimated track count frequencies at 21.2 tracks/km-track-day, and Golder (1997f) produced estimates of 22.4 tracks/km-track-day.

Red Squirrels

Red squirrel observations from track counts in the oil sands area are usually second only to snowshoe hares. Early surveys of Lease 17 (Alsands Project Group 1978) and Leases 88 and 89 (Skinner and Westworth 1981) yielded densities of 2.3 and 2.1 tracks/km-track-day, respectively. An estimate of 1.2 squirrels/ha, based on a midden study in Lease 17, was made by Penner (1976). A more recent track count survey yielded a density of 0.6 tracks/km-track-day (Westworth 1996), suggesting a drop in squirrel numbers. However, Golder (1997f) recorded a density of 5.7 tracks/km-track-day in the Project area.

Coyotes, Wolves and Foxes

Coyotes, wolves and foxes are all found in the boreal forest. Previous studies have found the coyote to be the most abundant large carnivore in the oil sands area. Track densities encountered during past winter track count surveys have ranged from a low of 0.1 tracks/km-track-day (Westworth 1996) in the Lease 12, 13 and 34 study area, to a high of 0.3 tracks/km-track-day (Alsands Project Group 1978) for the general Syncrude lease area. Winter track counts conducted in the Project area during March 1997 recorded 0.1 tracks/km-track day (Golder 1997f). Coyotes appear to be common, but present in low densities.

Previously, wolves in the Project area belonged to the Muskeg River pack, estimated to contain 9 to 13 animals with a home range of 1,289 to 1,779 km^2 (Fuller and Keith 1980). Due to the low population size and large home range, low track densities were previously recorded. Track densities range from 0.01 tracks/km-track-day for the Lease 88 and 89 study area (Skinner and Westworth 1981), to 0.05 tracks/km-track-day for the Lease 12, 13 and 34 area (Westworth 1996). Earlier estimates of density for the Lease 17 and 22 study area were 1 wolf/100 km^2 (Westworth 1979). Penner (1976) found a wolf track density of 0.1 tracks/km-track-day. While no wolf tracks were recorded in the Lease 13 area during March 1997 track surveys, an incidental observation was made of the tracks of seven wolves. Wolves may be considered present, but uncommon in the Lease 13 area. A study in northeastern Alberta estimated wolf density at 11.1 wolves/1,000 km^2 (Fuller and Keith 1980).

Foxes, like wolves, are present in the oil sands area at low densities. Track densities range from 0.01 tracks/km-track-day in the Lease 12, 13 and 34 study area (Westworth 1996), to 0.08 tracks/km-track-day in the Lease 88 and 89 study area (Skinner and Westworth 1981). No fox tracks were recorded during the 1997 field work (Golder 1997f). Foxes may be considered uncommon in the oil sands area.

Wolverines

Wolverines, due to their solitary nature and large home range (100-900 km^2; Banci 1994), are considered to be the most uncommon carnivore in the oil sands area. Westworth (1981) found a track density of 0.005 tracks/km-track-day for the Lease 88 and 89 area. No wolverine tracks were observed in the March 1997 studies in Lease 13 (Golder 1997f). Estimated population density for the Lease 17 area was calculated at 0.1 animals/100 km^2 (Westworth 1979).

Fishers

Fishers, although relatively more numerous, are similarly considered uncommon in the area. Track densities for the Lease 12, 13 and 34 area were 0.02 tracks/km-track-day (Westworth 1996). A density of 0.4 fishers/100 km^2 was estimated for the Fort McMurray area, based on trapping data (Westworth 1979).

Martens

Westworth (1979) classified martens as scarce in the Lease 17 area. Recently, Westworth (1996) reported that track densities for the Lease 12, 13 and 34 study area were 0.2 tracks/km-track-day, suggesting a possible resurgence of martens in the area. After combining fisher and marten tracks, a total of 1.3 tracks/km-track-day was recorded in the Project area in 1997 (Golder 1997f). This high number may be indicative of the continued resurgence of marten, but caution should be used in interpreting these numbers due to small sample size (total of 78 track-days of effort).

Weasels

Weasels, including ermines and least weasels, are the most common carnivores in the oil sands area. Ermines are considered to be abundant and least weasels uncommon, although the inability to distinguish the species based on tracks makes this speculative. Combined track densities for the two species were 1.1 tracks/km-track-day for the Lease 88 and 89 study area, and 1.2 tracks/km-track-day for the Lease 12, 13 and 34 study area (Westworth 1996). A track density of 1.12 tracks/km-track-day in the Project area was recorded by Golder (1997f).

Black Bears

Black bears are relatively common in the oil sands area, with populations remaining fairly stable from year to year. Fuller and Keith (1977) estimated bear density to be 25-50/100 km^2. Young and Ruff (1982) provided a lower estimation of bear density (18-25/100 km^2), based on habitat availability and densities recorded previously for the Cold Lake area.

Habitat

Snowshoe Hares

Snowshoe hares are most often found in areas with a well-developed shrub layer. Observations made at the peak of the snowshoe hare cycle were most often made in riparian white spruce, mixedwood and black spruce muskeg areas (Skinner and Westworth 1981), all areas with a prominent shrub component. Golder (1997f) observed that most snowshoe hare tracks were in white spruce and mixedwood forests.

Red Squirrels

Red squirrels rely on conifer cones for the majority of their food supply, and are subsequently found in conifer-dominated forests. Earlier studies found that red squirrels were most often found in upland white spruce and riparian white spruce areas (Alsands Project Group 1978, Skinner and Westworth 1981, Westworth 1996). Golder (1997f) determined that red squirrels were most common in closed white spruce and closed mixedwood-white spruce dominant vegetation communities.

Coyotes

Coyotes are generalist predators that tend to prefer cleared and agricultural fringe sites, while avoiding densely forested areas (Boyd 1977). Previous studies found a preference for riparian white spruce areas and cleared peatlands (Skinner and Westworth 1981, Westworth 1996). The 1997 track count survey indicated that coyote tracks were most often detected in closed balsam poplar forest (0.8 tracks/km-track-day), riparian shrub areas (0.2 tracks/km-track-day) and closed white spruce (0.3 tracks/km-track-day).

No tracks were recorded in black spruce bogs or tamarack fens (Golder 1997f).

Wolves

Wolves also tend to prefer open areas, avoiding heavy conifer cover in winter (Penner 1976). No wolf tracks were encountered along the study transects during the winter track count survey (Golder 1997f). However, during the owl survey, two wolves were sighted crossing the road 50 km east of Muskeg Creek. Examination of the site showed seven sets of wolf tracks in a white spruce/trembling aspen forest type.

Red Foxes

Red foxes are more commonly found in grassland regions (Banfield 1987). Previous studies have discovered tracks in jack pine and riparian white spruce areas (Skinner and Westworth 1981), and near garbage dumps (Alsands Project Group 1978). No red fox tracks or observations were recorded for the Project area winter track count survey (Golder 1997f).

Wolverines

Wolverines are thought to prefer undisturbed areas of coniferous forest (Pasitschniak-Arts and Larivière 1995). No tracks were found during the Project area 1997 winter track count survey (Golder 1997f). Due to the short duration of the survey and the large size of a wolverine's home range, occasional use of the Project area by wolverines cannot be discounted.

Martens

Martens and fishers are thought to prefer middle to late stage coniferous forests (Buskirk and Ruggiero 1994; Powell and Zielinski 1994). Inventory work in the Lease 12, 13 and 34 study area (Westworth 1996) showed that fisher tracks were found in greatest frequency in riparian balsam poplar forest. Closed aspen and mixed coniferous stands were more frequently used by fisher and marten than were peatland and fen habitats (Golder 1997f).

Weasels

The ermine and least weasel prefer riparian, deciduous and early successional habitats, due in part to the abundance of small mammal prey usually found in these areas (Banfield 1987). In the Lease 88 and 89 study area, Skinner and Westworth (1981) found the majority of tracks in black spruce muskeg, riparian white spruce and mixedwood areas. Westworth (1996) found a preference for open tamarack/bog-birch, black spruce/tamarack and cleared peatlands in the Lease 12, 13 and 34 study area. Golder (1997f) found a preference for closed mixedwood-white spruce dominant forests (7.77 tracks/km-track-day).

Black Bears

Bears are omnivores, and rely on a variety of foods. Food and shrub diversity is generally higher in deciduous stands or recently disturbed areas. For this reason, bears are most often found in aspen or mixedwood stands (Young and Ruff 1982, Banfield 1987). No information is available for black bear habitat use within the LSA.

D11.2.4 Semi-Aquatic Furbearers

Introduction

Semi-aquatic furbearers (beavers, muskrats, minks, otters) are important from both an economic and ecological perspective within the LSA. All are trapped for their pelts, and minks and otters are important carnivores in the boreal ecosystem. Beavers, through their dam-building activities, act as agents of change and thus are also important components of the ecosystem.

Abundance

Beavers

Surveys within the Aurora Mine study area determined a density of 0.09 colonies and food caches per km^2 (Fort McKay Environment Services 1996c). Half the active beaver lodges recorded during that study were found within the Alsands reclamation site. This site, with a density of 0.57 lodges and food caches per km^2, was considered by the authors to represent some of the best beaver habitat in the area. Drainage canals were constructed before abandonment of the site and beavers have since occupied these canals to feed on the aspen, alder and willow shrubs that have regenerated on the site. Penner (1976) estimated beaver density in the Lease 17 area to be 1.9 animals/km^2. Beaver density on the east side of the Athabasca River is thought to be lower, due to less favourable habitat. Westworth (1981) recorded 0.11 colonies/km^2 during an aerial survey of the Lease 88 and 89 study areas. Based on an estimate of 6.3 beavers/lodge (Searing 1979), this would yield an estimate of 0.69 beavers/km^2.

A density of 1.2 lodges and caches per km^2 was found for the Suncor Steepbank Mine LSA by Fort McKay Environment Services (1996b). Most (77%) of the lodges were observed on rivers and streams, with the remainder on lakes or ponds.

Muskrats

Muskrats are smaller aquatic rodents, common in marshes and other waterbodies throughout the parkland and boreal forest region (Banfield 1987). No muskrat houses or pushups were observed during a November 1995 study of the Aurora Mine area (Fort McKay Environment Services 1996c). Density of muskrats on the east side of the Athabasca River is thought to be low, due to poor-quality habitat. During an aerial survey of the Lease 88 and 89 study area, Skinner and Westworth (1981) recorded 0.03 muskrat houses/km. Two separate areas in Lease 17 were found to have densities of 2.5 muskrats/ha and 0.3 muskrats/ha.

Minks

Mink are considered to be common along watercourses in the oil sands area. The number of pelts collected in the Fort McMurray area for the years 1970 to 1975 was twice the provincial average (Westworth 1979). In other studies, track count densities have ranged from 0.1 tracks/km-track-day in the Leases 17, 88 and 89 study area (Penner 1976; Skinner and Westworth 1981) to 0.2 tracks/km-track-day for the Lease 12, 13 and 34 study area (Westworth 1996). Only 0.03 tracks/km-track-day were recorded for minks by Golder (1997f).

River Otter

Historically, and currently, local abundance of river otters in the oil sands area is low. Golder (1997f) recorded the frequency abundance of river otters in the Lease 13 area at 0.01 tracks/km-track day. Westworth (1979) estimated otter density for the Lease 17 area to be 0.2/100 km. Track count densities ranged from 0.01 tracks/km-track-day (Skinner and Westworth 1981) in the Lease 88 and 89 study area to 0.02 tracks/km-track-day (Westworth 1996) in the Lease 12, 13 and 34 study area.

Habitat

Beavers

Beavers prefer waterbodies with relatively deep water, located near stands of early deciduous vegetation. Preferred food includes aspen, birch and willow (Banfield 1987). The Lease 13 area is dominated by conifer bogs, and provides generally poor habitat. Most beaver lodges in the LSA are concentrated along the Muskeg River, the Alsands area and Isadore's Lake. A high density of inactive lodges occurs in the east end of the Project area and in the Kearl Lake area.

Muskrats

Muskrats also prefer waterbodies with relatively deep water. Good muskrat habitat is provided by waterbodies (most often marshes) with a well-developed zone of emergent plants, used for food and lodge construction (Banfield 1987). Wetlands in the Project area are generally shrubby bogs rather than marshes. For this reason, the Project area is thought to be poor-quality habitat for muskrats. Most muskrat houses have been found in the Kearl Lake and Green Stockings Creek areas east of the LSA. No muskrat houses or pushups were recorded west of the Muskeg River by Fort McKay Environment Services Ltd. (1996c).

Minks

Minks are semi-aquatic carnivores that hunt in and along watercourses. They are found most commonly along stream banks, lakeshores, forest edges and large marshes (Banfield 1987). Previous studies have found that most tracks were within riparian shrub and riparian white spruce communities (Skinner and Westworth 1981, Westworth 1996). The only tracks recorded in Lease 13 in 1997 were along the Muskeg River (Golder 1997f). The track frequency in the riparian shrub zone was 0.22 tracks/km-track-day.

River Otters

River otters are aquatic carnivores that feed almost exclusively on fish in streams and lakes. Tracks are most frequently encountered along the shores of deep lakes, rivers and large marshes (Banfield 1987). Previous studies have recorded tracks along the Muskeg and Athabasca rivers (Alsands Project Group 1978, Skinner and Westworth 1981; Westworth 1996). Tracks in the Project area were limited to the bank of the Muskeg River (Golder 1997f). The track frequency within the riparian shrub zone was 0.11 tracks/km-track-day.

D11.2.5 Waterfowl

Introduction

Waterfowl commonly found breeding in the LSA can be categorized as dabbling or diving ducks. Dabbling ducks feed on aquatic insects and plant material on the surface and within the first 20 to 30 cm of the water column. Diving ducks, in contrast, forage deeper in the water column, enabling them to exploit different food resources than those of dabblers.

Abundance

Seventeen species of waterbirds were observed during 1997 aerial and ground surveys within the LSA (Golder 1997g). In total, 81 species of waterbirds have been recorded in the RSA from 1974 to 1996 (summarized by BOVAR 1996a). Similarly, 47 waterbird species were recorded in the Aurora Mine LSA during OSLO surveys (R.L.&L. 1989). Mallards were the most abundant waterfowl species recorded during 1997 aerial surveys. Other species observed in relatively large numbers were ring-necked ducks, blue and green-winged teals, and buffleheads (Golder 1997g).

Results from an August aerial survey (Golder 1997g) indicated that the number of broods in the LSA was low. Broods were observed only for mallards, blue-winged teals and buffleheads. These results suggest that nesting densities in the LSA are low.

Habitat

The migration of most birds through the Muskeg River Mine Project area may be an indication that the nesting habitat is limited or insufficient to meet the requirements of many species. The lack of suitable nesting habitat for both ground nesting and overwater nesting species is the main reason for the low density of waterfowl in the Project area. Most of the wetlands did not have much emergent vegetation, which is required for overwater nesting species for nest construction as well as shelter. Although the density of waterfowl in the LSA was relatively low, observations indicated that the wetlands do support breeding populations, and provide a staging area for migrating waterfowl.

D11.2.6 Upland Game Birds

Introduction

Upland game birds (grouse, ptarmigan) are important game species, are enjoyed by non-consumptive users and form an important part of the food chain.

Abundance

Three species of upland game birds potentially occur in the Muskeg River Mine area; spruce, ruffed and sharp-tailed grouse. Willow ptarmigan may also be observed infrequently in the area. However, due to the difficulty involved in differentiating grouse tracks, all grouse/ptarmigan species were combined for analysis, and the following discussion is focused on ruffed grouse.

The ruffed grouse is common throughout the deciduous and mixedwood forests of North America. They are year-round residents, and are considered the second most abundant upland game bird in the Athabasca region after the spruce grouse (Francis and Lumbis 1979). Ruffed grouse density in northeastern Alberta ranges from 0.02 individuals/km^2 in poor-quality aspen jack pine and young black spruce habitat, to 0.3 and 0.5 grouse/km^2 in aspen and bottomland willow habitat (Francis and Lumbis 1979). An average of 1.7 grouse tracks per km-track-day were recorded in the Lease 13 area in March 1997 (Golder 1997f).

Habitat

Grouse distribution is tied to deciduous and mixedwood forest, particularly those seral stages that possess a well-developed shrub component (Bergerud and Gratson 1988). Young grouse feed almost exclusively on insects, but forage on plant matter as they mature (Ehrlich et al. 1988). Adults feed on berries and sedges during the summer, fruiting shrubs in the fall, and buds, twigs and catkins in the winter (Edminster 1954). Berry-producing shrubs and forbs are typically more abundant in deciduous and mixedwood stands.

In addition to providing forage, deciduous stands are also used for cover during and after the breeding season. During March 1997, grouse tracks were found more often than expected in open (6.2 tracks/km-track day) and closed (3.8 tracks/km-track day) aspen forest (Golder 1997f).

D11.2.7 Breeding Birds

Introduction

Breeding birds are an important wildlife group as their diversity in numbers makes them suitable for monitoring of biodiversity. They also represent many different life history strategies, including those of neotropical migrants. Breeding birds are particularly valued by non-consumptive users.

Abundance

The boreal forest of Canada has one of the highest diversities of breeding birds north of Mexico (Robbins et al. 1986). Approximately 72% of the total vertebrate fauna of the mixedwood boreal forest of western and northern Canada consists of avian species (Smith 1993). A total of 252 avian species has been recorded in the western boreal forest (Smith 1993). Thus, the boreal forest represents an important ecosystem for sustaining breeding populations of North American birds. Such diversity is a result of the wide variety of niches available to songbirds within the boreal forest.

The majority of the birds found in the Muskeg River Mine Project area are migrants, many of which winter south of the continental United States.

In the Project area, 67 songbird species were detected in 125 point counts (Golder 1997g). These numbers were similar to those observed by Westworth et al. (1996) and McLaren and Smith (1985). In a literature review, BOVAR (1996) reported 80 species within the Mildred Lake Facility area. Of the 67 species in the Project area, 50 species were assigned to a specific vegetation community type. The number of detections of each of these species is provided in Table D11-3. Over 60% of the species recorded had less than six detections, suggesting that, although diversity was high, the relative abundance of species was quite moderate.

Habitat

Bird use of vegetation communities was classified along an ecological gradient of upland black spruce, closed and open black spruce/tamarack fens and bogs, and upland trembling aspen, white spruce and mixedwood stands. The following three broad bird-vegetation community groupings were derived:

Type A - mixed softwood and closed black spruce bogs;
Type B - late successional wetlands (fens, riparian areas); and
Type C - upland hardwood, softwood and mixedwood stands.

Bird species strongly associated with Community Type A included the ruby-crowned kinglet, yellow-rumped warbler (Group 1) and common snipe and yellow-bellied flycatcher (Group 2). The relative abundance of all four species was significantly greater in Community Type A than Types B and C. Other species classified in the Group 2 assemblage and associated with Community Type A included the magnolia warbler, chipping sparrow and palm warbler. However, these species were also strongly correlated with vegetation communities that constituted Community Type B.

Community Type B was primarily composed of wetlands vegetation communities (fens and riparian areas). However, based on the bird-vegetation community associations, a mixed trembling aspen-white spruce vegetation community was also placed into this community type. The presence of the Cape May warbler in this vegetation community, riparian and the white spruce/balsam fir (Type C) vegetation communities suggests that these stands were likely in the later stages of succession. Community Type B was strongly associated with bird species from Group 3 (e.g., black and white warbler, alder flycatcher) and several species from Group 2 (e.g., Swainson's thrush, chipping sparrow, palm warbler). Based on relative abundance, the black and white warbler and Swainson's thrush showed a significant preference for this community type.

Type C was composed entirely of upland vegetation communities. Three of the vegetation communities had fewer than two point counts recorded, and subsequently, very few birds were detected in these stands. The remaining three vegetation communities (jack pine-trembling aspen, trembling aspen and trembling aspen-white spruce) were associated with bird species classified in Group 4 (Tennessee warbler, ovenbird, Connecticut warbler and rose-breasted grosbeak). However, many of these species were similarly distributed among Community Types A and B, which resulted in no significant difference in relative abundance among community types.

Overall, the majority of bird species were associated with wetlands vegetation communities in bird Community Types A and B. In no case was the relative abundance of a species in Community Type C greater than in Types A or B. In addition, species diversity and richness were significantly greater in the wetlands-dominated community types than in the upland-dominated community type.

While species diversity was determined to be moderate, the relative abundance of species was low. This was likely due to the limited amount and size of quality breeding habitats. Species diversity and richness was significantly greater in wetlands-dominated community types than in upland-dominated vegetation. These results are contrary to other studies of species-habitat associations, where species abundance, richness and diversity were greater in upland hardwood and mixedwood habitats than softwood community types associated with bog-fen complexes (Westworth et al. 1996 and Francis and Lumbis 1979). The difference between the studies may be related to the fact that upland habitat within the Project area was represented by a small number of small-sized patches interspersed among a relatively large wetlands complex. The degree of fragmentation of upland habitat may have been too large to support the rich and diverse bird assemblages observed in similar but less fragmented habitat.

D11.2.8 Raptors

Introduction

Raptors (birds of prey) are important carnivores within the boreal ecosystem and are highly valued by birdwatchers. They are also important for indigenous cultures.

Abundance

Observations of diurnal raptors are relatively rare in the LSA (Golder 1997g). During studies for the Aurora Mine EIA, seven bald eagles, five northern harriers and six red-tailed hawks were observed during a two-day survey (BOVAR 1996a). During aerial surveys for waterfowl, Golder (1997g) only observed one stick nest within the Project area. Owl surveys conducted by Golder (1997f) indicated the presence of boreal and great horned owls in the Project area. Great gray owls were also observed during completion of other winter field studies. Great gray owls rely on relatively open habitat. Owls breed and hunt in open coniferous, deciduous and mixed forests, interspersed with muskegs, marshes and wet meadows (Semenchuk 1992).

Habitat

Great gray owls, selected as a KIR for the EIA, rely on relatively open habitat. Owls breed and hunt in open coniferous, deciduous and mixed forest, interspersed with muskeg, marsh and wet meadow (Semenchuk 1992).

Amphibians and Reptiles

The wood frog, Canadian toad and the striped chorus frog are likely present in the LSA (Roberts et al. 1979) The red-sided garter snake may also be present; records for this species include observations at Kearl Lake to the east and the Birch Mountains (Roberts et al. 1979). No studies of reptiles and amphibians were conducted in 1997.

Table D11-3 Muskeg River Mine Project Bird Species Detected in Specific Vegetation Communities

Species	Number of Detections	Species	Number of Detections
Tennessee warbler	54	Black-capped chickadee	3
Gray jay	33	Greater yellowlegs	3
Ovenbird	32	Swamp sparrow	3
Chipping sparrow	30	Western tanager	3
Yellow-rumped warbler	28	Bay-breasted warbler	2
Ruby-crowned kinglet	23	Connecticut warbler	2
Palm warbler	22	Hairy woodpecker	2
Black and white warbler	19	Northern flicker	2
Magnolia warbler	15	Philadelphia vireo	2
Alder flycatcher	13	Rose-breasted grosbeak	2
Dark-eyed junco	12	Solitary vireo	2
Swainson's thrush	11	Black-backed woodpecker	1
Hermit thrush	10	Canada warbler	1
LeConte's sparrow	9	Common yellowthroat	1
White-throated sparrow	8	Evening grosbeak	1
Least flycatcher	7	Lincoln's sparrow	1
American redstart	6	Mourning warbler	1
Cedar waxwing	6	Olive-sided flycatcher	1
Common snipe	6	Pileated woodpecker	1
Boreal chickadee	5	Ruffed grouse	1
Cape May warbler	5	Spotted sandpiper	1
Northern waterthrush	5	Wilson's warbler	1
Orange-crowned warbler	5	Winter wren	1
Red-eyed vireo	5	White-winged crossbill	1
Yellow-bellied flycatcher	5	Yellow warbler	1

D11.3 Vulnerable, Threatened and Endangered Species

Species with vulnerable, threatened or endangered status according to the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 1997), or listed on Alberta's blue or red list (AEP 1996b) and which may occur within the LSA, are described in the following sections.

D11.3.1 Birds

Red-listed bird species that may occur within the LSA are the peregrine falcon and the whooping crane. These species are also listed as endangered by COSEWIC (1997). The peregrine falcon was not observed during 1997 field surveys, but is known to nest in the Fort Chipewyan-Lake Athabasca area (Munson et al. 1980). The whooping crane only nests in Wood Buffalo National Park and was observed migrating within Lease 17 in small numbers in 1973-75.

Blue-listed bird species that potentially occur within the LSA include the bay-breasted warbler, black-throated green warbler, Cape May warbler, ferruginous hawk and the short-eared owl. COSEWIC (1997) considers the short-eared owl to be vulnerable but does not list the other blue-listed species. It should be noted that the blue list in Alberta is not a threatened species list. It suggests species that may be at risk of extirpation in the province.

The bay-breasted warbler is blue-listed by AEP (1996b) due to its dependency on old-growth habitats and its unknown population status. The black-throated green warbler has similar old-growth habitat requirements to the bay-breasted warbler. Both species were considered in this EIA to be represented by the Cape May warbler and the pileated woodpecker.

The ferruginous hawk is currently recovering in Alberta and may soon be placed on the yellow list (AEP 1996b).

The status of the Cape May warbler, a KIR for this EIA, is discussed in Section D5.7. It is listed by AEP (1996b) due to its dependency on old-growth forests for breeding and its neotropical migratory habits. Habitat on its wintering grounds is under development pressures.

Two short-eared owls were observed in the Aurora LSA by AXYS (1996) during a 1995 survey. Golder Associates (1997f) did not record any during a late winter owl survey of the project LSA. The irruptive nature of the population of short-eared owls, which makes them a difficult species to monitor, has been recognized by AEP (1996b).

D11.3.2 Mammals

The wolverine is considered at risk by Alberta (blue-listed) and vulnerable by COSEWIC. AEP (1996a) estimates up to 1,000 wolverines may occur in the province. No wolverine tracks were observed during 1996 (Westworth 1996) or 1997 (Golder 1997f) winter track count studies. Woodland caribou are listed as vulnerable by COSEWIC and blue-listed by Alberta. However, no woodland caribou are known to reside within the LSA.

D11.3.3 Amphibians and Reptiles

No COSEWIC-listed species of amphibians and reptiles occur in the LSA. However, the Canadian toad, blue-listed by Alberta, does likely occur in the LSA.

D11.4 Introduced Species

Wood bison is an introduced species that was present in the area before increased colonization of the area by man.

Wood bison are currently found in the area as part of a Syncrude Canada Ltd. reclamation trial at their Mildred Lake Site.

D12 HUMAN HEALTH

D12.1 Human Health Baseline

A baseline human health study was beyond the scope of this EIA. To provide an indication of the general health of residential populations within the region, results of a baseline human health study completed as part of the Northern River Basins Study (Alberta Health 1997) are summarized here.

The Northern River Basins Study Human Health Monitoring Program (Alberta Health 1997) summarized the overall population health status of communities within the NRBS area. The NRBS area includes the Alberta and Northwest Territories portions of the Peace, Athabasca and Slave river basins. The Northern Lights Health Region of the NRBS area most closely matches the Regional Study Area for this EIA.

It should be noted that this study also considered cause-effect relationships between the reported human health conditions and chemicals from industrial and agricultural development in the north. However, correlation of environmental factors, such as levels of airborne chemicals, with disease incidences, was not possible because a variety of genetic, socioeconomic and lifestyle factors (e.g., smoking, exercise, diet, etc.) may contribute to manifestation and prevalence of a particular disease, and the study could not assess influences. Therefore, the following summary focuses only on the apparent trends in health status of human populations within the NRBS area and not on the potential linkages between health conditions and environmental factors.

D12.2 Current Status of Human Health Within the Northern River Basins Study Area

D12.2.1 Population Health Indicators

The following indicators of population health were evaluated: self-reported health status, life expectancy, fertility rate, infant mortality, low birth weight, teen birth rate, mortality rate and potential years of life lost. These indicators provide an overall indication of the general health status of an area and can be used to compare populations from different regions. Health measures for the NRBS area were compared with corresponding values for other rural and urban areas of Alberta (Alberta Health 1997).

Self-Reported Health Status

In 1996, a population health survey was conducted throughout Alberta in which respondents were asked to rate their overall health status as excellent, very good, good, fair or poor. Most Albertans rated their health as very good or excellent. The self-reported health status within the NRBS area was consistent with the ratings in other areas of Alberta.

Life Expectancy

Life expectancy at birth was not significantly lower within in the NRBS area than in other areas of Alberta.

Fertility Rate

The fertility rate (i.e., the average number of children born to women in the study area) for the NRBS area was compared with other regions of the province. In general, rural populations, such as the NRBS area had higher fertility rates than urban areas. In addition, the analysis indicated that women in the NRBS area tend to give birth and complete childbearing at a younger age than women in other areas of Alberta.

Infant Mortality

The rate of infant mortality within the NRBS area was consistent with other areas of Alberta. Infant mortality may be affected by prenatal care, the health of the mother, the social environment, the natural environment and the nature of the health care system. The infant mortality rate in Alberta is marginally but not significantly greater than the Canadian average.

Low Birth Weight

Low birth weight (i.e., less than 2.5 kg; 5.5 lbs.) may result in a higher incidence of complications related to birth, developmental delays, long-term health problems and premature death. Alberta has a higher percentage of low birth weight compared with the Canadian average. However, the NRBS area has fewer reported low birth weights than other areas of Alberta.

Teen Birth Rate

The teen birth rate is defined as the number of births to women under 20 years of age per 1,000 females between the ages of 13 and 19 years. Babies of young mothers are typically smaller and might have health problems associated with low birth weight. In addition, social and economic disadvantages might also result in adverse health effects in babies of young mothers. The teen birth rate reported for the Northern Lights Regional Health Region is not significantly different than the Alberta teen birth rate.

Mortality Rate

The rate of mortality is higher in the NRBS area than other areas of the province. However, the mortality rate for the Northern Lights Health Region is consistent with the rest of Alberta.

Potential Years of Life Lost

Potential years of life lost is a measure of the rate of premature death, defined as death that occurs before 70 years of age (excluding infant mortality). This value is slightly higher for women in Alberta compared with the Canadian average, but the value for Albertan men is consistent with the Canadian average.

Summary of Health Indicators

Overall, health indicators for the NRBS area are similar to other rural areas of Alberta. However, the fertility and teen birth rates within the NRBS area are greater than other areas of Alberta; although for the Northern Lights Region the teen birht rate is not specificly diferrent from other areas of Alberta. For this reason, irrespective of the potential for environmental exposure it is possible, higher than average rates of infant mortality, low birth weight, childbirth complications and congenital anomalies (i.e., medical conditions arising from birth, but diagnosed later in life) may occur for this region of Alberta (Alberta Health 1997).

D12.2.2 Health Outcomes

Health outcomes refer to reported incidences of disease within a population. In the NRBS study, health outcomes were measured in terms of the number of hospitalizations, physician visits and mortalities related to a specific disease. The five major causes of death in Alberta, in descending order of occurrence, are heart disease, cancer, injury and suicide, stroke and respiratory disease (Alberta Health 1997). The incidence of major diseases are described briefly below, emphasizing the health status of populations within the NRBS area in relation to other areas of Alberta and Canada as a whole.

Circulatory Diseases

Circulatory diseases refer to diseases of the heart or blood vessels (e.g., hypertension, stroke, coronary heart disease). Scientific research has indicated relationships between circulatory diseases and factors such as age, stress, oral contraceptives, genetics, diabetes, hyperlipidaemia, lifestyle (i.e., smoking, diet, exercise) and socio-economic status (Alberta Health 1997). Overall, the NRBS study concluded that there was no difference in frequency of contact with the health care system for circulatory diseases within the NRBS area compared with other regions of Alberta.

Respiratory Diseases

Respiratory diseases include asthma, bronchitis, emphysema and other lung ailments. Several factors, such as gender, genetic inheritance and lifestyle (e.g., smoking, income, education) have been associated with the incidence of respiratory diseases (Alberta Health 1997). There is also some evidence to suggest that air pollution may lead to an increased incidence of respiratory diseases. The NRBS study concluded that residents of the NRBS area are diagnosed more frequently with pneumonia and chronic bronchitis, but less frequently with asthma or acute upper respiratory infection than other areas of Alberta. For the reasons previously mentioned, it is not possible to correlate airborne chemical concentrations with a higher incidence of some respiratory diseases in the NRBS area.

Cancer

All types of cancer are included in this category. The probability of Albertans developing cancer during their lifetime is 1 in 3 (Alberta Health 1997). Several factors, such as family history, genetics, lifestyle (e.g., smoking, exercise, diet) and exposure to environmental carcinogens may lead to the development of cancer. Although the rate of hospitalization for cancer is higher in the NRBS area than in other regions of Alberta, the incidence of invasive cancers and cancer mortalities within the NRBS area is consistent with other areas of Alberta.

Gastrointestinal Diseases

Gastrointestinal diseases include all disorders of the digestive system (e.g., gastroenteritis, hepatitis, food and waterborne diseases, ulcers, renal failure). Several factors, such as family history, genetics, stress, microbial infection, alcohol and caffeine ingestion, and oral exposure to environmental contaminants may contribute to the development of gastrointestinal diseases (Alberta Health 1997). Due to the small sample sizes, comparisons between NRBS and other areas were unavailable.

Endocrine, Metabolic and Nutritional Disorders

Endocrine, metabolic and nutritional disorders include all diseases: affecting the endocrine system; showing evidence of nutritional deficiencies; or affecting metabolism (e.g., diabetes, anemia). Although the rate of hospitalization for these disorders is higher within the NRBS area than the rest of Alberta, the number of physician visits is lower, and the mortality rate is consistent with the rest of Alberta.

Neurological Diseases

Neurological diseases include diseases affecting the brain and nervous system (e.g., Alzheimer's, Parkinson's, multiple sclerosis, epilepsy). The majority of hospitalizations related to neurological diseases are for people greater than 60 years of age. The NRBS study concluded that there is no indication that NRBS residents are any more likely to be diagnosed with neurological disorders than in other areas of the province.

Reproductive System Diseases

Reproductive system diseases include menstrual cycle disorders, infertility, spontaneous abortion and endometriosis. Several factors, such as nutrition, alcohol intake during pregnancy, lifestyle and exposure to environmental contaminants may contribute to the development of these types of conditions (Alberta Health 1997). Generally, the rate of hospitalization is higher, but the number of physician visits is lower within the NRBS area. Only endometriosis shows consistently higher hospitalization and physician visit rates within the NRBS region. Potential causes for the increased incidence of endometriosis are unknown.

Stillbirth and Infant Death

The rate of post-neonatal deaths in the NRBS area is slightly higher than the rest of Alberta. Several factors, such as smoking and/or alcohol consumption during pregnancy, socio-economic disadvantages, complications of umbilical cord/placenta, low birth weight, birth defects and maternal health conditions (e.g., hypertension), also contribute to increased incidence of post-neonatal deaths (Alberta Health 1997). Because of this, it is not possible to determine a relationship between environmental toxicants and infant mortality.

Congenital Anomalies

Congenital anomalies are medical conditions arising from birth, although they may not be diagnosed until later in life (e.g., structural defects, chromosomal and monogenic syndromes). In general, the incidence rate and number of physician visits in the NRBS area are lower or comparable to the Alberta average. The Northern Lights Health Region has the lowest incidence of reported congenital anomalies in the NRBS region.

Summary of Health Outcomes

In general, the health status of the NRBS area is not significantly different from that of other areas of Alberta and Canada as a whole. Certain types of health outcomes, including pneumonia, chronic bronchitis, endometriosis and post neonatal death have a higher prevalence in the NRBS area. This may be due to several factors, including age, family history, lifestyle, socio-economics and environmental exposure (Alberta Health 1997).

D13 HISTORICAL RESOURCES

D13.1 Introduction

The purpose of this section is to review the historical resource status of the entire Lease 13 area. The Muskeg River Mine Project represents the latest in a series of proposals to develop Lease 13. Historical resource studies have been a component of previous proposals for this lease since 1974. Because different lease areas were proposed for development in the past, and different strategies and levels of intensity for discovery and assessment of historical resource sites were employed, varying levels of information on historical resources are available for different areas of the lease. As well, regulatory response to the results of each of the studies completed under the Alberta Historical Resources Act has varied. This has resulted in a situation where some areas of the lease have been cleared of historical resource concerns. Other areas have been investigated but outstanding study or avoidance requirements remain before development can proceed. Still other areas have never been examined and require inventory and assessment.

Historical resources are defined by the *Alberta Historical Resources Act* (1987) as:

"any work of nature or man that is primarily of value for its palaeontological, archaeological, prehistoric, historic, cultural, natural, scientific or aesthetic interest, including but not limited to, a palaeontological, archaeological prehistoric, historic or natural site, structure or object."

Consequently, historical resources include, as well as the sites where events took place in the past, all of the objects that they contain and any of the contextual information that may be associated with them, and will aid in their interpretation, including natural specimens and documents or verbal accounts. They are generally divided into three types, prehistoric archaeological, historic period archaeological and structural, and palaeontological. Natural objects and features have also been occasionally managed under the provisions of the Historical Resources Act.

Prehistoric archaeological resources in northern North America are the archaeological sites, objects and affiliated materials that represent occupations by Aboriginal peoples before the arrival of European goods, people and the historic records that characterize their culture. In this region of the province these consist of the locations where activities took place and remains of these activities, usually stone artifacts and features such as hearths. Generally, associated animal bone and other organic artifacts have been removed by the acid soils of the area. These can span the entire 10,000 year period of recognized prehistory in this region of the province.

Historic archaeological and structural resources generally include the sites, artifacts, structures and documents that relate to the Euro-Canadian occupation of the region and date to the last 250 years. These include remains related to the early fur trade conducted in the region as well as those relating to later economic developments such as trapping, forestry and oil sands exploration and production. A key component of the historic period record are the sites, artifacts and affiliated resources relating to post-contact Aboriginal people's use of the landscape. These include both archaeological sites and objects such as standing and collapsed cabins, campsites, graves, and traditional sites and resources such as special places, hunting and plant collecting areas, trap lines and their associated remains, oral traditions and various documents. These latter resources are usually identified through consultation procedures such as "Traditional Land Use" studies.

Palaeontological resources consist of physical remains representing the evidence of extinct multicellular plants and animals, and related contextual information, that inhabited the region in prehistoric times. These can include fossils, bone deposits, shells and the impressions of these remains and can occur in both bedrock and unconsolidated glacial and postglacial sedimentary deposits.

D13.2 Historical Resource Background

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 significant 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 information. The loss of historical resources is permanent and irreversible.

Historical resources are managed under the provisions of the Alberta Historical Resources Act. If significant historical resources may be damaged by a proposed development, the Minister of Community Development may require the proponent to undertake an HRIA that will:

- determine the presence and value of any historical resource in the immediate development area;
- forecast the nature of proposed impacts; and

- recommend mitigation procedures that will offset potential negative effects.

These provisions came into effect in 1973, but were not applied systematically until after Shell Canada Limited had sponsored the first archaeological studies directed toward a potential oil sands project on Lease 13 (Sims and Losey 1975). Since that time, HRIA requirements have been placed on several proposed developments scheduled within the lease area. A few government-sponsored research projects have obtained archaeological information from select portions of Lease 13. The studies relevant for understanding the prehistoric record of the area surrounding the lease are summarized in Table D13-1 (see also Reeves 1997). These studies have resulted in a far greater level of archaeological knowledge than is available for surrounding areas in the RSA.

D13.3 Previous Archaeological Study on Lease 13

Previous archaeological studies undertaken on Lease 13 have a direct bearing on the program completed. Therefore, the results of these studies are reviewed in some detail (see Tables D13-1 and D13-2, Figures D13-1 and D13-2).

Previous archaeological studies conducted in various areas within the Project area have identified a unique and important distribution of archaeological sites. This appears to be in significant contrast to similar areas in the Lower Athabasca River basin. The strategy undertaken for the Muskeg River Mine Project Historical Resources Impact Assessment (HRIA) considers the relevant research issues that arise from previous studies. Therefore the study for the Project was designed to build on previous results to supplement current understanding of regional prehistory, especially in the area of site distribution patterns.

D13.3.1 Oil Sands Related Work

Shell Canada Limited sponsored a pilot survey of a proposed Lease 13 development project in 1974 (Sims and Losey 1975). Forty-seven prehistoric archaeological sites were identified by visual examination of natural and modern human disturbances present in select areas of the lease. Areas examined included:

- cuts along the Athabasca and Muskeg rivers and Jackpine Creek;
- disturbances created by the Fort Chipweyan winter road (now Hwy. 963);
- the lease road; and
- clearing for an airstrip, a plant and various exploration programs.

Table D13-1. Historical Resource Studies in the Lease 13 Area

Permit	Project/Type	Reference	Sites Recorded
74-10	Hwy. 963 HRIA	Losey et al. 1975	4
74-31	Shell Lease 13	Sims and Losey 1975b	47
75-08	Athabasca River Survey	Donahue 1976	12
75-14	Hwy. 963: 12 - Survey	Sims 1975a	2
76-05	Athabasca River Survey	Sims 1976	32
77-43	Hwy. 963 HRIA	McCullough and Reeves 1978	8 new, 11 revisited
78-71	Hwy. 963 - test excavations	Head 1979	known sites
79-56	Alsands Plant and Mine Site	Conaty 1979	6
79-124c	Hwy. 963 excavations	Mallory 1980	known sites
80-91	Alsands Tailings Pond Gravel area, Mine, etc.; Energy Corridor Townsite, Airstrip	Ronaghan 1981a, b	59 new, 11 revisited
80-202	Northwest Utilities Pipeline - HRIA	Ronaghan 1981c	3 new 1 revisited
81-64	Alsands Plant Site and Mine Post-clearance Survey	Ives 1982	25 new 1 revisited
81-153c	Hwy. 963 - Controlled Surface Collection of the Cree Burn Lake Site	Ronaghan 1982	known site
82-41	Alsands Plant Site and Mine Post-clearance Survey	Ives 1988	8
83-53	Bezya Site excavations	LeBlanc 1986	known site
83-54	Beaver River Sandstone Geological Study	Ives and Fenton 1986	known site
88-32	Hwy. 963 Cree Burn Lake Site - excavation	Head and Van Dyke 1990	known site
96-13	SOLV-EX gas pipeline HRIA	Gorham 1996	1 new, 1 revisit, 3 hist.
96-72	Syncrude Aurora project Phase I	Shortt n.d.	8 new, 3 revisit

Table D13-2 Historical Resource Sites in the Lease 13 Area

Known Sites in or Near Development Zones				**Known Sites in Lease but Distant From Proposed Development**		**Post-Contact Traditional Sites in Lease 13**
HhOu 1	HhOu-31	HhOv 72	HhOv 112	HhOu 8	HhOv 51	Fred Boucher cabin
HhOu 2	HhOu-32	HhOv 73[a]	HhOv 113	HhOu 9	HhOv 52	4-25-95-10-W4
HhOu 3	HhOv 3	HhOv 74	HhOv 114	HhOu 10	HhOv 53	Raymond Boucher cabin
HhOu 4	HhOv 4	HhOv 75	HhOv 115	HhOu 11	HhOv 54	4-24-95-10-W4
HhOu 6	HhOv 5	HhOv 76	HhOv 116	HhOu 12	HhOv 55	Louis Tourangeau cabin
HhOu 7	HhOv 6	HhOv 77	HhOv 117	HhOu 13	HhOv 56	1-7-95-10-W4
HhOu 8	HhOv 10	HhOv 78	HhOv 118	HhOu 14	HhOv 61	Isadore Lacorde cabin/grave
HhOu 9	HhOv 11	HhOv 79	HhOv 119	HhOu 15	HhOv 62	(Mile 49)
HhOu 10	HhOv 16	HhOv 80	HhOv 120	HhOu 34	HhOv 63	15-18-95-W4
HhOu 11	HhOv 17	HhOv 81	HhOv 121	HhOv 22	HhOv 64	
HhOu 12	HhOv 18	HhOv 82	HhOv 122	HhOv 27	HhOv 68	
HhOu 13	HhOv 19	HhOv 83	HhOv 123	HhOv 28	HhOv 69	
HhOu 14	HhOv 20	HhOv 84	HhOv 124	HhOv 29	HhOv 146	
HhOu 15	HhOv 21	HhOv 85	HhOv 125	HhOv 49	HhOt-1	
HhOu [16(a)]	HhOv 22	HhOv 86	HhOv 126	HhOv 50		
HhOu 17	HhOv 31	HhOv 87	HhOv 127			
HhOu 18	HhOv 32	HhOv 88	HhOv 128			
HhOu 19	HhOv 33	HhOv 89	HhOv 129			
HhOu 20	HhOv 34	HhOv 90	HhOv 130			
HhOu 21	HhOv 36	HhOv 91	HhOv 131			
HhOu 22	HhOv 37	HhOv 93	HhOv 132			
HhOu 23	HhOv 38	HhOv 94	HhOv 133			
HhOu 24	HhOv 39	HhOv 96	HhOv 134			
HhOu 25	HhOv 40	HhOv-105	HhOv 135			
HhOu 26	HhOv 67	HhOv 106	HhOv 137			
HhOu 27	HhOv 68	HhOv 107	HhOv 138			
HhOu 28	HhOv 69	HhOv 108	HhOv 139			
HhOu 29	HhOv 70	HhOv 109				
HhOu-30	HhOv 71	HhOv 111				

(a) significant sites

Sites seemed to occur relatively frequently and tended to cluster along the Athabasca River and its tributary rivers and creeks. However, identification of three sites in the hinterlands of the lease hinted at an unusual site distribution, which has been further revealed and expanded on in subsequent studies. Sims (1975b) concluded that the site potential of the lease area was high and predicted that 185 sites might occur within Lease 13 (Sims and Losey 1975).

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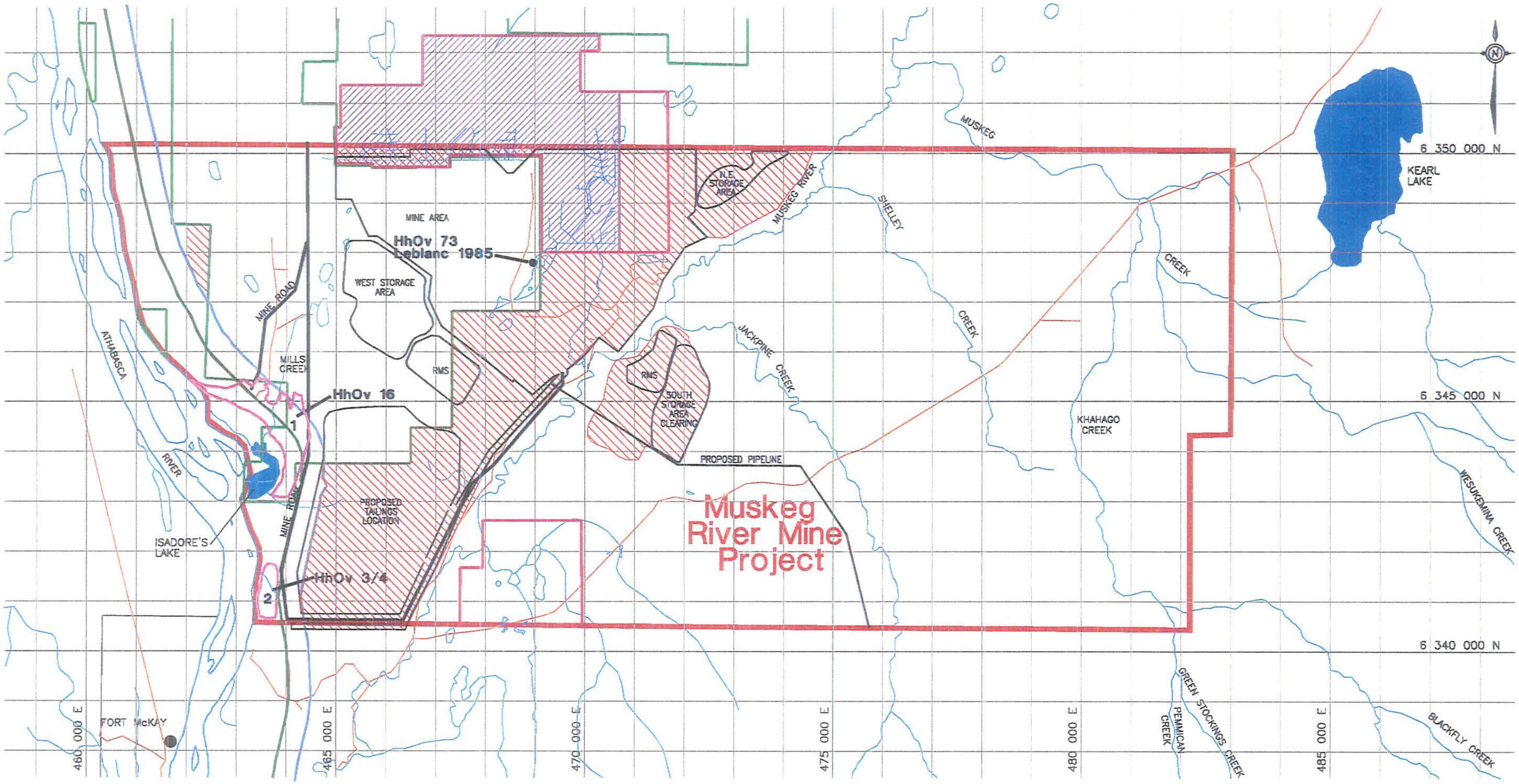

0 1000 2000 3000 4000 5000

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

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PREVIOUS HISTORICAL RESOURCES IMPACT ASSOCIATED STUDIES AND 1997 HRIA

06 DEC 97	Figure D13-1	DRAWN TM

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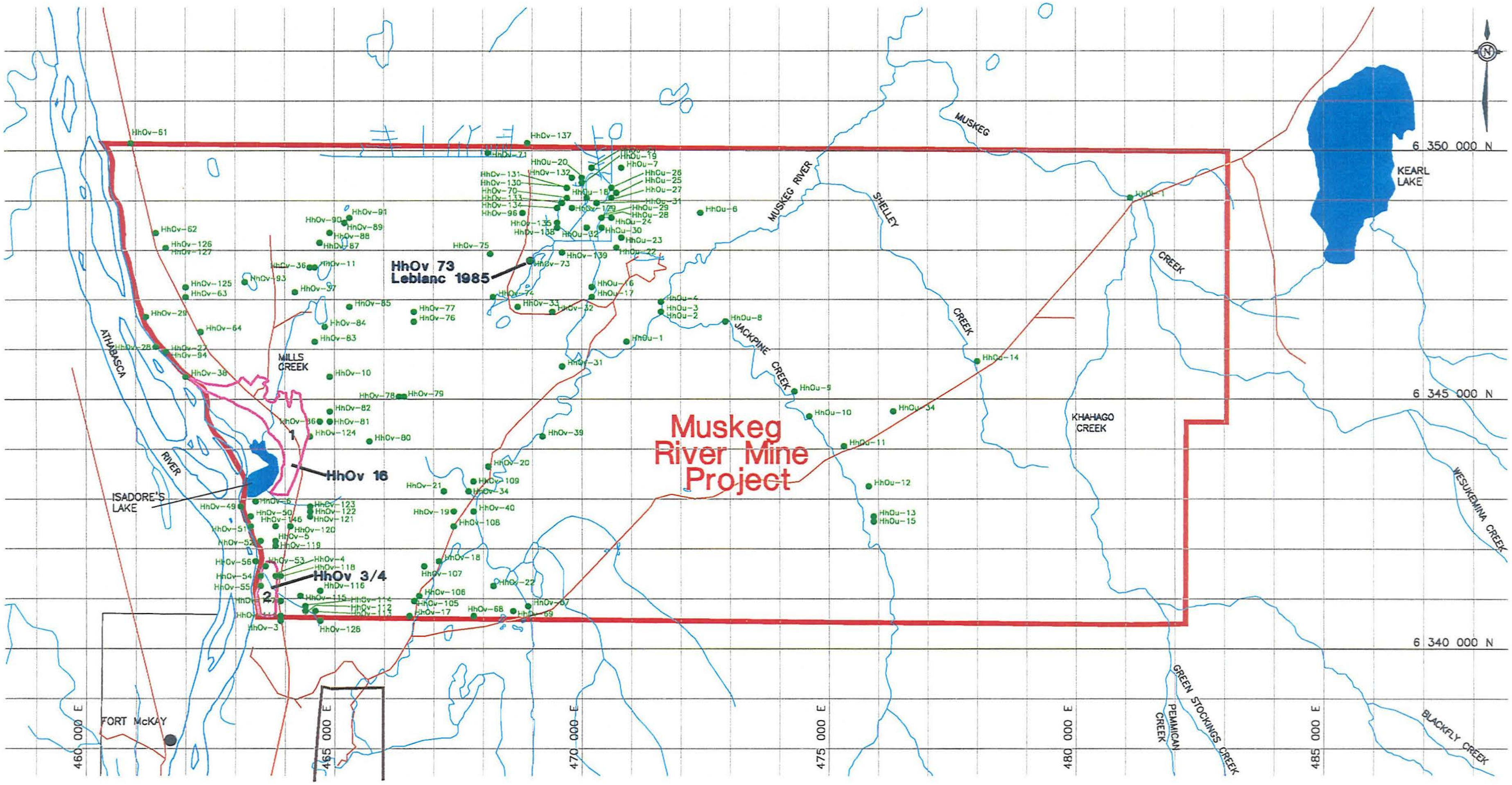

D13-7

LEGEND

1 Mallory 1980, Head 1979, Head and VanDyke 1990, Ronaghan 1980,1982
2 Mallory 1980, Head 1979
HhOu 1 ● Borden Location and Number

REFERENCE

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

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KNOWN ARCHAEOLOGICAL SITES ON LEASE 13

04 DEC 1997	Figure D13–2	DRAWN BY: TM

The project proposed in the early 1970s did not proceed, but HRIA studies were conducted for a revised project sponsored by a Shell Canada Limited-led a consortium known as Alsands. The first of these studies was conducted in 1979 by Conaty (1979). That study applied a sampling strategy that used a randomized technique to select areas to be examined, and a small judgemental examination component that selected areas for examination based on adjudged potentials. The project took place in areas defined for a proposed plant site, a mine site, a gravel extraction area, and a proposed transportation corridor (Figure D13-1). Despite considerable effort, only two sites were identified in the randomly distributed (probabilistic) sampling portion of the program and four sites were recorded in the judgmental component of the study.

In 1980, additional components of the proposed Alsands project were examined (Ronaghan 1981b). Based on topographic considerations, an intensive subsurface test program was instituted on features believed to have significant historical resource potential. Raised features were examined throughout areas proposed for development of a second mining area, a tailings pond, two muskeg storage areas, a second gravel resource area and three water intake areas along the Athabasca River (Figure D13-1). For a similar level of effort to that employed in 1979, the 1979/1980 study recorded 42 prehistoric and one historic period site. Also included in the areas examined was a 90 m wide corridor paralleling the Highway 963 right of way. This was to include various facilities, and extended well outside the lease area (Ronaghan 1981a). A further 27 prehistoric sites were recorded during that study.

In 1981 and 1982, Alberta Culture undertook a follow-up examination of the 1979 study areas, which had been cleared of forest cover under winter conditions (Ives 1982, 1988; Figure D13-1). Due to the excellent visibility, 33 new sites were recorded in the initially proposed mine and plant site area. These sites were situated on the same kinds of features that had been productive in the 1980 studies and confirmed a high site density in the hinterlands of Lease 13. It is significant that winter forest clearance had left many of these sites relatively intact, retaining a potential for more detailed study.

Finally, as a follow-up to the above studies, Alberta Culture archaeologists returned to conduct research excavations at one of the sites identified in the second mine area examined in 1980 (LeBlanc 1986). The site ("Bezya," HhOv 73) was determined to represent an occupation previously unknown outside the Northwest Territories and demonstrated a degree of resource variation not previously apparent. Sites identified in Lease 13 are shown in Figure D13-2.

D13.3.2 Research Studies

Two earlier research surveys sponsored by the Alberta government have a bearing on historical resource issues for the Muskeg River Mine Project. Examination of exposures along the Athabasca River by Donahue (1976) and Sims (1976) identified 12 and 32 sites, respectively, 13 of which occur within the Project area.

D13.3.3 Highway Transportation Corridor Studies

A considerable number of archaeological studies have been conducted in response to proposals to develop transportation facilities along a corridor paralleling the east bank of the Athabasca River (McCullough and Reeves 1978, Head 1979, Ronaghan 1981a and 1982, Head and Van Dyke 1990, and Gorham 1996). These studies have resulted in identification of a dense concentration of sites near the valley rim, especially above Isadore's (or Cree Burn) Lake. Many of these sites have suffered impacts, resulting in the destruction of some. Mitigation studies have been undertaken at other sites and some remain largely intact. The most significant of these sites, the Cree Burn Lake Site (HhOv 16), was recently recommended for designation as a provincial Historical Resource (Reeves 1997).

D13.4 Historical Resources Act Status

Historical resource management is a two-stage process, involving an impact assessment and a mitigation stage. When a final HRIA report is accepted, the first stage is considered complete for the area specified in the permit granted by Alberta Community Development (ACD). HRIA reporting requirements include formulation of management recommendations for the area in question and the resources identified. These recommendations are reviewed by ACD and the remaining requirements of the act are established before to development approval. Generally, fulfilling these requirements is considered to have mitigated project impacts and allows developments to proceed. Certain subareas and sites within the Muskeg River Mine Project area are at different stages in this management process and require different levels of attention depending on their relationship to the currently proposed Project.

The following paragraphs identify the status of previously examined development areas under the act. This interpretation formed the basis of the archaeological research permit application submitted to ACD for the 1997 Muskeg River Mine Project HRIA. In granting permit number 97-107 to cover the proposed study, ACD signified its acceptance of these interpretations.

D13.4.1 1974 Sample Survey (Sims and Losey 1975)

The areas examined by Sims and Losey (1975) represent only a small portion of those proposed for development. This study did not employ techniques that currently would be considered acceptable for an HRIA. Therefore, this study is not considered equivalent to an HRIA for the areas examined. Because review mechanisms for these types of projects were not fully established at the time it was completed, the regulated status of the areas examined and the sites identified is uncertain. Therefore, except for sites that may occur in currently proposed development areas, the coverage provided in that program has been discounted.

D13.4.2 Alsands Plant, Mine, Gravel Area (Conaty 1979, Ives 1982, 1988)

It is evident in correspondence that Alberta Culture's review of these studies concluded that they did not fully correspond with the objectives of an HRIA. The results of later studies indicate that not all significant resources were identified and that additional HRIA level work would be appropriate in these areas.

The post-clearance reconnaissance by Ives (1982, 1988) has confirmed the actual site density in the proposed Alsands campsite and mine examined by Conaty (1979), and has extracted comparative samples. The fact that the Ives studies constitute sufficient investigation to meet HRIA standards is confirmed in correspondence from Alberta Culture, wherein mitigation level requirements for the sites in question are discussed (W. J. Byrne to D. Dabbs of Alsands, Dec. 2, 1981 and S. Lobay to D. Dabbs May 28, 1982).

HRIA level studies, therefore, have been completed for the proposed Alsands first five-year mine site and portions of the plant site area. Mitigation requirements could be established by ACD after review of development plans. It is also concluded that, if a post-clearance survey similar to that applied by Ives were to be implemented in the gravel resource area south of the Muskeg River examined by Conaty (1979) (see Figure D13-2), HRIA requirements would be considered to have been met. No development is planned in this area for the Muskeg River Mine Project.

D13.4.3 1980 Alsands HRIA (Ronaghan 1981a)

Areas examined in this study are also shown in Figure D13-1. This study was reviewed and accepted by Alberta Culture in a letter dated Dec. 2, 1981 from Dr. W. J. Byrne to D. Dabbs of the Alsands Project Group. This letter establishes mitigation requirements for the sites recorded during the 1980 study. Hence, HRIA level requirements have been met in these areas and any necessary mitigation requirements can be implemented before development.

D13.4.4 1980 Energy Corridor (Ronaghan 1981b)

Areas examined in this study are also shown in Figure D13-2. This study was reviewed and accepted by Alberta Culture in a letter dated Dec. 1, 1981 from Dr. W. J. Byrne to D. Dabbs of the Alsands Project Group. This letter indicates the sites recorded during the 1980 study that are of concern. However, it does not establish specific mitigation requirements for them. It is concluded that HRIA level requirements have been met in these areas and that mitigation requirements can be established in discussion with ACD, to offset any impacts proposed in these areas.

D13.4.5 Highway HRIA/Mitigation

The studies relating to construction of Highway 63 have little bearing on the proposed Muskeg River Mine Project, since they were all dedicated toward the highway alignment that is now built.

D13.5 Historic Period and Traditional Resources

Six trapper's cabins and one grave site (traditional sites) have been identified in or adjacent to Lease 13 (Figure D13-3). Of these, only one collapsed and one standing cabin are situated near the Project development area. Although both sites were visited and re-examined during the 1997 HRIA, it appears that only one of these would be affected by the Project development plans.

D13.6 Palaeontological Resources

Palaeontological resource sensitivity in the vicinity of the Muskeg River Mine Project is shown in maps provided by the Tyrrell Museum of Palaeontology (see Figure D13-4). "High" potential is present at the mouth of the Muskeg River and "probable" potential is shown along the bluff of the Athabasca River. Neither of these locations would be affected by the Muskeg River Mine Project.

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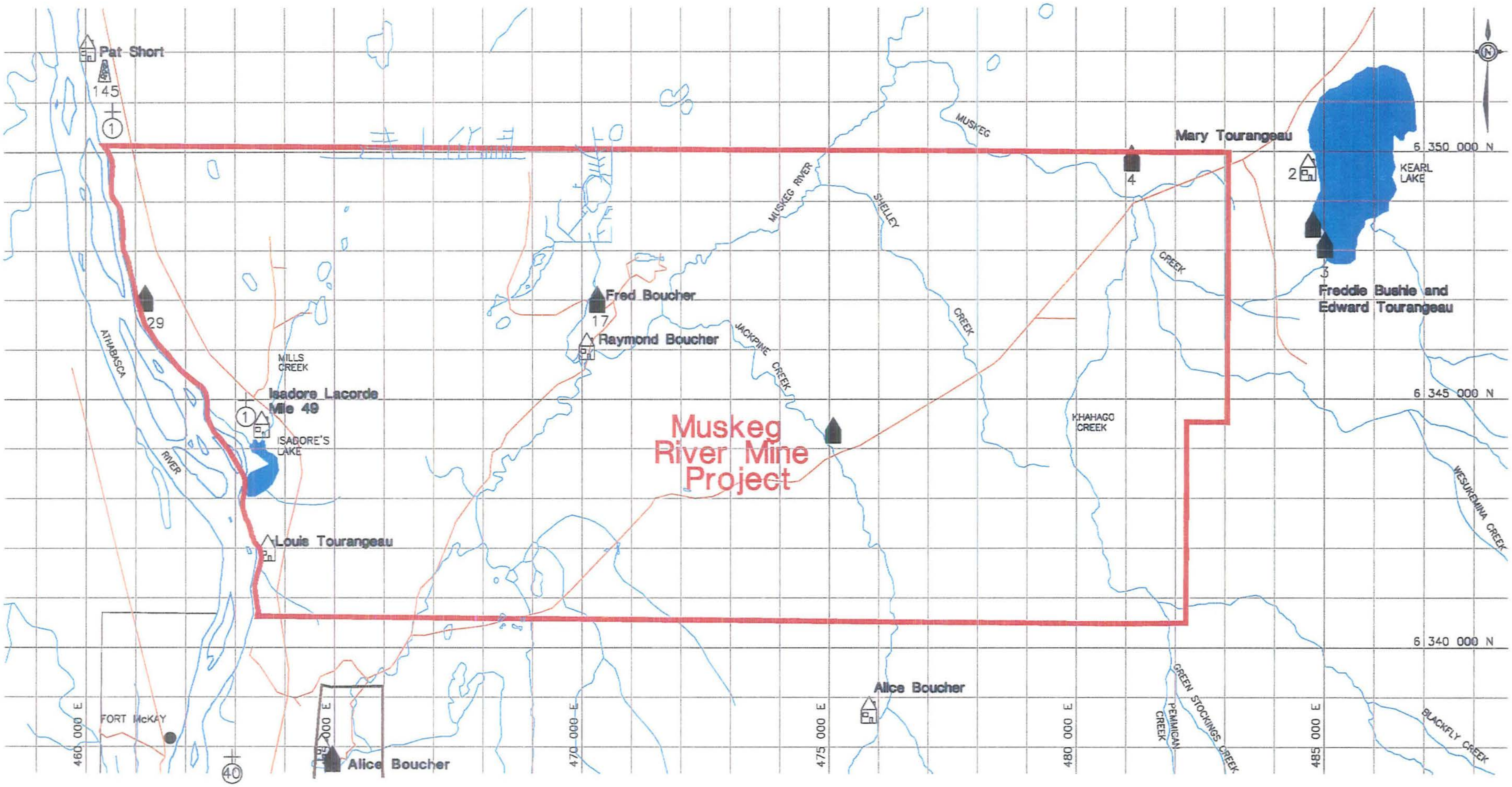

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SCALE IN METERS

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
- 40 Gravesite\Number of Graves
- Boiler and Rig Debris

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KNOWN TRADITIONAL SITES IN OR NEAR THE MUSKEG RIVER MINE PROJECT

03 DEC 1997	Figure D13–3	DRAWN BY TM

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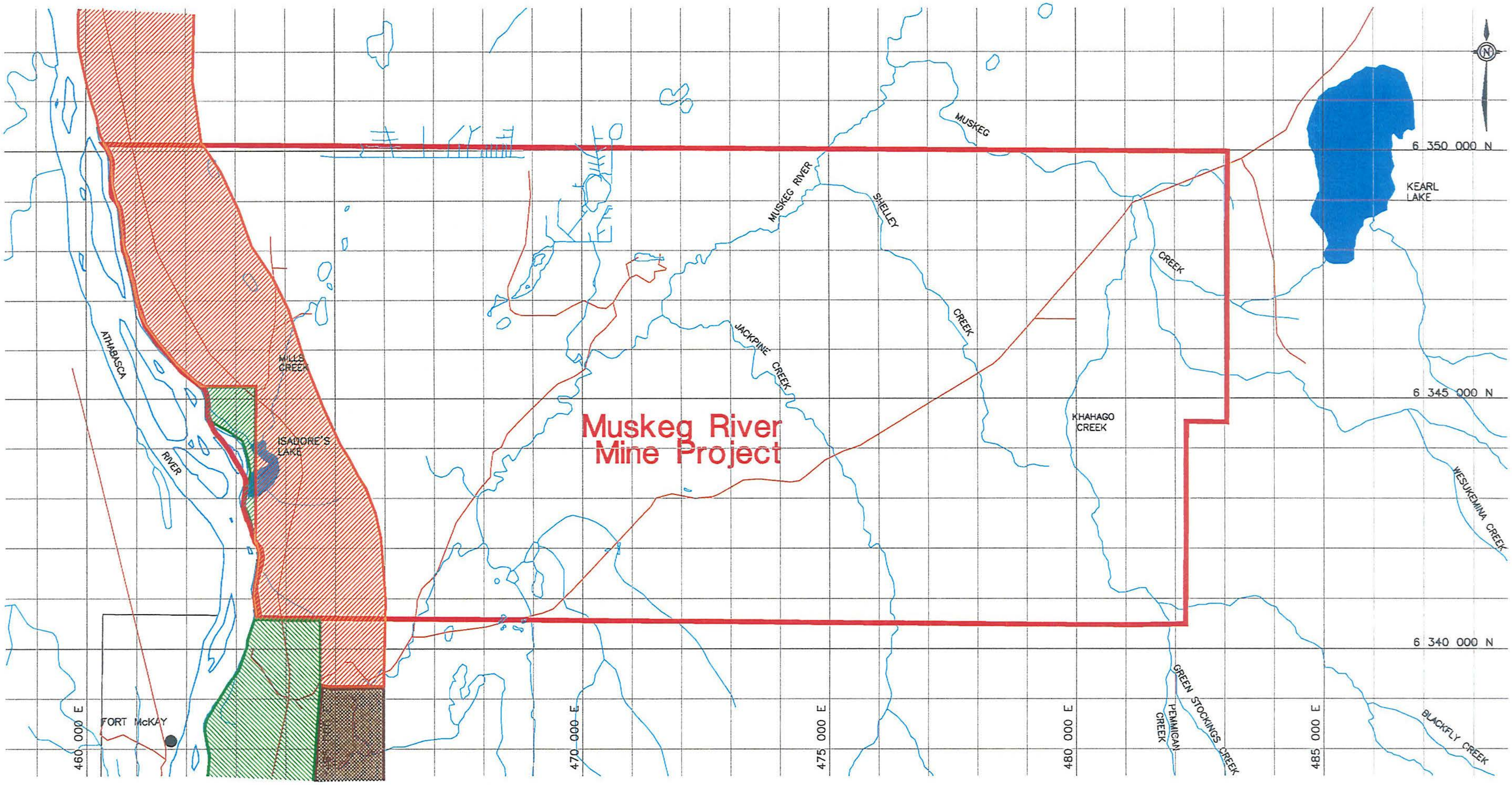

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SCALE IN METERS

REFERENCE

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

LEGEND

PALAEONTOLOGICAL RESOURCE SENSITIVTY ZONES

- Low
- Probable
- Medium
- High

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PALAEONTOLOGICAL SENSITIVITY

03 DEC 1997	Figure D13–4	DRAWN BY: TM

D14 NON-ABORIGINAL RESOURCE USE

D14.1 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 the existing land uses, including oil sands development, aggregate mining, tourism, forestry, trapping, fishing, hunting, cultural use, food collection and other outdoor recreation activities (TofR, Section 6.0).

Project-specific impacts on resource use are addressed in Section E14 of this EIA. The visual impact assessment is addressed in Section E17 (see Figures E17-2, E17-3 and E17-4). Cumulative effects on resource use are addressed in Section F14.

This section of the EIA summarizes the use of natural resources by non-aboriginal residents and non-residents in the Regional Study Area (RSA) and Local Study Area (LSA) of the Muskeg River Mine Project. These study areas are delineated in Figures D1-2 and D1-3. The topics reviewed include consumptive uses, such as hunting and fishing, and non-consumptive uses, such as camping and canoeing.

D14.1.1 Objectives

To describe current non-traditional consumptive and non-consumptive resource use in the Project RSA and LSA, the following objectives were set:

- determine which land resources are used in the LSA and RSA;
- determine how the resources are used, and to what extent; and
- determine where and when the resources are used.

Some factors affecting resource use (e.g., the dynamic nature of resource use, secondary economies and quality of life) are not reviewed in detail in this section but covered in the Socio-Economic sections D16 and E16. Natural resource use patterns constantly change due to population density, affluence and cultural backgrounds. As well, natural resources support various secondary economies, including:

- tourist accommodation;
- vehicle and fuel sales;
- hunting and fishing equipment; and
- retail, food and restaurant businesses.

In addition, regional government management and regulation requirements are associated with natural resource use.

Finally, a seldom-evaluated economic aspect of resource use is "quality of life." This aspect of resource use is important as some residents of Fort McMurray are drawn to the community and the region by opportunities to use and appreciate natural resources and by opportunities to escape from more urban life (BOVAR 1996f).

D14.2 Methodology

In this report, the term "non-traditional" refers to the general non-aboriginal population within the RSA and LSA, mainly in Fort McMurray. Use of resources by aboriginal peoples is discussed in the Traditional Land Use Section (D15).

Information sources used to evaluate non-traditional resource use in the RSA and LSA include:

- the non-traditional land use study completed by BOVAR (1996f);
- a resource use telephone survey (BOVAR 1996f);
- personal communications with various government and non-government agencies;
- various government reports and databases; and
- industry management plans.

A comprehensive resource use telephone survey, conducted by BOVAR Environmental (BOVAR 1996f), involved representatives from a variety of recreational organizations and other local resource sources (see Table D14-1).

Table D14-1 Potential Resource Users in the LSA and RSA

Alberta Forestry Conservation Community Committee
Alberta Snowmobile Association
Alberta Trapper's Association
All Terrain Vehicle (ATV) Association
Canadian Institute of Mining
Clearwater River Committee
Equestrian Group
Federation of Alberta Naturalists
Fort McMurray Field Naturalists Society
Fort McMurray Fish and Game Association
Fort McMurray Musher's Association
Fort McMurray Snow-Drifters
Fort McMurray Visitor's Bureau
Jetboaters and Large Motorized Watercraft Group
Lodges, Guides and Outfitter's Group
Muffaloose Trail Blazers
Northeast Alberta Off-Highway Vehicle (OHV) Association
Northern Alberta Native Plant Council
Professional Outfitters Association of Alberta
Ptarmigan Nordic Ski Club
Tarsands Canoe and Kayak Club

From BOVAR 1996f

Government and industry information sources used to evaluate non-traditional resource use included:

- significant natural features of the eastern boreal forest region of Alberta report by Westworth (1990);
- Forest Management Agreement by Alberta-Pacific Forest Industries Ltd., which provides projected timber harvest levels for Forest Management Areas (FMAs);
- Fort McMurray-Athabasca Oil Sands Subregional Integrated Resource Plan (AEP 1996a) that defines Resource Management Areas (RMAs) in the region and regional resource objectives;
- Alberta government information regarding surface dispositions;
- Special Places 2000 report, which identifies proposed natural areas for protection; and
- Wildlife Division databases that describe Wildlife Management Unit (WMU) areas in the RSA.

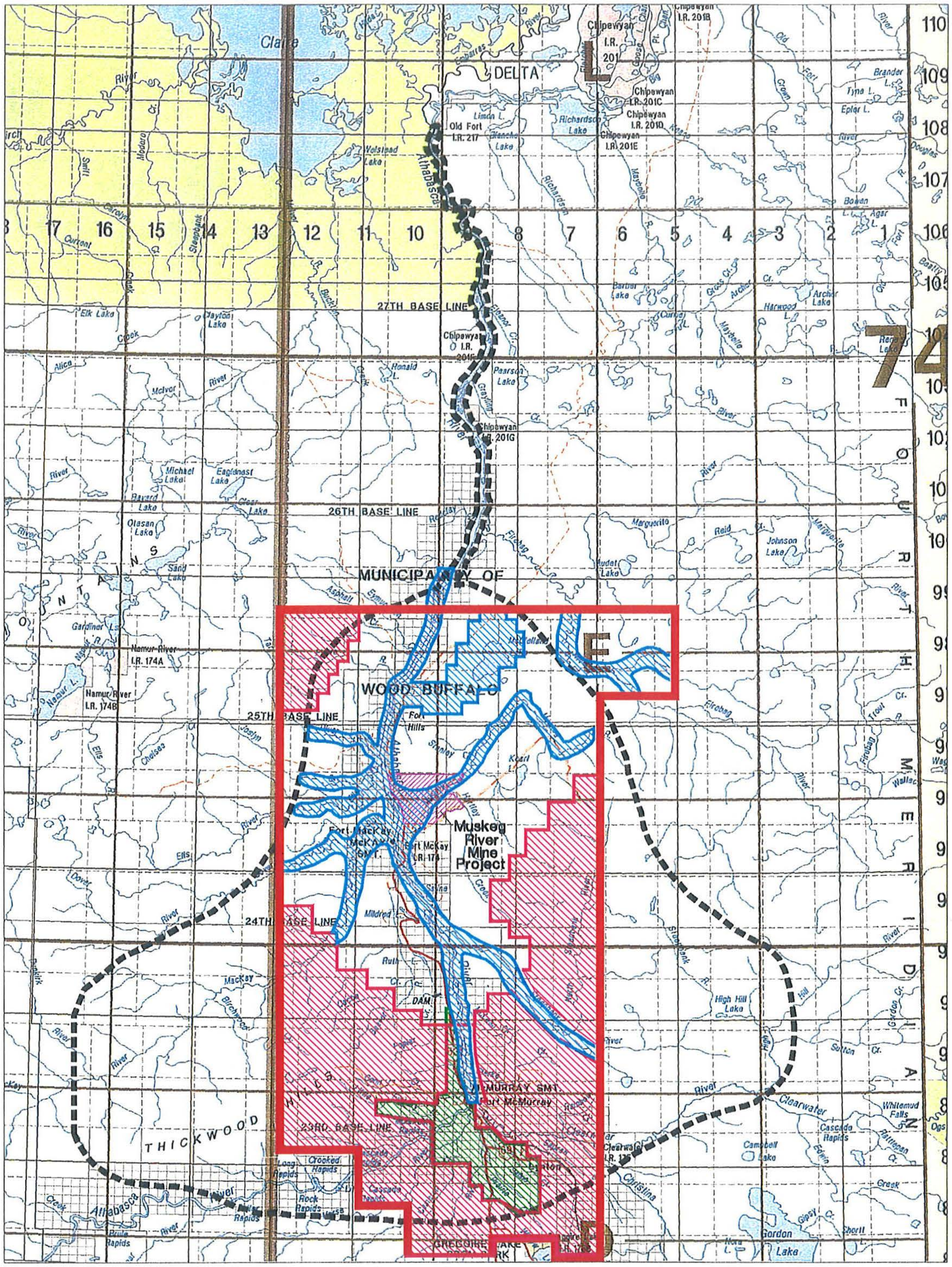
D14.2.1 Land Use Zoning

The LSA and a large part of the RSA are located within the proposed Fort McMurray-Athabasca Oil Sands Subregional Integrated Resource Plan (IRP) area (AEP 1996a). This IRP provides direction for the management of public land and resources through future actions of both the provincial government and the private sector. The IRP ensures development activities are compatible within each Resource Management Area (RMA). There are four RMAs in the RSA: Fort McMurray Fringe, Athabasca-Clearwater, Mildred-Kearl Lakes and Stoney-Birch (Figure D14-1). The LSA is within the Athabasca-Clearwater and Mildred-Kearl Lakes RMAs (Figure D14-2).

The IRP has listed specific objectives and guidelines for each RMA (AEP 1996a). The management intents for the RMAs within the LSA are to:

- manage public land and resources in recognition of the multiple uses required to service and enhance development of the urban service area of Fort McMurray in the Fort McMurray Fringe RMA;
- protect the natural landscape, which encompasses water, wildlife habitat, ecological and geological features, and to ensure aesthetic, recreational, traditional and environmental values in the Athabasca-Clearwater RMA;
- promote the orderly planning, exploration and development of resources with emphasis on the area's oil sands reserves in the Mildred-Kearl Lakes RMA; and
- manage the exploration, extraction and/or development of a range of resources while recognizing opportunities associated with the wildlife, fisheries and other valued ecological components in the Stoney-Birch RMA.

To ensure development activities are compatible within each RMA, IRP guidelines range from expressing a concern to limiting how or where an activity is conducted (Table D14-2). Guidelines were developed for mineral and surface material resources, forest resources, access and infrastructure, agriculture, recreation and tourism, ecological reserves, wildlife resources, fisheries and historical resources.



0 10 20 30 40 50km

SCALE 1:1,250,000 (Approx.)

LEGEND

- FORT McMURRAY- ATHABASCA OIL SANDS SUBREGIONAL INTEGRATED RESOURCE PLAN BOUNDARY
- ATHABASCA-CLEARWATER RMA
- STONY-BIRCH RMA
- FORT McMURRAY FRINGE RMA
- MILDRED-KEARL LAKES RMA

REFERENCE

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

Golder Associates	SHELL CANADA LIMITED	
INTEGRATED RESOURCE PLAN RESOURCE MANAGEMENT AREAS (RMAs) FOR THE RSA		
01 DEC 1997	Figure D14-1	DRAWN BY: CG/TM

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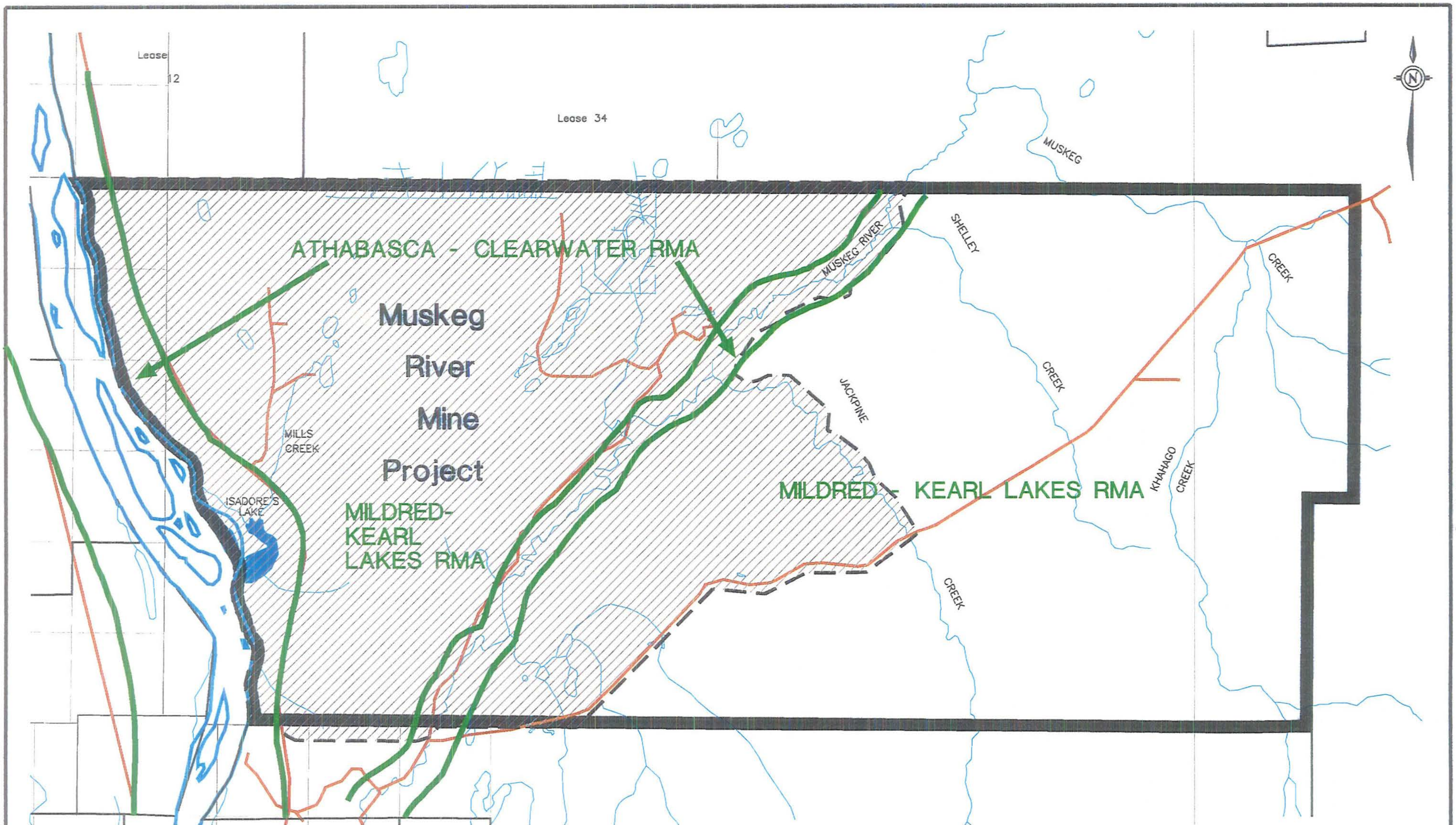


LEGEND

BOUNDARY FOR RMA's WITHIN THE FORT McMURRAY–ATHABASCA OILSANDS SUBREGIONAL INTEGRATED RESOURCE PLAN

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

INTEGRATED RESOURCE PLAN RESOURCE MANAGEMENT AREAS (RMA's) FOR THE LSA

01 DEC 1997	Figure D14–2	DRAWN BY: CG

Table D14-2 Integrated Resource Plan Guidelines (AEP 1996a)

Activity	Broad Guidelines	Fort McMurray Fringe RMA	Athabasca-Clearwater RMA	Mildred-Kearl Lakes	Stoney-Birch
Mineral and Surface Material Resources	• Impacts on the environment and other resource values should be minimized. • Mineral exploration and development is subject to current regulatory review and approval processes. • Surface disturbances must be progressively reclaimed or alternative reclamation approaches may be considered. • The location of aggregated deposits must be reported to Alberta Land and Forest Service.	• Surface mining is not permitted. • In-situ oil sands development will be permitted where conflict with other land uses can be mitigated. • Impacts on aesthetics and wildlife values must be minimized by limiting line-of-sight; retaining vegetation buffers between development and public roads; and clearing the site in an irregular shape.	• Oil sands development is not permitted in the Clearwater River valley, McClelland Lake wetlands and the MacKay River tributary. • Surface mining in other areas must mitigate impacts in highly sensitive areas. • Oil sands recovery will be considered within the Athabasca and Clearwater River valleys, associated tributaries and the upland drainage of the McClelland Lake wetlands. • Seismic and other mineral exploration within the Athabasca and Clearwater River valleys should maximize use of existing access. • Extraction of oil sands must be conducted such that impacts on watershed, wildlife, fisheries, vegetation, aesthetic and recreation values are minimized. • Instream gravel production is not permitted. Sand and gravel operations require a minimum 50 m buffer from rivers. • Surface mineable areas in the Athabasca River valley have a separate set of guidelines.	• Mineral exploration activities are subject to site-specific operating conditions.	• Within the Thickwood Hills, Birch Mountain and Stoney Mountain Upland areas, the development must be designed to minimize impacts on wildland recreational resources.

Activity	Broad Guidelines	Fort McMurray Fringe RMA	Athabasca-Clearwater RMA	Mildred-Kearl Lakes	Stoney-Birch
Forestry	• Harvesting and reforestation methods must be in accordance with the Forests Act, Timber Management Regulations, Timber Harvest Planning and Operating Ground Rules and other policies. • Timber salvage cutting should occur wherever possible. • Alberta Land and Forest Service will identify forestry lands (e.g., intensive forest management, future timber development, miscellaneous timber use areas).	• Recreation activities and aesthetics must be maintained.	• Impacts on watershed must be reduced through special conditions (e.g., cutblock size and configuration). • Buffers around sinkholes may be required in sensitive areas (e.g., McClelland Lake wetlands). • Timber harvesting should occur in accordance with the "Forest Landscape Management Strategies of Alberta" guidelines.	• Where loss of the forest land base occurs, reforestation is required.	• Alberta Land and Forest Service will select and manage sites for improved wood quality and timber productivity, with considerations for watershed integrity. • On the Stoney Mountain Upland, timber harvesting must use techniques defined in the "Forest Landscape Management Strategies for Alberta" and the "Timber Harvest Cutblock Design."
Agriculture	• Agriculture activity is limited to the Fort McMurray Fringe RMA and reclaimed areas as identified in the Landscape Reclamation Strategy.	• Future market gardening on Class 3 soils only; a 100 m undisturbed buffer along river edges. • Grazing is permitted on Class 4 soils or better. • Permanent residences are not allowed on agricultural leases. • Horse-holding areas will be considered in public land areas with road access.	• Agricultural activity is not compatible with the intent of this RMA.	• Agricultural activity in this RMA will be considered on a site-specific basis.	• Agricultural activity will be considered on a site-specific basis.
Recreation and Tourism	• Private sector and non-profit organizations should take an active role in identifying and encouraging recreational activities. • Alberta Tourism and Recreation will review proposals.	• Private sector and non-profit organizations should take an active role in identifying and encouraging recreational activities. • Alberta Economic Development and Tourism and Recreation and Protected Areas will review proposals.	• Development of support services (e.g., parking) must adhere to the Settlement Guidelines. • Surface access will not be permitted within 200 m of the river shoreline or lands identified for the proposed provincial recreation area within the Fort Hills.	• Alberta Economic Development and Tourism should be included in referral systems for proposals that affect river or stream crossings, significant wildlife habitats and viewing areas of special interest.	• Potential impacts from increased access or development in the Thickwood Hills, or the Birch Mountain and Stoney Mountain Uplands were addressed in the mineral resources, forest resources, and access guidelines section above.

Activity	Broad Guidelines	Fort McMurray Fringe RMA	Athabasca-Clearwater RMA	Mildred-Kearl Lakes	Stoney-Birch
Water Resources	• Water resources will be managed on a drainage-basin basis reflecting local, regional and provincial needs. • Water quantity and quality will be managed together. • The public should participate in water management planning programs. • Consultation between provincial agencies will continue. • Development conditions may be imposed to ensure protection of the water resource. • Re-routing of rivers and streams in the planning area is discouraged. • Water quality and quantity monitoring programs should be maintained. • The domestic water supply of Fort McMurray, Fort McKay and other settlements will be recognized.	• Where there is a risk of flooding, operating guidelines must be adhered to. • Buffers may be established in proximity to Fort McMurray and along river floodplains.	• The domestic water supply must be recognized in any planning scenario.	• Guidelines were not defined in the IRP.	• Special protective measures to preserve water quality in Surmount Creek (the primary source for Gregoire Lake) must occur for activities located in the creek's watershed.

Activity	Broad Guidelines	Fort McMurray Fringe RMA	Athabasca-Clearwater RMA	Mildred-Kearl Lakes	Stoney-Birch
Access and Infrastructure	• Linear developments will be encouraged to use existing or planned access routes or corridors. • Where possible, linear development will not occur parallel to rivers within valleys or within 100 m of the top of valley breaks. • Public access to recreation opportunities is a priority. • Off-highway vehicle use will be restricted in areas of industrial activity, reclamation sites, and environmentally sensitive areas.	• Guidelines were not defined in the IRP.	• River crossings must be constructed so as to meet all objectives in the IRP. • Riverbank disturbances must be mitigated. • Linear developments crossing the McClelland Lake wetlands should use the existing corridor. • New roads should be developed with recreation and tourism values in mind. • Resource development facilities should be screened from the river.	• Proponents of oil sands developments on the east side of the Athabasca River should use the Athabasca Oil Sands Multiple Use Corridor, proposed by AEP. • Surface access leading to disposition in areas designated as provincial recreational areas (e.g., Fort Hills) must maintain recreational potential.	• Access to recreational activities should be maintained. • In the Thickwood Hills, Birch Mountain or Stoney Mountain Uplands, route selections must avoid or minimize impacts on wildland recreational resources.
Fisheries	• The limited fisheries resource will be allocated to meet the demand of high priority user groups. • Fisheries habitat protection guidelines shall be applied to local plans and developments. • Fisheries production will continue to rely on naturally reproducing populations. • Stream and lake fisheries will be managed to maintain naturally reproducing fish populations. • Unrestricted legal public access to waterbodies containing fishery resources will be maintained.	• Guidelines were not defined in the IRP.	• Emphasis on site selection and erosion control measures should be made to maintain riparian habitats and shoreline vegetation, to protect water quality, and to protect fish-spawning and fish-rearing habitat.	• Guidelines were not defined in the IRP.	• Guidelines were not defined in the IRP.

Activity	Broad Guidelines	Fort McMurray Fringe RMA	Athabasca-Clearwater RMA	Mildred-Kearl Lakes	Stoney-Birch
Wildlife	• Hunting is managed under existing guidelines to achieve equitable use among subsistence users, recreational users and commercial users. • Wildlife habitat protection guidelines will be applied. In important wildlife areas, techniques to minimize habitat loss, wildlife disruption and lost recreational/commercial opportunities will be used. • Conflicts between trappers and other users will be reduced through consultation with trapping area holders. • Priority is management of the habitats and populations of rare and endangered species. • In important wildlife areas and for wildlife management purposes, techniques may be applied in situations of new industrial access. • Wildlife-viewing opportunities will be encouraged.	• Guidelines were not defined in the IRP.	• Developments will not be permitted in significant waterfowl nesting habitat (e.g., Horseshoe Lake, Saline Lake, McClelland Lake and Little McClelland Lake). • Critical habitat for moose must be maintained, especially in river valleys (e.g., Clearwater, Hangingstone, Lower Muskeg, Lower Steepbank and Athabasca).	• Where development activities affect moose habitat, off-site enhancement or special protective measures may be required. • For lakes (e.g., Kearl, Calumet), backshore buffers should be maintained to protect waterfowl nesting and staging and fish spawning sites.	• Developments are not allowed adjacent to Anzac Lake, which provides important waterfowl habitat. • Special protective measures (e.g., timing constraints) are required to maintain moose populations and moose habitat in the Christina and Clearwater rivers, lands between the Horse and Athabasca rivers, and various other locations.

Activity	Broad Guidelines	Fort McMurray Fringe RMA	Athabasca-Clearwater RMA	Mildred-Kearl Lakes	Stoney-Birch
Ecological Resources	• Ecological resources will be identified by government agencies and individual groups. Public land reservations will be established and maintained.	• Guidelines were not defined in the IRP.	• Development activity must not disturb the La Saline Natural Area. • Adverse impacts must be mitigated within significant areas (e.g., Athabasca River Tar Sands Reach, McClelland Lake Patterned Fen, Eymundson Sinkholes on Pierre River, Ells River, Firebag River and Clearwater River).	• Activity adjacent to the La Saline Natural Area must not disturb or adversely affect this resource.	• Guidelines were not defined in the IRP.
Historical Resources	• Before development, a Historical Resources Impact Assessment should be conducted.	• Guidelines were not defined in the IRP.	• Activity must not disturb the Beaver River Quarry Archeological Site or the Bitumount Historic Site.	• Before development, a Historical Resources Impact Assessment should be conducted.	• Guidelines were not defined in the IRP.

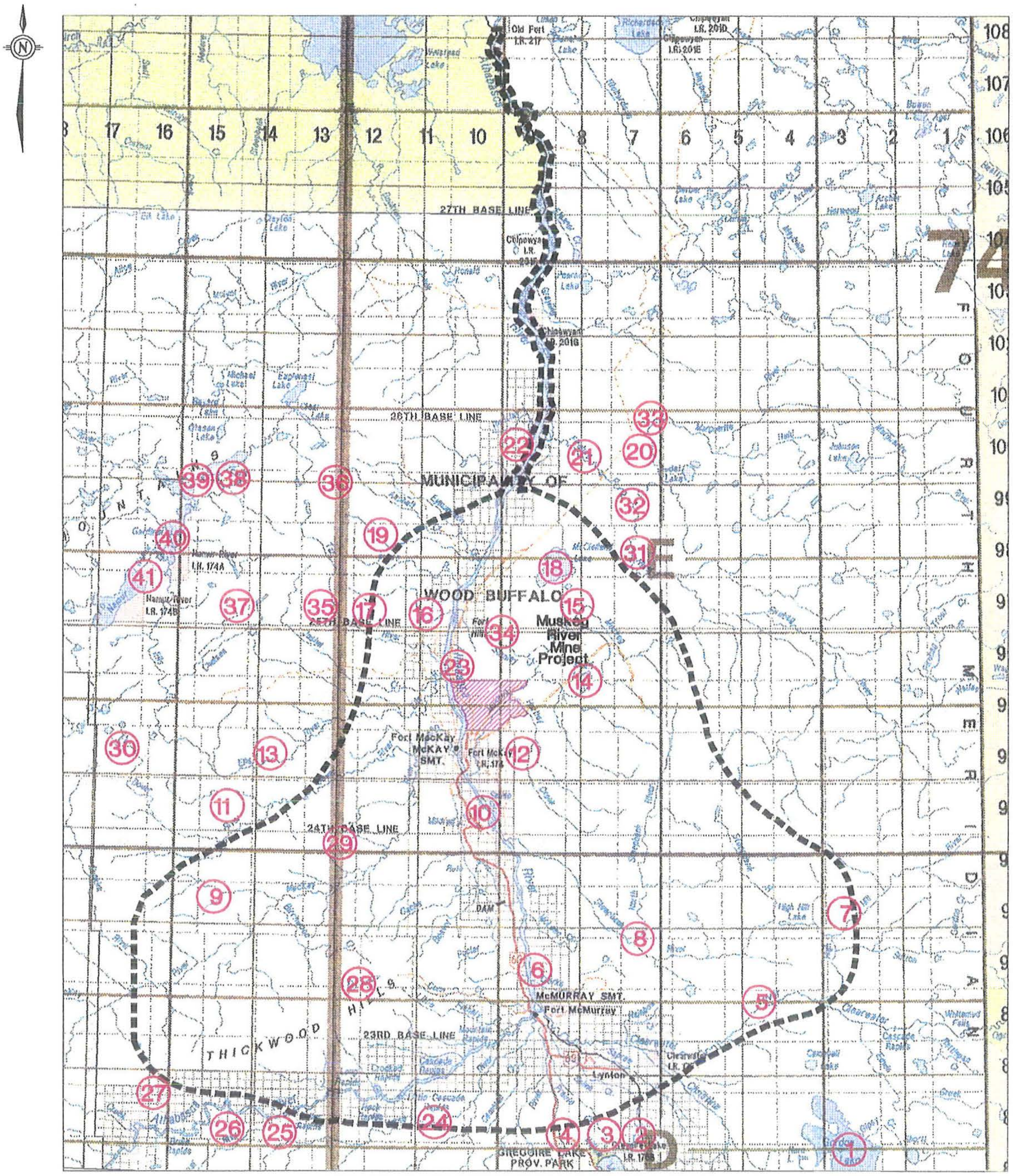
D14.2.2 Environmentally Significant Areas

Environmentally significant areas (ESAs) are areas that contain unique or representative landforms, rare or endangered vegetation, or significant or important wildlife habitat. Often ESAs contribute to biodiversity because they represent a unique combination of landscape features, vegetation communities, habitats (i.e., forest types), species populations and genetic resources that are otherwise uncommon in the region. Provincial legislation has been adopted to provide protection for many wilderness areas, ecological reserves, natural areas or other ESAs. *The Wilderness Areas, Ecological Reserves and Natural Areas Act* (1984) is one of the tools used in the conservation of ESAs. As well, the Fort McMurray-Athabasca Oil Sands Subregional Integrated Resource Management Plan (AEP 1996a) addresses the importance of protecting ESAs.

Several sensitive areas have been identified within the LSA and RSA (see Table D14-3 and Figures D14-3 and D14-4). These areas include special features that have been nominated either by the public or the Alberta government as areas in need of protection. The list includes ESAs, areas nominated for Special Places 2000 status, key wildlife areas, areas identified in the Fort McMurray Subregional Integrated Resource Plan (AEP 1996a), as well as other sensitive areas.

The LSA contains three regionally significant ESAs: the Muskeg River, Kearl Lake and East Jackpine (Hartley) Creek. The Muskeg River is an important sport fishery and provides habitat to 21 species (BOVAR 1996f). Kearl Lake is an important lake hydrologically. It also provides important waterfowl staging habitat and moose habitat. The lake is also an important wildlife movement corridor for a variety of wildlife species. East Jackpine Creek is a hydrologically important creek that provides important habitat for sport fish. The area also provides habitat for river otters.

There are several areas of particular importance within the RSA, including natural area and diversity areas and ESAs (Westworth 1990). Natural areas and diversity areas include the Horse River Diversity Area, the La Saline Natural Area and Schultz's Bog. The Horse River Diversity Area is 170 km^2 regionally significant area. This area has dune fields, high vegetation and landform diversity, as well as important concentrations of Canadian lynx. The La Saline Natural Area is provincially significant. This 290 ha area is situated on a terrace that feeds Saline Lake (an old oxbow of the Athabasca River. Saline Lake is the most productive area in the region for waterfowl (AEP 1996a). As well, its unique features include numerous mineral deposits, crystal formations and an extensive tufa cone (calcium porous rock). The area is significant for its saline spring features and rare vegetation, and wildlife are attracted to the springs as a source of salt. The Schultz's Bog Diversity Area is 58,000 ha in size and is considered provincially significant. This significant palsa bog and



LEGEND

1 GORDON LAKE
2 SAPRAE CREEK
3 SALINE CREEK
4 HANGINGSTONE RIVER
5 CLEARWATER RIVER
6 CLARKE CREEK
7 HIGH HILL RIVER
8 STEEPBANK RIVER
9 MacKAY RIVER
10 HORSESHOE LAKE
11 DOVER RIVER
12 JACKPINE (HARTLEY) CREEK
13 ELLS RIVER
14 KEARL LAKE
15 MUSKEG RIVER
16 TAR RIVER
17 CALUMET RIVER
18 McCLELLAND LAKE
19 PIERRE RIVER
20 MARGUERITE RIVER
21 FIREBAG RIVER
22 ATHABASCA RIVER – TAR SANDS REACH
23 LONG LAKE
24 HORSE RIVER
25 HORSE RIVER DIVERSITY AREA
26 ATHABASCA RIVER – RAPIDS REACH
27 SCHULTZ'S BOG DIVERSITY AREA
28 THICKWOOD HILLS
29 DOVER – McKAY MOOSE AREA
30 CLEARWATER LAKE DIVERSITY
31 KEARL LAKE MOOSE AREA
32 FIREBAG RIVER
33 FIREBAG MARTEN AREA
34 FORT HILLS
35 CALUMET PLAINS
36 BIRCH MOUNTAIN CARIBOU AREA
37 BIRCH MOUNTAIN ESCARPMENT
38 SAND LAKE
39 BIG ISLAND LAKE
40 GARDINER LAKES
41 NAMUR LAKE

REFERENCE

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

0 10 20 30 40 50km

SCALE 1:1,250,000 (Approx.)

Golder Associates

SHELL CANADA LIMITED

SIGNIFICANT NATURAL FEATURES FOR THE RSA

03 DEC 97	Figure D14–3	DRAWN BY: RFM

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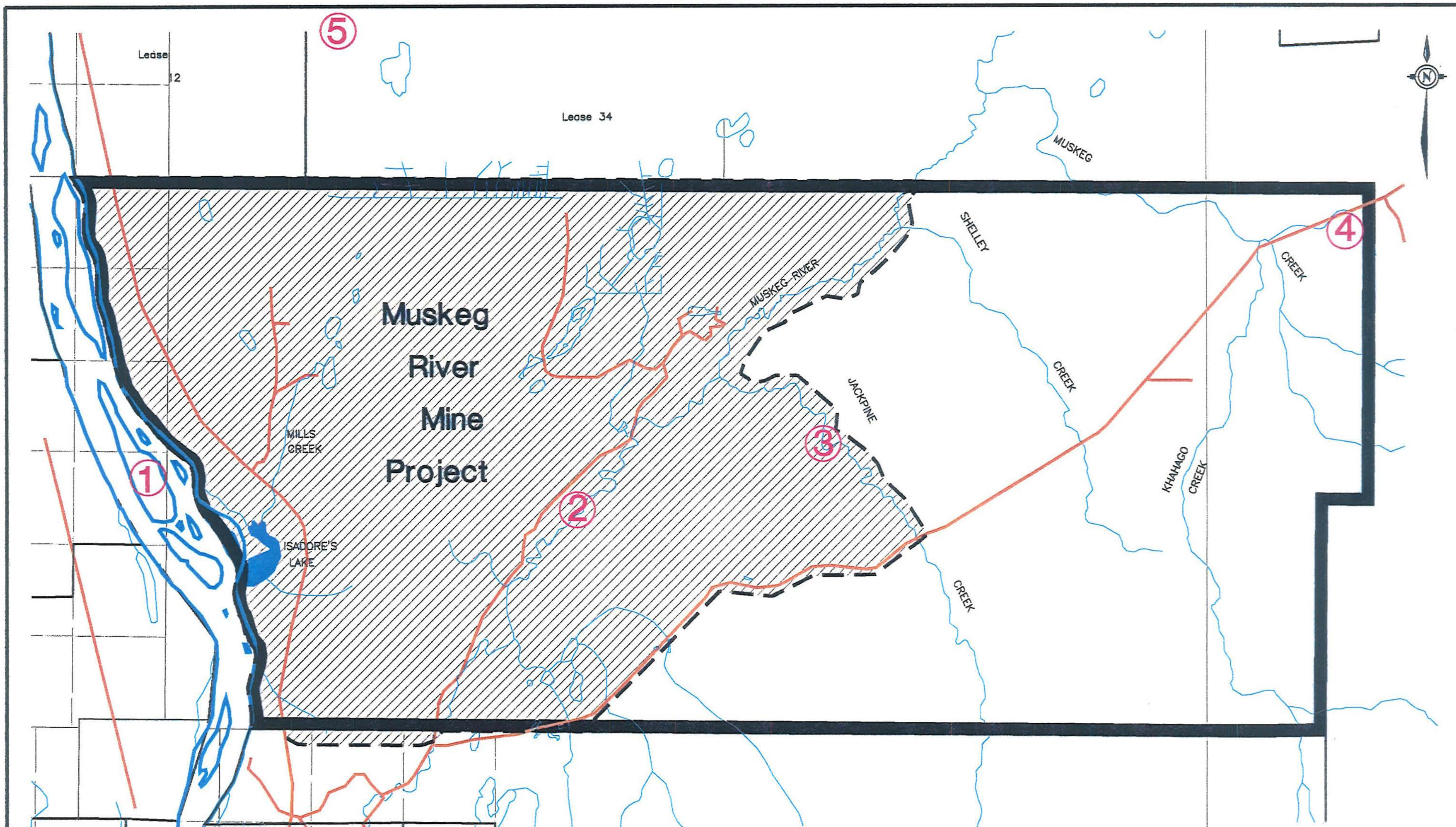


D14 - 15

LEGEND

1 ATHABASCA RIVER
2 MUSKEG RIVER
3 JACKPINE (HARTLEY) CREEK
4 KEARL LAKE MOOSE AREA
5 FORT HILLS

0 1 2 3 4 5km

SCALE 1:100,000

REFERENCE

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

Golder Associates

SHELL CANADA LIMITED

SIGNIFICANT NATURAL FEATURES FOR THE LSA

01 DEC 1997	Figure D14–4	DRAWN BY: CG

patterned fen is in a biologically diverse region. With high landform diversity, the area provides important caribou and Canada lynx habitat.

The RSA contains the following ESAs (Westworth 1990):

- Athabasca River Tar Sands Reach (nationally significant);
- Clearwater River (provincially significant);
- McClelland Lake Patterned Fens (provincially significant);
- McClelland Lake (regionally significant); and
- the Fort Hills (regionally significant).

The Athabasca River Tar Sands Reach is a hydrologically important river area with a wide, U-shaped river valley. A diversity of resources is found within the area, including wildlife (e.g., important moose habitat), aesthetics, water, important sport fishery, old-growth forest and traditional uses. Various landform features are also found, including floodplains, point bars, sand and gravel bars, and bitumen outcrops. The reach has been nominated for Special Places 2000 Status (key environmental protection area) (BOVAR 1996f).

The Clearwater River is an important sport fishery. Several rare vegetation species are found there, and the area supports high landform diversity within a U-shaped river valley. The Clearwater River is important moose habitat. As well, the river has been nominated as a candidate Heritage River (BOVAR 1996f).

Significant plant species, including rare vegetation are found within the McClelland Lake Patterned Fens. McClelland Lake is important hydrologically. It also provides important waterfowl staging habitat. Important bald eagle nesting sites and several rare vegetation species are found there. Both McClelland Lake Patterned Fens and McClelland Lake have been nominated for Special Places 2000 Status (BOVAR 1996f).

The Fort Hills is a "dissected kame" glacial landform, which means that it is a mound-shaped hill or ridge cut into two or more pieces. The Fort Hills supports high landform and bird diversity. As well, the area provides important habitat for moose and Canada lynx. These hills have also been nominated for Special Places 2000 Status (BOVAR 1996f).

Table D14-3 Significant Natural Features Within the RSA

Site Name	Significance Level	Significant Natural Features	Location
Athabasca River Tar Sands Reach	National	Important sport fishery Hydrologically important river Important moose habitat Various landform features including floodplains, point bars, sand and gravel bars, and bitumen outcrops Special Places 2000 nominee	95-11 W4M
Birch Mountain Caribou Area	Regional	Important caribou habitat Important furbearer habitat	97-12 W4M
Broken Springs	Regional	Significant spring features Wildlife mineral lick	89-05 W4M
Calumet OGF	Regional	Old-growth forest	97-10 W4M
Calumet Plains	Regional	Important moose habitat High landform diversity High vegetation diversity	98-11 W4M
Calumet River	Regional	Hydrologically important lake Important otter habitat Wildlife movement corridor	97-11 W4M
Clarke Creek	Regional	Important sport fish area Hydrologically important creek	90-08 W4M
Clearwater River	Provincial	Important sport fishery Important moose habitat High landform diversity Rare vegetation species Special Places 2000 nominee Heritage River candidate	89-05 W4M
Clearwater Springs	Provincial	Rare vegetation species Significant spring features	88-06 W4M
Cree Burn Lake Prehistoric Region	Regional	Historic site nomination	94-09 W4M
Dover-McKay Moose Area	Regional	Important moose habitat	93-13 W4M
Dover River	Regional	Important sport fishery High vegetation diversity Hydrologically important river	94-12 W4M
Dunkirk River	Regional	Important sport fishery area Hydrologically important river Wildlife movement corridor	90-17 W4M

Site Name	Significance Level	Significant Natural Features	Location
East Jackpine Creek (Hartley)	Regional	Important otter habitat Important sport fishery Hydrologically important creek	94-09 W4M
Ells River	Provincial	Important sport fishery Excellent example of oxbows High vegetation diversity	95-12 W4M
Ells River Old-Growth Forest	Regional	Old-growth forest	96-11 W4M
Eymundson Sinkholes	Provincial	Significant sinkhole features	98-10 W4M
Fort Hills	Regional	Dissected glacial kame landform High landform diversity Important moose and Canada lynx habitat High bird diversity Special Places 2000 nominee	97-9 W4M
Hangingstone River	Regional	Important sport fishery Wildlife movement corridor Hydrologically important river	88-09 W4M
High Hill River	Provincial	Important sport fishery Wildlife movement corridor Hydrologically important river	91-03 W4M
Horse River	Regional	Important sport fishery Important moose habitat Significant meander reach	89-09 W4M

Site Name	Significance Level	Significant Natural Features	Location
Horse River Diversity Area	Regional	Significant dune fields High vegetation diversity High landform diversity Important Canada lynx habitat	88-14 W4M
Horseshoe Lake	Regional	Important waterfowl area Significant plant species Hydrologically important lake	93-10 W4M
Joslyn Creek Old-Growth Forest	Regional	Old-growth forest	96-11 W4M
Kearl Lake	Regional	Important waterfowl staging area Rare vegetation species Hydrologically important lake Important wildlife movement corridor	96-08 W4M

		Important moose habitat	
Kearl Lake Moose Area	Regional	Important moose habitat Wildlife movement corridor Hydrologically important creek	96-08 W4M
La Saline Springs Natural Area	Provincial	Significant spring features Rare vegetation species Important waterfowl area Unique features including mineral deposits, crystal formations, and an extensive tufa cone Mineral lick for wildlife Special Places 2000 nominee	93-10 W4M
MacKay River	Regional	Important sport fishery Important moose habitat Significant meander reach	94-11 W4M
McClelland Lake	Regional	Hydrologically important lake Important waterfowl staging area Important bald eagle nesting area Rare vegetation species Special Places 2000 nominee	98-09 W4M
McClelland Lake Patterned Fens	Provincial	Significant patterned fen Rare vegetation species Significant plant species Special Places 2000 nominee	97-09 W4M
McClelland Lake Sinkholes	Provincial	Significant sinkhole features Hydrologically important lake	98-09 W4M
Muskeg River	Regional	Important sport fishery with 21 species	95-09 W4M
Pierre River	Regional	Wildlife movement corridor Important sport fishery area Important furbearer habitat	98-11 W4M
Saline Creek	Regional	Important sport fishery Hydrologically important creek	88-08 W4M
Schultz's Bog Diversity Area	Provincial	Important caribou and Canada lynx habitat Biologically diverse area Patterned fen Significant palsa bog High landform diversity	89-18 W4M
Steepbank River	Regional	Important sport fishery Wildlife movement corridor	91-08 W4M

		Hydrologically important river	
Tar River	Regional	Hydrologically important river Significant meander reach	96-11 W4M
Thickwood Hills	Regional	High landform diversity High vegetation diversity High wildlife diversity	90-12 W4M
Wood Slough	Regional	Important waterfowl area	92-09 W4M

Source: A. Sheehy, AEP, pers. comm., November 1997; Westworth 1990; BOVAR 1996f.

D14.2.3 Access

The principal access corridors within the LSA, as shown in Figure D1-2, are:

- the Highway 63 extension, north of the Peter Lougheed bridge on the east side of the Athabasca River, which provides access to the Barge Landing, the Alsands and Aurora Mine South access roads and Susan Lake gravel pit;
- the old Alsands access road, which continues north past the test pit through Leases 34 and 10 into the Fort Hills, and leads to Bitumount Tower, an AGT tower and a number of timber harvest cutblocks;
- the Aurora Mine South access road (Canterra Road) providing access to the Kearl Lake area; and
- trails, including cutlines, gravel roads and side roads.

D14.3 Resource Use

The LSA and RSA are located within the Green Zone and are composed primarily of public lands owned by the Government of Alberta (Alberta Agriculture, Food and Rural Development 1995). Forested lands in this area are managed mainly for forest production, watershed protection, recreation, fish and wildlife and industrial development. The RSA covers approximately 100 townships in the Regional Municipality of Wood Buffalo.

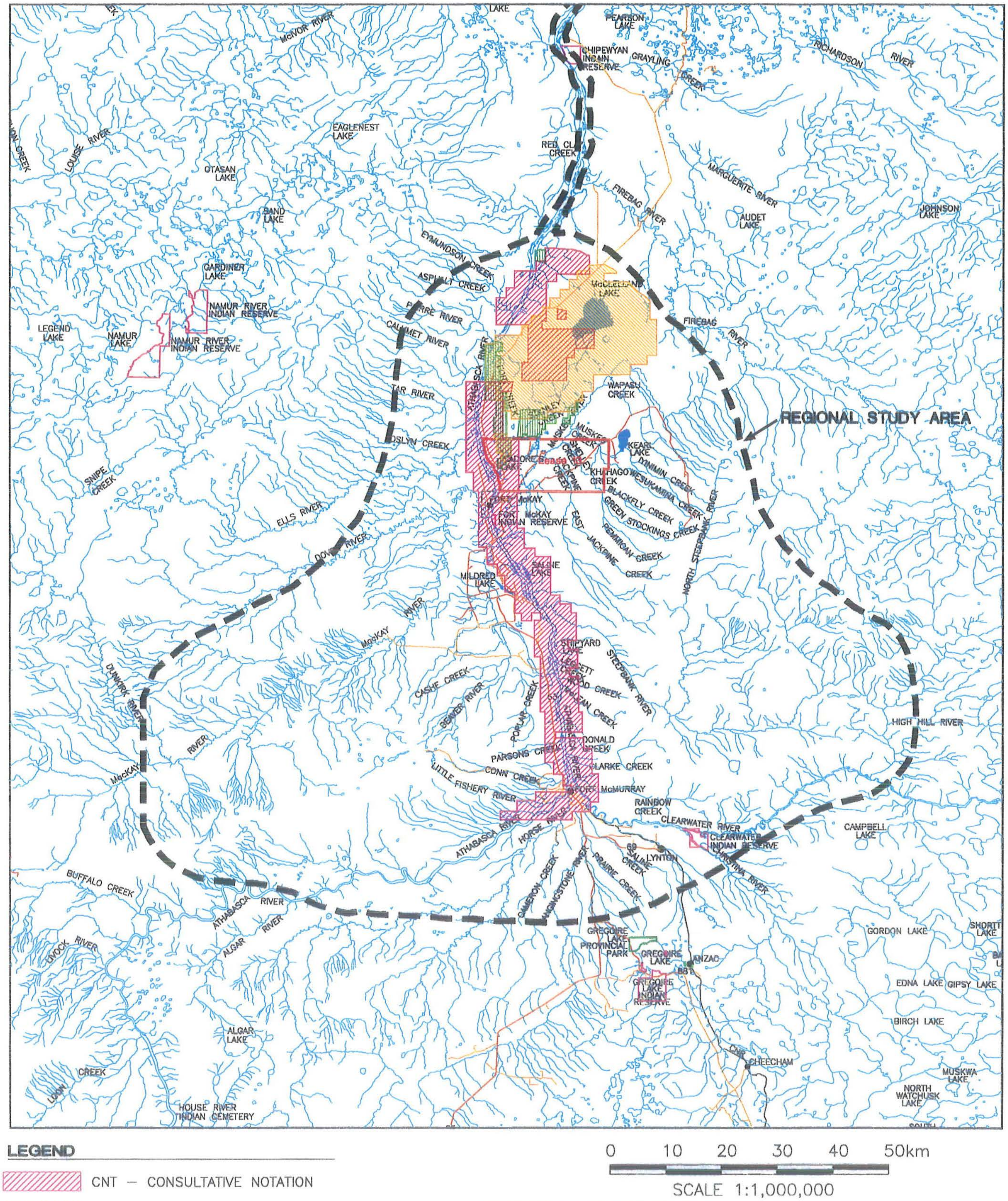
D14.3.1 Mineral and Surface Materials

Mineral and surface materials within the LSA and RSA include oil sands, petroleum and natural gas, other surface and subsurface minerals (AEP 1996a). All of these uses are compatible with the intent of the RMAs discussed above.

Non-linear surface dispositions within the RSA and LSA (as illustrated in Figures D14-5 and D14-6), include:

- Consultative Notations (CNT), which require contact with the disposition holder before conducting an activity;
- Protective Notations (PNT), which place restrictions on the types of activities that may occur; and
- Disposition Reservations (DRS), which are held by the provincial government for the protection of a facility (BOVAR 1996f).

Surface dispositions in the RSA are summarized in Table D14-4.



LEGEND

- CNT — CONSULTATIVE NOTATION
- DRS — DISPOSITION RESERVATION
- PNT — PROTECTIVE NOTATION

0 10 20 30 40 50km

SCALE 1:1,000,000

REFERENCE

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

INFORMATION FROM ALBERTA INFORMATION CENTRE, CALGARY ENERGY BRANCH (1996).

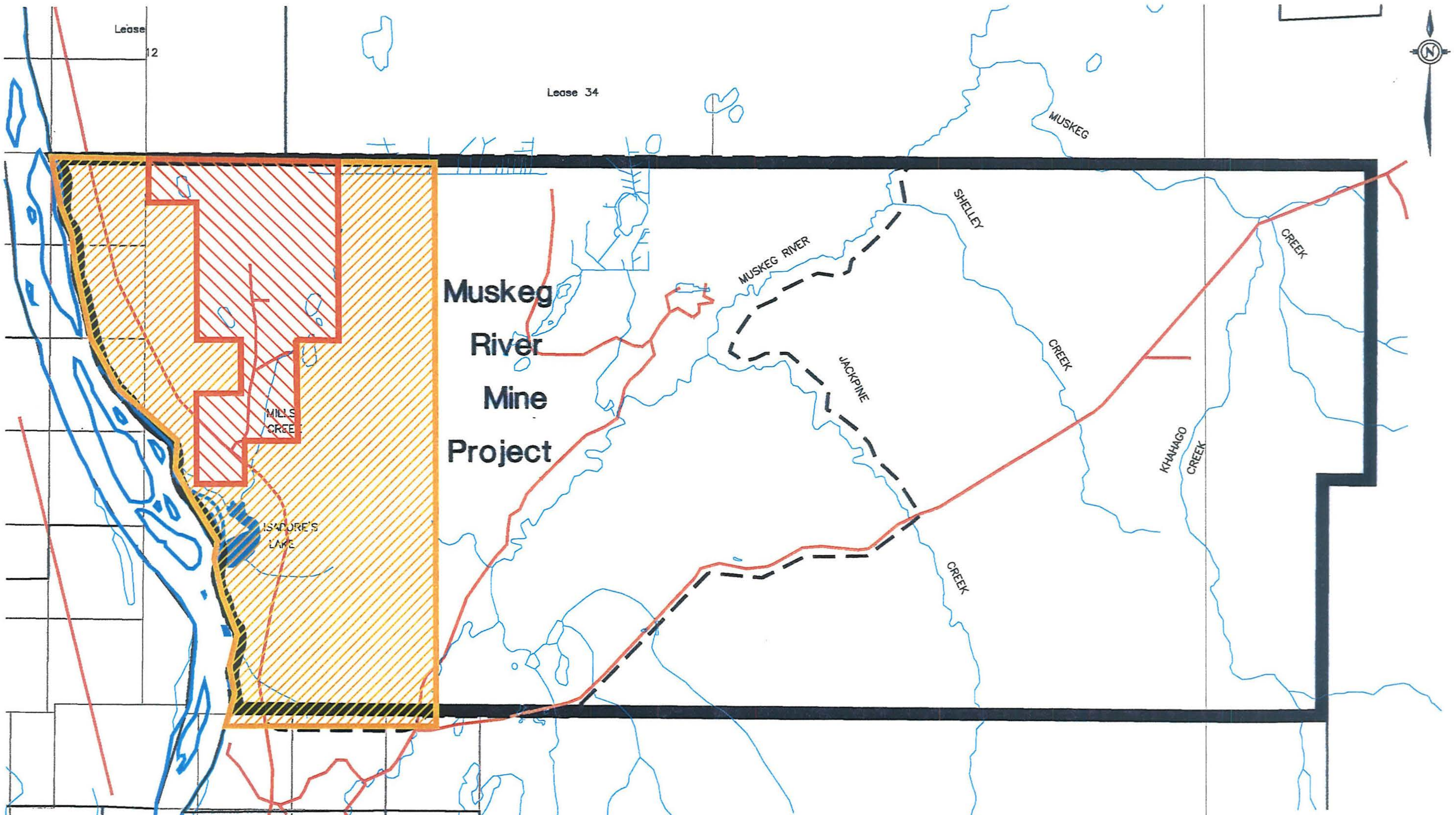
Golder Associates

SHELL CANADA LIMITED

SURFACE DEPOSITIONS IN THE RSA

03 DEC 97	Figure D14–5	DRAWN BY: RFM

J:\1997\223_\760\SURFLSA.dwg



LEGEND

- LOCAL STUDY AREA
- CNT – 96007100
  CNT – 96011000
- PNT – 87032600

0 1 2 3 4 5km

SCALE 1:100,000

REFERENCE

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

Golder Associates

SHELL CANADA LIMITED

SURFACE DISPOSITIONS IN THE LSA

01 DEC 1997	Figure D14–6	DRAWN BY: CG

Table D14-4 Summary of Surface Dispositions Within the RSA

Surface Disposition	Area	Comments
CNT - 78007100	259 ha	Surface material exploration
CNT - 96007100	50,900 ha	Nominee for Special Places 2000; Fort Hills-McClelland Lake
CNT - 96011000	81,770 ha	Nominee for Special Places 2000; Athabasca River Valley
DRS - 1043000	0.1 ha	Air quality monitoring and meteorological networks
DRS - 154200	2.3 ha	Bitumount Tower
DRS - 78011000	49 ha	Surface material removal
DRS - 84019000	0.9 ha	Ground water observation well
DRS - 84019200	0.2 ha	Ground water observation well
DRS - 88017100	4.9 ha	Research or sample plot
DRS - 900005100	1,117 ha	Surface material removal; "Susan Lake Pit"
PNT - 87032600	7,846 ha	Surface material removal; Gravel deposits ("Susan Lake" and "Bitumount)
PNT - 90016900	4 ha	Long term reforestation project

Source: BOVAR (1996b)

Alberta Environmental Protection and Alberta Agriculture, Food and Rural Development (AFRD) administer and manage sand and gravel resources on public land (AEP, Alberta Land and Forest Services and AFRD n.d.). Gravel is relatively scarce in the IRP area and the RSA (AEP 1996a). Deposits of gravel in the LSA are illustrated in Figure D14-6 (e.g., PNT-87032600). The IRP guidelines for management of aggregate resources in the Mildred-Kearl Lakes and Athabasca-Clearwater RMA, state that all aggregate resources discovered during exploration or development activities, but which not used during mineral development, should be stockpiled (AEP 1996a).

The main mineral extraction operations currently within the RSA include:

- Syncrude Mildred Lake and Aurora Mine (oil sands mining, extraction and upgrading);
- Suncor Lease 86, Steepbank Mine (oil sands mining, extraction and upgrading);
- SOLV-EX Lease 5 oil sands mining and bitumen and mineral extraction (operations currently suspended);
- SOLV-EX Ruth Lake oil sands tailings mineral extraction (operations currently suspended);
- Gibsons Petroleum Underground Test Facility in-situ bitumen extractions; and
- peat mining south of Fort McMurray.

D14.3.2 Agriculture

Agriculture in the LSA and RSA is limited, due to unfavourable climate in the region and generally low-quality soils (BOVAR 1996f). There are some small-scale market gardening ventures in the Clearwater River valley, located in the Fort McMurray Fringe RMA. There is little demand for cattle grazing, although some reclaimed habitat is used for bison ranching in the Syncrude Mildred Lake areas. There are small horse-holding (grazing) areas, averaging 5 ha in size in the vicinity of the Thickwood Tower and the Clearwater Lighthorse and Rodeo areas. Reclamation strategies in the IRP include other potential agricultural activities (e.g., livestock grazing, wild rice and berry production).

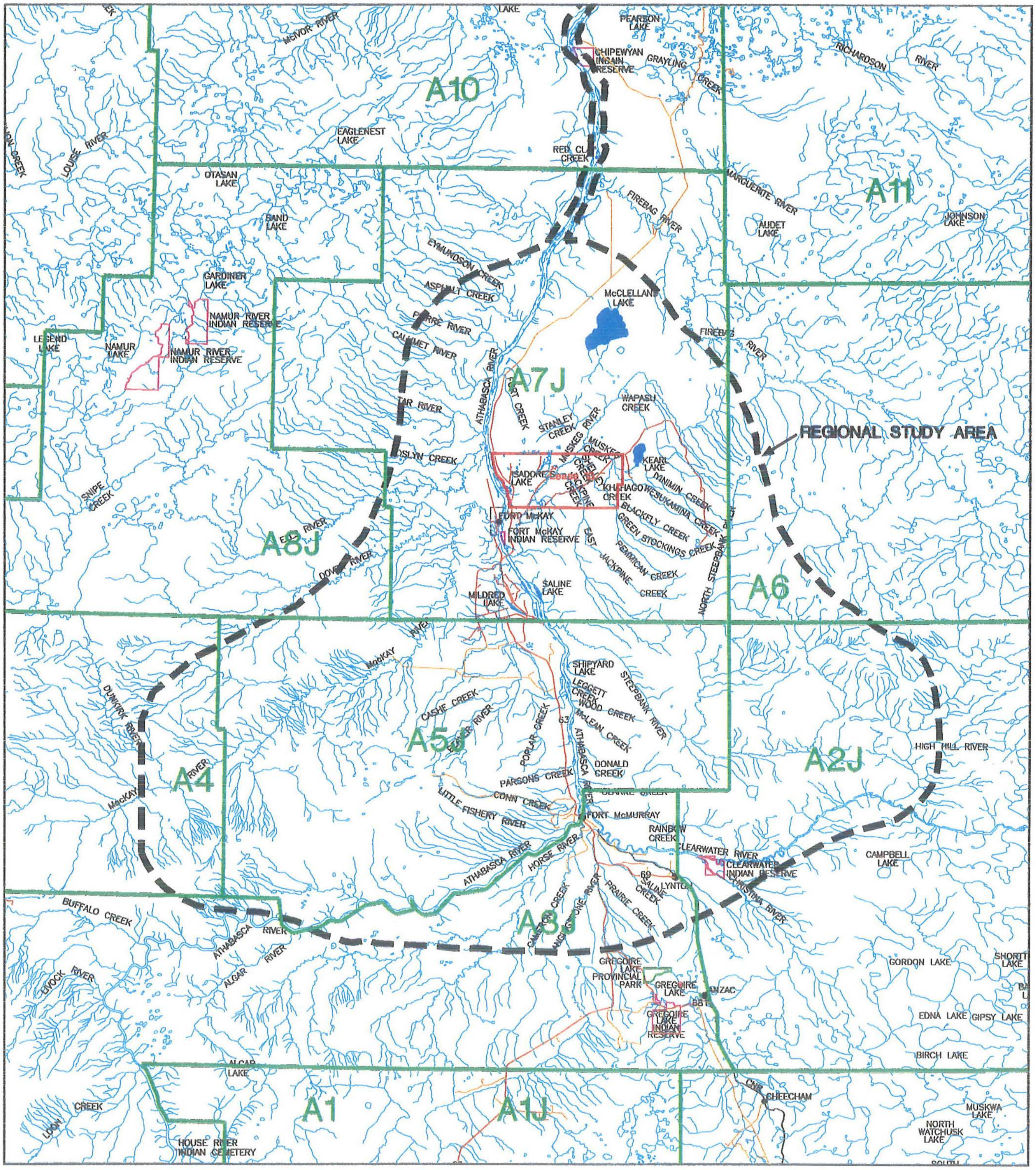
D14.3.3 Forestry

The Muskeg River Mine Project LSA occurs on Crown land within Forestry Management Unit A7 (Figure D14-7) of the Athabasca Forest. The RSA covers portions of the A2, A3, A4, A5, A6, A7 and A8 FMUs (Figure D14-7). Timber rights have been granted to Alberta-Pacific Industries Inc. (ALPAC) under a Forest Management Agreement. Additionally, a timber quota disposition has been granted to Northlands Products Ltd.

ALPAC (1997) developed a forest management plan for the purpose of identifying sustainable allowable cut and projected timber harvesting levels. This plan also includes projected harvest levels by Northlands Forest Products Ltd. The projected timber harvesting yields are presented in Table D14-5. ALPAC's harvest projections indicated that by 2016, 6,957 ha of deciduous and 5,534 ha of coniferous timber will be harvested.

Table D14-5 Twenty Year Harvest Schedule for Deciduous and Coniferous Timber in RSA Forest Management Units (1,000 m^3/5 year period)

5 Year Harvest Period	Deciduous (ha)	Coniferous (ha)
1996-2001	355	1,218
2001-2006	1,620	1,260
2006-2011	4,949	1,730
2011-2016	33	1,326
ALL YEARS	6,957	5,534



LEGEND

FOREST MANAGEMENT UNIT BOUNDARY

0 10 20 30 40 50km

SCALE 1:1,000,000

REFERENCE

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

INFORMATION PROVIDED BY D.A. WESTWORTH
AND ASSOCIATES LTD.

Golder Associates

SHELL CANADA LIMITED

FOREST MANAGEMENT UNIT BOUNDARY

03 DEC 97	Figure D14-7	DRAWN BY: RFM

In addition, ALPAC (1997) calculated the total coniferous and deciduous merchantable timber within their Forest Management Agreement (FMA). The coniferous volume of timber within the FMA is 154,145,000 m^3/ha and the deciduous volume is 243,228,000 m^3/ha. In the LSA, forest productivity for both deciduous and coniferous timber is highly variable. Productive stands in the LSA comprise only 35% of the LSA. Detailed information on Forestry Resources is provided in the Baseline Forestry Report.

When Alberta-Pacific harvests timber east of the Athabasca River in the vicinity of the LSA, logs are hauled along Highway 963, the Highway 963 extension and the Peter Lougheed Bridge. Northlands Forest Products uses the Highway 963 extension during the winter as a truck haul route for timber harvested on both sides of the Athabasca River, as well as the old Alsands and Aurora Mine South access roads, to access harvest in the Fort Hills and Muskeg Mountain areas.

Old-growth is defined as those forested areas where the annual growth equals annual losses. There is 19,831 ha of old-growth forest in the RSA (AEP 1996a), comprised primarily of white spruce and aspen forest communities (8,754 ha) and aspen communities (5,385 ha) as detailed in Table D14-6. The LSA only supports one stand, jack pine-dominant, that is classified as old-growth (<1%).

Table D14-6 Old-Growth Forest for the Regional Study Area[a]

Dominant Overstory Tree Species	Area (ha)
White spruce	280
White spruce/aspen	8,754
Jack pine/white spruce	526
Jack pine/aspen/white spruce	751
Jack pine/aspen	769
Jack pine/black spruce	294
Jack pine	2,724
Aspen	5,385
Aspen/white spruce/black spruce	145
Aspen/black spruce	192
Aspen/jack pine/black spruce	11
TOTAL	19,831

(a) Old growth minimum ages:
Aspen 100 years
White Spruce 160 years
Jack Pine 120 years

In 1996 BOVAR Environmental distributed a resource use questionnaire (RUQ) to local residents. The results of the RUQ indicated that apart from large-scale commercial forestry, only 29% of the respondents harvested trees in the area. The primary resource uses of the timber were for firewood, construction material (e.g., log cabins), and small-scale timber harvest and sales (BOVAR 1996f).

D14.3.4 Berry Harvesting

From their telephone survey, BOVAR (1996f) were able to report on plant-gathering activities in the RSA. They found that wild berries were harvested to some degree by approximately 80% of the respondents. Blueberries were the most commonly harvested. Other berries in the order of preference were cranberries, raspberries, saskatoons, chokecherries, rosehips and strawberries. One respondent also picked mushrooms. Locations at which berries were picked included: the Clearwater River valley, Thickwood Hills, Peter Lougheed Bridge, Highway 963 to the OSLO site, Kearl Lake, MacKay River, Mildred Lake, Muskeg River and east of the Athabasca River.

D14.3.5 Hunting

Big game animals with open seasons in the boreal region include white-tailed deer, mule deer, moose, black bears, wolves and coyotes (AEP 1997d, Smith 1993). Important upland game birds with open seasons in the boreal region include ruffed grouse, spruce grouse, sharp-tailed grouse and ptarmigan (AEP 1997d; Semenchuk 1992). Important waterfowl species include mallards, northern pintails, northern shovelers, blue-winged teals, green-winged teals, scaups, redheads and canvasbacks. White-fronted geese, Canada geese, snow geese and Ross' geese may also be hunted (AEP 1997d).

In the RSA, hunting is regulated within Wildlife Management Units (WMUs) 518, 519, 529, 530 and 531 (Figure D14-8; AEP 1997c). Before 1993, WMU 518 and 531 were a single unit. The LSA is located in WMU 530 and 531 (AEP 1997c). Information on the harvest and hunting efforts by big game hunters in Alberta for the 1990 to 1995 hunting seasons for WMUs 518 and 530 (encompasses the LSA) is summarized in Table D14-7. More recent data for harvest and effort by big game hunters were not available (Sylvia Birkholz, Alberta Fish and Wildlife, pers. comm., November 1997). These values do not include hunting activities by aboriginal hunters.

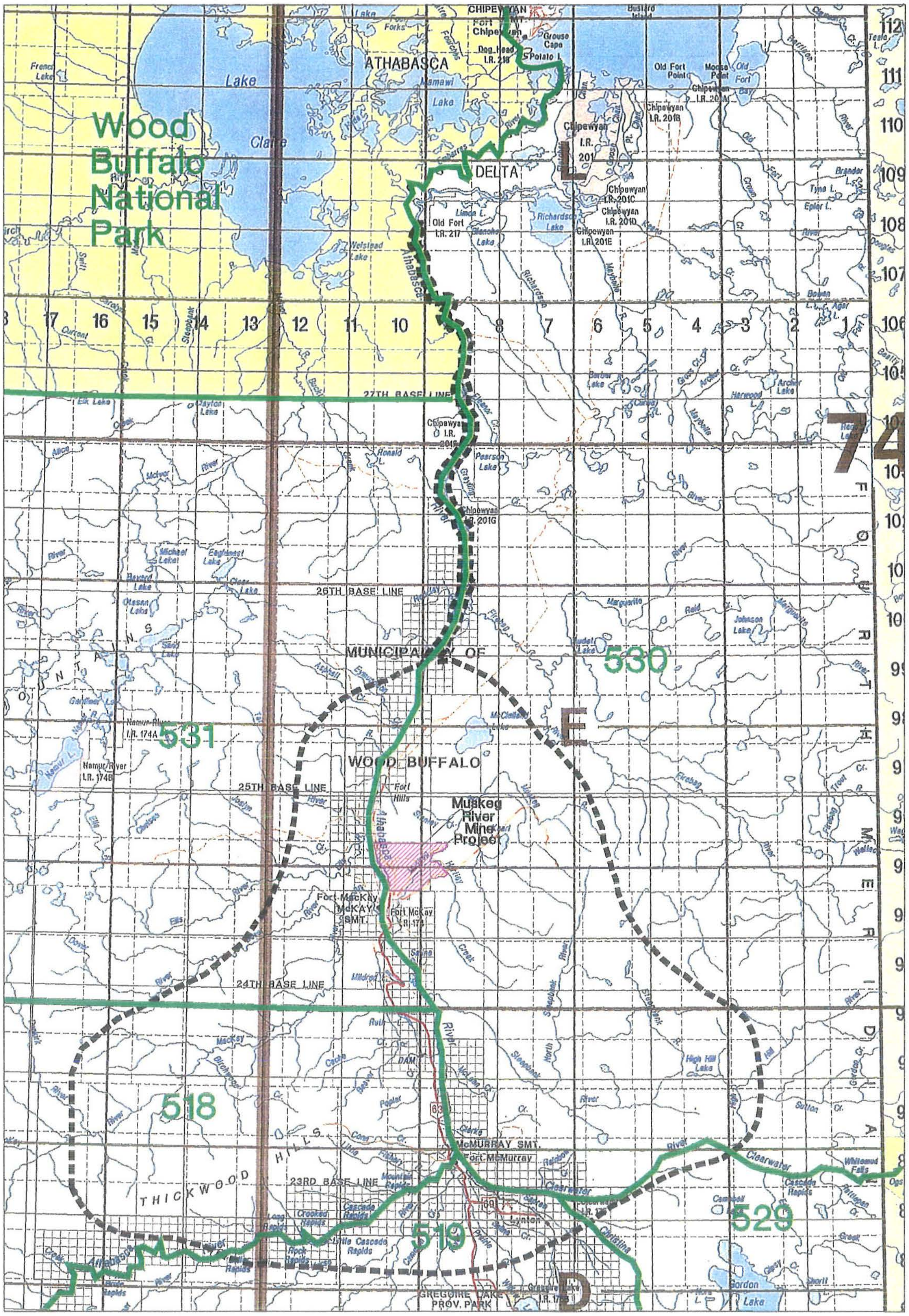
In general, hunting is not permitted in wildlife sanctuaries, natural areas, ecological reserves, provincial parks or national parks. Gamebird hunting is not permitted at Richardson Lake in WMU 530 (AEP 1997d).

A telephone survey conducted by BOVAR (1996f) indicated that approximately 70% of their respondents hunted. The most common purpose for hunting was to gather food. Other reasons cited for hunting were enjoyment, occupational reasons (e.g., professional guide/outfitting services) and as a source of food for dog teams. Most respondents preferred to hunt moose and deer. Other common game species included ruffed grouse, black bear, ducks, partridge, geese, spruce grouse and ptarmigan. Non-residents and foreign hunters prefer hunting for bear and moose over other game species (BOVAR 1996f).

According to the telephone survey, hunters spent an average of 14 days hunting per year, with a range of 4 to 30 days per year (BOVAR 1996f). The respondents all hunted with partners and most camped in the area in which they hunted. Hunting locations included: the Clearwater River valley, Athabasca River valley, Bitumount Tower, Kearl Lake, MacKay River, Highway 963 Extension, Alsands lease area and the Peter Lougheed Bridge area.

D14.3.6 Trapping

Furbearers in the region include wolf, fox, coyote, lynx, wolverine, fisher, marten, weasel, mink, otter, beaver, muskrat, squirrel and snowshoe hare (Fort McKay First Nations 1994). Beaver and muskrat are regarded as staple in the diets of trappers. Snowshoe hare is used year-round for food and seasonally for fur. The Registered Fur Management Areas (RFMAs) for the LSA and RSA are shown in Figure D14-9. According to AEP (P. Jansen, Commercial Licensing Administrator, AEP, pers. comm., July 1997), there are five traplines in the LSA. These are RFMA 1650, 1714, 2006, 2172 and 2718. Species trapped along these traplines from 1984 to 1996 are listed in Tables D14-8 to D14-12. An average annual fur harvest for each of the five traplines is presented in Table D14-13.



LEGEND

BOUNDARY BETWEEN WMUs

REFERENCE

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

0 10 20 30 40 50km

SCALE 1:1,250,000 (Approx.)

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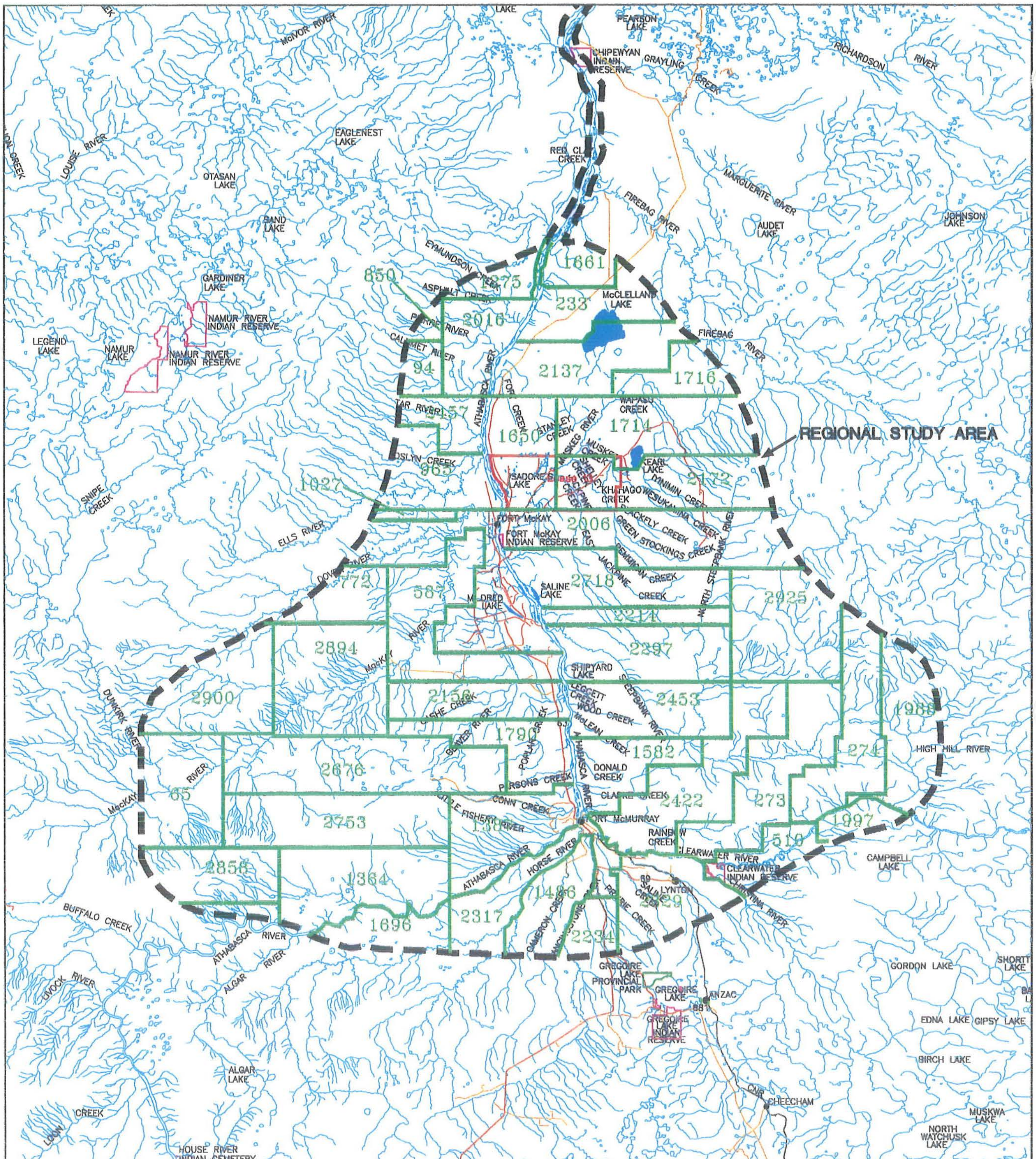
WILDLIFE MANAGEMENT UNITS (WMUs) FOR THE RSA

01 DEC 1997	Figure D14-8	DRAWN BY: CG

Table D14-7 Big Game Harvest for Wildlife Management Units 518 and 530

Species	Year	WMU	Animals Harvested		Number of Hunter Days	
			Estimated Number	Percentage of Provincial Harvest	Estimated Number	Percentage of Provincial Total
Moose	1990	WMU-518	355	3.0	12,495	3.8
		WMU-530	47	0.4	1,326	0.4
	1991	WMU-518	291	2.8	14,682	5.6
		WMU-530	66	0.6	2,721	1.0
	1992	WMU-518	279	3.3	11,383	5.0
		WMU-530	42	0.5	1,285	0.6
	1993	WMU 518	65	0.01	1,132	0.01
		WMU 530	53	0.01	937	0.01
		WMU 531	40	0.00	474	0.00
	1994	WMU 518	58	0.01	1,414	0.01
		WMU 530	33	0.01	569	0.00
		WMU 531	33	0.01	546	0.00
	1995	WMU 518	36	0.01	1,177	0.01
		WMU 530	61	0.02	1,324	0.02
		WMU 531	27	0.00	598	0.00
	Average	**WMU 518 (531)**	**197**	**1.5**	**7,317**	**2.41**
		WMU 530	**50**	**0.3**	**1,360**	**0.34**
White-tailed deer	1990	WMU 518	126	0.5	8,308	1.6
		WMU 530	6	0.1	410	0.1
	1991	WMU 518	321	1.1	10,020	2.0
		WMU 530	10	0.1	806	0.2
	1992	WMU 518	144	0.6	8,374	1.8
		WMU 530	12	0.1	516	0.1
	1993	WMU 518	36	0.00	1,555	0.00
		WMU 530	12	0.00	599	0.00
		WMU 531	6	0.00	222	0.00
	1994	WMU 518	14	0.00	562	0.00
		WMU 530	9	0.00	479	0.00
		WMU 531	0	0.00	260	0.00
	1995	WMU 518	31	0.00	1,015	0.00
		WMU 530	4	0.00	854	0.00
		WMU 531	4	0.00	212	0.00
	Average	**WMU 518 (531)**	**114**	**0.37**	**5,088**	**0.90**
		WMU 530	**9**	**0.05**	**611**	**0.07**
Black Bear	1990	WMU 518	25	2.9	764	1.7
		WMU 530	9	1.0	82	0.2
	1991	WMU 518	45	4.0	1,158	3.0
		WMU 530	3	0.3	189	0.5
	1992	WMU 518	20	2.9	624	4.6
		WMU 530	27	3.9	124	0.9
	1993	WMU 518	11	0.01	11	0.00
		WMU 530	11	0.01	183	0.01
		WMU 531	0	0.00	0	0.00
	1994	WMU 518	6	0.01	33	0.00
		WMU 530	6	0.01	155	0.01
		WMU 531	0	0.00	0	0.00
	1995	WMU 518	4	0.00	204	0.01
		WMU 530	8	0.01	567	0.02
		WMU 531	0	0.00	68	0.00
	Average	**WMU 518 (531)**	**19**	**1.6**	**48**	**1.55**
		WMU 530	**11**	**0.97**	**217**	**0.27**

Source: BOVAR (1996f); AEP 1997c; AEP 1997d.
Before 1993, WMU 518 and 531 were a single unit.



LEGEND

REGISTERED FUR MANAGEMENT AREA

0 10 20 30 40 50km

SCALE 1:1,000,000

Golder Associates

SHELL CANADA LIMITED

REFERENCE

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

INFORMATION FROM ALBERTA ENVIRONMENTAL PROTECTION

REGISTERED FUR MANAGEMENT AREAS (RFMAs) FOR THE RSA

03 DEC 97	Figure D14–9	DRAWN BY: RFM

Table D14-8 Furbearing Species Trapped Within 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 D14-9 Furbearing Species Trapped Within Registered Fur Management Area 1714 From 1984 to 1996

Year	Timber wolf	Red fox	Coyote	Canada lynx	Wolverine	Fisher	Marten	Weasel	Mink	River otter	Beaver	Muskrat	Squirrel
1984/1985	---	---	---	---	--	---	---	---	---	---	---	---	---
1985/1986	---	---	1	---	--	1	---	---	---	---	10	13	---
1986/1987	---	---	---	---	--	---	---	---	---	---	1	---	---
1987/1988	---	---	---	1	--	---	---	22	9	---	---	---	31
1988/1989	---	---	---	---	--	---	---	---	---	---	---	---	---
1989/1990	---	---	---	---	--	---	---	---	---	---	---	---	---
1990/1991	---	---	---	---	--	---	---	---	1	---	---	---	---
1991/1992	---	---	---	1	--	2	---	---	---	---	4	---	---
1992/1993	---	---	---	1	--	1	3	8	---	2	---	---	55
1993/1994	---	---	---	---	--	---	---	---	---	---	---	---	---
1994/1995	---	---	---	---	--	---	---	---	---	---	--	---	---
1995/1996	---	1	---	---	--	2	8	6	---	---	1	---	3
Total	0	1	1	3	0	6	11	36	10	2	16	13	89

Table D14-10 Furbearing Species Trapped Within Registered Fur Management Area 2006 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	---	16	---	---	15	---	8
1985/1986	---	---	---	---	--	2	---	---	---	---	29	16	---
1986/1987	---	1	1	---	--	12	1	19	1	---	51	---	---
1987/1988	---	---	---	---	--	---	---	---	1	---	21	---	---
1988/1989	---	2	---	1	--	1	---	---	---	---	---	---	---
1989/1990	---	---	---	9	--	2	---	---	---	---	3	---	---
1990/1991	---	1	1	7	--	2	---	9	1	---	27	---	4
1991/1992	---	5	1	8	--	6	1	13	---	2	34	---	4
1992/1993	---	---	---	3	--	3	---	2	---	1	---	---	1
1993/1994	---	---	---	---	--	2	1	---	---	1	7	2	---
1994/1995	---	---	---	---	--	---	---	---	---	---	5	---	---
1995/1996	---	---	---	---	--	---	---	---	---	---	5	---	---
Total	0	9	3	29	0	31	3	59	3	4	197	18	17

Table D14-11 Furbearing Species Trapped Within 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

Table D14-12 Furbearing Species Trapped Within Registered Fur Management Area 2718 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	---	---	---	---	3	---	4	2	1	---	---	3
1985/1986	---	---	---	---	---	---	---	---	---	---	2	40	---
1986/1987	---	1	---	1	---	2	---	21	8	---	2	31	41
1987/1988	---	---	---	---	---	---	---	9	13	---	---	107	---
1988/1989	---	---	---	1	---	---	1	13	1	---	---	---	---
1989/1990	---	---	---	---	---	2	1	---	---	---	---	---	---
1990/1991	---	2	---	7	---	5	2	---	---	---	---	---	---
1991/1992	---	2	---	1	---	5	7	1	---	---	1	---	---
1992/1993	---	---	---	---	---	---	---	---	---	---	---	---	---
1993/1994	---	---	---	---	---	---	---	---	---	---	---	---	---
1994/1995	---	---	---	1	---	---	---	---	---	---	1	---	---
1995/1996	---	---	---	---	---	1	9	---	---	---	---	---	---
Total	1	5	0	11	0	18	20	48	24	1	6	178	44

Table D14-13 Average Annual Fur Harvest for the 5 Traplines Within the LSA From 1984 to 1996

RFMA	Timber wolf	Red fox	Coyote	Canada lynx	Wolverine	Fisher	Marten	Weasel	Mink	River otter	Beaver	Muskrat	Squirrel
1650	0	0	0.08	0	0	0.16	0.08	0.42	0.92	0	4.08	1.58	2.17
1714	0	0.08	0.08	0.25	0	0.5	0.92	3	0.83	0.17	1.33	1.08	7.42
2006	0	0.75	0.25	2.42	0	2.58	0.25	4.92	0.25	0.33	16.4	1.5	1.42
2172	0.17	1.08	0.25	1.75	0.08	3	0.5	1.42	0.35	0.25	20.33	25.08	3.83
2718	0.08	0.42	0	0.92	0	1.5	1.67	4	2	0.08	0.5	14.83	3.67

D14.3.7 Fishing

The LSA and RSA occur within Fish Management Area (FMA) 8 (AEP 1997). This FMA encompasses the watersheds of the Athabasca, Birch, Clearwater and Slave rivers and their tributaries. Common game fish in FMA 8 include goldeye, burbot, lake and mountain whitefish, northern pike, Arctic grayling, walleye, lake trout and yellow perch (Nelson and Paetz 1992). The Northern River Basins Study Project (R.L.&L. 1994) provided a baseline fish/fish habitat inventory for various reaches and site locations. This study determined that fish species diversity and abundance were generally greater in the lower reaches of the Athabasca River. The Muskeg River is also an important sport fishery in which 21 species were identified (Westworth 1990).

In FMA 8, sport fishing is allowed on flowing waters only from June 1 to October 31. Lakes, ponds and reservoirs are open to fishing all year. Exceptions to these regulations are described in AEP (1997f).

Significant natural fish habitats occur within the RSA are listed in Table D14-14 (Westworth 1990). Additional details on fish habitats in the LSA are presented in Section D6. Larry Rhude of AEP, Fisheries Management Division, (pers. comm., November 1997) identified the Muskeg River up to the bridge and Jackpine Creek as important fisheries locations. Although the Athabasca River is included in this list, its high natural turbidity limits most sport fishing to the mouths of tributary streams. As well, most anglers practice catch and release on the Athabasca River due to a fear of contaminated fish from all the industry on the river (L. Rhude, pers. comm., November 1997). In addition to sport fishing, commercial fishing also occurs on the Athabasca River, especially in the vicinity of Fort McKay (L. Rhude, pers. comm., November 1997).

Most of the respondents to BOVAR's (BOVAR 1996f) telephone survey participated in fishing activities (16 of 17). Most fishing activity occurred in the summer season, although 19% of the respondents fished all year. The preferred location for fishing was the Clearwater River, followed by the Athabasca River. Other identified fishing locations were the Muskeg, Horse, Hangingstone, MacKay and Firebag rivers. The preferred sport fish species were northern pike and walleye, followed by pickerel, grayling, perch, whitefish, lake trout and rainbow trout.

Table D14-14 Significant Fish Habitat in the Regional Study Area[a]

Location	Significance Level	Important Fish Species								
		Wall-eye	Lake White-fish	Arctic Grayling	Mountain White-fish	Pike	Yellow Perch	Rainbow Trout	Goldeye	Burbot
Athabasca River	National	X	X	X		X			X	
Christina River: Lower Reach	Provincial	X	X	X	X	X	X		X	X
Clarke Creek	Regional			X						
Clearwater River	Provincial	X	X	X	X	X			X	X
Dover River	Provincial				X	X				
Ells River	Provincial	X	X	X	X	X	X		X	X
Hangingstone River	Regional	X		X	X	X				
Horse River	Regional	X		X		X	X		X	
Horseshoe Lake	Regional							X		
Jackpine Creek	Regional			X	X	X				
MacKay River	Regional	X		X	X	X	X			X
Muskeg River	Regional	X	X	X	X	X				X
Saline Creek	Regional		X							
Steepbank River	Regional	X	X	X		X				
High Hill River	Provincial			X	X	X				
Pierre River	Regional	X		X		X				

(a) Source: Westworth 1990.

D14.3.8 Recreation (Non-Consumptive)

Non-consumptive resource use includes activities such as camping, hiking, boating, photography, birdwatching, kayaking and snowmobiling. Another significant recreation activity involves tours of the operating oil sands developments. The Fort McMurray Visitor's Bureau organizes tours from May to October for Syncrude Canada Ltd. and from June to September for Suncor Energy (Ref. Jan Bourassa, Visitor's Bureau pers. comm., Dec. 1997). BOVAR (1996f) determined that the most common non-consumptive activity, as noted by 71% of the respondents to their telephone survey, was camping. Other activities were hiking, canoeing, snowmobiling, river boating, cross-country skiing, driving quads (all-terrain recreational vehicles), kayaking, sightseeing, plant studies, bird-watching, photography, water-skiing, dog mushing, swimming, picnics and snowshoeing. Individuals often engaged in more than one recreational activity during any given outing.

Another recreational opportunity associated with the oil sands involves visits to the Fort McMurray Oil Sands Discovery Centre (formerly the Fort McMurray Oil Sands Interpretive Centre). There were 8,616 visitors to the centre in 1996. (Jan Bourassa, Visitor's Bureau, pers. comm., Dec. 1997). The Oil Sands Discovery Centre has recently launched a multimillion dollar campaign to redevelop the exhibition hall.

According to BOVAR (1996f), the main locations for recreational activities were:

- the Clearwater River valley (boating, camping and dog-mushing);
- the Athabasca River valley (camping, boating and snowmobiling);
- Thickwood Tower Road (camping, hiking and plant studies);
- Muskeg River (canoeing, kayaking and camping);
- Hangingstone River (canoeing and kayaking);
- Saline Lake (wildlife viewing, rare plants and photography);
- McClelland Lake (birdwatching);
- Birch Mountain (camping and hiking); and
- along the Fort Chipewyan Road (camping and snowmobiling).

Several activities take place in areas developed by major oil sands companies. These activities and their locations include:

- wildlife viewing area, temporary Boy Scout camp and canoeing at Poplar Creek Reservoir;
- wildlife viewing area at Wood Bison Gateway and Wood Bison Trail (where Highway 63 passes through the Syncrude Mildred Lake Mine);
- hiking trails at Matcheetawin Discovery Trails;
- wildlife viewing area at Wood Bison Viewpoint (Syncrude Mildred Lake);
- canoeing at Ruth Lake;
- canoeing at Beaver Creek Reservoir; and
- wildlife viewing area and nature trail at Suncor's Crane Lake.

In addition, a lake is planned for the Syncrude Mildred Lake mine pit west of Wood Bison Trail (BOVAR 1996f). It is expected this lake will be 2,000 ha in size and will offer boating, fishing and general recreation opportunities.

D14.4 Contacts

Contacts for current information on non-traditional resource are listed in Table D14-15.

Table D14-15 Non-Traditional Resource Use Contacts

Name	Affiliation	Phone Number
Berkholz, Sylvia	AEP, Wildlife Management Division	(403) 422-9534
Bourassa, Jan	Fort McMurray Visitor's Bureau	(403) 791-4336
Graham, Laura	Special Places 2000	(403) 427-2330
Jansen, Pat	AEP, Fur Management	(403) 427-9332
Lee, Peter	Alberta Endangered Species/World Wildlife Fund	(403) 451-9260
Rhude, Larry	AEP, Fisheries Management Division	(403) 743-7200
Sheehy, Amanda	AEP, Strategic and Regional Support Division	(403) 427-2096
Steber, Jennifer	AEP, Strategic and Regional Support Division	(403) 427-0047

D15 TRADITIONAL LAND USE

D15.1 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 is addressed in this section:

- identification of aboriginal traditional land uses in the Study Area, including recreation uses, hunting, trapping, fishing, cultural use and food collection (TofR, Section 6.0).

Project-specific impacts on traditional land and resource use are addressed in Section E15 of this EIA. Cumulative effects on traditional land and resource use are addressed in Section F15.

The purpose of conducting the traditional knowledge and land use component for the Muskeg River Mine Project EIA is to: a) identify the resources and locations that have been of traditional use and cultural significance to the Fort McKay and other aboriginal communities in the Fort McMurray area; b) outline the current uses of these resources and locations; and c) provide an estimate of the impacts the proposed development will have on the traditional ways of life practised by the Fort McKay and nearby aboriginal communities. The information gathered will be useful in achieving an equally important objective: assessing the cumulative impacts that will be experienced by the Fort McKay and nearby aboriginal communities through the development or expansion of oil sands mining, extraction and processing projects and other industrial development in the region.

The following subsections provide a summary of the current status of information available relating to traditional knowledge and land use in the region surrounding the Project area. This information served as a basis for structuring the study undertaken for this component of the project and assisted in development of a program of study that provides new insights into the specific uses local aboriginal communities have traditionally made of the renewable resources of the Project area.

D15.1.1 Traditional Land Use Background

The aboriginal communities of North America have traditionally practised ways of life intimately tied with the landscapes in which they lived. The resources provided by the land allowed these communities to survive and flourish and to develop cultural expressions unique to those areas. This detailed understanding of the environment and its resources is important for ensuring the survival of these unique communities today, when non-aboriginal commercial and recreational uses are increasing, and frequently compete with traditional uses of the land. It also serves as a basis for educating aboriginal and non-aboriginal communities about the values inherent in the natural landscape that cannot be fully appreciated when the landscape is changed.

The nearest aboriginal community in the region (Fort McKay) includes Treaty Indians, both Chipweyan and Cree, and the non-status Indians (Metis) who live in the vicinity of Fort McKay. Fort McKay has become a permanent base of residence in recent times for this community, as schools, government services and employment opportunities have gained importance and acceptance for community members. However, this area has always served as a focal point in the seasonal round of traditional activities associated with hunting, trapping and fishing, practised for generations throughout the surrounding region. With the signing of Treaty 8 in 1899, along with three reserves situated in their traditional territory, this community was provided the freedom to hunt, trap and fish.

The regional natural resources have made, and are currently making, a significant contribution to the economic, social and spiritual life of the aboriginal communities. Understanding these contributions provides a basis for developing a strategy that will allow various land uses to be accommodated and the interests of all parties to be satisfied.

D15.2 Previous Regional Studies

Aboriginal peoples have made use of bitumen seeps in the region for decades. European explorers made note and described their presence as early as the late 1700s (e.g., Mackenzie 1971). However, it was not until the late 1960s that technology had developed sufficiently to allow large-scale industrial exploitation. As industrial development progressed in the region, and large numbers of non-aboriginal people migrated to the area to find employment, it became apparent that the lifestyles of the original inhabitants would be changed significantly. This recognition led to the desire to document the character of the regional aboriginal communities, their traditional economy and system of land use. This information provides a means for understanding the impacts of modern industrial development, and provides the basis for developing strategies to lessen those impacts and allow these communities to flourish.

Several studies focusing on the Fort McKay aboriginal communities and their traditional land use have been completed since the early 1980s. Some of these have been regional in scope while others have targeted particular areas in response to specific development proposals. These studies, which represent the baseline information on which the current study seeks to expand, are reviewed below.

D15.2.1 From Where We Stand

In 1983, the Fort McKay Tribal Administration released a document "From Where We Stand" which presented the results of a comprehensive 18-month study outlining a broad spectrum of issues relating to the Fort McKay community. Several objectives were outlined for this study:

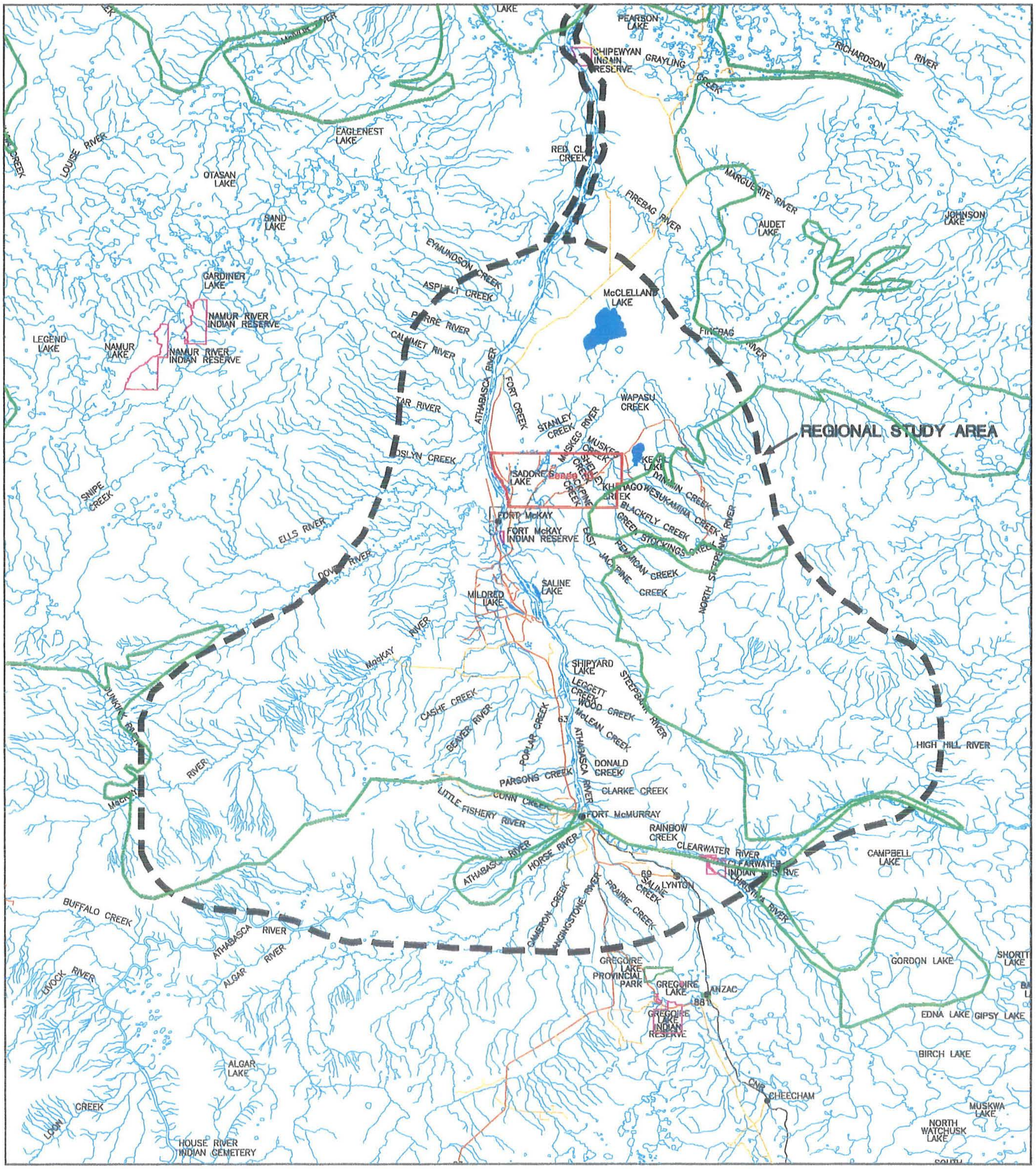
- a historical and cultural description of the community and its people;
- a detailed identification, assessment and mapping of traditional resource use and harvesting patterns and related impacts of development;
- a community profile for the past 15 years;
- an inventory of the benefits that could accrue to community members from present and future development; and
- training of community members in research coordination, field research and mapping (Fort McKay Tribal Administration 1983).

These objectives were accomplished by:

- completing a literature search and review relating to the resident aboriginal community, and developments throughout the region;
- interviewing 53 adult community members regarding past and present life and their aspirations for the future;
- interviewing elders regarding community history;
- assembling a community profile;
- constructing and compiling land use maps;
- interviewing aboriginal people outside the community; and
- preparing a report summarizing these studies.

One of the significant outcomes of this study was comprehensive definition of the lands considered to represent the traditional territory of the Fort McKay communities, through collection of information relating to hunting, trapping, fishing, plant harvesting and the location of cabins (Figure D15-1). This area includes the proposed Muskeg River Mine Project development area. Another important outcome was definition of two patterns of seasonal activities in the traditional lifestyle, one for periods before 1960, and one for periods after 1960 (Figures D15-2 and D15-3). The difference between these two maps shows the centralizing influence of the services provided at Fort McKay (e.g., schools, health services, housing employment) as well as the ongoing participation in the "bush economy."

An extensive section of the report, produced as a result of these studies, details the losses incurred by the Fort McKay communities due to industrial development and non-aboriginal use of the territory considered to represent their traditional lands. It also outlines the responses developed by the communities to deal with these pressures.



LEGEND

TRADITIONAL HUNTING AND TRAPPING TERRITORY

0 10 20 30 40 50km

SCALE 1:1,000,000

Golder Associates

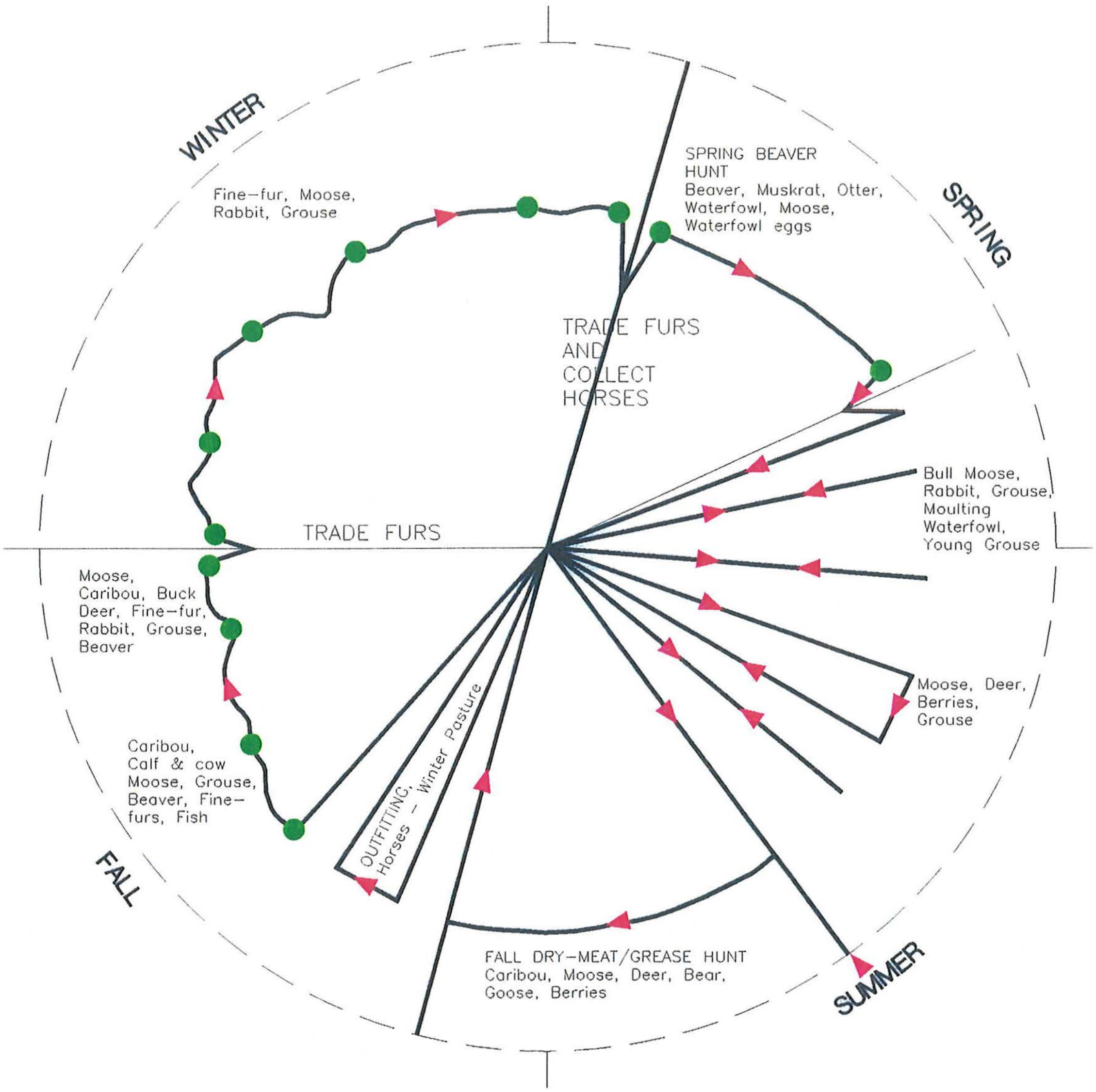
SHELL CANADA LIMITED

TRADITIONAL HUNTING AND TRAPPING TERRITORY OF THE FORT McKAY COMMUNITY (After "FROM WHERE WE STAND" 1983)

03 DEC 97	Figure D15-1	DRAWN BY: RFM

REFERENCE

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



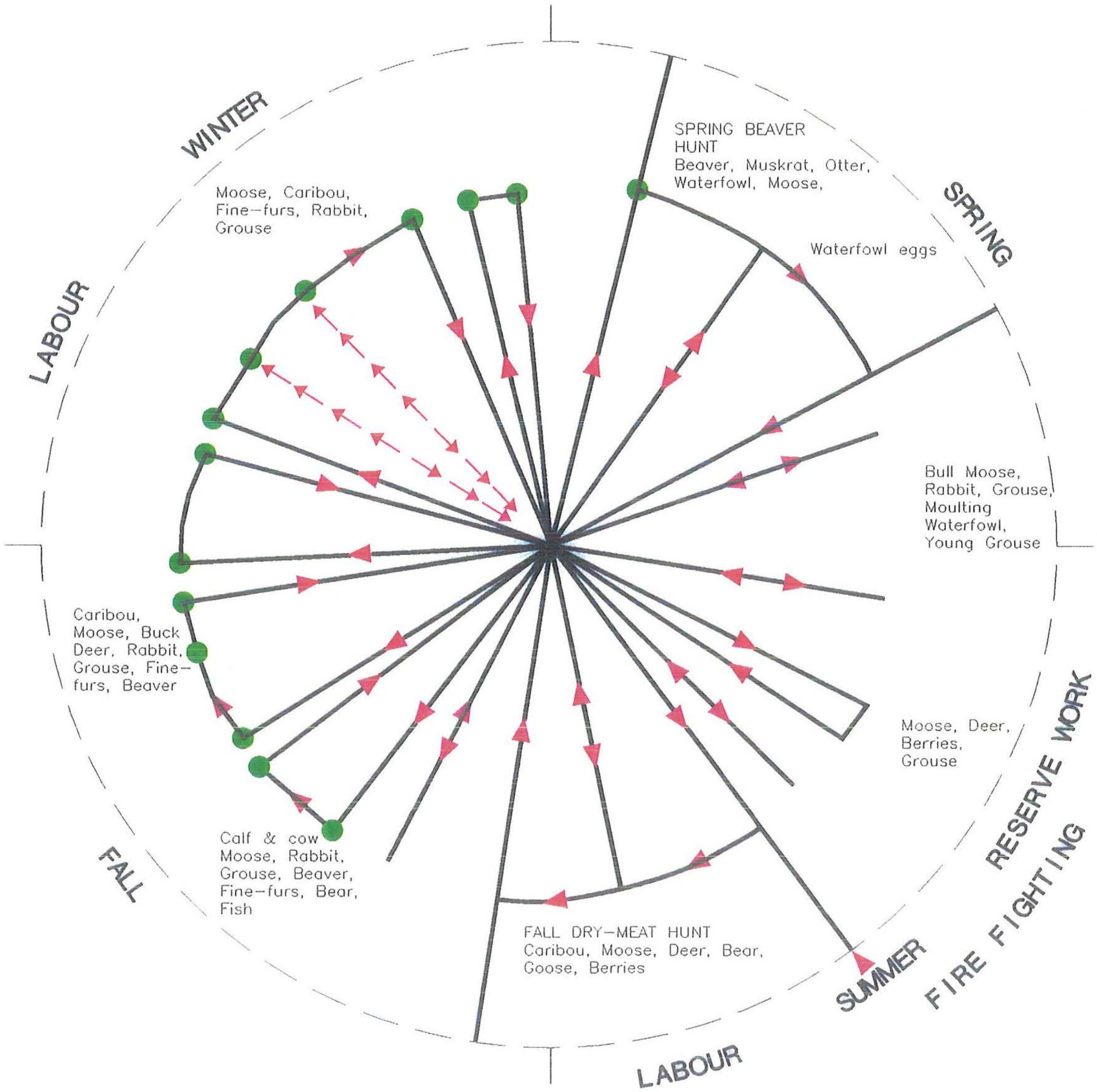
REFERENCE

FORT McKAY TRIBAL ADMINISTRATION, 1982. "FROM WHERE WE STAND".

Golder Associates | SHELL CANADA LIMITED

SEASONAL ROUND PRE-1960

12 DEC 1997	Figure D15–2	DRAWN BY: CG



REFERENCE

FORT McKAY TRIBAL ADMINISTRATION, 1982. "FROM WHERE WE STAND".

Golder Associates

SHELL CANADA LIMITED

SEASONAL ROUND POST-1960

12 DEC 1997	Figure D15-3	DRAWN BY: CG

Perhaps one of the most important results of the study is documentation of the significant role the "bush economy" plays in the overall life of the Fort McKay community residents. For example, data from hunters and trappers indicate that the bush economy produces enough hunted meat to supply each community resident with 500 g per day, or an equivalent of $869 of meat per year, if bought in a store. In addition, annual income from the fur industry in 1983 would have provided $12,585 to each household as gross income. This analysis clearly conveys the overall heavy reliance of the community on the "bush economy," in spite of the numerous restrictions that accompany the increasing non-traditional land uses in the region.

D15.2.2 There Is Still Survival Out There

A report on a second regional level study conducted within the Fort McKay communities was published in 1994 with the title "There Is Still Survival Out There" (Fort McKay First Nations 1994). This study was conducted in conjunction with the Arctic Institute of North America and employs their techniques for traditional land use and occupancy studies. This study builds on the previous work, but adopted a study area boundary that corresponded to the 1:250,000 scale national topographic system, Birch Mountain Firebag River map. This map includes the area proposed for development for the Muskeg River Mine Project.

The methodology applied focuses on an interview process conducted by trained community members, to illicit information on traditional land use. Interviewers used question sheets that identify use of specific resources: big game, furbearers, fish, waterfowl, fruit plants, birds, herbs, roots, plants, trees and shrubs. Questions were asked relating to special products sought, special areas, places, names and especially productive habitat. Interviews are said to have been free flowing so as not to direct or inhibit the person being interviewed. During the interview process, a map series was created using symbols to denote locations where certain resources were obtained. Information accumulated on these maps as the interviews progressed, resulting in a detailed inventory of resources used and the locations in which they were harvested, as well as the names and locations of special sites and areas.

Although the maps consolidate the information accumulated as a result of this process, the interviews conducted provide the basis for establishing a clearer picture of traditional land use in the Project area. They relate much valuable information that could not be mapped, pertaining to techniques used for harvesting resources and their later use within the community. Interviews were conducted with 67 First Nations people during this program. These interviews were taped for archival purposes and were transcribed from the original Cree and Chipweyan by the interviewers. These transcripts form the appendix to the report prepared for the study, with resource use information abstracted from them to provide an appendix entitled "Ethnographic Notes."

The mapped information obtained in this study, called traditional environmental knowledge (TEK), is summarized and analyzed in the central portion of the report. Sections are devoted to each of the 10 maps produced, and show information on the following land use categories: trails and cabins, spiritual (grave) and habitation sites, furbearers, big game, fish, birds, berries, trees and plants, place names and traplines. Seasonal information is included with this analysis and enabled creation of a diagrammed seasonal round of harvest activities in each of the resource categories mapped.

The final section of the report presents recommendations made to the Fort McKay communities that arise from the study and pertain to:

- use of the report and maps for educational promotional and resource management purposes;
- preparation of a proposal by the Fort McKay community to the Alberta Government for co-management of intensive areas of traditional use;.
- active attempts by the Fort McKay community to recover lost traplines and expand registration throughout their traditional territory;
- creation of a TEK centre to continue and expand on the information obtained in the study using geographic information systems; and
- establishment of a co-management committee to interact with government and industry.

D15.2.3 Previous Study Within the Muskeg River Mine Project Area

A recent traditional land use study was conducted in the area that encompasses the Muskeg River Mine Project. This study was completed in conjunction with planning for the Syncrude Aurora Mine Project (Fort McKay Environment Services 1996b), but because the area examined includes portions of the Muskeg River Mine Project development area, it is reviewed here.

The objectives of the study were to:

- conduct a review of regionally relevant literature on aquatic mammals in and adjacent to the study area;
- integrate this information with that obtained from maps and air photos of the area;
- conduct interviews with trappers with registered traplines that would be directly affected by the proposed development, and to integrate this information with that obtained above;
- conduct surveys to document the status of beaver populations and other wildlife species associated with riparian habitats in the study area; and
- prepare a report detailing this information.

The methods employed in this study include the following. Background information was secured from various reports completed in conjunction with proposed developments in the region. Two trappers with registered lines in the study area (Raymond Boucher and Mary Tourangeau) were interviewed to obtain traditional ecological information. An aerial survey was undertaken to document aquatic mammal sites and to calculate a per linear kilometre density according to a recognized methodology. This survey was accompanied by two community members. Ground surveys were included in the program and entailed four 500 m transects walked under snowcover conditions, with records of the number of animal tracks observed and tabulated according to recognized sampling techniques. This technique allowed calculation of an "observed wildlife abundance index."

The results of the in-field investigations indicated that active and inactive beaver lodges exist in modest numbers throughout the area. Active sites occur primarily in association with willow/alder shrubland, which provides a preferred source of food, and secondarily, with spruce/tamarack muskeg. During the wildlife transect portion of the study, 248 tracks were observed, representing 22 different species of furbearing mammals, big game and birds. Each transect produced varying results. The one situated within the area previously cleared for the former Alsands Project in 1979 exhibited far more productivity than the others. These data were then compared with similar information obtained from areas outside the study area, but within the region.

The density of beaver lodges within the area is considered to be low when compared to other areas in northern Alberta. However, within the old Alsands site, where drainage canals have been in place for 16 years, and have been used by beaver, densities were found to be 6.3 times greater than in the remainder of the Project area. This is also seen as a factor of the prevalence of shrubby vegetation communities whose regrowth has been encouraged by the improved drainage conditions in that part of the Project area and by the character and youth of the tree canopy. The wildlife surveys revealed an even more dramatic variation associated with the cleared Alsands site. The willow/alder shrubland complex that has regenerated since the forest was cleared and the area drained appears to support an abundance and diversity of wildlife that is unparalleled by any other habitat type examined in the region. Wildlife activity here exceeds other comparable areas by between 4 and 30 times.

D15.3 Historic and Traditional Resources Documented in the Muskeg River Mine Project Area

Six trapper's cabins and one gravesite have been identified in the lease area (Figure D15-4). Only one collapsed and one standing cabin are situated near the proposed Muskeg River Mine Project development area. Although both sites were visited and re-examined during the archaeological component of the EIA program conducted for the proposed Muskeg River Mine Project development area, it appears that only one of these would be affected by current development plans.

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

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

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

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

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

DL	Detection Limit. The lowest concentration at which individual measurement results for a specific analyte are statistically different from a blank (that may be zero) with a specified confidence level for a given method and representative matrix.
Dose	A measure of integral exposure. Examples include (1) the amount of chemical ingested, (2) the amount of a chemical taken up, and (3) the product of ambient exposure concentration and the duration of exposure.
Dose Rate	Dose per unit time, for example in mg/day, sometimes also called dosage. Dose rates are often expressed on a per-unit-body-weight basis, yielding units such as mg/kg body weight/day expressed as averages over some period, for example a lifetime.
Dose-Response	The quantitative relationship between exposure of an organism to a chemical and the extent of the adverse effect resulting from that exposure.
Drainage Basin	The total area that contributes water to a stream.
Ecological Land Classification	A means of classifying landscapes by integrating landforms, soils and vegetation components in a hierarchical manner.
Ecoregion	Ecological regions that have broad similarities with respect to soil, terrain and dominant vegetation.
Ecosection	Clearly recognizable landforms such as river valleys and wetlands, at a broad level of generalization.
Ecosite	Subdivisions of the ecosection described and analyzed in greater detail (e.g., subdivisions of the river valley). The focus at this level is on specific vegetation associations (e.g., wetlands shrub) and the particular soil, drainage and site conditions that support it.
Ecosystem	An integrated and stable association of living and nonliving resources functioning within a defined physical location.
Edaphic	Referring to the soil. The influence of the soil on plant growth is referred to as an edaphic factor.
Edge	Where plant communities meet.
Effects Assessment	The process of determining the amount (concentration or dose) of a chemical to which a receptor may be exposed without the development of adverse effects.
Effluent	Stream of water discharging from a source.
Environmental Impact Assessment	A review of the effects that a proposed development will have on the local and regional environment.
Environmental Media	One of the major categories of material found in the physical environment that surrounds or contacts organisms (e.g., surface water, groundwater, soil, food or air) and through which chemicals can move and reach the organism.
Ephemeral	A phenomenon or feature that last only a short time (i.e., an ephemeral stream is only present for short periods during the year).
ER (Exposure Ratio)	A comparison between total exposure from all predicted routes of exposure and the exposure limits for chemicals of concern. This comparison is calculated by dividing the predicted exposure by the exposure limit.

EROD	Ethoxyresorufin-O-deethylase (EROD) are enzymes that can increase in concentration and activity following exposure of some organisms to chemicals such as polycyclic aromatic hydrocarbons. EROD measurement indirectly measures the presence of catalytical proteins that remove a CH_3CH_2-group from the substrate ethoxyresorufin.
Escarpment	A cliff or steep slope at the edge of an upland area. The steep face of a river valley.
Exposure	The contact reaction between a chemical and a biological system, or organism.
Exposure Assessment	The process of estimating the amount (concentration or dose) of a chemical that is taken up by a receptor without the development of adverse effects.
Exposure Concentration	The concentration of a chemical in its transport or carrier medium at the point of contact.
Exposure Limit or Toxicity Reference Value	For a non-carcinogenic chemical, the maximum acceptable dose (per unit body weight and unit of time) of a chemical that a specified receptor can be exposed to, without the development of adverse effects. For a carcinogenic chemical, the maximum acceptable dose of a chemical to which a receptor can be exposed to, assuming a specified risk (e.g., 1 in 100,000). May be expressed as a Reference Dose (RfD) for non-carcinogenic (threshold-response) chemicals or as a Risk Specific Dose (RsD) for carcinogenic (non-threshold response) chemicals. Also referred to as a toxicity reference value.
Exposure Pathway or Route	The route by which a receptor comes into contact with a chemical or physical agent. Examples of exposure pathways include the ingestion of water, food and soil, the inhalation of air and dust, and dermal absorption.
Exposure Ratio (ER) or Hazard Quotient (HQ)	A comparison between total exposure from all predicted routes of exposure and the exposure limits for chemicals of concern. This comparison is calculated by dividing the predicted exposure by the exposure limit. Also referred to as hazard quotient (HQ).
Exposure Scenario	A set of facts, assumptions and inferences about how exposure takes place, that helps the risk assessor evaluate, estimate and quantify exposures.
Fate	In the context of the study of contaminants, fate refers to the chemical form of a contaminant when it enters the environment and the compartment of the ecosystem in which that chemical is primarily concentrated (e.g., water or sediments). Fate also includes transport of the chemical within the ecosystem (via water, air or mobile biota) and the potential for food chain accumulation.
Fauna	An association of animals living in a particular place or at a particular time.
Fecundity	The most common measure of reproductive potential in fishes. It is the number of eggs in the ovary of a female fish. It is most commonly measured in gravid fish. Fecundity increases with the size of the female.
Filter-Feeders	Organisms that feed by straining small organisms or organic particles from the water column.

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

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

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

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

LOEL	Lowest Observed Effect Level. In toxicity testing it is the lowest concentration at which effects on the measurement end point are observed.
LSI	Liver Somatic Index. Ratio of liver versus total body weight. Expressed as a percentage of total body weight.
m^3/s	Cubic metres per second. The standard measure of water flow in rivers; i.e., the volume of water in cubic metres that passes a given point in one second.
Mature Fine Tailings (MFT)	These are fine tailings that have dewatered to a level of about 30% solids over a period of about three years after deposition. The rate of consolidation beyond this point is substantially reduced. Mature fine tailings behave like a viscous fluid.
Mature Forest	A forest greater than rotation age with moderate to high canopy closure; a multilayered, multispecies canopy dominated by large overstory trees; some with broken tops and other decay; numerous large snags and accumulations of downed woody debris.
Mature Stand	A stand of trees for which the annual net rate of growth has peaked.
Media	The physical form of the environmental sample under study (e.g., soil, water, air).
Mesic	Pertaining to, or adapted to an area that has an intermediate supply of water; neither wet not dry.
Metabolism	Metabolism is the total of all enzymatic reactions occurring in the cell; a highly coordinated activity of interrelated enzyme systems exchanging matter and energy between the cell and the environment. Metabolism involves both the synthesis and breakdown (catabolism) of individual compounds.
Metabolites	Organisms alter or change compounds in various ways, such as removing parts of the original or parent compound, or in other cases adding new parts. Then, the parent compound has been metabolized and the newly converted compound is called a metabolite.
MFO	Mixed Function Oxidase. A term for reactions catalyzed by the Cytochrome P450 family of enzymes, occurring primarily in the liver. These reactions transform organic chemicals, often altering toxicity of the chemicals.
Microclimate	The temperature, precipitation and wind velocity in a restricted or localized area, site or habitat.
Microtox©	A toxicity test that includes an assay of light production by a strain of luminescent bacteria (*Photobacterium phosphoreum*).
Modelling	A simplified representation of a relationship or system of relationships. Modelling involves calculation techniques used to make quantitative estimates of an output parameter based on its relationship to input parameters. The input parameters influence the value of the output parameters.
Multilayered Canopy	Forest stands with two or more distinct tree layers in the canopy; also called multistoried stands.
NOAEL	No observed adverse effect level. No observed effect level. In toxicity testing, it is the highest concentration at which no adverse effects on the measurement end point are observed.

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

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

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

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

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

Successional Stage	A stage or recognizable condition of a forest community that occurs during its development from bare ground to climax.
Suncor	Suncor Energy Inc., Oil Sands
Surficial Aquifer	A surficial deposit containing water considered an aquifer.
Surficial Deposit	A geologic deposit (clay, silt or sand) that has been placed above bedrock. (See also "Overburden")
Suspended Sediments	Particles of matter suspended in the water. Measured as the oven dry weight of the solids, in mg/L, after filtration through a standard filter paper. Less than 25 mg/L would be considered clean water, while an extremely muddy river might have 200 mg/L of suspended sediments.
Sustainable Landscape	Capability of landscape (including landforms, drainage, waterbodies and vegetation) to survive extreme events and natural cycles of change, without causing accelerated erosion and environmental impacts much more severe than that of the natural environment.
Syncrude	Syncrude Canada Ltd.
Tailings	A byproduct of oil sands extraction composed of water, sands and clays, with minor amounts of residual bitumen.
Tailings Ponds	Man-made impoundment structures required to contain tailings. Tailings ponds are enclosed by dykes made with tailings sand and/or overburden materials to stringent geotechnical standards.
TDS	Total dissolved solids. See filterable residue.
Thalweg	The (imaginary) line connecting the lowest points along a streambed or valley. Within rivers, the deep channel area.
TID	Tar Island Dyke
Till	Sediments laid down by glaciers.
TOC	Total Organic Carbon. TOC is composed of both dissolved and particulate forms. TOC is often calculated as the difference between total carbon (TC) and total inorganic carbon (TIC). TOC has a direct relationship with both biochemical and chemical oxygen demands, and varies with the composition of organic matter present in the water. Organic matter in soils, aquatic vegetation and aquatic organisms are major sources of organic carbon.
Total Dissolved Solids (TDS)	The total concentration of all dissolved compounds solids found in a water sample.
Toxic	A substance, dose or concentration that is harmful to a living organism.
Toxic Threshold	Almost all compounds (except genotoxic carcinogens) become toxic at some level with no evident harm or adverse effect below that level. Scientists refer to the level or concentration where they can first see evidence for an adverse effect on an organism as the toxic threshold. Genotoxic carcinogens exhibit some toxic potential at any level.
Toxicity	The inherent potential or capacity of a material to cause adverse effects in a living organism.

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

Watershed	The entire surface drainage area that contributes water to a lake or river.
Wetlands	Term for a broad group of wet habitats. Wetlands are transitional between terrestrial and aquatic systems, where the water table is usually at or near the surface or the land is covered by shallow water. Wetlands include features that are permanently wet, or intermittently water-covered such as swamps, marshes, bogs, muskegs, potholes, swales, glades, slashes and overflow land of river valleys.
Worst-Case	A semi-quantitative term referring to the maximum possible exposure, dose or risk, that can conceivably occur, whether or not this exposure, dose or risk actually occurs is observed in a specific population. It should refer to a hypothetical situation in which everything that can plausibly happen to maximize exposure, dose, or risk does happen. The worst-case may occur in a given population, but since it is usually a very unlikely set of circumstances in most cases, a worst-case estimate will be somewhat higher than what occurs in a specific population.
WSC	Water Survey of Canada
Xeric	Referring to habitats in which plant production is limited by availability of water.
YOY	Young of the year. Fish at age 0, within the first year after hatching.

Alberta
ENVIRONMENTAL PROTECTION

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November 7, 1997

Mr. Neil J. Camarta
Vice President - Oil Sands
Shell Canada Limited
400 - 4th Avenue, SW
P.O. Box 100, Station M
Calgary, AB
T2P 2H5

Dear Mr. Camarta:

RE: FINAL TERMS OF REFERENCE FOR
SHELL CANADA LIMITED'S
ENVIRONMENTAL IMPACT ASSESSMENT (EIA) REPORT

Enclosed is the final Terms of Reference, dated November 6, 1997, issued by Alberta Environmental Protection under Section 46(3) of the Environmental Protection and Enhancement Act (EPEA), for the Environmental Impact Assessment (EIA) report for the proposed Lease 13 Project, in the Athabasca Oil Sands Region. The Terms of Reference also reflect the requirements of the Energy & Utilities Board (EUB) and the Canadian Environmental Assessment Agency (CEAA).

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

Sincerely,

Robert L. Stone
Director of
Environmental Assessment

Enclosure

cc: R. Houlihan (EUB)
R. Christie (CEAA)

FINAL TERMS OF REFERENCE

ENVIRONMENTAL IMPACT ASSESSMENT (EIA) REPORT

FOR THE PROPOSED

SHELL CANADA LIMITED

LEASE 13 PROJECT

FORT MCMURRAY, ALBERTA

Issued By Alberta Environmental Protection

Date: November 7, 1997

TABLE OF CONTENTS

1.0 INTRODUCTION

1.1 Purpose

The purpose of this document is to identify for Shell Canada Limited (Shell) and for the public the information required by government agencies for an Environmental Impact Assessment (EIA) report. Shell will prepare and submit an EIA report which examines the environmental effects of the construction and operation of its proposed commercial bitumen production project on Lease 13 (the Project), approximately 70 km north of Fort McMurray, Alberta.

1.2 Scope of Environmental Impact Assessment (EIA) report

The EIA report shall be prepared in accordance with these Terms of Reference and the environmental information requirements prescribed under the Environmental Protection and Enhancement Act (EPEA) and Regulations, the Energy & Utilities Board (EUB) Act and Regulations and applicable federal laws. The EIA report will address all impacts of the initial phase of development on the western portion of Lease 13 (the Project) and will consider impacts of the future development on Lease 13 east, as appropriate. The EIA report will address all impacts, mitigation options and residual effects that are relevant to the assessment of the Project. The EIA will assist the public and government in understanding the environmental consequences of the Lease 13 development, operation and reclamation plan and will assist Shell in its decision making process.

The EIA report will identify development activities and describe the nature and significance of environmental effects and impacts associated with them. Impact predictions should be presented in terms of magnitude, frequency, duration, seasonal timing, reversibility, and geographic extent. The EIA report will also discuss measures to prevent or mitigate impacts, monitoring of environmental protection measures and will identify residual and cumulative impacts and their significance. Proposed mitigation measures, protection plans , monitoring or research programs and other follow-up actions related to proposed activities, environmental performance objectives and anticipated regulatory requirements will be discussed.

The EIA report will form part of Shell's application to the EUB.

1.3 Public Participation

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

2.0 PROJECT OVERVIEW

2.1 The Proponent and Lease 13 History

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

Shell's Lease 13 has been the subject of a number of studies and proposals for surface oil sands mining over the years. Describe the history of proposed development, resource characterization and environmental studies.

2.2 The Project Area and EIA Study Area(s)

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

The EIA Study Area(s) include the Project Area, as well as, the spatial and temporal areas of individual environmental components outside the Lease 13 boundaries where an effect can be reasonably expected. The boundaries of individual environmental component Study Areas will be established through the public consultation process. The EIA Study Area(s) will include both a Regional Study Area (RSA) similar to the one recently established by other oil sands operators in the region (Suncor Energy Inc. and Syncrude Canada Ltd.) as well as Local Study Areas (LSAs). Maps of these areas should include township and range lines for easy identification and comparisons with other information within the EIA report.

Describe the rationale and assumptions used in establishing the Study Area boundaries, including those related to cumulative effects.

Provide maps of appropriate scale identifying the Lease 13 boundaries, the status of land tenure in the area, the proposed location of the facilities (mine infrastructure, plant, pipelines, access routes, utility corridors) and other related infrastructure components. Include lakes, streams and other geographical information on the maps.

2.3 Project Components and Development Schedule

Provide an overview of the Project components, including the mining operations, processing facilities, buildings, transportation infrastructure and utilities. Discuss the proposed pipeline project to Scotford and the proposed Scotford upgrader project.

Provide a development schedule outlining the proposed phasing and sequencing of components, including pre-construction, construction, operation, reclamation and decommissioning. The key factors controlling the schedule and uncertainties should be identified.

Identify and describe major components of the Project which are to be applied for and constructed within the duration (e.g., up to 10 years) of approvals under the Environmental Protection and Enhancement Act (EPEA) and the Water Resources Act (WRA).

2.4 Project Need and Alternatives

Present an analysis of the need for the Project and summarize the alternatives to the Project, including a no-development scenario. As well, identify potential cooperative development opportunities for all aspects of the Project. Provide a summary of reasons for selecting the Project and major Project components.

Discuss alternative means of carrying out the Project, their environmental impacts and any contingencies if the selected major project components of the Project prove to be unfeasible.

2.5 Regulatory Approval

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

3.0 PROJECT DESCRIPTION

3.1 General Information

Describe the mining, extraction and waste management components of the Project and provide a map showing the location of the proposed facilities. Locate the buildings, road access, pipeline routes, water pipelines, utility corridors and sand and waste disposal sites of the Project. Identify the criteria and assumptions used in locating these facilities with consideration of the Fort McMurray-Athabasca Oil Sands Subregional Integrated Resource Plan (IRP) and other approved government policies. Describe the planned accommodation for the workforce during construction and operations.

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

Provide placement information and a schedule for location and relocation of out of pit storage.

Delineate proposed setbacks from the Athabasca and Muskeg rivers and other associated tributaries. Demonstrate that the location of project facilities follow the setback guidelines in the IRP.

3.2 Process Description

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

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

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

3.3 Mining Description

Describe the mining methods to be used, with discussion of alternative mining methods considered and their environmental implications (e.g., potential to minimize fine tailings generation).

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

3.4 Utilities and Transportation

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

Discuss the amount and source of energy required for the mine and the plant facilities.

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

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

Describe the methodology and determine the projected frequency and location of increased traffic volumes on Highway 63 and its northward extension (Fort Chipewyan winter road) during the construction and operating periods. Discuss mitigation options. Discuss options for cooperative development of infrastructure with other oil sand and industry operators.

Describe how regional access requirements eastward through Lease 13 will be addressed.

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

Describe any river and stream crossing of utility lines and pipelines.

3.5 Air Emissions Management

Indicate the type, rate and source of air emissions from the Project including construction and vehicle emissions.

Identify emission points on the site plan and the potential sources of fugitive emissions.

Describe the monitoring and control systems to be employed.

Describe 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.

Estimate greenhouse gas emissions from the Project. Place emission estimates in context with total emissions provincially and nationally. Discuss the proponent's overall greenhouse gas management plans and comment on the effect of this Project on its greenhouse gas management plans.

3.6 Water Supply and Management

Identify the process water requirements and any chemicals to be used. Discuss design considerations to ensure efficient use of water for all aspects of the Project, including emergency operating conditions.

Describe the source of water to be used in the development and the options for water sourcing considered. Discuss seasonal variability with regard to water use, diversion and potential environmental impacts.

Describe the general nature, location, volume, quality and any fluctuations in any proposed water effluents.

Show the location of any water intake and associated facilities (ponds, pipelines, treatment plant), if required.

Provide a water management plan addressing site run-off and containment, groundwater protection and depressurization, and wastewater treatment and disposal. Include a water balance containing any changes that are anticipated during the life of the Project.

Describe alternatives considered to minimize wastewater (e.g., to minimize generation, inventory, contained contaminants and long-term risk or liabilities).

Describe alternatives considered to minimize changes to water flows in the Muskeg River and associated tributaries.

3.7 Waste Management

Describe the management plan for the produced tailings, overburden and other mining wastes, as well as, those wastes generated at work camp sites. Include evaluations to minimize fine tailings production considering mining methods, minimum ore grades selected for mining and extraction processes.

Identify on a plot plan all on-site disposal areas for the above wastes and indicate the strategy for these disposal areas, their location and timing. Include plans to minimize above ground storage of overburden and tailings.

Describe the waste management strategy for on-site industrial landfills and provide estimates of the quantity and composition of routine landfill wastes.

Describe plans for waste minimization and recycling.

Describe the waste management strategy for hazardous wastes and provide the quantity and composition of hazardous wastes generated by the Project.

Describe the proposed storage and handling methods for these wastes.

3.8 Monitoring, Operating and Contingency Plans

Outline plans for monitoring of all inputs to the project and of products and waste streams from the Lease 13 Project and associated facilities.

Discuss the key elements of the operating plans and performance standards to be developed prior to the commissioning of the plant, such as policies and corporate procedures, operator training and emergency reporting procedures for spill containment and management, emergency response and safety.

4.0 ENVIRONMENTAL ASSESSMENT

4.1 Assessment Requirements

Provide information on the environmental resources and resource uses that could be affected by the Project. Provide a sufficient base for the prediction of positive and negative impacts and the extent to which negative impacts may be mitigated by planning, project design, construction techniques, operational practices and reclamation techniques. Impact significance will be quantified where possible and assessed including consideration of spatial, temporal and cumulative aspects.

Discuss the sources of information used in the assessment. Identify any limitations, both in terms of data collected and knowledge gap, that the information may place on the analysis or conclusions in the EIA report. Information sources will include literature and previous EIA reports and environmental studies, operating experience from current oil sands operations, industry study groups, traditional knowledge and government sources. Where required, Shell will undertake studies and investigations to obtain additional information.

From a broad-based examination of all ecosystem components including previous environmental assessment work, describe and rationalize the selection of key components and indicators examined.

For each environmental parameter, Shell will:

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

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

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

iv) Identify residual impacts and comment on their significance.

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

vi) Present recommendations for environmental protection or mitigation which may require joint resolution by government, industry, and the community.

4.1.1 Cumulative Environmental Effects

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

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

- Consider the environmental effects from other existing and proposed projects or reasonably foreseeable activities in the region. Proposed projects are defined as the projects that have been advanced to the public disclosure stage.

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

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

4.2 Climate, Air Quality and Noise

Discuss the baseline climatic and air quality conditions in the area.

Identify components of the Project that will affect air quality from a local and regional perspective. In particular, document appropriate air quality parameters, including oxides of nitrogen (NOx), volatile organic compounds (VOCs), ground level ozone, total reduced sulphur compounds (TRS), total hydrocarbons, acidifying emissions and particulates.

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

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

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

Identify a program to monitor air quality during construction and operation of the Project.

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

Assess the cumulative effects on the air quality of the Study Area.

4.3 Geology, Terrain and Soils

Describe and map the bedrock and surficial geology and topography of the Study Area relating them in a regional context to include areas such as the Susan Lake Moraine. Describe and map the drainage patterns in the Study Area.

Provide an assessment of the anticipated changes (type and extent) to the pre-disturbed topography, elevation and drainage patterns within the Project Area resulting from surface disturbance during construction, operation and reclamation. Identify these changes on a map.

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

Provide a pre- and post-disturbance land capability assessment of the Project Area and describe the impacts to land capability due to the Project. Identify the distribution of pre- and post-disturbance land capability on a map.

Develop a soils reclamation management plan for the Project Area.

Describe the availability and suitability of soils within the Project Area for reclamation.

Outline the criteria to be used in salvaging soils for reclamation within the Project Area.

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

Identify any soil related constraints or limitations which would affect reclamation. Identify activities which may cause soil contamination.

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

Describe the impact of each ecological land classification unit from disturbance based upon the key characteristics of the soil.

4.4 Vegetation and Forest Resources

Describe and map the vegetation communities in the Study Area and identify any rare, threatened or endangered plant species.

Identify the amount of land to be disturbed and the types of the vegetation communities affected in the Project Area.

Describe the mitigative measures to be implemented to offset the impacts on vegetation communities, including rare and endangered species in the Project Area.

Evaluate forest and peatlands/wetlands resources according to the standards outlined in the Alberta Vegetation Inventory Standards Manual (AVI) Version 2.2.

Describe the impact that development and reclamation will have on commercial forest opportunities in the Project Area.

Assess how development and mitigation of the Project will affect peatlands/wetlands in the Study Area.

Identify and evaluate the extent of potential impacts of the Project, including cumulative impacts within the Study Area.

Illustrate on a conceptual end land use map and the type and distribution of plant communities proposed to revegetate the reclaimed landscape.

4.5 Wildlife

Describe wildlife habitat types and use of the Study Area by wildlife and identify any rare or endangered species and their habitat requirements. Identify seasonal habitat use in significant areas.

Describe and map moose and other key indicator species, significant local habitat, seasonal habitat use patterns, extent of winter and summer range and seasonal movement corridors.

Comment on the sensitivity of key species and significant habitat areas impacted by the Project.

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

Provide a mitigation plan and schedule for wildlife and significant wildlife habitat areas.

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

Assess the cumulative effects on the wildlife within the Study Area.

4.6 Surface Hydrology

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

Identify the mining and development activities that may impact surface hydrology and assess the potential impacts on local and regional hydrology, including impacts on the thermal regime of surface water flows, in particular, the Muskeg River and associated tributaries.

Describe any alterations in timing, volume and duration of peak flows from the Project Area as a result of mining operations on the western portion of Lease 13, and future development on Lease 13 east, as appropriate.

Describe the design parameters and plans to protect the Muskeg River and its tributaries, including the location and dimensions of buffers.

Describe a surface water monitoring program to assess the design and performance of the water management structures for handling, collection, treatment, containment and discharge.

Describe the design parameters for all water management plans and facilities, including settling ponds, drainage ditches, infrastructure required within the duration (e.g., up to ten years) of an WRA approval.

Describe and discuss the Project with respect to other projects in the region in terms of water resources and discuss any potential cumulative effects.

Identify 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. Describe surface water management plans, mitigation measures and monitoring programs.

Discuss probable maximum flood or probable maximum precipitation events and indicate how these events influence project design and development of contingency plans.

4.7 Groundwater

Discuss the groundwater regime of the Study Area by summarizing the existing regional databases including flow patterns, groundwater quality and interaction with regional groundwater flows.

Describe the effects of the Project on the existing groundwater resources of the Study Area, including water quality, quantity and thermal regime.

Discuss the effects of the Project on the basal aquifer.

Discuss the relationship between groundwater and surface water in the Study Area.

Describe groundwater monitoring programs and mitigative measures to address impacts on groundwater.

Describe both the surficial and upper bedrock groundwater regimes in the Project Area.

4.8 Water Quality

Describe the existing baseline water quality conditions in the Study Area .

Identify the activities which may influence water quality before, during and after the project development and operations. Describe the potential impacts of the Project on surface water quality within the Study Area with respect to location, magnitude, duration and extent and significance.

Describe the proposed mitigation measures during the construction, operation and reclamation phases of the Project.

Discuss seasonal variation and effects.

Describe a surface water monitoring program to assess the design and performance of the water management system for collection, handling, treatment and discharge.

Assess the cumulative effects of the Project on the water quality of the Study Area.

Predict water quality conditions in the Muskeg River and Athabasca River downstream from the Lease 13 Project and any other water bodies potentially affected by the Project.

Compare the predicted water quality and existing water quality to the Alberta Ambient Surface Water Quality Interim Guidelines, relevant United States Environmental Protection Agency Guidelines, and the Canadian Water Quality Guidelines. Consider the recommended procedure for using existing guidelines which is described in the document entitled: "Protocol to Develop Alberta Water Quality Guidelines for Protection of Freshwater Aquatic Life." Discuss the implications for any differences with surface water quality guidelines for short and long-term water quality, existing users and aquatic life.

4.9 Aquatic Resources

Describe the fish resources in the Study Area. Identify species composition, distribution, relative abundance, movements and general life history parameters. Discuss the relevance of the fish resources to existing or potential domestic, sport or commercial fisheries.

Describe and map as appropriate the fish habitat of the Athabasca River, Muskeg River and other tributaries likely to be affected by the Project. Identify critical or sensitive habitats such as spawning, rearing, overwintering and migration areas.

Describe the existing information base, any deficiencies in information and any studies proposed to evaluate the status of the fish and aquatic resources in the Study Area.

Identify key indicator species and provide the rationale and selection criteria used.

Identify impacts on fish and fish habitat that are likely to result from project construction or operation. Describe how stream alterations and changes to substrate conditions, water quality and water quantity may affect fish and fish habitat in the Study Area. Discuss the nature, extent, duration, magnitude, and significance of anticipated impacts. Identify proposed mitigation for each impact identified.

Discuss 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 release of contaminants, increased sedimentation and general habitat changes.

Discuss the design, construction and operational factors to be incorporated into the Project that will protect fish resources.

Identify residual impacts on fish and fish habitat and discuss their significance in the context of local and regional fisheries. Identify plans proposed to offset any loss in the productivity of fish habitats.

Discuss any cooperative mitigation strategies which might be planned with other oil sands and industrial operators.

Assess potential cumulative effects of the Project in combination with other proposed developments in the area on the fish and fish habitat resources of the Study Area.

Discuss how the proposed development and mitigation plans will achieve 'No Net Loss' of fish habitat.

Identify any monitoring programs that will be initiated by Shell or conducted in cooperation with other oil sands operators to monitor the status of the fish resources and to measure the effectiveness of proposed mitigation strategies.

5.0 RECLAMATION/MINE CLOSURE

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 is incorporated into mine planning.

Describe the reclamation implications with respect to water quality and other relevant ecosystem components of the technology selected for managing fine tailings, as well as, for the alternative technologies considered.

Describe the reclamation plans for management and disposal of water to be released and 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.

Provide a review of relevant reclamation research and experience and a description of future research initiatives to be undertaken by Shell and other oil sand operators to further reclamation technology in the oil sands region.

6.0 LAND USE

Identify aboriginal traditional land uses in the Study Area, including recreation uses, hunting, trapping, fishing, cultural use and food collection.

Identify the existing land uses, including oil sands development, aggregate mining, tourism, forestry, trapping, fishing, hunting, cultural use, food collection and other outdoor recreation activities.

Identify the potential impact of the Project on these land uses and possible mitigative strategies.

7.0 PUBLIC HEALTH AND SAFETY ISSUES

Describe 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.

Describe plans to participate in the Alberta Oil Sands Community Exposure and Health Effects Assessment Program currently underway in the Fort McMurray area.

Provide an outline of the proposed emergency response plan and discuss mitigation plans that will be implemented to ensure work force and public safety during construction and operation of the Project. This will include prevention and safety measures for wildfire occurrences, accidental releases of chemicals to the atmosphere or water and failures of structures retaining water or fluid wastes.

8.0 PUBLIC CONSULTATION

Document the public consultation program implemented for the Project including methods, the type of information provided and the level and nature of Shell's response.

Describe the consultative process and show how public input was obtained and addressed.

Describe and document the concerns and issues expressed by the public and the actions taken to address those concerns and issues.

Describe how resolution of the concerns and issues was incorporated into the Project development, impact mitigation and monitoring.

Describe plans to maintain the public consultation process following completion of the EIA review, to ensure that the public will have an appropriate forum for expressing their views on the ongoing development, operation and reclamation of the Project.

9.0 SOCIO-ECONOMIC ASSESSMENT

Describe the existing socio-economic conditions and the expected Project effects. Define the measures proposed to enhance positive effects or mitigate negative effects, as well as, the residual impacts. The socio-economic impact assessment is to focus on the community of Fort McKay and the Regional Municipality of Wood Buffalo and will include:

- local employment and training;
- opportunities and procurement;
- local services and infrastructure;
- timing and size of workforce during construction and operation; and
- population changes.

Discuss Shell's policies and programs respecting the use of local, Alberta and Canadian goods and services.

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

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

10.0 HISTORICAL RESOURCES

Consult 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.

Complete a field investigation of the Study Area and develop appropriate mitigation plans. The investigation will meet the requirements of Alberta Community Development.

APPENDIX II

Dispersion Model Approach

II-1 ISC3BE

II-1.1 Model Description

The BOVAR (1996e) modelling assessment for the Steepbank and Aurora mine applications used a modified version of the U.S. EPA model ISCST3. The ISCST3 (Industrial Source Complex, Short-Term, Version 3) model is frequently used for regulatory applications in Alberta (AEP 1994b). This model is a simple Gaussian plume model that can be used to predict ambient concentrations from point, area, volume and mine pit sources. When used with an hourly sequential time series of meteorological data, the model can predict hourly, daily and annual average concentrations. When used in Alberta, AEP recommends that the model predictions be multiplied by a 0.55 averaging time correction factor to provide hourly average concentrations.

When applied to the oil sands region, this model was found to predict more frequent high SO_2 concentrations during the night than were observed. For this reason, the model assumptions were reviewed and modifications were made to produce a model that predicted concentrations whose magnitude, frequency and diversal variation were similar to those observed. The modifications are summarized in Table II-1 and the modified model is referred to as ISC3BE.

II-1.2 Input Parameters

The model requires the following key input parameters:

- **Source Characterization.** For point sources, the required parameters include stack height, diameter, exit velocity, exit temperature and contaminant emission rate. The Muskeg River Mine Project (the Project) source parameters are given in Table E2-9. For mine pit sources, the required parameters include pit area, pit volume and contaminant emission rate. The model assumes a rectangular pit. The mine pit parameters are given in Table E2-2 and E2-4. For area sources (e.g., tailings settling pond), the model requires area and contaminant emission rates. These parameters are given in Table E2-12. The characterization for non Project area sources are provided in BOVAR (1996b).

- **Meteorological Characterization.** The model requires hourly meteorological data that includes wind speed, wind direction, ambient temperature, PG stability class and mixing height. Meteorological data are available from the OSLO background monitoring site (March 1988 to December 1989; 22 months) and from the Mannix ambient monitoring site (November 1993 to June 1995; 20 months). AEP (1994b) recommends a minimum of 12 months of site-specific time

Table II-1 Modifications Made to ISCST3

Plume Rise

For neutral and unstable conditions, the plume rise is taken as 87% of that predicted by ISCST3. This is equivalent of using a 1.4 coefficient in the "2/3 law" plume rise calculation instead of the 1.6 coefficient used in ISCST3. For stable conditions, the plume rise is taken as 69% of that predicted by ISCST3. This is equivalent of using a 1.8 coefficient in the calculation of stable plume rise instead of 2.6. The selection of the 1.4 and 1.8 coefficients is based on an analysis of photographic data collected in 1976 and 1977 (Davison and Leavitt 1979). This modification will have the effect of increasing ground-level concentrations since the plume will be closer to the ground.

Vertical Plume Spread

The modified model uses vertical plume spread coefficients recommended by Briggs (1973) for rural areas instead of the Pasquill-Gifford values used by ISCST3.

Horizontal Plume Spread (Valley Locations)

The relationships proposed by Briggs (1973) for rural areas instead of the Pasquill Gifford values were used as a basis. The Briggs stability dependent coefficients of 220, 160, 110, 80, 60, 40 were modified to 220, 160, 110, 80, 80, 80 for receptors located in the valley (that is, for receptor elevations less than 270 m).

Horizontal Plume Spread (Non-Valley Locations)

The relationships proposed by Briggs (1973) for rural areas instead of the Pasquill Gifford values were used as a basis. For non-valley receptors, the coefficients of 220, 160, 110, 80, 110 and 160 were used to account for the increased horizontal plume spreads observed under stable conditions (Slawson et al. 1979).

For distances greater than 10 km, the effect of increased meander due to wind shear for longer travel times was accounted for by further increasing the Briggs coefficients by a factor of $(x/10)^{0.5}$, where x is equal distance in km. Briggs forced his plume spreads to increase as $x^{0.5}$ for large travel times while field studies have indicated that the lateral dispersion is proportional to $x^{0.8}$ or $x^{1.2}$ for large travel distances (Draxler 1984). The use of the $(x/10)^{0.5}$ correction factor forces Briggs' values to converge to $x^{1.0}$ at these large distances. Models that do not account for wind shear enhanced turbulence for distances beyond 10 km may over-estimate concentrations (Davison and Leavitt 1979). Draxler (1984) indicates "any approach that considers wind shear at these distances is likely to provide more realistic estimates than those from extrapolation of short-term data beyond their range of applicability".

Terrain Coefficients

The modified model uses the same "half height" type of approach as the ADEPT2 model for unstable and neutral conditions. Specifically, terrain correction coefficients of 0.8, 0.7, 0.6 and 0.5 are used for PG stability classes A through D, respectively. For stable atmospheric conditions (PG stability class E and F), the neutral coefficients (0.5) are used.

series meteorological data for air quality assessments. The meteorological data are discussed in Section D2.4.

- **Receptor Characterization.** For each receptor where concentrations are to be calculated, the model requires an x location (east-west coordinate), a y location (north-south coordinate) and a corresponding elevation (m ASL). For the LSA, a total of 2,286 receptor locations were selected. Near the Muskeg River Mine the receptor spacing was 25 m. At the edges of the LSA, the receptor spacing was increased to 1000 m.

II-1.3 Model Performance

The ISC3BE model was evaluated by comparing SO_2 predictions to observations at 13 air quality monitoring sites (BOVAR 1996e). Table II-2 compares the predictions with the observations.

A comparison between observed and predicted SO_2 concentrations indicates that the average maximum ISCST3 prediction (0.31 ppm) corresponds well with the average maximum observed (0.28 ppm). The ISCST3 model predicts a relatively large value of 0.70 ppm at AQS2 (Fort McMurray) where the maximum observed value is 0.21 ppm. The ISCST3 model also predicts many more exceedences (377) of 0.17 ppm than observed (119).

The ISC3BE maximum predicted values are about 75% of the maximum observed values. The maximum predicted values are very similar to the 5th highest observed values. While the number of exceedences of 0.17 ppm value (209) is greater than the observed value (119), it is less than that predicted using the ISCST3 model.

The application of the Mannix meteorology indicates that the ISCST3 model does not predict the preference towards the daytime occurrence of SO_2 events that has been observed. The modified ISC3BE model, however, shows the daytime preference that has been observed.

In summary, the ISC3BE model is better able to predict the diurnal trends associated with high concentration events, better predict the frequency of exceedences and the maximum values fall between the highest and 5th highest observations. On this basis, the model was deemed to provide a realistic simulation of air quality in the region.

Table II-2 Observed and Predicted (Using Mannix Meteorology) SO_2 Concentrations (ppm) (from BOVAR (1996e)

Monitoring Site	Observed			Predicted			
	Maximum	5th Highest	N > 0.17[a]	ISCST3		ISC3BE	
				Maximum	N > 0.17[b]	Maximum	N > 0.17[b]
Mannix	0.42	0.32	29 (17)	0.58	197 (118)	0.31	75 (45)
Lower Camp	0.32	0.20	8 (5)	0.27	12 (7)	0.27	25 (15)
Fina	0.39	0.27	30 (18)	0.29	67 (40)	0.27	23 (14)
Poplar Creek	0.36	0.17	4 (2)	0.21	6 (4)	0.26	17 (10)
Athabasca	0.30	0.22	8 (5)	0.14	0 (0)	015	0 (0)
AQS1	0.40	0.25	11 (7)	0.34	11 (7)	0.24	12 (7)
AQS2	0.21	0.17	5 (3)	0.70	25 (15)	0.21	8 (5)
AQS3	0.41	0.21	12 (7)	0.51	37 (22)	0.29	47 (28)
AQS4	0.26	0.20	6 (4)	0.23	6 (4)	0.18	2 (1)
AQS5	0.18	0.11	1 (1)	0.22	11 (7)	0.16	0 (0)
Fort McKay	0.25	0.17	4 (2)	0.18	1 (1)	0.15	0 (0)
Fort McMurray	0.17	0.13	1 (1)	0.25	4 (2)	0.15	0 (0)
Birch Mountain	0.08	0.06	0 (0)	0.12	0 (0)	0.10	0 (0)
Average	0.28	0.18	9 (5)	0.31	29 (17)	0.21	16 (10)
Total			119 (71)		377 (227)		209(125)

[a] Values in brackets are analyzed for an annual period.

II-1.4 NO to NO_2 Conversion

The ISCST3 and ISC3BE models do not incorporate chemistry and as such will only predict ambient NO_x (the sum of NO and NO_2) concentrations. The ozone limiting method was applied to the model predictions to estimate ambient NO_2 concentrations. This method assumes:

$$NO_2 = 0.1\ [NO_x] + MIN\ (0.9\ [NO_x], [O_3])$$

and is based on 10% of the NO to NO_2 conversion taking place by thermal means in the stacks (or exhausts), and the remaining 90% of the NO to NO_2 conversion depending on the amount of ambient ozone present. In the application of this method, AEP (1994b) recommends a background O_3 value of 26 ppb. This use of the value compares favourably with observations in the region (BOVAR 1997). The above approach assumes all concentrations expressed in a volumetric basis (e.g., ppb).

II-2 CALPUFF

II-2.1 Model Description

The AEP model ADEPT2 has been historically used in Alberta to predict the wet and dry deposition of SO_2 and SO_4^{2-} from SO_2 emitting sources. The ADEPT2 model, however, does not account for NO_x chemistry and removal and because of the relative increase in NO_x emissions and decrease of SO_2 emissions in the region, an alternate model was selected to predict deposition. The criteria for selecting an alternate model were as follows:

- The model has to include both SO_2 and NO_x chemistry.
- The model has to include wet and dry removal processes (deposition).
- The model has to be applicable for spatial scales ranging from a few kilometres to 100 km.
- It is preferable if the model has a recognized regulatory agency support.
- It is preferable that the model documentation is readily available for stakeholder review.
- It is preferable that the computer requirements for the model be reasonable.

On this basis, the CALPUFF model was selected (U.S. EPA et al. 1996). The development of this model was based on producing a technically sound, regional air quality model for regulatory assessments. Major features of this model are provided in Table II-3. The model provides the user with a considerable number of options to meet specific needs.

II-2.2 Input Parameters

The model requires similar types of input as other models.

Meteorological Characterization. The same Mannix data used for the ISC3BE model was used for the CALPUF model. However, in order to incorporate chemistry and deposition, the following additional hourly data are required:

- ***Friction Velocity (U*).*** While values of U* are not required for ISC3BE, values from the Mannix station are available (BOVAR 1996d).
- ***Monin-Obukhov Length (L).*** Similarly, values from the Mannix station are available (BOVAR 1996d).
- ***Surface Roughness (Z).*** A constant surface roughness value of 1 m was used.
- ***Precipitation Code.*** For ambient temperatures less than 0°C, the precipitation was assumed to be frozen and for ambient temperatures greater than 0°C, the precipitation was assumed to be in the liquid state.
- ***Precipitation Rate.*** Hourly precipitation data from Fort McMurray Airport for the corresponding time period were used (see Section D2.4.5).
- ***Potential Lapse Rate.*** Hourly values based on stability class and Mannix tower observations were used.
- ***Short Wave Radiation.*** Short wave radiation values were calculated from the net radiation data collected at Mannix.
- ***Relative Humidity.*** Relative humidity values observed at Mannix were used.

Table II-3 Major Features of the CALPUFF Model

Source types
- Point sources (constant or variable emissions)
- Line sources (constant emissions)
- Volume sources (constant or variable emissions)
- Area sources (constant or variable emissions)

Non-steady-state emissions and meteorological conditions
- Gridded 3-D fields of meteorological variables (winds, temperature)
- Spatially-variable fields of mixing height, friction velocity, convective velocity scale, Monin-Obukhov length, precipitation rate
- Vertically and horizontally-varying turbulence and dispersion rates
- Time-independent source and emissions data

Dispersion Coefficient (σ_v, σ_z) Options
- Direct measurements of σ_v and σ_w
- Estimated values of σ_v and σ_w based on similarity theory
- Pasquill-Gifford (PG) dispersion coefficients (rural areas)
- McElroy-Pooler (MP) dispersion coefficients (urban areas)

Vertical Wind Shear
- Puff splitting
- Differential advection and dispersion

Plume Rise
- Partial penetration
- Buoyant and momentum rise
- Stack tip effects
- Vertical wind shear

Dry Deposition
- Gases and particulate matter
- Three options:
  - Full treatment of space and time variations of deposition with a resistance model
  - User-specified diurnal cycles for each pollutant
  - No dry deposition

Chemical Transformation Options
- Pseudo-first-order chemical mechanism for SO_2, SO, NO_x, HNO_3, and NO (MESOPUFF II method)
- User-specified diurnal cycles of transformation rates

Wet Removal
- Scavenging coefficient approach
- Removal rate a function of precipitation intensity and precipitation type

Graphical User Interface
- Click-and-point model set-up and data input
- Enhanced error checking of model inputs

Chemistry and Deposition Characterization. Default model values were used to estimate the chemistry, wet and dry deposition. Deposition to a forest canopy with a Leaf Area Index (LAI) of 7 was assumed. This value was assumed to be constant with time of year and hence may overestimating the depodition during the non-summer period. Background ozone and ammonia concentrations of 26 ppb and 0.22 ppb were used.

Receptors. Like ISCST3, the model requires the location and elevation of receptors. A total of 1527 receptors with a spacing of 4 km were used for the RSA. The terrain adjusted factors were assigned the same values used in the ISC3BE model.

II-2.3 Evaluation (SO_2 Sources)

The CALPUFF model was selected to predict annual deposition of SO_2 (and NO_x). Prior to use, the annual CALPUFF predictions were compared to those provided in BOVAR 1996e (referred to as BE96e). For the purposes of comparison, the 1995 Suncor and Syncrude SO_2 emissions are used:

- Suncor Powerhouse SO_2 = 211 t/d
- Suncor Incinerator SO_2 = 17 t/d
- Syncrude Main SO_2 = 213 t/d

The CALPUFF model was used to predict regional study area contours for:

- Annual average SO_2 concentrations (μg/m^3). These are compared to the annual values provided in Figure 4.13 of BE96e.
- Annual average SO_2 and SO_4^{-2} dry depositions (kg SO_4^{-2} equivalent/ha/a). These are compared to annual values provided in Figure 5.4 of BE96e.
- Annual SO_2 and SO_4^{-2} wet depositions (kg SO_4^{-2} equivalent/ha/a). These are compared to annual values predicted in Figure 5.8 of BE96d.

The overall maximum predicted annual value and the shape of the contour patterns were compared. The maximum values are presented in Table II-4. The maximum annual average SO_2 concentrations are similar while CALPUFF predicts a larger maximum dry deposition and a smaller maximum wet deposition. The larger dry deposition is likely due to the CALPUFF assumption of a canopy resistance that is uniform for the whole year. The ADEPT2 model assumes larger canopy resistances during the winter which would reduce the predicted deposition during this season. The differences between the wet deposition could be due to

Table II-4 Comparison of ISC3BE/ADEPT2 and CALPUFF Model SO_2 Related Predictions

Maximum Annual Value	ISC3BE/ADEPT2	CALPUFF
SO_2 concentration (μg/m³)	12.0	10.6
Wet deposition (kg SO_4^{-2}/ha/a)	18.3	14.6
Dry deposition (kg SO_4^{-2}/ha/a)	10.0	17.8

Suncor Powerhouse:	SO_2 = 211 t/d
Suncor Incinerator:	SO_2 = 17 t/d
Syncrude Main Stack:	SO_2 = 213 t/d

differences between the model approaches. CALPUFF assumes hourly precipitation while ADEPT2 assumes long-term climatological averages.

Figures II-1 and II-2 compare the annual average SO_2 concentration from the ISC3BE and CALPUFF models, respectively. Figure II-1 is taken from Figure 4.13 in BE96e. The general shape of the annual average concentration pattern is similar for the two models.

Figures II-3 and II-4 compare the annual average dry deposition from the ADEPT2 and CALPUFF models, respectively. Figure II-3 is taken from Figure 5.4 in BE96e. The shape differs for the two models. The CALPUFF pattern more closely replicates that associated with the ISC3BE concentration pattern. As such CALPUFF is predicting higher deposition values to the east and northwest of the source areas than ADEPT2.

Figures II-5 and II-6 compare the annual average wet deposition from the ADEPT2 and CALPUFF models, respectively. Figure II-5 is taken from Figure 5.8 of BE96e. The CALPUFF model is predicting larger wet deposition values closer to the source region than the ADEPT2 model.

Based on this comparison, the CALPUFF model predictions are sufficiently similar to those provided by ISC3BE and ADEPT2 and as such is acceptable for evaluating air quality in the region.

II-2.4 Evaluation (NO_x Sources)

ISCST3 and ISC3BE treat open pit mines explicitly providing for an initial in-pit dilution, allowing the emissions to escape from the pit at the upwind portion of the pit and calculating the dispersion at and beyond the downwind edge of the pit. The CALPUFF model does not allow the mine to be explicitly replicated and as such the mine has to be treated as an area or volume source. The challenge is to select appropriate area or volume source parameters such that the concentration, magnitude and pattern predicted by CALPUFF is similar to that provided by the ISCST3 based models.

A preliminary comparison of the ISCST3 and ISC3BE model predictions indicated these models overpredict the maximum hourly NO_x concentration from a mine pit by a factor of about 1.8 (BOVAR 1997). This is equivalent to applying the 0.55 averaging time correction factor recommended by Alberta Environmental Protection (1994b). This 0.55 factor was applied to the prediction of concentrations from mine pit sources. The 0.55 correction factor was not applied to other sources since there were no supporting measurements.

Figure II-1 Annual Average SO_2 Concentration ($\mu g/m^3$) Predicted Using the ISC3BE Model (from Figure 4.13 in BE96e)

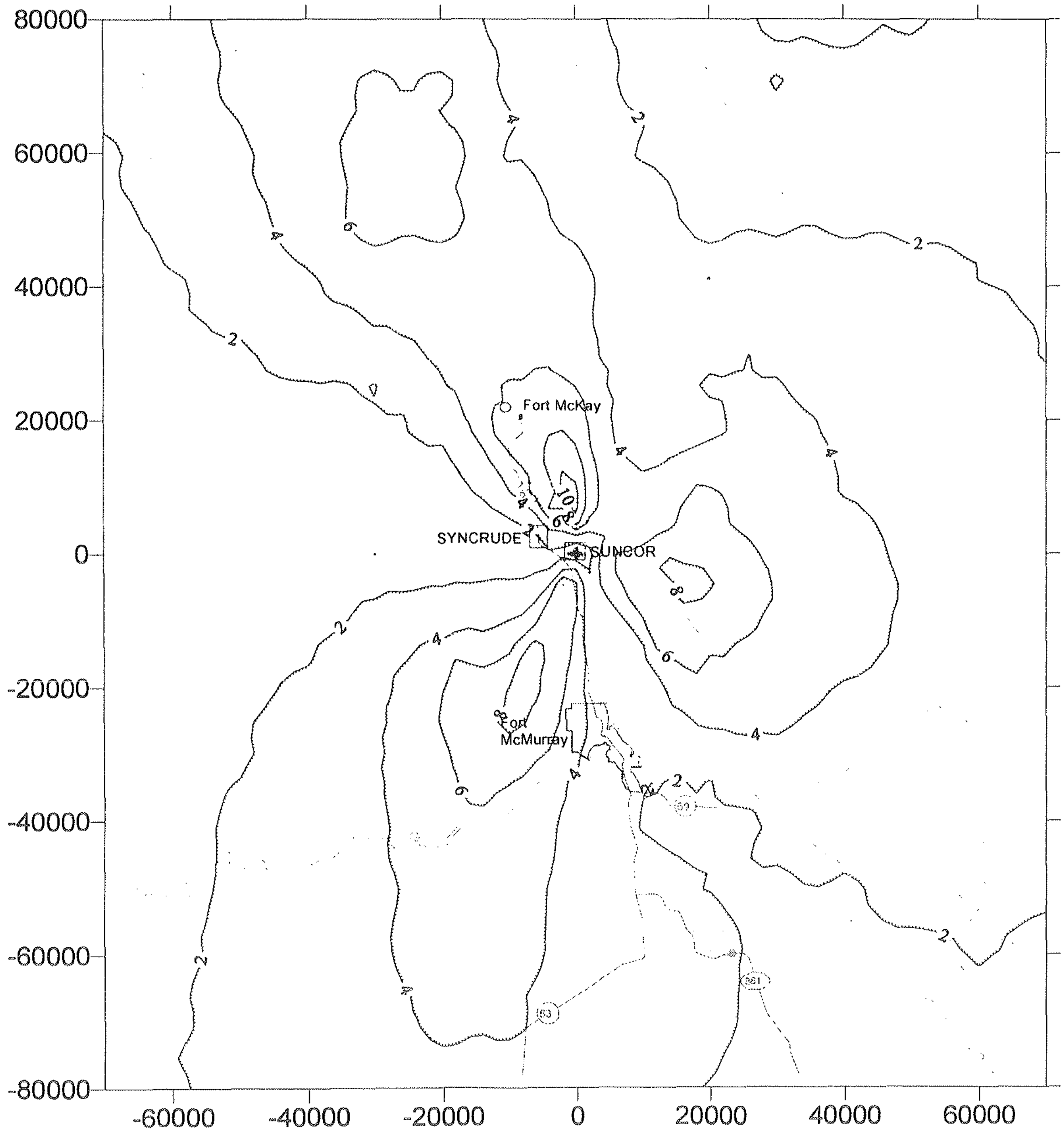


Figure II-2 Annual Average SO_2 Concentration (µg/m^3) Predicted Using the CALPUFF Model

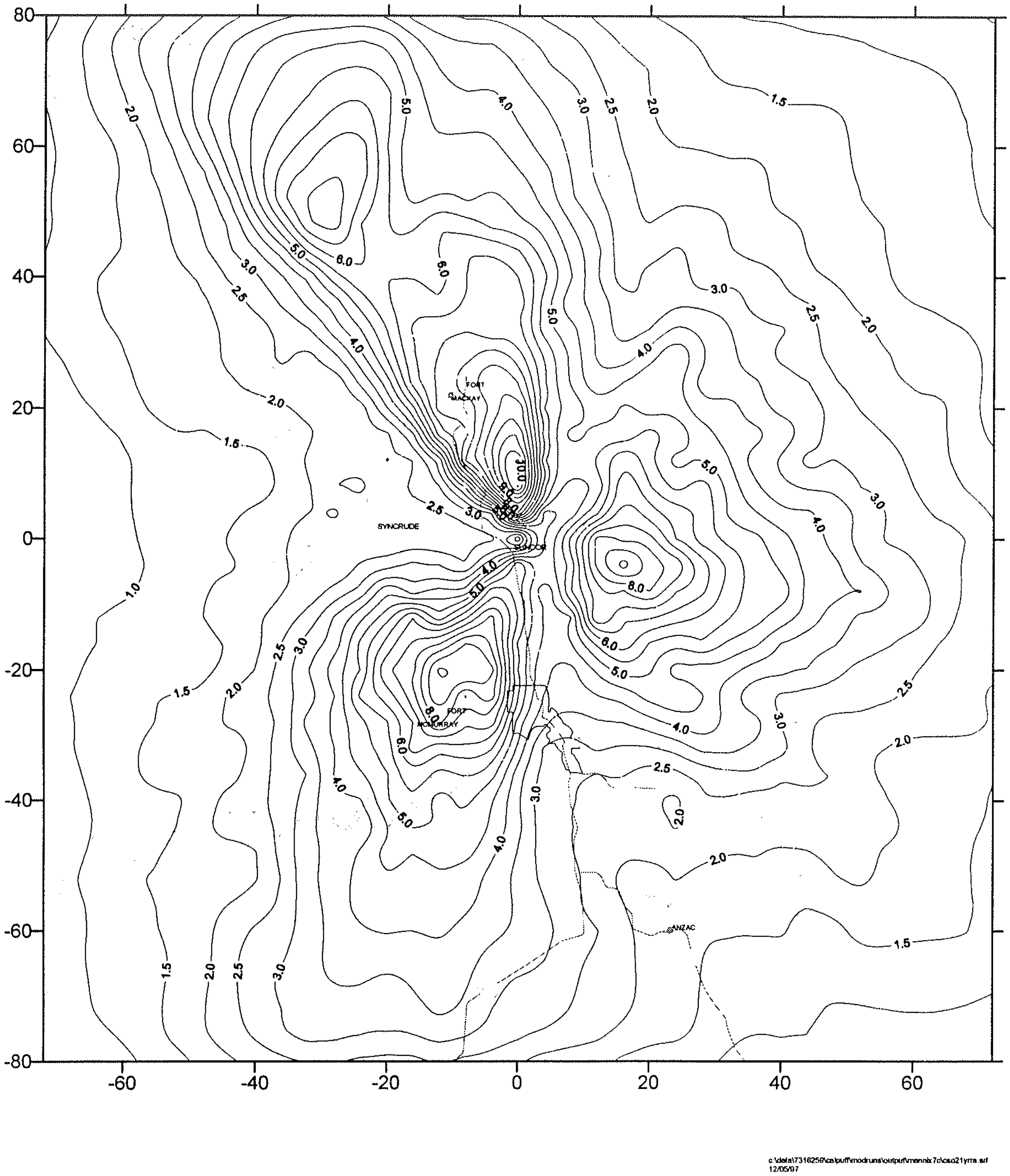


Figure II-3 **Annual Dry Deposition (kg SO_4^{-2}/ha/a) Predicted Using the ADEPT2 Model (from Figure 5.4 in BE96e)**

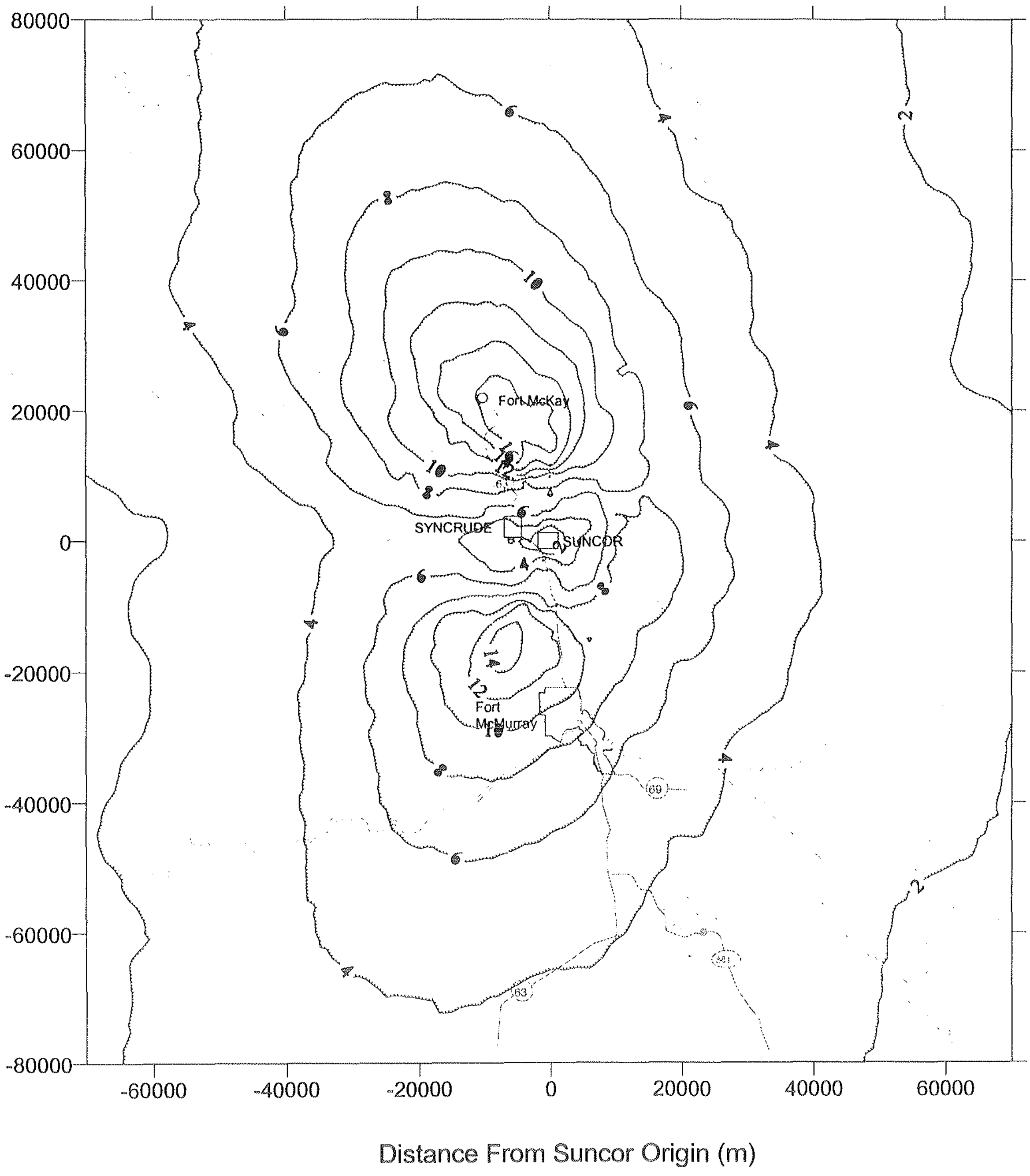
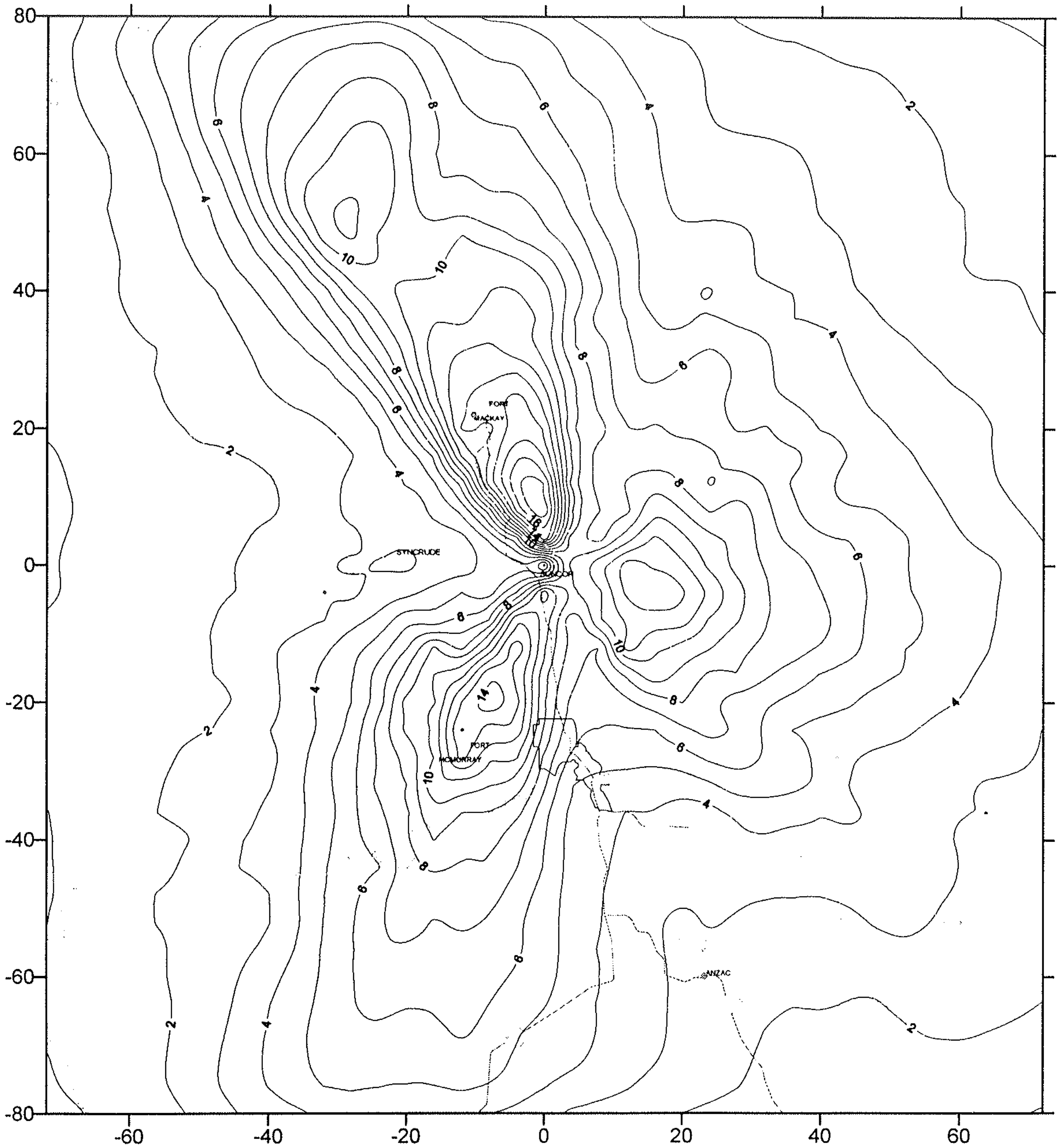


Figure II-4 Annual Dry Deposition (kg SO_4^{-2}/ha/a) Predicted Using the CALPUFF Model



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12/05/97

Figure II-5 Annual Wet Deposition (kg SO_4^{-2}/ha/a) Predicted Using the ADEPT2 Model (from Figure 5.8 in BE96e)

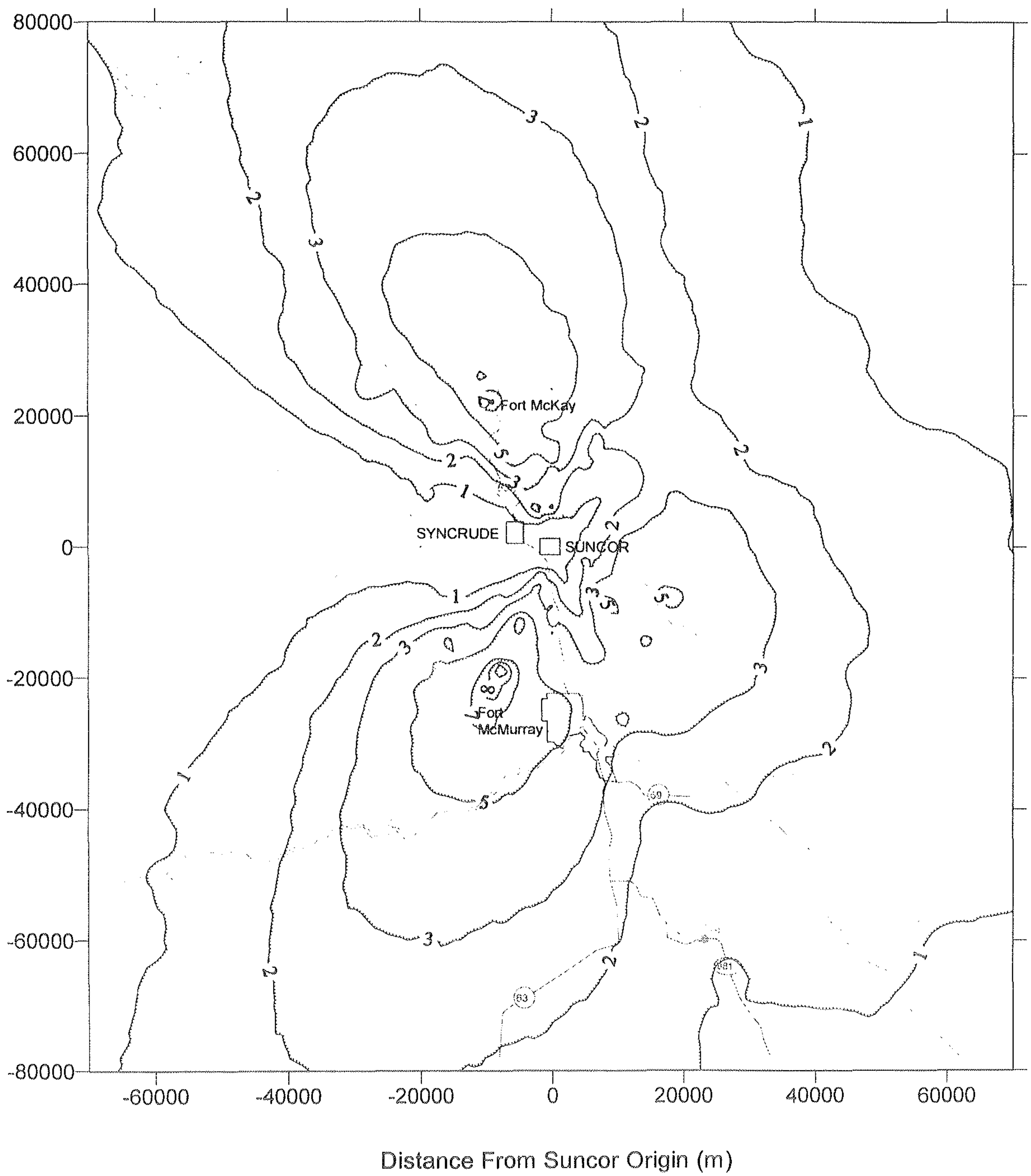
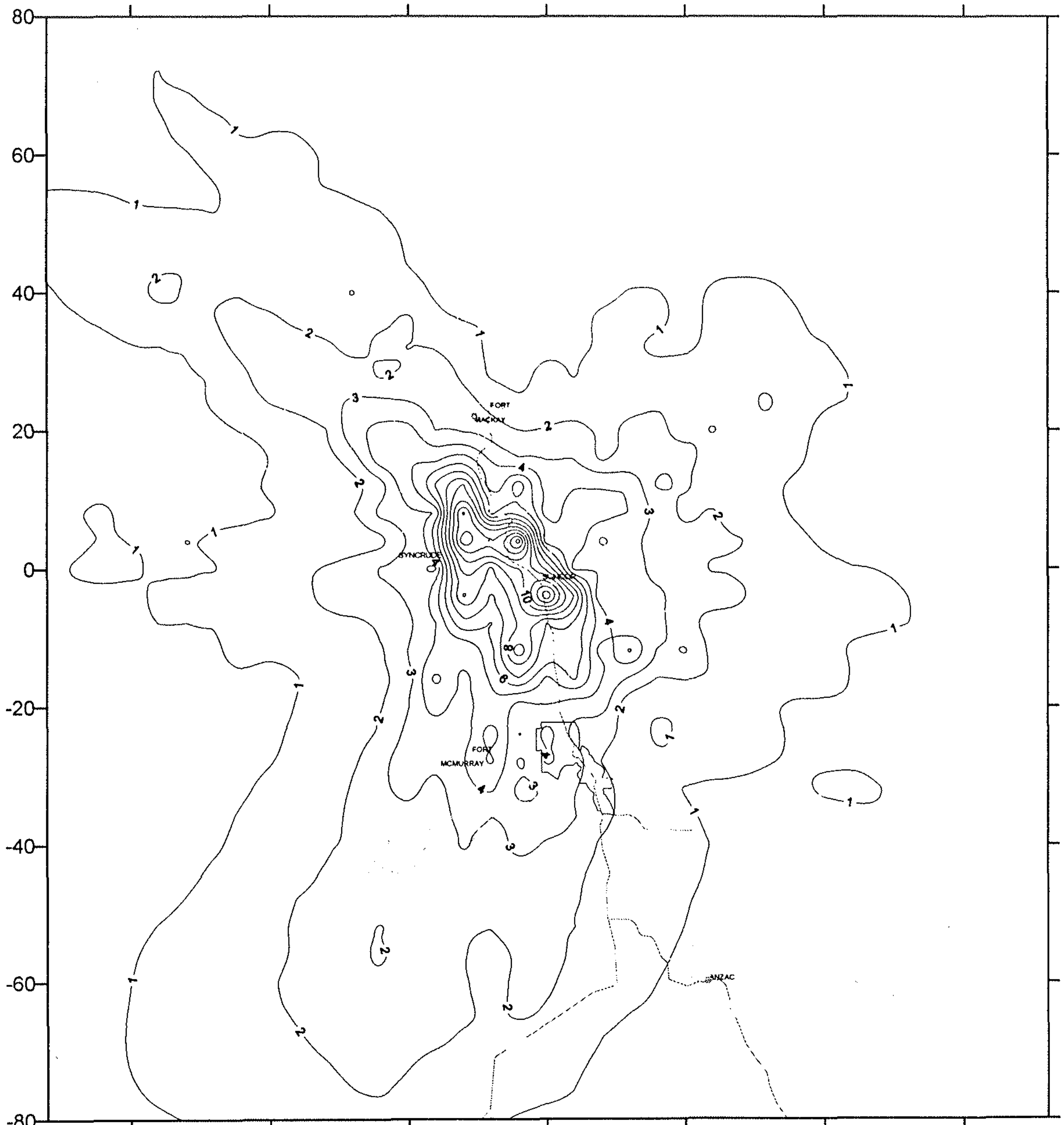


Figure II-6 Annual Wet Deposition (kg SO_4^{-2}/ha/a) Predicted Using the CALPUFF Model



The mine source assumptions and associated maximum values are compared in Table II-5. While the corresponding values predicted by CALPUFF are lower than those predicted using ISC3BE, the annual concentrations further downwind from the mine are more similar.

Figure II-7 shows the maximum annual average NO_x concentrations from the Project fleet emissions using the ISC3BE model. The model shows very strong concentration gradients immediately adjacent to the mine. The 10 $\mu g/m^3$ concentration gradient has a north-south extent of about 20 km.

Figure II-8 shows a similar concentration contour pattern predicted using the CALPUFF model. Lower concentrations are predicted to occur in the immediate vicinity of the Project. The north-south extent of the 10 $\mu g/m^3$ contour is similar to that predicted by ISC3BE.

In summary, the CALPUFF model does not replicate the concentrations adjacent to the mine (i.e., it underpredicts). However, the concentration profiles further downwind are more similar.

There are no previous predictions of NOx deposition to compare to those provided by CALPUFF. Nonetheless, the predicted wet and dry nitrate equivalent deposition associated with the mine are provided in Figures II-9 and II-10, respectively. The comparison and further analysis ndicates the deposition is completely dominated by the dry deposition of NO_2.

II-2.3 Resolution

Compared to the ISC3BE model predictions, a related cross grid system was used for the CALPUF predictions (i.e., a cartesion grid system with a spacing of 4 km). The use of this grid system, along with the assumption of homogeneous wind at receptor levels will limit five scale resolution. In summary, the resolution of the CALPUF model predictions are in the order of the grid spacing. This scale, however is a much finer scale than the earlier scale presented in Section D2.6.4.

Table II-5 Comparison of Mine Source Assumptions and Associated CALPUFF and ISC3BE Model Predictions for the Muskeg River Mine NO_x Emissions

	CALPUFF	ISC3BE
Source Type	Volume	Mine Pit
Pit volume (m^3)	-	$2.61 \cdot 10^8$
Release height (m)	10	5.5
Pit length (m)	-	3101
Pit width (m)	-	1495
Initial σ_y (m)	3360 (diagonal)	-
Initial σ_z (m)	2.3 (10/4.3)	-
Time Correction factor	0.55	0.55
Meteorology	Mannix	OLSO
Maximum 1 hour concentration ($\mu g/m^3$)	1400	1580
Maximum 1 day concentration ($\mu g/m^3$)	400	672
Maximum annual concentration ($\mu g/m^3$)	98	155

Figure II-7 Annual Average NO_x Concentrations ($\mu g/m^3$) Predicted to Occur for the Muskeg River Mine Pit Using the ISC3BE Model

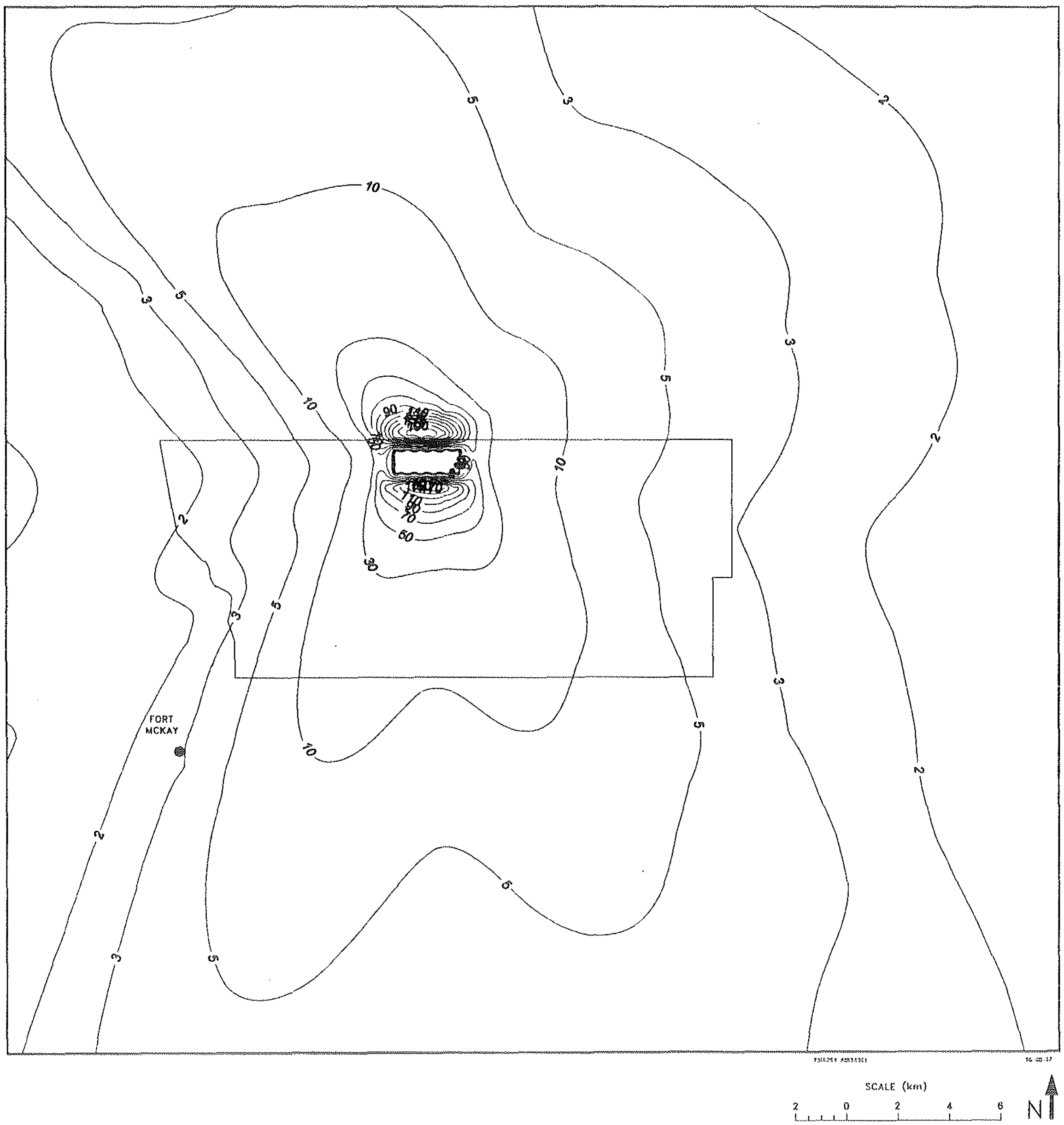


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Figure II-8 **Annual Average NO_x Concentrations ($\mu g/m^3$) Predicted to Occur for the Muskeg River Mine Pit Using the CALPUFF Model**

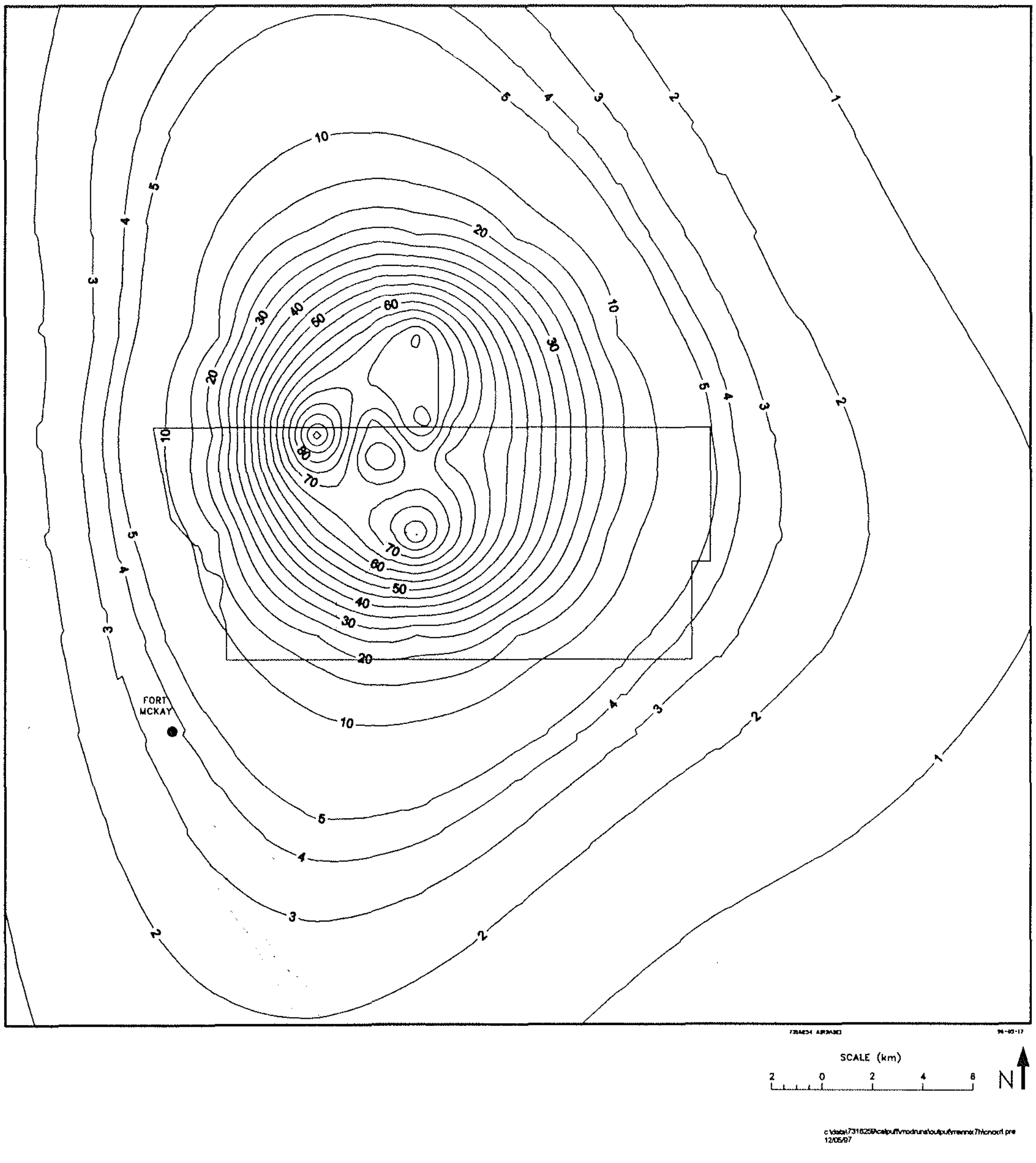


Figure II-9 **Nitrate Equivalent Dry Deposition Associated With the Muskeg River Mine Fleet NO_x Emissions**

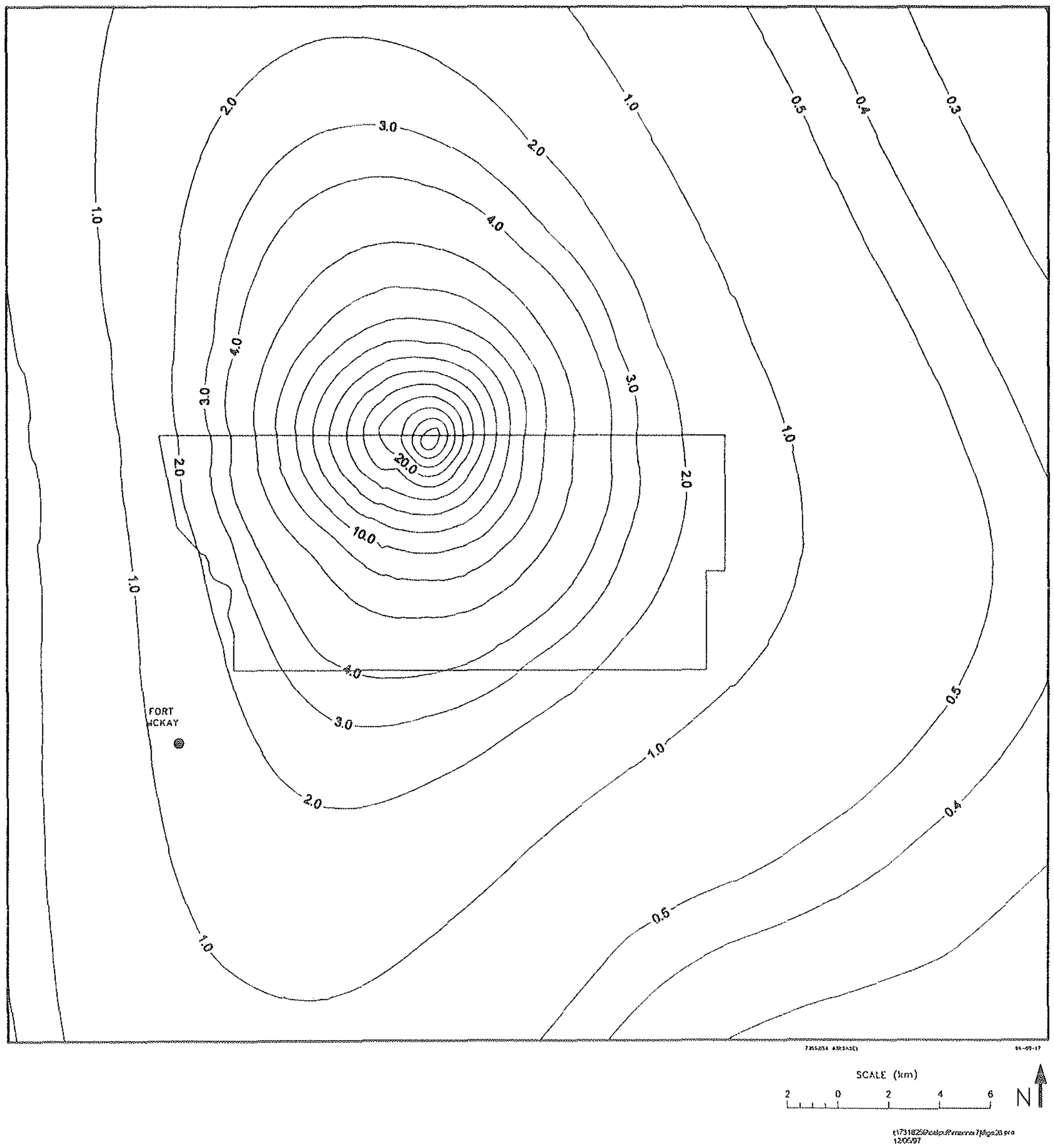
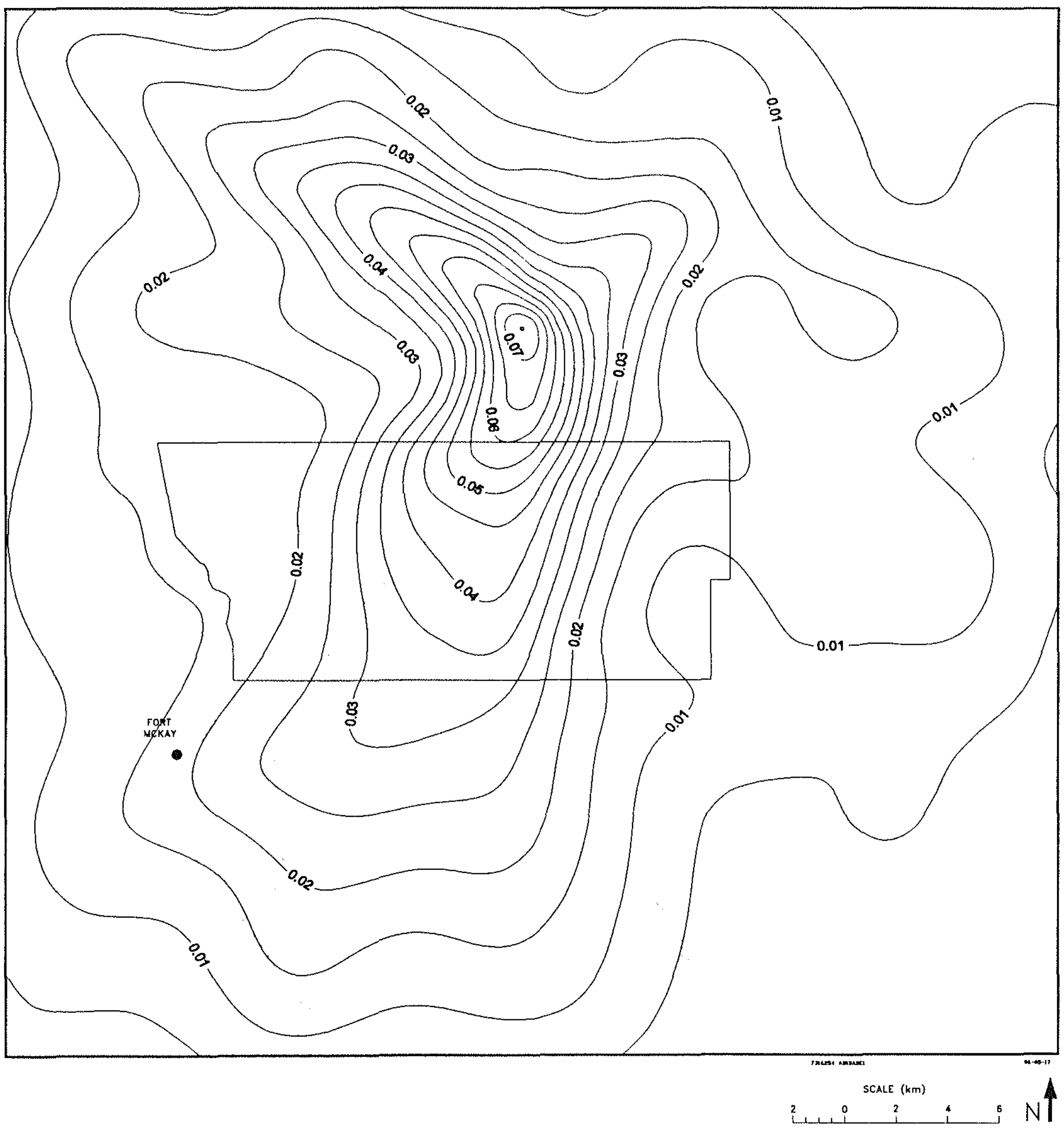


Figure II-10 **Nitrate Equivalent Wet Deposition Associated With the Muskeg River Mine Fleet NO_x Emissions (kg NO_3^-/ha/a)**



Common Name	*Scientific Name*
VEGETATION	
awned hair cap	*Polytrichum piliferum*
balsam fir	*Abies balsamea*
balsam poplar	*Populus balsamifera*
beaked hazelnut	*Corylus cornuta*
bearberry	*Arctostaphylos uva-ursi*
bishop's cap	*Mitella nuda*
blueberry	*Vaccinium angustifolium var. myrtilloides*
bog cranberry	*Vaccinium vitis-idaea*
bracted honeysuckle	*Lonicera involucrata*
brown moss	*Drepanocladus spp.*
brown-foot cladonia	*Cladonia gracilis*
buck-bean	*Menyanthes trifoliata*
bulrush	*Scirpus spp.*
bunchberry	*Cornus canadensis*
Canada buffalo-berry	*Sheperdia canadensis*
cattail	*Typha latifolia*
choke cherry	*Prunus virginiana*
cloudberry	*Rubus chamaemorus*
common horsetail	*Equisetum arvense*
common pink wintergreen	*Pyrola asarifolia*
cotton grasses	*Eriophorum sp.*
cream-colored vetchling	*Lathyrus ochroleucus*
creeping spike-rush	*Eleocharis palustris*
currant	*Ribes spp.*
dewberry	*Rubus pubescens*
dogwood	*Cornus stolonifera*
dwarf birch	*Betula pumila*
dwarf scouring rush	*Equisetum scirpoides*
feathermoss	*Pleurozium spp.*
fireweed	*Epilobium angustifolium*
golden moss	*Tomenthypnum nitens*
green alder	*Alnus crispa*
hairy wild rye	*Elymus innovatus*
jack pine	*Pinus banksiana*
knight's plume moss	*Ptilium crista-castrensis*
Labrador tea	*Ledum groenlandicum*

Common Name	*Scientific Name*
lichens	*Cladonia sp., and Cladina sp*
low-bush cranberry	*Viburnum edule*
marsh cinquefoil	*Potentilla palustris*
marsh marigold	*Caltha palustris*
marsh reed grass	*Calamagrostis canadensis*
marsh skullcap	*Scutellaria galericulata*
meadow horsetail	*Equisetum pratense*
midway peat moss	*Sphagnum magellanicum*
northern reed grass	*Calamagrostis inexpansa*
northern willowherb	*Epilobium ciliatum*
oak fern	*Gymnocarpium dryopteris*
palmate-leaved coltsfoot	*Petasites palmatus*
peat moss	*Sphagnum spp.*
peat moss	*Sphagnum angustifolium*
peat moss	*Sphagnum fuscam*
pin cherry	*Prunus pensylvanica*
pitcher plants	*Sarracenia purpurea*
prickly rose	*Rosa acicularis*
ragged moss	*Brachythecium spp.*
reed grass	*Phalaris spp./Phragmites spp.*
reindeer lichen	*Cladina spp.*
river alder	*Alnus tenuifolia*
rushes	*Juncus sp., Luzula sp.*
sand heather	*Hudsonia tomentosa*
saskatoon	*Amelanchier alnifolia*
Schreber's moss	*Pleurozium schreberi*
scorpion feathermoss	*Scorpidium scorpioides*
sedges	*Carex spp.*
shield fern	*Dryopteris carthusiana*
shore-growing peat moss	*Sphagnum. riparium*
showy aster	*Aster conspicuus*
slender hair-cap moss	*Polytrichum strictum*
small bog cranberry	*Oxycoccus microcarpus*
snowberry	*Symphoricarpos albus*
stair-step moss	*Hylocomium splendens*
stiff club-moss	*Lycopodium annotinum*
sweet gale	*Myrica gale*

Common Name	*Scientific Name*
sweet-scented bedstraw	*Galium triflorum*
tall lungwort	*Mertensia paniculata*
tamarack	*Larix laricina*
three-leaved Solomon's seal	*Smilacina trifolia*
trembling aspen	*Populus tremuloides*
tufted moss	*Aulacomnium palustre*
twin-flower	*Linnaea borealis*
water smartweed	*Polygonum amphibium*
white birch	*Betula papyrifera*
white spruce	*Picea glauca*
wild lily-of-the-valley	*Maianthemum canadense*
wild mint	*Mentha arvensis*
wild red raspberry	*Rubus idaeus*
wild sarsaparilla	*Aralia nudicaulis*
wild strawberry	*Frageria virginiana*
willow	*Salix spp.*
woodland horsetail	*Equisetum sylvaticum*
algae	*Selenastrum capricornutum*
INVERTEBRATES	
chironomid midge larvae	*Chironomus tentans*
amphipod	*Hyallela azteca*
oligocaete worm	*Lumbriculus*
stoneflies	*Plecoptera*
mayflies	*Ephemeroptera*
dragonflies and daselflies	*Odonata*
caddishflies	*Trichoptera*
water flea	*Daphnia magna*
water flea	*Ceriodaphnia dubia*
luminescent bacteria	*Vibrio fischeri*
FISH	
arctic grayling	*Thymallus arcticus*
brook stickleback	*Culaea inconstans*
bull trout	*Salvelinus Confluentus*
burbot	*Lota Lota*
cisco	*Coregonus artedi*
emerald shiner	*Notropis atherinoides*
Fathead Minnow	*Pimephales promelas*

Common Name	*Scientific Name*
finescale Dace	*Platygobio gracilis*
goldeye	*Hiodon alosoides*
Iowa Darter	*Etheostoma exile*
lake Chub	*Couesius plumbeus*
lake whitefish	*Coregonus clupeaformis*
longnose Dace	*Rhinichthys cataractae*
longnose Sucker	*Catostomus catostomus*
mountain Whitefish	*Prosopium williamsoni*
ninespine Stickleback	*Pungitius pungitius*
northern Pike	*Esox lucius*
northern Redbelly Dace	*Phoxinus eos*
pearl Dace	*Semotilus margarita*
rainbow trout	*Oncorhynchus mykiss*
river Shiner	*Notropis blennius*
shiner Species	*Notropis sp.*
slimy Sculpin	*Cottus cognatus*
spoonhead Sculpin	*Cottus ricei*
spottail Shiner	*Notropis hudsonius*
trout Perch	*Percopsis omiscomaycus*
walleye	*Stizostedion vitreum*
white Sucker	*Catostomus commersoni*
yellow Perch	*Perca flavescens*
REPTILES AND AMPHIBIANS	
Canadian toad	*Bufo hemiophrys*
red-sided garter snake	*Thamnophis sirtalis*
stripped chorus frog	*Pseudacris triseriata*
wood frog	*Rana sylvatica*
BIRDS	
alder flycatcher	*Empidonax alnorum*
American bittern	*Botaurus lentiginosus*
American coot	*Fulica americana*
American crow	*Corvus brachyrhynchos*
American goldfinch	*Carduelis tristis*
American kestrel	*Falco sparverius*
American pipit	*Anthus rubescens*
American redstart	*Setophaga ruticilla*
American robin	*Turdus migratorius*

Common Name	*Scientific Name*
American tree sparrow	*Spizella arborea*
American white pelican	*Pelecanus erythrorhynchos*
American wigeon	*Anas americana*
bald eagle	*Haliaeetus leucocephalus*
bank swallow	*Riparia riparia*
barn swallow	*Hirundo rustica*
bay-breasted warbler	*Dendroica castanea*
belted kingfisher	*Ceryle alcyon*
black tern	*Chlidonias niger*
black-and-white warbler	*Mniotilta varia*
black-backed woodpecker	*Picoides arcticus*
black-billed magpie	*Pica pica*
black-capped chickadee	*Parus atricapillus*
black-throated green warbler	*Dendroica virens*
blackpoll warbler	*Dendroica striata*
blue jay	*Cyanocitta cristata*
blue-winged teal	*Anas discors*
bohemian waxwing	*Bombycilla garrulus*
Bonaparte's gull	*Larus philadelphia*
boreal chickadee	*Parus hudsonicus*
boreal owl	*Aegolius funereus*
Brewer's blackbird	*Euphagus cyanocephalus*
broad-winged hawk	*Buteo platypterus*
brown creeper	*Certhia americana*
brown-headed cowbird	*Molothrus ater*
bufflehead	*Bucephalus albeola*
California gull	*Larus californicus*
Canada goose	*Branta canadensis*
Canada warbler	*Wilsonia canadensis*
canvasback	*Aythya valisineria*
Cape May warbler	*Dendroica tigrina*
cedar waxwing	*Bombycilla cedrorum*
chipping sparrow	*Spizella passerina*
clay-colored sparrow	*Spizella pallida*
cliff swallow	*Hirundo pyrrhonota*
common goldeneye	*Bucephala clangula*
common grackle	*Quiscalus quiscula*

Common Name	*Scientific Name*
common loon	*Gavia immer*
common merganser	*Mergus merganser*
common nighthawk	*Chordeiles minor*
common raven	*Corvus corax*
common redpoll	*Carduelis flammea*
common snipe	*Gallinago gallinago*
common tern	*Sterna hirundo*
common yellowthroat	*Geothlypis trichas*
Connecticut warbler	*Oporonis agilis*
dark-eyed junco	*Junco hyemalis*
double-crested cormorant	*Phalacrocorax auritus*
downy woodpecker	*Picoides pubescens*
eastern kingbird	*Tyrannus tyrannus*
eastern phoebe	*Sayornis phoebe*
European starling	*Sturnus vulgaris*
evening grosbeak	*Coccothraustes vespertinus*
fox sparrow	*Passerella iliaca*
Franklin's gull	*Larus pipixcan*
gadwall	*Anas strepera*
golden eagle	*Aquila chrysaetos*
golden-crowned kinglet	*Regulus satrapa*
gray jay	*Perisoreus canadensis*
great blue heron	*Ardea herodias*
great gray owl	*Strix nebulosa*
great-crested flycatcher	*Myiarchus crinitus*
great-horned owl	*Bubo virginianus*
greater yellowlegs	*Tringa melanoleuca*
green-winged teal	*Anas crecca*
hairy woodpecker	*Picoides villosus*
hermit thrush	*Catharus guttatus*
herring gull	*Larus argentatus*
hooded merganser	*Lophodytes cucullatus*
horned grebe	*Podiceps auritus*
horned lark	*Eremophila alpestris*
house sparrow	*Passer domesticus*
killdeer	*Charadrius vociferus*
least flycatcher	*Empidonax minimus*

Common Name	*Scientific Name*
least sandpiper	*Calidris minutilla*
LeConte's sparrow	*Ammodramus leconteii*
lesser scaup	*Aythya affinis*
lesser yellowlegs	*Tringa flavipes*
Lincoln's sparrow	*Melospiza lincolnii*
magnolia warbler	*Dendroica magnolia*
mallard	*Anas platyrhynchos*
marbled godwit	*Limosa fedoa*
marsh wren	*Cistothorus palustris*
merlin	*Falco columbarius*
mew gull	*Larus canus*
mountain bluebird	*Sialia currucoides*
mourning warbler	*Oporornis philadelphia*
northern flicker	*Colaptes auratus*
northern goshawk	*Accipiter gentilis*
northern harrier	*Circus cyaneus*
northern hawk owl	*Surnia ulula*
northern pintail	*Anas acuta*
northern shoveler	*Anas clypeata*
northern waterthrush	*Seiurus noveboracensis*
olive-sided flycatcher	*Contopus borealis*
orange-crowned warbler	*Vermivora celeta*
osprey	*Pandion haliaetus*
ovenbird	*Seiurus aurocapillus*
palm warbler	*Dendroica palmarum*
peregrine falcon	*Falco peregrinus*
Philadelphia vireo	*Vireo philadelphicus*
pied-billed grebe	*Podilymbus podiceps*
pileated woodpecker	*Dryocopus pileatus*
pine siskin	*Carduelis pinus*
purple finch	*Carpodacus purpureus*
red crossbill	*Loxia curvivostra*
red-breasted merganser	*Mergus serrator*
red-breasted nuthatch	*Sitta canadensis*
red-eyed vireo	*Vireo olivaceus*
red-necked grebe	*Podiceps grisegena*
red-tailed hawk	*Buteo jamaicensis*

Common Name	*Scientific Name*
red-winged blackbird	*Agelaius phoeniceus*
redhead	*Aythya americana*
ring-billed gull	*Larus delawarensis*
ring-necked duck	*Aythya collaris*
rock dove	*Columba livia*
rose-breasted grosbeak	*Pheucticus ludovicianus*
ruby-crowned kinglet	*Regulus calendula*
ruddy duck	*Oxyura jamaicensis*
ruffed grouse	*Bonasa umbellus*
rusty blackbird	*Euphagus carolinus*
sandhill crane	*Grus canadensis*
savannah sparrow	*Passerculus sandwichensis*
Say's phoebe	*Sayornis saya*
semipalmated plover	*Charadrius semipalmatus*
sharp-shinned hawk	*Accipiter striatus*
sharp-tailed grouse	*Tympanuchus phasianellus*
sharp-tailed sparrow	*Ammodramus caudacutus*
short-billed dowitcher	*Limnodramus griseus*
solitary sandpiper	*Tringa solitaria*
solitary vireo	*Vireo solitarius*
song sparrow	*Melospiza melodia*
sora	*Porzana carolina*
spotted sandpiper	*Actitis macularia*
spruce grouse	*Dendragapus canadensis*
Swainson's thrush	*Catharus ustulatus*
swamp sparrow	*Melospiza georgiana*
Tennessee warbler	*Vermivora peregrina*
three-toed woodpecker	*Picoides tridactylus*
tree swallow	*Tachycineta bicolor*
vesper sparrow	*Pooecetes grammineus*
warbling vireo	*Vireo gilvus*
western tanager	*Piranga ludoviciana*
western wood-pewee	*Contopus sordidulus*
white-crowned sparrow	*Zonotrichia leucophrys*
white-throated sparrow	*Zonotrichia albicollis*
white-winged crossbill	*Loxia leucoptera*
Wilson's phalarope	*Phalaropus tricolor*

Common Name	*Scientific Name*
Wilson's warbler	*Wilsonia pusilla*
winter wren	*Troglodytes troglodytes*
yellow warbler	*Dendroica petechia*
yellow-bellied flycatcher	*Empidonax flaviventris*
yellow-bellied sapsucker	*Sphyrapicus varius*
yellow-headed blackbird	*Xanthocephalus xanthocephalus*
yellow-rumped warbler	*Dendroica coronata*
MAMMALS	
arctic shrew	*Sorex arcticus*
beaver	*Castor canadensis*
big brown bat	*Eptesicus fuscus*
black bear	*Ursus americanus*
Canada lynx	*Lynx canadensis*
caribou	*Rangifer tarandus*
coyote	*Canis latrans*
deer mouse	*Peromyscus maniculatus*
dusky shrew	*Sorex monticolus*
ermine	*Mustela erminea*
fisher	*Martes pennanti*
gray wolf	*Canis lupus*
heather vole	*Phenacomys intermedius*
hoary bat	*Lasiurus cinereus*
least chipmunk	*Tamias minimus*
least weasel	*Mustela nivalis*
little brown bat	*Myotis lucifugus*
marten	*Martes americana*
masked shrew	*Sorex cinereus*
meadow jumping mouse	*Zapus hudsonius*
meadow vole	*Microtus pennsylvanicus*
mink	*Mustela vison*
moose	*Alces alces*
mule deer	*Odocoileus hemionus*
muskrat	*Ondatra zibethicus*
northern bog lemming	*Synaptomys borealis*
northern flying squirrel	*Glaucomys sabrinus*
northern long-eared bat	*Myotis septentrionalis*
porcupine	*Erethizon dorsatum*

Common Name	*Scientific Name*
pygmy shrew	*Sorex hoyi*
red fox	*Vulpes vulpes*
red squirrel	*Tamiasciurus hudsonicus*
river otter	*Lutra canadensis*
silver-haired bat	*Lasionycteris noctivagans*
snowshoe hare	*Lepus americanus*
southern red-backed vole	*Clethrionomys gapperi*
striped skunk	*Mephitis mephitis*
water shrew	*Sorex palustris*
white-tailed deer	*Odocoileus virginianus*
wolverine	*Gulo gulo*
woodchuck	*Marmota monax*

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