Impact Analysis Steepbank Mine EIA Surface Water and Groundwater

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Prepared for:

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A INTRODUCTION

A1.0 DOCUMENT SCOPE

This report is one of a series that address potential environmental and socio-economic impacts of the Suncor Steepbank Mine project (Figure A1.0-1). In particular, this report identifies changes to surface water or groundwater resulting from the proposed mine development. Some of this information is used to identify the effect of mine development on other environmental resources as well as assess the impact on four water-related issues of special concern. These issues are encapsulated in four hypothesis statements (numbers 24 through 27) which are presented along with the hypothesis statements for the other reports in the series in Table A1.0-1.

A2.0 SPATIAL AND TEMPORAL BOUNDARIES

The local study area of the hydrologic and hydrogeologic impact assessments is shown in Figure A2.0-1. The western edge of the study area is defined by the Athabasca River. The north and south boundaries are the Steepbank River and McLean Creek drainage basins, respectively. The temporal boundaries of the Impact Analysis have been selected to capture the four main stages of the mine development:

- Baseline Condition (1995);
- Construction Phase (1997 to 2001);
- Operational Phase (2001 to 2020); and
- Post Reclamation.

The construction and operation stages have been assessed by evaluating the conditions that are expected to exist in 2001, 2009 and 2020. The closure of the mine (post reclamation) has been assessed as the long-term, steady state condition that will exist several years after closure and reclamation of the mine. As necessary, other time periods between these reference points have been evaluated.

TABLE A1.0-1
STEEPBANK MINE EIA IMPACT HYPOTHESES SUMMARY LIST

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

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

33	Construction, operational or reclamation activities might lead to changes in fish abundance or quality of fish flesh which might result in a decreased use of the fish resource.
34	Construction, operational or reclamation activities might cause changes in Athabasca River water quality which limit downstream use of the water.
AIR	
35	Global climate change could be affected by increased release of greenhouse gases associated with production expansion related to the Steepbank Mine.
HISTORICAL RESOURCES	
36	Significant archaeological, paleontological or historical resources could be affected by the development and operation of the Steepbank Mine.

B KEY FACTORS USED TO ASSESS IMPACT

The impacts to water resources that have been evaluated are the changes in flow and water quality.

The impacts on surface water have been evaluated on the basis of changes in:

- direction of surface water flow;
- rate of surface water runoff; and
- water quality.

The impacts on groundwater have been evaluated on the basis of changes in:

- direction of groundwater flow;
- rate of groundwater discharge to surface water bodies; and
- groundwater quality.

The term "water quality" refers to the concentration of dissolved and suspended compounds found, either naturally or otherwise, in surface waters and groundwater.

The degree of significance of various impacts was assessed by a qualitative evaluation of the severity, duration and anticipated areal extent of each impact. Severity was assessed as either high, medium or low, based on the impacts to either flow or water quality. Duration was short term if the impact occurred through the life of the mine and long-term if beyond the life of the mine. Areal extent was considered local if the effect was in the immediate mine area and regional if beyond the immediate mine area. A final assessment of the degree of concern was made based on the expected impact on the receiving water body (either the Athabasca or Steepbank Rivers), as described in Hypothesis 24, in Table A1.0-1.

C MINE DEVELOPMENT

Following is a brief description and chronology of the components of mine development pertinent to the assessment of impacts on water resources in the study area. Baseline (1995) conditions are shown in Figure C-1. Plans showing the overall mine development and drainage in 2001, 2009, 2020 and post reclamation are attached (Figures C-2 to C-5).

- 1995 Baseline Conditions
  - Background conditions.
- 1997 - 2001 (Facility Construction)
  - Bridge construction will start in 1997 and is expected to be completed in 1999. Until this time, the Athabasca River will be crossed by barge or using an ice bridge.
  - Permanent access roads will be constructed in 1998.
  - A gravel pit will be developed in 1997 and 1998.
  - Initial site drainage for Pit 1, stormwater retention basins A, B, C and D will be completed by 2000.
  - Surficial deposits at Pit 1 are dewatered, and groundwater is diverted around the pit.
  - The excavation of Pit 1 will start in 2000. Overburden will be placed in the active mine area.
  - Plant facilities, water supply systems and sewage disposal system will be constructed between 1997 and 2000.
  - Two water wells for supplying plant and shop facilities have been completed in the surficial deposits on the Athabasca River floodplain. Total well production is estimated to be approximately 7.6 L/s (650 m^3/day).
  - The bridge is constructed, and plant and shop facilities are in place.
  - The North Dump is being used for overburden.
  - Channels 0-D, 0-E and 0-F have been constructed to intercept natural runoff flowing west towards Pit 1 and convey it to Shipyard Lake.
- 2001 - 2009 (Pit 1 Development)
  - Excavation of Pit 1 continues until 2009.

- Construction of the dyke for Pond 7 starts in 2002. Until 2005, there will be limited opportunity for storing excess mine drainage in Pit 1. It is assumed that the dyke will be revegetated as construction progresses.
- A dyke bisecting Pit 1 is built in 2007 and 2008. This dyke, together with the surrounding dykes will permit the use of Pond 7 for tailings disposal while the south portion of Pit 1 is being excavated.
- Overburden material is being placed on the North, West and East Dumps. It is planned to construct the West Dump over part of Shipyard Lake, reducing the total area of this wetlands from 128 to 90 hectares and the area of open water from 23 to 19 hectares.
- Channels 9-A and 9-B are constructed in 2008 to intercept natural runoff. The north portion of the runoff is conveyed to Shipyard Lake in Channel 9-A and the southern portion of the drainage is conveyed to Leggett Creek in Channel 9-B.
- Mine stormwater retention Basin E is constructed.
- It is assumed that de-pressurizing the Basal Aquifer under the southern portion of Pit 1 commences in this period, if required.
- The mining of Pit 1 is completed in 2009 and the excavated area is used for disposal of consolidated tailings (CT) (Pond 7). The water surface elevation in the ponds will be 297 m ASL.
- The excavation of Pit 2 starts in 2009.
- The construction of Dyke 11 at the west edge of Pit 2 is started.

• 2009 - 2020 (Pit 2 Development)
  - The mining of Pit 2 continues until 2020.
  - Surficial deposits at Pit 2 are dewatered and shallow groundwater is diverted around the pit.
  - Overburden is being placed on the South Dump.
  - The Basal Aquifer and Upper Devonian limestone under Pit 2 have been de-pressurized, if required.
  - In 2015, consolidated tailings (CT) disposal begins in Pond 8.
  - Perimeter drainage channels 15-A and 15-B are constructed in 2012 and Channel 15-C in 2015. These channels divert natural runoff from the area to the east of the mine to Wood Creek. Construction of the perimeter channel will increase the area draining to Wood Creek and will reduce the area draining to Shipyard Lake.

- Construction of the dyke for Pond 8 is completed in 2016. Two dykes within the Pond 8 area are built between 2013 and 2016, and 2015 and 2019, respectively. The construction of the dyke at the east side of Pond 8 is started in 2017.
- As of 2020, the mining in Pit 2 is finished. The static level in the deep bedrock aquifers (Basal Aquifer and Upper Devonian) is expected to have returned to pre-mine levels.
- The water surface elevation in Pond 7 and Pond 8 is 326 m and 304 m, respectively.

• Post Closure Equilibrium
  - It is expected that the same closure philosophy proposed for the existing Lease 86 mine will be adopted for the Steepbank Mine. This will include ongoing reclaiming and vegetating disturbed areas, vegetating overburden dumps and exposed dyke slopes, providing drainage systems to remove excess water from the tailings areas and vegetating the dry tailings surfaces.
  - As the tailings consolidate, water is released. Initially, the water release rate is estimated to be approximately 90 L/s from Pond 7 and 100 L/s from Pond 8. This discharge is expected to reduce to nearly zero over a period of 60 to 80 years.
  - Both Ponds 7 and 8 have been filled with to 327 m elevation.

D SURFACE WATER IMPACT ASSESSMENT

D1.0 EXISTING SURFACE WATER ENVIRONMENT

The major watercourses in the vicinity of the proposed mine are the Steepbank and Athabasca Rivers. Smaller watercourses in the area include an unnamed creek (which drains to Shipyard Lake), Wood Creek, Leggett Creek and McLean Creek. Existing drainage areas in the local study area are shown on Figure C-1. Approximate drainage areas for the major basins are provided in Table D1.0-1. There is one large permanent wetlands, known as Shipyard Lake, on the Athabasca River floodplain within the study area. It is located approximately 6 km south of the Steepbank River confluence with the Athabasca River.

The Athabasca River is the major surface water drainage in the area and all other creeks are tributaries. The Athabasca River is located in a stream-cut valley incised at the proposed mine site approximately 60 m to 90 m below the upland. The river has eroded into the Devonian bedrock throughout the Suncor Study area. The valley walls are dominated by closed aspen and mixed aspen white spruce forest while the floodplain consists of a mosaic of shrub and mixed forest communities. The floodplain is moderately to poorly drained and locally covered with extensive wetlands-muskeg. The river has an unstable thalweg and the channel has irregular meanders with occasional islands and bars.

The uppermost reaches of the local watercourses are poorly drained and covered with muskeg. Relatively steep slopes in the middle and lower reaches of the Steepbank River, and the lower reaches of the smaller creeks have resulted in a moderately to well defined entrenched channel system at the Athabasca escarpment. The downstream end of the Steepbank River valley cuts through the surficial deposits and, close to its confluence with the Athabasca River, it has incised into the Cretaceous (McMurray Formation Oil Sands) and underlying Devonian bedrock. On smaller creeks the entrenched channel systems are generally limited to the immediate vicinity of the Athabasca River valley sides.

Discharge to the Steepbank River from the mine area is from overland flow. No developed stream channels are present in this reach of the catchment.

Of the smaller Athabasca tributaries, Leggett Creek and the unnamed creek have their drainage basins entirely within the study area. Others have substantial portions of their drainage outside these limits.

Three small basins designated as Athabasca 1, Athabasca 2 and Athabasca 3 (Figure C-1), have no defined watercourses and discharge runoff through overland flow or ephemeral streams only directly to the Athabasca River.

TABLE D1.0-1
MAJOR DRAINAGE BASINS IN THE SUNCOR STUDY AREA

Basins	Total Approximate Drainage Area (km^2)
Steepbank River	1 320
Shipyard Lake at Outlet	40.9
Shipyard Lake at Athabasca	44.1
Leggett Creek	35.0
Wood Creek	36.8
McLean Creek	53.4

Note: Drainage areas measured to gauging station or, where ungauged, to the outlet of the basin.

D1.1 PRECIPITATION, EVAPORATION AND EVAPOTRANSPIRATION

The average annual precipitation in the local study area is estimated to be 398 mm, of which 269 mm is rainfall and the balance falls as snow (Environment Canada 1995). The average annual snowfall is 172 cm and the average water equivalent is 0.76 mm/cm. Table D1.0-2 presents the mean monthly precipitation including rainfall and snow. The monthly variation of precipitation including maximum, minimum and average values are shown on Figure D1.0-1. Estimates of the annual precipitation for the 1 in 100 year drought to the 1 in 100 year wet conditions are presented on Table D1.0-3.

Intensity-Duration-Frequency curves for short duration high intensity rainfall events are shown on Figure D1.0-2. These curves show the relationship between rainfall intensity and storm duration for a range of storms that are expected to occur from once every two years to once every 100 years. It can be seen that the rainfall intensity increases with shorter duration storms.

TABLE D1.0-2
MEAN MONTHLY PRECIPITATION AT THE SUNCOR STUDY AREA
(based on 85 years of data - Environment Canada 1995)

Precipitation (mm)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall	0.4	0.5	1.0	7.6	28.5	54.8	66.5	52.6	41.3	14.7	1.9	0.4
Snow Water Equivalent[1]	21.9	15.3	19.4	12.2	2.4	0.0	0.0	0.0	2.0	10.6	23.0	22.2
Total Precipitation	22.3	15.8	20.4	19.8	30.9	54.8	66.5	52.6	43.3	25.3	24.9	22.6

[1] Snow water equivalent is the water content of the snow.

TABLE D1.0-3
ANNUAL PRECIPITATION FOR THE SUNCOR STUDY AREA
(Environment Canada 1995)

Conditions	Total Annual Precipitation (mm)
1 in 100 Year Drought	240
1 in 50 Year Drought	250
1 in 10 Year Drought	290
1 in 5 Year Drought	321
Average Year	398
1 in 5 Year Wet Year	468
1 in 10 Year Wet Year	523
1 in 50 Year Wet Year	644
1 in 100 Year Wet Year	695

Estimates of lake evaporation and evapotranspiration available for Fort McMurray from Alberta Environmental Protection (1995) are presented on Tables D1.0-4 and D1.0-5, respectively. These values are considered to be representative of the study area. Lake evaporation is the loss of water from open bodies of water to the atmosphere. Evapotranspiration represents the loss of water to the atmosphere by transpiration from foliage and by evaporation from water at the soil surface.

TABLE D1.0-4
LAKE EVAPORATION AT FORT MCMURRAY(AEP 1995)
(in mm)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Minimum	-5	-3	0	38	77	102	104	74	31	10	-5	-6	531
Average	-2	0	17	60	104	120	128	99	42	15	-2	-3	572
Maximum	-1	6	30	83	133	139	144	123	57	18	3	-1	627

TABLE D1.0-5
EVAPOTRANSPIRATION AT FORT MCMURRAY (AEP 1995)
(in mm)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Minimum	-5	-3	0	10	22	52	69	40	12	7	-4	-5	251
Average	-2	0	12	19	39	65	79	54	16	10	-1	-2	288
Maximum	0	6	20	30	58	81	91	66	21	15	3	-1	342

D1.2 STREAMFLOW CHARACTERISTICS

Average annual, maximum mean daily, mean monthly flows, flood and drought characteristics were prepared for each watercourse. Flow data is measured by Environment Canada (1994) on the Athabasca River, Steepbank River, Muskeg River, Hartley Creek and Beaver River. Details of the streamflow monitoring stations are presented on Table D1.0-6. Streamflow characteristics for the

Athabasca and Steepbank Rivers at the mine site are based on data for stations 07DA001 and 07DA006, respectively. Flow records are not available for Leggett Creek, Wood Creek and watercourses draining to Shipyard Lake.

Streamflow characteristics for flows to Shipyard Lake, Leggett Creek, Wood Creek and local inflow to the Athabasca River have been estimated based on data for Muskeg River and Hartley Creek. These basins are close to the local study area and are similar (in terms of orientation, vegetation and topography) to basins in the local study area. Data for the Beaver River above Syncrude were not used for watercourses in the local study area because the topography and, in particular, orientation of its drainage basin is quite different.

TABLE D1.0-6
WATER SURVEY OF CANADA
STREAMFLOW MONITORING STATIONS IN THE SUNCOR STUDY AREA
(Environment Canada 1995)

Gauge Station Name	Station Number	Location	Streamflow Record		Drainage Area (km^2)	Sediment Record
			Period	Type		
Athabasca River below Fort McMurray	07DA001	56°47'N 111°24'W	1957 1958 - 1993	Seasonal Continuous	133 000	1967 - 1972
Steepbank River near Fort McMurray	07DA006	57°01'N 111°25'W	1972 - 1973 1974 - 1986 1987 - 1993	Seasonal Continuous Seasonal	1 320	1975 - 1983
Muskeg River near Fort McKay	07DA008	57°12'N 111°34'W	1974 - 1986 1987 - 1993	Continuous Seasonal	1 460	1976 - 1983
Hartley Creek near Fort McKay	07DA009	57°16'N 111°28'W	1975 1976 - 1987 1988 - 1993	Seasonal Continuous Seasonal	358	1976 - 1983
Beaver River above Syncrude	07DA018	56°56'N 111°34'W	1975 - 1987 1988 - 1993	Continuous Seasonal	165	1976 - 1980

Estimates of annual runoff for each watercourse are presented on Table D1.0-7. Mean monthly flow hydrographs showing the range of variation in flows for each water course are presented on Figures D1.0-3 and D1.0-4, and estimates of mean peak daily flows for the 1 in 5 year to 1 in 100 year return period floods are shown on Figures D1.0-5 and D1.0-6.

TABLE D1.0-7
ESTIMATED AVERAGE ANNUAL DISCHARGE FOR WATERCOURSES IN THE SUNCOR STUDY AREA

Conditions	Average Annual Discharge (m^3/s)				
	Athabasca River	Steepbank River	Shipyard Lake Outlet[1]	Leggett Creek	Wood Creek
1 in 100 Year Drought	396	1.22	0.000	0.000	0.000
1 in 50 Year Drought	425	1.46	0.008	0.006	0.007
1 in 10 Year Drought	507	2.35	0.040	0.033	0.036
1 in 5 Year Drought	555	3.00	0.060	0.049	0.055
Average Year	655	4.86	0.111	0.091	0.102
1 in 5 Year Wet	755	6.61	0.158	0.130	0.145
1 in 10 Year Wet	809	7.62	0.191	0.156	0.176
1 in 50 Year Wet	901	10.1	0.253	0.208	0.233
1 in 100 Year Wet	932	11.0	0.280	0.230	0.257

1 Includes Unnamed Creek's ephemeral streams and overland flows catchments discharging to this wetlands.

D1.3 SURFACE WATER QUALITY

Sediment sampling has been performed by Environment Canada (1994) in the study area at its gauging stations on the Athabasca River below Fort McMurray, the Steepbank River and the Muskeg River and Hartley Creek. No sampling has been performed on the smaller watercourses in the local study area (the unnamed creek, Leggett Creek and Wood Creek). Sediment sampling on the Athabasca River was continuous from 1970 through 1972. Random sediment sampling was performed at other times. Suspended sediment concentrations tend to increase with flow as shown on Figure D1.0-7. Concentrations are highest during the spring snow melt and lowest over the winter months when flows are low. The minimum, average and maximum recorded sediment concentrations are presented on Table D1.0-8.

TABLE D1.0-8
RECORDED SEDIMENT CONCENTRATIONS IN WATERCOURSES IN THE SUNCOR STUDY AREA
(Environment Canada 1994)

Gauging Station	Sediment Concentration (mg/L)		
	Minimum	Average[1]	Maximum
Athabasca River below Fort McMurray	1	493	4820
Steepbank River near Fort McMurray	3	92	741
Muskeg River near Fort McKay	3	9	41
Hartley Creek near Fort McKay	1	15	106

[1] This is the average for all sediment samples.

Surface water chemistry data are available for the Athabasca River, the Steepbank River, Shipyard Lake, Unnamed Creek, Wood Creek and other bodies in the region. These data are presented in detail in the Aquatics Impact Assessment (Golder 1996a). A Piper Plot showing the major ion chemistry for the surface water points sampled as part of the 1995 Environmental Impact Sampling Program is included as Figure D1.0-8.

D2.0 SURFACE WATER IMPACT DESCRIPTION

Changes to the existing surface water drainage systems as a result of construction, operation and closure of the mine are discussed in terms of changes to the average annual flows and expected quality at each time period. Tables D2.0-1 and D2.0-2 show estimated annual runoff and peak flood flows, respectively, at various points in the local study area for the time periods of interest, 2001, 2009, 2020 and post reclamation. Table D2.0-3 shows estimated changes to the water balance in Shipyard Lake. Figure D2.0-1 summarizes the changes in surface water flows described below. Figure D2.0-2 illustrates factors relating to water quality changes.

The effects of the proposed mine on water quantity and quality are discussed in the following sections.

D2.1 DESIGN PHILOSOPHY

Surface drainage for the Steepbank Mine will be controlled in a similar manner to current operations; all natural runoff and shallow groundwater will be discharged to the Athabasca River, while runoff that is exposed to oil sands and mining operations will be contained. The Steepbank Mine will contain two drainage systems for surface runoff waters:

- An interception drainage system for run-on water from undisturbed areas and groundwater from the shallow aquifers. This water will be discharged to the Athabasca River.
- A mine drainage system for surface runoff from mined, stripped and developed areas and any Basal Aquifer depressurization waters. This water will be routed through collection channels to internal storm water retention basins. Wherever feasible, the mine drainage water will be used as process water. Until Pond 7 is available to store water, mine drainage water in excess of process requirements will be pumped back to the tailings/extraction system on the west side of the Athabasca River or stored in temporary storm water retention facilities within the mine area constructed as part of mine advance, similar to the current practice on Lease 86/17.

Diversion and collection channels will be sized to handle estimated maximum flows during the 1 in 100 year flood event. The mine retention storage volumes will be sized to handle the 1 in 10 year annual runoff. Water will be pumped from storage to the mine process water system or to the tailings ponds as required from April through November to ensure the mine storage will be empty at the end of November, ready for the following spring runoff. As some mine facilities are located within the Athabasca River valley, Suncor recognizes the importance of minimizing the potential for uncontrolled water releases.

TABLE D2.0-1
ANNUAL RUNOFF (NATURAL FLOWS)

Drainage Basin	Drainage Area (km²)	Average Annual Flow (L/s)		
		1 in100 Year Dry	Average	1 in 100 Year Wet
1995				
Shipyard Lake at Athabasca River	44.1	0	121	305
Shipyard Lake Outlet	40.9	0	111	279
Leggett Creek	35.0	0	91	229
Wood Creek	36.8	0	102	257
Athabasca River (1)	6.4	0	22	55
Athabasca River (2)	1.0	0	3	8
Athabasca River (3)	7.2	0	22	55
2001				
Shipyard Lake at Athabasca River		0		37
Shipyard Lake Outlet	45.5	0	126	316
Leggett Creek	35.0	0	91	229
Wood Creek	36.4	0	101	254
Athabasca River (1)	3.3	0	11	29
Athabasca River (2)	1.0	0	3	8
Athabasca River (3)	7.2	0	22	55
2009				
Shipyard Lake at Athabasca River	1.0	0	91	231
Shipyard Lake Outlet	35.3	0	88	223
Leggett Creek	35.3	0	92	231
Wood Creek	36.4	0	101	254
Athabasca River (1)	2.6	0	9	23
Athabasca River (2)	1.0	0	3	8
Athabasca River (3)	7.2	0	22	55
2020				
Shipyard Lake at Athabasca River	6.9	0	3	9
Shipyard Lake Outlet	5.9	0	18	46
Leggett Creek	0.0	0	0	0
Wood Creek	87.2	0	227	573
Athabasca River (1)	2.6	0	9	23
Athabasca River (2)	1.0	0	3	8
Athabasca River (3)	2.6	0	9	23
Post Reclamation				
Shipyard Lake at Athabasca River	27.9	0	60	177
Shipyard Lake Outlet	26.1	0	53	157
Leggett Creek	0.0	0	0	0
Wood Creek	92.8	0	243	619
Athabasca River (1)	3.5	0	11	29
Athabasca River (2)	1.0	0	3	8
Athabasca River (3)	2.6	0	9	23

Note 1. Drainage in years 2001 to 2020, inclusive, do not include runoff from the mine area. Runoff from the mine area is collected by an internal drainage system for use in the oil sands extraction process.

2. Long run includes rehabilitated mine areas.

3. Lowland unit runoff (from muskeg and fen) is assumed to be 50% of the upland unit runoff.

4. The Athabasca River drainage basins represent contribution to flow in the Athabasca River and not the discharge in the river.

TABLE D2.0-2
FLOOD FLOWS (NATURAL RUNOFF)
(Klohn-Crippen 1996a)

Drainage	Drainage	Peak Mean Daily Flow (m^3/s)		
Basin	Area (km^2)	1 in 10 Year	1 in 50 Year	1 in 100 Year
1995				
Athabasca	133 000	3810	5050	5600
Steepbank	1320	74.3	120.0	141.0
Shipyard Lake Outlet	40.9	3.6	5.3	5.9
Leggett Creek	35.0	2.8	4.1	4.6
Wood Creek	36.8	2.9	4.2	4.8
Athabasca River (1)	6.4	0.8	1.1	1.2
Athabasca River (2)	1.0	0.2	0.3	0.3
Athabasca River (3)	7.2	0.8	1.2	1.4
2001				
Shipyard Lake Outlet	45.5	3.8	5.4	6.2
Leggett Creek	35.0	2.8	4.1	4.6
Wood Creek	36.4	2.9	4.2	4.7
Athabasca River (1)	3.3	0.5	0.7	0.7
Athabasca River (2)	1.0	0.2	0.3	0.3
Athabasca River (3)	7.2	0.8	1.2	1.4
2009				
Shipyard Lake Outlet	35.3	3.0	4.3	4.8
Leggett Creek	35.3	2.8	4.1	4.6
Wood Creek	36.4	2.9	4.2	4.7
Athabasca River (1)	2.6	0.4	0.6	0.6
Athabasca River (2)	1.0	0.2	0.3	0.3
Athabasca River (3)	7.2	0.8	1.2	1.4
2020				
Shipyard Lake Outlet	6.9	0.9	1.3	1.5
Leggett Creek	0.0	0.0	0.0	0.0
Wood Creek	87.2	5.7	8.2	9.3
Athabasca River (1)	2.6	0.4	0.6	0.6
Athabasca River (2)	1.0	0.2	0.3	0.3
Athabasca River (3)	2.6	0.4	0.6	0.6
Post Reclamation				
Shipyard Lake Outlet	27.4	3.8	6.4	7.6
Leggett Creek	0.0	0.0	0.0	0.0
Wood Creek	92.8	6.4	9.6	10.9
Athabasca River (1)	4.3	0.6	1.0	1.1
Athabasca River (2)	1.0	0.2	0.3	0.3
Athabasca River (3)	2.6	0.4	0.6	0.6

Note: 1. Drainage in years 2001 to 2020, inclusive, do not include runoff from the mine area.
2. Post Reclamation includes reclaimed mine areas.

TABLE D2.0-3
WATER BALANCE FOR SHIPYARD LAKE
(Klohn-Crippen 1996a)

	Average Inflow (L/s)			Evaporation/Evapotranspiration Losses (L/s)			Net Inflow or Loss (L/s)		
	1 in 100 Year Dry	Average	1 in 100 Year Wet	1 in 100 Year Dry	Average	1 in 100 Year Wet	1 in 100 Year Dry	Average	1 in 100 Year Wet
1995									
Minimum[1]	0	111	279	14	14	14	-14	97	266
Average	0	111	279	15	15	15	-15	95	264
Maximum	0	111	279	18	18	18	-18	93	262
2001									
Minimum	0	111	279	14	14	14	-14	97	266
Average	0	111	279	15	15	15	-15	95	264
Maximum	0	111	279	18	18	18	-18	93	262
2009									
Minimum	0	88	223	8	8	8	-8	80	215
Average	0	88	223	9	9	9	-9	79	214
Maximum	0	88	223	10	10	10	-10	78	212
2020									
Minimum	0	15	37	8	8	8	-8	7	29
Average	0	15	37	9	9	9	-9	6	28
Maximum	0	15	37	10	10	10	-10	4	27
Post Reclamation									
Minimum	0	53	157	8	8	8	-8	46	150
Average	0	53	157	9	9	9	-9	45	149
Maximum	0	53	157	10	10	10	-10	43	147

Notes: 1. Refers to minimum recorded annual evaporation and evapotranspiration.
2. It is assumed that the area of Shipyard Lake and associated wetlands does not vary between the 1 in 100 year dry and 1 in 100 year wet conditions.

D2.2 FACILITY CONSTRUCTION (1997 - 2001)

Surface water from Athabasca 1, Athabasca 2, Shipyard Lake and the Steepbank River basins (Figure C-2) will be affected during this stage of development. The effects on flow include increased runoff from areas which have been cleared and stripped as well as routing of flows to different discharge points from the baseline condition. Potential water quality effects include increased sediment load and surface water contamination from the accidental release of equipment fluids and/or construction materials.

D2.2.1 Surface Water Flow (1997 - 2001)

Construction of the main components of the Mine Drainage System, including stormwater retention basins A through D, is part of the facilities construction program. The runoff system will be designed to handle the 1 in 100 year wet annual runoff. This volume is sufficient for even the 1-in-100 year peak flood to be stored in the mine stormwater retention basins, allowing Suncor time to dispose of the runoff. In addition, temporary retention storage upstream of the main ponds will be incorporated in the detailed mine plans to limit flow and volume.

After 2005, the operation plans will include provisions to divert flow from run-on channels into Pit 1.

D2.2.2 Surface Water Quality (1997 - 2001)

The effects of the mine on surface water quality during this period are related to sediment generation and potential contaminant release. These effects will be short term and local with a low degree of concern in the uplands. If the effects were left unmitigated, there would be concern for surface water quality on the escarpments of the Athabasca and Steepbank Rivers. Concern would also be high for facilities at the bottom of the Athabasca escarpment adjacent to Shipyard Lake and the Athabasca River as discussed below.

a) <u>Athabasca Bridge</u>

Hydrotransport, hot water, tailings and recycle pipelines on the Athabasca River Bridge will be equipped with emergency isolation valves and other protective measures to prevent discharge to

Athabasca River in the event of a pipeline seal break or other release during operations. Sufficient storage capacity at the bridge approaches will be provided for the full capacity of all lines on the bridge deck between isolation valves. In addition, provisions will be made to collect and treat bridge deck traffic lane runoff in the event of a fuel or other contaminant release on the bridge.

b) <u>Facilities Construction</u>

Shop facilities for the Steepbank mine will include vehicle shops, lube storage and distribution, warehousing, potable water and sewage treatment facilities, gas, fuel and lube islands and other support facilities. Sudden and accidental contaminant releases such as fuel spills as well as chronic, cumulative releases such as slow leaks from underground oil separation sumps, diesel pipelines, underground oil storage tanks in shops and gradual accumulation of contaminants as a result of normal operations are potential impacts. The effects of these impacts on surface water quality are high, short term and regional, and if left unmitigated, the degree of concern would be high.

Mitigation measures for these impacts are standard design features and include measures such as a separate surface drainage system for the shop facilities which includes retention storage capacity for runoff from this area and sediment settling basins. Regular maintenance of the basins will be conducted. Where necessary, individual drainage systems for high risk facilities such as shops and fuel islands will be employed. Containment of tanks and active leak detection systems will be employed. No surface runoff from the facilities area will be released to the environment unless it meets water quality requirements.

Additional general mitigation measures include:

- containment sumps with impervious linings for liquid storage facilities (for example, fuel tanks); rapid-response clean-up procedures for accidental spills;
- drainage channels with settlement ponds to collect runoff from disturbed areas, roads and paved areas;
- cross-berms on sloped disturbed areas to retard runoff and reduce surface erosion; and
- quickly re-vegetating disturbed areas after construction activities have finished.

c) **East Access Corridor**

If left unmitigated, the effects of liquid spills in the access corridor on surface water quality are potentially of high severity, short term duration and regional in extent, due to the possibility of release to Athabasca River. To mitigate potential impacts, the east access corridor plant roads and utility corridors will be provided with separate containment berms on traffic lanes and pipeline corridors. The containment structures will be lined to prevent infiltration of contaminants to the shallow groundwater or escape to surface runoff channels. Adequate storage to contain the volume in the pipelines between isolation valves will be provided. In addition, adequate provisions will be in place to protect the surface waters from the rupture of the hydrotransport, hot water and underground diesel fuel pipelines where they cross drainage courses along the East Corridor Road crossing.

D2.2.3 Other Issues

The impact on flow depths, scour, deposition and ice formation in the Athabasca River from construction activities associated with the new bridge across the Athabasca River was assessed in 1995/96 by AGRA Earth and Environmental in association with Trillium Engineering and Hydrographics Inc. (AGRA, 1996a). They indicate that the bridge is not expected to increase the likelihood of ice jamming or bank erosion in this reach of the Athabasca River in the long-term.

During construction, cofferdams built for pier construction will be removed to reduce the potential for ice jams to form.

The 1 in 100 year ice jam flood elevation is expected to be about elevation 241.0 m ASL. All structures adjacent to the Athabasca River will be constructed above this elevation to minimize concerns with respect to flooding of the mine infrastructure in this area.

Some sediment deposition is expected on the west abutment both upstream and downstream of the bridge. On the east bank, deposition downstream of the bridge is anticipated. These impacts will not affect the hydrology of the river. Aquatic impacts are addressed in other reports in this series.

To accommodate navigation, there is a minimum clearance of 15.2 m between the underside of one span of the bridge at the maximum water level during the 1 in 10 year flood.

D2.3 PIT 1 DEVELOPMENT (2001 - 2009)

Surface water from the Athabasca 1 and Athabasca 2 sub-catchments, Shipyard Lake and the Steepbank River basins (Figure C-1) will be affected during this stage of development. Leggett Creek basin will be impacted in 2008 with the construction of Pre-Mine Channel 9-B. See Figures C-2 and C-3 for details of mine development and drainage systems in 2001 through 2009.

About 60% of the Athabasca 1 basin is restructured during this time frame. The northern portion of the basin becomes the North overburden dump and the southern portion becomes Pit 1. Except for the extreme northern portion of the catchment on the headland at the confluence of the Athabasca and Steepbank Rivers, the entire runoff from the basin is routed through the mine drainage system and is removed from the hydrologic cycle during this period.

The portion of the Steepbank River catchment in the mine area is impacted by the North Overburden Dump, East Overburden Dump and Pit 1. All disturbed runoff is routed to Mine Drainage which is subsequently removed to process and all natural run-on is routed to Shipyard Lake through Channels 9-A and 9-B.

Shipyard Lake catchment is impacted by the East Overburden Dump, the southern portion of Pit 1 and the mine facilities.

D2.3.1 Surface Water Flow (2001 - 2009)

The drainage area of Athabasca 1 catchment contributing flow to the river shown on Figure C-1 is reduced from 6.4 to 2.6 km^2 and the average annual flow from the basin is reduced from 22 to 9 L/s as shown in Table D2.0-1.

Although the average annual flow into Shipyard Lake will be reduced by approximately 20% from 110 to 88 L/s, the surface area of the wetlands will also have been reduced by the construction of the West Dump, commencing in 2004. The total wetlands area will be reduced by about 30% from 128 to 90 hectares and the area of open water will be cut by approximately 17% from 23 to 19 hectares. Therefore, the runoff per unit area of wetlands will be increased and the retention time in the open water area reduced. Impacts on Shipyard Lake are described in the Impact Analysis of Terrestrial Resources Associated with the Steepbank Mine report (Golder 1996b).

D2.3.2 Surface Water Quality (2001 - 2009)

There is the possibility of increased sediment concentration in flows to Shipyard Lake from erosion of channels constructed to intercept runoff from outside the mine area, and the facilities area. The potential for increased sediment load will be mitigated by minimizing flow velocities in the channels, constructing sediment ponds to trap the sediment, lining the channels with erosion resistant materials and/or re-vegetating disturbed areas adjacent to the channels. Any sediment ponds will be sized to ensure that sediment concentration in the outflow does not exceed the concentration in the receiving watercourse.

In 2003, channels will be constructed to conduct peak storm flows to Shipyard Lake during peak storm events. The channel will require flow control through retention basins and energy dissipation structures, such as flow diffusers and a bypass, to prevent erosion of the natural slope materials and development of deep scour at the outlet in Shipyard Lake.

There is an ongoing potential for surface water contamination from the accidental release of equipment fluids and/or construction materials as discussed in previous sections and appropriate mitigation measures will remain in place.

D2.4 PIT 2 DEVELOPMENT (2009 - 2020)

D2.4.1 Surface Water Flow (2009 - 2020)

With the development of Pit 2 and associated overburden dumps, the average annual flow into Shipyard Lake may be further reduced by approximately 83% from 88 to 15 L/s due to diversion of run-on water to Wood Creek, while runoff from Leggett Creek will be eliminated. The average annual flow in Wood Creek may be increased by about 2.3 times from approximately 100 to 230 L/s as shown in Table D2.0-1.

The impact of the reduced runoff on the water balance of Shipyard Lake is shown on Table D2.0-3.

In 2015, Channel 15-C will be constructed to divert peak storm flow runoff from the unnamed creek to Wood Creek. Estimated velocities in the discharge channel from the uplands to Wood Creek may be as high as 12 to 15 m/s, which represent a high erosion potential. This will require erosion protection measures to prevent severe erosion of the channel.

The surface water flow impacts in this time frame are considered high severity, long-term and local with regard to the individual creeks (unnamed creek, Leggett Creek and Wood Creek). However, the overall degree of concern with regard to impacts on Athabasca River is low.

D2.4.2 Surface Water Quality (2009 - 2020)

There is the possibility of increased sediment concentration in flows to Wood Creek originating from channels constructed to intercept natural runoff and route it around Pit 2 and the South Dump as well as from channel degradation resulting from increased flows downstream of the Channel 15-C discharge. The potential for increased sediment discharge to the receiving water bodies will be mitigated by minimizing flow velocities in the channels, constructing retention basins to trap the sediment, lining the channels with erosion resistant materials and/or re-vegetating disturbed areas adjacent to the channels.

Sediment issues are considered moderate, short term and local. The overall degree of concern is low in terms of discharge to the Athabasca River.

As in the previous time frames, there is a potential for surface water contamination from the accidental release of equipment fluids and/or construction materials.

D2.5 RECLAMATION DRAINAGE POST-2020

D2.5.1 Surface Water Flow (Reclamation Drainage Post-2020)

Post reclamation effects on annual flows are presented in Table D2.0-4. As shown, total average annual flow from the Suncor study area is expected to decrease by about 30 L/s after closure in comparison to the pre-mine conditions. This effect is considered low severity, long-term and local.

These changes in flow have negligible effects on the Steepbank and Athabasca flow. Therefore, the overall degree of concern is low with respect to the impacts on the Steepbank and Athabasca Rivers.

D2.5.2 Surface Water Quality (Reclamation Drainage Post-2020)

The impact of re-vegetating landforms and redirecting surface runoff from the overburden storage areas to Wood Creek will increase the average annual flow in the creek by about 4% from 230 L/s to approximately 240 L/s. Mine reclamation and erosion control measures implemented previously will result in little or no increase in sediment concentrations in the water courses on site. Closure and reclamation plans, as discussed in other sections of this submission, result in low concern for impacts to surface water quality impacts in the Steepbank and Athabasca Rivers.

D3.0 SUMMARY OF SURFACE WATER IMPACTS ANALYSIS

In terms of the impact hypotheses considered, all impacts with respect to surface water will be low to negligible due to the mitigation measures employed.

Hypothesis 24 Flows in the Athabasca and Steepbank Rivers would be significantly changed by mine development withdrawals for extraction and upgrading, or reclamation.

Result: There are negligible impacts on flows in the Steepbank and Athabasca Rivers.

Hypothesis 25 Ice jams, floods or other hydrological events could cause structure damage and flooding of facilities which will result in subsequent impacts to hydrological/aquatic systems and downstream users.

Result: Ice jams, flooding and other hydrological events will be considered for in the final bridge design. All facilities will be located above the 1 in 100 year ice jam flood level.

TABLE D2.0-4
STEEPBANK MINE - RECLAMATION DRAINAGE POST 2020

Drainage Basin	Change in Annual Flow (L/s)			Change in Annual Flow (%)		
	1 in 100 Year Dry	Average	1 in 100 Year Wet	1 in 100 Year Dry	Average	1 in 100 Year Wet
Steepbank River	negligible	negligible	negligible	negligible	negligible	negligible
Athabasca River	negligible	negligible	negligible	negligible	negligible	negligible
Shipyard Lake at Athabasca River	0.0	-61.0	-128.0	0%	-50%	-42%
Shipyard Lake at Outlet	0.0	-57.2	-122.1	0%	-52%	-44%
Leggett Creek	0.0	-90.6	-229.0	0%	-100%	-100%
Wood Creek	0.0	140.9	361.7	0%	138%	141%
Athabasca River (1)	0.0	-10.3	-25.4	0%	-48%	-46%
Athabasca River (2)	0.0	0.0	0.0	0%	0%	0%
Athabasca River (3)	0.0	-12.6	-31.9	0%	-58%	-58%
Total Change	0.0	-90.8	-174.7			

Hypothesis 26 Navigation along the Athabasca River could be affected by bridge construction.
Result: Navigation is not affected by the Athabasca bridge.

A summary of the surface water impacts on flow and quality are presented in Figures D2.0-1 and D2.0-2.

E GROUNDWATER IMPACT ASSESSMENT

E1.0 GROUNDWATER SETTING

E1.1 DATA COLLECTION

The hydrogeologic baseline study (Klohn-Crippen, 1996b) was conducted in the following two stages:

- literature review, including regional data; and
- detailed investigation of the study area.

Sources of regional information and data are listed with the references at the end of this report.

The detailed hydrogeologic investigation of the study area comprised the following components:

- geophysical surveys (electromagnetic and ground penetrating radar);
- interpretation of geologic logs from over 300 boreholes;
- dite reconnaissance on ground and helicopter;
- installation of standpipe and pneumatic piezometers; and
- analysis of groundwater samples for inorganics, organics, Microtox©, and stable isotopes.

E2.0 HYDROGEOLOGIC RESOURCE INVENTORY

A detailed evaluation of the hydrogeologic setting of the Suncor study area has been conducted. The results of the evaluation are described in full in the technical report prepared by Klohn-Crippen (1996b). A synopsis of the study area's hydrogeology is provided below.

E2.1 GEOLOGY

The site's landforms are divided into upland, valley slopes and floodplain, as shown in Figure A2.0-1. The upland slopes gently toward the Athabasca River, is poorly drained, and covered with muskeg. The upland is cut by the steep valley slopes of the Steepbank and Athabasca Rivers. The Athabasca floodplain is moderately to poorly drained, and overlain in places with muskeg.

The stratigraphy of the surficial deposits in the upland can be characterized, from top to bottom, as:

- muskeg
- stratified sediments (sand)
- till
- bedrock

The total thickness of the surficial deposits in the upland ranges from 1 to 40 m.

In the floodplains, the stratigraphy of the surficial deposits can be characterized as:

- muskeg (discontinuous)
- stratified sediments (silt, clay, sand and gravel)
- bedrock

The total thickness of the surficial material in the floodplain ranges from 1 to greater than 30 m.

The bedrock stratigraphy, as shown in the cross sections in Figure E2.0-1 is:

- Clearwater Formation
- McMurray oil sands
- Basal Aquifer
- Upper Devonian limestone

The Athabasca River has incised into the surface of the Upper Devonian limestone exposing the shallower units on the valley escarpment. Within the Athabasca River valley, the Clearwater

Formation, McMurray oil sands and basal aquifer are absent. The Steepbank River has eroded below the top of the McMurray Formation within the entire study area. Near the confluence of the Steepbank and Athabasca Rivers, the Steepbank has incised into the Upper Devonian.

E2.2 MAJOR AQUIFERS

The major aquifers beneath the study area are the surficial sand and gravel deposits, the Basal Aquifer, and the Upper Devonian. In the upland, the surficial sand deposit is an extensive but discontinuous unit, ranging in thickness from 1 to 10 m. The top of the sand deposit is up to 10 m below existing ground, covered with till. On average, the sand is less than 3 m thick, with a mean hydraulic conductivity of 3.7×10^{-6} m/s.

In the Athabasca River valley, the deposit of sand and gravel is much thicker. The hydraulic conductivity of these deposits has been determined on Lease 86/17 to be as high as 1×10^{-3} m/s. It is expected to be similar in the study area, on the east side of the river.

The Basal Aquifer is a discontinuous zone of lean oil sands in the McMurray Formation. The thickness of the aquifer ranges from zero to 50 m. It is thickest where it overlies depressions in the surface of the Upper Devonian limestone. The mean hydraulic conductivity of the aquifer is 4.1×10^{-6} m/s, as measured on site.

The Upper Devonian is limestone of the Waterways Formation. The upper surface of the Devonian is highly irregular, consisting of depressions and knolls with a total relief of 80 m within the Steepbank Mine study area. The upper-most rock is weathered and fractured. The hydraulic conductivity measured in the Suncor study area is 5.8×10^{-6} m/s. This value is within the range of hydraulic conductivity measured in the Upper Devonian elsewhere in the oil sands region.

There is hydraulic evidence to suggest that the Basal Aquifer and Upper Devonian are connected aquifers.

E2.3 DIRECTION OF GROUNDWATER FLOW

Maps showing contours of the piezometric surface and the direction of groundwater flow in the surficial and bedrock aquifers are presented in Figures E2.0-2 and E2.0-3. The direction of groundwater flow in the surficial sand aquifer in the upland is generally horizontal, toward the Athabasca and Steepbank Rivers.

The principal direction of flow in the Basal Aquifer and Upper Devonian is horizontal, toward the Athabasca River.

There is also a small component of flow toward the Steepbank River. The hydraulic head in the Basal Aquifer and Upper Devonian is up to 50 m above the base of the oil sands deposit. In the region encompassing the Steepbank Mine, the Athabasca River is a groundwater divide. In other words, the groundwater from both sides of the river discharges into it. Within the depth of investigation of the study boundaries, groundwater does not cross the Athabasca River.

E2.4 GROUNDWATER DISCHARGE TO SURFACE WATERS

The calculated rates of groundwater discharge from the surficial and bedrock aquifers into the major surface water bodies under natural conditions are presented in Table E2.0-1. The techniques utilized to determine the groundwater discharge rates are described in Klohn-Crippen (1996b). These represent flows that can be impacted by activity at the mine.

In comparison to groundwater, the minimum monthly flows recorded in the Athabasca and Steepbank Rivers (Figure D1.0-3) are:

- Athabasca River 101 000 L/s
- Steepbank River 168 L/s

The average inflow to the Shipyard Lake wetlands (Table D2.0-3) is estimated as:

- Shipyard Lake 111 L/s

The groundwater discharge from the mine area is less than 1% of the minimum recorded surface water flow in the Athabasca and Steepbank Rivers, and the average flow in Shipyard Lake.

TABLE E2.0-1
FLOW RATES OF GROUNDWATER DISCHARGE TO SURFACE WATER BODIES FROM STEEPBANK MINE AREA
(Groundwater Discharge, in L/s)

Destination	1995	2001	2009	2020	Post Reclamation Equilibrium
Surficial Groundwater					
Athabasca River	0.44	0.44	0.2	0	0
Steepbank River	0.22	0.22	0	0	0
Shipyard Lake	0.17	0.17	0.40	0.20	0.20
Leggett Creek	0	0	0.23	0	0
Wood Creek	0	0	0	0.63	0.63
Bedrock Groundwater					
Athabasca River	0.93	0.93	0.93	0.93	0.93
Steepbank River	0.20	0.20	0.20	0.20	0.20
Shipyard Lake	0.56	0.56	0.56	0.56	0.56
Leggett Creek	0	0	0	0	0
Wood Creek	0	0	0	0	0
CT Water from Tailings Pond					
Athabasca River	0	0	2.20	5.80	5.83
Steepbank River	0	0	1.10	1.40	1.30
Shipyard Lake	0	0	0.30	0.40	0.43
Leggett Creek	0	0	0	0	0
Wood Creek	0	0	0	0	0
Total discharge to surface waters	**2.52**	**2.52**	**6.12**	**10.12**	**10.08**

E2.5 GROUNDWATER QUALITY

A summary of the chemistry of groundwater determined from samples collected at the Steepbank Mine site is shown in Tables E2.0-2, E2.0-3 and E2.0-4.

The groundwater in the surficial sand aquifer in the upland is fresh (TDS ranges from 24 to 620 mg/L). The major ions are calcium, sodium and bicarbonate. Low levels of naphthenic acid (ranging from 4 to 7 mg/L) are present in the surficial groundwater. No other organic compounds were detected in groundwater samples from the surficial deposits.

The basal aquifer yields brackish groundwater, with TDS ranging from 2,600 to 30,000 mg/L.

The major ions are sodium, chloride and bicarbonate. Naphthenic acid was found in the Basal Aquifer, at concentrations ranging from 8 to 36 mg/L. The groundwater in the aquifer also contains low levels of PAH's, PANH's and phenolic compounds.

The groundwater in the Upper Devonian limestone is similar to that found in the Basal Aquifer. The water is brackish, (TDS = 4, 700 mg/L), with sodium, chloride and bicarbonate being the major ions. The concentration of naphthenic acid in the limestone appears to be relatively high, ranging from 47 to 57 mg/L in the three samples that have been analyzed. The groundwater in the limestone also contains low concentrations of PAHs, PANHs and phenolic compounds as shown on Table E2.0-4.

The groundwater in the floodplain aquifer is expected to have a mixture of the chemistries found in the surficial aquifer in the upland, the bedrock aquifers, and the Athabasca River.

E2.6 GROUNDWATER AS A RESOURCE

Currently, there are no groundwater users in the Steepbank Mine area. There are no water wells on the east side of the Athabasca River or south of the Steepbank River within 10 km of the mine area.

TABLE E2.0-2
GROUNDWATER MAJOR ION CHEMISTRY AND FIELD MEASURED PARAMETERS, (mg/L)

	Basal Aquifer				Limestone				Surficial Sand			
	Min	Median	Max	No of Samples	Min	Median	Max	No of Samples	Min	Median	Max	No of Samples
Calcium	13.7	**85.4**	198	15	24.1	**26.1**	27.7	4	3.3	**21.0**	79.8	18
Magnesium	7.8	**82.7**	223	15	20.5	**21.1**	24.7	4	0.89	**4.8**	22	18
Sodium	1080	**3290**	10700	15	1560	**1855**	1870	4	1.66	**9.35**	195	18
Potassium	17.8	**28.6**	85.3	15	21	**24.3**	25.8	4	0.51	**1.7**	4.18	18
Chloride	599	**4090**	16850	15	1440	**1613**	1860	4	< 0.5	**4.25**	14.2	18
Sulphate	< 0.5	**1.2**	80	15	< 0.5	**1.45**	16.5	4	0.7	**10.2**	28.8	18
Total Alkalinity	1445	**2045**	2161	15	1602	**1864**	1913	4	7.14	**148**	576	18
Bicarbonate	1761	**2493**	2634	15	1953	**2271.6**	2332	4	8.7	**180.4**	702	18
Total Hardness	66.4	**566.9**	1413	15	144.6	**153.5**	167	4	12.0	**72.1**	286	18
Silicon	2.09	**2.5**	4.02	15	2.36	**2.6**	3.02	4	3.69	**5.345**	9.24	18
Fluoride	0.28	**0.8**	1.33	15	1.49	**1.5**	1.62	4	< 0.05	**0.16**	0.8	18
Total Dissolved Solids	2620	**8613**	29383	15	4051	**4700**	4934	4	23.8	**183.2**	623	18
Field Conductivity (µS/cm)	3820	**14100**	43500	11	7620	**7770**	8150	3	47	**515**	4290	11
Field pH (units)	6.17	**7.06**	8.03	11	7.55	**7.55**	7.66	3	5.93	**7.515**	8.46	12
Phenols	< 0.001	**0.1**	0.093	11	< 0.001	**0.03**	0.029	3	< 0.001	**0.0025**	0.047	12
Dissolved Organic Carbon	3	**5.4**	46.1	11	27.1	**28.2**	52.7	3	2.4	**6.85**	12.1	12
Nitrite + Nitrate	< 0.03	**< 0.01**	0.053	15	< 0.03	**0.014**	0.016	4	< 0.03	**0.031**	0.204	18
Total Phosphorus	0.038	**0.1**	0.75	11	0.075	**0.085**	0.12	3	0.047	**0.27**	5.1	12

TABLE E2.0-3
GROUNDWATER CONCENTRATIONS OF DISSOLVED METALS AND CYANIDE, (mg/L)

	Basal Aquifer				Limestone				Surficial Sand			
	Min	Median	Max	No of Samples	Min	Median	Max	No of Samples	Min	Median	Max	No of Samples
Aluminum	< 0.01	**0.02**	0.07	15	0.02	**0.025**	0.04	4	< 0.01	**0.05**	0.5	18
Arsenic (µg/L)	< 0.2	**0.2**	1.6	5	0.6	**0.6**	0.6	1	< 0.2	**0.3**	0.5	6
Barium	0.16	**0.75**	3	15	0.17	**0.205**	0.24	4	< 0.01	**0.06**	0.21	18
Beryllium	< 0.001	< **0.001**	0.002	15	< 0.001	< **0.001**	< 0.001	4	< 0.001	< **0.001**	0.002	18
Boron	2.33	**3.87**	4.45	15	3.2	**3.735**	4	4	< 0.01	**0.025**	0.79	18
Cyanide	< 0.001	**0.001**	0.002	11	0.001	**0.001**	0.001	3	< 0.001	**0.001**	0.001	12
Cadmium (µg/L)	< 3	< **3**	3	15	< 3	< **3**	< 3	4	< 3	< **3**	4	18
Chromium	< 0.002	< **0.002**	0.018	15	< 0.002	< **0.002**	0.002	4	< 0.002	< **0.002**	0.013	18
Cobalt	< 0.003	**0.005**	0.031	15	< 0.003	< **0.003**	0.004	4	< 0.003	< **0.003**	0.004	18
Copper	< 0.001	**0.002**	0.008	15	0.001	**0.0015**	0.004	4	< 0.001	**0.001**	0.003	18
Iron	< 0.01	**0.7**	5.63	15	< 0.01	**0.75**	0.82	4	< 0.01	**0.07**	0.42	18
Lead	< 0.02	< **0.02**	0.04	15	< 0.02	< **0.02**	< 0.02	4	< 0.02	< **0.02**	< 0.02	18
Lithium	0.355	**0.753**	1.79	15	0.291	**0.3655**	0.387	4	< 0.001	**0.005**	0.055	18
Manganese	0.029	**0.277**	4.02	15	0.034	**0.0835**	0.099	4	0.007	**0.068**	0.589	18
Mercury (µg/L)	< 0.05	< **0.05**	1.6	9	< 0.05	**0.075**	0.23	4	< 0.05	< **0.05**	0.1	12
Molybdenum	< 0.003	< **0.003**	0.019	15	0.003	**0.005**	0.009	4	< 0.003	< **0.003**	0.006	18
Nickel	< 0.005	< **0.005**	0.113	15	< 0.005	< **0.005**	0.007	4	< 0.005	**0.0065**	0.018	18
Phosphorus	< 0.1	< **0.1**	0.7	15	< 0.1	< **0.1**	< 0.1	4	< 0.1	< **0.1**	0.4	18
Selenium (µg/L)	< 0.2	< **0.2**	0.8	8	< 0.2	< **0.2**	< 0.2	4	< 0.2	< **0.2**	0.4	12
Silver (µg/L)	< 2	< **2**	5	15	< 2	< **2**	3	4	< 2	< **2**	3	18
Sulphur	1.4	**2.6**	25.7	15	2.8	**3.45**	3.7	4	0.5	**3.5**	10	18
Strontium	0.487	**4.14**	14.7	15	1.26	**1.38**	1.49	4	0.027	**0.101**	0.302	18
Titanium	< 0.003	< **0.003**	0.012	15	< 0.003	< **0.003**	< 0.003	4	< 0.003	< **0.003**	0.012	18
Uranium	< 0.5	< **0.5**	< 0.5	15	< 0.5	< **0.5**	< 0.5	4	< 0.5	< **0.5**	< 0.5	18
Vanadium	< 0.002	< **0.002**	0.009	15	< 0.002	< **0.002**	< 0.002	4	< 0.002	< **0.002**	0.003	18
Zinc	< 0.001	**0.004**	0.009	15	0.004	**0.004**	0.014	4	0.004	**0.012**	0.04	18

TABLE E2.0-4
SUMMARY OF ORGANIC COMPOUNDS DETECTED IN GROUNDWATER, (µg/L)

	Basal Aquifer				Limestone				Surficial Sand			
	Min	Median	Max	No of Samples	Min	Median	Max	No of Samples	Min	Median	Max	No of Samples
PAH and Alkylated PAH's												
Naphthalene	< 0.02	< 0.02	0.05	5	< 0.02	0.035	0.05	2	< 0.02	< 0.02	< 0.02	6
Acenaphthene	< 0.02	0.03	0.04	5	0.04	0.06	0.08	2	< 0.02	< 0.02	< 0.02	6
Fluorene	< 0.02	0.02	0.06	5	0.07	0.075	0.08	2	< 0.02	< 0.02	< 0.02	6
Dibenzothiophene	< 0.02	< 0.02	< 0.02	5	< 0.02	0.02	0.02	2	< 0.02	< 0.02	< 0.02	6
Phenanthrene	0.02	0.03	0.07	5	0.11	0.125	0.14	2	< 0.02	< 0.02	< 0.02	6
Anthracene	< 0.02	< 0.02	< 0.02	5	< 0.02	< 0.02	< 0.02	2	< 0.02	< 0.02	< 0.02	6
Fluoranthene	< 0.02	< 0.02	< 0.02	5	< 0.02	< 0.02	< 0.02	2	< 0.02	< 0.02	< 0.02	6
Pyrene	< 0.02	< 0.02	< 0.02	5	< 0.02	0.025	0.03	2	< 0.02	< 0.02	0.02	6
Benzo(a)anthracene/Chrysene	< 0.02	< 0.02	0.02	5	< 0.02	0.03	0.04	2	< 0.02	< 0.02	< 0.02	6
Methyl naphthalene	< 0.02	0.04	0.07	5	< 0.02	0.03	0.04	2	< 0.02	< 0.02	< 0.02	6
C2 sub'd naphthalene	< 0.04	0.09	0.32	5	< 0.04	0.05	0.06	2	< 0.04	< 0.04	< 0.04	6
C3 sub'd naphthalene	0.04	0.12	0.82	5	0.31	0.42	0.53	2	< 0.04	< 0.04	0.17	6
C4 sub'd naphthalene	< 0.04	0.09	0.5	5	0.19	0.27	0.35	2	< 0.04	< 0.04	0.2	6
Biphenyl	< 0.04	< 0.04	< 0.04	5	< 0.04	< 0.04	< 0.04	2	< 0.04	< 0.04	< 0.04	6
Methyl biphenyl	< 0.04	< 0.04	< 0.04	5	< 0.04	0.04	0.04	2	< 0.04	< 0.04	< 0.04	6
C2 sub'd biphenyl	< 0.04	< 0.04	< 0.04	5	< 0.04	0.075	0.11	2	< 0.04	< 0.04	< 0.04	6
Methyl acenaphthene	< 0.04	< 0.04	0.06	5	< 0.04	0.06	0.08	2	< 0.04	< 0.04	< 0.04	6
Methyl fluorene	< 0.04	0.04	0.14	5	0.08	0.125	0.17	2	< 0.04	< 0.04	0.04	6
C2 sub'd fluorene	< 0.04	0.07	0.13	5	0.09	0.155	0.22	2	< 0.04	< 0.04	0.06	6
Methyl phenanthrene/anthracene	0.05	0.1	0.13	5	0.22	0.265	0.31	2	< 0.04	< 0.04	< 0.04	6
C2 sub'd phenanthrene/anth	< 0.04	0.09	0.23	5	0.15	0.25	0.35	2	< 0.04	< 0.04	0.05	6
C3 sub'd phenanthrene/anth	< 0.04	0.05	0.21	5	0.11	0.2	0.29	2	< 0.04	< 0.04	0.06	6
C4 sub'd phenanthrene/anth	< 0.04	< 0.04	0.16	5	0.04	0.085	0.13	2	< 0.04	< 0.04	< 0.04	6
Methyl dibenzothiophene	< 0.04	0.06	0.16	5	0.12	0.18	0.24	2	< 0.04	< 0.04	< 0.04	6
C2 sub'd dibenzothiophene	< 0.04	0.08	0.13	5	0.15	0.29	0.43	2	< 0.04	< 0.04	0.04	6
C3 sub'd dibenzothiophene	< 0.04	0.09	0.24	5	0.19	0.32	0.45	2	< 0.04	< 0.04	0.06	6
C4 sub'd dibenzothiophene	< 0.04	< 0.04	0.06	5	< 0.04	0.15	0.26	2	< 0.04	< 0.04	< 0.04	6
Methyl fluoranthene/pyrene	< 0.04	< 0.04	0.06	5	< 0.04	0.045	0.05	2	< 0.04	< 0.04	< 0.04	6
Methyl B(a)A/chrysene	< 0.04	< 0.04	0.05	5	< 0.04	0.045	0.05	2	< 0.04	< 0.04	< 0.04	6
C2 sub'd B(a)A/chrysene	< 0.04	< 0.04	0.05	5	< 0.04	0.05	0.06	2	< 0.04	< 0.04	< 0.04	6
Phenolic Compounds in Water												
o-Cresol	< 2	< 0.2	< 0.1	5	0.1	0.1	0.1	2	< 0.2	< 0.1	< 0.1	6
p-Cresol	< 2	< 0.2	0.2	5	0.3	0.3	0.3	2	< 0.2	< 0.1	< 0.1	6
2,4-Dimethylphenol	< 2	< 0.2	< 0.1	5	0.1	0.15	0.2	2	< 0.2	< 0.1	< 0.1	6
PANH and Alkylated PANH's												
7-Methyl quinoline	< 0.02	< 0.02	4	5	< 0.02	< 0.02	< 0.02	2	< 0.02	< 0.02	< 0.02	6
C2 Alkyl subst'd quinolines	< 0.02	< 0.02	0.32	5	< 0.02	< 0.02	< 0.02	2	< 0.02	< 0.02	< 0.02	6
Volatile Organics (MS):Water	nd	nd	nd		nd	nd	nd		nd	nd	nd	
Naphthenic Acid (mg/l)	8	21	36	11	47	52	57	3	< 4	4	7	12
Hydrocarbons, Recoverable (mg/l)	< 1	3	5	3	< 1	< 1	< 1	1	< 1	< 1	< 1	3

nd = not detected

The potential uses of groundwater in the study area are limited by the productivity of the aquifers, and the naturally-occurring water quality of the groundwater. The productivity of the aquifers has been assessed using the estimated long-term yield (20 year) as employed by Alberta Environmental Protection.

In the upland, the long-term yield of the surficial aquifer is less than 0.012 L/s (1 m^3/day) over most of the Steepbank Mine area. This is less than the recommended minimum for a single dwelling in Alberta (Alberta Environment 1983). The productivity of the surficial aquifer is limited by the following factors:

- relatively low hydraulic conductivity;
- the thinness of the aquifer (generally less than 3 m); and
- lack of available hydraulic head (the aquifer is quite shallow).

As a result, the surficial aquifer in the upland is not a particularly valuable source of groundwater for water supply purposes.

In the Athabasca River valley, the surficial sand and gravel deposit is expected to be more productive. Although it is limited to the valley sidewalls, the aquifer is hydraulically connected to the river. Therefore, wells can probably be constructed in the aquifer which will divert water from the Athabasca River. Long-term yields over 9 L/s (780 m^3/day) would be expected.

The long-term yield of the Basal Aquifer and Upper Devonian limestone is estimated to be 0.5 L/s (40 m^3/day). However, as discussed in Section E2.5, the water quality in the bedrock aquifers is poor. It is brackish, and contains naturally occurring organic compounds. Table E2.0-5 lists parameters which exceed the maximum concentrations recommended by the Canadian Council of Ministers of the Environment (1991) for domestic and agricultural water supplies. The high levels of sodium, chloride, mercury, iron, manganese, total dissolved solids and the presence of organic compounds make it unsuitable for drinking water without pre-treatment. The high levels of chloride and total dissolved solids also make it unsuitable for agricultural use. The bedrock aquifers are therefore not a valuable water resource.

TABLE E2.0-5
GROUNDWATER QUALITY PARAMETERS WHICH EXCEED CCME GUIDELINES

	Sodium (mg/L)	Chloride (mg/L)	TDS (mg/L)	Iron (mg/L)	Mercury [1] (mg/L)	Manganese (mg/L)
Median Concentration Found in Groundwater at Steepbank Mine						
Basal Aquifer	3290	4090	8613	0.7	1.6	0.28
Limestone	1855	1613	4700	0.75	0.23	0.08
Surficial Aquifer	9.4	4.3	183	0.07	1	0.07
CCME Guidelines						
Drinking Water	200	250	500	0.3	1	--
Irrigation	--	--	500-3500	5	--	0.01-0.05
Watering Livestock	--	100-700	3000	--	--	0.5

[1] Maximum concentration of mercury detected

E3.0 GROUNDWATER IMPACT DESCRIPTION

E3.1 CONSTRUCTION PHASE (1997 - 2000)

The only effect that the construction phase is expected to have on the hydrogeologic system is associated with the water supply wells for the new facility. It is planned that two or three water wells will be constructed in the sand and gravel, between the Athabasca River and the proposed facilities area. None of the other aquifers are affected by mine activity in this time frame. A water demand of approximately 7.6 L/s (650 m^3/day) has been proposed.

Because the water wells will be close to the river, it is expected that they will induce infiltration of water from the Athabasca River. While they are pumped, the wells will lower the water level in the aquifer within the vicinity. The change in the water level in the aquifer is expected to be small, because of recharge from the river. There will be very little effect on the aquifer to the east of the water wells. The flow direction, discharge rate and quality of groundwater in the upland surficial aquifer and bedrock aquifers will not be affected by these wells.

The small impact that the water wells will have on the local groundwater will cease within weeks of discontinuing the use of the wells.

Construction of the contamination mitigation measures at the Athabasca Bridge, East Access Corridor and Facilities area as described in Section D2.0 are expected to prevent contamination of the groundwater from routine operations. Prior to any construction, a thorough site investigation will be conducted to determine whether features such as compacted liners will be required. Monitoring wells will be installed at appropriate facilities including the stormwater retention basins, to evaluate the performance of the mitigation measures and provide notice of any release for which remedial measures may be required.

E3.2 MINE OPERATIONS (2000 - 2009)

During the first ten years of the operation of the mine, the effects imposed on the hydrogeologic system will be associated with the excavation of Pit 1. The impacts which will occur, commencing in 2001, when mining starts in earnest are described below:

In the surficial aquifer, the direction of groundwater flow will change, as a result of dewatering of the overburden in the areas of Pits 1 and 2.

- The rate of groundwater discharge from the surficial aquifer will not be affected by the changes in flow direction.
- In the bedrock aquifers, the direction of groundwater flow near Pit 1 will change, because Pit 1 will be excavated below the pre-mine piezometric level in the aquifers.
- The rate of groundwater discharge from the bedrock aquifers will change, as a result of the change in the direction of its flow.
- There will be no changes to the quality of the groundwater in the surficial or bedrock aquifers.

As a component of the stripping of overburden during the development of Pit 1, the surficial deposits in the area will be dewatered. The surficial aquifer will be intercepted with a diversion system on the east side of the mine, and the groundwater will be diverted to Shipyard Lake through the surface water pre-mine drainage system. The total volume of groundwater discharging from the aquifer to the surface water environment will not change. However, the nature of groundwater discharge from the aquifer to surface water will change. Currently, the discharge occurs as seepage to the Athabasca River, Steepbank River and Shipyard Lake, along the reach of these water bodies adjacent to the Suncor study area. The broad discharge will be replaced by discharge from point sources into Shipyard Lake. By 2009, groundwater in the surficial aquifer up gradient of both Pits 1 and 2 will be diverted to Shipyard Lake and Leggett Creek. From there, it will ultimately discharge into the Athabasca River.

As shown in Table E2.0-1, the discharge of groundwater from the surficial aquifer to the Athabasca River will decrease from 0.44 L/s in 1995 to 0.2 L/s by 2009. The groundwater discharge to the Steepbank River will reduce to near zero as the surficial aquifer will have been mined out. The discharge into Shipyard Lake will increase from 0.17 to 0.4 L/s, due to point source discharge. The discharge into Leggett Creek in 2009 will be approximately 0.23 L/s. Because the groundwater contribution to the rivers is such a minor component of their flow (less than 1 %), the severity of these changes in direction and rate of flow will be very low. The areal extent of this effect will be limited to within approximately 300 m of the diversion system. The change in the direction of flow and rate of discharge from the surficial aquifer will be long-term. The diversion of groundwater from the surficial aquifer is expected to continue after the closure of the mine.

In the bedrock aquifers, the groundwater flow in the Basal Aquifer and Upper Devonian will become directed toward Pit 1. The result will be reduced rates of discharge to the Athabasca and Steepbank Rivers and Shipyard Lake. While the pit is being mined, the discharge to these water bodies from the Pit 1 area will reduce to near zero. Because the groundwater contribution to the rivers and Shipyard Lake is such a minor component of their flow (less than 1 %), the severity of this impact will be very low. The areal extent of this effect will be limited to within 2 km of Pit 1. The duration of this change in discharge will be relatively short term. In 2009, once Pit 1 is filled with consolidated tailings, groundwater from the bedrock aquifers will once again discharge to the Athabasca and Steepbank Rivers at pre-mine rates.

There is the potential, while Pit 1 is being mined, that water will recharge the bedrock aquifers from the Steepbank River and flow toward the pit; since, as shown in the cross section in Figure E2.0-1, the elevation of the Steepbank River is greater than the elevation of the base of the pit on the north side of the site. Based on the hydraulic conductivity of the bedrock aquifers, and the difference in elevation between the river and the pit, the maximum amount of water that may be diverted under steady state conditions is approximately 1.1 L/s. This is less than 1% of the recorded minimum monthly flow in the Steepbank River. Therefore, it does not represent a severe impact on the flow in the river. The areal extent of this effect will be limited to within 2 km of Pit 1. The duration of impact will be relatively short term. In 2009, once Pit 1 is filled with consolidated tailings, groundwater from the aquifer will once again discharge to the Steepbank River.

To summarize the impacts of mining on the hydrogeologic setting between 2000 and 2009, the overall degree of concern is low. The impacts of mining Pit 1 on the direction and rate of groundwater flow are not severe. Furthermore, they are limited to a small area around the pit, and are predominantly short term. There will be negligible changes to the groundwater quality during the period.

E3.3 MINE OPERATIONS (2009 - 2020)

During the period 2009 to 2020, Pit 2 will be mined, and Pond 7 (formerly Pit 1) will be filled with consolidated tailings (CT). These activities are expected to result in the following impacts:

- In the surficial aquifer, the direction of groundwater flow will be changed, as dewatering of the overburden in the areas of Pits 1 and 2 continues.
- The rate of groundwater discharge from the surficial aquifer will not be affected by the changes in flow direction.
- In the bedrock aquifers, the direction of groundwater flow will change, because Pit 2 will be excavated below the equipotential level in the aquifers.
- The rate of groundwater discharge from the bedrock aquifers will change, as a result of the change in the direction of its flow.
- The quality of groundwater in the bedrock aquifers will be changed, because pore water will seep from CT in Ponds 7 and 8 through bedrock toward the Athabasca and Steepbank Rivers and Shipyard Lake.

By the year 2020, it is expected that all groundwater flowing toward the mine in the surficial aquifer will be intercepted, and discharged into Shipyard Lake and Wood Creek. As shown in Table E2.0-1 approximately 0.2 L/s will be discharged to Shipyard Lake. Approximately 0.63 L/s will be discharged to Wood Creek. This water will then flow to the Athabasca River. As the contribution of groundwater to the Athabasca River is so low, the severity of this impact will be very low. The areal extent of this effect will be limited to within about 300 m of the surface interceptor channels. The change in the direction of flow and rate of discharge from the surficial aquifer will be long-term. The diversion of groundwater from the surficial aquifer is expected to continue after the closure of the mine.

The effect on groundwater discharge from the bedrock aquifers of mining from Pit 2 will be the same as for Pit 1. There will be a short term reduction of discharge from the Basal Aquifer and Upper Devonian to the Athabasca River and Shipyard Lake. The severity of this impact will be low. The impact will be limited to the area in the immediate vicinity of Pit 2. In 2020, once mining from Pit 2 is finished, the groundwater discharge from these aquifers will return to pre-mine conditions.

The CT placed in Pond 7 (Figure C-3) will interact with the groundwater in the bedrock aquifers once the mined pits are filled with the tailings. By 2020 (Figure C-4), pore water from the CT is expected to seep from the base of both Ponds 7 and 8. The rate of seepage from the ponds will be a function of the hydraulic conductivity of the CT, the vertical hydraulic gradient between the CT and underlying bedrock aquifers, and the area of the ponds. The hydraulic conductivity of the CT has been estimated to be 1×10^{-9} m/s (AGRA 1996b). Estimates of the seepage from the CT in the ponds into bedrock are shown in Table E2.0-1.

The impact of this seepage from the ponds will be the result of the combined effects of the rate of flow of the seepage and the chemical composition of the pore water. Tables E3.0-1 and E3.0-2 show the results of inorganic analyses of CT pore water. Table E3.0-3 shows the concentrations of organic compounds that have been detected in CT pore water.

TABLE E3.0-1
CONSOLIDATED TAILINGS (CT) - MAJOR IONS IN PORE WATER

Parameter	Detection Limits	Units	Min	Max	Median	No. of Samples
Calcium	0.003	mg/L	< 0.003	0.0066	<0.003	9
Magnesium	0.01	mg/L	7.2	28	12	18
Sodium	0.01	mg/L	347	1170	445	18
Potassium	0.02	mg/L	11.5	29	16.6	18
Chloride	0.5	mg/L	45.4	510	55	18
Sulphate	0.5	mg/L	555	1290	659	18
Total Alkalinity	0.5	mg/L	277	688	353.5	18
Bicarbonate	0.5	mg/L	331	800	409	18
Silicon	0.02	mg/L	< 2.3	5.6	2.9	8
Total Dissolved Solids	1	mg/L	1400	1805	1600	7
Specific Conductance	0.1	µS/cm	1891	4900	2337	9
pH	0.01	Units	7.9	8.5	8.3	18
Phenols	0.001	mg/L	< 0.002	0.016	0.004	5
Dissolved Organic Carbon	0.2	mg/L	52	65.3	60.6	8
Nitrite + Nitrate	0.003	mg/L	< 0.003	0.05	0.016	18
Total Phosphorus (ICP)	0.1	mg/L	< 0.1	0.1	<0.1	6

Data obtained from Chemex Labs (Suncor ID: RW 162, 163, 164)
Samples collected in July, August, September 1995
Other CT samples from Suncor: CT1219

TABLE E3.0-2
CONSOLIDATED TAILINGS (CT) - METALS AND CYANIDE IN PORE WATER

Parameter	Detection Limits	Units	Min	Max	Median	No. of Samples
Aluminum	0.01	mg/L	< 0.01	1.92	0.05	9
Arsenic	0.0002	mg/L	0.0007	0.0058	0.0029	8
Barium	0.01	mg/L	0.05	0.18	0.1	9
Beryllium	0.001	mg/L	< 0.001	0.004	<0.001	9
Boron	0.01	mg/L	2.26	4.26	3.19	9
Cyanide	0.001	mg/L	< 0.001	0.055	<0.001	8
Cadmium	0.003	mg/L	< 0.003	0.0066	<0.003	9
Chromium	0.002	mg/L	< 0.002	0.003	<0.002	9
Cobalt	0.003	mg/L	< 0.003	0.007	<0.003	9
Copper	0.001	mg/L	< 0.001	0.004	0.002	9
Iron	0.01	mg/L	< 0.01	1.01	0.04	9
Lead	0.02	mg/L	< 0.0003	0.02	0.02	9
Lithium	0.001	mg/L	0.16	0.27	0.19	9
Manganese	0.001	mg/L	< 0.001	0.058	0.024	9
Mercury	0.05	ug/L	< 0.05	0.05	<0.05	7
Molybdenum	0.003	mg/L	0.15	1.42	1.15	9
Nickel	0.005	mg/L	< 0.005	0.030	0.018	9
Selenium	0.0002	mg/L	< 0.0002	0.04	0.0015	8
Silver	0.002	mg/L	< 0.0002	0.002	<0.002	9
Strontium	0.002	mg/L	0.75	2.12	1.02	9
Titanium	0.003	mg/L	< 0.003	0.016	<0.003	9
Uranium	0.5	mg/L	0.0068	0.5	0.5	9
Vanadium	0.002	mg/L	< 0.002	0.17	0.006	9
Total Ammonia	0.01	mg/L	0.098	3.98	0.7	17
Total Sulphur	0.2	mg/L	186	266	229	7
Total Kjeldhal Nitrogen	0.05	mg/L	0.95	6.8	1.82	16
Total Dissolved Solids	1	mg/L	1400	1805	1600	7
Titanium	0.003	mg/L	< 0.003	0.016	<0.003	9
Total Organic Carbon	0.2	mg/L	56.1	68	64.5	6
Total Alkalinity	0.5	mg/L	277	688	354	18
Total Phosphorus	0.003	mg/L	0.006	0.096	0.037	16
Total Suspended Solids	0.4	mg/L	< 0.4	17	6	6
Uranium	0.5	mg/L	0.0068	0.5	0.5	9
Vanadium	0.002	mg/L	< 0.002	0.17	0.006	9
Zinc	0.001	mg/L	0.003	0.056	0.043	9

Data obtained from Chemex Labs (Suncor ID: RW 162, 163, 164)
Samples collected in July, August, September 1995
Other CT samples from Suncor: CT1219

TABLE E3.0-3
ORGANIC COMPOUNDS DETECTED IN PORE WATER FROM CONSOLIDATED TAILINGS (CT) AND GROUNDWATER SAMPLES (µg/L)

	Suncor Consolidated Tailings				Basal Aquifer				Limestone				Surficial Sand			
Parameter	Min	Median	Max	No of Samples	Min	Median	Max	No of Samples	Min	Median	Max	No of Samples	Min	Median	Max	No of Samples
PAH & Alkylated PAH's																
Naphthalene	< 0.02	<0.02	0.05	16	< 0.02	< 0.02	0.05	5	< 0.02	0.035	0.05	2	< 0.02	< 0.02	< 0.02	6
Acenaphthene	0.02	<0.02	0.08	16	< 0.02	0.03	0.04	5	0.04	0.06	0.08	2	< 0.02	< 0.02	< 0.02	6
Acenaphthylene	< 0.02	0.03	0.16	16	< 0.02	< 0.02	< 0.02	5	< 0.02	< 0.02	< 0.02	2	< 0.02	< 0.02	< 0.02	6
Fluorene	< 0.02	<0.02	0.03	16	< 0.02	0.02	0.06	5	0.07	0.075	0.08	2	< 0.02	< 0.02	< 0.02	6
Dibenzothiophene	< 0.02	<0.02	0.07	14	< 0.02	< 0.02	< 0.02	5	< 0.02	0.02	0.02	2	< 0.02	< 0.02	< 0.02	6
Phenanthrene	< 0.02	<0.02	0.09	16	0.02	0.03	0.07	5	0.11	0.125	0.14	2	< 0.02	< 0.02	< 0.02	6
Pyrene	< 0.02	<0.02	0.04	16	< 0.02	< 0.02	< 0.02	5	< 0.02	0.025	0.03	2	< 0.02	< 0.02	0.02	6
Benzo(a)anthracene/Chrysene	< 0.02	<0.02	0.27	16	< 0.02	< 0.02	0.02	5	< 0.02	0.03	0.04	2	< 0.02	< 0.02	< 0.02	6
Methyl naphthalene	0.02	<0.04	0.08	14	< 0.02	0.04	0.07	5	< 0.02	0.03	0.04	2	< 0.02	< 0.02	< 0.02	6
C2 sub'd naphthalene	< 0.04	<0.04	0.25	16	< 0.04	0.09	0.32	5	< 0.04	0.05	0.06	2	< 0.04	< 0.04	< 0.04	6
C3 sub'd naphthalene	< 0.04	<0.04	0.3	16	0.04	0.12	0.82	5	0.31	0.42	0.53	2	< 0.04	< 0.04	0.17	6
C4 sub'd naphthalene	< 0.04	<0.04	2	16	< 0.04	0.09	0.5	5	0.19	0.27	0.35	2	< 0.04	< 0.04	0.2	6
Methyl biphenyl	0.04	<0.04	0.08	16	< 0.04	< 0.04	< 0.04	5	< 0.04	0.04	0.04	2	< 0.04	< 0.04	< 0.04	6
C2 sub'd biphenyl	< 0.04	<0.04	0.25	16	< 0.04	< 0.04	< 0.04	5	< 0.04	0.075	0.11	2	< 0.04	< 0.04	< 0.04	6
Methyl acenaphthene	< 0.04	<0.04	0.19	16	< 0.04	< 0.04	0.06	5	< 0.04	0.06	0.08	2	< 0.04	< 0.04	< 0.04	6
Methyl fluorene	< 0.04	<0.04	0.3	16	< 0.04	0.04	0.14	5	0.08	0.125	0.17	2	< 0.04	< 0.04	0.04	6
C2 sub'd fluorene	< 0.04	<0.04	1.1	16	< 0.04	0.07	0.13	5	0.09	0.155	0.22	2	< 0.04	< 0.04	0.06	6
Methyl phenanthrene/anthracene	< 0.04	<0.04	0.79	16	0.05	0.1	0.13	5	0.22	0.265	0.31	2	< 0.04	< 0.04	< 0.04	6
C2 sub'd phenanthrene/anth.	< 0.04	<0.04	4.5	16	< 0.04	0.09	0.23	5	0.15	0.25	0.35	2	< 0.04	< 0.04	0.05	6
C3 sub'd phenanthrene/anth.	< 0.04	<0.04	3.6	16	< 0.04	0.05	0.21	5	0.11	0.2	0.29	2	< 0.04	< 0.04	0.06	6
C4 sub'd phenanthrene/anth.	< 0.04	<0.04	1.7	15	< 0.04	< 0.04	0.16	5	0.04	0.085	0.13	2	< 0.04	< 0.04	< 0.04	6
Methyl dibenzothiophene	< 0.04	<0.04	0.65	16	< 0.04	0.06	0.16	5	0.12	0.18	0.24	2	< 0.04	< 0.04	< 0.04	6
C2 sub'd dibenzothiophene	< 0.04	<0.04	2.2	16	< 0.04	0.08	0.13	5	0.15	0.29	0.43	2	< 0.04	< 0.04	0.04	6
C3 sub'd dibenzothiophene	< 0.04	<0.04	4.1	16	< 0.04	0.09	0.24	5	0.19	0.32	0.45	2	< 0.04	< 0.04	0.06	6
C4 sub'd dibenzothiophene	< 0.04	<0.04	4.4	16	< 0.04	< 0.04	0.06	5	< 0.04	0.15	0.26	2	< 0.04	< 0.04	< 0.04	6
Methyl fluoranthene/pyrene	< 0.04	<0.04	0.65	16	< 0.04	< 0.04	0.06	5	< 0.04	0.045	0.05	2	< 0.04	< 0.04	< 0.04	6
Methyl B(a)A/chrysene	< 0.04	<0.04	0.5	16	< 0.04	< 0.04	0.05	5	< 0.04	0.045	0.05	2	< 0.04	< 0.04	< 0.04	6
C2 sub'd B(a)A/chrysene	< 0.04	<0.04	0.83	16	< 0.04	< 0.04	0.05	5	< 0.04	0.05	0.06	2	< 0.04	< 0.04	< 0.04	6
Phenolic Compounds in Water																
Phenol	< 0.1	0.2	0.2	6	< 2	< 0.2	< 0.1	5	< 0.1	< 0.1	< 0.1	2	< 0.2	< 0.1	< 0.1	6
m-Cresol	< 0.1	0.3	0.5	5	< 2	< 0.2	< 0.1	5	< 0.1	< 0.1	< 0.1	2	< 0.2	< 0.1	< 0.1	6
m-Cresol	1	1	1	3												
p-Cresol	0.1	<0.1	0.2	5	< 2	< 0.2	0.2	5	0.3	0.3	0.3	2	< 0.2	< 0.1	< 0.1	6
2,4-Dimethylphenol	< 0.2	0.35	1	4	< 2	< 0.2	< 0.1	5	0.1	0.15	0.2	2	< 0.2	< 0.1	< 0.1	6
PANH & Alkylated PANH's	nd	nd	nd		nd	nd	nd		nd	nd	nd		nd	nd	nd	
Volatile Organics (MS):H2O	nd	nd	nd		nd	nd	nd		nd	nd	nd		nd	nd	nd	
Naphthenic Acids (mg/l)	62	76	94		8	21	36	11	47	52	57	3	< 4	4	7	12
Hydrocarbons,Recoverable (mg/l)	< 1	<1	22	18	< 1	3	5	3	< 1	< 1	< 1	1	< 1	< 1	< 1	3

Data obtained from Envirotest Laboratories (Suncor ID: RW 162, 163, 164) & PD5, CT1219

Samples Collected in July, August, September 1995

Additional CT900 & CT1400 obtained from Syncrude Research Center.

nd = not detected

The duration of any impact associated with seepage of CT water will be long-term. The seepage from the ponds will flow through the bedrock aquifers toward the Athabasca and Steepbank Rivers. The result is expected to be increased discharge to these water bodies. As shown in Table E2.0-1, by the year 2020, the rate of discharge of the seepage water to the Athabasca River is estimated to be 5.8 L/s. The discharge rates to the Steepbank River and Shipyard Lake are estimated to be 1.4 and 0.4 L/s, respectively. The rate of seepage represents less than 1 % of the flow in any of these water bodies. The impact of this increased flow on the flow rates in the surface water will be negligible.

Comparison of the chemical composition of the CT water to groundwater chemistry in the bedrock aquifers indicates that although CT has a higher pH, and contains higher levels of dissolved organic carbon (DOC) than the bedrock groundwater, the chemistry is similar. The concentration of naphthenic acids in the CT water (62 to 94 mg/L) is also higher than in the bedrock aquifers. However, the types and concentrations of organic compounds found in the CT are similar to the naturally-occurring organic composition of the bedrock groundwater. Therefore, the severity of the impact of introducing CT water to the bedrock groundwater system is low. With respect to its effect on the future use of the groundwater, the expected change in the groundwater chemistry will be negligible.

To summarize the impacts of mining on the hydrogeologic setting between 2009 and 2020, the overall degree of concern is low. The impacts of mining Pits 1 and 2 are limited to the mine site. Although some of the changes imposed by the mine will be long-term, the severity of the impacts will be very low. The direction of groundwater flow in the bedrock aquifers will not be affected. The groundwater in the surficial aquifer will be diverted to Shipyard Lake and Wood Creek. The flow rate of seepage from the ponds will not be much greater than the rate of natural groundwater discharge currently flowing into surface water bodies at the site. The changes in the rates of groundwater discharge to surface water, as a result of diversion of surficial groundwater and seepage of CT water are small in comparison to the rates of flow in the Athabasca and Steepbank Rivers. The contribution of groundwater flow to the water balance of Shipyard Lake is also very minor. Finally, the composition of the CT pore water that is expected to seep from Ponds 7 and 8 is similar in quality to the natural groundwater in the bedrock. Therefore, the degree of concern associated with the long-term changes in groundwater flow and seepage of CT water from the ponds is low.

E3.4 POST RECLAMATION

There will be no additional impacts to the hydrogeologic system as a result of closure and reclamation. These impacts have already been identified as:

- Changes in the direction of groundwater flow in the surficial aquifer to discharge points into Shipyard Lake and Wood Creek; and
- Small changes in flow rate and water quality in the bedrock aquifers, as seepage of pore water from the CT in Ponds 7 and 8, flows through the aquifers, to the Athabasca River, Steepbank River, and Shipyard Lake.

As has been discussed above, the level of concern associated with these impacts is low.

E4.0 SUMMARY OF GROUNDWATER IMPACT ANALYSIS AND ENVIRONMENTAL MONITORING

In terms of the impact hypotheses considered in Section A.1-0, all residual impacts of the mine related to groundwater are of low concern. The impacts that the Steepbank Mine is expected to have on groundwater in the surficial and bedrock aquifers are shown diagrammatically in Figures E4.0-1, E4.0-2 and E4.0-3, in terms of changes in the flow direction, discharge rate and quality.

Hypothesis 24 Flows in the Athabasca and Steepbank Rivers would be significantly changed by mine development withdrawals for extraction, upgrading and/or reclamation.

Result: The changes to groundwater discharge to surface waters will have a negligible impact on flows in the Athabasca and Steepbank Rivers.

Hypothesis 27 Groundwater quality could be affected by contaminant migration from processing and extraction activities.

Result: Groundwater quality will not be affected by contaminant migration from processing and extraction activities.

Although the impacts of the mine on groundwater will be negligible, a comprehensive sampling and analysis program similar to that conducted as part of the existing operation will be conducted up gradient and down gradient of the mine area, to confirm that mining impacts are as expected, and provide notice of any water quality and flow concerns.

A groundwater monitoring network will be installed down gradient of all potential sources of groundwater contamination, to ensure that accidental releases are detected early.

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G GLOSSARY

Aquifer	A body of rock or soil which contains sufficient amounts of saturated permeable material to yield economic quantities of water to wells or springs.
Aquitard	A lithologic unit that impedes groundwater movement and does not yield water freely to wells or springs but that may transmit appreciable water to or from adjacent aquifers. Where sufficiently thick, may act as a groundwater storage zone. Synonymous with confining unit.
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.
ASL	Above sea level
Baseline	A surveyed condition which serves as a reference point to which later surveys are coordinated or correlated.
Bedrock	The body of rock which underlies the gravel, soil or other superficial material.
Borehole Log	The record of geologic units penetrated, drilling progress, depth, water level, sample recovery, volumes and types of materials used, and other significant details regarding the drilling of an exploratory borehole or well.
Confined Aquifer	An aquifer in which the potentiometric surface is above the top of the aquifer.

Consolidated Tailings	Consolidated Tailings (CT) is a non-segregating mixture of plant tailings which consolidates relatively quickly in tailings deposits. At Suncor, consolidated tailings will be prepared by combining mature fine tails with thickened (cycloned) fresh sand tailings. This mixture is chemically stabilized to prevent segregation of the fine and coarse solids using gypsum ($CaSO_4$).
Consolidation	The gradual reduction in volume of a soil mass.
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.)
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.
De-pressurize	The process of reducing the pressure in an aquifer, by withdrawing water from it.
Deuterium	A stable isotope of hydrogen, which has two neutrons.
Energy Dissipation	A structure designed to dissipate the excessive structure energy of a high velocity fluid (i.e., water), to establish a safe flow condition and prevent scour or minimize erosion. (See also "Hydraulic structure")
Ephemeral	A phenomena or feature which only lasts for a short time (i.e., an ephemeral stream is only present for short periods during the year).
Equipotential Level	The level on which the potential everywhere is constant; the level at surface which the pressure head of a body of groundwater is the same.
Floodplain	Land near rivers and lakes that may be inundated during seasonally high water levels (i.e., floods).

Fluvial	Relating to a stream or river.
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.
Glacio-Lacustrine	Relating to the lakes that formed of the edge of glaciers as the glaciers receded. Glacio-lacustrine sediments are commonly laminar deposits of fine sand, silt and clay.
Ground Penetrating	Method of mapping subsurface layer geometry using radar.
Groundwater	That part of the subsurface water which 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. The way that the term is used in this document, it technically refers to the average linear velocity of the groundwater.
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.
Hydraulic Conductivity	The permeability of soil or rock to water.

Hydraulic Gradient	A measure of the force 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, ft/ft.
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 which is designed to handle water in any way. This includes the 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.
Inorganics	Pertaining or relating to a compound that contains no carbon.
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 produces by natural processes (e.g., hill, valley, plateau).
Lean Oil Sands	Oil bearing sands, which do not have a high enough saturation of oil to make extraction of them economically feasible.
Microtox©	A toxicity test which includes an assay of light production by a strain of luminescent bacteria (*Photobacterium phosphoreum*).

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 which has to be removed to expose the ore.
Oxygen-18	A stable isotope of oxygen which has two more neutrons than the more common oxygen-16.
Piezometer	A pipe in the ground in which the elevation of water level ca 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.
Pneumatic Piezometer	A type of piezometer in which the hydraulic head is measured using a compressed gas.
Pore Water	Water that is present between the grains of a soil or rock.
Potentiometric Surface	An imaginary surface representing the static head of groundwater. The water table is a particular potentiometric surface.
Run-off	The portion of water from rain and snow which flows over land to streams, ponds or other surface water bodies. It is the portion of water from precipitation which does not infiltrate into the ground, or evaporate.

Run-on	Essentially the same thing as run-off, but referring to water that flows onto a property, or any piece of land of interest. Includes only those waters which have not been in contact with exposed oil sands, or with oil sands operational area.
Sediment Sampling	A field procedure relating to a methodology for determining the configuration of sediment deposits.
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.
Stable Isotopes	Isotopes of a particular element have the same number of protons; but different numbers of neutrons. Isotopes are stable if they do not naturally undergo radioactive decay.
Static Water Level	The elevation of the top of a column of water in a monitoring well or piezometer that is not influenced by pumping.
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.
Surficial Aquifer	A surficial deposit containing water to be considered an aquifer.
Surficial Deposit	A geologic deposit (like clay, silt or sand) that has been placed above bedrock. (See also "Overburden")
Tailings	A by-product of oil sands extraction which are comprised of water, sands and clays, with minor amounts of residual bitumen.

Thalweg	The (imaginary) line connecting the lowest points along a streambed or valley. Within rivers, the deep channel area.
Total Dissolved Solids (TDS)	The total concentration of all dissolved compounds solids found in a water sample.
Toxicity	The inherent potential or capacity of a material to cause adverse effects in a living organism.
Twenty Year Safe Yield (Q_{20})	An estimation of the long term rate at which a water well will produce water. The Q20 is the rate at which a well can be pumped continuously for 20 years, without the water level dropping below the top of the aquifer. (See also "Available drawdown").
Unconfined Aquifer	An aquifer in the which the water level is below the top of the aquifer.
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.
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 such as swamps, marshes, bogs, muskegs, potholes, swales, glades, slashes and overflow land of river valleys.

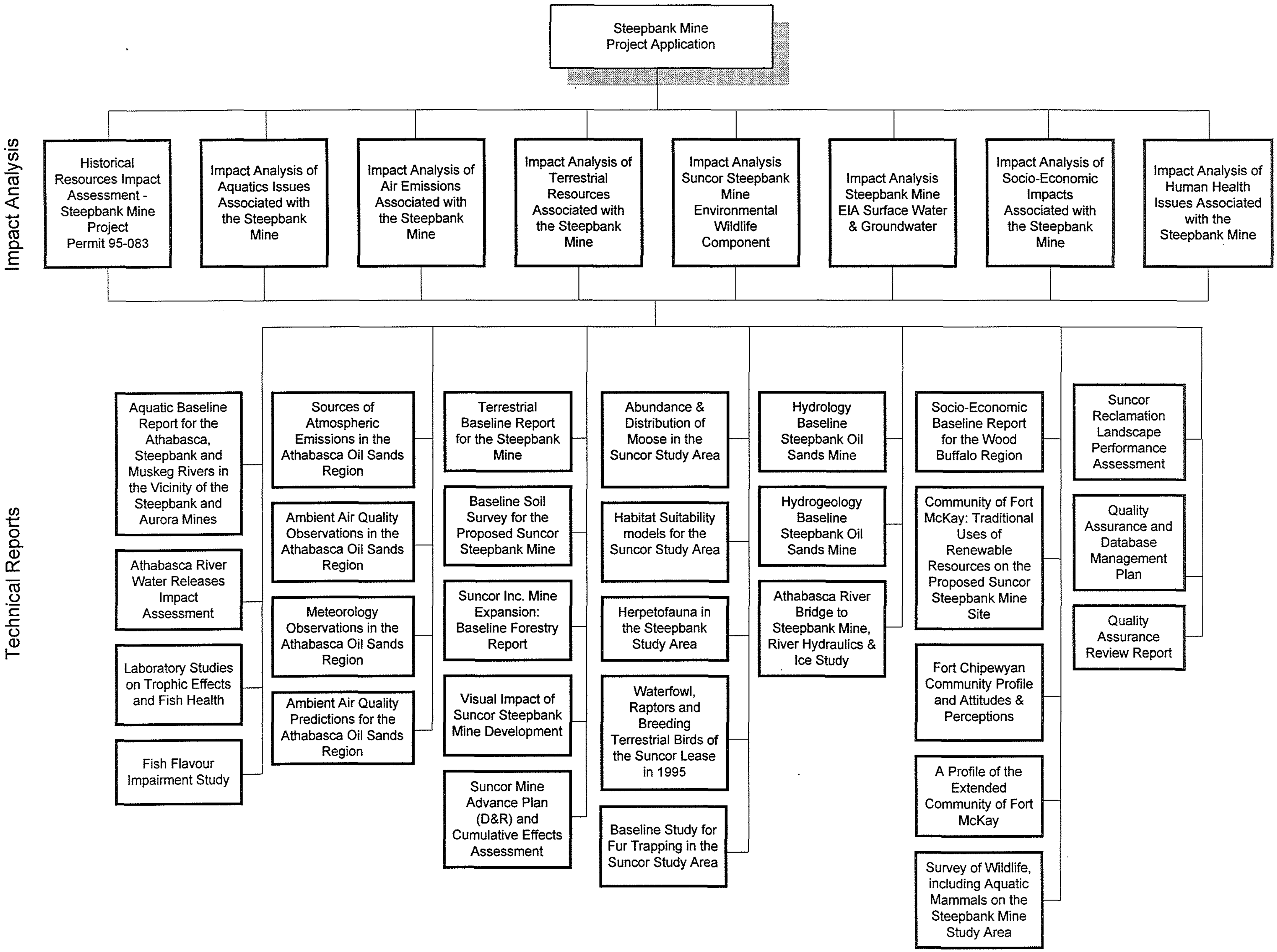

Figure A1.0-1 **Reports Prepared for the Steepbank Mine Environmental Assessment**

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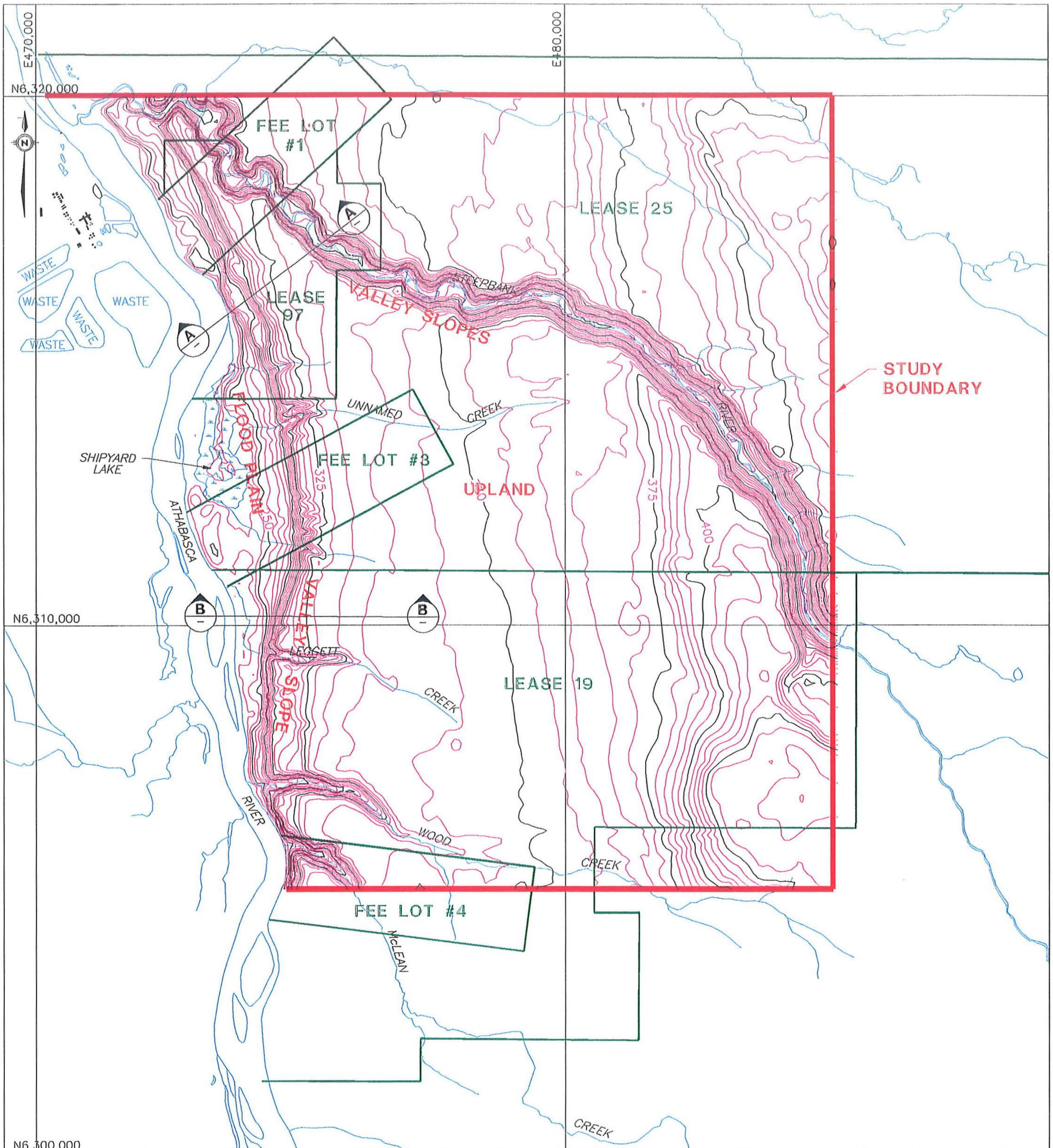
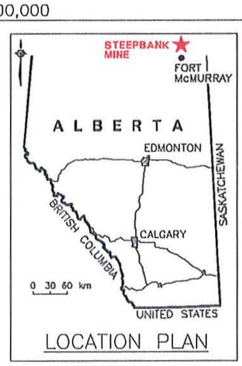




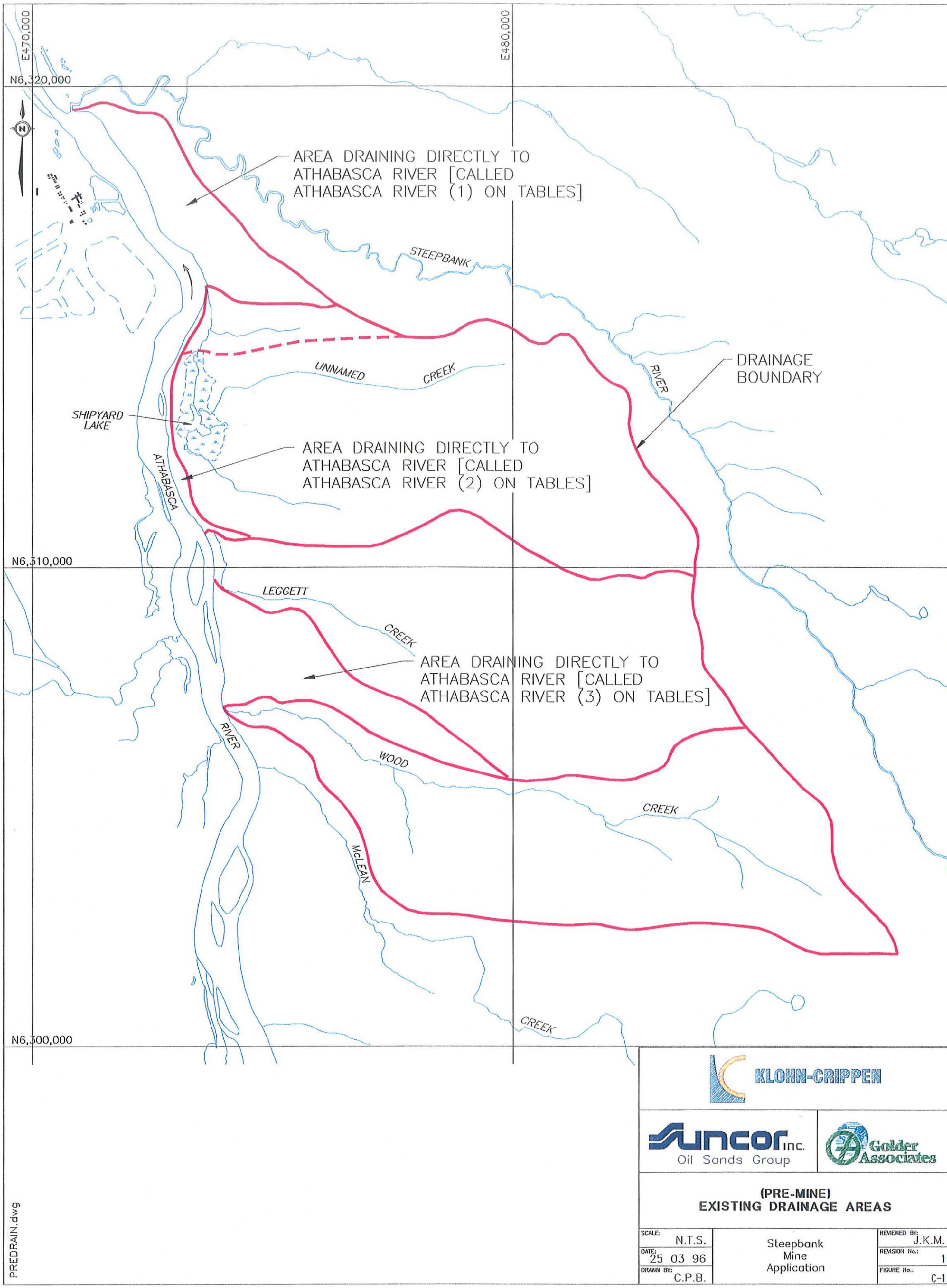
KLOHN-CRIPPEN

Suncor Inc. Oil Sands Group

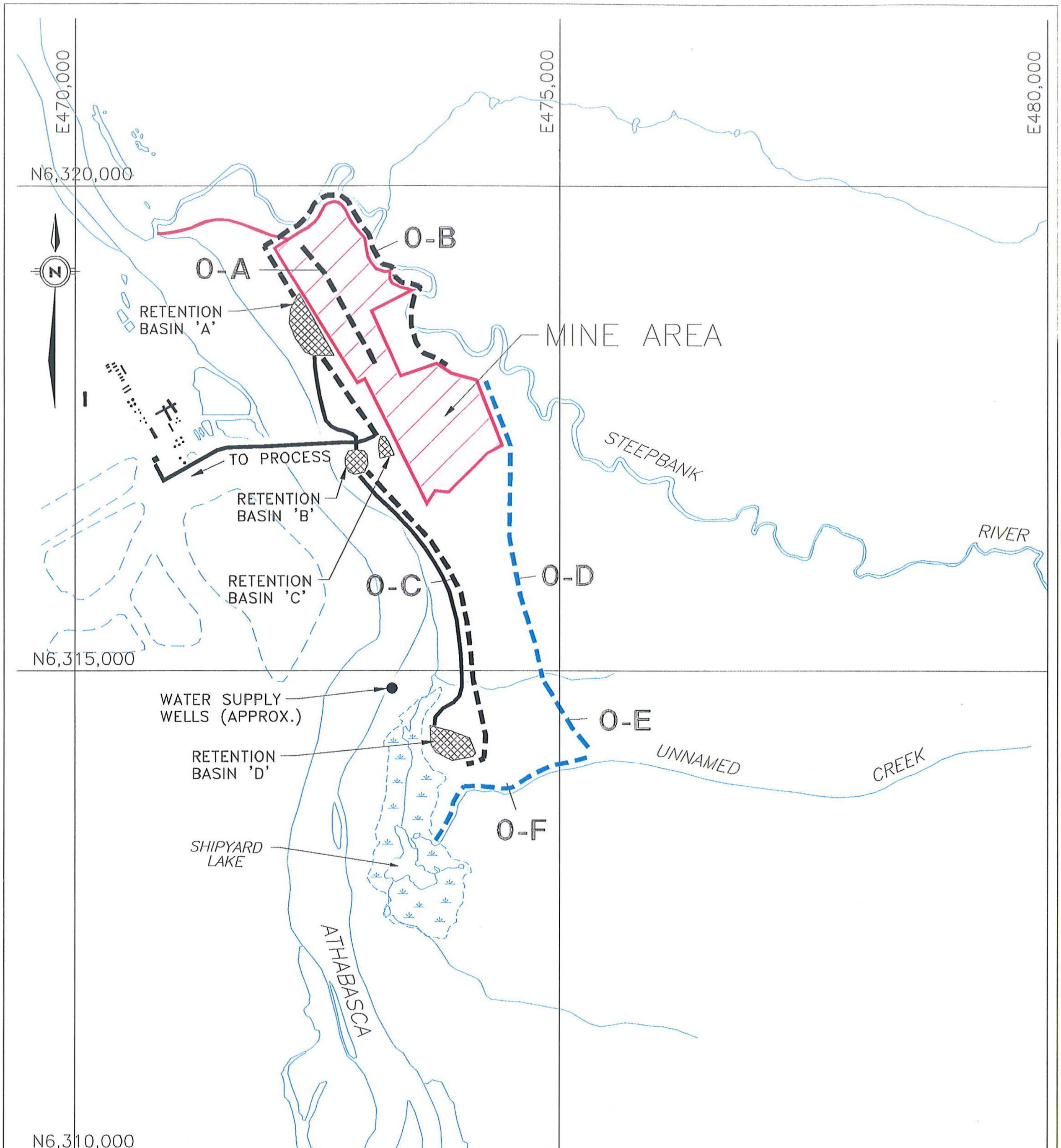
Golder Associates

PRE-MINE (1995) SITE MAP

SCALE: 1:100,000	Steepbank Mine Application	REVIEWED BY: J.K.M.
DATE: 25 03 96		REVISION No.: 1
DRAWN BY: C.P.B.		FIGURE No.: A2.0-1



E470,000
E480,000
N6,320,000
N6,310,000
N6,300,000
N
AREA DRAINING DIRECTLY TO ATHABASCA RIVER [CALLED ATHABASCA RIVER (1) ON TABLES]
STEEPBANK
RIVER
UNNAMED CREEK
DRAINAGE BOUNDARY
SHIPYARD LAKE
AREA DRAINING DIRECTLY TO ATHABASCA RIVER [CALLED ATHABASCA RIVER (2) ON TABLES]
ATHABASCA
LEGGETT
CREEK
AREA DRAINING DIRECTLY TO ATHABASCA RIVER [CALLED ATHABASCA RIVER (3) ON TABLES]
RIVER
WOOD
CREEK
McLEAN
CREEK
KLOHN-CRIPPEN
Suncor inc.
Oil Sands Group
Golder Associates
(PRE-MINE)
EXISTING DRAINAGE AREAS
SCALE: N.T.S.
DATE: 25 03 96
DRAWN BY: C.P.B.
Steepbank Mine Application
REVIEWED BY: J.K.M.
REVISION No.: 1
FIGURE No.: C-1
PREDRAIN.dwg



LEGEND

- O-E — MINE DESIGNATION
- INTERCEPTION CHANNEL
- MINE DRAINAGE CHANNEL
- DRAINAGE PIPELINE

KLOHN-CRIPPEN

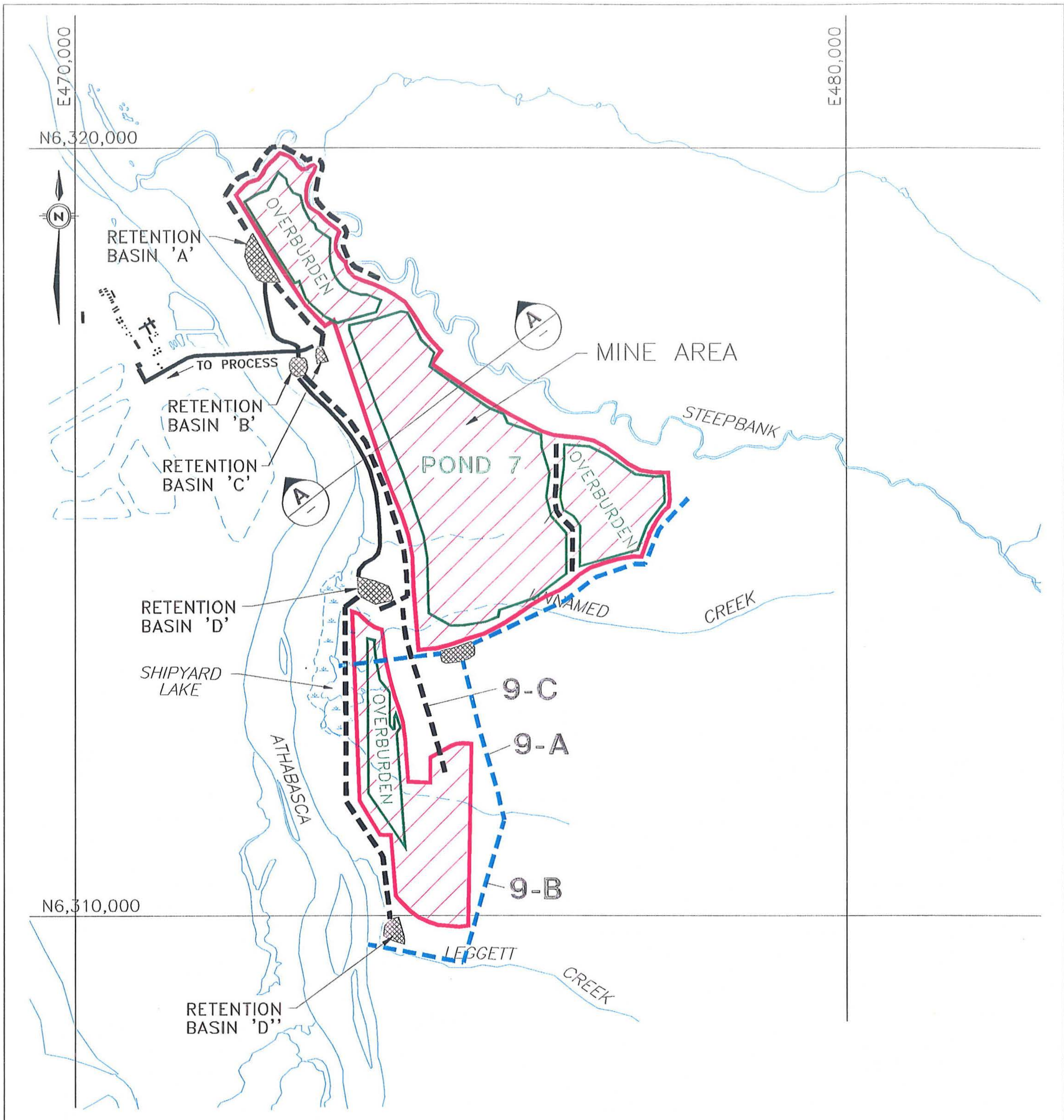
Suncor Inc. Oil Sands Group

Golder Associates

YEAR 2001
STEEPBANK MINE DEVELOPMENT

SCALE: N.T.S.	Steepbank Mine Application	REVIEWED BY: J.K.M.
DATE: 25 03 96		REVISION No.: 1
DRAWN BY: C.P.B.		FIGURE No.: C-2

2001.dwg



LEGEND

0-E	MINE DESIGNATION
– – – – (blue)	INTERCEPTION CHANNEL
– – – – (black)	MINE DRAINAGE CHANNEL
———	DRAINAGE PIPELINE

KLOHN-CRIPPEN

Suncor Inc. Oil Sands Group

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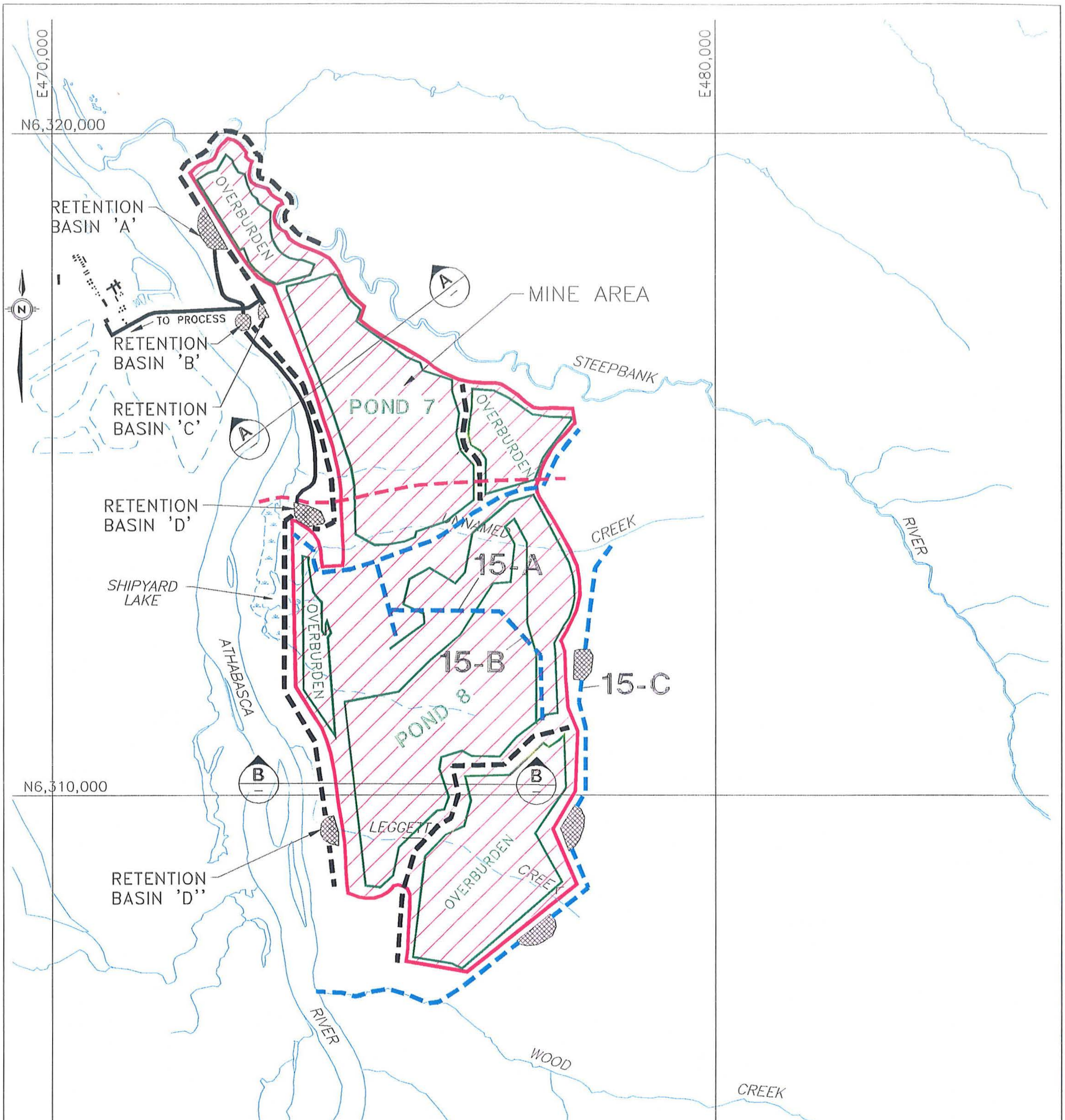
YEAR 2009
STEEPBANK MINE DEVELOPMENT

SCALE: N.T.S.	Steepbank Mine Application	REVIEWED BY: J.K.M.
DATE: 25 03 96		REVISION No.: 1
DRAWN BY: C.P.B.		FIGURE No.: C-3

2009.dwg



LEGEND

0-E	MINE DESIGNATION
(blue dashed line)	INTERCEPTION CHANNEL
(black dashed line)	MINE DRAINAGE CHANNEL
(solid line)	DRAINAGE PIPELINE

KLOHN-CRIPPEN

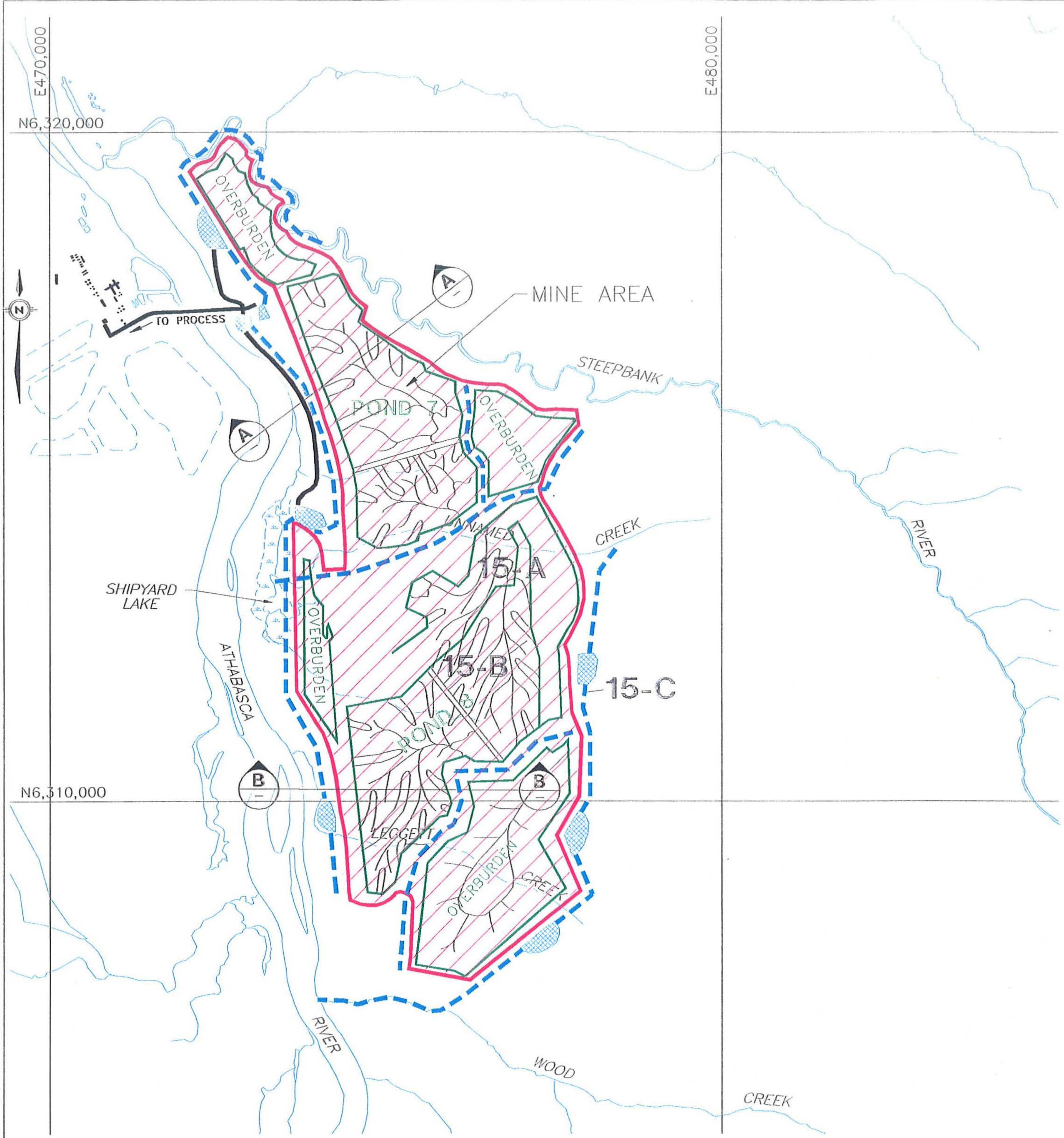
Suncor Inc. Oil Sands Group

Golder Associates

YEAR 2020
STEEPBANK MINE DEVELPMENT

SCALE: N.T.S.	Steepbank Mine Application	REVIEWED BY: J.K.M.
DATE: 25 03 96		REVISION No.: 1
DRAWN BY: C.P.B.		FIGURE No.: C-4

2020.dwg



LEGEND

0-E	MINE DESIGNATION
– – – –	RECLAMATION DRAINAGE CHANNEL
———	DRAINAGE PIPELINE

KLOHN-CRIPPEN

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Oil Sands Group

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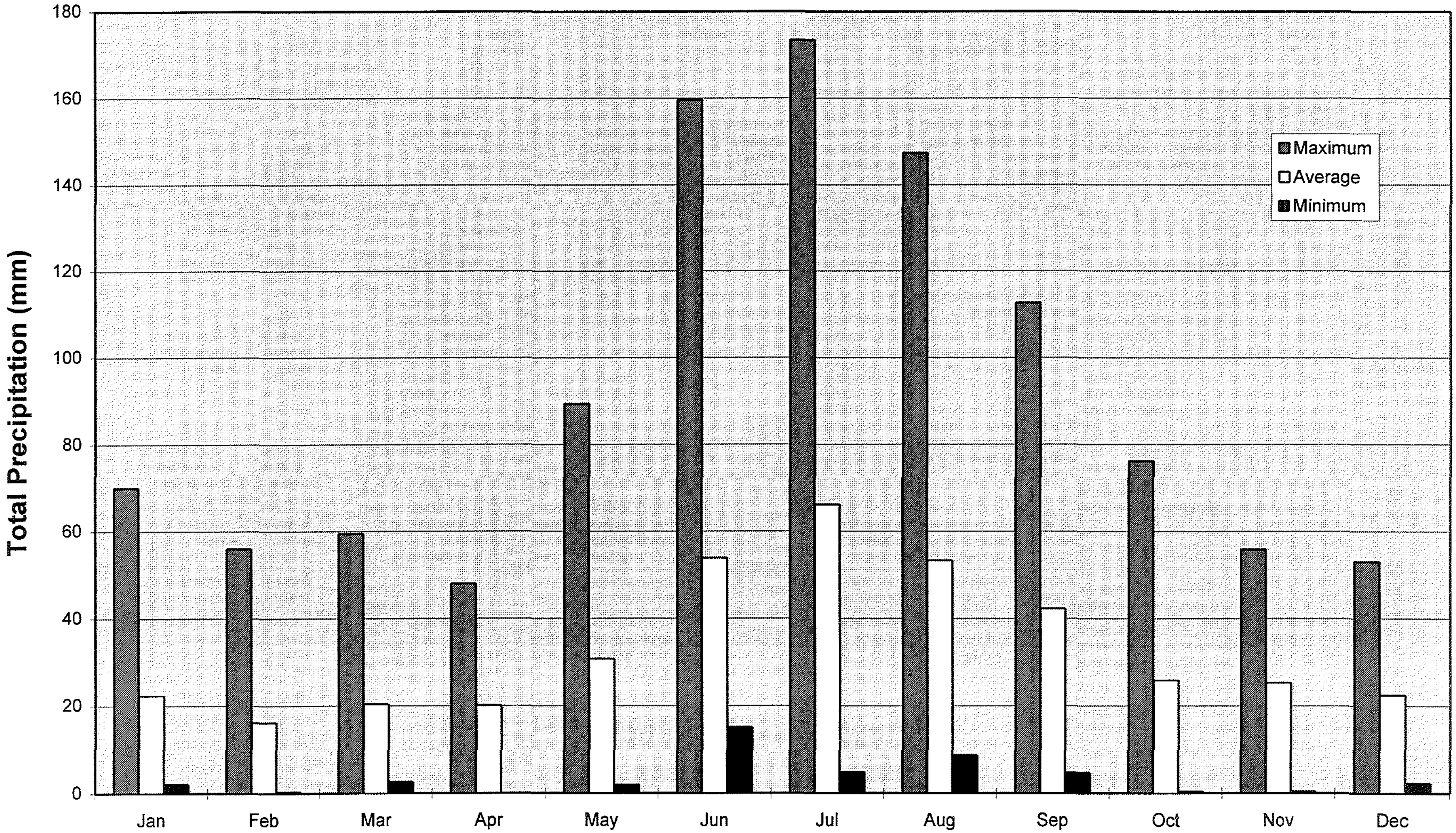
POST RECLAMATION DRAINAGE

SCALE: N.T.S.	Steepbank Mine Application	REVIEWED BY: J.K.M.
DATE: 25 03 96		REVISION No.: 1
DRAWN BY: C.P.B.		FIGURE No.: C-5

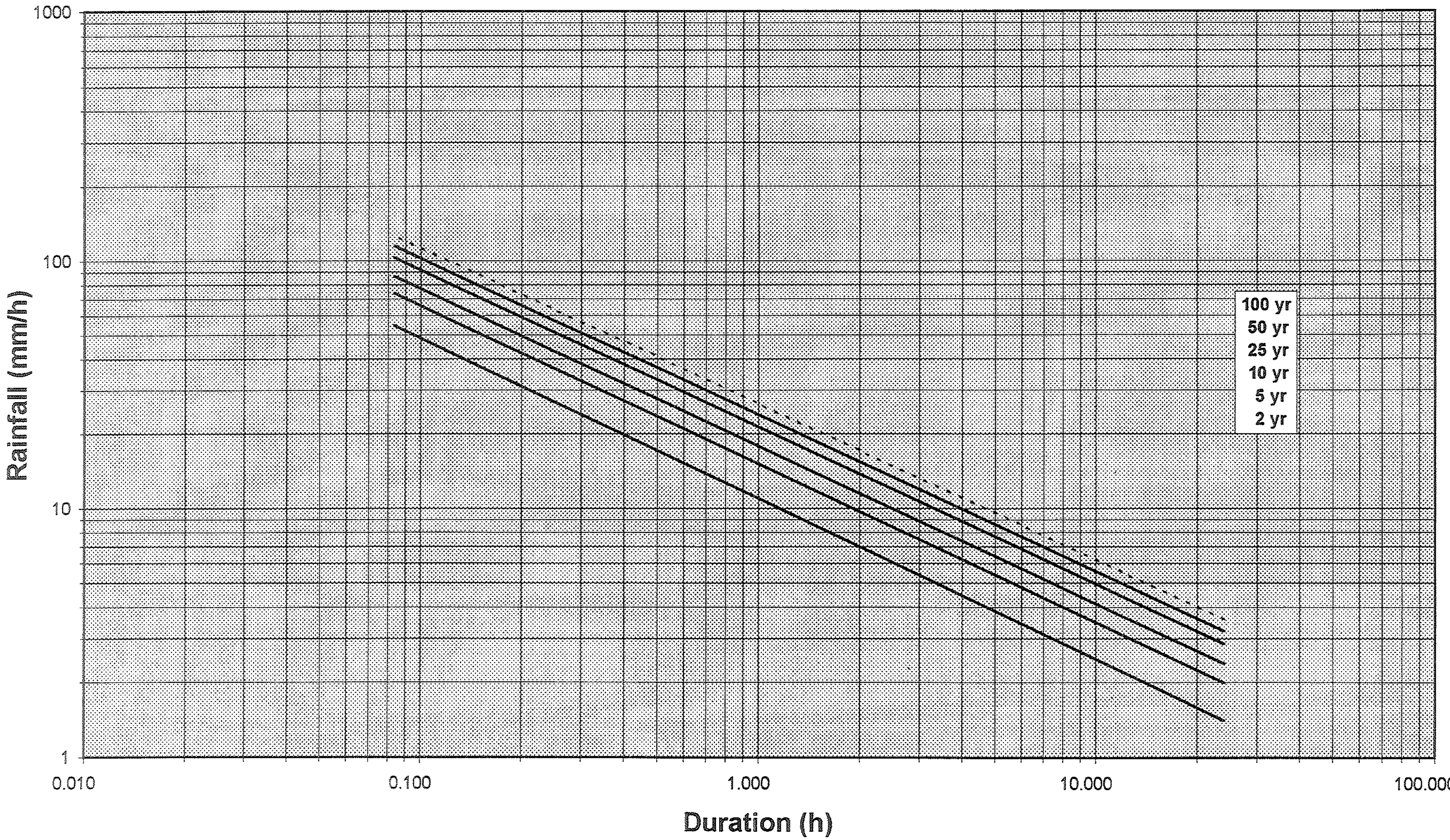
POSTDRN.dwg

Figure D1.0-1
Variation in Precipitation at the Suncor Study Area
(Environment Canada 1995)



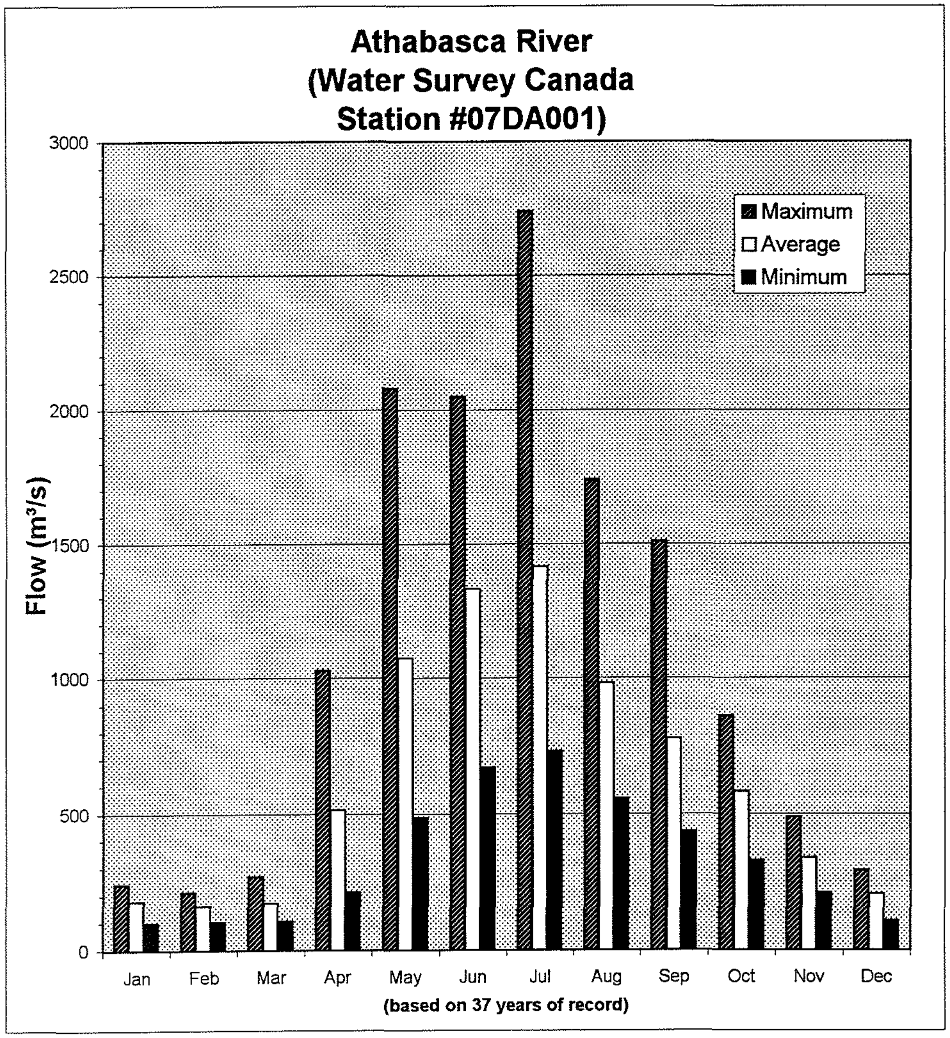
Klohn-Crippen

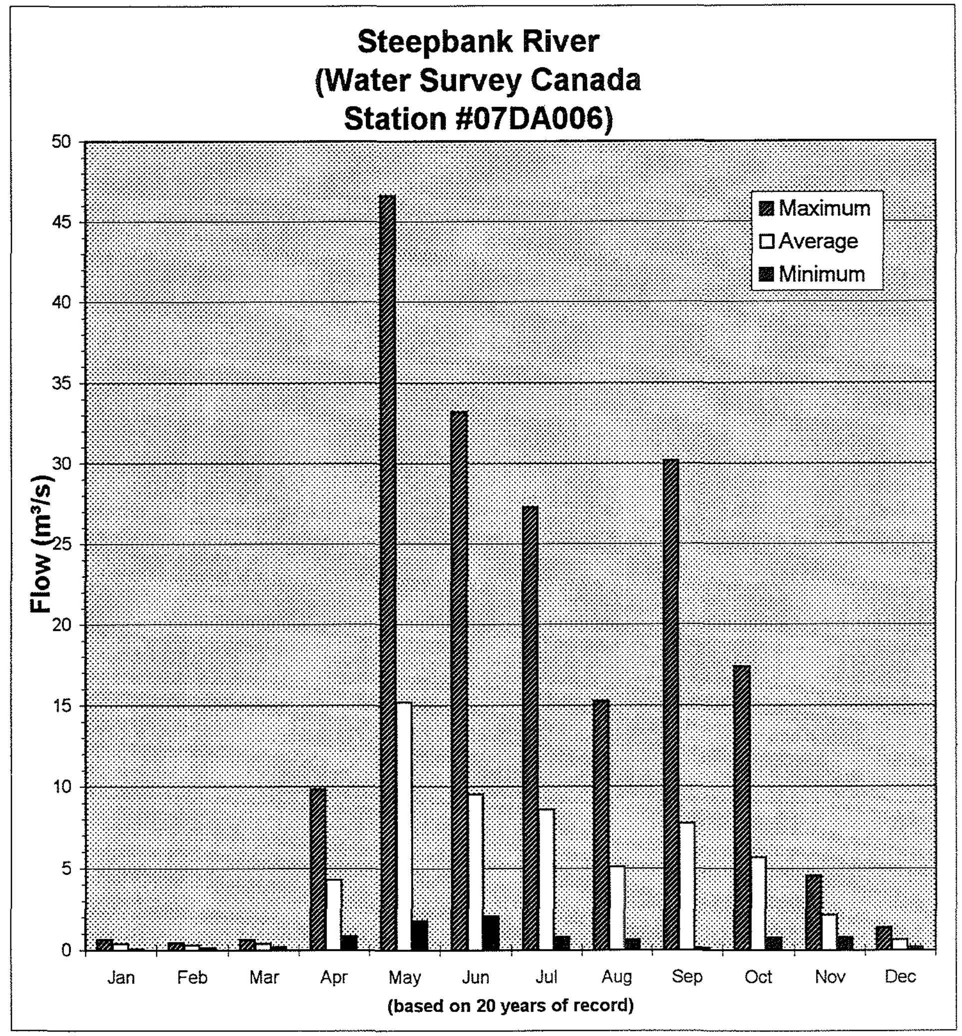
Figure D1.0-2
Rainfall Intensity-Duration-Frequency Curves for the Suncor Study Area (Klohn-Crippen 1996a)



Klohn-Crippen

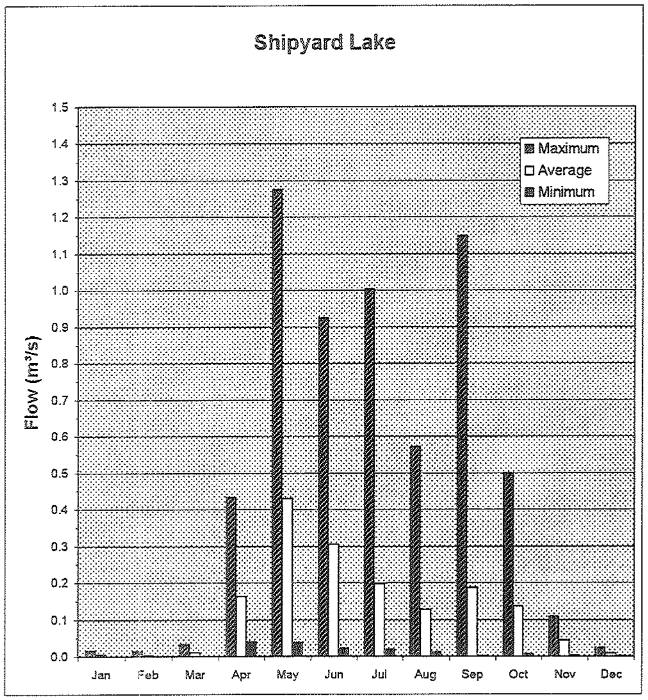
Figure D1.0-3
Monthly Flows for Athabasca and Steepbank Rivers
(Environment Canada 1994)

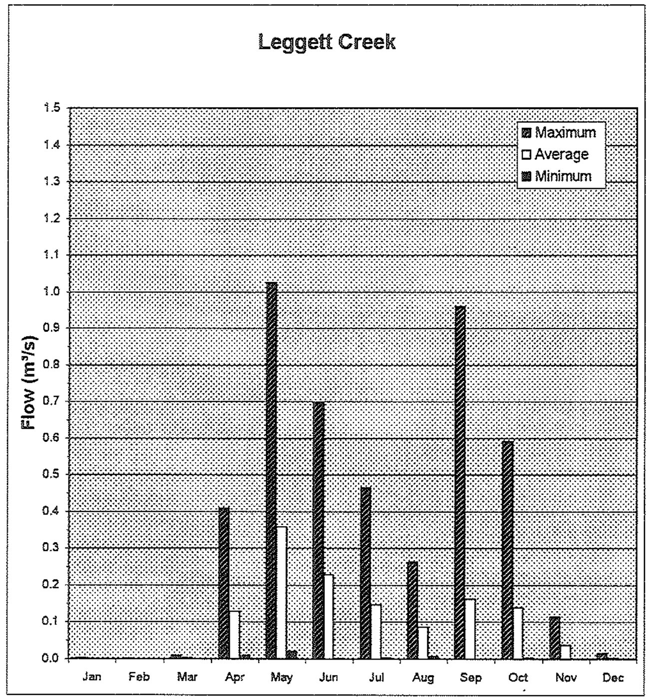




Klohn-Crippen

Figure D1.0-4
Estimated Monthly Flows for Watercourses in Local Study Area
(Klohn-Crippen 1996a)





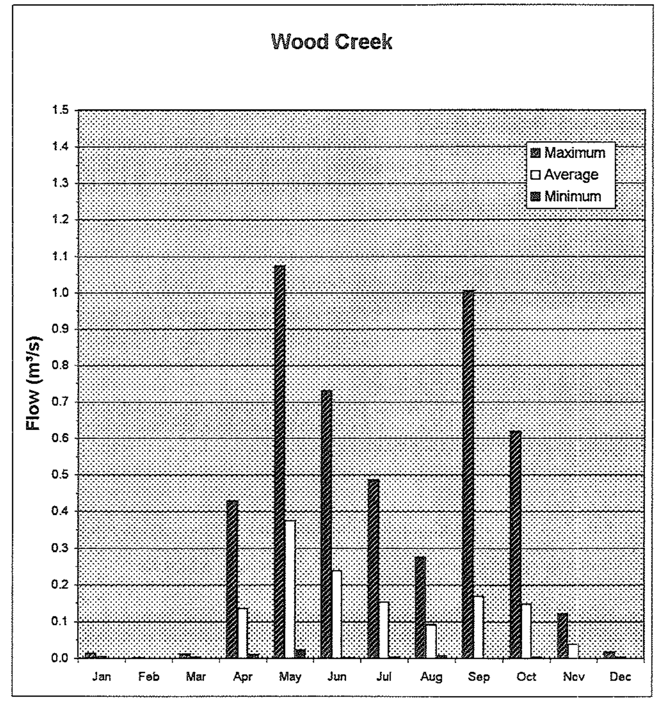
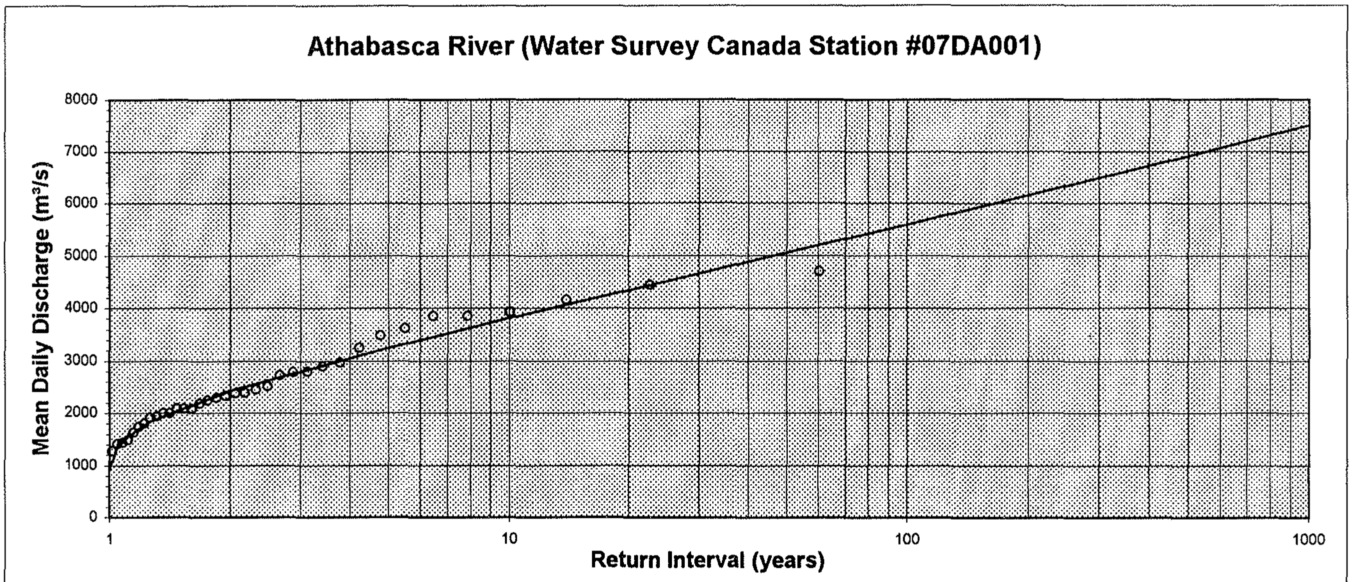


Figure D1.0-5
Flood Frequency Curves for Athabasca and Steepbank Rivers
(Environment Canada 1994)



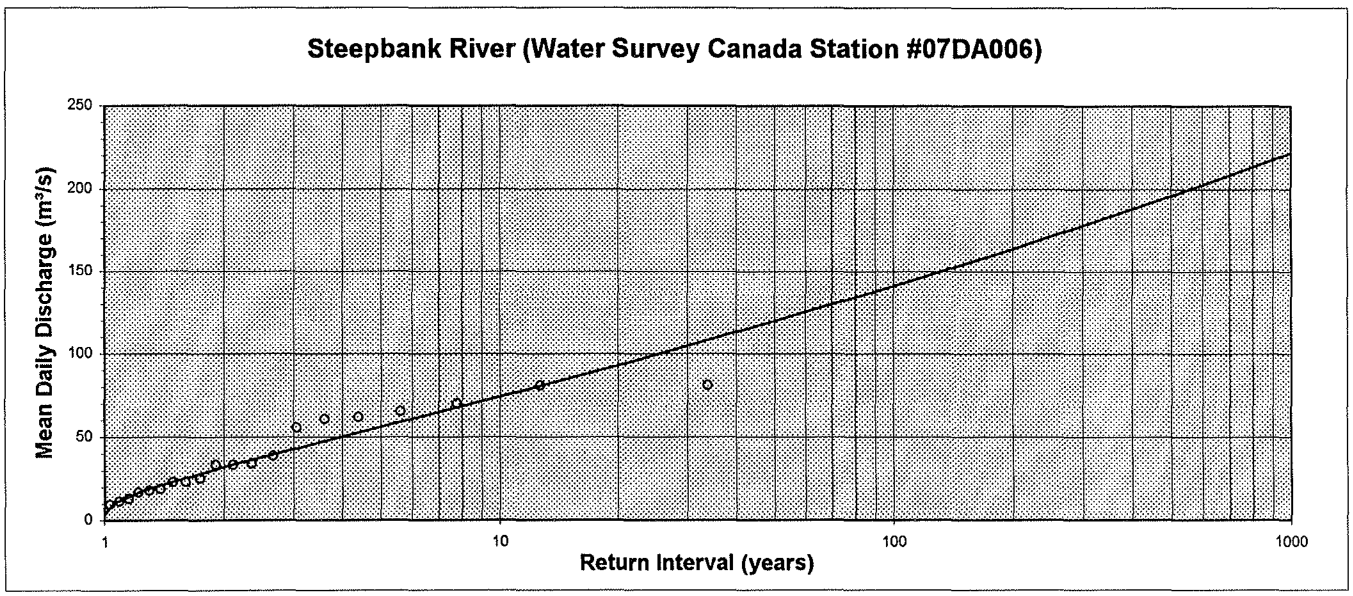
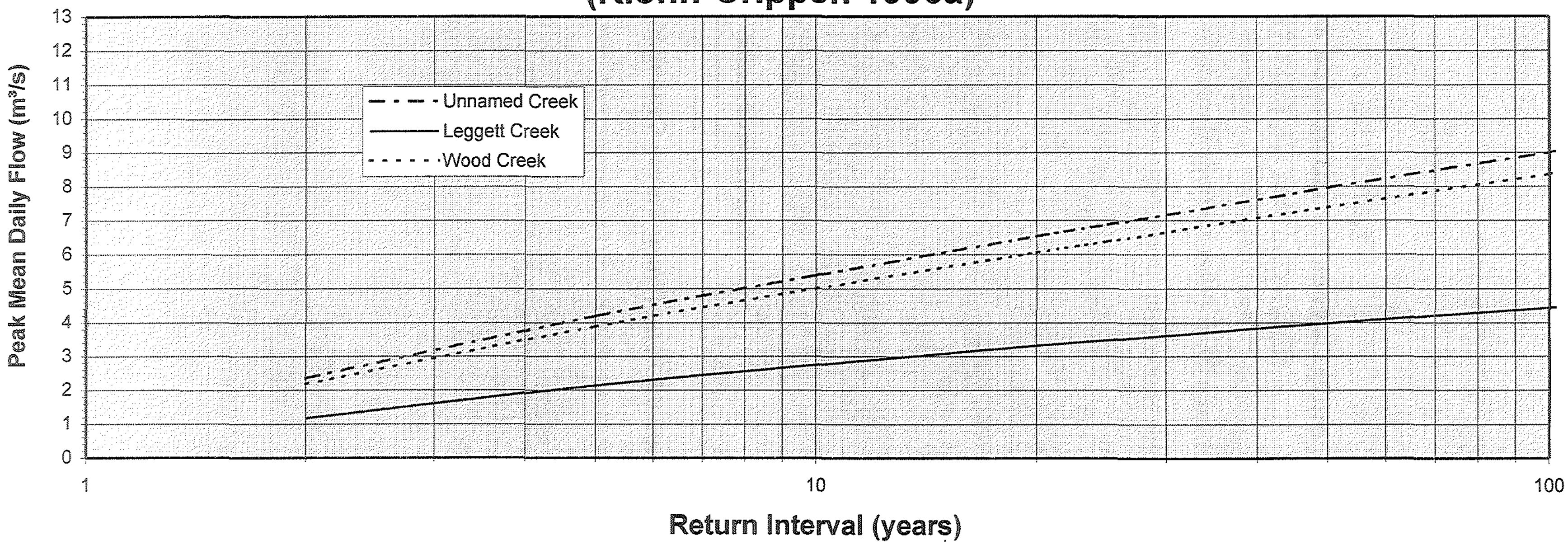


Figure D1.0-6
Estimated Flood Frequency Curves for Watercourses in Local Study Area (Klohn-Crippen 1996a)



Klohn-Crippen

Figure D1.0-7
Variation of Sediment Load with Flow

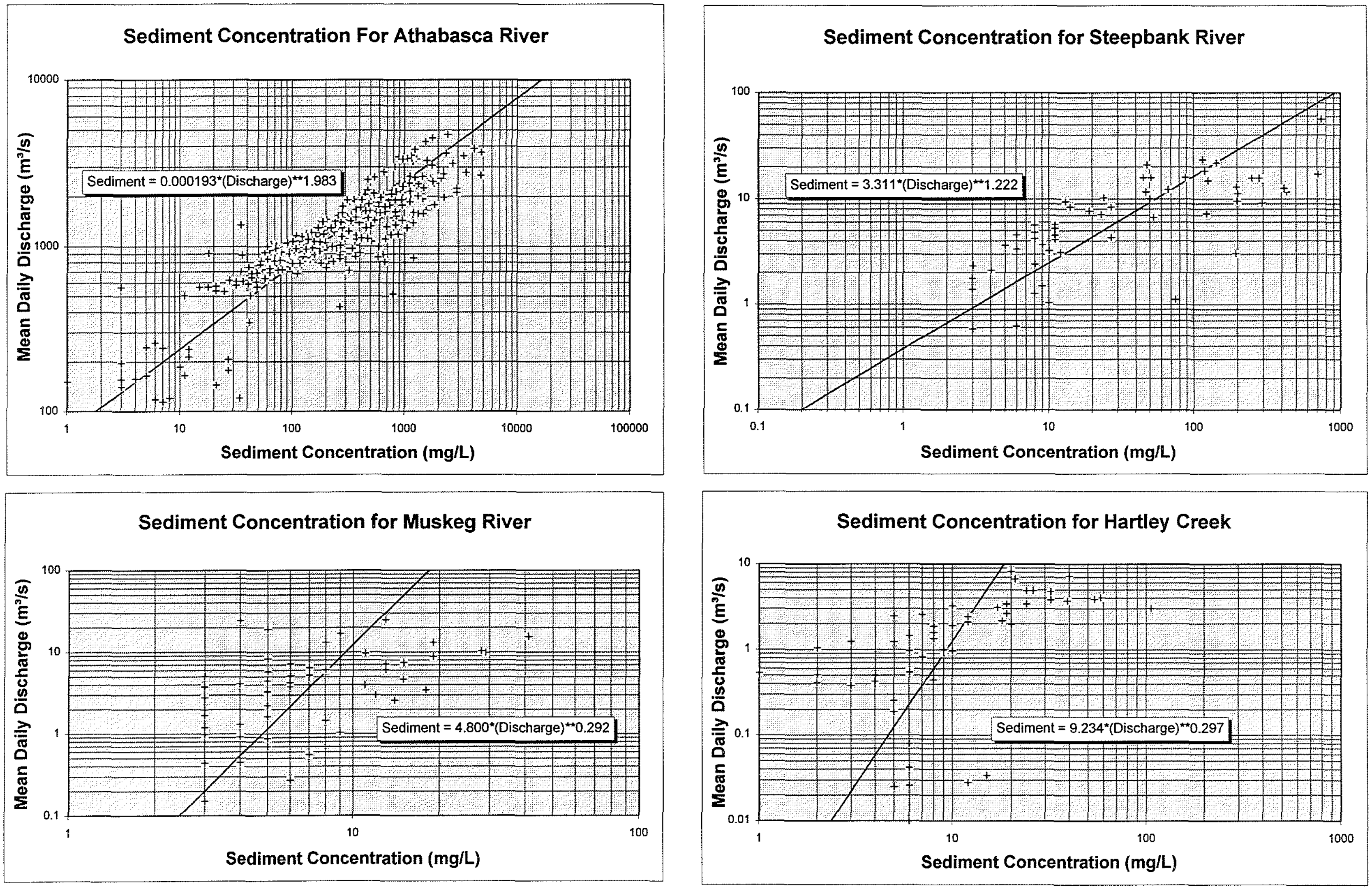
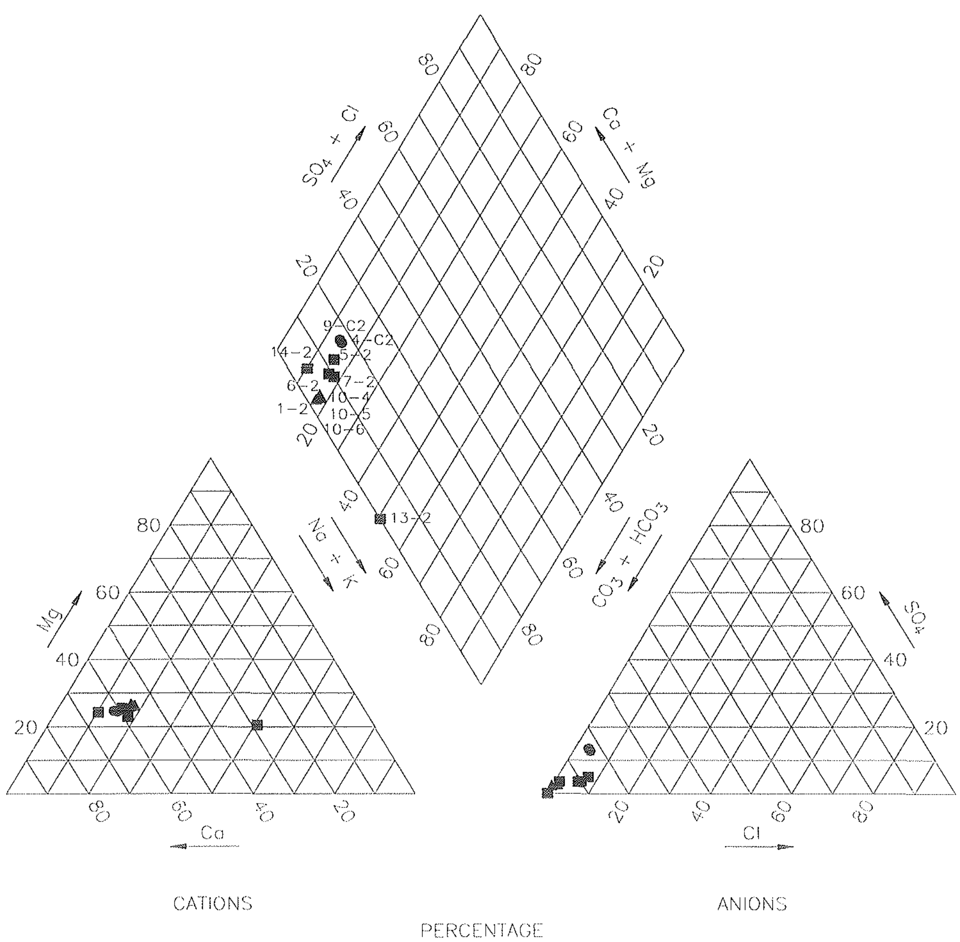


Figure D1.0-8

Surface Water - Major Ion Characterization

1995 Sampling Program

Site	Plot No	Location	Matrix	Ca	Mg	Na	K	Cl	SO4	Alkalinity
AW001-S002	1-2	Steepbank-L19 border	surface	22.5	6.4	7.5	0.63	0	1.6	79.7
AW005-S002	5-2	McLean creek-mouth	surface	38.5	10.1	11	0.92	8	7.3	132
AW006-S002	6-2	Wood creek-mouth	surface	51.7	13.6	16.3	0.6	7	5.8	157
AW007-S002	7-2	Reference wetland outlet	surface	48.2	11.4	16.2	1.47	8	6.6	161
AW010-S004	10-4	Steepbank-mouth	surface	26.3	7.2	9	0.41	0.8	2.2	89.3
AW010-S005	10-5	Steepbank-mouth	surface	25.4	7.1	9	0.48	0.9	2.1	89.6
AW010-S006	10-6	Steepbank-mouth	surface	25	7.1	9.1	0.5	0.8	2.1	90.1
AW013-S002	13-2	Unnamed creek field blank	surface	0.3	0.13	0.57	0.06	0	0	3.2
AW014-S002	14-2	Legget creek-mouth	surface	50.1	11.3	8.6	0.68	1.2	5.3	148
AW004-C002	4-C2	Athabasca-u/s L19	composite	32.5	8	8.6	0.9	3.1	13.1	88.2
AW009-C002	9-C2	Athabasca-u/s L25	composite	33.5	8.2	8.3	0.7	2.6	14.2	90.3



Klohn-Crippen

Figure D2.0-1
Summary of Changes in Surface Water Flows

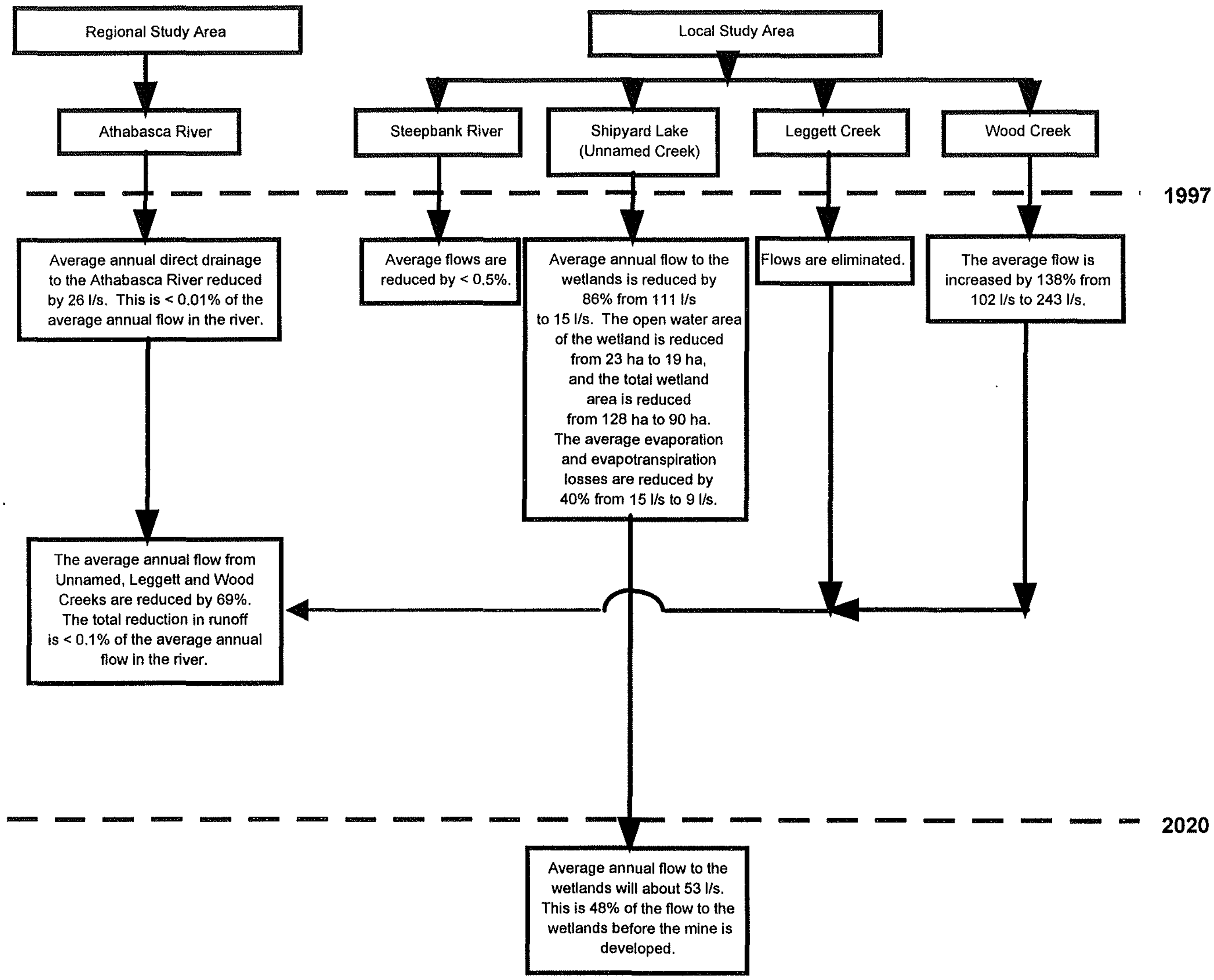
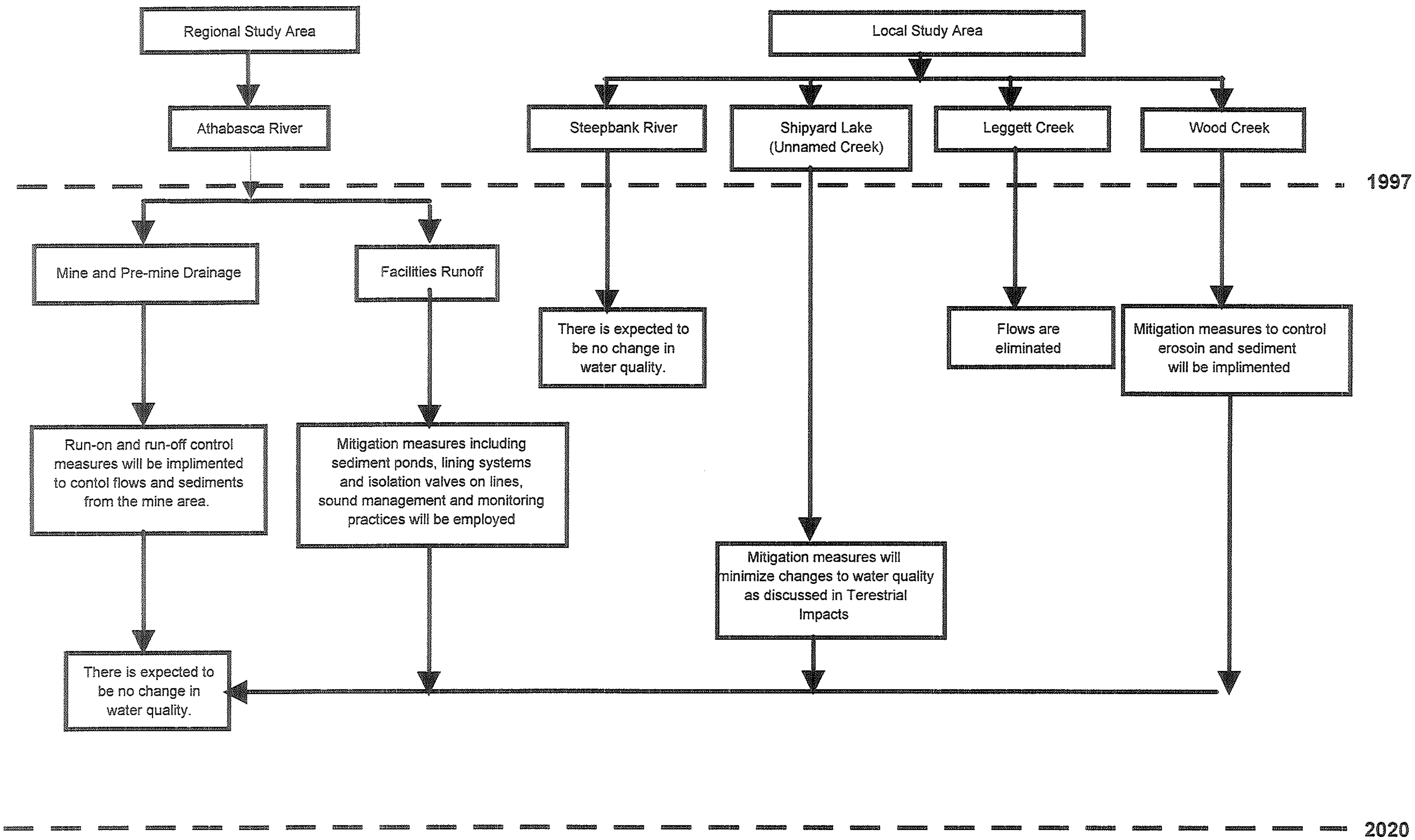
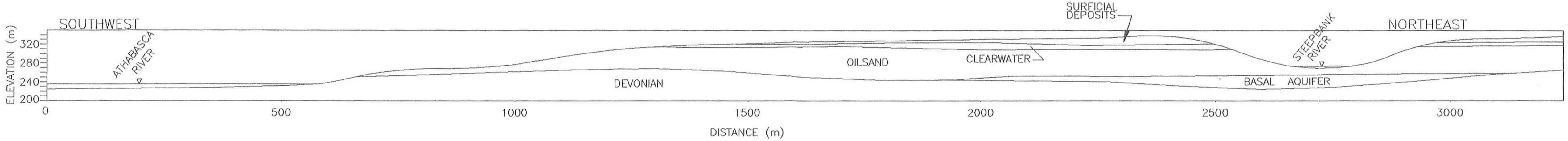


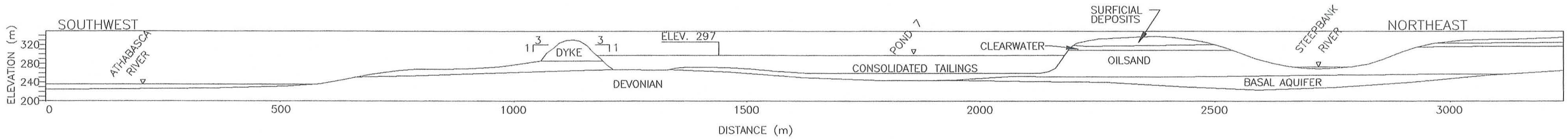
Figure D2.0-2 Summary of Changes in Surface Water Quality





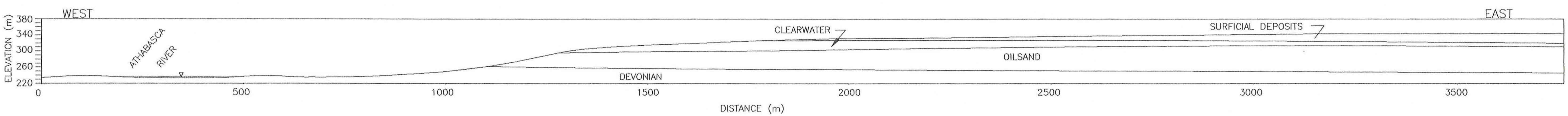
PRE–MINE EXISTING CONDITIONS

SECTION A
HOR: SCALE B
VERT: SCALE A



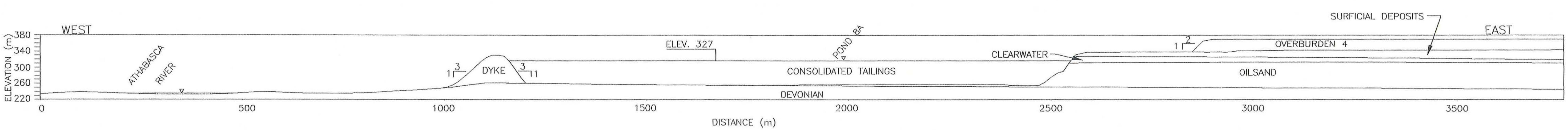
YEAR 2009 MINE CONDITIONS

SECTION A
HOR: SCALE B
VERT: SCALE A



PRE–MINE EXISTING CONDITIONS

SECTION B
HOR: SCALE B
VERT: SCALE A



YEAR 2020 MINE CONDITIONS

SECTION B
HOR: SCALE B
VERT: SCALE A

(1:10000) 0 100 200m (SCALE B)
(1:10000) 0 100 200m (SCALE A)

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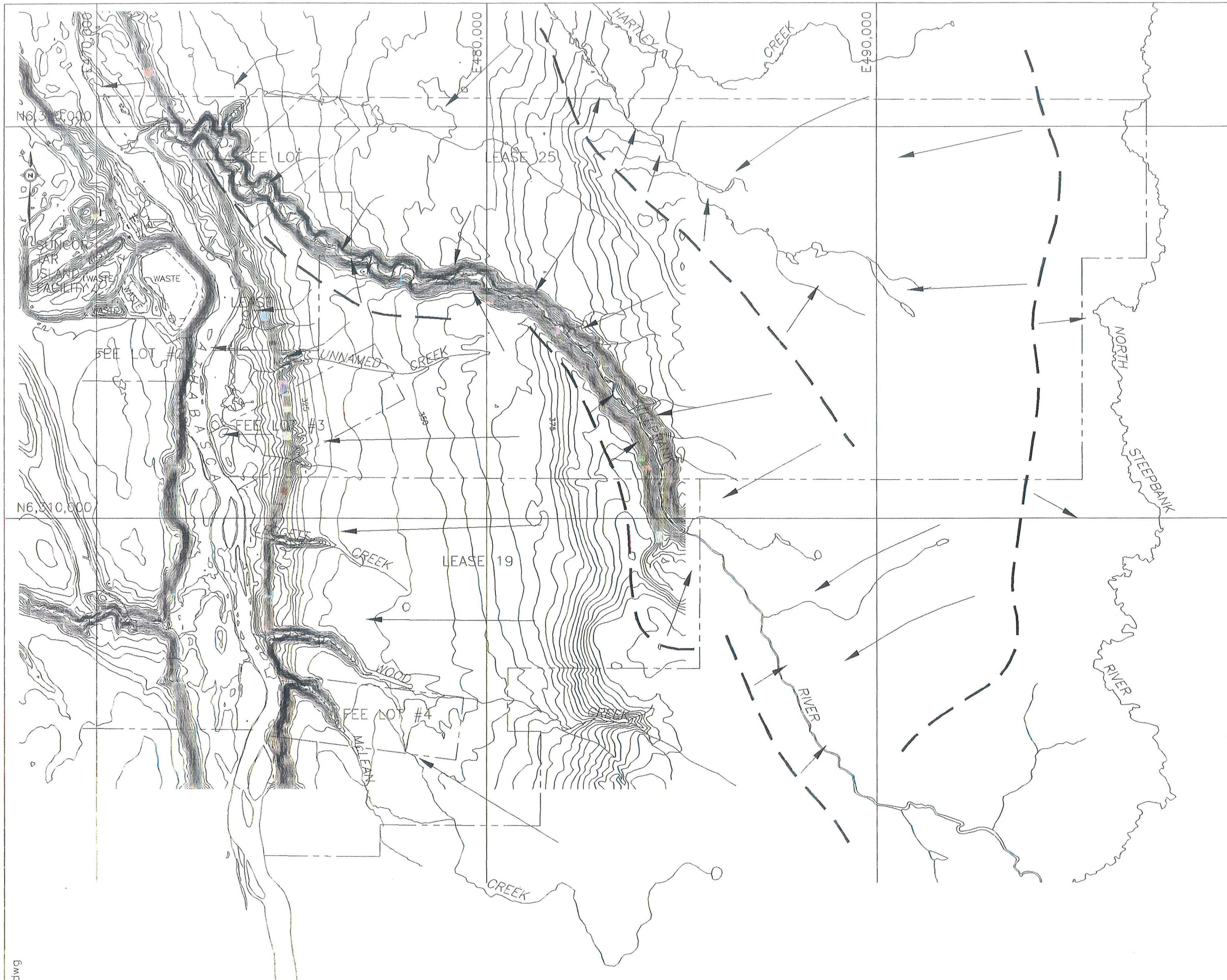
GEOLOGIC CROSS SECTIONS

SCALE: N.T.S.	Steepbank Mine Application		REVIEWED BY: J.K.M
DATE: 25 03 96			REVISION No.:
DRAWN BY: C.P.B.			FIGURE No.: E2.0

GEOL.dwg



LEGEND

GROUNDWATER FLOW DIRECTION

GROUNDWATER DIVIDE

0 1000 2000m

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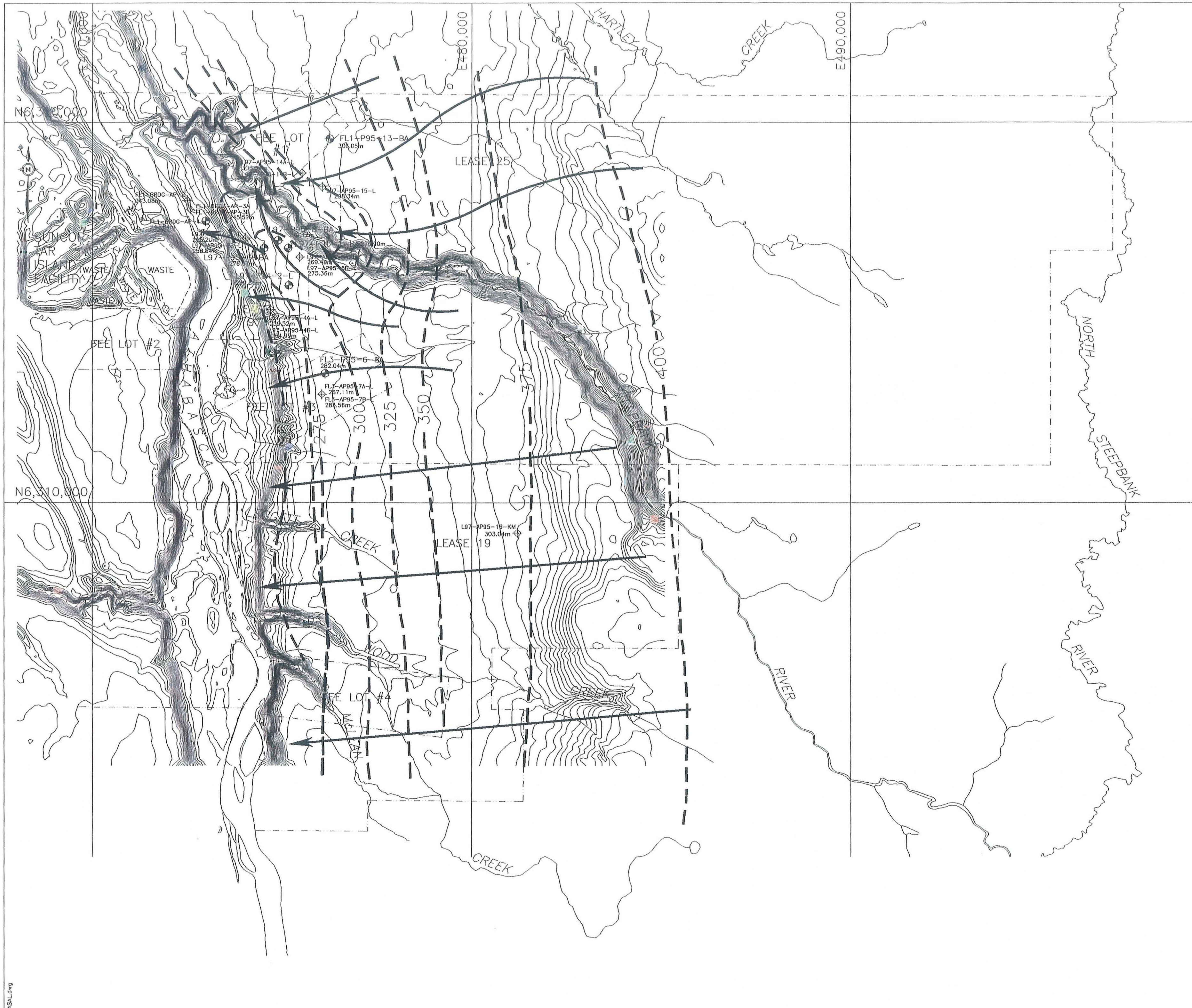
GROUNDWATER FLOW DIRECTIONS IN SURFICIAL AQUIFER

SCALE: N.T.S.	Steepbank Mine Application	REVIEWED BY: J.K.M.
DATE: 25 03 96		REVISION No.: 1
DRAWN BY: C.P.B.		FIGURE No.: F2.0-2

GRNDWTR.dwg



LEGEND

- - - LEASE BOUNDARY

— — PIEZOMETRIC SURFACE CONTOUR (MARCH 1995 DATA)

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GROUNDWATER FLOW DIRECTIONS IN BASAL AQUIFER AND UPPER DEVONIAN

SCALE: N.T.S.	Steepbank Mine Application	REVIEWED BY: J.K.M.
DATE: 25 03 96		REVISION No.: 1
DRAWN BY: C.P.B.		FIGURE No.: F2.0-3

BASAL.dwg

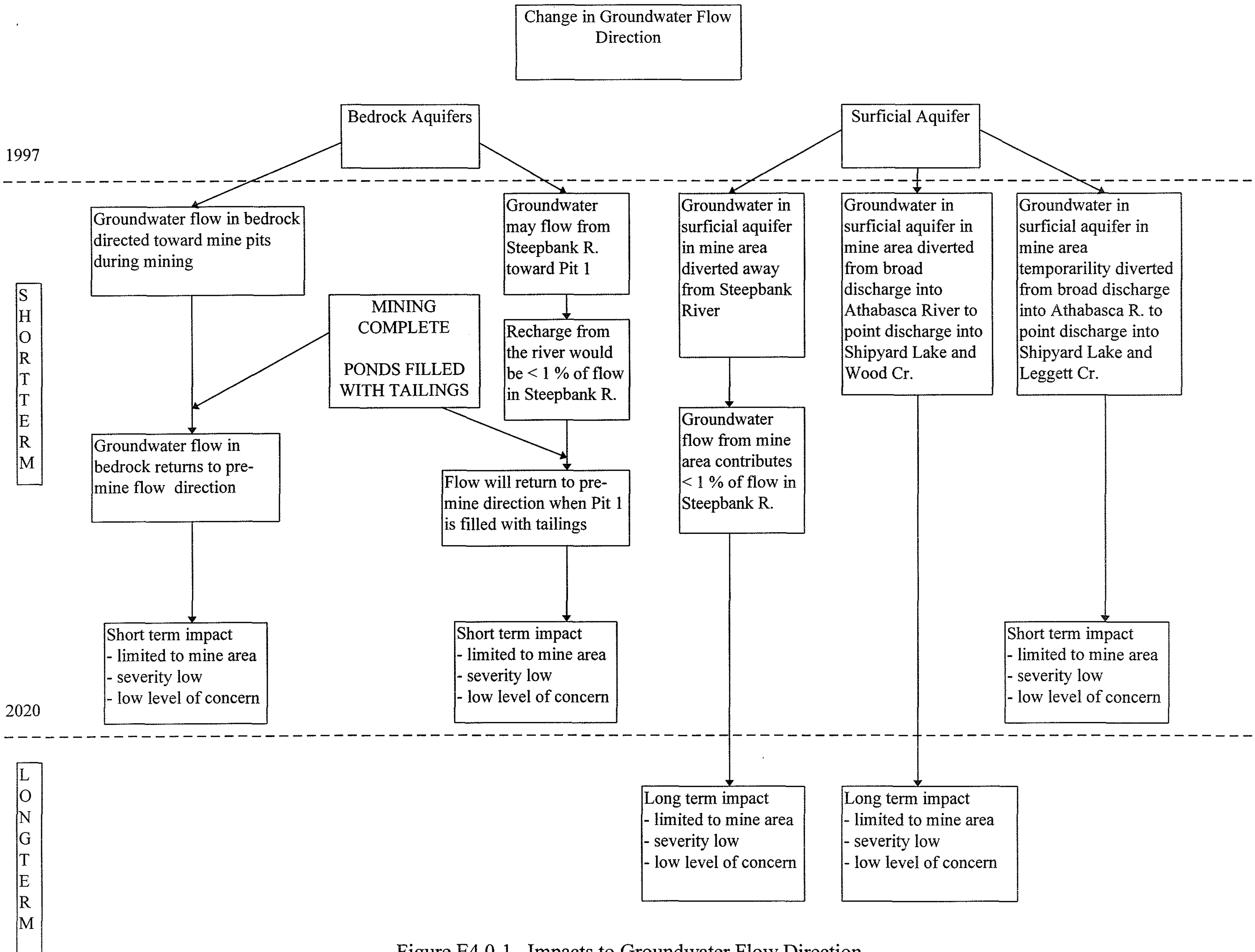

Figure E4.0-1. Impacts to Groundwater Flow Direction

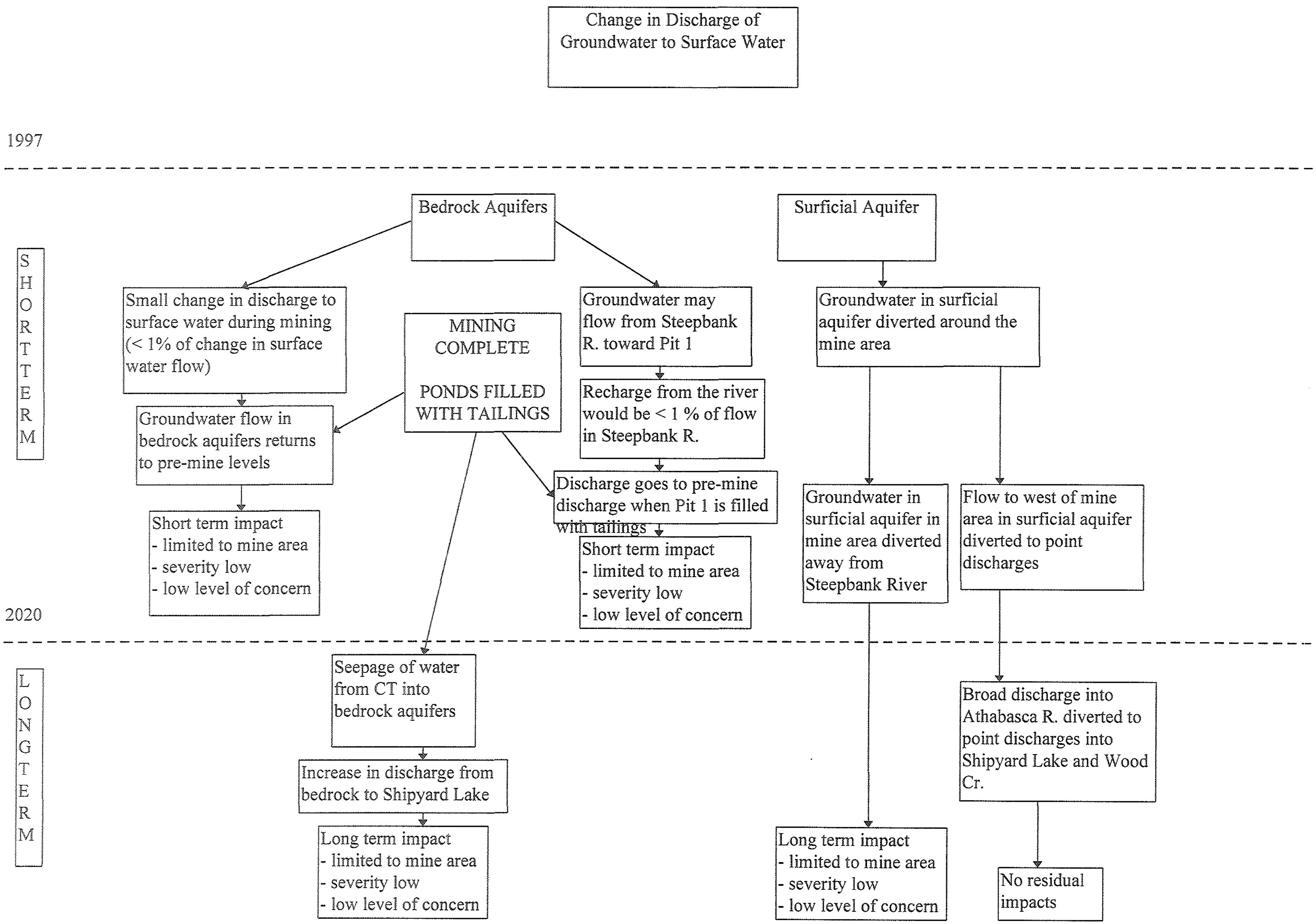

Figure E4.0-2 Impacts to Discharge of Groundwater to Surface Water

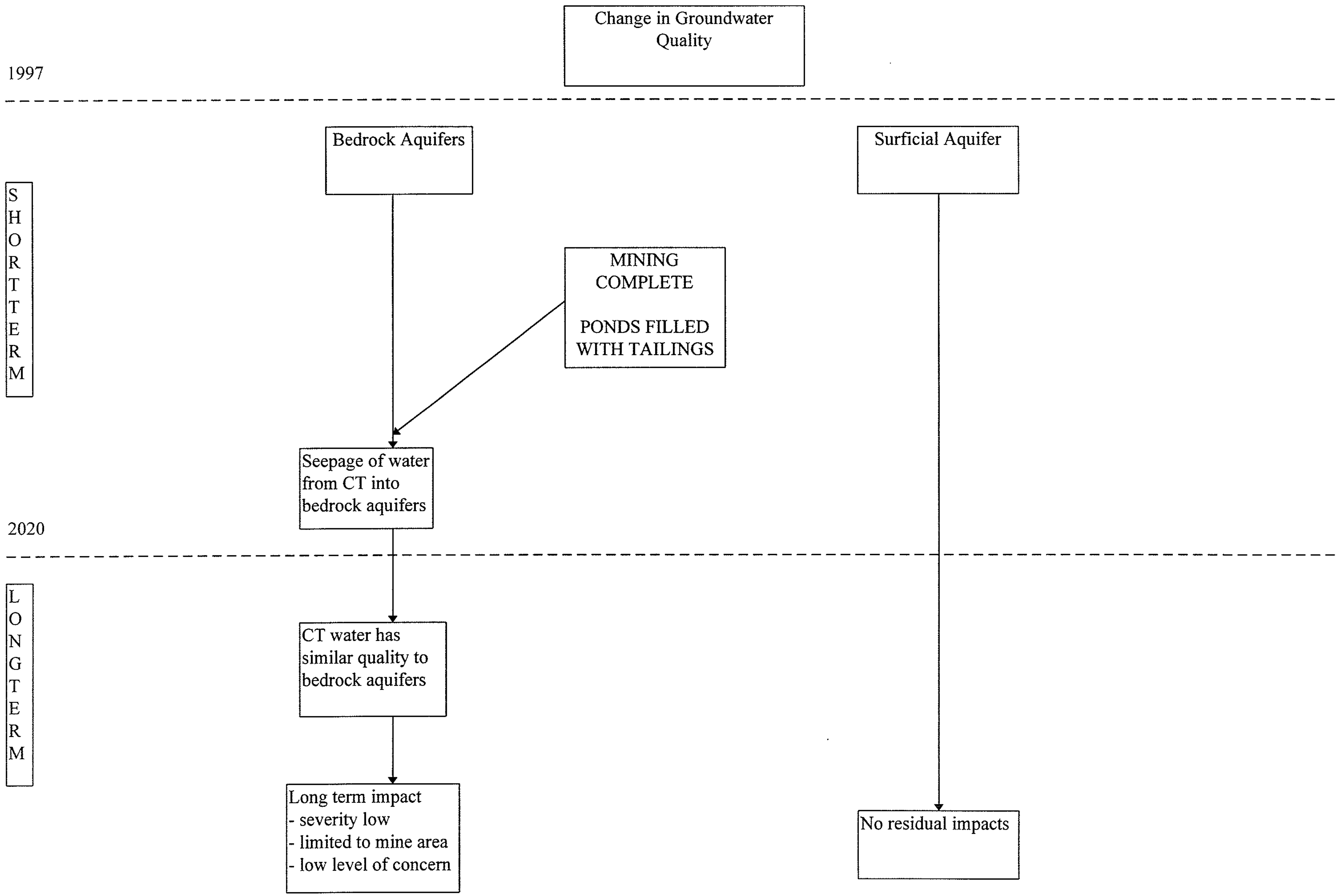

Figure E4.0-3 Impacts to Groundwater Quality