# Hydrology Baseline
# Steepbank Oil Sands Mine

**May, 1996**

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**This report is one of a series of reports prepared for Suncor Inc. Oil Sands Group for the Environmental Impact Assessment for the development and operation of the Steepbank Mine, north of Fort McMurray, Alberta. These reports provided information and analysis in support of Suncor's application to the Alberta Energy Utilities Board and Alberta Environmental Protection to develop and operate the Steepbank Mine, and associated reclamation of the current mine (Lease 86/17) with Consolidated Tailings technology.**

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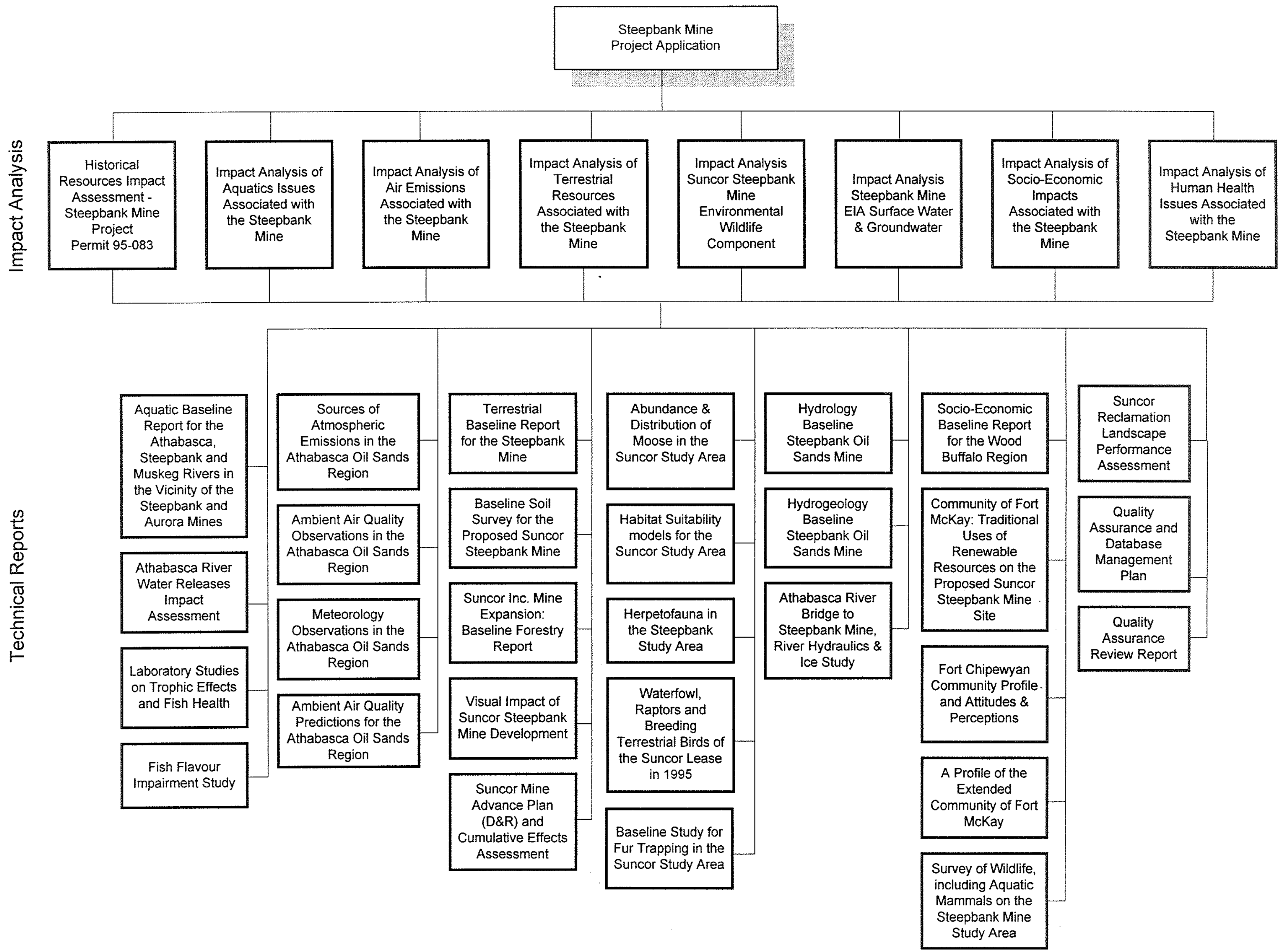


**Reports Prepared for the Steepbank Mine Environmental Assessment**

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SUNCOR INC.

# HYDROLOGY BASELINE

# STEEPBANK OILSANDS MINE

MAY 1996

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Klohn-Crippen

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# 1. INTRODUCTION

## 1.1 Project Description

Suncor's Steepbank Mine Project comprises the development of a new mining area together with reclamation of the current mine on Lease 86/17. This study encompasses the proposed new mine which will be located on the east side of the Athabasca River, east of Suncor's existing facilities, as shown on Drawing B-2779-03-001. The area that will be directly affected includes portions of Leases 19, 25 and 97 as well as Fee Lots 1 and 3. Drawing B-2779-03-002 shows the Leases and Fee Lots affected as well as an outline of the Suncor study area adopted for the hydrology component of the Environmental Impact Assessment (EIA). The temporal boundaries of the Impact Analysis study area were selected to capture the four main stages of the mine development:

- baseline conditions (1995);
- construction (1997 to 2001);
- operational base (2001 to 2020); and
- closure and reclamation.

The construction and operation stages have been assessed by evaluating the conditions that are expected to exist in 2001, 2009 and 2020. The final closure of the mine has been assessed as the long-term, steady state condition that will exist several years after closure of the mine.

## 1.2 Terms of Reference

This memorandum describes the results of an evaluation of existing surface water hydrology and the potential impact of the mine on surface water resources during operation and after closure. The interaction between surface runoff and groundwater is described in detail in Technical Memorandum No. 1 (Klohn-Crippen, 1996). In general, the groundwater contribution to surface water flows in very small - typically less than 1%. The purpose of the hydrology component of the EIA is to assess whether the proposed mine is likely to impact the surface water in any way that will affect their value to the ecosystem or society.

The impact hypotheses addressed are:

- Flows in the Athabasca and Steepbank Rivers would be significantly changed by mine development withdrawals for extraction and upgrading, or reclamation.
- Ice jams, floods or other hydrogeological events could cause structure damage and flooding of facilities which will result in subsequent impacts to hydrological/aquatic systems and downstream users.
- Navigation along the Athabasca River could be affected by bridge construction.

## 1.3 Key Factors

The impacts to water resources that have been evaluated are the changes in discharges and water quality[1] in the Athabasca River, Steepbank River and watercourses in the Suncor study area (Leggett Creek, Wood Creek and those draining to Shipyard Lake).

The degree of significance of various impacts was assessed by a qualitative evaluation of the severity, duration and anticipated areal extent of each impact on each basin and watercourse. 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 impact on the receiving water body; either the Athabasca or Steepbank River.

Note that only the changes to water quality and quantity as a result of the Steepbank Mine development are assessed in the report. The impact of those changes on humans, aquatic ecosystem and wildlife are discussed in other technical memoranda prepared to support the EIA.

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[1] The term "quality" refers to the concentration of dissolved and suspended compounds found naturally or otherwise in the water.

# 2. STUDY BACKGROUND

## 2.1 Regional Setting

Although new mining activities will be restricted to a relatively confined area (see Drawing D-2779-03-002), mine development and operation will influence the hydrologic regime inside and, possibly, outside the mine area. It is necessary to consider the potential impact on the hydrology of all surface waters that may be affected by the mine. This includes the large wetland adjacent to the Athabasca River (Shipyard Lake) as well as creeks in the immediate vicinity of the proposed mine; for example, those draining to Shipyard Lake, Leggett Creek and Wood Creek. Surface water flows to MacLean Creek will be unaffected by the proposed mine.

The topography of most of the upland portion of the study area is flat to gently rolling. Relief across the study area is about 80 m ranging from elevation 235 m in the Athabasca River floodplain to about elevation 315 m in the upland part of the site. Elevations increase to 450 m in the Muskeg Mountains, east of the proposed mine site, where the Steepbank River and its tributaries have their headwaters.

The major watercourses in the vicinity of the proposed mine are the Steepbank and Athabasca Rivers. The Athabasca River and the lower reaches of the Steepbank River are incised approximately 80 m into the surrounding landscape. Detailed topography of the Suncor study area is shown on Drawing B-2779-03-002.

The Athabasca River is located in a stream-cut valley. The valley walls (or escarpment slopes) and flood plain are moderately forested. The flood plain is moderately to poorly drained and locally covered with extensive wetland-muskeg (Schwartz, 1980). The river has an unstable thalweg and the channel has irregular meanders with occasional islands and bars.

Relatively steep slopes in the middle and lower reaches of the Steepbank River, an Athabasca River tributary, and the lower reaches of smaller creeks in the area have resulted in a moderately to well defined entrenched channel system. At the downstream end of Steepbank River, its valley cuts through the surficial deposits and, close to its confluence with the Athabasca River, the Cretaceous (McMurray Formation) and underlying Devonian bedrock are exposed. On smaller local creeks the entrenched channel systems are generally limited to the immediate vicinity of the Athabasca River valley escarpment slopes while the upper reaches are poorly drained and covered with muskeg.

There is a large permanent wetland on the Athabasca River floodplain within the Suncor study area called Shipyard Lake on some maps and is also referred to as the "Shipwreck Lake" and "Reference Wetland". It is located approximately 6 km upstream (southeast) of the confluence between the Athabasca and Steepbank Rivers. The location is also shown on Drawing B-2779-03-002.

## 2.2 Drainage

The regional drainage is shown on Drawing B-2779-03-003. Drawing B-2779-03-004 presents details of drainage basins in the Suncor study area. The principle drainage is via the Athabasca River, which forms the western boundary of the Suncor study area. It flows northward past the proposed mine site and eventually discharges through a vast delta complex into Lake Athabasca. Secondary drainage is by the Steepbank River system which discharges into the Athabasca River opposite the existing Suncor mine, as shown on Drawing B-2779-03-004. As stated in Section 2.1, there are three small watercourses in the Suncor study area to the south of Steepbank River. All three drain directly to the Athabasca River (see Drawing A-2779-03-004).

The largest basin in the vicinity of the mine, that of the Steepbank River, crosses Leases 19, 25, 97 and Fee Lot No. 1. Where mine development is proposed, only a narrow strip of land averaging less than a kilometre in width drains into the Steepbank

River. The remainder of the land in the Suncor study area drains directly to the Athabasca River.

Of the smaller Athabasca tributaries, Leggett Creek and the unnamed creek (which flows into Shipyard Lake) have their drainage basins entirely within the Suncor study area. Wood Creek, in contrast, has a substantial portion of its drainage outside the proposed mine limits. There are also three small drainage basins that drain to the Athabasca River and do not contain any well defined watercourses. They are named Athabasca 1, Athabasca 2, and Athabasca 3 on Drawing B-2779-03-004. Drainage basin areas for watercourses within the Suncor study area are tabulated on Table 1 and basin boundaries are shown on Drawings B-2779-03-003 and A-2779-03-004.

**Table 1 - Drainage Basins in Suncor Study Area**

| Basins | Leases and Lots Affected | Total Drainage Area ($km^2$) |
|---|---|---|
| Steepbank River | Leases 19, 25 and 97: Fee Lot #1 | 1 320 |
| An unnamed creek (Shipyard Lake) | Leases 19, 25 and 97: Fee Lots # 1 and #3 | 44.1 |
| Leggett Creek | Lease 19 | 35.0 |
| Wood Creek | Lease 19: Fee Lot #4 | 36.8 |
| McLean Creek | Lease 19: Fee Lot #4 | 53.4 |
| Athabasca 1 | Lease 97: Fee Lot #1 | 4.0 |
| Athabasca 2 | Leases 19 and 97: Fee Lot #3 | 1.0 |
| Athabasca 3 | Lease 19 | 7.2 |

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

Muskeg covers most of the Suncor study area and is one of the most dominant features controlling surface runoff. In muskeg, most of the moisture exchange takes place within an "active layer" at the surface. Literature (Radforth and Brawner, 1977) suggests that this layer is approximately 200 mm to 450 mm thick. Although, significant interflow can occur within the active layer, vertical permeability rapidly reduces with depth. At the lower boundary, decomposed and compressed organic material produces a relatively impervious zone. Ivarov (1953) and Boelter (1965, 1972) cite values of hydraulic conductivity of $1 \times 10^{-7}$ m/s, $0.75 \times 10^{-7}$ m/s and $2.2 \times 10^{-7}$ m/s for the highly decomposed peat typically found at the lower boundary of an active layer. Because of the low vertical permeability, runoff may cease altogether if the water level drops below the lower boundary unless the watercourses have cut through a lower aquifer.

Hydrologically, the initial abstraction (absorption to satisfy soil moisture deficit) of rainfall during storm events to these soils will be significant and highly variable. Once saturated, infiltration to lower surficial materials will be low and a large proportion of the net rainfall will run off.

## 2.3 Climate

The climate in the Athabasca Oil Sands area is characterized by long cold winters and short cool summers. Mean daily temperatures at Fort McMurray in January average about -20°C while July temperatures average 17°C. The mean annual temperature at this location is 0.2°C. There are usually less than 120 frost-free days per year (Atmospheric Environment Service, 1993).

The average annual precipitation at Fort McMurray Airport is about 446 mm, of which almost three-quarters falls as rain during the summer and fall. Snowfall averages about 147 cm each year with the maximum occurring during November and December.

## 2.4 Surficial Geology

The surficial geology of the region has been mapped by L.A. Bayrock and T.H.F. Reimchem of the Research Council of Alberta in 1973 and by R.A. McPherson and C.P. Kathol in 1977. The surficial sediments are characterized by abrupt changes in lithology and grain size over short distances. The distribution of sediments can be characterized into three physiographic areas; uplands, valley escarpment slopes, and floodplain. For a more in-depth discussion of the geologic and groundwater regime in the study area, see Technical Memorandum No. 1 (Klohn-Crippen, 1996).

### 2.4.1 Upland Plain

The major portion of the Suncor study area is overlain by muskeg. Discontinuous deposits of sandy stratified sediments of glacial origin underlie the muskeg. Low relief till rests upon bedrock over the entire upland area. The till is generally an unsorted mixture of clay, silt, sand cobbles and boulders of glacial origin.

Muskeg covers most of the upland organic/lacustrine plain within the study area and dominates the hydrologic regime over the spring, summer and fall. From borehole information, the muskeg varies in thickness from 0.3 m to about 1.7 m, with an average thickness of about 0.5 m. Winter flows in the tributary streams, as discussed in Technical Memorandum No. 1 (Klohn-Crippen, 1996) appear to be dominated by discharge from surficial and bedrock aquifers.

### 2.4.2 Valley Escarpment Slopes

Colluvial slope wash material, chiefly composed of sandy and silty material with a admixture of bituminous sand, discontinuously overlies McMurray formation bedrock along the escarpment valley slopes east of the Athabasca River and along the slopes of the Steepbank River and some of the smaller tributaries. At the downstream end of the Steepbank River and at locations along the Athabasca River, surficial materials are completely eroded and the bedrock is exposed.

### 2.4.3 Floodplain

The valley floor of the lower downcut reaches of the local tributaries consist of discontinuous alluvial gravel, sand, silt and clay. Where the McMurray oil sands are exposed the gravels are bitumen covered and bitumen rich sand bars and banks are common. The floodplain on the east bank of the Athabasca River contains organic material and alluvial deposits consisting of sand, clay and silt, and meltwater channel deposits of sand and gravel.

# 3. PRECIPITATION AND EVAPORATION

## 3.1 Available Data

There are a number of stations in the vicinity of the study area where precipitation is or has been monitored and recorded. The principal stations, which are operated by the Atmospheric Environment Service (AES) of Environment Canada or by the Alberta Forest Service, are listed on Table 2 and their locations are shown on Drawing A-2779-03-005. Not listed on Table 2 or shown on the drawing are rainfall gauges that have been set up in the past by Suncor and others to gather project-specific data over a short period of time. One example of these project-specific sites is the gauge set up as part of a wetlands project being conducted by Suncor at its existing mine site. At this particular location, two years of seasonal rainfall data is available.

**Table 2 - Precipitation Monitoring Stations**
**AES and Alberta Forest Service**

| Station | Location | Period of Record | Type of Record | Elevation (m) |
|---|---|---|---|---|
| Bitumount Lookout | 57°22'N 111°32'W | 1962-1995 | Seasonal | 349 |
| Ells Lookout | 57°11'N 112°20'W | 1961-1995 | Seasonal | 610 |
| Fort McMurray Airport | 56°39'N 111°13'W | 1908-1923<br>1924-1995 | Partial<br>Annual | 369 |
| Mildred Lake | 57°05'N 111°35'W | 1973-1982 | Annual | 310 |
| Muskeg Lookout | 57°08'N 110°54'W | 1959-1995 | Seasonal | 652 |
| Tar Island | 56° 59'N 111° 28'W | 1970-1984 | Annual | 346 |
| Thickwood Lookout | 56°53'N 111°39'W | 1957-1995 | Seasonal | 604 |

The precipitation monitoring stations at Mildred Lake and Tar Island are located on the left bank of the Athabasca River near the proposed mine. The Mildred Lake station is approximately 15 km northwest and the Tar Island station is approximately 5 km northwest of the centroid of the Steepbank Mine. The station elevations of 310 m and 346 m, respectively, are within the range of elevation (300 m to 350 m) across the proposed mine site. Precipitation was recorded at Mildred Lake from 1973 to 1982 and at Tar Island from 1970 to 1984. While the precipitation is considered to be representative of the study area, both record lengths are too short for meaningful statistical analysis. In contrast, the climate station at Fort McMurray has been in operation for almost 90 years and provides an excellent basis for determining precipitation normal and extremes in the study area.

A comparison of data using regression techniques demonstrates that there is a consistent relationship between the rainfall recorded at both Mildred Lake and Tar Island, and the rainfall recorded at Fort McMurray. Based on the common months of records (daily data is not available for Mildred Lake), the rainfall at Mildred Lake and Tar Island is approximately 85% and 86% of the rainfall at Fort McMurray, respectively. This relationship is confirmed by the rainfall data gathered for Suncor in 1992 and 1993 (EVS, 1993 and 1994) as part of a wetlands project. Using regression techniques, rainfall recorded in these two years is approximately 88% of the rainfall at Fort McMurray. It is assumed, therefore, that the rainfall over the study area is 85% of that measured at the AES station at Fort McMurray airport. No adjustment was considered necessary for possible variations in precipitation across the study area due to differences in elevation.

The relationship between snowfall (snow-water equivalent) is not as consistent. Based on common months of record, the snowfall recorded at Mildred is the same as that recorded at Fort McMurray. The snowfall at Tar Island on the other hand is approximately 79% of the snowfall at Fort McMurray. It should be noted, however, that the correlation (multiple R) between the snowfall data at Tar Island and Fort McMurray is only 0.67 compared with a value of 0.85 for the Mildred Lake and Fort McMurray data. No snow data was recorded as part of the Suncor wetland project.

Since the data at Mildred Lake has a higher correlation, it was assumed that the snowfall (snow-water equivalent) recorded at Fort McMurray is typical of the study area.

Using these relationships for rainfall (85%) and snowfall (100%), a long-term precipitation data set was developed. This data set is taken as being representative of the study area. Other stations in the geographic area were not used as they are no closer to the project area than Mildred Lake and their periods of record are not as long as that at Fort McMurray.

## 3.2 Precipitation Normals and Extremes

The average annual precipitation at Fort McMurray and Mildred Lake is 446 mm and 399 mm, respectively. Of this amount, 318 mm and 271 mm, respectively, is rainfall. The average total annual snowfall at both locations is 147 cm and has an average water equivalent of 0.87 mm/cm. The water equivalent of snow varies, on average, from a minimum of 0.69 mm/cm in January to a maximum of 1.00 mm/cm in September. Month-end snow cover typically increases to a maximum of 31 cm to 32 cm in January and February and has usually melted by the end of April. The average monthly variation in precipitation at Mildred Lake is shown on Figure 1 and Table 3.

**Table 3 - Mean Monthly Precipitation for the Suncor Study Area**

| 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 |

The results of a frequency analysis of annual precipitation using the Gumbel distribution are presented on Table 4.

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

**Table 4 - Annual Precipitation Frequency Analysis for the Suncor Study Area**

| Conditions | Total Annual Precipitation (mm) |
|---|---|
| 1 in 100 dry year | 240 |
| 1 in 50 dry year | 250 |
| 1 in 10 dry year | 290 |
| 1 in 5 dry year | 321 |
| Average Year | 398 |
| 1 in 5 wet year | 468 |
| 1 in 10 wet year | 523 |
| 1 in 50 wet year | 644 |
| 1 in 100 wet year | 695 |

Note: Based on the Gumbel Distribution.

Precipitation extremes are only presented for Fort McMurray as daily data is not available from AES for Mildred Lake. The maximum recorded daily rainfall at Fort McMurray was 94.5 mm and occurred on August 26, 1976. The maximum daily snowfall at Fort McMurray of 29.7 cm occurred on March 16, 1951 and, because of the close correlation, can be considered to be typical of the study area. Monthly variations in extreme daily events at Fort McMurray are presented on Table 5.

**Table 5 - Precipitation Extremes at Fort McMurray**

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Maximum daily rainfall (mm) | 6.4 | 4.8 | 8.0 | 15.4 | 38.4 | 46.0 | 51.6 | 94.5 | 60.5 | 29.4 | 15.2 | 84.4 |
| Maximum daily snowfall (cm) | 16.3 | 13.2 | 29.7 | 26.2 | 15.2 | 0.3 | 0.0 | 0.2 | 27.9 | 17.2 | 18.0 | 22.6 |

A rainfall intensity-duration-frequency analysis was performed by AES on data from the airport at Fort McMurray from 1966 through 1990. The results are presented on Figure 2 for the Suncor study area based on a rainfall correlation coefficient of 0.85.

## 3.3 Evaporation and Evapotranspiration

Data from Alberta Environmental Protection (Bothe and Abraham, 1987 and 1990, and Abraham, 1996) indicates that annual deep lake evaporation at Fort McMurray varies between 531 mm and 627 mm per year. Potential evapotranspiration, calculated by the Alberta Environmental Protection using the CRAE model, varies between 684 mm and 891 mm while the areal evapotranspiration varies from 251 mm to 342 mm per year. Average monthly potential evapotranspiration exceeds average monthly precipitation at Fort McMurray Airport from April through September. It also exceeds precipitation on a total annual basis. Average monthly areal precipitation marginally exceeds precipitation in June and July.

Variations in mean monthly lake evaporation and areal evapotranspiration are presented on Figure 3 and Table 6. The values are for Fort McMurray for the period 1972 to 1994, and are considered to be representative of the study area.

**Table 6 - Evaporation and Evapotranspiration at Fort McMurray (in mm)**

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Lake Evaporation and Areal Evapotranspiration** | | | | | | | | | | | | | |
| 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 |
| **Areal Evapotranspiration** | | | | | | | | | | | | | |
| 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 |

# 4. STREAMFLOW AND SEDIMENT

## 4.1 Hydrometric Records

Streamflow gauging stations in the vicinity of the study area are listed on Table 7 and their locations are shown on Drawing A-2779-03-006. All of these stations are operated by the Water Survey of Canada (WSC). The WSC gauges on the Steepbank River, Beaver River, Muskeg River and Hartley Creek are the only flow records available in the vicinity of the Suncor study area.

**Table 7 - Streamflow Monitoring Stations**

| Gauge | Station Number | Location | Streamflow Record | | Drainage Area (km²) | Period of Sediment Record |
|---|---|---|---|---|---|---|
| | | | Period | Type | | |
| Athabasca River below Fort McMurray | 07DA001 | 56°47'N<br>111°24'W | 1957<br>1958-93 | Seasonal<br>Continuous | 133 000 | 1967-72 |
| Steepbank River near Fort McMurray | 07DA006 | 57°01'N<br>111°25'W | 1972-73<br>1974-86<br>1987-93 | Seasonal<br>Continuous<br>Seasonal | 1320 | 1975-83 |
| Poplar Creek near Fort McMurray | 07DA007 | 56°55'N<br>111°28'W | 1973-86 | Continuous | 151 | 1974-83 |
| Muskeg River near Fort MacKay | 07DA008 | 57°12'N<br>111°34'W | 1974-86<br>1987-93 | Continuous<br>Seasonal | 1 460 | 1976-83 |
| Hartley Creek near Fort MacKay | 07DA009 | 57°16'N<br>111°28'W | 1975<br>1976-87<br>1988-93 | Seasonal<br>Continuous<br>Seasonal | 358 | 1976-83 |
| Unnamed Creek near Fort MacKay | 07DA011 | 57°40'N<br>111°31'W | 1975-80<br>1981-93 | Continuous<br>Seasonal | 274 | n/a |
| Joslyn Creek near Fort MacKay | 07DA016 | 57°16'N<br>111°45' | 1975-80<br>1981-93 | Continuous<br>Seasonal | 257 | 1976-83 |
| Ells River near the Mouth | 07DA017 | 57°16'N<br>111°43'W | 1975-86 | Continuous | 2450 | 1976-83 |
| Beaver River above Syncrude | 07DA018 | 56°56'N<br>111°34'W | 1975-87<br>1988-93 | Continuous<br>Seasonal | 165 | 1976-80 |
| MacKay River near Fort MacKay | 07DB001 | 57°13'N<br>111°42'W | 1972-86<br>1987-93 | Continuous<br>Seasonal | 5570 | 1975-83 |
| Firebag River near the Mouth | 07DC001 | 57°39'N<br>111°11'W | 1971<br>1972-86<br>1987-93 | Seasonal<br>Continuous<br>Seasonal | 5 990 | 1976-83 |

## 4.2 Basin Characteristics

The results of land and vegetation classification adapted from satellite imagery by Golder Associates is presented on Table 8.

Table 8 - Basin Vegetation Classification

| Basin | Lowland Fen (%) | Muskeg (%) | Upland Treed (%) |
|---|---|---|---|
| Steepbank River | 25.6 | 12.6 | 61.8 |
| Muskeg River | 22.1 | 20.5 | 57.4 |
| Hartley creek | 12.9 | 26.5 | 60.6 |
| Beaver River | 7.5 | 22.0 | 70.5 |
| Unnamed Creek | 3.4 | 28.1 | 68.5 |
| Leggett Creek | 0.8 | 50.6 | 48.6 |
| Wood Creek | 0.8 | 40.7 | 58.5 |
| Athabasca 1 | 3.6 | 1.1 | 95.3 |
| Athabasca 2 | 26.0 | 0.0 | 74.0 |
| Athabasca 3 | 2.1 | 24.3 | 73.6 |

Note: Vegetation measured as a percentage of catchment area to gauging station or, where watercourse is not gauged, to the outlet at the Athabasca River. Data from Golder Associates Ltd.

Comparing the GIS data and flow characteristics, the vegetation groups shown on Table 6 have a relatively close correlation to runoff. When considering the average annual runoff, the portion of "upland" in the drainage basin is the dominant factor. Both the fen and muskeg, as expected, reduce runoff. This is a result of the high soil-moisture holding characteristics of the muskeg described in Section 2.2. Similar relationships have been observed for drainage basins on the west side of the Athabasca River, notably the Beaver River (AGRA, 1995).

The relative proportions of fen, muskeg and uplands do not fully explain the differences in flow characteristics between the watercourses draining the east (or right) side of the Athabasca River and the Beaver River on the west side. The residual differences are considered a result of the different aspect (orientation to North) of the drainage basins. The significant impact that basin aspect can have on streamflow was also noted on a study of precipitation-runoff relationships for the existing Suncor mine (AGRA, 1995).

## 4.3 Streamflow Characteristics

### 4.3.1 Athabasca River

The Athabasca River is largely unregulated apart from the outflows from Lesser Slave Lake and Paddle River Dam. Flows at Lesser Slave Lake and Paddle River Dam represent approximately 6% of the flow in the Athabasca River at the study area.

As stated in Section 4.1, flows have been recorded continuously upstream of the study area at Fort McMurray since 1957. There is only a 1.5% difference in catchment area between the study area and the gauging station at Fort McMurray. Discharge data for Fort McMurray are, therefore, considered to be representative of flows at the proposed mine site.

The average flow at Fort McMurray is 655 $m^3/s$, while the maximum and minimum recorded mean daily flows are 4 700 $m^3/s$ and 89 $m^3/s$, respectively. The maximum recorded instantaneous flow is 4 790 $m^3/s$. Peak flows are typically experienced at Fort McMurray during the month of July. Variations in mean monthly flows are shown on Figure 4, and flow duration curves are presented on Figure 5. Results of a flood frequency analysis of recorded annual peak mean daily flows are presented on Figure 6, and Table 9 presents the results of a statistical analysis of annual runoff at this gauging station.

**Table 9 - Annual Runoff at Athabasca River at Fort McMurray**

| Condition | Annual Runoff | |
|---|---|---|
| | Total ($dam^3$) | Depth (mm) |
| 1 in 100 dry year | 13 400 000 | 101 |
| 1 in 50 dry year | 14 100 000 | 106 |
| 1 in 10 dry year | 16 300 000 | 123 |
| 1 in 5 dry year | 17 700 000 | 133 |
| Average year | 20 700 000 | 156 |
| 1 in 5 wet year | 23 500 000 | 177 |
| 1 in 10 wet year | 25 200 000 | 189 |
| 1 in 50 wet year | 28 300 000 | 213 |
| 1 in 100 wet year | 29 400 000 | 221 |

Note: Based on Log Pearson Type III Distribution

### 4.3.2 Steepbank River

The average streamflow in the Steepbank River at the WSC gauging station near its confluence with the Athabasca River is 7.13 $m^3/s$, approximately 1% of the average flow in the Athabasca River. The maximum recorded mean daily flow is 81.0 $m^3/s$ and the maximum instantaneous flow was 92.0 $m^3/s$. The ratio of maximum instantaneous flow to daily peak flow of 1.14 is fairly typical of the flat hygrographs usually produced by snowmelt. Peak monthly flows are due to snowmelt and are usually experienced during the month of May. Secondary peak monthly flows, from rainfall, typically occur in September.

Typical flood hydrographs for spring snowmelt and summer rainstorms are shown on Figure 7 for Steepbank River, Muskeg River and Hartley Creek. Variations in mean monthly flows are presented on Figure 8 and flow duration curves are shown on Figure 9.

The results of a frequency analysis of maximum recorded annual peak mean daily flows are presented on Figure 10. Recorded maximum instantaneous flows are between 1% and 25% higher than the maximum daily flows with an average value of approximately 6% Table 10 presents the results of a statistical analysis of annual runoff to the Steepbank River. Between 11% and 47% of the estimated annual precipitation for the Suncor study area contributes to runoff with the percentage increasing in wetter years. The remainder will be lost as evapotranspiration, tension storage in the soil near the ground surface and infiltration to aquifers.

Streamflows occur throughout the winter months and are due to groundwater discharge from surficial and bedrock aquifers as well as drainage from lowland fen and muskeg areas. The lowest flows each year typically tend to occur during January, February or March. Winter flows were recorded on this watercourse at the WSC gauging station from 1975 through 1987, and during this period, the minimum mean monthly flow for these months was 0.081 $m^3/s$.

Table 10 - Annual Runoff to Steepbank River

| Return Interval | Runoff | |
|---|---|---|
| | Total ($dam^3$) | Depth (mm) |
| 1 in 100 dry year | 38 700 | 29.3 |
| 1 in 50 dry year | 48 500 | 36.7 |
| 1 in 10 dry year | 81 000 | 61.4 |
| 1 in 5 dry year | 103 000 | 78.0 |
| Average year | 162 000 | 123 |
| 1 in 5 wet year | 219 000 | 166 |
| 1 in 10 wet year | 259 000 | 196 |
| 1 in 50 wet year | 344 000 | 261 |
| 1 in 100 wet year | 379 000 | 287 |

### 4.3.3 Muskeg River

Flows have been recorded on Muskeg River since 1974 at a gauging station approximately 10 km (measured along the valley) upstream of its outlet to the Athabasca River. The average streamflow at this location is 5.6 $m^3/s$ while maximum and minimum recorded mean daily flow was 66.1 $m^3/s$ and 0.095 $m^3/s$, respectively. The maximum recorded instantaneous peak and discharge was 66.4 $m^3/s$. Like the Steepbank River, peak monthly flows tend to occur in May from snowmelt with secondary peaks from rainfall in September.

Variations in mean monthly flows are presented on Figure 11 and flow duration curves are shown on Figure 12 for monthly and daily discharges. The results of frequency analyses of flood flows and annual runoff volumes are presented on Figure 13 and Table 11, respectively. Between about 8% and 33% of the estimated annual precipitation for the Suncor study area contributes to runoff.

Table 11 - Annual Runoff to Muskeg River

| Condition | Runoff | |
|---|---|---|
| | Total ($dam^3$) | Depth (mm) |
| 1 in 100 dry year | 0 | 0 |
| 1 in 50 dry year | 13 300 | 9.1 |
| 1 in 10 dry year | 58 500 | 40.1 |
| 1 in 5 dry year | 83 300 | 57.1 |
| Average | 127 000 | 87.0 |
| 1 in 5 wet year | 178 000 | 122 |
| 1 in 10 wet year | 203 000 | 139 |
| 1 in 50 wet year | 239 000 | 164 |
| 1 in 100 wet year | 249 000 | 171 |

### 4.3.4 Hartley Creek

Variations in mean monthly flows in Hartley Creek, a tributary of the Muskeg River, are presented on Figure 14 and the flow-duration curves are shown on Figure 15. The results of a frequency analysis of flood and annual runoff are presented on Figure 16 and Table 12, respectively. Again, the Log Pearson Type III distribution is considered to provide the "best fit". Between 4% and 41% of the annual precipitation contributes to runoff, again, with the percentage increasing in wetter years.

### 4.3.5 Ungauged Basins

With a drainage area of 358 $km^2$, Hartley Creek is the smallest gauged basin in the vicinity of the Steepbank Mine which has a similar basin shape, topography and aspect to ungauged watercourses in the Suncor study area. For these reasons, drainage data for this basin has been used as the basis for determining flows to Shipyard Lake, Leggett Creek and Wood Creek. Based on a regional analysis of streamflow records, data was transposed using the following equations:

| | |
|---|---|
| Maximum Mean Daily Flows | $- Q_1 = (A_1 / A_2)^{0.77} Q_2$ |
| Mean Daily Flows | $- Q_1 = (A_1 / A_2)^{0.90} Q_2$ |
| Mean Annual Flows | $- Q_1 = (A_1 / A_2) Q_2$ |

where Q is the flow in $m^3/s$, A is the catchment area in $km^2$ and the subscripts 1 and 2 refer to the ungauged and gauged basins, respectively.

Table 12 - Annual Runoff to Hartley Creek

| Condition | Runoff | |
|---|---|---|
| | Total ($dam^3$) | Depth (mm) |
| 1 in 100 dry year | 0 | 0 |
| 1 in 50 dry year | 2 220 | 6.2 |
| 1 in 10 dry year | 11 300 | 31.7 |
| 1 in 5 dry year | 17 200 | 48.1 |
| Average year | 31 600 | 88.3 |
| 1 in 5 wet year | 45 100 | 126 |
| 1 in 10 wet year | 54 400 | 152 |
| 1 in 50 wet year | 72 300 | 202 |
| 1 in 100 wet year | 79 500 | 222 |

As discussed in Section 4.2, the proportion of treed upland in the drainage basin has an impact on streamflow characteristics.

Another study (AGRA, 1996a) proposed that the "upland" portion of a drainage basin contributes approximately twice the annual runoff when compared with "lowland" areas. Although AGRA's definition of "upland" is based on gradient rather than on vegetation, a similar trend is exhibited when comparing runoff from lowland fen and muskeg, as a single grouping, with runoff from treed upland based on vegetation classification. Also, a comparison of typical gradients of treed upland areas indicates that this vegetation classification can be approximated to the "upland" concept adopted by AGRA.

Table 13 presents the annual unit runoff for treed upland based on data for Hartley Creek. The unit runoff for lowland fen and muskeg will be 50% of the values given on

Table 13. The values presented on Table 13 are similar to those estimated for the existing mine (AGRA, 1996a).

**Table 13 - Annual Runoff From Treed Upland Areas**

| Return Interval | Annual Unit Runoff[2] (mm) |
|---|---|
| 1 in 100 dry year | 0 |
| 1 in 50 dry year | 6.8 |
| 1 in 10 dry year | 40.0 |
| 1 in 5 dry year | 63.0 |
| Average year | 110 |
| 1 in 5 wet year | 164 |
| 1 in 10 wet year | 190 |
| 1 in 50 wet year | 260 |
| 1 in 100 wet year | 278 |

For comparison, the equivalent annual unit runoffs for Steepbank and Muskeg Rivers are presented on Table 14. The differences are considered to be a result of impact of basin aspect on annual runoff.

**Table 14 - Comparison of Annual Unit Runoff (in mm) for Various Basins**

| Watercourse | Condition | | | Drainage Area ($km^2$) | Basin Aspect |
|---|---|---|---|---|---|
| | 1 in 100 Dry Year | Average Year | 1 in 100 Wet Year | | |
| Steepbank River | 29.3 | 123 | 287 | 1320 | S |
| Muskeg River | 0 | 87.0 | 171 | 1460 | NW |
| Hartley Creek | 0 | 88.3 | 222 | 358 | W |

[2] A theoretical depth of water over the entire drainage area.

Using the GIS data provided by Golder Associates, the areas of lowland fen, muskeg and treed upland were calculated for each of the main drainage basins in the Suncor study area. The total drainage areas and proportion of vegetation groups are presented on Table 15.

**Table 15 - Drainage Areas for Ungauged Basins**

| Watercourse or Basin | Drainage Area ($km^2$) | Proportion of Drainage Area (%) | | |
|---|---|---|---|---|
| | | Lowland Fen | Muskeg | Treed Upland |
| Unnamed Creek (Shipyard Lake) | 44.1 | 3.6 | 39.4 | 57.0 |
| Leggett Creek | 35.0 | 0.8 | 50.6 | 48.6 |
| Wood Creek | 36.8 | 0.8 | 40.7 | 58.5 |
| Athabasca 1 | 4.0 | 3.6 | 1.1 | 95.3 |
| Athabasca 2 | 1.0 | 26.0 | 0.0 | 74.0 |
| Athabasca 3 | 7.2 | 2.1 | 24.3 | 73.6 |

Note: Areas calculated for outlet to Athabasca River.

Using the unit runoff values presented on Table 13, the annual runoff was estimated for the drainage areas in the local study assuming that muskeg and lowland fen contribute 50% of the runoff from treed upland. The results are presented on Table 16.

**Table 16 - Estimated Annual Runoff For Ungauged Basins**

| Watercourse or Basin | Average Annual Discharge (L/s) | | |
|---|---|---|---|
| | 1 in 100 dry year | Average Year | 1 in 100 wet year |
| Unnamed Creek (Shipyard Lake) | 0 | 158 | 365 |
| Leggett Creek | 0 | 124 | 288 |
| Wood Creek | 0 | 133 | 307 |
| Athabasca 1 | 0 | 16 | 36 |
| Athabasca 2 | 0 | 4 | 9 |
| Athabasca 3 | 0 | 28 | 64 |

Flood events were found to be more closely related to basin size rather than to basin characteristics. Table 17 shows the estimated peak mean daily discharges for gauging stations in the vicinity of the proposed mine. Note that they have been adjusted to a common basin area of 1000 km$^2$ using the power function shown on page 19.

**Table 17 - Unit Mean Peak Daily Flows (m$^3$/s/1000 km$^2$) for Gauged Basins**

| Return Interval | Watercourse | | |
|---|---|---|---|
| | Steepbank River | Muskeg River | Hartley Creek |
| 5 years | 45.3 | 29.4 | 28.5 |
| 10 years | 60.0 | 37.3 | 36.6 |
| 50 years | 96.9 | 55.0 | 52.9 |
| 100 years | 114 | 62.5 | 58.9 |

Note: Runoff has been adjusted to a common drainage area of 1000 km$^2$ using the relationship (drainage area/1000)$^{0.77}$.

The values for Hartley Creek were used for flood events with no adjustment to take account of differences in proportions of treed upland, muskeg and lowland fen.

Estimated peak flood flows for the ungauged basins in the Suncor study area are presented on Table 18.

**Table 18 - Estimated Flood Flows for Ungauged Basins**

| Watercourse or Basin | Peak Mean Daily Discharge (m$^3$/s) | | | |
|---|---|---|---|---|
| | 1 in 5 yr | 1 in 10 yr | 1 in 50 yr | 1 in 100 yr |
| Unnamed Creek (Shipyard Lake) | 2.7 | 3.3 | 4.8 | 5.3 |
| Leggett Creek | 2.2 | 2.8 | 4.0 | 4.5 |
| Wood Creek | 2.2 | 2.9 | 4.2 | 4.6 |
| Athabasca 1 | 0.4 | 0.5 | 0.8 | 0.8 |
| Athabasca 2 | 0.1 | 0.2 | 0.3 | 0.3 |
| Athabasca 3 | 0.6 | 0.8 | 1.2 | 1.3 |

The estimated mean, maximum and minimum monthly flows for the ungauged creeks, based on the average distribution of monthly flows for Hartley Creek, are presented on Figure 17. The average peak daily flows for floods are shown on Figure 18. Note that the estimated flows are at the outlet of each creek to the Athabasca River.

### 4.3.6 Wetlands

As described earlier, there is one large wetlands within the study area; Shipyard Lake. Shipyard Lake and associated wetlands has been used as a reference site for studies by Suncor into the use of constructed wetlands for treating fine tailings waste (EVS, 1992, 1993 and 1994). The wetlands is a marsh-swamp-shallow open water complex that is periodically flooded by the Athabasca River. The wetland system is in transition from a shallow open water wetland to a marsh (EVS, 1992). While studies of water chemistry, sediments and plant species were performed, no measurements were taken of water level, inflow or outflow. Surface water inflow is from two creeks; the unnamed creek which discharges into the north end of the wetland and a much smaller creek to the south. Drainage from the wetland flows north before discharging into the Athabasca River.

The total area of the wetland complex based on available maps is approximately 128 ha, of which about 23 ha is open water. Assuming that loss from the open water will be equal to the lake evaporation and that the loss from the emergent vegetation will be equal to the areal evapotranspiration, the annual loss from Shipyard Lake is estimated to vary between 14 L/s and 18 L/s with an average value of 15 L/s. Table 19 shows expected gross and net inflow for Shipyard Lake based on these losses. The values presented are only intended to show the limited impact of evaporation and evapotranspiration on the hydrology of Shipyard Lake and do not take into consideration the impact of changes in water surface elevation and extent of the wetland complex that are expected to occur. These effects are discussed more completely in the Aquatics and Terrain impacts studies. Note that the drainage area for Shipyard Lake is 40.9 $km^2$, or 93% of the total drainage area for the unnamed creek.

Table 19 - Net and Gross Inflow to Shipyard Lake

| | Average Inflow (L/s) | | | Average Net Inflow or Loss (L/s) | | |
|---|---|---|---|---|---|---|
| | 1 in 100 Dry Year | Average Year | 1 in 100 Wet Year | 1 in 100 Dry Year | Average Year | 1 in 100 Wet Year |
| Minimum | 0 | 145 | 336 | -14 | 131 | 322 |
| Average | 0 | 145 | 336 | -15 | 130 | 321 |
| Maximum | 0 | 145 | 336 | -18 | 127 | 318 |

Note: Minimum, average and maximum refer to the respective estimated annual evaporation and evapotranspiration.

## 4.4 Water Balance

The water balance equation for a basin states that precipitation equals the sum of the runoff, evapotranspiration and change in storage. With the availability of reliable estimates of evapotranspiration, it is possible to assess the seasonal variations in these components at gauged basins.

Figure 19 shows the average annual water balances for Steepbank River, Muskeg River and Hartley Creek. The charts are based on the correlated precipitation at Mildred Lake, flow records from Water Survey of Canada and estimates of evapotranspiration at Fort McMurray from Alberta Environmental Protection (Bothe and Abraham, 1987 and 1990). The top line is the average accumulated (or mass curve) of precipitation starting at the beginning of September. The difference between the top and middle lines is the evapotranspiration, while the difference between the middle and lower lines is the accumulated unit runoff. The area at the bottom represents basin storage and has been subdivided to show estimates of accumulated snow pack using measurements of snow on the ground at Fort McMurray airport.

The mass curve of precipitation and evapotranspiration are typical of a continental climate where the precipitation is high during the summer months when evapotranspiration is at its highest and low during the winter when evapotranspiration rates are negligible. All the curves are similar with decreasing flows in September and

October and very low discharges over the winter. Storage in the Steepbank River basin has changed little over the period of simulation (1975-1988) while storage in the Muskeg River and Hartley Creek basins appear to have increased over the period of simulation (1975-1988 and 1976-1988, respectively).

On an annual basis, the estimated average precipitation is 399 mm with about 288 mm (or about 70%) being lost to evapotranspiration. Total average unit runoff varies from a maximum of 152 mm for Steepbank River to 90 mm and 87 mm for Hartley Creek and Muskeg River, respectively.

## 4.5 Water Quality

### 4.5.1 Sediment

Sediment samples are obtained at a number of gauging stations operated in the area by Water Survey of Canada. At the gauging station on the Athabasca River below Fort McMurray, sediment samples were taken each day on a seasonal basis in 1969 and continuously from 1970 through 1972. In 1976 and 1977, only random sediment sampling was performed. At gauging stations on tributary watercourses samples were typically obtained once a month throughout the open water season. Data from these latter stations are considered to be representative of conditions within the study area. In general, the suspended sediment load in watercourses in the study area vary with flow. Concentrations are highest during spring snowmelt and summer floods and are lowest during the winter when flows are at a minimum. Variations in sediment concentration with mean daily discharge are presented on Figure 20 for the Athabasca River, and on Figure 21 for the Steepbank River, Muskeg River and Hartley Creek.

The annual suspended sediment load on the Athabasca River below Fort McMurray is estimated to be about 1 million tonnes. Sediment concentration varied from a maximum of 4 820 mg/l on July 2, 1970 to a minimum of 1 mg/l on January 17, 1969. The corresponding mean daily flows were 3 650 $m^3/s$ and 151 $m^3/s$, respectively. The maximum and minimum sediment concentrations on the Steepbank River were 741 mg/l and 3 mg/l, respectively. As discussed above, only spot sampling of sediments was performed on the Athabasca River tributaries in the vicinity of the proposed mine: namely, Steepbank River, Muskeg River and Hartley Creek. An analysis of daily sediment load data was performed for these three tributary watercourses. Based on the results, the daily sediment load can be estimated using the equation:

$$L = 12.3\ (A)^{-0.5}\ (Q)^{1.3}$$

where L is the daily load in tonnes, Q is the mean daily flow in $m^3/s$, and, A is the catchment area in $km^2$.

The expected average annual sediment loads, based on this relationship are presented on Table 20 for the tributary watercourses.

**Table 20 - Estimated Annual Sediment Loads**

| Watercourse | Sediment Load (Tonne) |
|---|---|
| Steepbank River | 21 000 |
| Hartley Creek | 490 |
| Unnamed Creek (Shipyard Lake) | 190 |
| Leggett Creek | 180 |
| Wood Creek | 180 |

It can be seen that, on an annual basis, the sediment loads in the tributaries (except for the Steepbank River) are less than 1% percent of the load in the Athabasca River. The sediment load in the Steepbank River is approximately 2% of the load in the Athabasca River.

### 4.5.2 Chemistry

Sediment sampling has been performed by Environment Canada 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 Suncor study area (the unnamed creek, Leggett Creek and Wood Creek). Sediment sampling on the Athabasca from 1970 through 1972 was continuous. Random sediment sampling was performed at other times. Suspended sediment concentrations tend to increase with flow as shown on Figure 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 8.

**Table 21 -Recorded Sediment Concentrations in Watercourses In The Suncor Study Area**

| 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 MacKay | 3 | 9 | 41 |
| Hartley Creek near Fort MacKay | 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 (Suncor 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 22.

# 5. IMPACT OF MINING ACTIVITIES

## 5.1 Mine Development

Following is a brief chronology of the components of the mine development pertinent to the assessment of impacts on surface water resources in the study area. Plans showing the overall mine development in 2001, 2009 and 2020, and long-term equilibrium conditions are attached (Drawings A-2779-03-008 to A-2779-03-011, inclusive).

<u>1995 Baseline Conditions</u>

- 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.
- The gravel pit will be developed in 1997 and 1998.
- Initial site drainage for Pit 1, stormwater retention ponds 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.
- Channel 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.

- The mining of Pit 1 is completed in 2009 and the excavated area is used for disposal of consolidated tailings (CT) (Ponds 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.

<u>2009 - 2020 (Pit 2 Development)</u>

- 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 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 consolidated tailings (CT) to 327 m elevation.

## 5.2 Drainage 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 ditches 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 22 shows the estimated volumes of runoff from the 1 in 100 year rain storm event and 1 in 100 year wet annual runoff for the years 2001, 2009 and 2020. Losses, including percolation and evapotranspiration, used to estimate the water balance for Steepbank Mine were based on those adopted for the existing mine (AGRA, 1996a). The Soil Conservation Service rainfall-runoff model was used to estimate runoff volumes from storm events. The Chicago Method was used to develop the storm hyetograph. To generate runoff hydrographs, a Curve Number of 90 was used with initial abstractions varying from zero to 10 mm. The estimated volumes are considered to be conservative and are included to demonstrate the relative magnitude of runoff to the different mine retention ponds. As mentioned above, it is Suncor's intention to use mine runoff as process water.

## 5.3 Surface Water Impacts

The existing surface water drainage flows in the study area will be affected in two ways. First, the development of the mine, including construction of overburden dumps will reduce the total drainage area and overall runoff. As noted in Section 5.2, runoff from the mine will be retained and used as process water. Secondly, the construction of drainage ditches will affect the overall drainage patterns. For example, under the proposed mine layout, flows in Wood Creek will increase when the perimeter channels to the east of Pit 2 are constructed in 2012 and 2015. Table 23 shows the drainage areas to various points in the Suncor study area for the time "snap shots" of interest, namely 2001, 2009 and 2020, as well as for post-closure equilibrium conditions.

Table 22 - Estimated Mine Drainage

| Sump | 1 in 100 Year Runoff ($m^3$) | |
|---|---|---|
| | Rain Storm Event | Annual Total |
| **2001** | | |
| A | 33 000 | 1 100 000 |
| B | 400 | 20 000 |
| C | 9 000 | 370 000 |
| D | 24 000 | 920 000 |
| D′ | - | - |
| **2009** | | |
| A | 21 000 | 490 000 |
| B | 10 000 | 240 000 |
| C | 7 000 | 220 000 |
| D | 64 000 | 2 270 000 |
| D′ | 13 000 | 460 000 |
| **2020** | | |
| A | 45 000 | 800 000 |
| B | 16 000 | 230 000 |
| C | 12 000 | 230 000 |
| D | 170 000 | 2 920 000 |
| D′ | 21 000 | 305 000 |

The annual runoff to each location for the selected years and post-closure are presented on Table 24. These flows were estimated based on the proportion of lowland fen, muskeg and treed upland and using the unit runoff values presented in Section 4.5.5. Again, note that these flows do not include any contribution from the mine itself. Drainage within the mine is assumed to be pumped across the Athabasca River for use by Suncor as process water.

Expected peak flood mean daily flows to each location for the same time periods are shown on Table 25 for return intervals of up to 1 in 100 years. Again, it is assumed that there is no contribution from the Steepbank Mine itself. The flood flows were estimated based on total drainage area to each location using the methodology outlined in Section 4.5.5.

Changes in surface water drainage are outlined diagrammatically on Figure 23 while Figure 24 illustrates expected factors relating to changes in surface water quality.

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

**Table 23 - Impact of Mine Development on Suncor Study Area**

| Drainage Basin | Drainage Area ($km^2$) | Proportion of Drainage Area (%) | | |
|---|---|---|---|---|
| | | Lowland Fen | Muskeg | Treed Upland |
| **2001** | | | | |
| Shipyard Lake at Athabasca River | 45.4 | 3.0 | 11.5 | 85.5 |
| Shipyard Lake Outlet | 40.9 | 3.6 | 41.3 | 55.1 |
| Leggett Creek | 35.0 | 0.8 | 50.6 | 48.6 |
| Wood Creek | 36.8 | 0.8 | 40.7 | 58.5 |
| Athabasca River 1 | 2.0 | 4.7 | 0.1 | 95.2 |
| Athabasca River 2 | 1.0 | 26.0 | 0.0 | 74.0 |
| Athabasca River 3 | 7.2 | 2.1 | 24.3 | 73.6 |
| **2009** | | | | |
| Shipyard Lake at Athabasca River | 35.3 | 3.3 | 48.2 | 48.5 |
| Shipyard Lake Outlet | 34.3 | 3.1 | 49.7 | 47.2 |
| Leggett Creek | 35.3 | 0.7 | 50.7 | 48.6 |
| Wood Creek | 36.8 | 0.8 | 40.7 | 58.5 |
| Athabasca River 1 | 1.3 | 5.5 | 0.00 | 94.4 |
| Athabasca River 2 | 1.0 | 26.0 | 0.00 | 74.0 |
| Athabasca River 3 | 7.2 | 2.1 | 24.3 | 73.6 |
| **2020** | | | | |
| Shipyard Lake at Athabasca River | 6.9 | 11.5 | 37.0 | 50.5 |
| Shipyard Lake Outlet | 5.9 | 12.1 | 44.3 | 43.6 |
| Leggett Creek | 0.0 | | | |
| Wood Creek | 87.2 | 1.0 | 5.0 | 49.0 |
| Athabasca River 1 | 1.3 | 5.5 | 0.00 | 94.5 |
| Athabasca River 2 | 1.0 | 26.0 | 0.00 | 74.0 |
| Athabasca River 3 | 2.6 | 3.6 | 0.00 | 96.4 |
| **Post Reclamation** | | | | |
| Shipyard Lake at Athabasca River | 28.2 | | | |
| Shipyard Lake Outlet | 26.1 | | | |
| Leggett Creek | 0.0 | | | |
| Wood Creek | 92.8 | | | |
| Athabasca River 1 | 2.1 | | | |
| Athabasca River 2 | 1.0 | | | |
| Athabasca River 3 | 2.6 | | | |

**Table 24 - Annual Runoff (Natural Flows)**

| Drainage Basin | Average Annual Flow (L/s) | | |
|---|---|---|---|
| | 1 in 100 Dry Year | Average | 1 in 100 Wet Year |
| **2001** | | | |
| Shipyard Lake at Athabasca River | 0 | | 37 |
| Shipyard Lake | 0 | 126 | 316 |
| Leggett Creek | 0 | 91 | 229 |
| Wood Creek | 0 | 101 | 254 |
| Athabasca River 1 | 0 | 11 | 29 |
| Athabasca River 2 | 0 | 3 | 8 |
| Athabasca River 3 | 0 | 22 | 55 |
| **2009** | | | |
| Shipyard Lake at Athabasca River | 0 | 91 | 231 |
| Shipyard Lake | 0 | 88 | 223 |
| Leggett Creek | 0 | 92 | 231 |
| Wood Creek | 0 | 101 | 254 |
| Athabasca River 1 | 0 | 9 | 23 |
| Athabasca River 2 | 0 | 3 | 8 |
| Athabasca River 3 | 0 | 22 | 55 |
| **2020** | | | |
| Shipyard Lake at Athabasca River | 0 | 3 | 9 |
| Shipyard Lake | 0 | 18 | 46 |
| Leggett Creek | 0 | 0 | 0 |
| Wood Creek | 0 | 227 | 573 |
| Athabasca River 1 | 0 | 9 | 23 |
| Athabasca River 2 | 0 | 3 | 8 |
| Athabasca River 3 | 0 | 9 | 23 |
| **Post Reclamation** | | | |
| Shipyard Lake at Athabasca River | 0 | 60 | 177 |
| Shipyard Lake | 0 | 53 | 157 |
| Leggett Creek | 0 | 0 | 0 |
| Wood Creek | 0 | 243 | 619 |
| Athabasca River 1 | 0 | 11 | 29 |
| Athabasca River 2 | 0 | 3 | 8 |
| Athabasca River 3 | 0 | 9 | 23 |

## Table 25 - Flood Flows (Natural Runoff)

| Drainage Basin | | | |
|---|---|---|---|
| **2001** | | | |
| Shipyard Lake at Athabasca River | 3.4 | 4.9 | 5.4 |
| Shipyard Lake | 3.1 | 4.5 | 5.0 |
| Leggett Creek | 2.8 | 4.0 | 4.5 |
| Wood Creek | 2.9 | 4.2 | 4.6 |
| Athabasca River 1 | 0.3 | 0.4 | 0.5 |
| Athabasca River 2 | 0.2 | 0.3 | 0.3 |
| Athabasca River 3 | 0.8 | 1.2 | 1.3 |
| **2009** | | | |
| Shipyard Lake at Athabasca River | 2.8 | 4.0 | 4.5 |
| Shipyard Lake | 2.7 | 3.9 | 4.4 |
| Leggett Creek | 2.8 | 4.0 | 4.5 |
| Wood Creek | 2.9 | 4.2 | 4.6 |
| Athabasca River 1 | 0.2 | 0.3 | 0.4 |
| Athabasca River 2 | 0.2 | 0.3 | 0.3 |
| Athabasca River 3 | 0.8 | 1.2 | 1.3 |
| **2020** | | | |
| Shipyard Lake at Athabasca River | 0.9 | 1.3 | 1.4 |
| Shipyard Lake | 0.7 | 1.0 | 1.1 |
| Leggett Creek | 0.0 | 0.0 | 0.0 |
| Wood Creek | 5.6 | 8.1 | 9.0 |
| Athabasca River 1 | 0.2 | 0.3 | 0.4 |
| Athabasca River 2 | 0.2 | 0.3 | 0.3 |
| Athabasca River 3 | 0.4 | 0.5 | 0.6 |
| **Post Reclamation** | | | |
| Shipyard Lake at Athabasca River | 4.0 | 6.6 | 7.8 |
| Shipyard Lake | 3.6 | 6.1 | 7.2 |
| Leggett Creek | 0.0 | 0.0 | 0.0 |
| Wood Creek | 6.3 | 9.4 | 10.6 |
| Athabasca River 1 | 0.3 | 0.5 | 0.6 |
| Athabasca River 2 | 0.2 | 0.3 | 0.3 |
| Athabasca River 3 | 0.4 | 0.5 | 0.6 |

### 5.3.1 Bridge Construction (1997 - 1999)

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 were assessed in 1995 and 1996 (AGRA, 1996b). The report indicates 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 may increase the potential for ice jams to form. This will be mitigated by removing the dams prior to breakup.

The 1 in 100 year ice jam flood elevation is expected to be about elevation 241.0 m above Geodetic datum. 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.

### 5.3.2 Facility Construction (1997 - 2001)

Surface water from Athabasca 1, Athabasca 2, Shipyard Lake and the Steepbank River basins 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.

**Surface Water Flow**

Construction of the main components of the Mine Drainage System, including stormwater retention ponds A through D, is part of the facilities construction program. The mine retention storage ponds (A, B, C, and D) will be designed to handle the 1 in 10 year wet annual runoff. This volume is sufficient for even the 1 in 100 year flood to be stored in the mine stormwater retention ponds, 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 ditches into Pit 1.

Until the bridge is completed in 1999, however, there will be no opportunity to use mine runoff as process water. To mitigate this impact, Suncor is planning to increase the size of the mine retention ponds to store the runoff in 1997 and 1998 assuming that the 1 in 100 year wet runoff occurs in one of the two years and the estimated average runoff occurs in the other year.

**Surface Water Quality**

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 left unmitigated, concern for surface water quality issues on the escarpments of the Athabasca and Steepbank Rivers would be high. 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) Athabasca Bridge

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 unexpected 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) Facilities Construction

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 adequate quality standards or is treated in the site treatment facility.

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 ditches with settlement ponds to collect runoff from disturbed areas, roads and paved areas;
- Cross-berms on sloping disturbed areas to retard runoff and reduce surface erosion; and
- Quickly re-seeding disturbed areas after construction activities have finished.

c) East Access Corridor

If left unmitigated, the effects of liquid spills along the east access corridor on surface water quality are potentially high severity, short term duration and regional due to the possibility of release to Athabasca River. To mitigate these potential impacts, the east access corridor plant roads and utilidors 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 for protection of the surface waters from rupture of the hydrotransport, hot water and underground diesel fuel pipelines where they cross drainage courses along the East Corridor Road crossing will be provided.

### 5.3.3 Pit 1 Development (2001 - 2009)

Surface water from the Athabasca 1 and Athabasca 2 sub-catchments, Shipyard Lake and the Steepbank River basins 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 Drawings A-2779-03-008 and A-2779-03-009 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 Channel 9-A and Channel 9-B.

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

**Surface Water Flow (2001 - 2009)**

The drainage area of Athabasca 1 catchment contributing flow to the river shown on Drawing A-2779-03-004 is reduced from 6.4 to 2.6 $km^2$ and the average annual flow from the basin is reduced from 22 L/s to 9 L/s as shown in Table 24.

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 reduced 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. The impacts on Shipyard Lake are described in Terrestrial Resources reports (Golder, 1996b).

**Surface Water Quality (2001 - 2009)**

There is the possibility of increased sediment concentration in flows to Shipyard Lake from erosion of ditches constructed to intercept natural runoff as well as the facilities area. The potential for increased sediment load will be mitigated by minimizing flow velocities in the ditches, constructing sediment ponds to trap the sediment, lining the ditches with erosion resistant materials and/or re-seeding disturbed areas adjacent to the ditches. 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, Channel 3-A and Channel 3-B will be constructed to conduct 5.0 $m^3/s$ to Shipyard Lake during peak storm events. The ditch will require flow control through retention ponds 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.

### 5.3.4 Pit 2 Development (2009 - 2020)

**Surface Water Flow (2009 - 2020)**

With the development of Pit 2 and associated overburden dumps, the average annual flow into Shipyard Lake will be further reduced by approximately 83% from 88 L 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 will be increased by about 2.3 times from approximately 100 L/s to 230 L/s as shown in Table 24.

The impact of the reduced runoff on the water balance of Shipyard Lake is shown on Table 26.

In 2015, Channel 15-C will be constructed to divert about 7 $m^3/s$ runoff during peak storm from the unnamed Creek to Wood Creek. Estimated velocities in the discharge channel from the uplands to Wood Creek are about 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 due to the small flows.

## Table 26 - Water Balance for Shipyard Lake During Mine Development and Closure

| | Average Inflow (L/s) | | | Evaporation/Evapotranspiration Losses (L/s) | | | Net Inflow or Loss (L/s) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 in 100 Dry Year | Average Year | 1 in 100 Wet Year | 1 in 100 Dry Year | Average Year | 1 in 100 Wet Year | 1 in 100 Dry Year | Average Year | 1 in 100 Wet Year |
| **1995** | | | | | | | | | |
| 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 |
| **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 100 year dry and 100 year wet conditions.

**Surface Water Quality (2009 - 2020)**

There is the possibility of increased sediment concentration in flows to Wood Creek originating from ditches 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 sediment will be mitigated by minimizing flow velocities in the ditches, constructing ponds to trap the sediment, lining the ditches with erosion resistant materials and/or revegetating disturbed areas adjacent to the ditches.

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.

### 5.3.5 Reclamation Drainage Post-2020

**Surface Water Flow (Reclamation Drainage Post-2020)**

Post reclamation effects on annual flows are presented in Table 27. 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.

**Surface Water Quality**

The impact of re-vegetating 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 watercourses on site. Closure and reclamation plans, as discussed in other sections of this EIA result in low concern for impacts to surface water quality in the Steepbank and Athabasca Rivers.

# Table 27 - Reclamation Drainage Post 2020

| Watercourse or Drainage Basin | Change in Drainage Area (km²) | Change in Annual Flow (L/s) | | | Change in Annual Flow (%) | | |
|---|---|---|---|---|---|---|---|
| | | 1 in 100 Dry Year | Average Year | 1 in 100 Wet Year | 1 in 100 Dry Year | Average Year | 1 in 100 Wet Year |
| Steepbank River | negligible | negligible | negligible | negligible | negligible | negligible | negligible |
| Athabasca River | negligible | negligible | negligible | negligible | negligible | negligible | negligible |
| Shipyard Lake at Athabasca River | -0.4 | 0.0 | -61.0 | -128.0 | 0% | -50% | -42% |
| Shipyard Lake at Outlet | -0.4 | 0.0 | -57.2 | -122.1 | 0% | -52% | -44% |
| Leggett Creek | -1.0 | 0.0 | -90.6 | -229.0 | 0% | -100% | -100% |
| Wood Creek | 1.5 | 0.0 | 140.9 | 361.7 | 0% | 138% | 141% |
| Athabasca River 1 | -0.5 | 0.0 | -10.3 | -25.4 | 0% | -48% | -46$ |
| Athabasca River 2 | 0.0 | 0.0 | 0.0 | 0.0 | 0% | 0% | 0% |
| Athabasca River 3 | -0.6 | 0.0 | -12.6 | -31.9 | 0% | -58% | -58% |
| Total Change | -1.3 | 0.0 | -90.8 | -174.7 | | | |

# 6. SUMMARY OF SURFACE WATER IMPACTS

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

**Hypothesis 1** 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 2** 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.

**Hypothesis 3** 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 23 and 24.

# 7. 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 ground water 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 ground water 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. |
| 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 | The portion of ore that is deposited after washing and milling and which has undergone a reduction in volume and increase in density. (See also "Consolidation") |
| Consolidation | The gradual reduction in volume of a soil mass resulting from an increase in applied load.<br>a) Initial consolidation (initial compression): A comparatively sudden reduction in volume of a soil mass under an applied load due principally to release or the squeezing out and compression of gas in the soil voids preceding primary consolidation<br>b) Primary consolidation (primary compression) (primary time effect): The reduction in volume of a soil mass caused by the application of a sustained load to the mass and due principally to a squeezing out of water from the void spaces of the mass and accompanied by a transfer of the load from the soil water to the soil solids. |

| | |
|---|---|
| | c) Secondary consolidation (secondary compression) (secondary time effect): The reduction in volume of a soil mass caused by the application of a sustained load to the mass and due principally to the adjustment of the internal structure of the soil mass after most of the load has been transferred from the soil water to the soil solids. |
| 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, feature, marriage which only lasts for a short time (ie., 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 flooded during seasonally high water levels. |
| 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, and consisting of a heterogeneous mixture of clay, silt, sand, gravel and boulders 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 | Water that is found below the ground surface, in soil and rock. |
| 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, and the related geologic aspects of surface water. |
| Inorganics | Pertaining or relating to a compound that contains no carbon. (See also "Organic compounds") |
| Landform | Any physical, recognizable form or feature of the Earth's surface, having a characteristic shape, and produced by natural causes. |

| | |
|---|---|
| Lean Oil Sands | Oil bearing sands, which do not have a high enough saturation of oil to make mining of them economically feasible. |
| Microtox | A measure of toxicity in a sample. (See also "Toxicity") |
| Organic Compounds | Chemicals (naturally occurring or otherwise) which contain carbon, with the exception of carbon dioxide ($CO^2$) and carbonates (e.g., CACO3) |
| 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 | An instrument for measuring pressure. In groundwater and geotechnical investigations, piezometers are commonly Poly Vinyl Chloride pipe that has been sealed in a drill hole. The height to which groundwater rises in the pipe is a measure of the water pressure at the bottom of the piezometer. |
| 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. |
| 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 | The portion of ore, after washing and milling, which is too low grade to warrant further processing. |
| Total Dissolved Solids (TDS) | The total concentration of all dissolved compounds solids found in a water sample. |
| Toxicity | The tendency of a chemical or condition to cause harm to the life process. |
| 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 | Area of surface water ponding which forms the habitat for a variety of wildlife including water fowl. |

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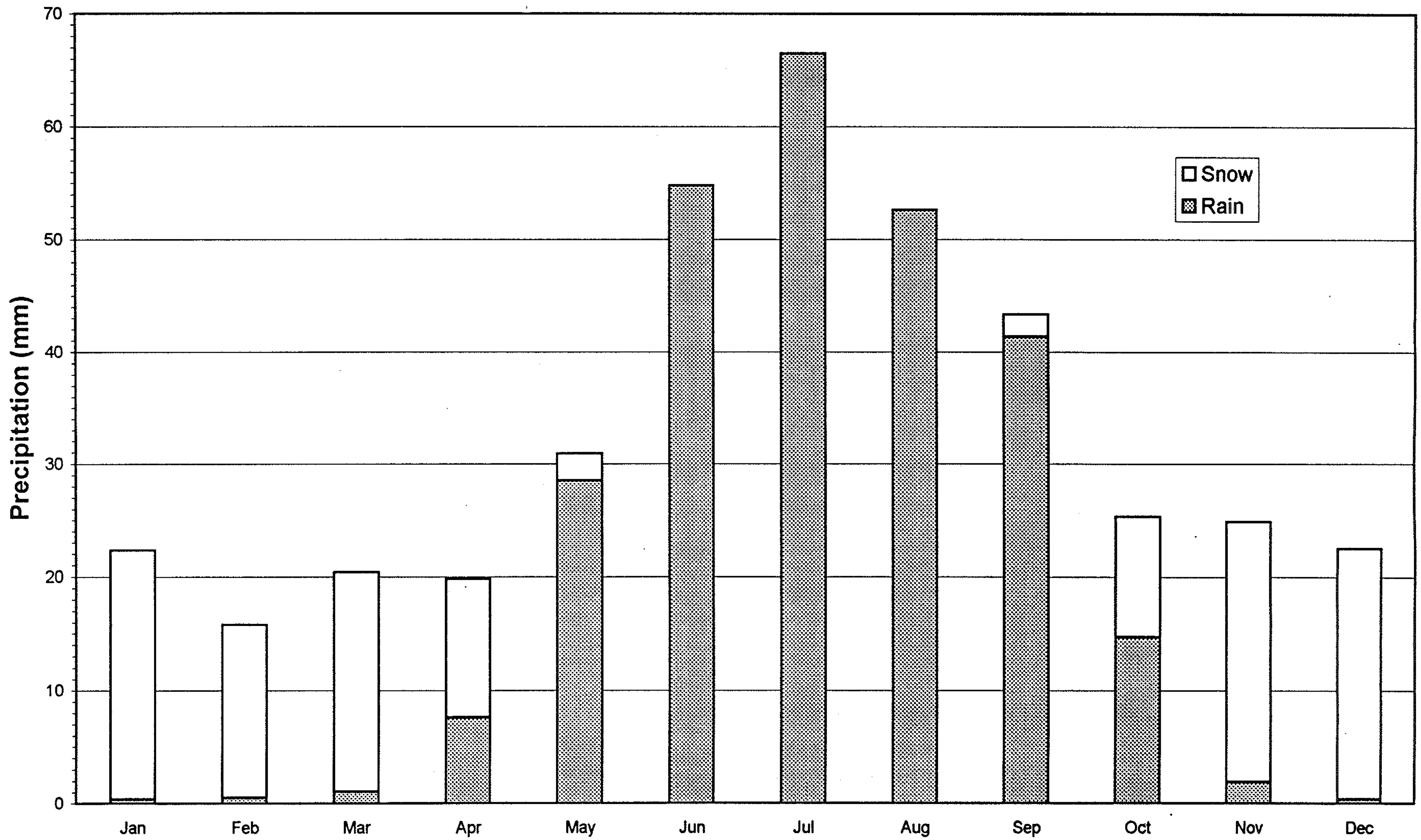
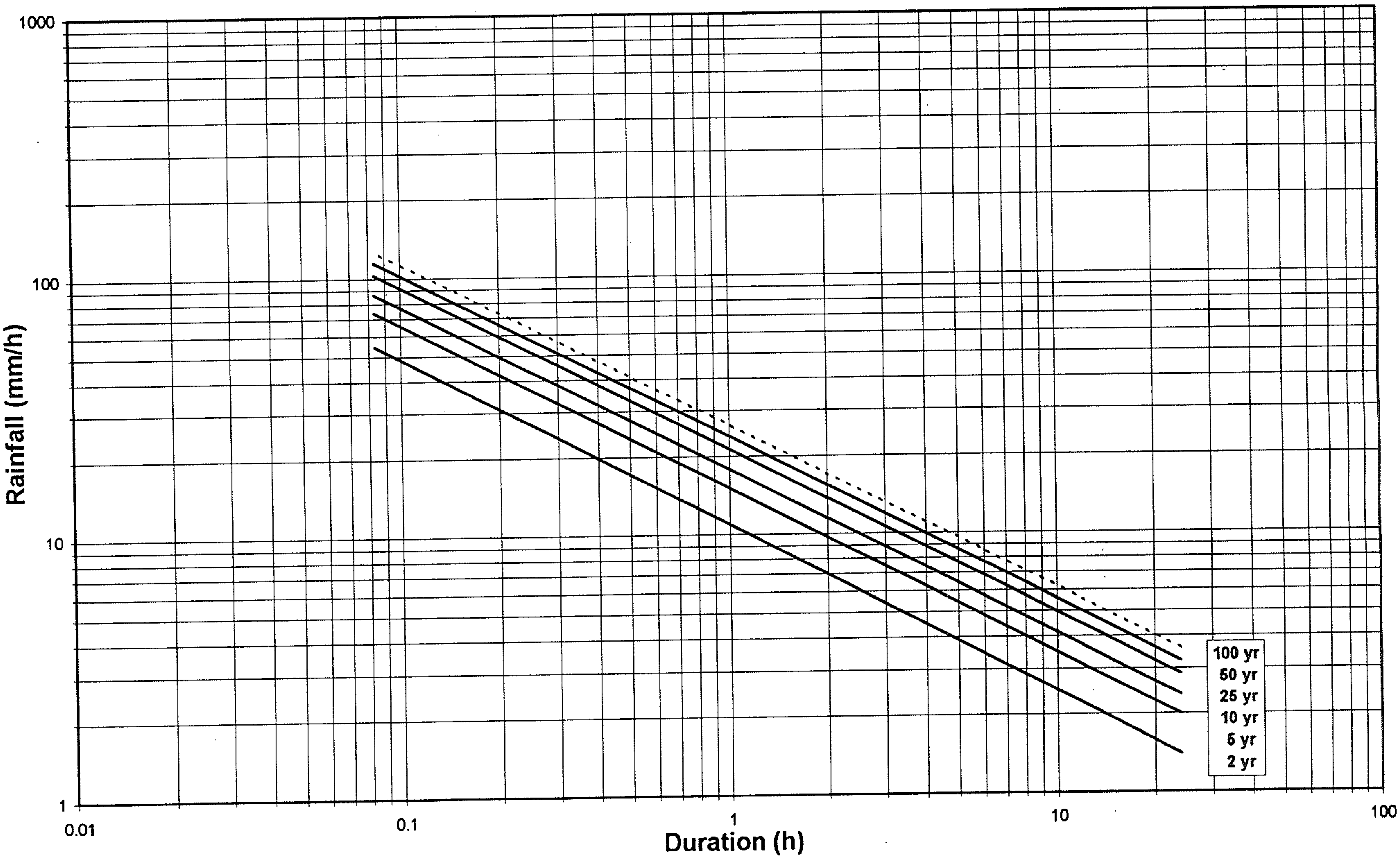
# FIGURES

# Figure 1
# Estimated Mean Monthly Precipitation for Local Study Area

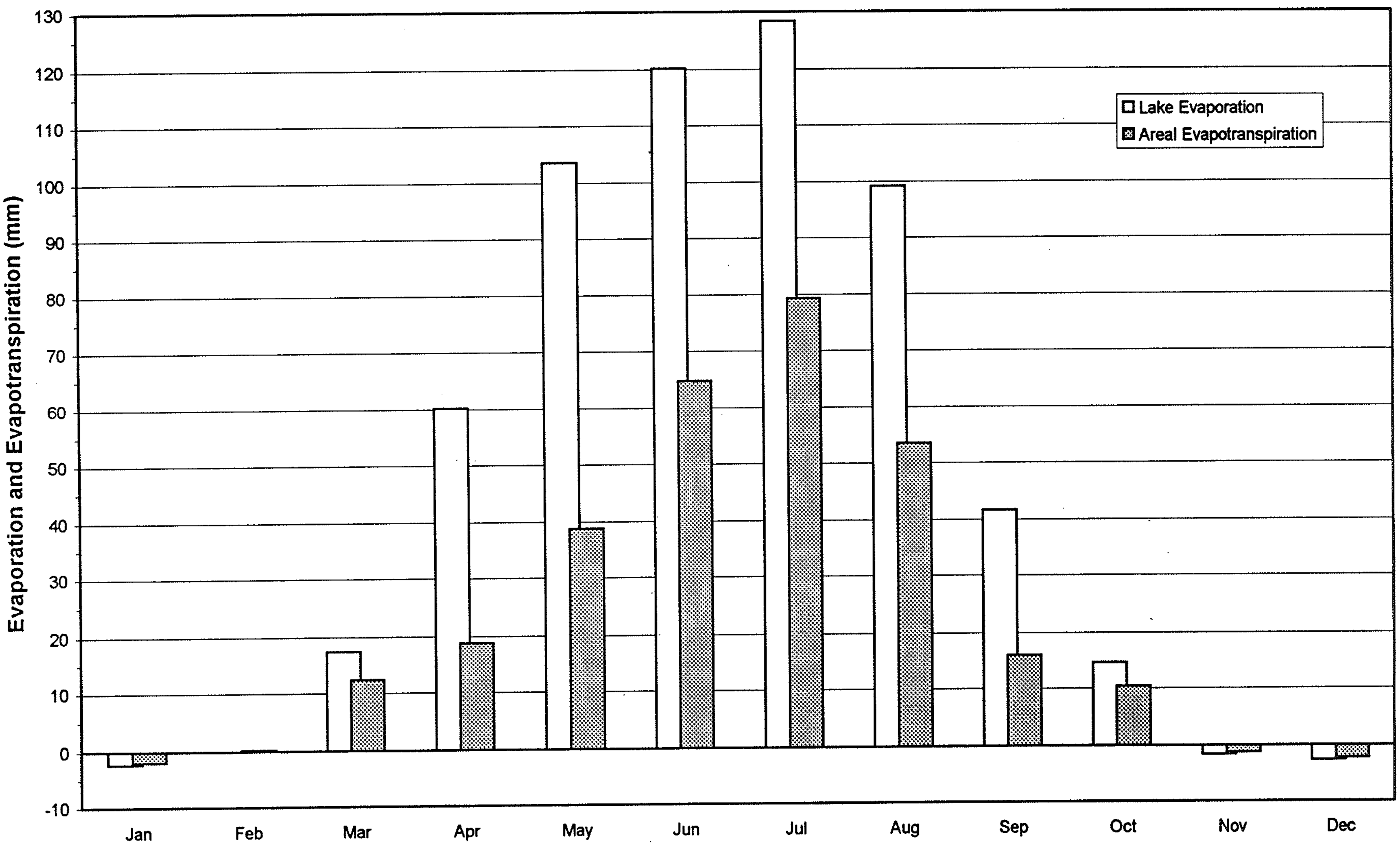



*Based on correlated data from Fort McMurray for the period 1908 - 1993*

## Figure 2
## Rainfall Intensity-Duration-Frequency Curves for Local Study Area

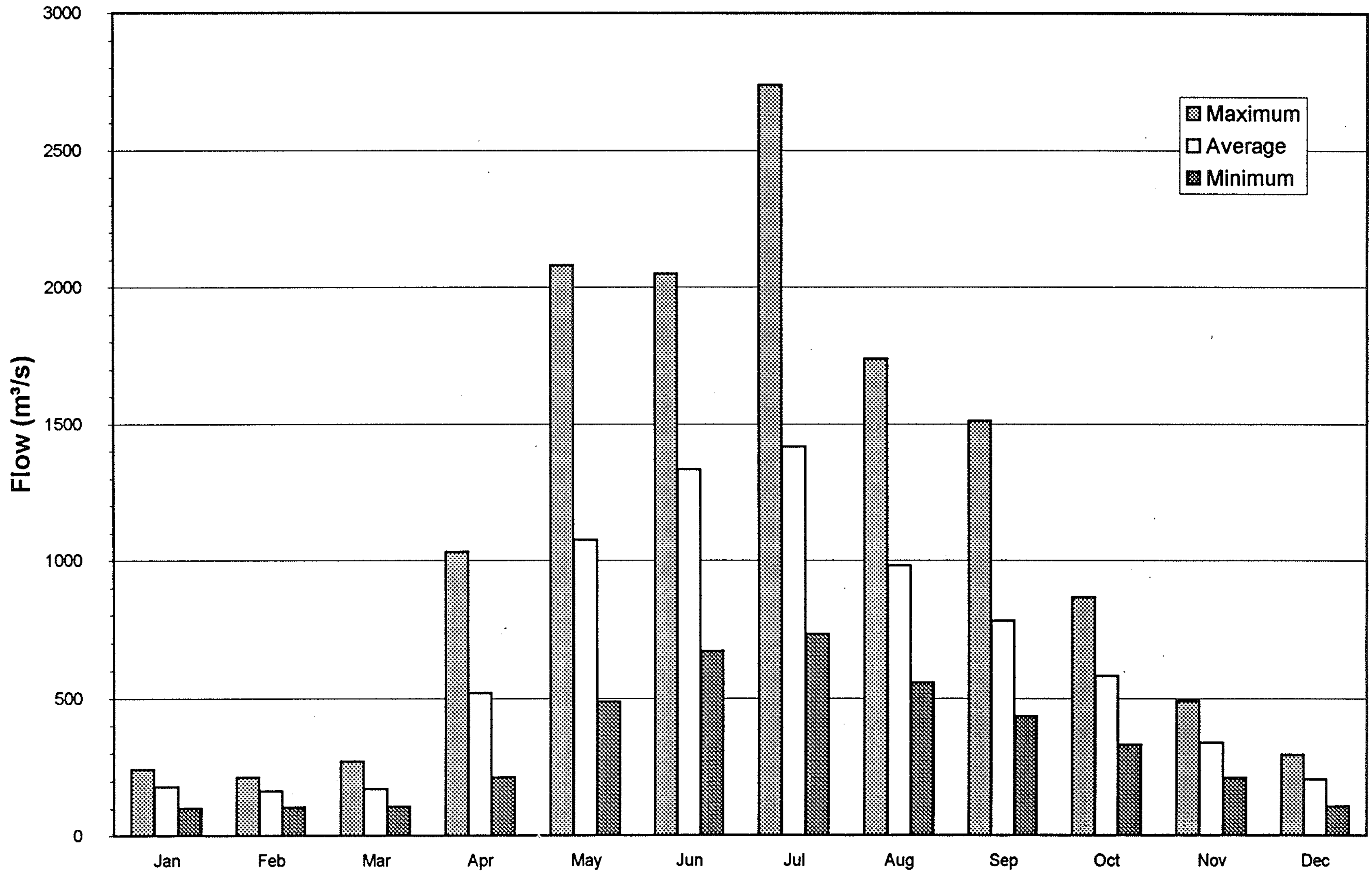


# Figure 3
## Mean Monthly Evaporation and Evapotranspiration for Fort McMurray

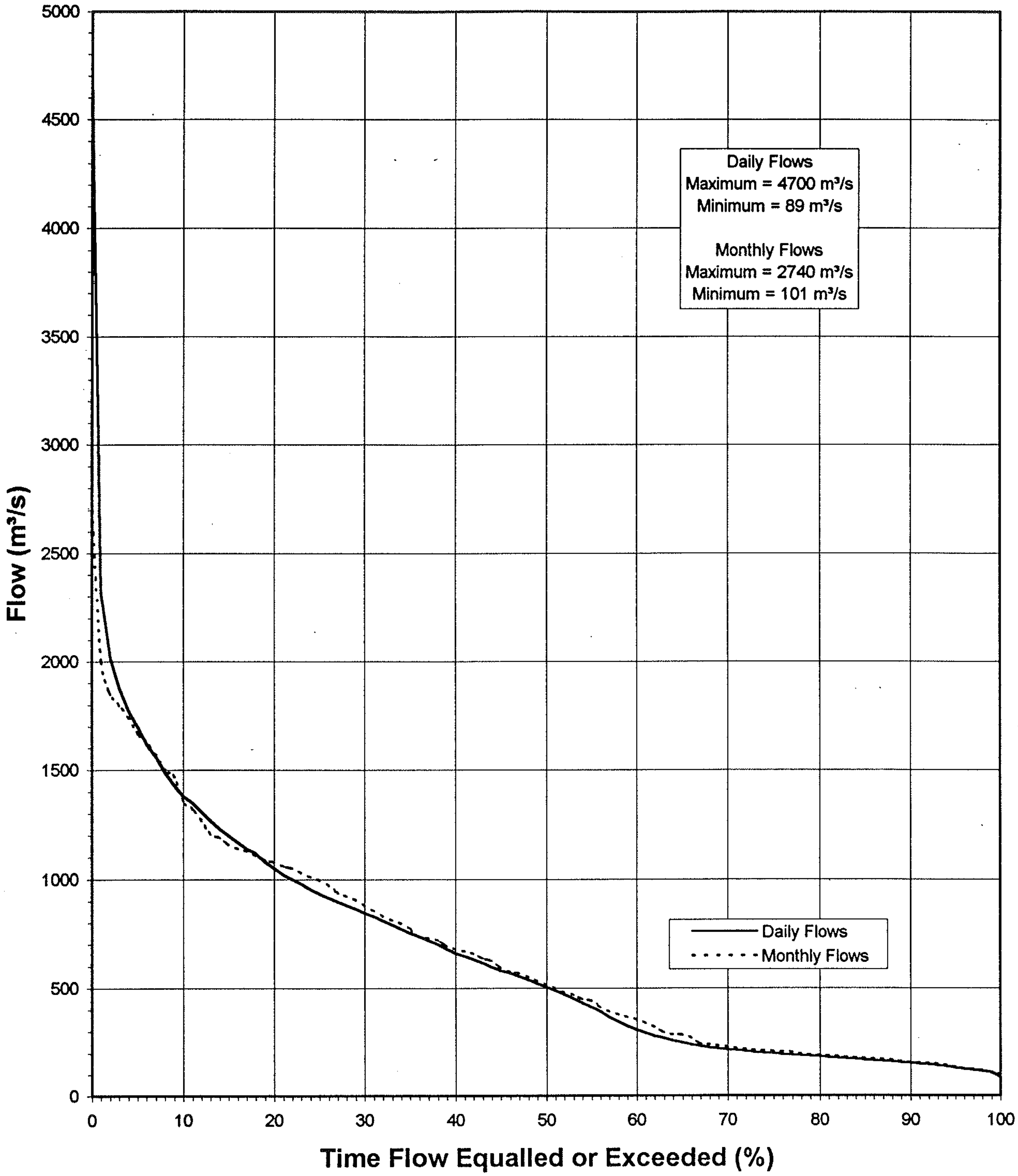



*Data from Alberta Environmental Protection for Fort McMurray*

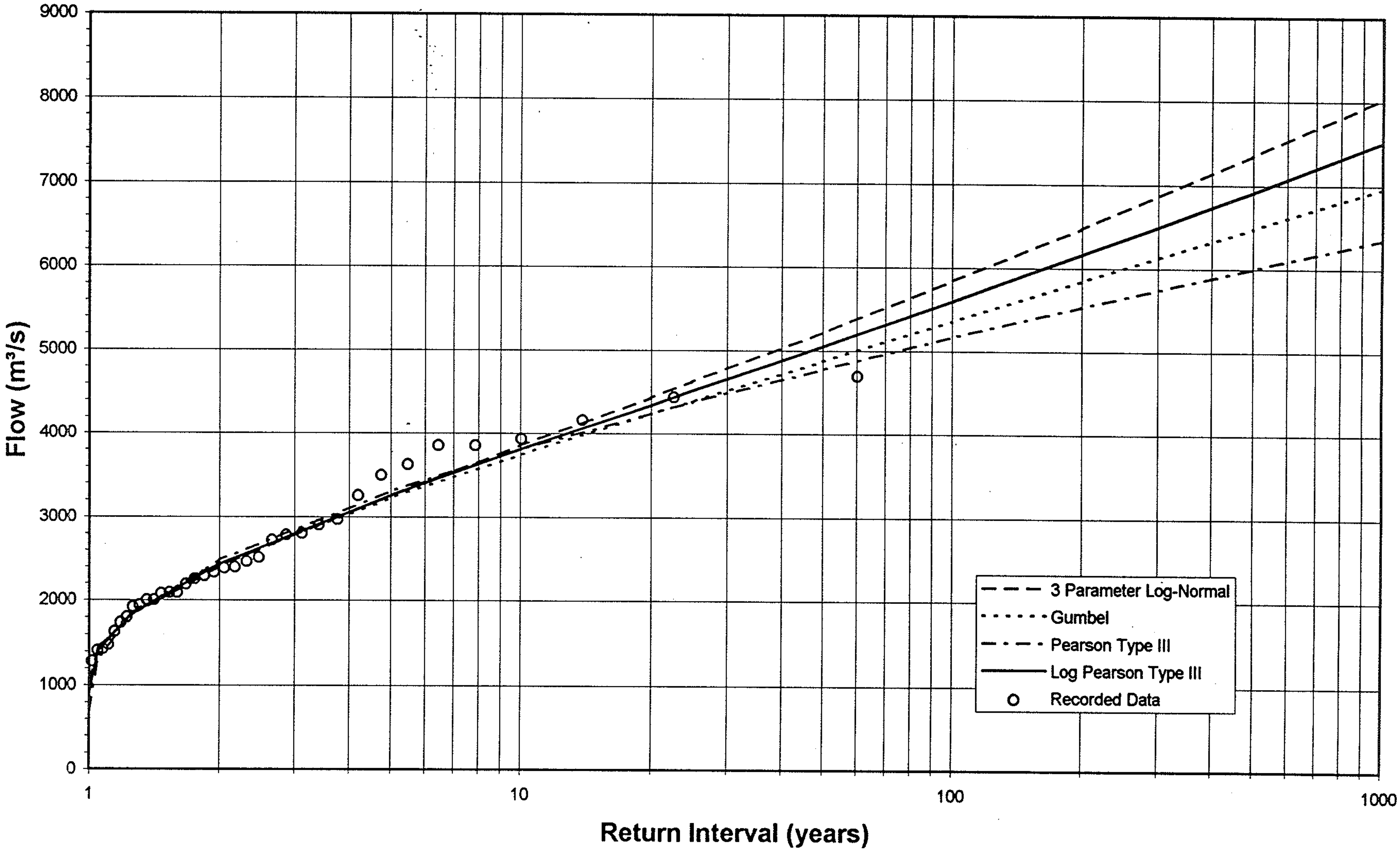
## Figure 4
## Monthly Flows for Athabasca River (07DA001)



# Figure 5
# Flow Duration Curves for Athabasca River (07DA001)

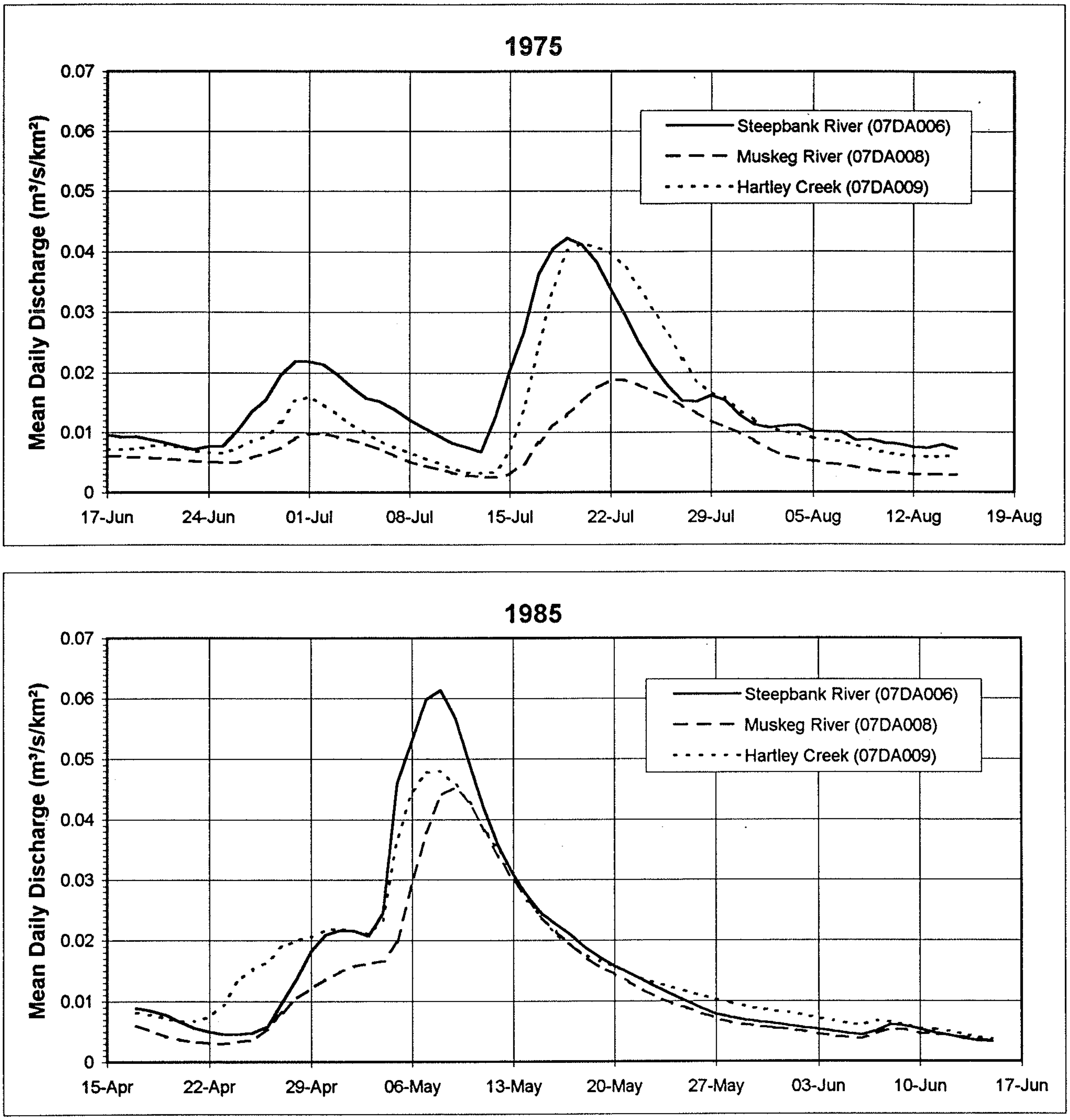


## Figure 6
## Flood Frequency Analysis for Athabasca River (07DA001)



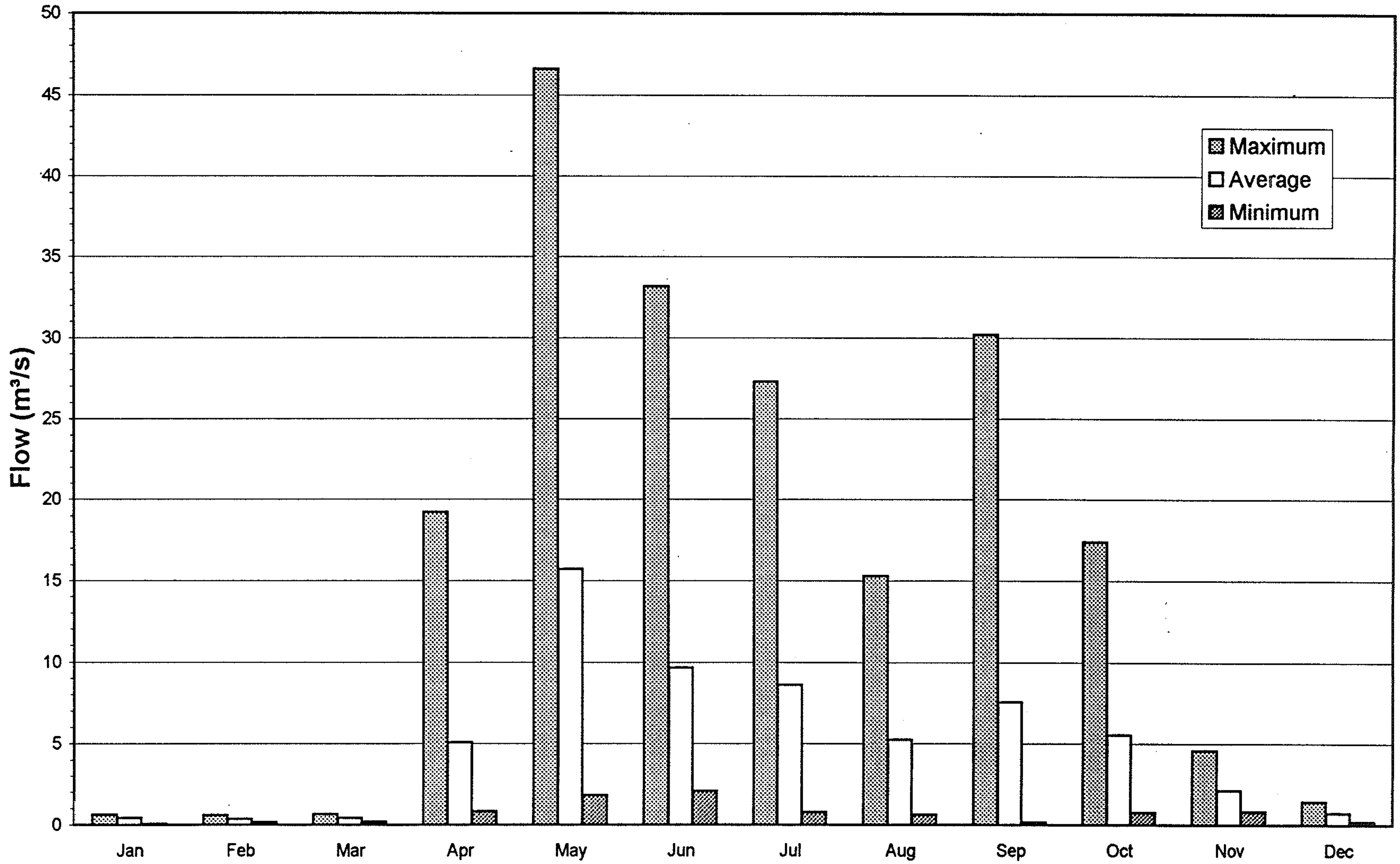

*Based on data from Water Survey of Canada for the period 1957 - 1993*

# Figure 7
# Flood Hydrographs for Tributary Watercourses



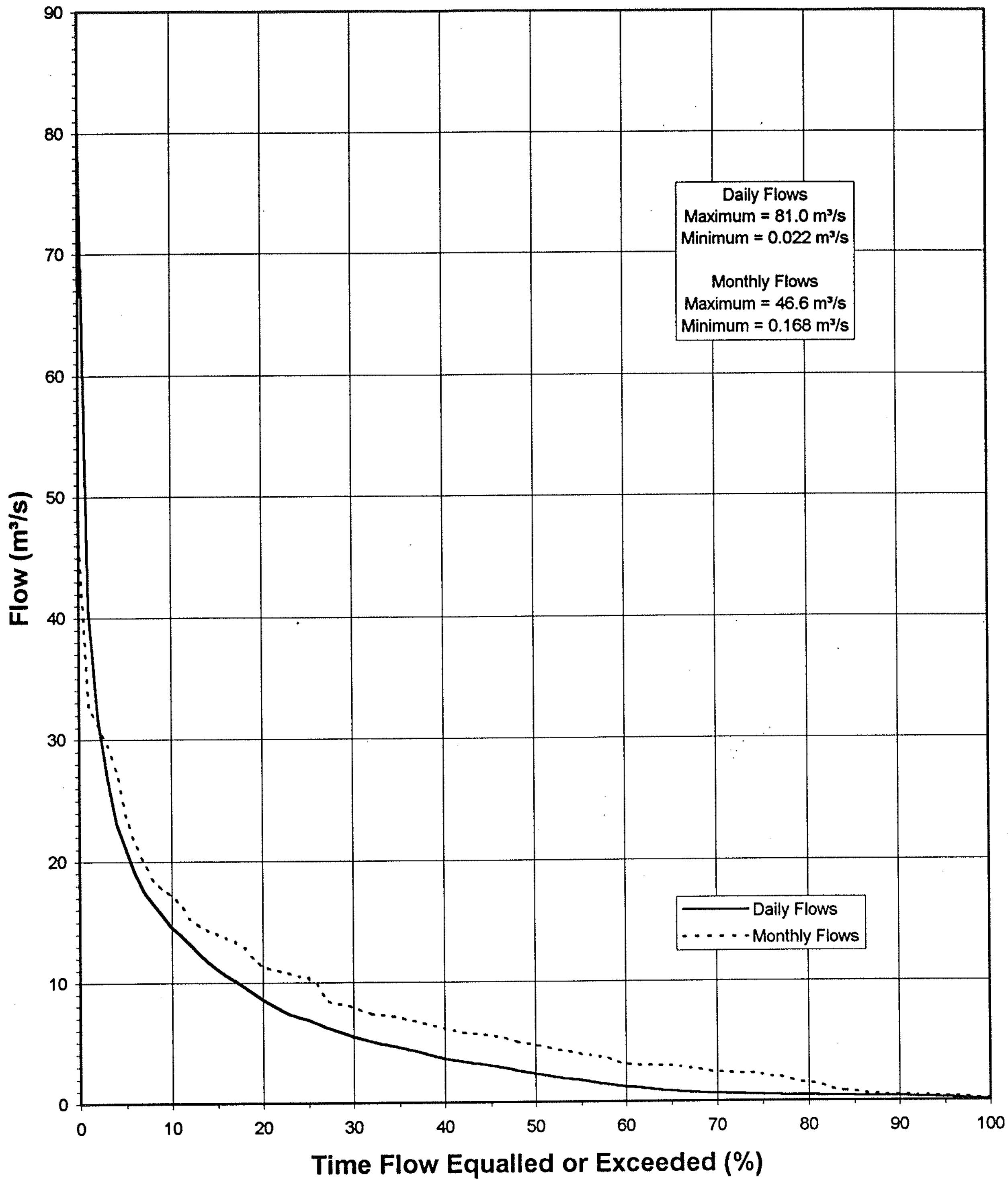

*Based on data from Environment Canada.*

# Figure 8
## Monthly Flows for Steepbank River (07DA006)



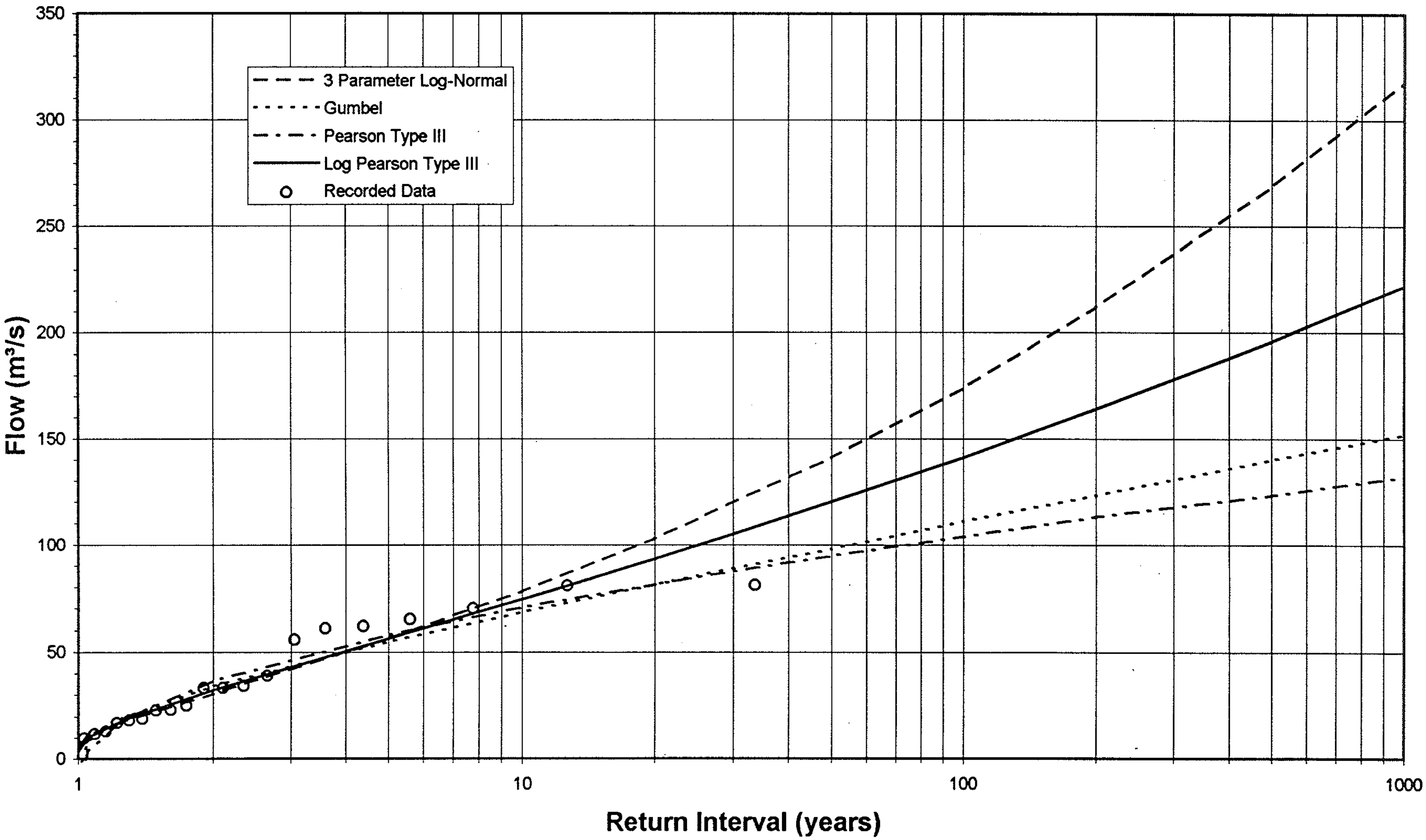

*Based on data from Water Survey of Canada for the period 1972 - 1993*

# Figure 9
# Flow Duration Curves for Steepbank River (07DA006)



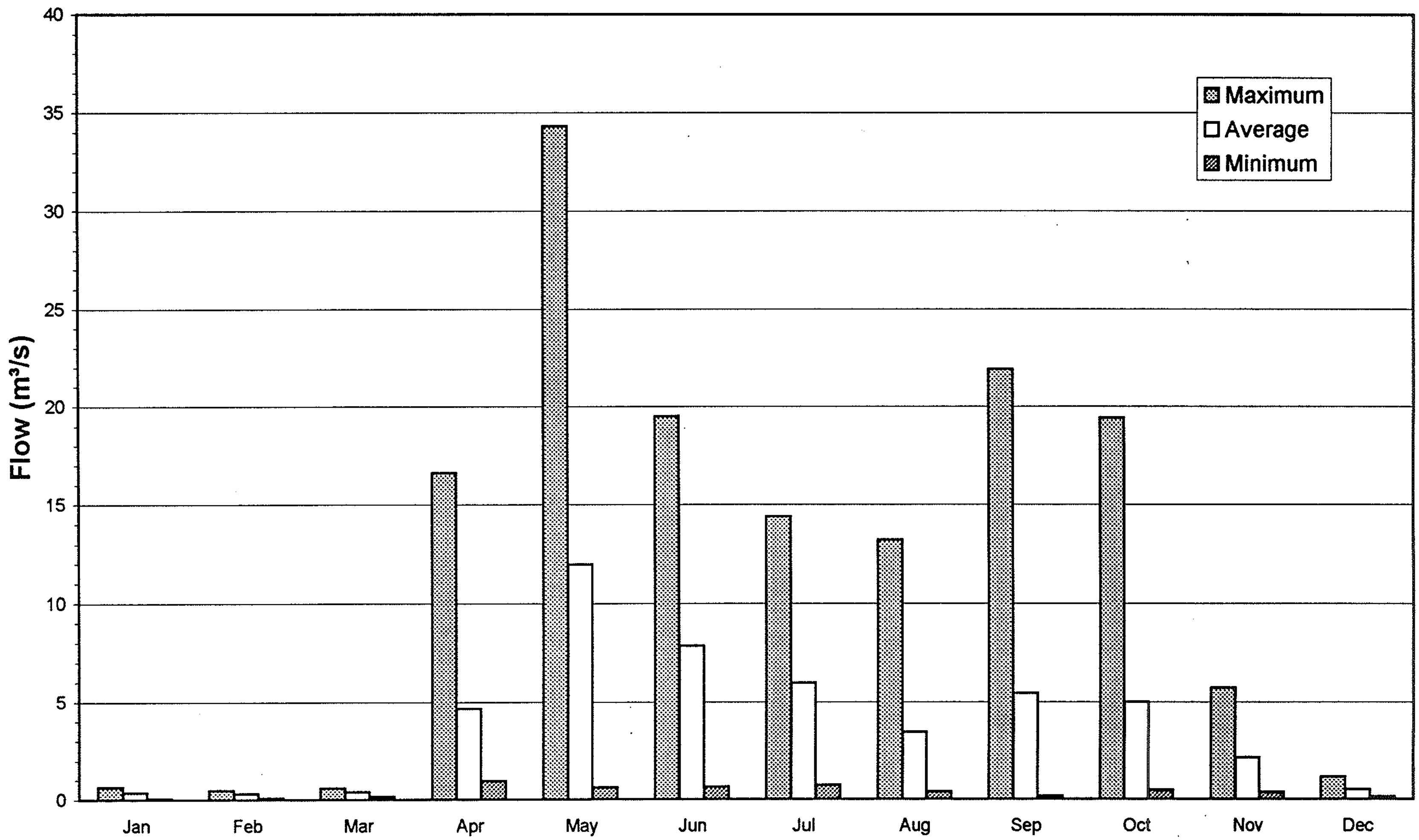

*Based on data from Water Survey of Canada for the period 1972 - 1993*

# Figure 10
# Flood Frequency Analysis for Steepbank River (07DA006)



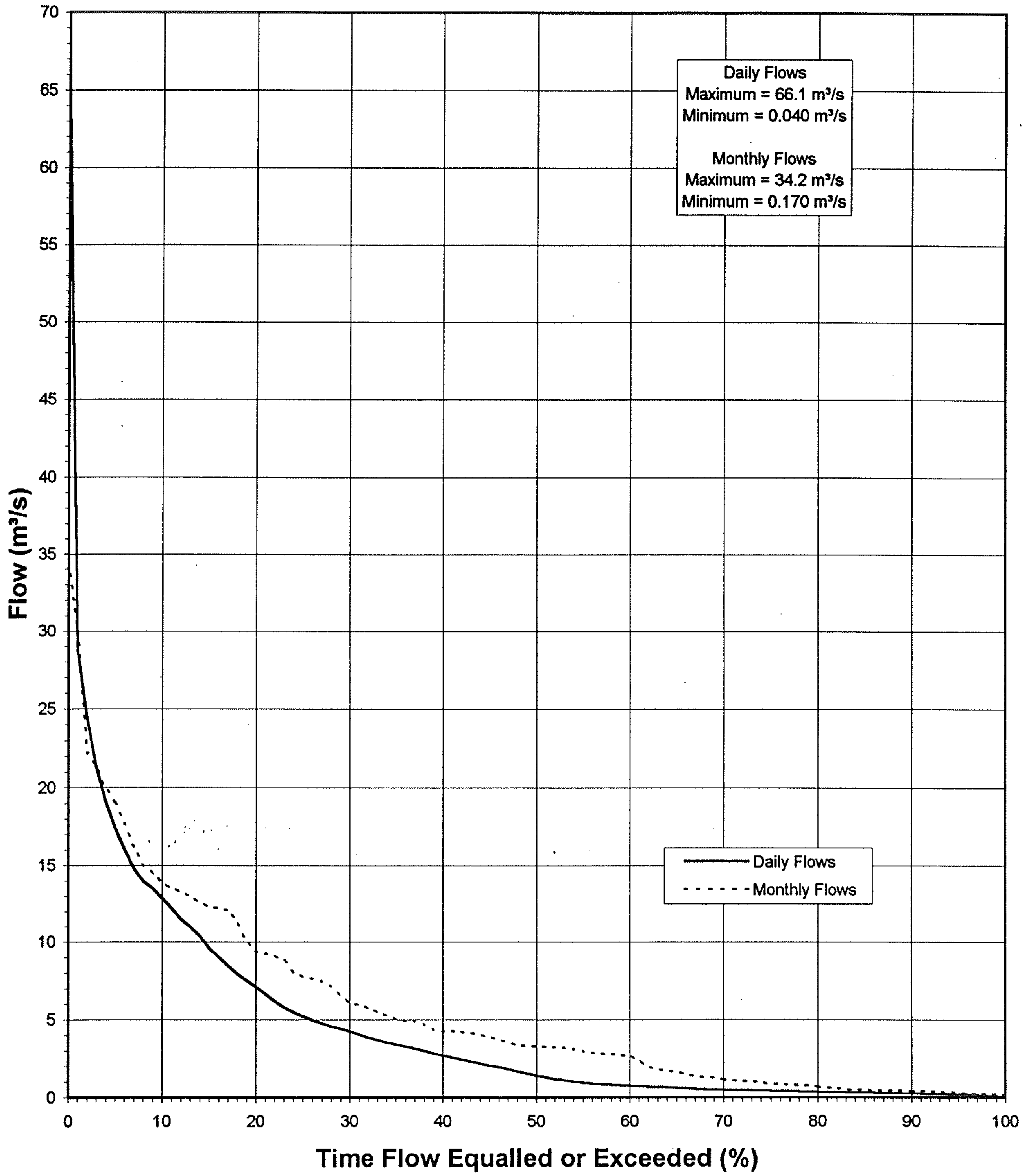

*Results from FFAME program using data from Water Survey of Canada for the period 1972 - 1993*

# Figure 11
# Monthly Flows for Muskeg River (07DA008)



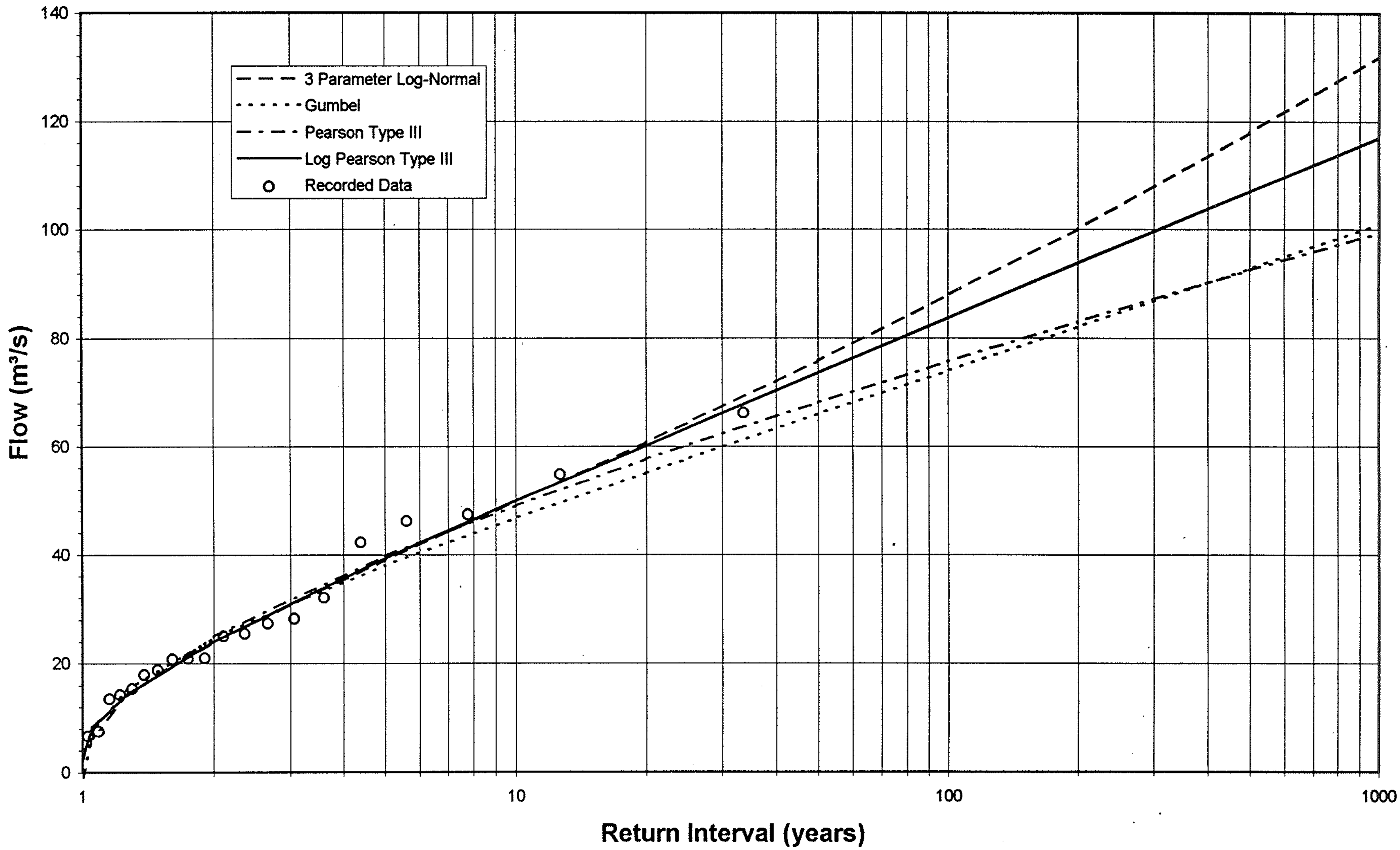

*Based on data from Environment Canada for the period 1974 - 1993*

# Figure 12
# Flow Duration Curves for Muskeg River (07 DA008)



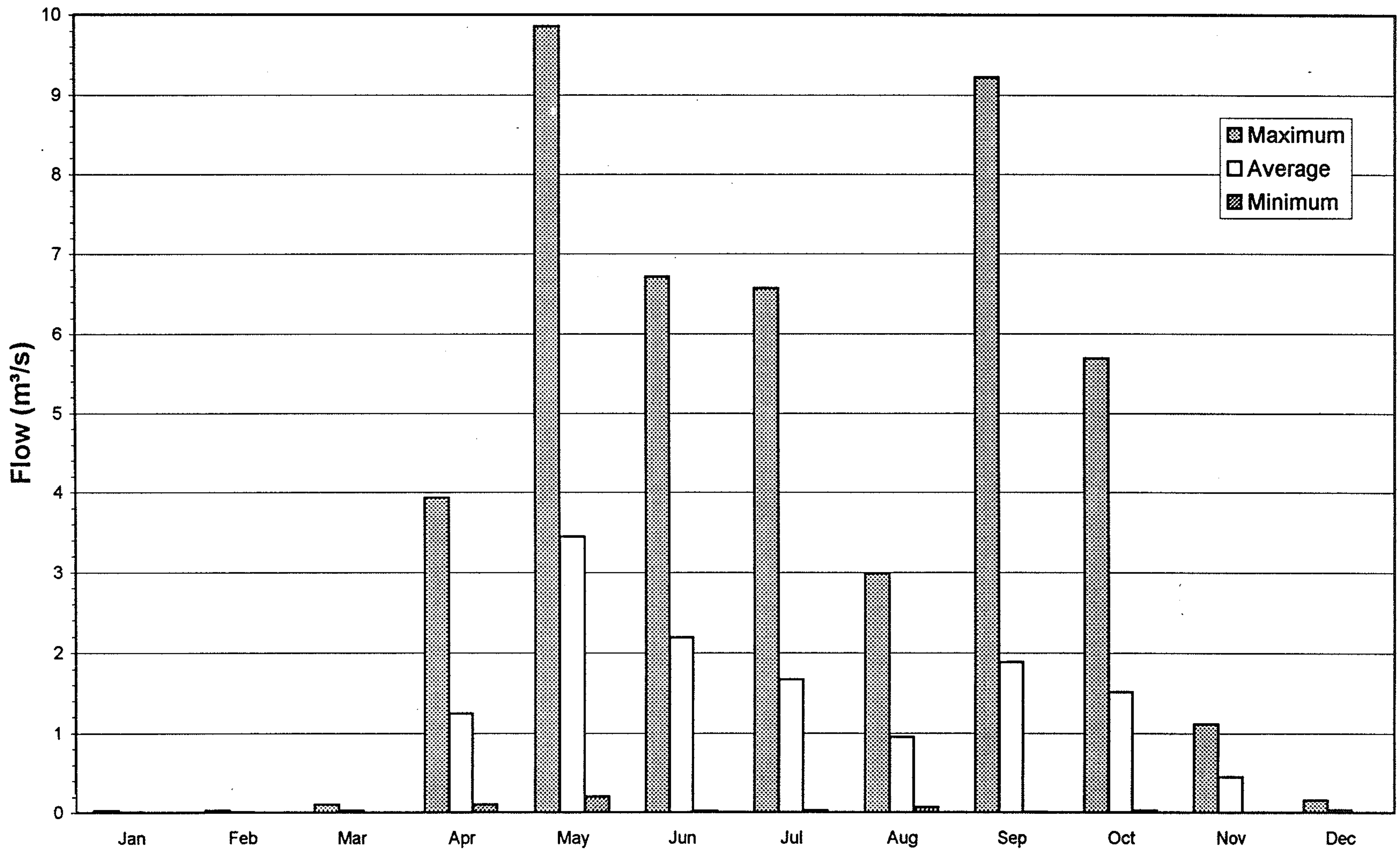

*Based on data from Environment Canada for the period 1974 - 1993*

# Figure 13
# Flood Frequency Analysis for Muskeg River (07DA008)



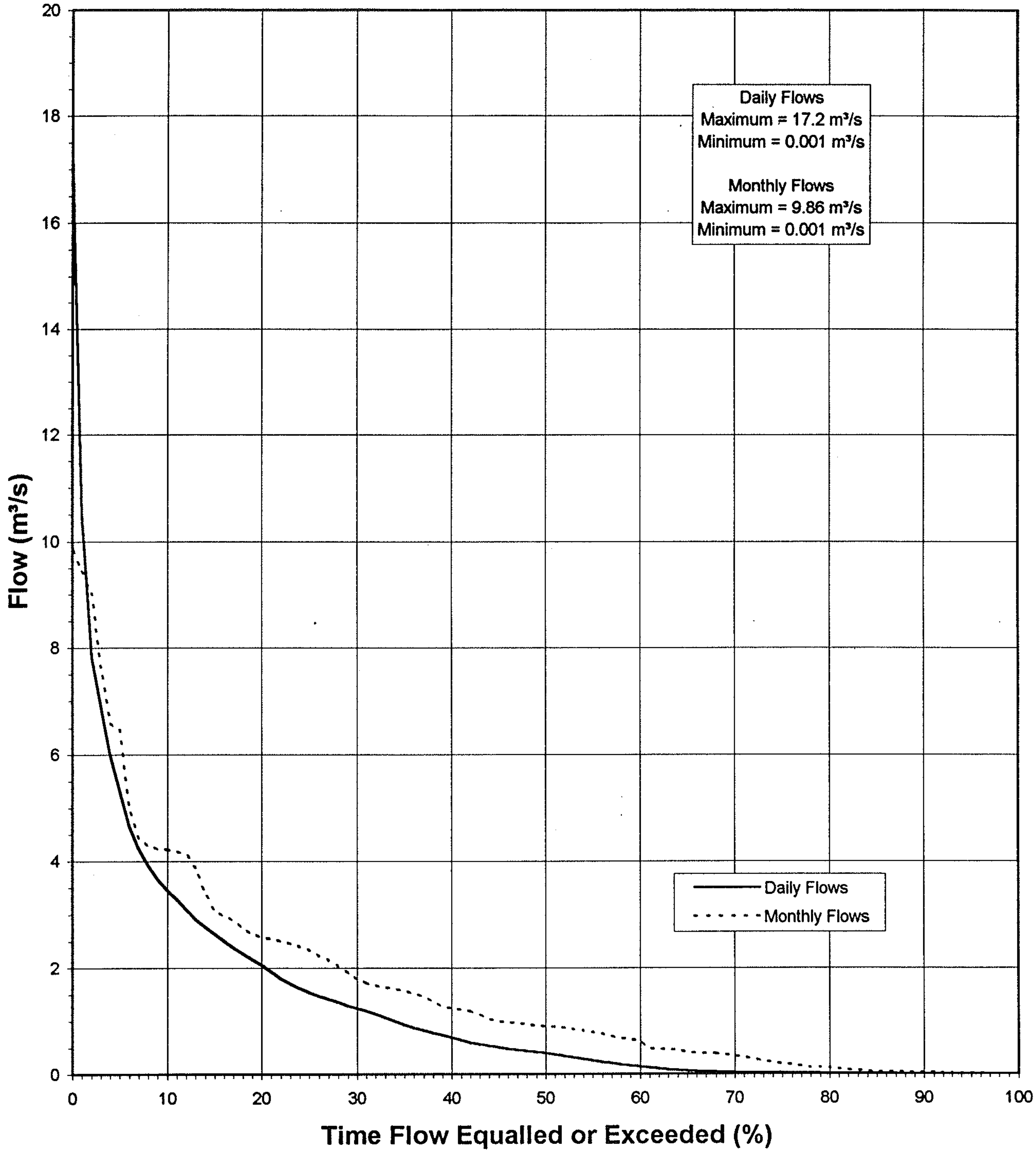

*Results from FFAME program using data from Environment Canada for the period 1974 - 1993*

# Figure 14
# Monthly Flows for Hartley Creek (07DA009)



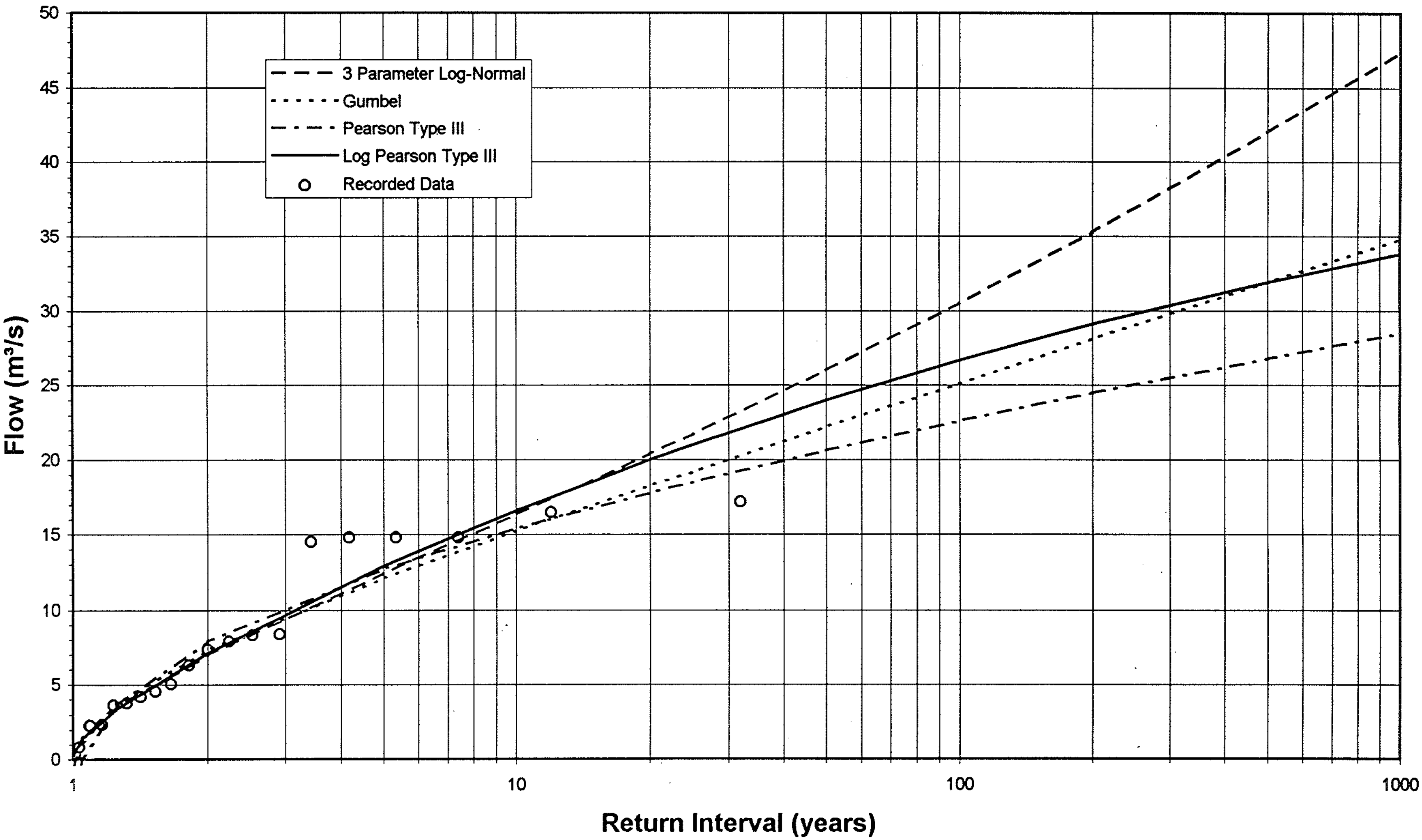

*Based on data from Environment Canada for the period 1975 - 1993*

# Figure 15
# Flow Duration Curves for Hartley Creek (07DA009)



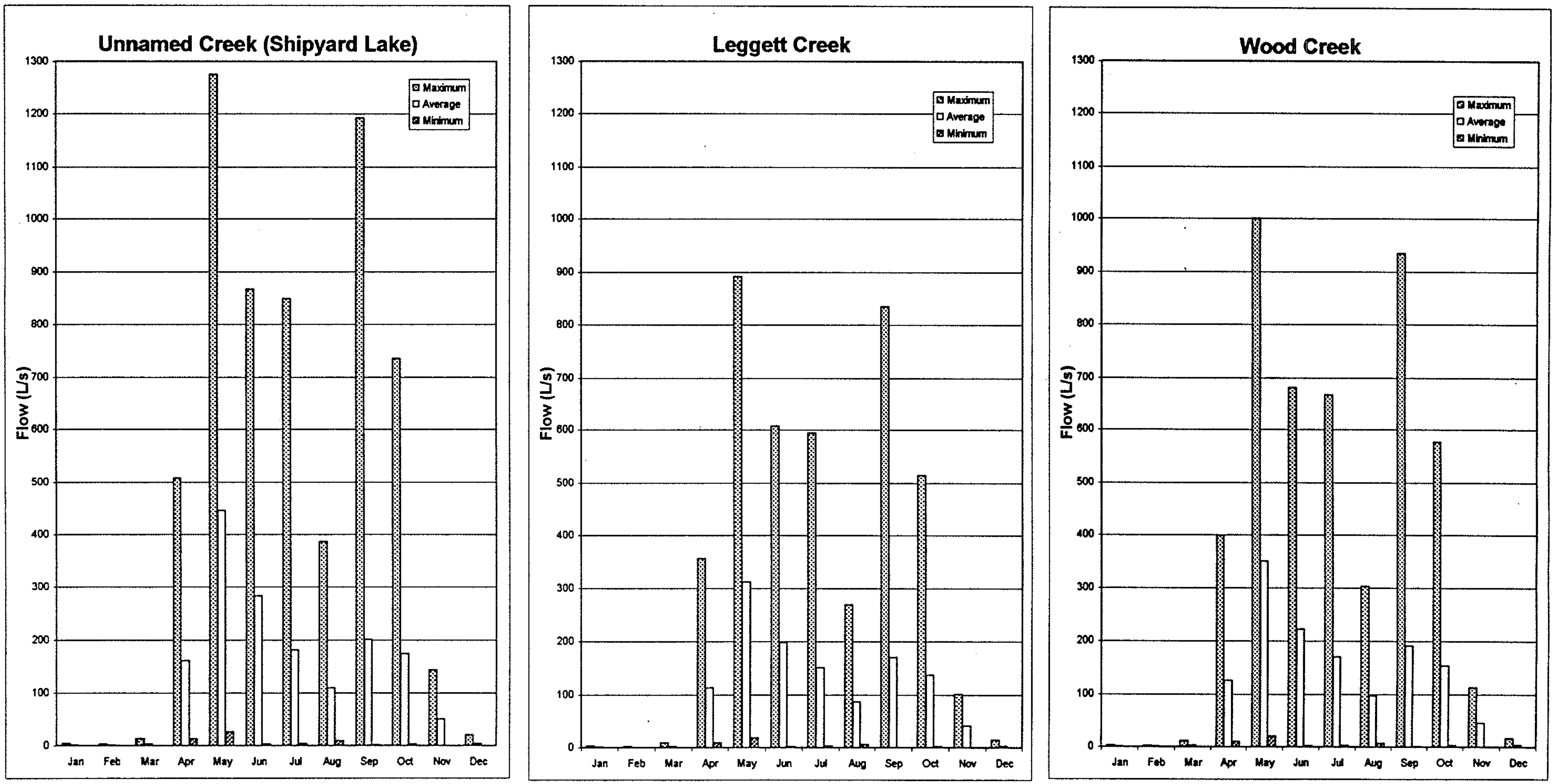

*Based on data from Environment Canada for the period 1975 - 1993*

## Figure 16
## Flood Frequency Analysis for Hartley Creek (07DA009)

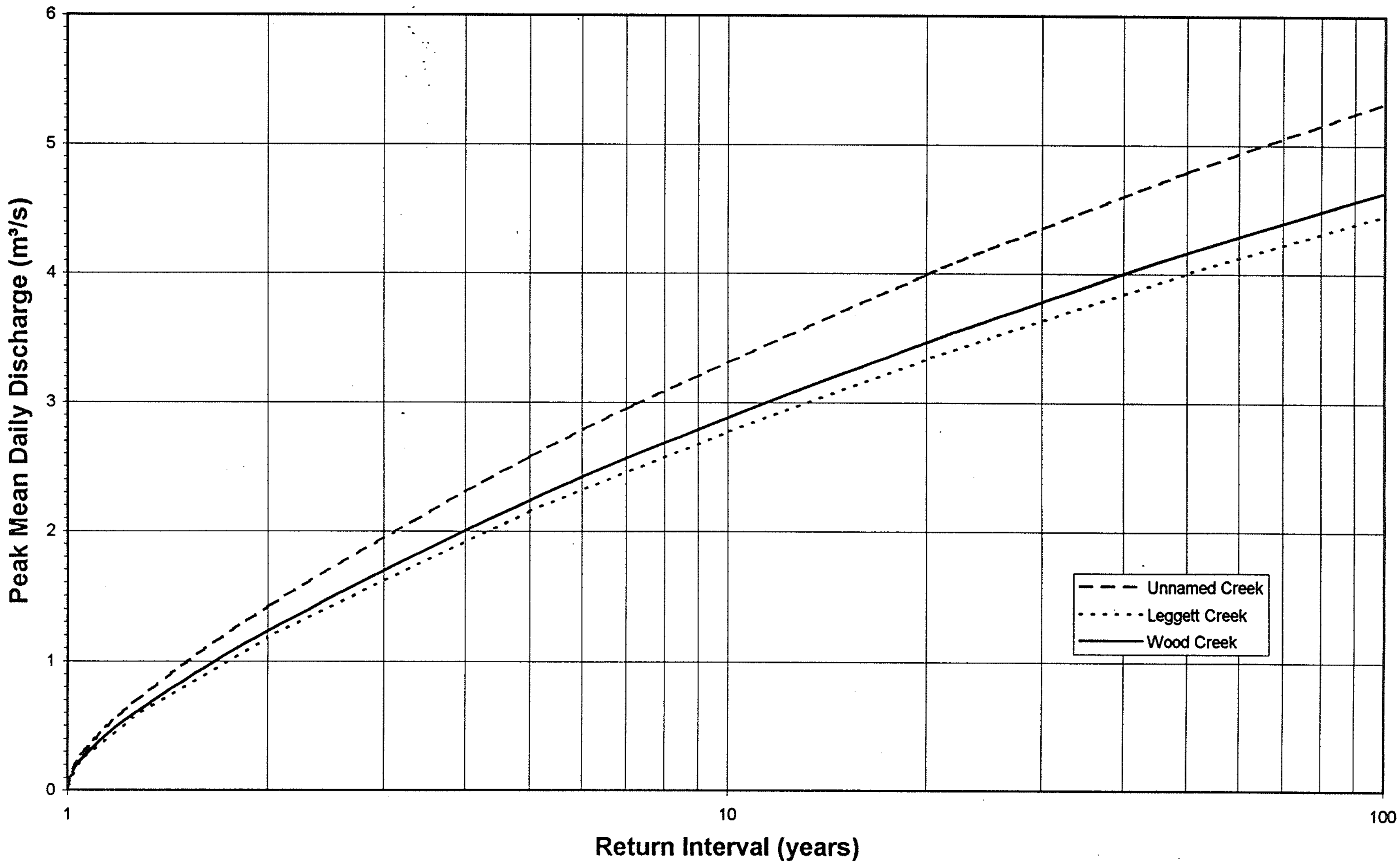



*Resultd from FFAME program using data from Environment Canada for the period 1975 - 1993*

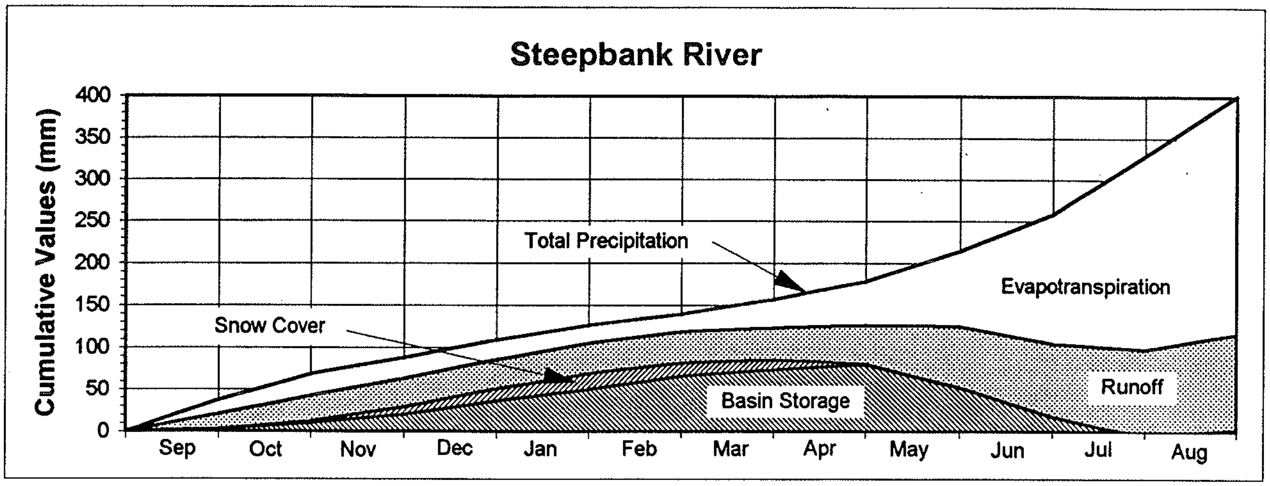
# Figure 17
# Estimated Monthly Flows for Ungauged Watercourses

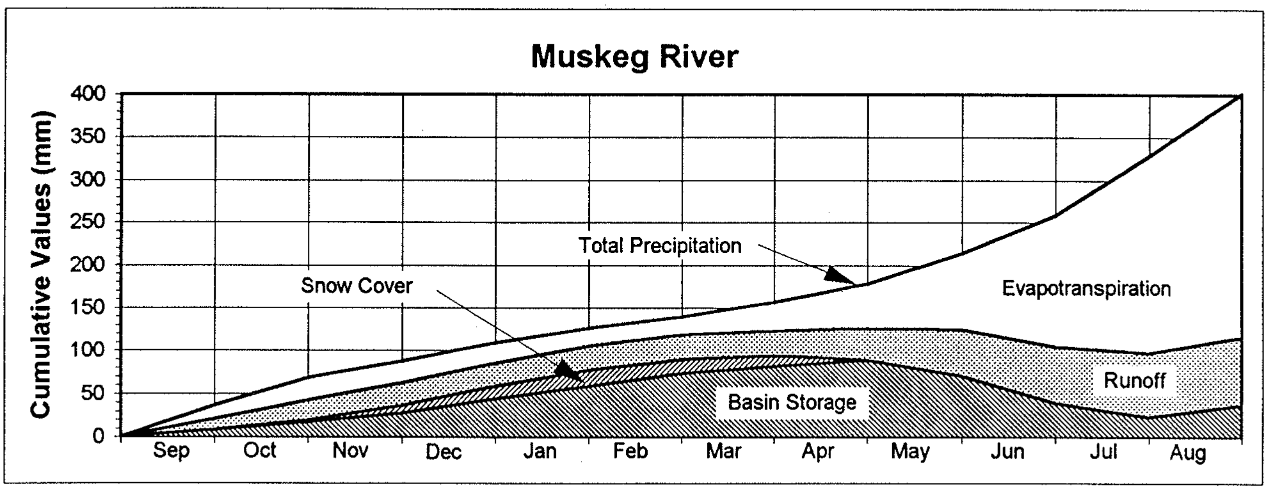


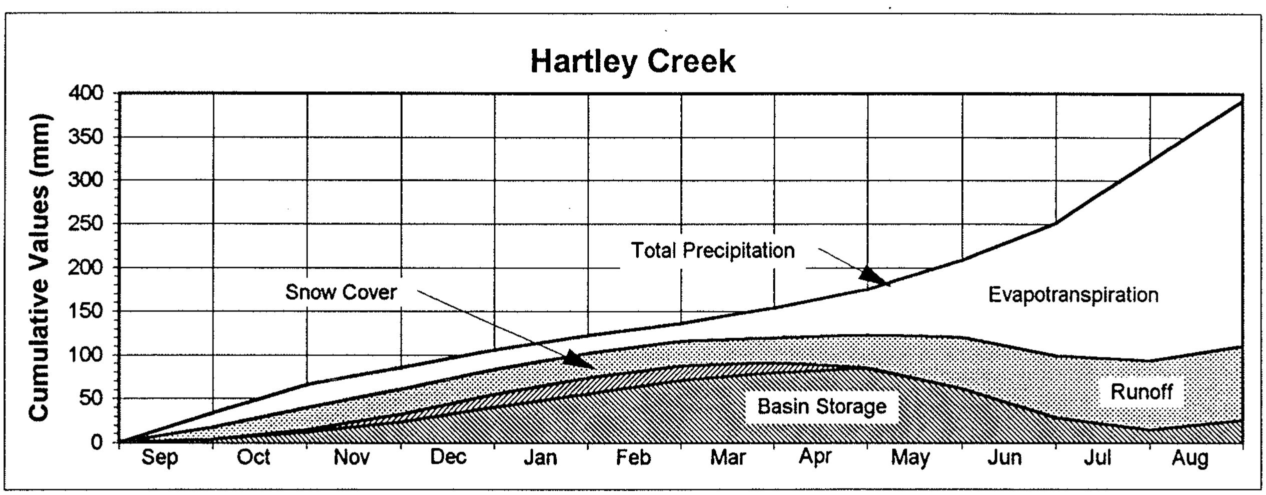
## Figure 18
## Estimated Flood Frequency Curves for Ungauged Watercourses



# Figure 19
# Average Annual Water Balance

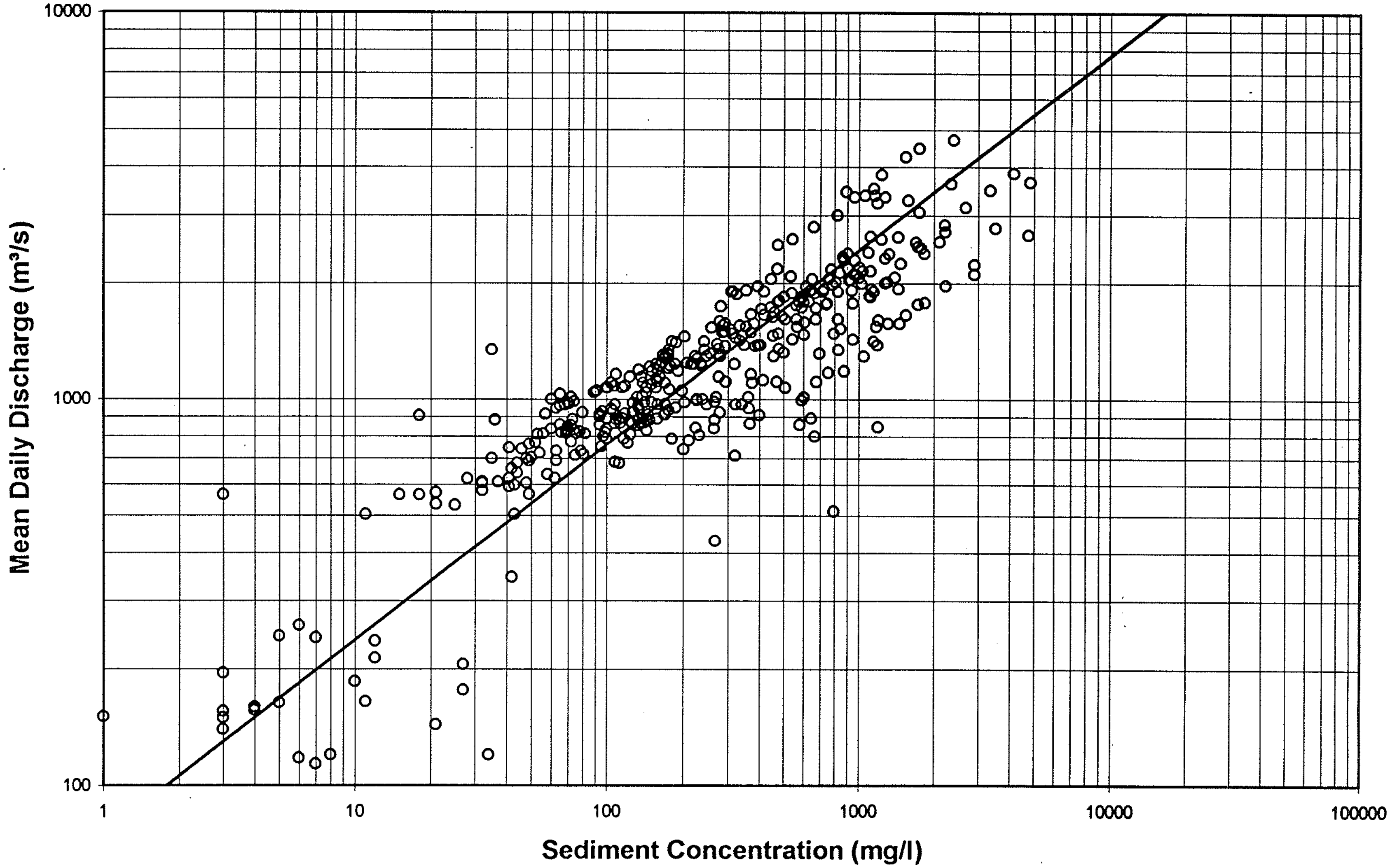


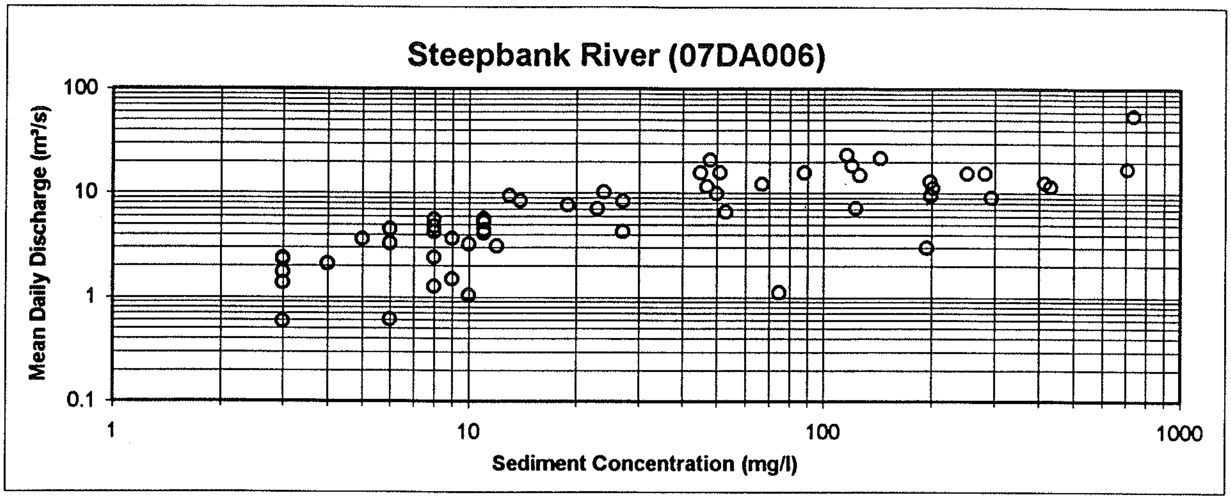

*Based on data from Environment Canada and Alberta Environmental Protection*

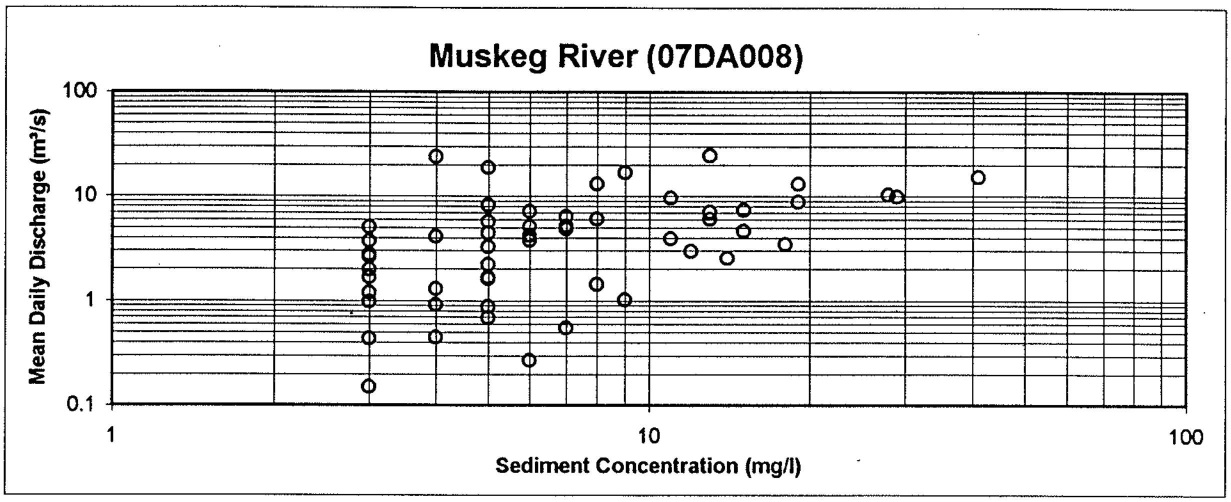
# Figure 20
## Sediment Concentration in Athabasca River

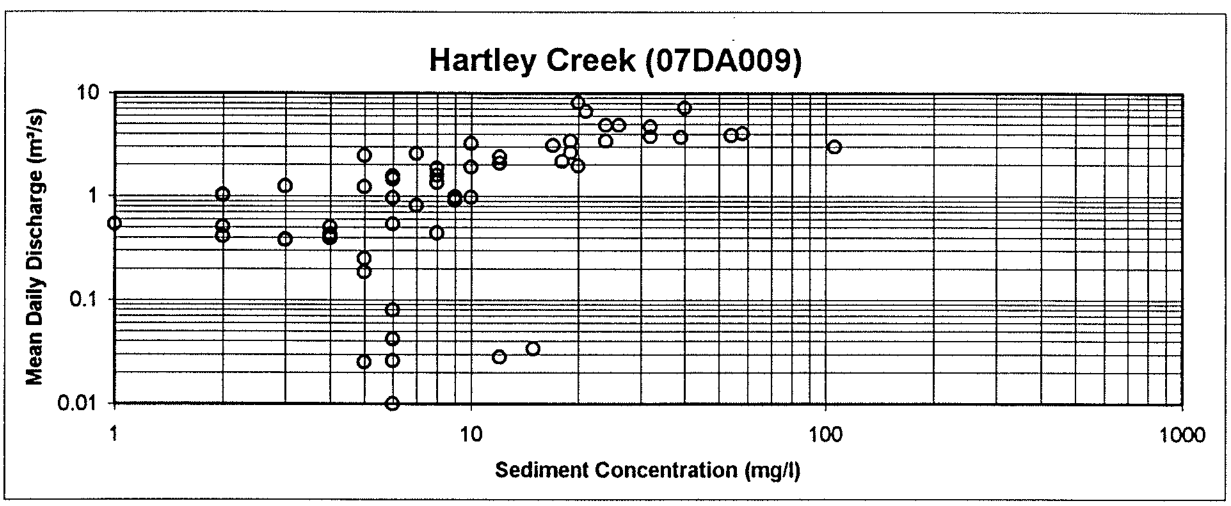



*Based on data from Environment Canada for the period 1967-1972*

## Figure 21
## Sediment Concentration in Tributary Watercourses

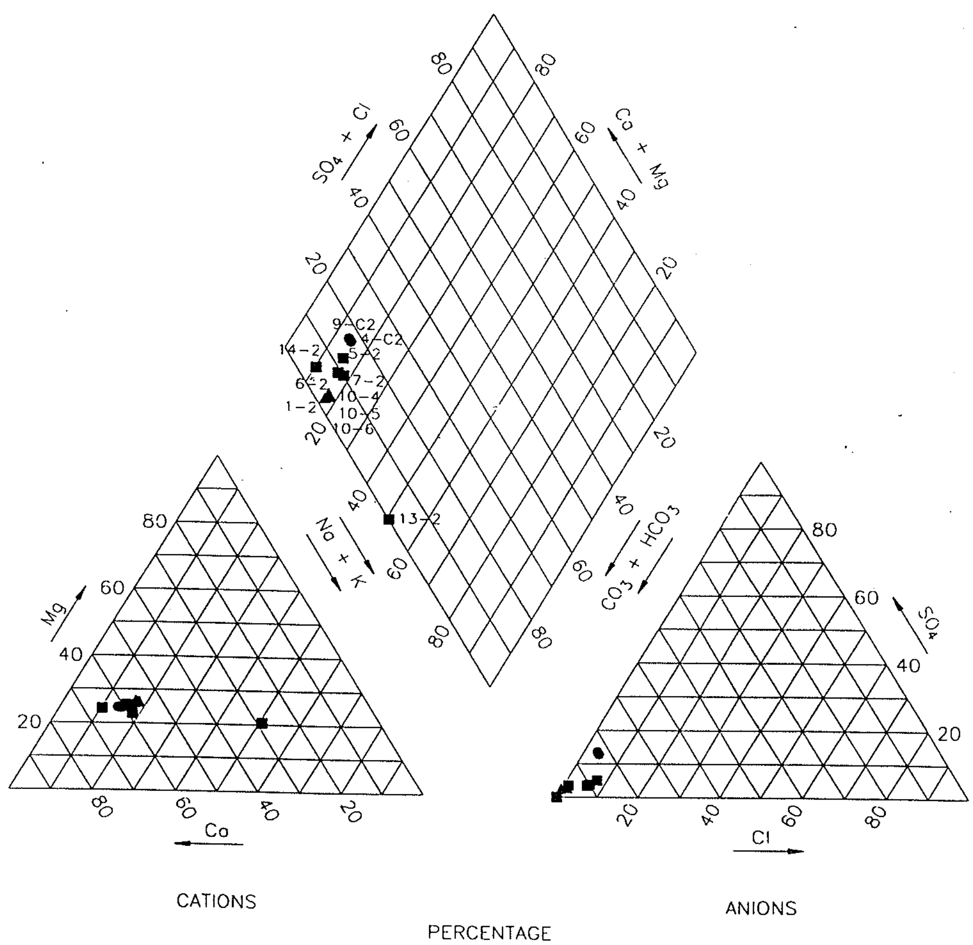


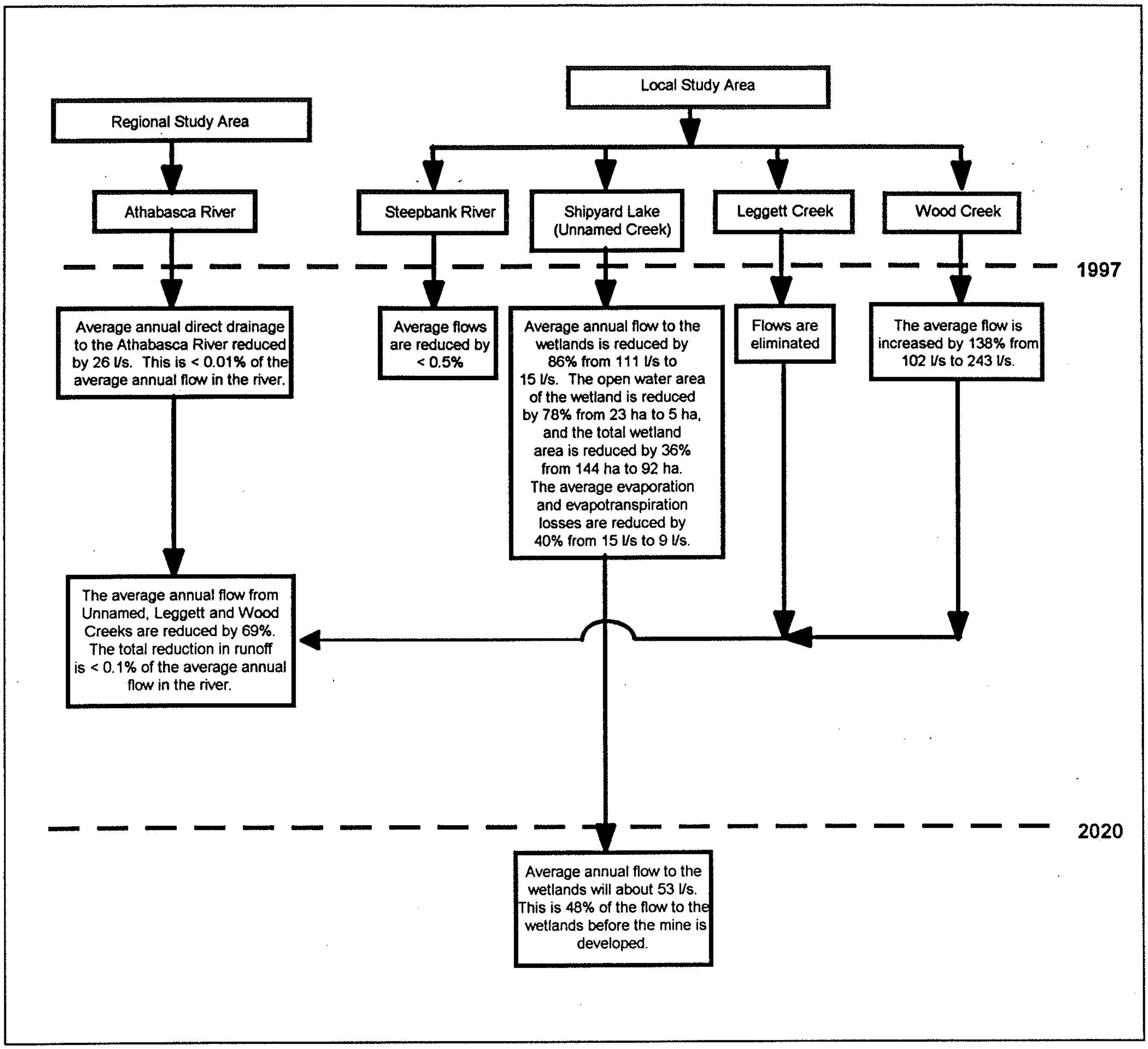



# Figure 22
# Piper Plot - Surface Water Chemistry

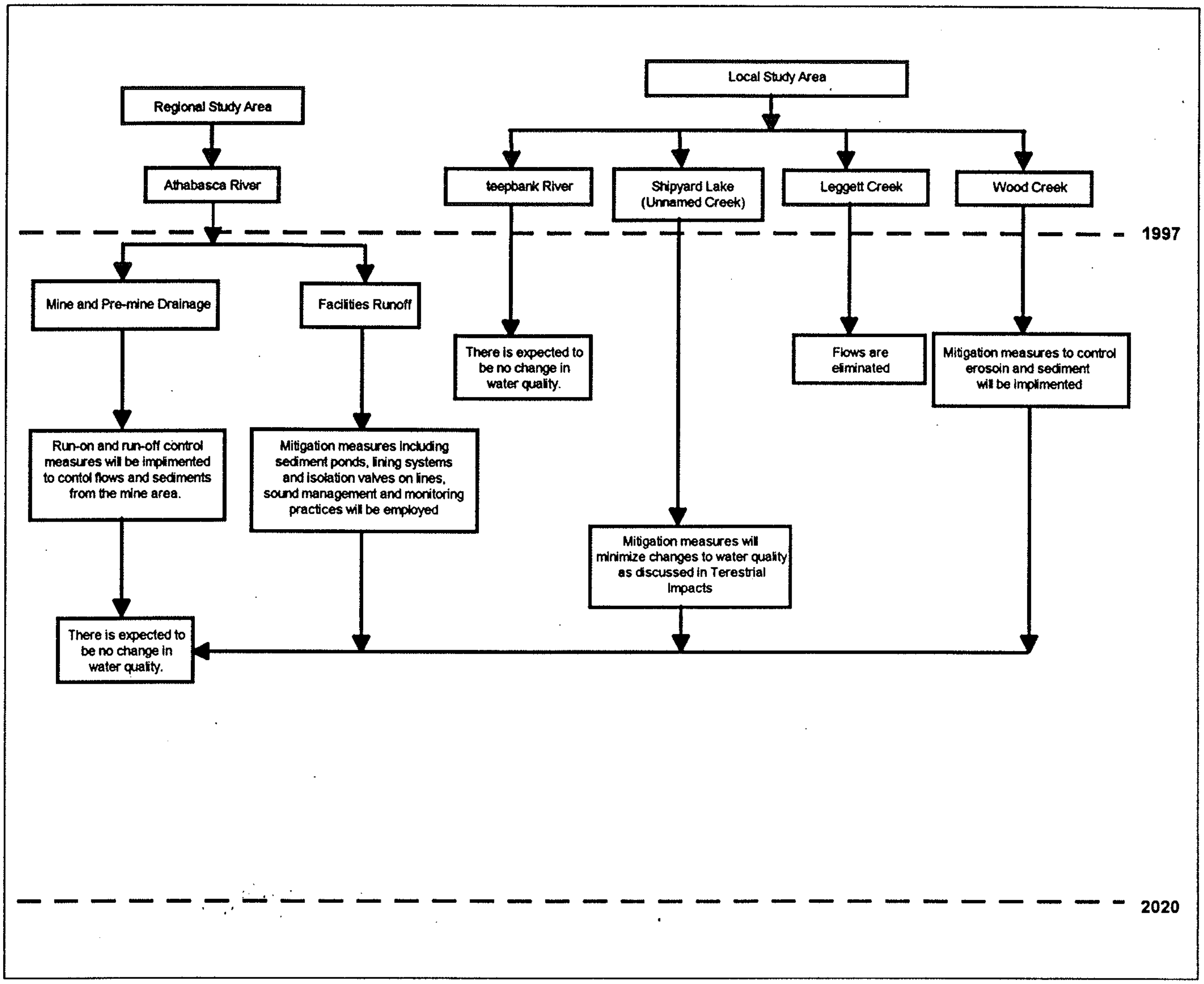
| Site | Plot No | Location | Matrix | Ca | Mg | Na | K | Cl | SO4 | Alkalinity |
|---|---|---|---|---|---|---|---|---|---|---|
| AW001-S002 | 1-2 | Steepbank-L19 border | surface | 22.5 | 6.4 | 7.5 | 0.63 | 0 | 1.6 | 79.7 |
| AW005-S002 | 5-2 | McLean creek-mouth | surface | 38.5 | 10.1 | 11 | 0.92 | 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 |



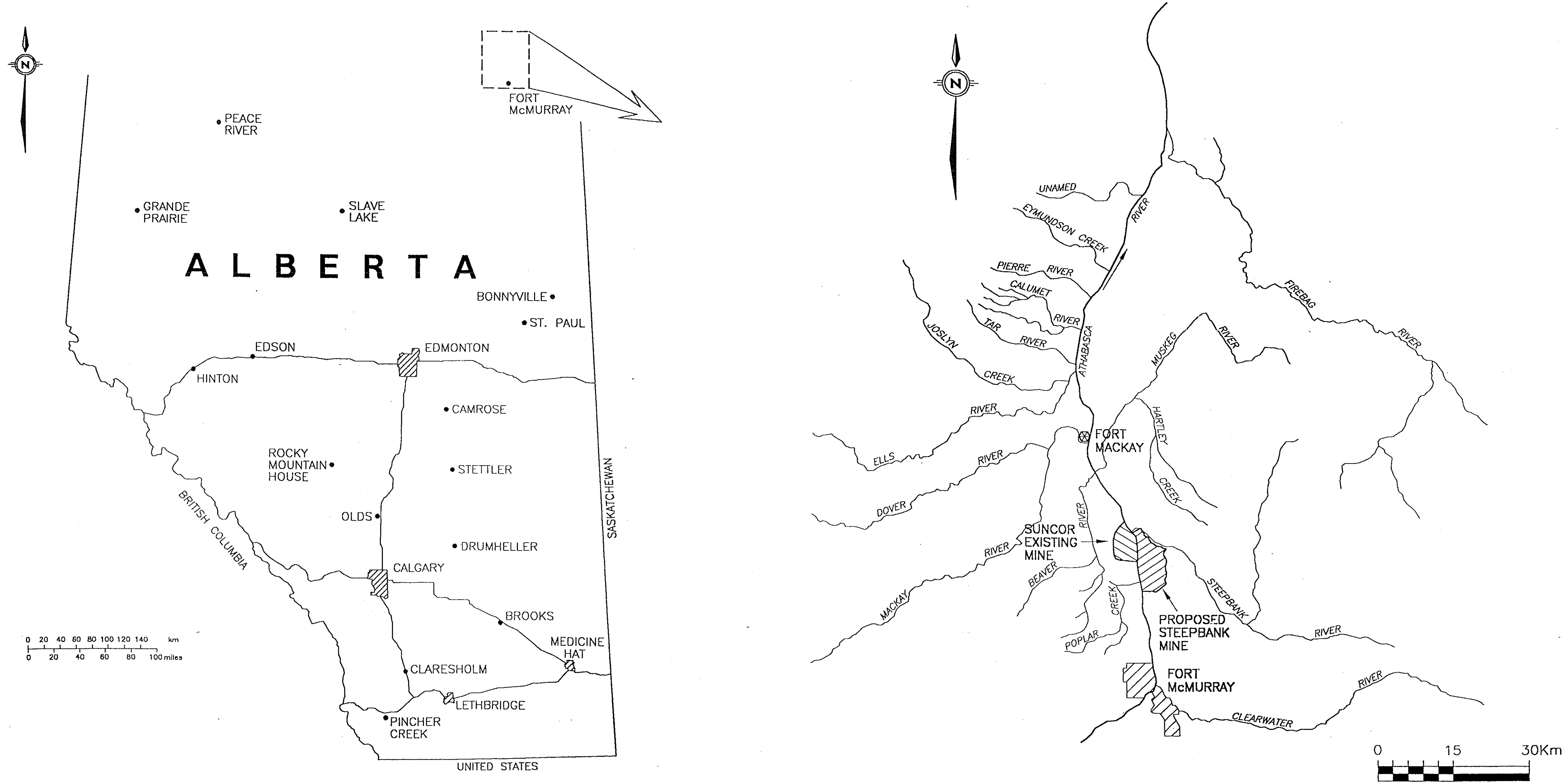
# Figure 23
## Summary of Changes in Surface Water Flows



# Figure 24
# Summary of Changes in Surface Water Quality



# DRAWINGS



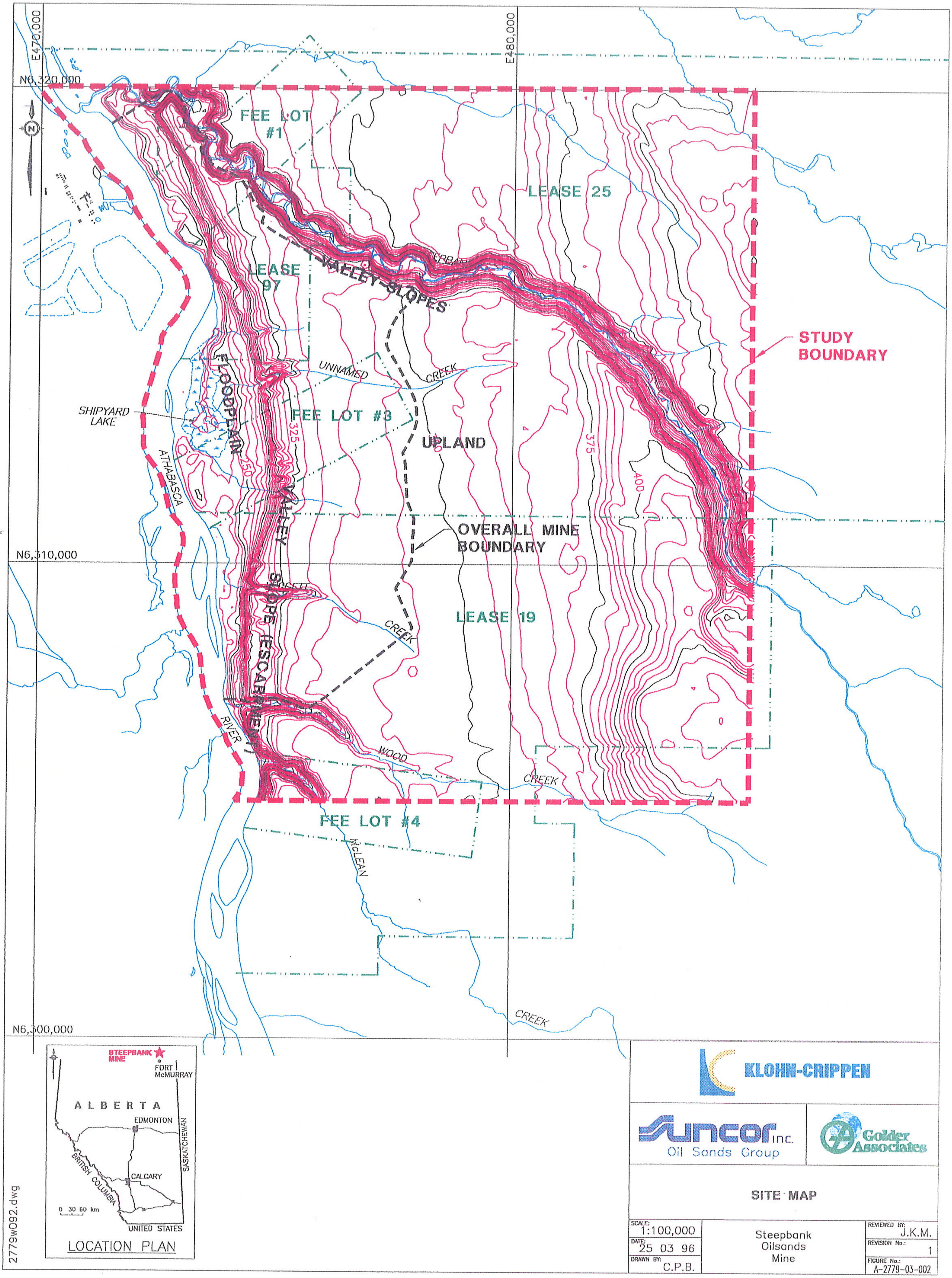

KLOHN-CRIPPEN

Suncor inc. Oil Sands Group | Golder Associates

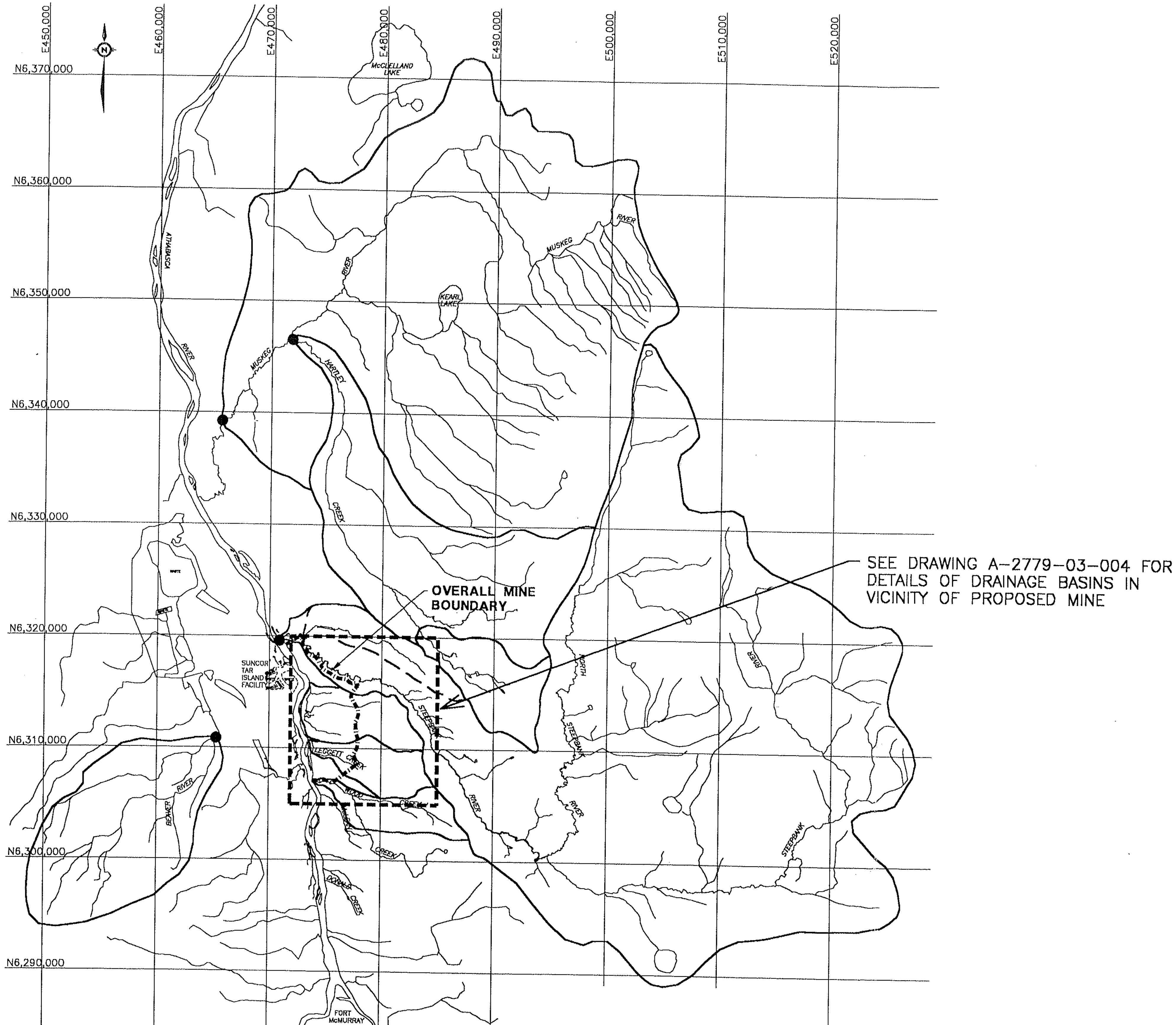
**LOCATION PLAN**

| | | |
|---|---|---|
| SCALE: AS SHOWN | Steepbank Oilsands Mine | REVIEWED BY: J.K.M. |
| DATE: MAY 96 | | REVISION No.: 1 |
| DRAWN BY: C.P.B. | | FIGURE No.: B-2779-03-001 |

2779w101.dwg



E470,000
E480,000
N6,320,000
N6,310,000
N6,300,000
FEE LOT #1
LEASE 25
LEASE 97
VALLEY SLOPES
STUDY BOUNDARY
UNNAMED
CREEK
SHIPYARD LAKE
FLOODPLAIN
FEE LOT #3
325
UPLAND
375
400
250
ATHABASCA
VALLEY
OVERALL MINE BOUNDARY
SLOPE (ESCARPMENT)
LEASE 19
CREEK
RIVER
WOOD
CREEK
FEE LOT #4
McLEAN
CREEK
STEEPBANK MINE
FORT McMURRAY
ALBERTA
EDMONTON
SASKATCHEWAN
BRITISH COLUMBIA
CALGARY
0 30 60 km
UNITED STATES
LOCATION PLAN
2779w092.dwg
KLOHN-CRIPPEN
Suncor Inc.
Oil Sands Group
Golder Associates
SITE MAP
SCALE: 1:100,000
DATE: 25 03 96
DRAWN BY: C.P.B.
Steepbank Oilsands Mine
REVIEWED BY: J.K.M.
REVISION No.: 1
FIGURE No.: A-2779-03-002




LEGEND

- ——— DRAINAGE BASIN BOUNDARY
- — — — SUB-BASIN BOUNDARY
- LEASE BOUNDARIES AND FEE LOTS
- ● WATER SURVEY OF CANADA GAUGING STATION

0 8 16Km

(1:400,000)

KLOHN-CRIPPEN

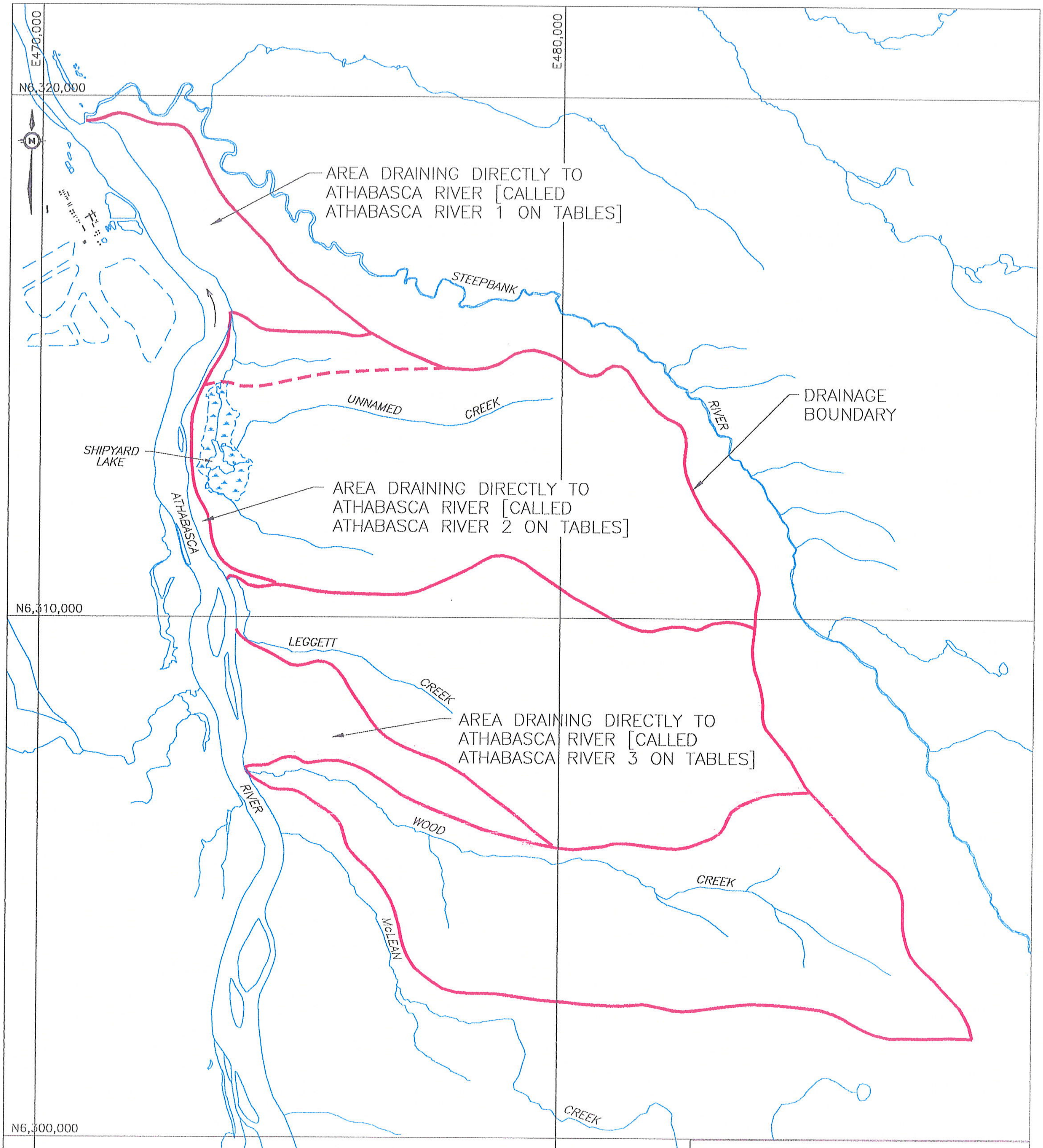
Suncor Inc. Oil Sands Group

Golder Associates

**DRAINAGE BASINS IN VICINITY OF MINE**

| | | |
|---|---|---|
| SCALE: AS SHOWN | Steepbank Oilsands Mine | REVIEWED BY: J.K.M. |
| DATE: MAY 96 | | REVISION No.: 1 |
| DRAWN BY: C.P.B. | | FIGURE No.: B-2779-03-003 |

2779w100.dwg




KLOHN-CRIPPEN

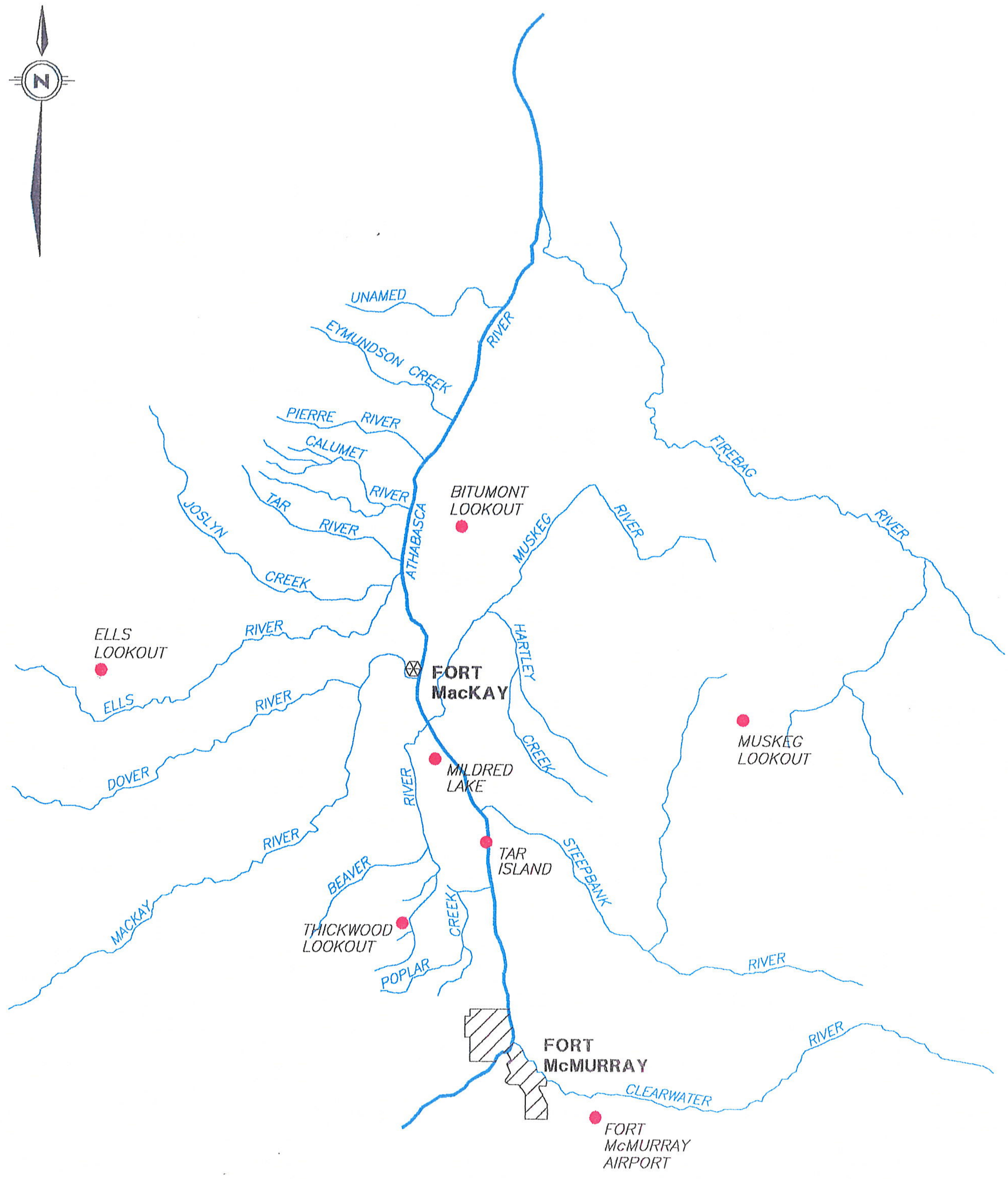
Suncor Inc. Oil Sands Group

Golder Associates

**DRAINAGE BASINS IN LOCAL STUDY AREA**

| | | |
|---|---|---|
| SCALE: N.T.S. | Steepbank Oilsands Mine | REVIEWED BY: J.K.M. |
| DATE: 25 03 96 | | REVISION No.: 1 |
| DRAWN BY: C.P.B. | | FIGURE No.: A-2779-03-004 |

2779w093.dwg




**LEGEND**

● PRECIPITATION MONITORING STATION

0 15 30Km

KLOHN-CRIPPEN

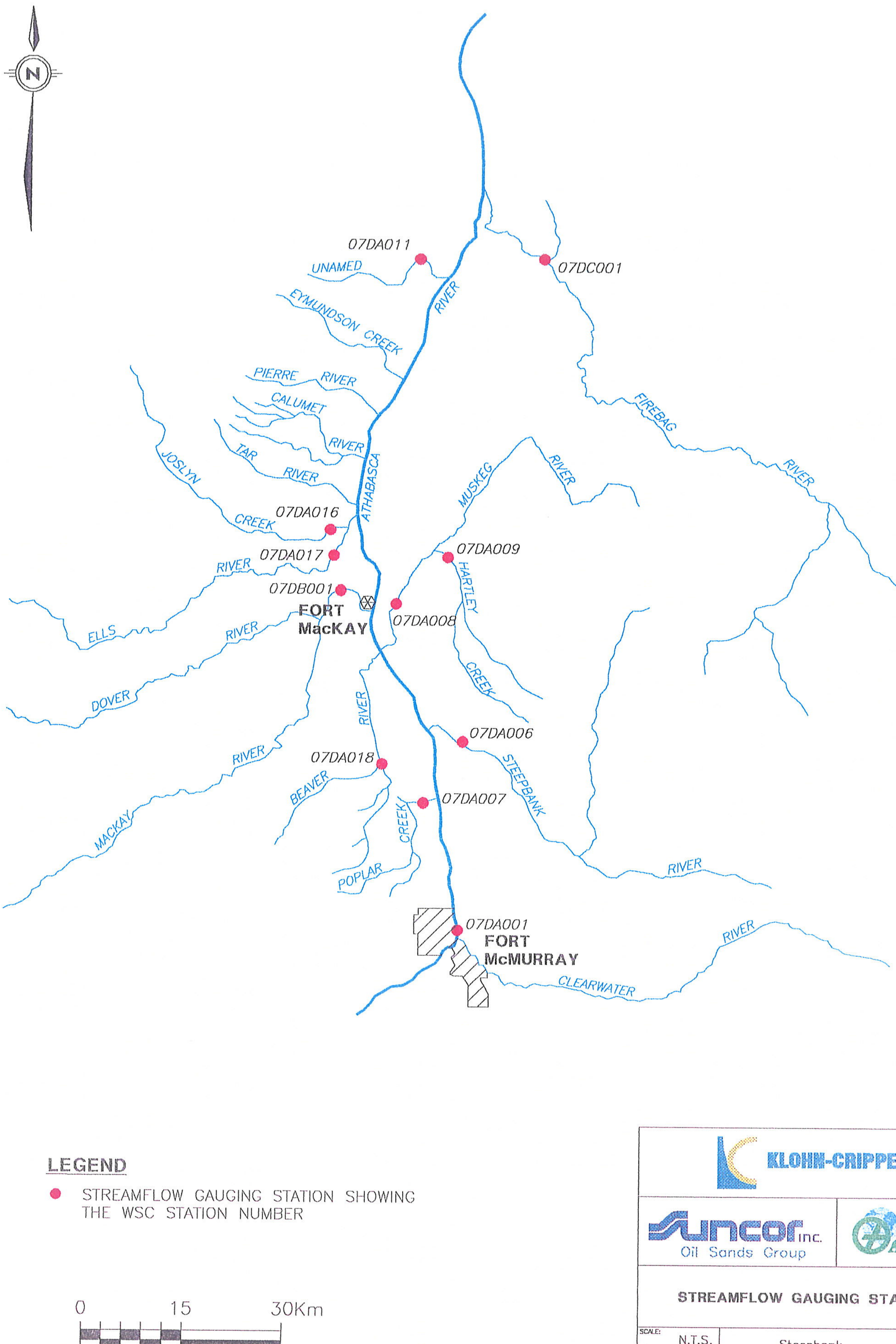
Suncor Inc. Oil Sands Group

Golder Associates

**PRECIPITATION MONITORING STATIONS**

| | | |
|---|---|---|
| SCALE: N.T.S. | Steepbank Oilsands Mine | REVIEWED BY: J.K.M. |
| DATE: 25 03 96 | | REVISION No.: 1 |
| DRAWN BY: C.P.B. | | FIGURE No.: A-2779-03-005 |

2779w095.dwg




**LEGEND**

● STREAMFLOW GAUGING STATION SHOWING THE WSC STATION NUMBER

KLOHN-CRIPPEN

Suncor Inc. Oil Sands Group

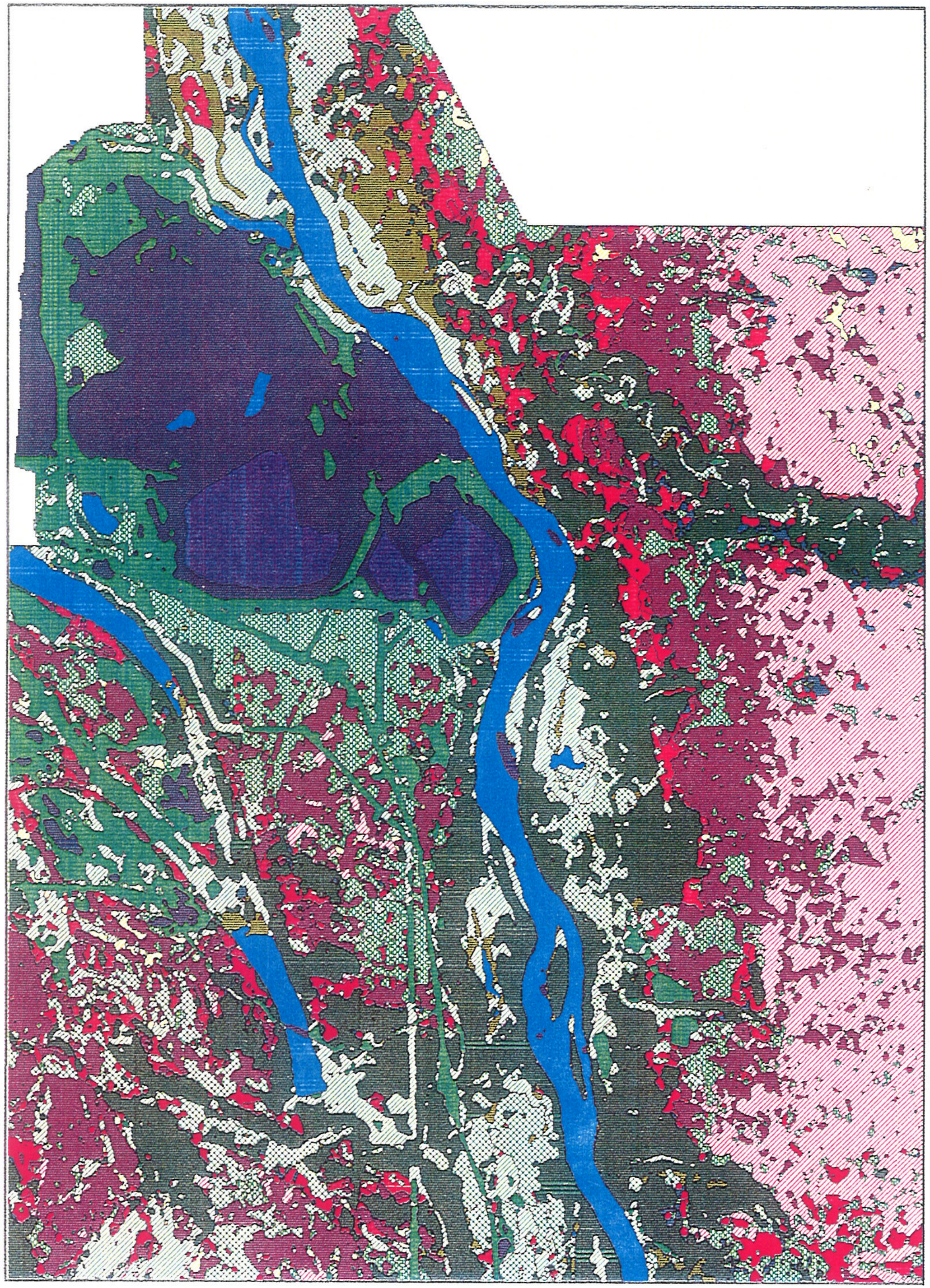
Golder Associates

STREAMFLOW GAUGING STATIONS

| | | |
|---|---|---|
| SCALE: N.T.S. | Steepbank Oilsands Mine | REVIEWED BY: J.K.M. |
| DATE: 25 03 96 | | REVISION No.: 1 |
| DRAWN BY: C.P.B. | | FIGURE No.: A-2779-03-006 |

2779w094.dwg

# SUNCOR ELC CLASSIFICATION
## LOCAL STUDY AREA, YEAR 1995



**LEGEND**

- Closed Jack Pine
- Closed White Spruce
- Deciduous forest
- Closed Mixedwood
- Closed Mixed Coniferous, Black Spruce Dominant
- Peatland: Closed Black Spruce Bog
- Peatland: Black Spruce-Tamarack Fen
- Closed Mixedwood, White Spruce Dominant
- Peatland: Open Black Spruce Bog
- Peatland: Open Tamarack Fen
- Wetland Closed Shrub Complex
- Disturbed/Herb, Grasses
- Industrial/Sparsely Vegetated
- Industrial Open Water
- Wetland Open Water-Emergent Vegetation Zone

N

Scale = 1:100,000

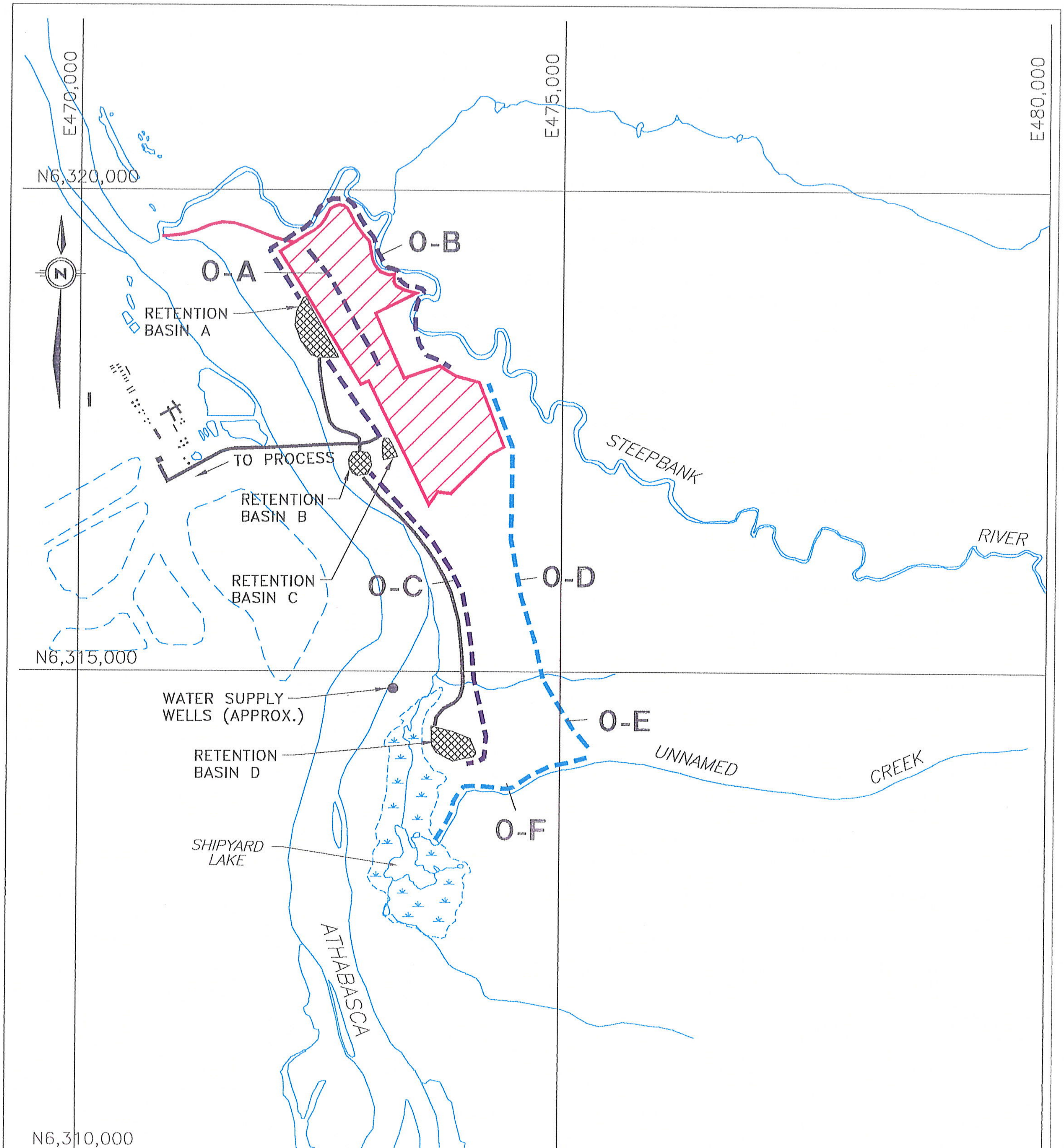
0 2 4 6

KILOMETRES

Suncor Inc. | Golder Associates

**VEGITATION CLASSIFICATION**

| | | |
|---|---|---|
| 4-19-96 RP/KS | Steepbank Oilsands Mine | Figure No. |
| 952-2307.5685 | | A-2779-03-007 |




**LEGEND**

| | |
|---|---|
| O-E | CHANNEL DESIGNATION |
| ▬ ▬ ▬ (blue) | INTERCEPTION CHANNEL |
| ▬ ▬ ▬ (purple) | MINE DRAINAGE CHANNEL |
| ▬▬▬ | DRAINAGE PIPELINE |
| ▨ | MINE AREA |

KLOHN-CRIPPEN

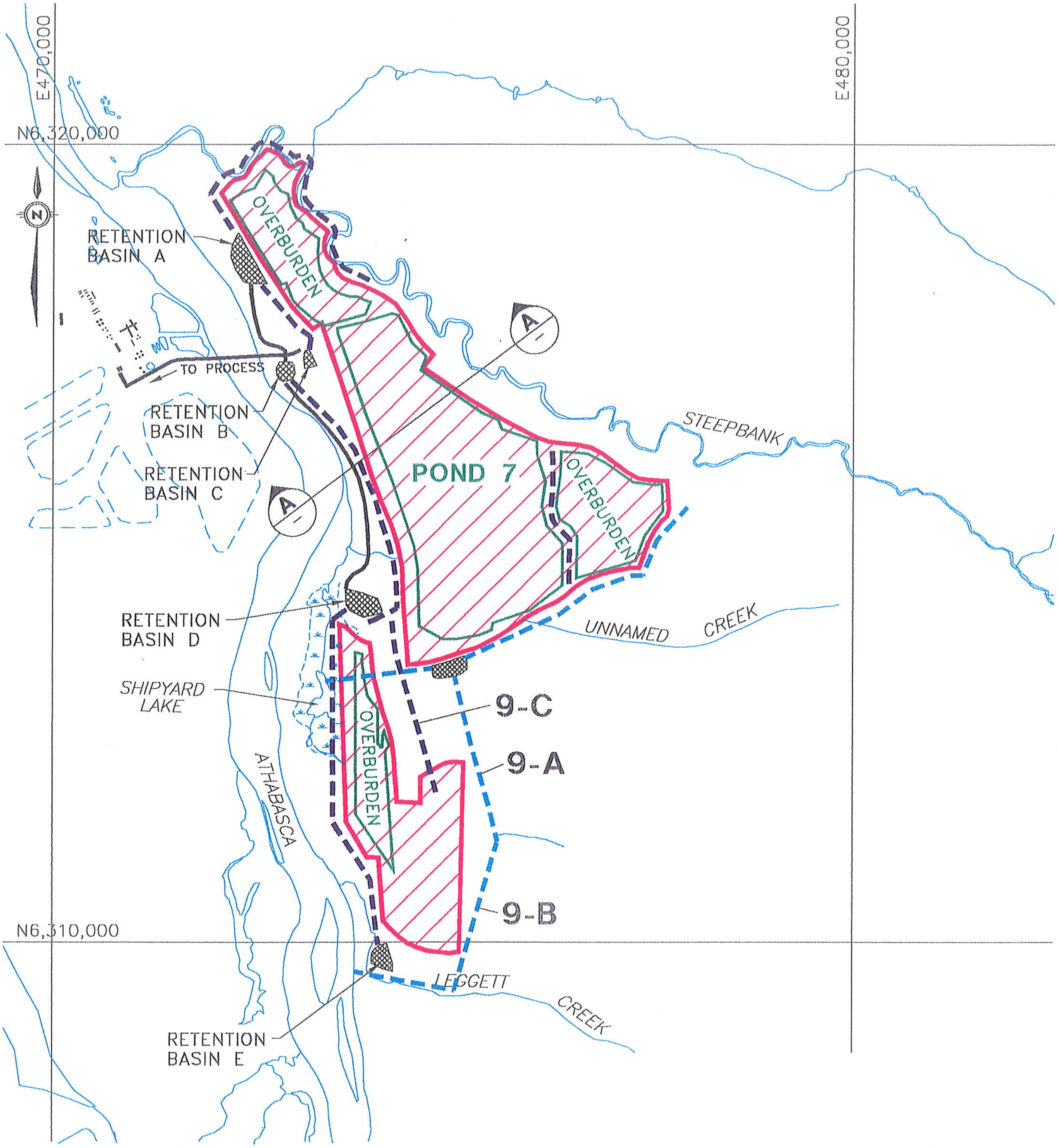
Suncor Inc. Oil Sands Group

Golder Associates

**YEAR 2001**
**STEEPBANK MINE DEVELOPMENT**

| | | |
|---|---|---|
| SCALE: N.T.S. | Steepbank Oilsands Mine | REVIEWED BY: J.K.M. |
| DATE: 25 03 96 | | REVISION No.: 1 |
| DRAWN BY: C.P.B. | | FIGURE No.: A-2779-03-008 |

2779w096.dwg




**LEGEND**

| | |
|---|---|
| 0-E | CHANNEL DESIGNATION |
| (light blue dashed line) | INTERCEPTION CHANNEL |
| (dark dashed line) | MINE DRAINAGE CHANNEL |
| (solid line) | DRAINAGE PIPELINE |
| (hatched area) | MINE AREA |

KLOHN-CRIPPEN

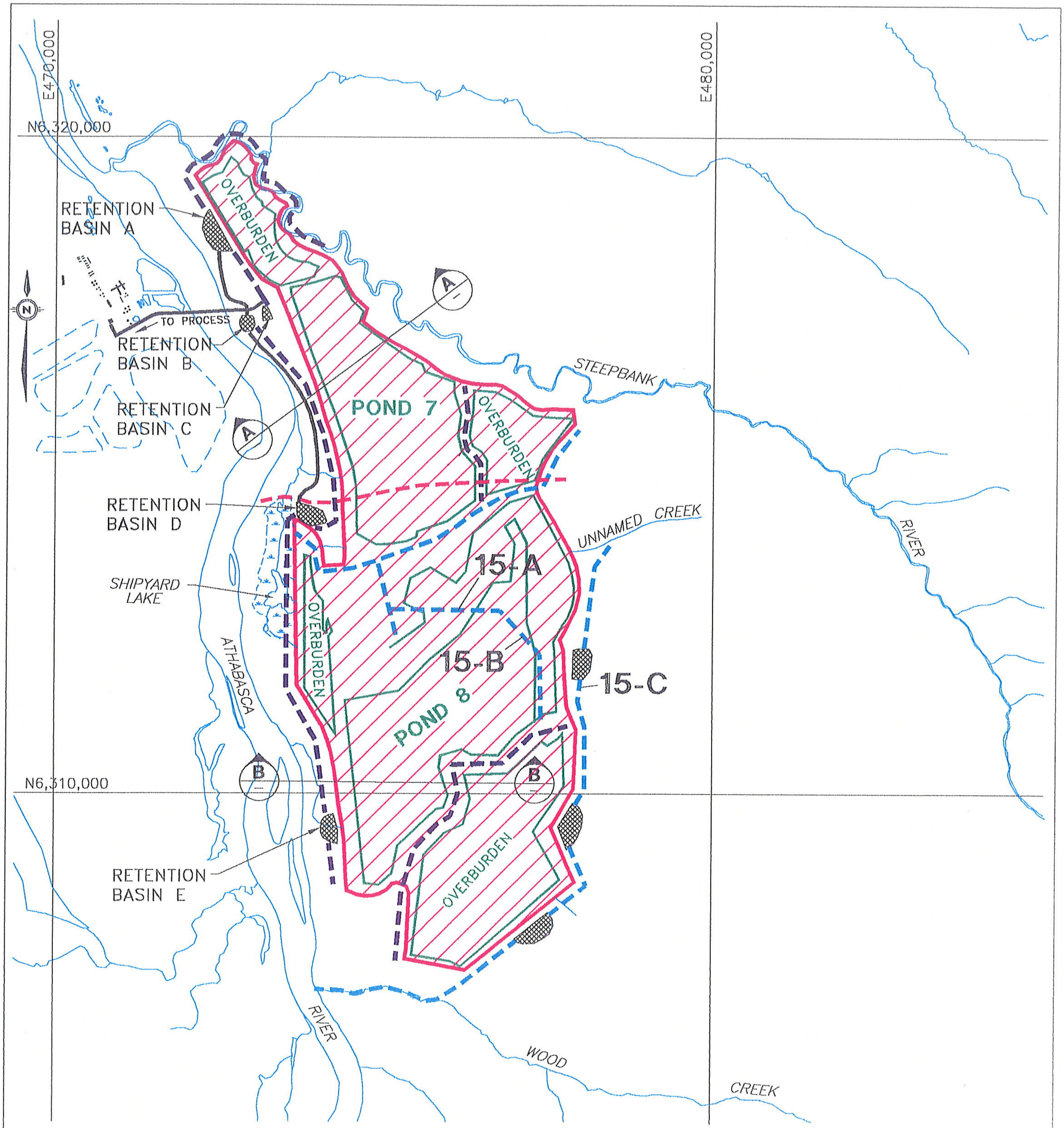
Suncor Inc. Oil Sands Group

Golder Associates

**YEAR 2009**
**STEEPBANK MINE DEVELOPMENT**

| | | |
|---|---|---|
| SCALE: N.T.S. | Steepbank Oilsands Mine | REVIEWED BY: J.K.M. |
| DATE: 25 03 96 | | REVISION No.: 1 |
| DRAWN BY: C.P.B. | | FIGURE No.: A-2779-03-009 |

2779w097.dwg




## LEGEND

| | |
|---|---|
| O-E | CHANNEL DESIGNATION |
| (blue dashed line) | INTERCEPTION CHANNEL |
| (purple dashed line) | MINE DRAINAGE CHANNEL |
| (solid line) | DRAINAGE PIPELINE |
| (hatched area) | MINE AREA |

KLOHN-CRIPPEN

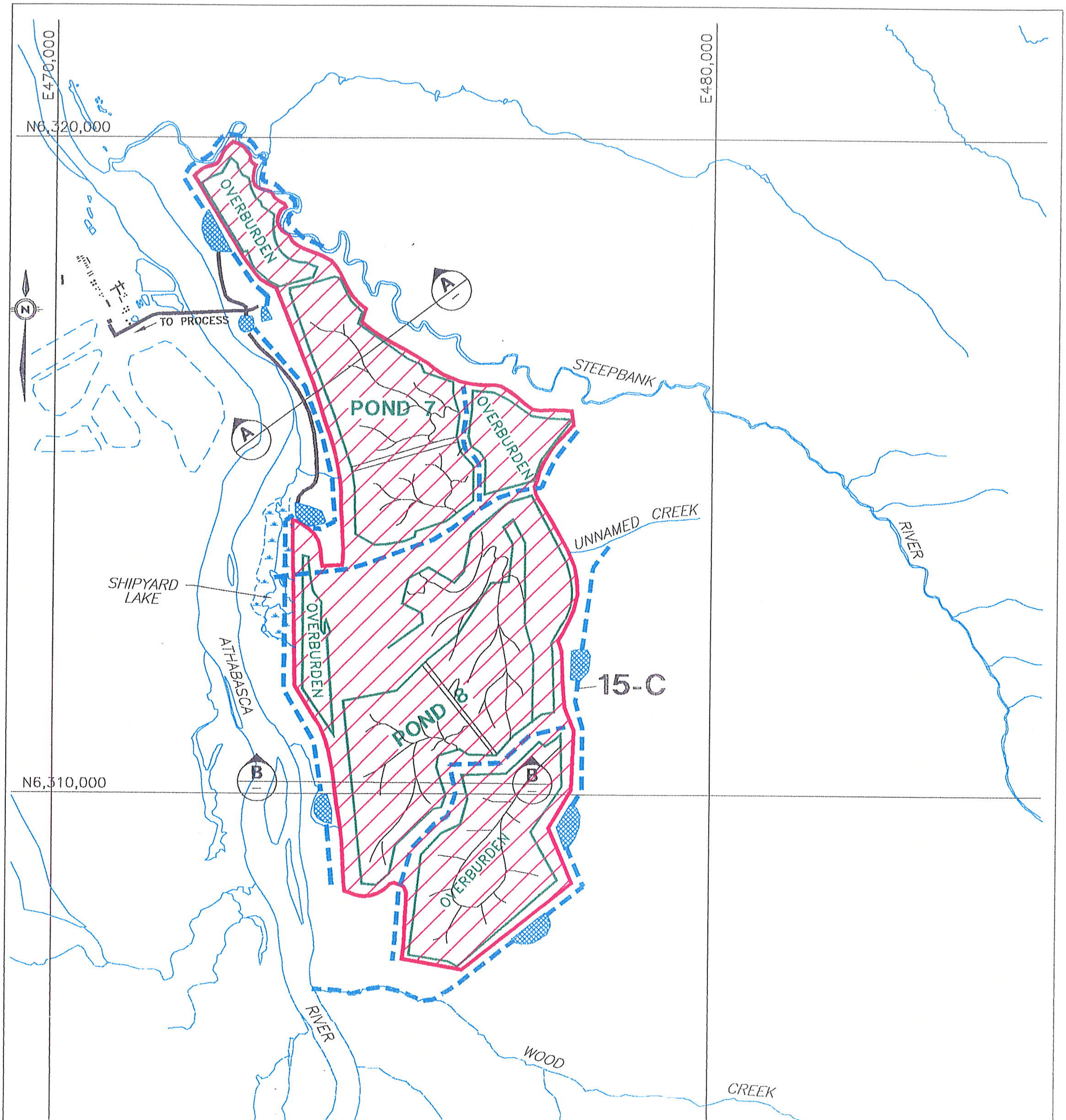
Suncor Inc. Oil Sands Group

Golder Associates

**YEAR 2020**
**STEEPBANK MINE DEVELPMENT**

| | | |
|---|---|---|
| SCALE: N.T.S. | Steepbank Oilsands Mine | REVIEWED BY: J.K.M. |
| DATE: 25 03 96 | | REVISION No.: 1 |
| DRAWN BY: C.P.B. | | FIGURE No.: A-2779-03-010 |

2779w098.dwg




## LEGEND

| | |
|---|---|
| O-E | MINE DESIGNATION |
| (dashed blue line) | RECLAMATION DRAINAGE CHANNEL |
| (solid line) | DRAINAGE PIPELINE |
| (hatched area) | MINE AREA |

KLOHN-CRIPPEN

Suncor Inc. Oil Sands Group

Golder Associates

**POST RECLAMATION DRAINAGE**

| | | |
|---|---|---|
| SCALE: N.T.S. | Steepbank Oilsands Mine | REVIEWED BY: J.K.M. |
| DATE: 25 03 96 | | REVISION No.: 1 |
| DRAWN BY: C.P.B. | | FIGURE No.: A-2779-03-011 |

2779w099.dwg