Application for Approval of the
Jackpine Mine Expansion Project and
Pierre River Mine Project

## Environmental Impact Assessment

# Volume 4B:
# Aquatic Resources
# Appendices

Submitted to:
Alberta Energy and Utilities Board
and Alberta Environment

Submitted by:
Shell Canada Limited

December 2007

## APPENDICES CD

Bolded appendices for the Jackpine Mine Expansion & Pierre River Mine Project EIA are provided in hard copy in respective volumes. The remaining appendices have been provided on CD. The following is a list of these appendices.

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# 1 INTRODUCTION

## 1.1 BACKGROUND

Shell Canada Limited (Shell) is applying to develop the Jackpine Mine Expansion & Pierre River Mine Project (the Project). The Jackpine Expansion Mining Area (JEMA) is a northern expansion of Jackpine Mine – Phase 1 and will be within the Muskeg River watershed. The development activities in the expansion area would potentially affect directly or indirectly Muskeg River, Muskeg Creek, Wapasu Creek and Kearl Lake. The JEMA includes expansion into Leases 88 and 89, and for the purposes of this closure drainage plan, includes the Fort McKay Indian Reserve No. 174C**.**

This document presents the closure drainage plan and pre-feasibility drainage design for the JEMA. Its objectives are to demonstrate the feasibility of the proposed mine closure drainage plan and to support Shell's application for the JEMA. This document describes the design approach, criteria, assumptions and typical plans and cross-sections of the proposed closure landscape and drainage systems.

## 1.2 SCOPE OF WORK

The scope of work for the development of the closure drainage plan and the pre-feasibility design of the closure drainage systems included the following tasks:

- identify and define the criteria for designing the closure drainage systems;
- analyze flood hydrology and derive flood peak discharges and design parameters of extreme winds;
- identify and evaluate alternative closure drainage schemes; and
- provide a conceptual design of the proposed closure drainage systems including shoreline protection for the pit lakes.

The closure drainage plan and the conceptual designs of the closure drainage systems were prepared to provide a sound basis for assessing the environmental impacts and long-term sustainability of the proposed closure drainage systems. The results of this work include the following:

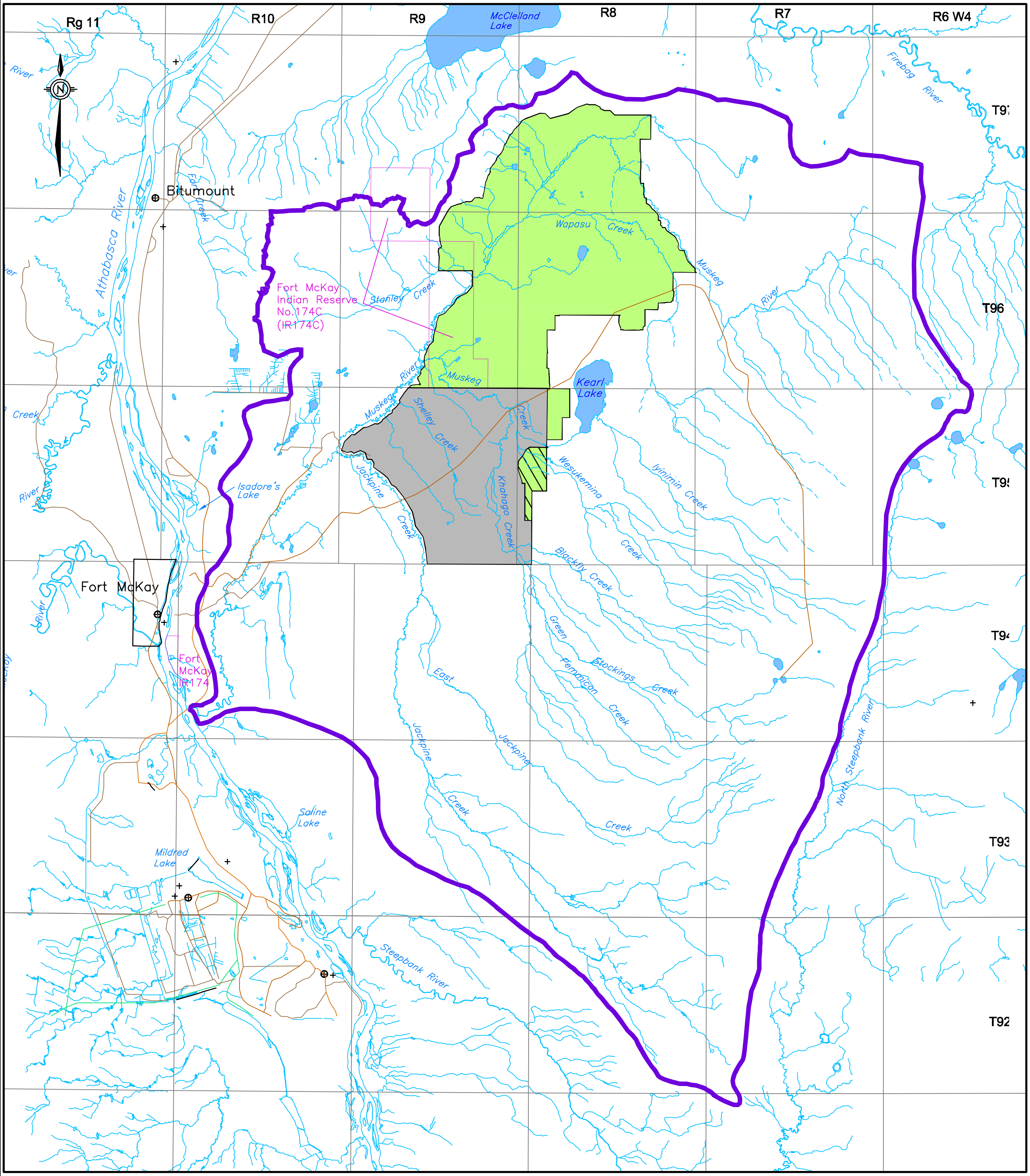
- recommended design criteria;
- proposed drainage scheme and drainage system layout; and
- conceptual design of the main closure drainage facilities, including typical plans, profiles and cross-sections.

## 1.3 PRE-DEVELOPMENT NATURAL DRAINAGE

As shown in Figure 1, the JEMA development area is situated in the upper and central areas of the Muskeg River watershed. The major streams and waterbody that would be potentially affected by the JEMA include the Muskeg River, Muskeg Creek, Wapasu Creek and Kearl Lake. Other streams will be affected by the development activities of Jackpine Mine – Phase 1, including Khahago Creek and its tributaries, Shelley Creek, Jackpine Creek and Wesukemina Creek.

The tributaries of the Muskeg River generally convey flows in a northwesterly direction. The Muskeg River basin has a drainage area of 1,476 $km^2$ at the river mouth, which includes an upland area of 749 $km^2$ (or 51% of the total drainage area); a lowland area of 722 $km^2$ (or 49% of the total area); and a lake surface area of 5.5 $km^2$ (less than 1% of the total area).

The lowland terrain within most of the JEMA development area is relatively flat, with elevations ranging from 300 to 400 masl. The dominant coversoils within the lowland areas are organic soils, which are highly absorbent, generally poorly drained and characterized by high groundwater tables at or near the ground surface throughout the year. The organic soils in the JEMA area are typically 0.5 to 2 m thick and lay over relatively impervious lacustrine (lake origin) deposits. Ground slopes of less than 0.5% are typical of the poorly drained lowland area. Slopes of 1 to 3% are typical of the better-drained upland areas at elevations above 340 m. All elevations are calculated above sea level.




LEGEND

- EXISTING ROAD
- JACKPINE EXPANSION MINING AREA
- LEASE SWAPPED TO SYNCRUDE
- JACKPINE MINE - PHASE 1
- MUSKEG RIVER WATERSHED BOUNDARY

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PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

# PRE-DEVELOPMENT NATURAL DRAINAGE

Shell Canada Limited

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| PRO | 06–1346–022.9500 | | FILE No. | pre–dev drainage |
| DESIGN | FLA | 26/09/07 | SCALE NA | REV. 0 |
| CADD | PSR | 07/12/07 | | |
| CHECK | FLA | 07/12/07 | | |
| REVIEW | WES | 07/12/07 | | |

**FIGURE: 1**

L:\2006\1344–OIL SANDS\1346\06–1346–022 Shell\9500\9530\CLOSURE DRAINAGE DESIGN\ Drawing file: Fig 1__pre–dev Natural drainage.dwg Dec 07, 2007 – 12:51pm

The natural streams in the JEMA development area display similar geomorphic characteristics, with the stream bank materials in the lowland area composed primarily of organic soils with varying proportions of sand with some small gravel. The streams in the steeper upland areas typically have well-defined channels with bed materials that include clay and silt in varying proportions. There is a great deal of beaver activity in the lowland areas with beaver dams at numerous locations. Beaver lodges are also present at permanently inundated lowland areas.

## 1.4 GENERAL LAYOUT OF CLOSURE DRAINAGE SYSTEMS

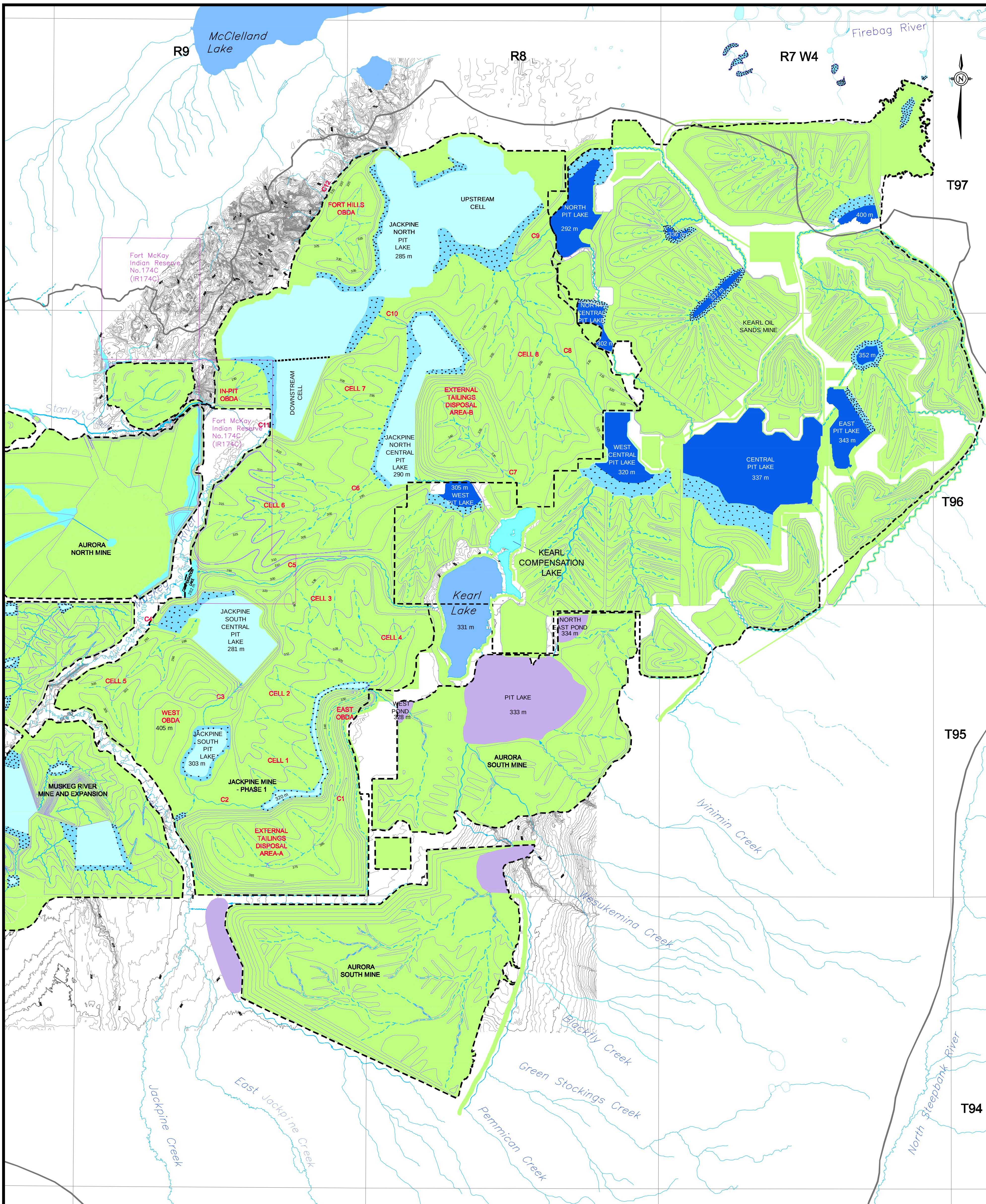
Figure 2 shows the layout of the proposed closure drainage system for the JEMA and its integration with closure drainage systems for Kearl Oil Sands Project (Imperial Oil Resources Ventures Limited) and Aurora South Mine Project (Syncrude Canada Ltd.). The closure drainage system for JEMA shows main channels, secondary channels, reclaimed tailings storage cells, shallow wetlands and pit lakes. There are three drainage subsystems: a south drainage system (Jackpine South Central Pit Lake drainage system), a north drainage system (Jackpine North Pit Lake drainage system) and the Kearl Lake drainage system. The north and south drainage subsystems are separated by the Kearl Lake outlet drainage channel and both discharge into the Muskeg River through pit lakes.

The proposed closure drainage system includes such natural features as floodplains, wetlands and pit lakes for flood flow attenuation and bioremediation of runoff and seepage from reclaimed areas. Littoral zones with shallow wetlands are provided along the shorelines of the pit lakes. Each littoral zone occupies 10 to 30% of the total surface area of each pit lake.

The closure drainage plan for JEMA was developed to accomplish the objectives of long-term sustainability and minimal aquatic impacts on receiving streams. The drainage routes were selected and designed to maximize long-term sustainability, minimize the changes in flows in the surrounding creeks and rivers, and to allow for fish migration.

A groundtruthing study was completed for the Muskeg River upper tributaries as part of Imperial Oil Kearl Oil Sands Project EIA to determine pre-development hydrography (stream network topology). Based on this information, ephemeral and permanent streams were determined and included in Figure 1. The closure drainage plan (Figure 2) includes post-disturbance alignment and condition of all ephemeral and permanent streams and waterbodies created as part of the JEMA.

L:\2006\1344–OIL SANDS\1346\06–1346–022 Shell\9500\9530\CLOSURE DRAINAGE DESIGN\Fig 2_Conceptual Integrated Closure Drainage Plan–MRWB.dwg Dec 07, 2007 – 12:32pm




## LEGEND

- MINE DEVELOPMENT BOUNDARY
- NATURAL WATERSHED DIVIDE
- 300 EXISTING CONTOUR
- 330 FINAL RECLAIMED SURFACE CONTOUR
- MAIN CHANNEL
- SECONDARY CHANNEL
- WETLANDS AND LITTORAL ZONE
- RECLAIMED SURFACE
- LAKE
- KEARL PIT LAKE
- SYNCRUDE PIT LAKE / WETLANDS
- SUBMERGED DYKE
- LAKE PERIMETER LEVEE

**NOTE :**

OBDA - OVERBURDEN DISPOSAL AREA

**REFERENCE**

ALBERTA DIGITAL DATA OBTAINED FROM ALTALIS LTD. (SEPTEMBER 2004.)
USED UNDER LICENSE.
PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83
COORDINATE SYSTEM: UTM ZONE 12

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PROJECT
JACKPINE MINE EXPANSION &
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TITLE
**CONCEPTUAL INTEGRATED CLOSURE DRAINAGE PLAN IN THE MUSKEG RIVER WATERSHED**

Shell Canada Limited

| PROJECT 06–1346–022.9530 | | | FILE No. ICD PLAN–MRWB |
|---|---|---|---|
| DESIGN | FLA | 24/09/07 | SCALE AS SHOWN REV. 0 |
| CADD | PSR | 07/12/07 | |
| CHECK | FLA | 07/12/07 | **FIGURE: 2** |
| REVIEW | WES/TC | 07/12/07 | |

The general layouts of the proposed closure drainage subsystems are described in the following subsections.

### 1.4.1 Jackpine South Central Pit Lake Drainage System

Jackpine Mine – Phase 1 (Shell 2002) has been approved and some of the drainage systems from this project have been modified to accommodate the expansion plans. The Jackpine South Central Pit Lake Drainage system is similar to the Jackpine Mine – Phase 1 drainage system with slight changes to the mine configuration to integrate with JEMA. The External Tailings Disposal Area-A (ETDA-A) is larger than the original Jackpine Mine – Phase 1 plan to accommodate for additional Thickened Tailings (TT).

As shown in Figure 2, the drainage system for the Jackpine South Central Pit Lake drainage system includes the ETDA-A, Cells 1 through 5, the West Overburden Disposal Area (OBDA), the East OBDA, the Jackpine South Pit Lake and the Jackpine South Central Pit Lake. At closure, surface runoff from the ETDA-A will be conveyed through Channel C1 through the East OBDA into a wetlands area at an elevation of 320 m. This wetlands area also collects surface runoff from Cells 1 through 4, and treated outflows from the West Pond of the Syncrude Aurora South Mine. The water quality from the Syncrude West Pond will meet water quality objectives before it is accepted by the Jackpine pit lakes. Outlet Channel C2 conveys flows from the wetlands area across the reclaimed plant site into the Jackpine South Pit Lake. Channel C3 connects the Jackpine South Pit Lake with the Jackpine South Central Pit Lake at an elevation of 281 m. Outflows from Jackpine South Central Pit Lake will be discharged to the Muskeg River through Channel C4.

Channels C1, C3 and C4 are built on overburden caps placed on top of tailings material. These caps consist of an approximately even mix of sand and waste materials that were originally stripped from the mine site. Channel C2 is built on natural ground at the reclaimed mine site. The downstream reach of C4 is constructed on natural ground.

### 1.4.2 Jackpine North Pit Lake Drainage System

This drainage system includes Cells 6, 7, 8, ETDA-B, Fort Hills OBDA, In-Pit OBDA, Jackpine North Pit Lake, Jackpine North Central Pit Lake, as well as the drainage systems of the pit lakes for the Kearl Oil Sands Project (Figure 2). General slopes of the channels within the overburden caps of Cells 6, 7, 8 and the ETDA-B are 0.5%.

Channel C6 conveys runoff from Cell 6 to the Jackpine North Central Pit Lake and Channel C7 conveys the surface runoff from the ETDA-B across Cell 8 to the confluence with Channel C8. Channel C8 connects the West Central Pit Lake for the Kearl Oil Sands Project to the Jackpine North Pit Lake. Channel C11 connects Jackpine North Pit Lake to the Muskeg River. Channel C9 connects the treated effluent from the North Pit Lake for the Kearl Oil Sands Project to the Jackpine North Pit Lake. A portion of the Jackpine North Pit Lake shore adjacent to the Kearl North Pit Lake will be backfilled to protect the shoreline from erosion that could connect the two pit lakes. Channel C10 conveys flows from the Jackpine North Central Pit Lake to the Jackpine North Pit Lake. Channel C12 drains the Fort Hills OBDA and it will be constructed by cut and fill in the natural ground to convey flows to the Jackpine North Pit Lake.

Channels C6, C7, C8 and C10 will be constructed in overburden caps placed on top of tailings materials. These caps consist of an approximately even mix of sand and waste materials that were originally stripped from the mine site. Channel C11 is constructed in the natural ground. Channels C9 and C12 are constructed on natural ground and overburden fill.

### 1.4.3 Kearl Lake Drainage System

The Kearl Lake drainage system will consist of drainages from the undisturbed watersheds of Iyinimin Creek, Wesukemina Creek, Khahago Creek tributaries and reclaimed watersheds from the Aurora South Mine. Outflows from Kearl Lake will be discharged to the Muskeg River through an outlet channel and the Jackpine Mine Compensation Lake. The outlet channel (C5) separates the south and north drainage subsystems.

Channel C5 will be a 10-km-long channel with an average valley slope of 0.5%. The drainage channel will be built between the dyke walls of Cell 3 and Cell 4 of the south drainage subsystem and Cell 6 of the north drainage subsystem and lined with overburden material. Channel C5 will replace Muskeg Creek by connecting Kearl Lake to the Muskeg River.

During operation, a partial perimeter dyke will be constructed around Kearl Lake and Kearl Compensation Lake to prevent spillage during extreme flood events. Upon closure, the dyke will be revegetated and remain in the closure landscape. The inside side slope of the dyke will be at 4H:1V and the outside slope will be 10H:1V.

# 2 DESIGN APPROACH, CRITERIA AND ASSUMPTIONS

## 2.1 PERFORMANCE OBJECTIVES

A closure design plan is necessary to develop sustainable landforms after mine closure, to maximize beneficial changes and to minimize negative impacts. The following objectives should be incorporated:

- minimize changes to surface flow regime of receiving waters;
- minimize negative aquatic impacts on the receiving waters;
- provide drainage to achieve suitable moisture conditions at dry land and wet land terrain types;
- avoid excessive erosion and sedimentation that would lead to failure of the landform;
- avoid catastrophic failure of liquid impoundments;
- target maintenance-free condition after prolonged periods of monitoring;
- control salinity of the closure landscape;
- provide for biological productivity and ecological sustainability; and
- provide biodegradation and water treatment capability (e.g., wetlands, floodplains, and pit lakes).

Self-sustaining closure drainage systems are designed to have the same characteristics as the pre-development natural drainage systems in terms of dynamic stability, robustness, longevity and self-healing mechanisms. This can be accomplished by designing drainage systems that are patterned after natural analogues subject to similar climatic, topographic and soil conditions. Although it is not possible to recreate the original natural drainage systems, it is possible to replicate the stability, robustness and function of the original natural systems.

In addition, the closure drainage systems will be designed to provide a biologically productive landscape and have the capability to handle extreme hydrologic events. This can be accomplished by incorporating drainage features such as shallow wetlands, floodplains and pit lakes for biodegradation of the surface runoff and seepage from the reclaimed surfaces and for attenuating flood peak discharges.

## 2.2 DESIGN APPROACH

Conventional approaches for design of reclamation drainage systems often provide rigid, non-erodible drainage facilities that are designed to handle specific extreme flood events. This results in uniformity of design and construction but does not necessarily accomplish the performance objectives of the closure drainage systems to provide biological productivity and to minimize erosion and achieve long-term sustainability.

A major deficiency of conventional approaches is the absence of a self-healing mechanism. Man-made channels may fail because of overtopping, washout of erosion protection or channel degradation. Such failures often lead to accelerated erosion and/or channel relocation, conditions that typically cause high sediment yields resulting in alteration of aquatic habitats.

The alternative to rigid systems designed for specific extreme events is a dynamic system capable of adjusting to change without accelerated erosion or unacceptable environmental impacts. Such a dynamic system must have robust drainage facilities with several lines of defence and a self-healing capability that can be built into reclamation drainage systems by design. This dynamic system approach was used for the design of closure drainage systems for the JEMA.

This closure approach is based on the recognition that natural drainage systems will change over time. Similar changes are anticipated in the closure drainage systems. Anticipation of such natural changes enables the design and construction of robust drainage systems with second and third lines of defence. The types of anticipated changes that could occur to the closure drainage systems over time include the following:

- deposition of sediment that could raise the channel bed and reduce the channel conveyance capacity;
- erosion of the channel bed that could lower the channel bed and result in channel degradation;
- vegetation growth on the channel bed and banks, which would increase the channel roughness, decrease channel velocities and protect against erosion;
- reduction of the width of the channel because of sedimentation on one side of a channel that is built wider than the regime width;
- overtopping and consequent relocation of drainage channels because of excessive sedimentation, beaver dams or icing; and

- bank erosion and subsequent failure because of slope instability or slumping.

Natural channels are in regime and exhibit sediment equilibrium. Channels in regime have morphological characteristics, including cross-section, longitudinal slope and sinuosity, of a watercourse that is in long-term equilibrium. The existing literature has extensive data collected by fluvial geomorphologists to correlate channel regimes with hydrologic, topographic and soil conditions. These data provide a sound basis for designing channels in regime to replicate the dynamic character of natural channels and to avoid progressive and rapid channel degradation or aggradation.

Closure drainage channels will be capable of handling extreme flood events. Rigid erosion control measures are unnecessary because regime channels will be designed to accommodate erosion. Reduction of flow velocities during extreme flood events will be achieved by building drainage channels in well-defined swales or valleys, just like natural drainage systems. Floodplains and wetlands provide extra storage to attenuate flood peak discharges.

Natural geomorphic processes are accounted for in the design of the reclamation drainage systems, including self-sustaining pit lake shorelines to accommodate the change processes such as erosion and sedimentation.

## 2.3 DESIGN CRITERIA

Table 1 presents the design criteria developed to achieve the performance objectives of the closure drainage systems by following the fluvial geomorphic approach. These design criteria were adopted for the evaluation of various surface drainage alternatives, selection of the proposed scheme and conceptual design of the drainage systems.

**Table 1 Design Criteria for Developing Closure Drainage Systems**

| Design Criteria | Design Considerations or Features Provided for Drainage Systems |
|---|---|
| self-sustaining in geological time frames | Structures such as dams and reservoirs that could cause rapid deterioration of the landscape in the event of an extreme flood event should be excluded from the closure landscape. Channels should be subject to gradual change over geologic time frames and sediment yields from reclaimed surfaces should be similar to those from similar natural systems. |
| drainage effectiveness | Drainage effectiveness and landscape stability should be similar to pre-development conditions. |
| channel in regime | Regime channels should be designed by selecting appropriate channel parameters, including cross-section, longitudinal slope and sinuosity, based on hydrologic and soil conditions and to replicate natural analogues. |
| channel dimensions | Channel dimensions and width-depth ratios should be selected based on regime relationships. Normal channel side slope of the main channel should be a maximum of 2H:1V and vegetated channel side slope should be 3H:1V for all three types of soils (sand, overburden and natural) and minimum channel bed width should be 3 m for major channels and 1 m for minor channels. |

## Table 1 Design Criteria for Developing Closure Drainage Systems (continued)

| Design Criteria | Design Considerations or Features Provided for Drainage Systems |
|---|---|
| channel slope | Main and secondary drainage channel slopes should be designed based on regime relationships. Minimum slope of main drainage channels on sandy soils should be 0.08% to allow adequate drainage and to minimize channel erosion. |
| channel sinuosity | Channels should have a sinuous pattern to replicate natural systems and reduce channel bed slopes. |
| floodplains | Main drainage channels should be sized to convey low flows and small frequent flood events. Floodplains should be provided to convey high flows and large flood events with low recurrence intervals. |
| drainage density of secondary drainage channels | Secondary drainage channels should be built on the reclaimed landscape to suit the characteristic drainage density of the terrain. Design drainage densities, defined as length of channels per unit area in a drainage basin, are estimated to be as follows: sand or overburden material at 0.5% slope = 1.0 $km/km^2$. |
| vegetated/grassed waterways on overburden storage areas | Grassed waterways on overburden storage areas should be designed as follows:<br>• width = 10 $A^{0.5}$, where A = drainage area ($km^2$);<br>• organic soil depth = 0.8 m; and<br>• slopes (%) $\leq 0.5 \times \frac{1}{A}$, where A = drainage area ($km^2$). |
| channels on bouldery ground | Where channels cannot meet the erosion control specification indicated below, supply bouldery ground beneath the channel and beside the channel with an initial armour layer on the channel bed. Bouldery ground will consist of select silt/clay overburden material mixed with gravel, cobble or boulder. |
| channel erosion protection | Regime channels should be characterized by sediment equilibrium, subject to gradual evolution over geologic time frames and allowable erosion levels for unlined regime channels are as follows:<br>• no erosion during the 10-year flood event;<br>• little erosion during the 100-year flood event; and<br>• moderate erosion during the Probable Maximum Flood (PMF) event.<br>Maximum allowable flow velocities for channels in sandy soils are as follows:<br>• 2-year flood event: 0.5 m/s;<br>• 10-year flood event: 1.0 m/s;<br>• 100-year flood event: 1.5 m/s; and<br>• PMF: 2.0 m/s.<br>Maximum allowable flow velocities for channels in overburden or natural ground (clay/silt/gravel materials) are as follows:<br>• 2-year flood event: 1.0 m/s;<br>• 10-year flood event: 1.5 m/s;<br>• 100-year flood event: 2.0 m/s; and<br>• PMF: 3.0 m/s. |
| shallow wetlands | Shallow wetlands with an average depth of 1 m should be built into the drainage systems to provide for biodegradation and flood attenuation. Shallow wetlands should be sized with a total combined surface area of 5 to 10% of the catchment area and shallow wetlands should consist of an open-water area of about 1.5 m deep and a shallow area of about 0.5 m deep with wetlands vegetation. The open-water surface area should be approximately equal to the shallow vegetated area. |
| pit lake | A pit lake should have a zone of littoral vegetation, occupying between 10 and 30% of the lake surface area to ensure biological productivity. The top layer of the littoral zone substrate should consist of a minimum of 20 cm of low-organic content soil. Average water depth of the littoral zone should be about 0.5 m. The littoral zone should be protected by a breakwater designed to protect against waves associated with the 100-year wind. The breakwater will enable the initial development of the littoral zone and the breakwater should be designed to prevent damage during the 100-year wind and to allow about 5% damage by the 1,000-year wind. This modest criteria is acceptable because shoreline protection of pit lakes is not a major concern and because shoreline erosion would not threaten the containment or spillage of the lake and would not cause catastrophic sedimentation to occur. |

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**Table 1 Design Criteria for Developing Closure Drainage Systems (continued)**

| Design Criteria | Design Considerations or Features Provided for Drainage Systems |
|---|---|
| sand ridges on in-pit Non-Segregating Tailings (NST) storage areas with sand caps | Ridges of sand (underflow sand) should be provided in the in-pit NST storage area with sand cap. Sand ridges are necessary to provide drained soil conditions to ensure access, leach tailings porewater residue and support small patches of vegetative cover during initial period of reclamation when consolidation of the NST results in upward flux of tailings porewater. Appropriate reclamation soil material should be placed on the surface of sand to provide the appropriate moisture balance to support deciduous trees or a mixedwood forest cover with dense understorey vegetation, composed mainly of grasses for upland erosion protection. |

There are various types of channel regime relationships governing channel width, depth, width-depth ratio, sinuosity and meander wave length. These parameters are normally a function of mean annual 2-year flood peak or bankfull discharge, soil type and slope, although the regime formulations are not exact. There is a range of acceptable channel parameters as illustrated by the scatter in the original data from which the relationships were used to guide the channel design. Different sets of applicable regime equations were used for channels built in sandy soils and overburden or natural grounds.

The following regime relationships provided by Schumm (1977), were used to guide the designs of channels in sandy soils with mild slopes in natural grounds. The assumed silt/clay content for the sandy bed materials is 30%.

$$W = 37\frac{Q^{0.38}}{M^{0.39}} \qquad \{\text{ft}\}$$

$$D = 0.6M^{0.342} \cdot Q^{0.29} \qquad \{\text{ft}\}$$

$$S = \frac{60}{M^{0.38} \cdot Q^{0.32}} \qquad \{\text{ft/mile}\}$$

$$\lambda = 1890\frac{Q^{0.34}}{M^{0.74}} \qquad \{\text{ft}\}$$

$$P = 0.94M^{0.25}$$

where, Q = mean annual discharge [$ft^3$/s];

M = silt/clay content of the bed material [%];

W = channel bankfull width [ft];

D = channel bankfull depth [ft];

S = channel bed slope;

$\lambda$ = channel wave length; and

P = channel sinuosity.

Channels in overburden soils are to be built out of select overburden materials with dominant gravel material mixed with sand, silt and clay. Channels cut through natural ground are assumed to have bed materials with dominant gravel material mixed with sand, silt and clay. Otherwise, placement of selected overburden materials will be provided to ensure stable channel slopes over the geological time frames.

The regime equations for channels with relatively steep slopes to be built in natural ground and overburden soils were based on the Kellerhals equations for gravel rivers in Alberta (Bray 1972), as listed below.

$$Wsm = 1.8Q^{0.5} \qquad \{ft\}$$

$$D = 0.256Q^{0.331}Dg(50)^{-0.025} \qquad \{ft\}$$

$$S = 0.096Q^{-0.344}Dg(50)^{0.586} \qquad \{ft/ft\}$$

where, Q = 2-year flood peak discharge [$ft^3/s$];

Wsm = channel bankfull width [ft];

D = channel bankfull depth [ft];

Dg(50) = median grain size of channel bed material [ft]; and

S = channel bed slope [ft/ft].

Valley slopes of the channels built in overburden soils and natural ground were assumed to be about 1% and to have similar sinuosity as the natural channels in the upper watershed of the Muskeg River. The above regime relationship for channel bed slope was used to estimate the equivalent median size of the required bed materials to support the specified channel slopes. The regime relationships were also used to estimate the channel bankfull width and depth based on the 2-year flood peak discharge and median grain size of assumed bed materials. The bottom width was then estimated based on the estimates of bankfull width and channel depth.

In addition to the regime equations discussed above, Manning's equation (1889) (Bretting 1946) was used to calculate channel flow based on selected channel geometry. Manning's equation is a function of flow area, channel velocity and slope. Manning's equation is listed below.

$$Q = \frac{1}{n} A R^{2/3} S^{1/2} \qquad \{m^3/s\}$$

where, Q = flood peak discharge [$m^3/s$];

n = coefficient of roughness [0.039 main channel, 0.15 flood plain];

A = area of flow [$m^2$];

R = hydraulic radius [m]; and

S = channel bed slope [m/m].

As previously stated, the design approach is to create dynamic stability within the closure plan that will allow for the channels to accommodate changes over time. This method allows for the channel to respond to changes in hydrologic or sediment flow through erosion or deposition.

## 2.4 DESIGN FEATURES

This pre-feasibility level design of closure reclamation drainage systems was conducted to provide the following desirable features in the reclaimed landscape:

- Provision of Drainage Outlets - The closure landscape will be equipped with surface drainage systems that discharge to natural receiving waters. Closed systems that could result in saline lake areas and reduced flows in the receiving streams will be excluded from the closure landscape.
- No Man-Made Dams - Dams containing large bodies of ponded water are excluded from the closure landscape. Any potentially ponded areas will be limited to shallow wetlands or lakes with depths less than 2 m. Any landmass containing ponded water or liquefiable material will be equipped with a 10 m minimum freeboard and a small overall hydraulic gradient no greater than 20H: 1V.
- Provision for Beaver Dams - The minimum invert of the closure outlet channels from the pit lakes are equal to or greater than 4 m below natural ground. The maximum height of beaver dams found in the Oil Sands Region is about 2.5 m. Therefore, beaver dam blockage would be unable to cause channel overtopping.
- Permanent Walk-Away Mine Closure - The drainage systems and landscape must be permanent walk-away closure systems after a period of monitoring and management.

- Reclamation Surface Soil Cover - Sufficient depth of reclamation surface soil will be placed to provide the necessary soil moisture storage to support a self-sustaining tree cover with a dense understorey. This tree cover and undercover will provide good erosion resistance.
- Consolidation of TT Materials - Consolidation of TT materials and differential settlement will be accommodated by providing managed drainage outlet channels. The invert of a managed drainage channel is lowered during a management period following the end of mining to suit the rate of TT consolidation.
- Topographic Slope - Microtopography will be built into the landscape to create a landform with diverse drainage conditions and local hydraulic gradients that resist soil salinization. A maximum slope of 30% will be provided to support vegetation and a minimum overall slope of about 0.5% will be provided to achieve positive drainage.
- Change in Flow Regime of Receiving Water - The 10-year flood flows of natural receiving waters will not exceed pre-development flows by more than 30%. The 2-year flood flows and mean annual flows of natural receiving waters should not deviate from pre-development flows by more than +100% and -30%.
- Leaching of Salts from Sand Caps - Microtopography will be designed in the form of ridges and swales to provide a mechanism for leaching salts.
- Regime Channel - The drainage systems will be designed to replicate natural channel regime relationships. These regime relationships include various channel parameters such as width, depth, width/depth ratio, meander wavelength, sinuosity, bed material, gradient and bank slope. Channels constructed in accordance with regime relationships based on natural channels will be subject to very slow values of erosion.
- No Side Hill Channels - Side hill channels that run parallel to contours will be excluded from the closure landscape. If a closure channel is aligned across the natural ground slope, a landform will be designed to ensure that overbank flow during flood events is conveyed along the preferred direction of flow rather than forming a new channel oriented along the natural ground fall line.
- Pit Lakes for Biodegradation - All drainage from disturbed areas that contain process-affected water will drain through a pit lake to bioremediate to safe and acceptable discharge standards before release to the natural environment.

# 3 HYDROLOGIC AND WIND DESIGN PARAMETERS

This section summarizes the methodology and results of the analyses related to flood hydrology and extreme wind estimates required for the design of the closure drainage systems. A detailed discussion of the methodology and results of the hydrologic analyses is presented in the Aquatics Environmental Setting Report (ESR) (Golder 2007).

Climatic variables analyzed in the ESR include air temperature, precipitation, evaporation and evapotranspiration, relative humidity, solar radiation and wind speed and direction. Sources of climatic data include historical records of the long-term monitoring stations operated by the Atmospheric Monitoring Division of Environment Canada, seasonal monitoring stations by Alberta Sustainable Resource Development (ASRD), short-term stations by the Regional Aquatics Monitoring Program (RAMP) and oil sands operators, and environmental setting field work conducted for the Project.

Hydrologic variables analyzed in the Aquatics ESR include stream flows, basin water yields, suspended sediments in streams, basin sediment yields and stream geomorphology. Sources of hydrologic data include records of the long-term monitoring stations operated by the Water Survey Division of Environment Canada, short-term monitoring stations by RAMP and environmental setting field work conducted for the Project. Site-specific stream geomorphic data were acquired and analyzed in and around the JEMA.

## 3.1 HYDROLOGIC ANALYSES

Detailed hydrologic analyses were conducted as part of the Surface Water Hydrology Environmental Setting Report (ESR) (Golder 2007). The analyses included a derivation of the climatic and hydrologic parameters to characterize the environmental setting in the study areas.

The simulated daily flows at various locations in the JEMA watersheds were analyzed to obtain the predevelopment mean and extreme flow parameters. Hydrologic modelling was conducted to derive simulated flow series for various types of reclaimed surfaces, which were analyzed to derive the hydrologic parameters for quantifying runoff characteristics of the reclaimed surfaces.

## 3.2 TYPES OF RECLAIMED LANDFORMS FOR CLOSURE

### 3.2.1 Landform Types

There are five principal types of reclaimed landforms planned for the JEMA as listed below:

- reclaimed ETDA, constructed above the original ground, that is constructed of TT, overburden and tailings sands at closure;
- reclaimed Non-Segregating Tailings (NST) capped with overburden materials in the mined-out pits;
- reclaimed plant site;
- reclaimed overburden disposal areas constructed above original ground; and
- pit lakes with Mature Fine Tailings (MFT) stored beneath a water cap.

### 3.2.2 In-Pit Tailings and Overburden Storage Areas

All of the mined-out pit cells, except for those to be used for creation of the pit lakes, will be used to store tailings or overburden. The tailings storage areas will be capped with overburden to raise the elevations of the final topography such that surface runoff will flow to pit lakes. Table 2 lists the average pit bottom and final ground or water surface elevations for Pit Cells 1 through 8.

**Table 2 In-Pit Non-Segregating Tailings**

| Pit Cell | Cell Storage Material | Average Pit Bottom Elevation [masl] | Average Final Surface Elevation [masl] | Average Height of Tailings Cell [m] |
|---|---|---|---|---|
| 1 | NST with overburden cap | 227 | 326 | 99 |
| 2 | NST with overburden cap | 238 | 328 | 90 |
| 3 | NST with overburden cap | 245 | 328 | 83 |
| 4 | NST with overburden cap | 237 | 330 | 93 |
| 5 | NST with overburden cap in west and overburden in east | 198 | 296 | 98 |
| 6 | NST with overburden cap in north and overburden in south | 239 | 303 | 64 |
| 7 | NST with overburden cap | 228 | 297 | 69 |

**Table 2 In-Pit Non-Segregating Tailings (continued)**

| Pit Cell | Cell Storage Material | Average Pit Bottom Elevation [masl] | Average Final Surface Elevation [masl] | Average Height of Tailings Cell [m] |
|---|---|---|---|---|
| 8 | NST with sand cap in north and overburden in south | 213 | 300 | 87 |

### 3.2.3 Reclaimed External Tailings Disposal Area

The ETDA in the Jackpine Mine – Phase 1 plan is extended in the closure drainage plan. The reclaimed ETDA-A will contain sand-capped TT in its western cell, and tailings sand only in its eastern cell. The MFT contained in the eastern cell during operations will be moved to a mine pit lake before closure. The average surface elevation will be about 375 masl (Table 3), about 55 m higher than the original ground on average. The average overland slope of the reclaimed ETDA-A surface is 0.5%.

The ETDA-B is located north of Kearl Lake. This disposal area consists of a tailings cell and will be built above the original ground level to an average elevation of 350 masl. This facility will store tailings sand. At closure, some material will be moved to the Jackpine North Central Pit Lake. The reclaimed surface will range from 320 to 340 masl with an average elevation of 337 masl.

The top surface and side slopes of the reclaimed ETDA-A and ETDA-B will be capped with a layer of reclamation surface soil composed of organic and mineral soil. The surface of the sand storage cell is expected to have a relatively high groundwater recharge rate and a relatively low potential for gullying after the establishment of mature vegetation.

The secondary drainage swells created on the reclaimed area will be characterized by relatively wet conditions, while the upland ridges created on the reclaimed area will be relatively dry. The sand storage cell will have relatively dry soil conditions capable of supporting upland vegetation. Lowland areas within the ETDA and in seepage zones around its perimeter will be covered with riparian scrublands and wetlands vegetation.

**Table 3 External Tailings Disposal Areas**

| ETDA Cell | Average Ground Elevation [masl] | Average Final Surface Elevation [masl] | Average Height of ETDA [m] |
|---|---|---|---|
| ETDA - A | 320 | 375 | 55 |
| ETDA - B | 298 | 337 | 39 |

### 3.2.4 Overburden Disposal Areas

Out-of-pit overburden disposal areas will be built above original ground level. Sides slopes will range from about 4H:1V to 10H:1V. These structures will be reclaimed with reclamation surface soil and subsoil as per the Closure, Conservation and Reclamation (C,C&R) Plan (Volume 5, Appendix 5-1). The reclaimed overburden disposal areas will be subject to relatively low surface water yield in the summer due to the high porosity of the reclamation soils and well-drained conditions of the relatively steep topography.

Table 4 lists the average bottom and surface elevations of the reclaimed out-of-pit overburden disposal areas. The top surfaces at these OBDAs will be crowned to encourage drainage to the edges or contoured to create secondary drainage systems with adequate drainage densities. The drainage channels at the out-of-pit overburden disposal areas will be mostly constructed of grass waterways.

**Table 4 Out-of-Pit Overburden Disposal Areas**

| Overburden Disposal Area | Average Ground Elevation [masl] | Average Final Surface Elevation [masl] | Average Height of OBDA [m] |
|---|---|---|---|
| west | 302 | 405 | 103 |
| east | 321 | 350 | 29 |
| Fort Hills | 295 | 330 | 35 |

### 3.2.5 Pit Lakes

Pit lakes are important features of the mine closure that provide important water quality benefits such as biodegradation of surface runoff and seepage waters that potentially include process-affected water from tailings materials. Water in pit lakes will receive treatment by dilution, biodegradation and settling before they are released to other watercourses. The pit lakes will be self-sustaining and eventually support a naturally diverse aquatic ecosystem.

Research on pit lakes and wetlands is ongoing, and key findings will continue to be incorporated in the pit lake design process. For example, related wetlands and pit lake work for CEMA (Golder 2006) is assisting in identifying key physical and chemical factors that will control the concentrations of dissolved substances in reclamation wetlands and pit lakes. These factors include surface area, depth, shape, surrounding landscape material, contributing water quantity and quality, as well as climate.

After the initial filling period of the pit lakes, water balance will be governed by surface runoff, direct precipitation, evaporation and groundwater inflows or outflows. The lakes would become highly saline (see Oil Sands End Pit Lake Review Document for CEMA End Pit Lakes Subgroup (Clearwater 2007) for effects of salinity on pit lakes) without sufficient surface inflows to compensate for evaporation losses and to provide for throughflow. Therefore, sufficient surface runoff will be routed through the pit lakes to provide for productive lakes in the closure landscape. The pit lakes will be equipped with a 10 m minimum freeboard to prevent overtopping in a flooding event.

Four waterbodies are proposed for JEMA at closure. They include the Jackpine North, Jackpine North Central, Jackpine South Central and Jackpine South pit lakes. The North Pit Lake is presented in Table 5 as two cells separated by a submerged dyke. Table 5 also lists the final normal water surface levels, final water depths for these waterbodies and the types of tailings to be stored under the water caps where applicable.

**Table 5 Pit Lakes**

| Pit Lake | Normal Lake Water Level [masl] | Average Water Cap Depth [m] | Materials on Lake Bottom |
|---|---|---|---|
| Jackpine North Central | 290 | 11 | MFT |
| Jackpine North Downstream Cell | 285 | 29 | no tailings deposit |
| Jackpine North Upstream Cell | 285 | 12 | MFT |
| Jackpine South | 303 | 15 | MFT |
| Jackpine South Central | 281 | 11 | MFT |

Note: MFT = Mature Fine Tailings.

## 3.3 HYDROLOGY OF RECLAIMED SURFACES

### 3.3.1 Hydrologic Modelling Analysis

The Hydrologic Simulation Program-Fortran (HSPF) model was used to simulate surface runoff from reclaimed surfaces and to route surface flows through channels and lakes. The HSPF model is a continuous simulation hydrologic model from the United States Environmental Protection Agency (U.S. EPA). It uses a combination of empirical and physically based relationships to predict runoff, evaporation and changes in soil moisture storage. This model can be used to simulate both rainfall runoff and snowmelt runoff.

The HSPF model was validated for the natural upland and lowland areas using recorded streamflow and water level data in the Muskeg River basin and other regional watersheds. The calibrated model parameters for the natural basins provided a basis for estimating the model parameters for the reclaimed surfaces. The estimation of these parameters was also based on a good understanding of the runoff processes of the reclaimed surfaces as described below.

**Overburden Disposal Areas:** The OBDAs are expected to have similar hydrologic characteristics as the natural upland areas in the upper Muskeg River watershed, because most of the overburden materials are a mixture of till, sands and gravel. However, long-term water yield and flood peak discharges of the overburden disposal areas, following establishment of equilibrium conditions, are expected to be somewhat greater than the natural upland areas because of steeper slopes and reduced surface soil storage capacities.

**In-Pit Non-Segregating Tailings Storage Areas:** The final surface elevations of most of the reclaimed in-pit storage areas will be close to or slightly above original ground levels. The relatively well-drained ridges at the sand-capped NST areas will have comparable runoff characteristics to the reclaimed out-of-pit overburden storage areas. However, the swales between the ridge areas will be very wet and have similar runoff characteristics as the natural lowland muskeg terrain. The swale areas will be underlain by sand to relieve elevated groundwater pressures and provide an outlet for any residual upward flux of NST porewater.

**External Tailings Disposal Area:** The TT cell in the ETDA area will be capped by sand that will be constructed by controlled spigotting to form a final surface consisting of a series of ridges and swales. The reclaimed surface will be characterized by wet conditions in the swales formed between the sand ridges, and drier conditions on the ridge tops. The hydrologic conditions in the swales are expected to be similar to lowland muskeg terrain, while hydrologic conditions on ridge tops are expected to be similar to natural upland areas. The areas at the periphery of the ETDA that are built of sand overburden on pervious foundation soils are also expected to be relatively dry and supportive of dry upland vegetation. Recharge to the groundwater from the TT cell is expected to be very small. A wetlands will be constructed at the outlet of Channel C1 to collect surface water from the ETDA-A.

**Topography:** Sand ridges are needed to provide suitable conditions to support upland vegetation. The high elevation of sand ridges will create hydraulic gradients that will provide well-drained soil conditions necessary for upland vegetation, particularly following initial reclamation when consolidation of tailings results in upward flux of tailings porewater. The ridges will enable early planting of upland vegetation so that the vegetation progression can begin upon mine closure, during a time when the upward flux of tailings porewater would otherwise cause most of the area to perform as wetlands.

The sand ridges and swales will be constructed to form a dendritic pattern of secondary drainage watercourses, with runoff flowing through the swales to main channels and wetlands at the outlet of the tailings area.

The wet areas of the sand cap tailings storage areas will be subject to relatively high evapotranspiration losses because of the greater available soil moisture. Consequently, the annual water yield and flood discharge characteristics of these areas are expected to be similar to the existing lowland muskeg terrain. Annual water yield of the reclaimed NST storage areas is expected to be greater than the natural lowland because of the smaller soil moisture storage capacity of reclamation soil and the presence of sand ridges that have similar runoff characteristics as natural sandy uplands.

The sand storage cell area will be composed of free-draining sandy subsoils. The sand material will limit the moisture storage in the surficial soils because any increase in soil moisture above field capacity will be lost to percolation through the free-draining sands. Without relatively impervious subsoil, this sandy cell will have less moisture available for evapotranspiration and surface runoff. The reduced evapotranspiration will result in increased interflow and deep percolation, which will report to surficial aquifer storage and seepage discharges to perimeter ditches and the toe of the out-of-pit storage areas and other receiving waterbodies.

**Shallow Wetlands:** Shallow wetlands will be built into the reclaimed landscape of the in-pit tailings disposal areas and the out-of-pit tailings area. The wetlands will attenuate flood peak discharges and provide for residence time that will improve drainage water quality through biological treatment and settling of suspended sediments. The wetlands areas are sized to occupy 5 to 10% of the contributing catchment area.

**Pit Lakes:** Pit lakes are important features of the closure landscape. They are beneficial for biodegradation of surface runoff from reclaimed areas, including tailings porewater and seepage inflows. They also contribute to the balance of dry and wet landscape in the reclaimed JEMA. Littoral zones occupying about 10 to 30% of the pit lake surface areas will be developed along the shores to provide for biological productivity.

The presence of pit lakes in the reclaimed landscape will reduce flood flows by providing lake storage for flow attenuation. However, the lakes will have a small reduction on the net annual water yield from the mine area due to evaporation losses from the lake surfaces.

### 3.3.2 Annual Runoff From Reclaimed Surfaces

The estimated annual water yields from the various types of reclaimed and natural surfaces are presented in Table 6 based on the analysis described in Section 3.3.1.

**Table 6 Estimated Annual Runoff From Natural and Reclaimed Surfaces**

| Land Type | Parameter | Annual Water Yields [mm][(a)(b)] | | | | |
|---|---|---|---|---|---|---|
| | | 100-Year Dry | 10-Year Dry | Mean | 10-Year Wet | 100-Year Wet |
| all land types | precipitation | 221 | 275 | 356 | 442 | 527 |
| natural upland (silt and clay sub-surface soil) | total runoff | 5 | 15 | 48 | 92 | 150 |
| | evapotranspiration | 216 | 260 | 308 | 350 | 377 |
| | surface runoff | 0 | 1 | 3 | 5 | 8 |
| | interflow runoff | 3 | 10 | 33 | 62 | 102 |
| | groundwater flow | 1 | 4 | 13 | 24 | 40 |
| | deep percolation loss | 0 | 0 | 0 | 0 | 0 |
| natural upland (silt, clay and sand sub-surface soil) | total runoff | 0 | 10 | 40 | 77 | 146 |
| | evapotranspiration | 221 | 265 | 316 | 365 | 377 |
| | surface runoff | 0 | 1 | 3 | 6 | 11 |
| | interflow runoff | 0 | 7 | 29 | 57 | 107 |
| | groundwater flow | 0 | 2 | 8 | 15 | 28 |
| | deep percolation loss | 0 | 0 | 0 | 0 | 0 |
| natural upland (sandy sub-surface soil) | total runoff | 20 | 36 | 76 | 125 | 194 |
| | evapotranspiration | 201 | 239 | 280 | 317 | 333 |
| | surface runoff | 0 | 0 | 1 | 1 | 2 |
| | interflow runoff | 4 | 8 | 17 | 27 | 43 |
| | groundwater flow | 16 | 28 | 59 | 97 | 150 |
| | deep percolation loss | 0 | 0 | 0 | 0 | 0 |
| natural lowland (silt and clay sub-surface soil) | total runoff | 0 | 1 | 24 | 50 | 101 |
| | evapotranspiration | 221 | 276 | 332 | 392 | 426 |
| | surface runoff | 0 | 0 | 2 | 3 | 7 |
| | interflow runoff | 0 | 1 | 17 | 37 | 74 |
| | groundwater flow | 0 | 0 | 5 | 10 | 20 |
| | deep percolation loss | 0 | 0 | 0 | 0 | 0 |

## Table 6 Estimated Annual Runoff From Natural and Reclaimed Surfaces (continued)

| Land Type | Parameter | Annual Water Yields [mm][(a)(b)] | | | | |
|---|---|---|---|---|---|---|
| | | 100-Year Dry | 10-Year Dry | Mean | 10-Year Wet | 100-Year Wet |
| natural lowland (silt, clay and sand sub-surface soil) | total runoff | 0 | 2 | 25 | 53 | 106 |
| | evapotranspiration | 221 | 275 | 331 | 389 | 421 |
| | surface runoff | 0 | 0 | 2 | 4 | 8 |
| | interflow runoff | 0 | 1 | 20 | 41 | 81 |
| | groundwater flow | 0 | 0 | 4 | 8 | 16 |
| | deep percolation loss | 0 | 0 | 0 | 0 | 0 |
| natural lowland (sandy sub-surface soil) | total runoff | 0 | 6 | 27 | 53 | 97 |
| | evapotranspiration | 221 | 269 | 329 | 389 | 430 |
| | surface runoff | 0 | 0 | 1 | 3 | 5 |
| | interflow runoff | 0 | 4 | 15 | 30 | 54 |
| | groundwater flow | 0 | 2 | 11 | 21 | 38 |
| | deep percolation loss | 0 | 0 | 0 | 0 | 0 |
| reclaimed NST with sand capping | total runoff | 20 | 40 | 86 | 143 | 215 |
| | evapotranspiration | 201 | 235 | 270 | 299 | 312 |
| | surface runoff | 1 | 2 | 4 | 6 | 9 |
| | interflow runoff | 8 | 16 | 34 | 57 | 85 |
| | groundwater flow | 11 | 22 | 48 | 80 | 121 |
| | deep percolation loss | 0 | 0 | 0 | 0 | 0 |
| reclaimed NST without sand capping | total runoff | 1 | 10 | 42 | 81 | 107 |
| | evapotranspiration | 220 | 265 | 314 | 361 | 420 |
| | surface runoff | 0 | 3 | 10 | 20 | 27 |
| | interflow runoff | 0 | 5 | 20 | 39 | 51 |
| | groundwater flow | 0 | 3 | 11 | 22 | 29 |
| | deep percolation loss | 0 | 0 | 0 | 0 | 0 |
| reclaimed overburden - silt and clay | total runoff | 3 | 19 | 62 | 115 | 161 |
| | evapotranspiration | 218 | 256 | 294 | 327 | 366 |
| | surface runoff | 1 | 6 | 21 | 38 | 53 |
| | interflow runoff | 1 | 10 | 34 | 62 | 87 |
| | groundwater flow | 0 | 2 | 8 | 15 | 20 |
| | deep percolation loss | 0 | 0 | 0 | 0 | 0 |
| reclaimed overburden - sand | total runoff | 26 | 47 | 94 | 150 | 217 |
| | evapotranspiration | 195 | 228 | 262 | 292 | 310 |
| | surface runoff | 5 | 8 | 16 | 26 | 38 |
| | interflow runoff | 6 | 11 | 22 | 36 | 52 |
| | groundwater flow | 15 | 27 | 55 | 88 | 127 |
| | deep percolation loss | 0 | 0 | 0 | 0 | 0 |
| reclaimed sand storage | total runoff | 33 | 54 | 104 | 164 | 235 |
| | evapotranspiration | 188 | 221 | 252 | 278 | 292 |
| | surface runoff | 1 | 2 | 4 | 6 | 8 |
| | interflow runoff | 11 | 18 | 34 | 54 | 77 |
| | groundwater flow | 21 | 34 | 66 | 104 | 149 |
| | deep percolation loss | 0 | 0 | 0 | 0 | 0 |

**Table 6 Estimated Annual Runoff From Natural and Reclaimed Surfaces (continued)**

| Land Type | Parameter | Annual Water Yields [mm][(a)(b)] | | | | |
|---|---|---|---|---|---|---|
| | | 100-Year Dry | 10-Year Dry | Mean | 10-Year Wet | 100-Year Wet |
| reclaimed plant site | total runoff | 17 | 36 | 84 | 143 | 221 |
| | evapotranspiration | 204 | 239 | 272 | 299 | 306 |
| | surface runoff | 14 | 31 | 71 | 121 | 187 |
| | interflow runoff | 2 | 4 | 10 | 18 | 27 |
| | groundwater flow | 1 | 1 | 3 | 5 | 7 |
| | deep percolation loss | 0 | 0 | 0 | 0 | 0 |
| lake | evaporation | 686 | 645 | 594 | 542 | 498 |

(a) Based on the simulation between 1954 and 2006, assuming precipitation at Fort McMurray Airport, corrected to estimated local elevation (350 masl), was applied to all land types.

(b) Frequency analyses were applied to 53 years of annual precipitations, lake evaporations and simulated runoffs independently.

Note: NST = Non-Segregating Tailings.

### 3.3.3 Flood Peak Discharges From Reclaimed Surfaces

The simulated flows from the HSPF model were analyzed to determine flood peak discharges from reclaimed surfaces. The resulting flood flow parameters provided a basis for designing the closure reclamation drainage systems. Table 7 presents the derived flood peak discharges for each main channel shown in Figure 2. The Probable Maximum Flood (PMF) peak discharges were assumed to be about ten times of the 100-year flood flow. This approach is consistent with other closure drainage plans produced for the Oil Sands Region.

**Table 7 Summary of Flood Peak Discharges for Main Drainage Channels**

| Channel | Drainage Area [$km^2$] | Flood Peak Discharges [$m^3/s$] | | | |
|---|---|---|---|---|---|
| | | 2-Year Flood | 10-Year Flood | 100-Year Flood | PMF |
| C1 | 13.7 | 0.43 | 1.07 | 2.37 | 24.4 |
| C2 | 61.5 | 1.72 | 4.85 | 6.59 | 67.9 |
| C3 | 72.9 | 1.59 | 4.36 | 8.43 | 86.8 |
| C4 | 95.6 | 1.14 | 3.38 | 5.87 | 60.5 |
| C5 | 278 | 2.73 | 7.24 | 16.0 | 165 |
| C6 | 21.4 | 1.18 | 2.54 | 4.69 | 48.3 |
| C7 | 11.7 | 0.33 | 0.78 | 1.98 | 20.4 |
| C8 | 105 | 2.37 | 4.84 | 8.24 | 84.9 |
| C9 | 231 | 2.23 | 4.72 | 8.00 | 82.4 |
| C10 | 62.7 | 0.72 | 1.81 | 2.98 | 30.7 |
| C11 | 478 | 2.68 | 6.14 | 11.0 | 113 |
| C12 | 26.6 | 0.72 | 1.42 | 2.27 | 23.4 |

## 3.4 DESIGN WIND PARAMETERS

Design wind parameters for the JEMA development area were required to provide a basis for designing shoreline protection for the pit lakes. The available wind data at the Aurora Climate Station and other nearby climate stations have short periods of record.

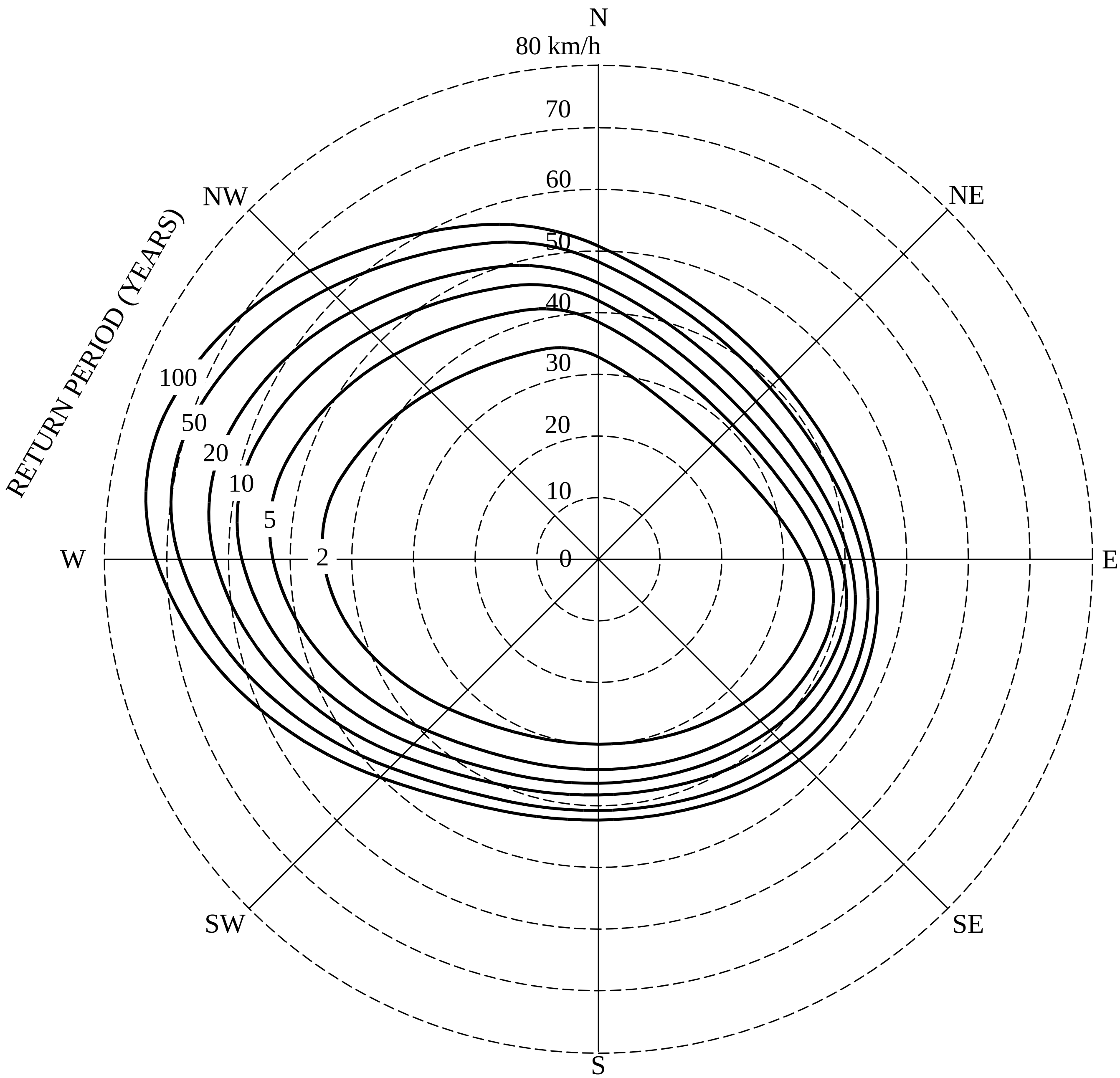
However, reliable wind design parameters require a long period of record and therefore the long-term (1959 to 2002) hourly wind data recorded at the Fort McMurray Airport Climate Station were used to derive the design wind parameters for the JEMA development area. However, the long-term wind characteristics at the Fort McMurray Airport Climate Station are expected to be different from the JEMA development area due to the differences in topographic features including elevation and surrounding landscape. This may introduce some uncertainty to the derived design wind parameters at the site but the accuracy is considered adequate for this stage of analysis and concept design.

Table 8 and Figure 3 present the derived design wind parameters for various return periods and for various directions. They show that the extreme winds from the west and northwest directions are stronger than the extremes from any other directions. The extreme hourly 100-year wind speed from the west and northwest directions are 71.6 and 65.7 km/hr, respectively.

**Table 8 Frequency Analysis of Extreme Hourly Wind Speeds at Fort McMurray Airport**

| Wind Direction From | Extreme Hourly Wind Speeds[(a)] [km/hr] | | |
|---|---|---|---|
| | 2-Year | 10-Year | 100-Year |
| north | 32.9 | 41.8 | 50.8 |
| northeast | 26.0 | 33.4 | 41.6 |
| east | 33.4 | 38.9 | 44.6 |
| southeast | 32.6 | 39.5 | 45.7 |
| south | 30.0 | 36.2 | 42.3 |
| southwest | 34.2 | 42.3 | 49.9 |
| west | 44.6 | 57.6 | 71.6 |
| northwest | 38.2 | 51.8 | 65.7 |

(a) Based on the data recorded at the Fort McMurray Airport from 1959 to 2006.




## NOTES

1. BASED ON DATA AT THE FORT McMURRAY AIRPORT CLIMATE STATION FROM 1959 TO 2006.

2. INTERPOLATE ALONG MAIN DIRECTIONS.

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

**FREQUENCY ANALYSIS OF EXTREME HOURLY WIND SPEEDS AT FORT McMURRAY AIRPORT CLIMATE STATION**

**Shell Canada Limited**

| | | | | |
|---|---|---|---|---|
| PRO | 06-1346-022.9500 | | FILE No. | Wind Speeds |
| DESIGN | FLA | 26/09/07 | SCALE NA | REV. 0 |
| CADD | TRE | 26/09/07 | | |
| CHECK | FLA | 27/09/07 | **FIGURE: 3** | |
| REVIEW | WES/TC | 28/11/07 | | |

L:\2006\1344-OIL SANDS\1346\06-1346-022 Shell\9500\9530\CLOSURE DRAINAGE DESIGN\ Drawing file: Fig 3_ Hourly Wind Speeds-McM-Airport.dwg Dec 07, 2007 - 12:55pm

# 4 DESIGN OF RECLAMATION DRAINAGE SYSTEMS

## 4.1 GENERAL DRAINAGE SCHEME

The layout of the proposed closure drainage systems is shown in Figure 2. The figure shows the main and secondary drainage systems and the reclamation topography at the JEMA development area. Figure 2 also shows that the closure drainage system for the JEMA has been integrated with the closure drainage systems for the Kearl Oil Sands Project and the Aurora South Mine. The integrated closure drainage plan for the JEMA has been designed with a capacity to handle both the local runoff from the JEMA along with the routed outflows from the two adjacent closure drainage systems.

## 4.2 MAIN DRAINAGE SYSTEMS

### 4.2.1 Jackpine South Central Pit Lake Drainage System

As shown in Figure 2, the drainage route to the Jackpine South Central Pit Lake starts by collecting runoff from the ETDA-A via Channel C1, which exits at an elevation of 355 masl and then drains northbound through an overburden dump (East OBDA), until it reaches the northwestern tip of a wetlands area at 320 masl. Its total length is 11 km. The recipient wetlands area also acts as a drainage collector for runoff from Cells 1 through 4 and from the Syncrude West Pit Lake. The wetlands area drains into a 3 km Channel C2 at its south-easterly end, from where it flows into Jackpine South Pit Lake. This drainage system will collect and convey surface runoff from the tailings cells, the West OBDA and the ETDA-A as well as upward flux of porewater due to NST consolidation from backfilled mine pits. The outlet channel C3 flows into Jackpine South Central Pit Lake across the reclaimed ore preparation area. Jackpine South Central Pit Lake is discharged to the Muskeg River via Channel C4.

Channel C1 will be built on overburden material on top of tailings. Channel C2 will be built on natural ground at the reclaimed plant site. Outflows from Jackpine South Pit Lake will drain into Jackpine South Central Pit Lake via Channel C3. Channel C3 is about 2 km in length and it is built in overburden material on top of tailings. Finally, Jackpine South Central Pit Lake is discharged into the Muskeg River through Channel C4, which was designed primarily as the lake outlet with a short stretch of about 200 m in length before it joins the Muskeg River.

Channel C4 will be built on natural ground. The valley slope for the main channel varies between 0.1 and 1.0% in Channels C1 through C4. The proposed channels have shallow depths to accommodate the small annual water yield, and large floodplains to accommodate flood flows.

Figure 4 presents the designs of the main drainage channels for the Jackpine South Central Pit Lake drainage system (Channels C1 through C4) and shows the plans of the channel alignment, profiles and a summary of the channel design parameters. The channels' width, depth, meander wavelength and sinuosity (channel length to valley length ratio) were designed based on the regime equations and Manning's equation described in Section 2.

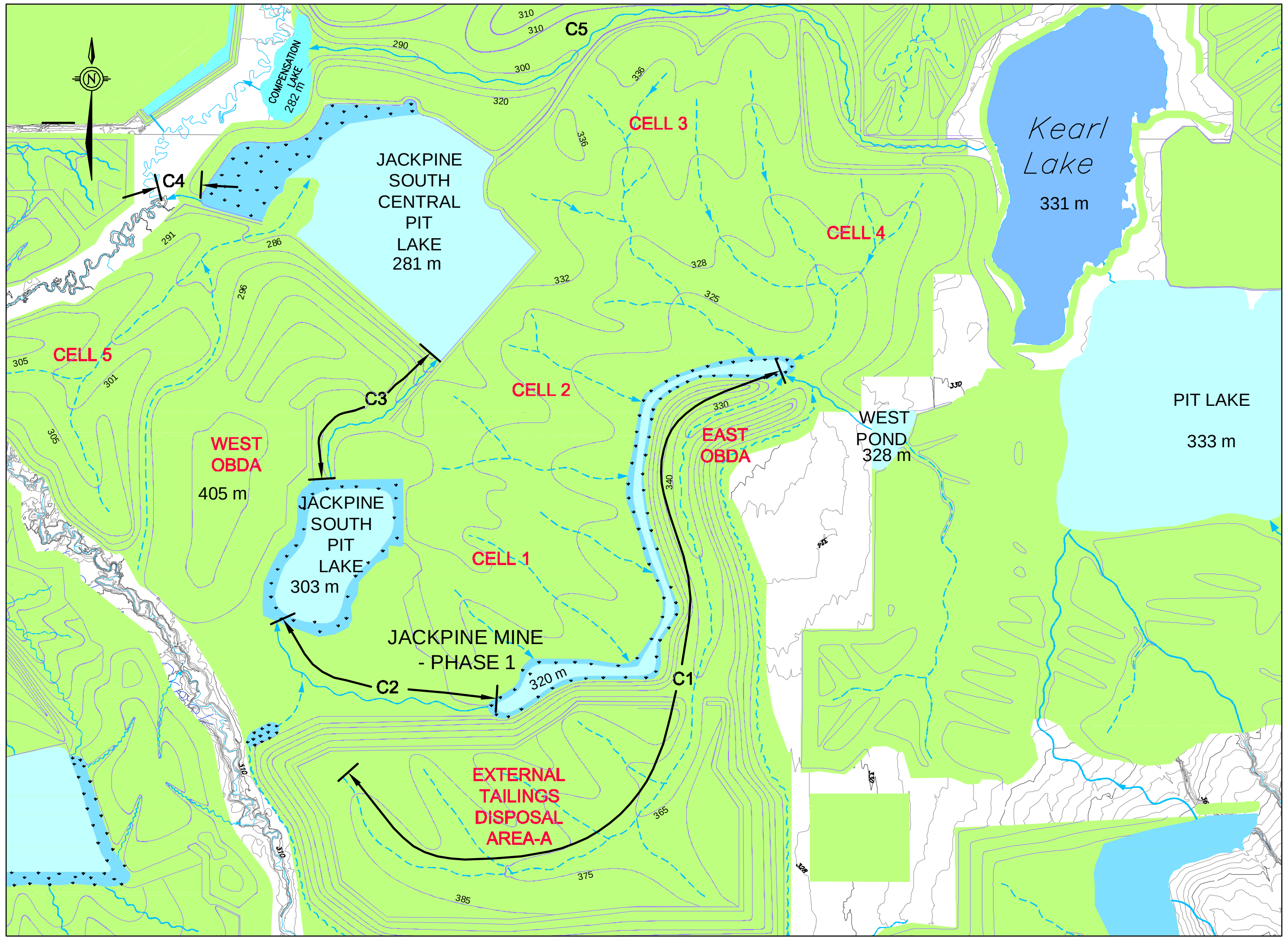
Channel design follows the natural analogues, with three typical cross-sections shown in Figure 5. These three cross-sections represent the channel at its straight segment and meander benders. As in natural water courses, straight segments are rare and short. Most of the channel segments have unequal side slopes ranging from 1H:1V on the steep side to 6H:1V on the mildly-sloped opposite side where the eroded channel bed material is deposited. The design side slopes of 3H:1V shown in the design tables on the figures should therefore be understood as the average of the left and right channel side slopes.

The valley slope for the main channel varies between 0.5% and 0.6% in C1, C2 and C4 to 1.1% in C3. Typical values for channel sinuosity are 1.3. The proposed channels have shallow depths to suit the small annual water yield and larger floodplains to accommodate larger flood flows. The average channel depth is 0.5 m.

The west OBDA is located between Cell 5 and Jackpine South Pit Lake. Its drainage does not require design of any drainage channels because surface runoff can be transmitted to the toe of the OBDA by sheet flow with no channelization. A perimeter ditch will collect drainage from the West OBDA on its northwesterly side. This perimeter ditch would eventually form part of the drainage of Cell 5, while the southeasterly perimeter ditch was not required due to the close proximity of Jackpine South Pit Lake. This overburden disposal area will act as a permanent and self-sustaining barrier to prevent side hill diversion and possible re-routing of Channel C3 due to possible blockage of the drainage channel by debris, beaver dams or mud slides.

## PLAN OF DRAINAGE SYSTEM INTO JACKPINE SOUTH PIT LAKE AND JACKPINE SOUTH CENTRAL PIT LAKE

1.5 0 1.5
SCALE KILOMETRES



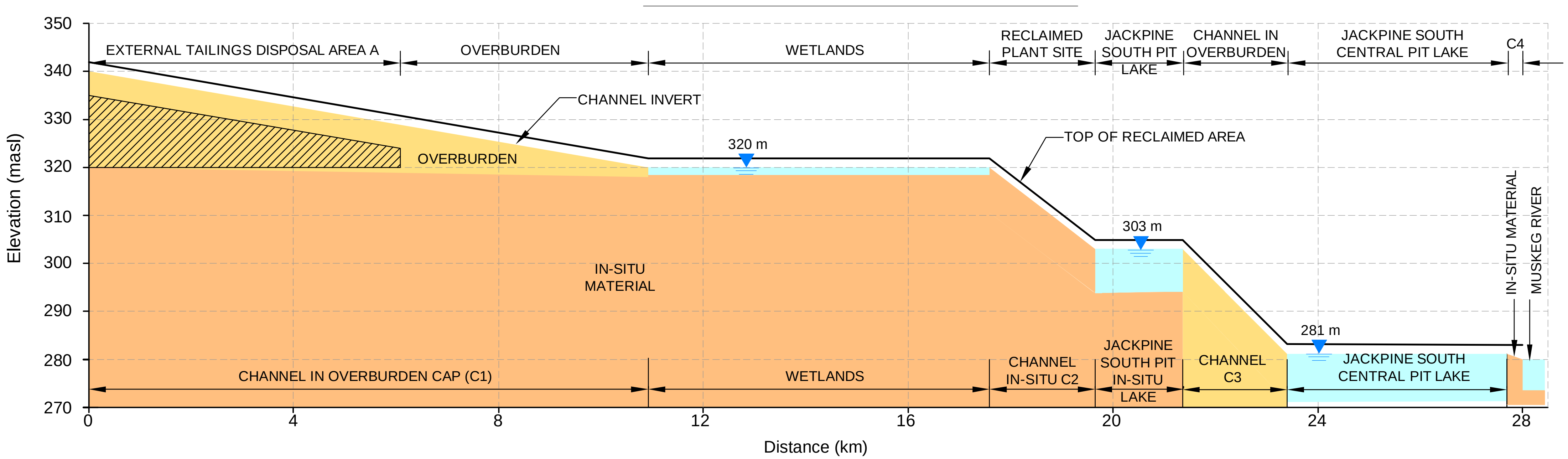

LEGEND

- Existing Contour
- Final Reclaimed Surface Contour
- Main Channel
- Secondary Channel
- Wetlands and Littoral Zone
- Reclaimed Surface
- Lake
- In-Situ Material
- Overburden
- Tailings

### SUMMARY OF CHANNEL DESIGN PARAMETERS

| Distance [m] | Channel | Drainage Area [km²] | Mean Annual Flow [m³/s] | Return Period [years] | Peak Flow [m³/s] | Assumed Bed Material | Channel Bed Slope | Valley Slope | Channel Side Slope [H:V] | Channel Sinuosity | Recommended Bottom Width Wc [m] | Main Channel Depth [m] | Channel Flow Depth [m] | Channel Flow Velocity [m/s] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10800 | C1 | 13.74 | 0.06 | 2 | 0.43 | Overburden | 0.0050 | 0.0060 | 3 | 1.2 | 1 | 0.3 | 0.32 | 0.70 |
| | | | | 10 | 1.07 | | | | | | | | 0.49 | 0.89 |
| | | | | 100 | 2.37 | | | | | | | | 0.70 | 1.10 |
| | | | | PMF | 24.4 | | | | | | | | 1.22 | 1.97 |
| 3000 | C2 | 61.53 | 0.18 | 2 | 1.72 | In-Situ | 0.0044 | 0.0057 | 3 | 1.3 | 2 | 0.5 | 0.52 | 0.93 |
| | | | | 10 | 4.85 | | | | | | | | 0.86 | 1.23 |
| | | | | 100 | 6.59 | | | | | | | | 0.99 | 1.34 |
| | | | | PMF | 67.9 | | | | | | | | 1.78 | 2.42 |
| 2000 | C3 | 72.94 | 0.22 | 2 | 1.59 | Overburden | 0.0079 | 0.0110 | 3 | 1.4 | 4 | 0.4 | 0.31 | 1.03 |
| | | | | 10 | 4.36 | | | | | | | | 0.55 | 1.41 |
| | | | | 100 | 8.43 | | | | | | | | 0.78 | 1.71 |
| | | | | PMF | 86.8 | | | | | | | | 1.57 | 3.19 |
| 300 | C4 | 95.57 | 0.25 | 2 | 1.14 | In-Situ | 0.0038 | 0.0050 | 3 | 1.3 | 3 | 0.4 | 0.37 | 0.76 |
| | | | | 10 | 3.38 | | | | | | | | 0.65 | 1.05 |
| | | | | 100 | 5.87 | | | | | | | | 0.86 | 1.22 |
| | | | | PMF | 60.5 | | | | | | | | 2.53 | 2.88 |

## PROFILE OF MAIN DRAINAGE CHANNELS C1 THROUGH C4

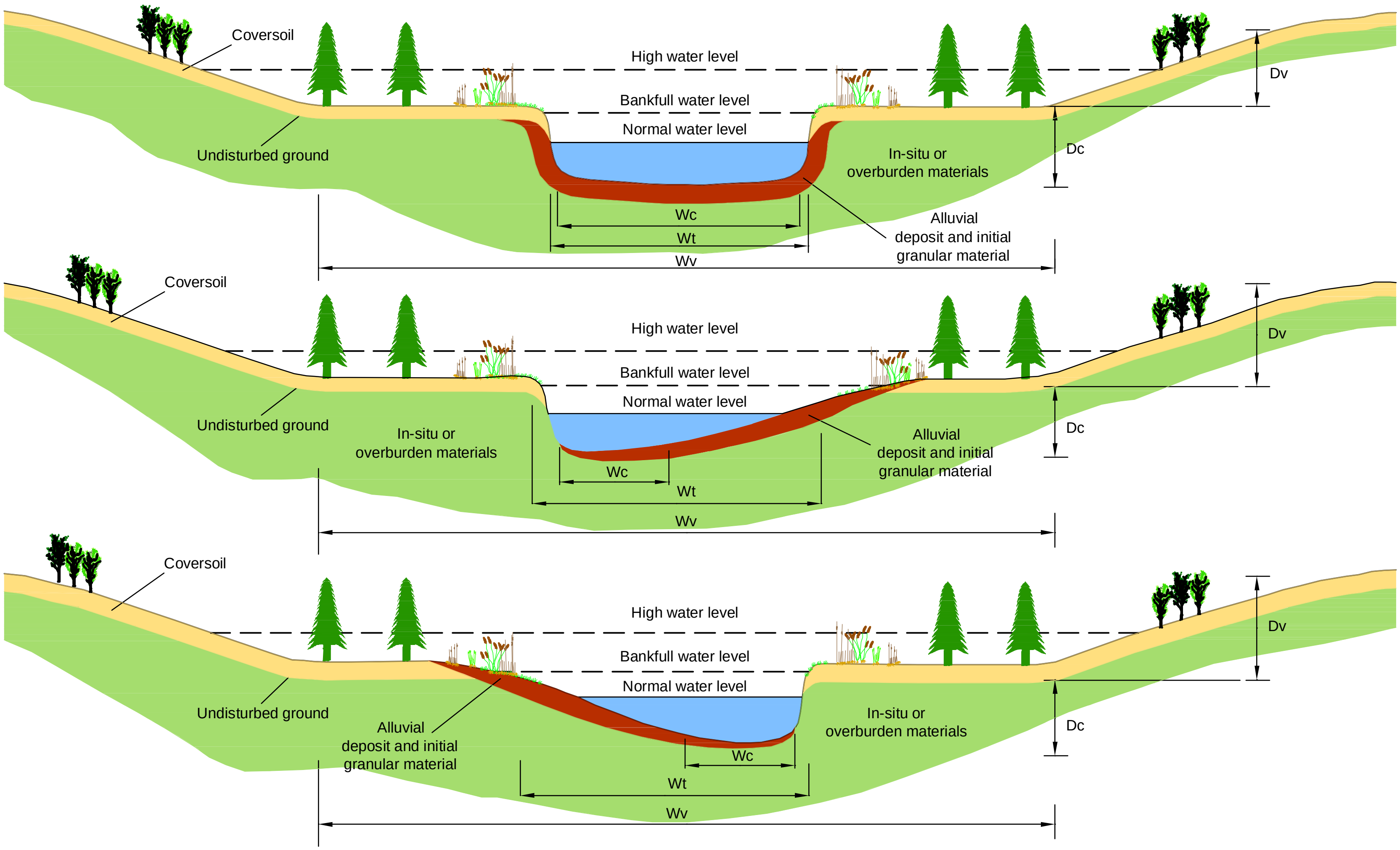



PROJECT
JACKPINE MINE EXPANSION & PIERRE RIVER MINE PROJECT

TITLE
# JACKPINE SOUTH CENTRAL PIT LAKE DRAINAGE SYSTEM

Shell Canada Limited

| PROJECT 06–1346–022.9500 | | FILE No. Pit Lake 1–2 | |
|---|---|---|---|
| DESIGN | FLA | 26/09/07 | SCALE AS SHOWN REV. 0 |
| CADD | TRE | 08/11/07 | |
| CHECK | FLA | 27/09/07 | FIGURE: 4 |
| REVIEW | WES/TC | 28/11/07 | |




LEGEND

| | |
|---|---|
| Wc | Channel bottom width |
| Wt | Top channel width |
| Wv | Valley width (50 to 100 m) |
| Dc | Channel depth |
| Dv | Valley depth |

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

**TYPICAL CROSS-SECTIONS OF CLOSURE DRAINAGE CHANNELS**

**Shell Canada Limited**

| | | | |
|---|---|---|---|
| PROJECT 06-1346-022.9500 | | | FILE No. Typical X-Section |
| DESIGN | EK | 24/09/07 | SCALE AS SHOWN REV. 0 |
| CADD | PSR | 11/10/07 | **FIGURE: 5** |
| CHECK | FLA | 11/10/07 | |
| REVIEW | WES/TC | 28/11/07 | |

### 4.2.2 Kearl Lake Drainage System

The drainage system into Kearl Lake includes outflows from the Aurora South Mine pit lake. This pit lake also receives drainage from the upland areas of Iyinimin and Wesukemina creeks. The total drainage at the outlet of Kearl Lake is 278 $km^2$.

Channel C5 conveys flows from Kearl Lake to the Muskeg River through the Jackpine Mine Compensation Lake, located 8 km to the east of Kearl Lake and near the eastern banks of the Muskeg River. Channel C5 is built in overburden, with average valley slope of 0.5%. The channel design parameters are given in Figure 6.

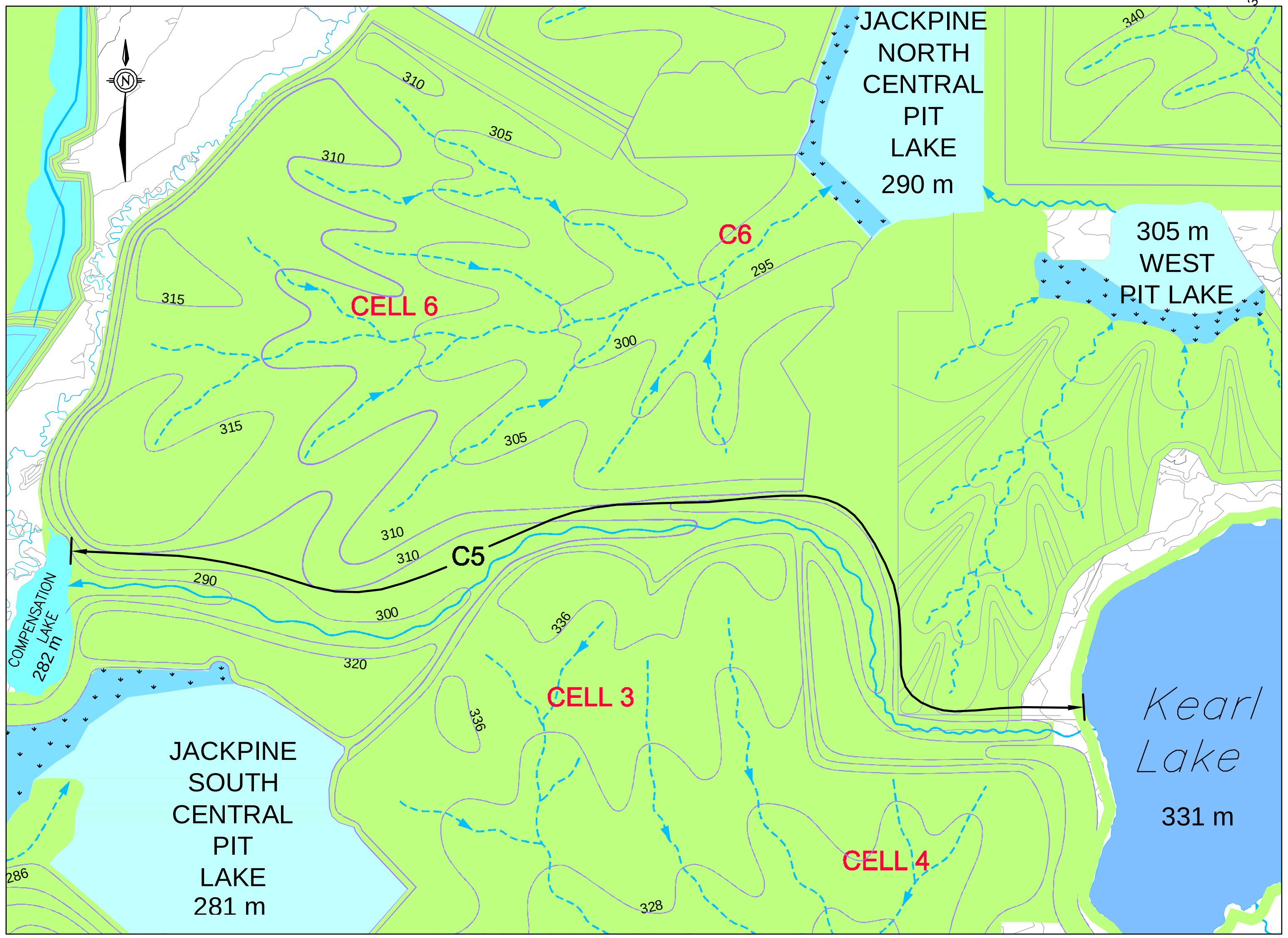
An alternative route was considered for drainage of Kearl Lake, draining outflows from Kearl Lake into the north end of the wetlands area located west of East OBDA. Despite lower costs of aiding flow capacity to Channels C2, C3 and C4 (as opposed to building a separate Channel C5 reserved exclusively for drainage of the Kearl Lake outflows), this route would be unable to sustain sufficient fresh water inflows into the Jackpine Mine Compensation Lake.

### 4.2.3 Jackpine North Pit Lake Drainage System

The Jackpine North Pit Lake is a large waterbody in the northern portion of the development area. The pit lake is separated into two cells by a submerged dyke and distinguished by different water depths which are 12 and 29 m for the upstream and downstream cells, respectively. The drainage system includes reclaimed Cells 6 and 7, which jointly drain into Jackpine North Central Pit Lake, along with the outflow from the West Pit Lake from the Kearl Oil Sands Project. Channel C10 routes outflows from the Jackpine North Central Pit Lake to the Jackpine North Pit Lake.

The ETDA-B drains in the southeasterly direction via Channel C7 which then turns in the northwesterly direction to join Channel C8 which also routes outflows from the West Central Pit Lake from the Kearl Oil Sands Project. Additional inflow into Jackpine North Pit Lake originates from the outflow of the North Pit Lake (Kearl Oil Sands Project) which is routed through Channel C9, and the two overburden dumps (Fort Hills OBDA and the in-pit OBDA) located at the north and west ends of the Jackpine North Pit Lake. Outflows from this pit lake are routed into the existing Muskeg River channel. Channels C6 through C10 are all built in overburden sand cap. The northern portion of Cell 8 is filled entirely with overburden material. Average valley slopes for all channels are 0.5%. The channel design parameters are given in Figure 7.

## PLAN OF KEARL LAKE OUTLET CHANNEL



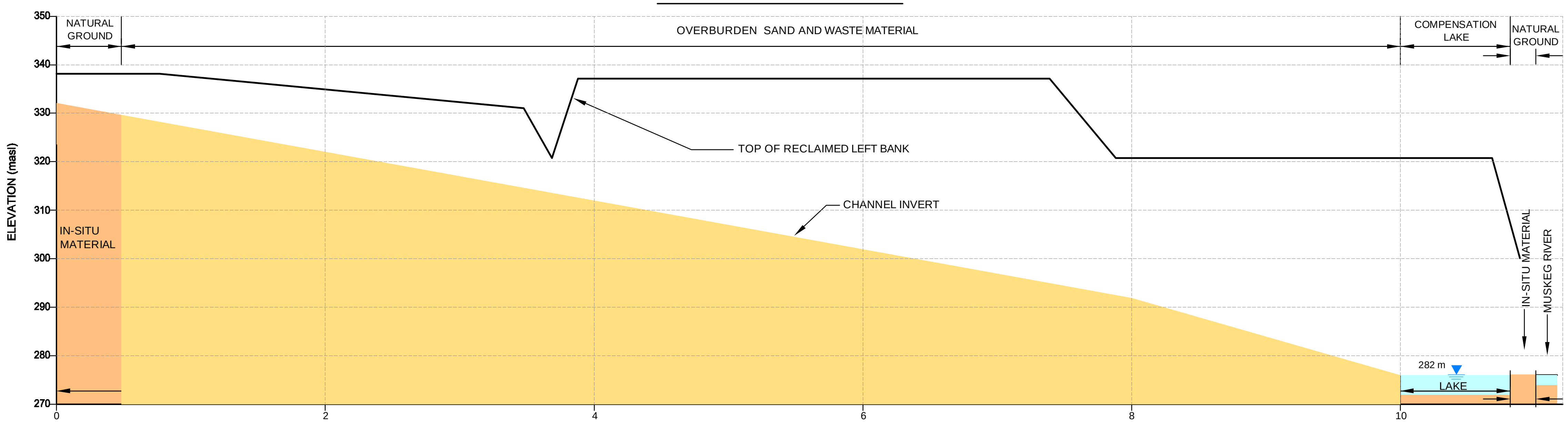

LEGEND

- Existing Contour
- Final Reclaimed Surface Contour
- Main Channel
- Secondary Channel
- Wetlands and Littoral Zone
- Reclaimed Surface
- Lake
- In-Situ Material
- Overburden
- Lake Perimeter Levee

### SUMMARY OF CHANNEL DESIGN PARAMETERS

| Distance [m] | Channel | Drainage Area [$km^2$] | Mean Annual Flow [$m^3/s$] | Return Period [years] | Peak Flow [$m^3/s$] | Assumed Bed Material | Channel Bed Slope | Valley Slope | Channel Side Slope [H:V] | Channel Sinuosity | Recommended Bottom Width Wc [m] | Main Channel Depth [m] | Channel Flow Depth [m] | Channel Flow Velocity [m/s] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10000 | C5 | 278.26 | 0.9 | 2 | 2.73 | Overburden | 0.0038 | 0.0049 | 3 | 1.3 | 4 | 0.5 | 0.52 | 0.95 |
| | | | | 10 | 7.24 | | | | | | | | 0.87 | 1.26 |
| | | | | 100 | 15.98 | | | | | | | | 1.30 | 1.56 |
| | | | | PMF | 164.6 | | | | | | | | 1.42 | 2.09 |

## PROFILE DRAINAGE CHANNEL C5




PROJECT

JACKPINE MINE EXPANSION & PIERRE RIVER MINE PROJECT

TITLE

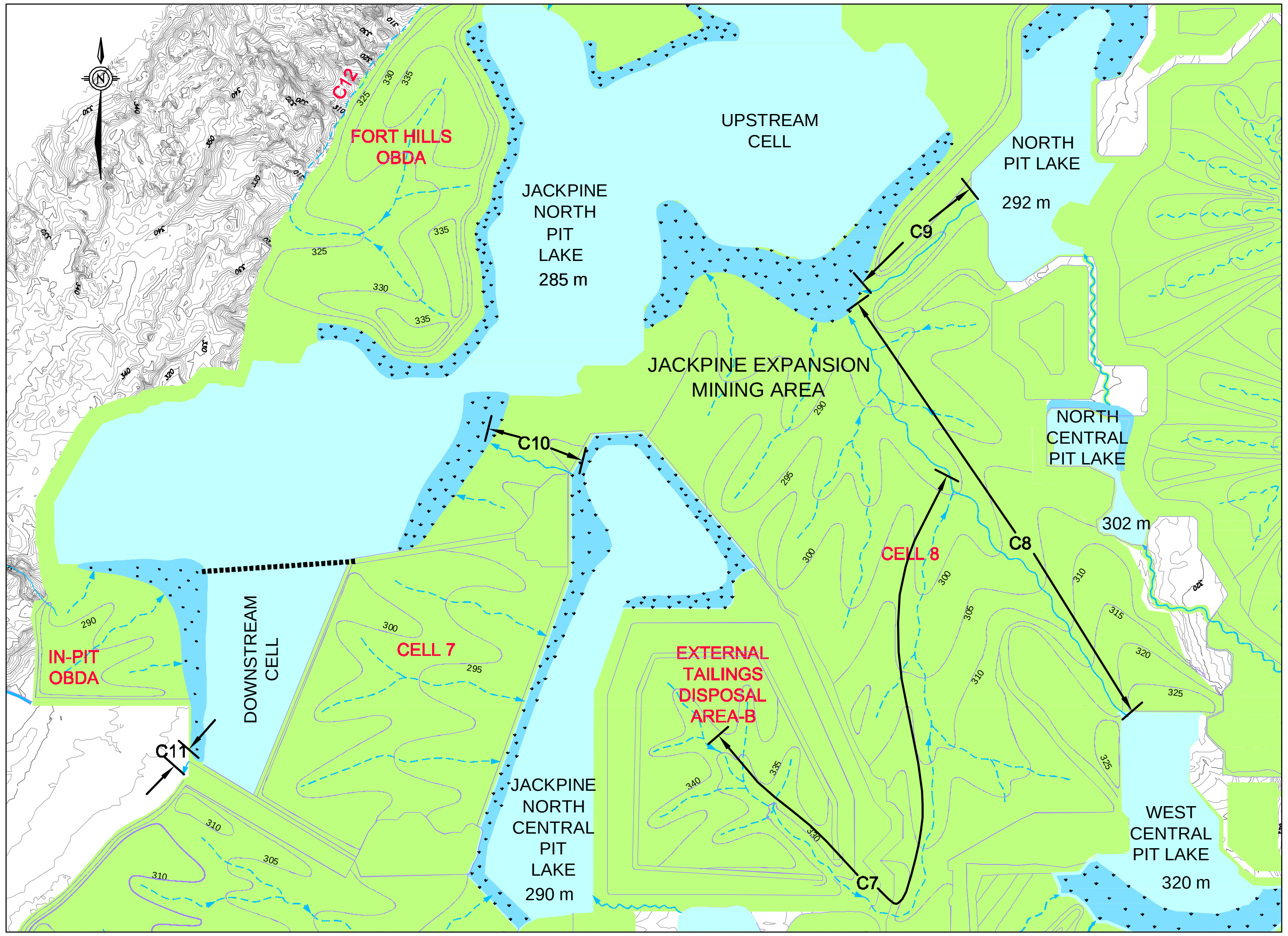
**KEARL LAKE OUTLET CHANNEL**

Shell Canada Limited

| PROJECT 06–1346–022.9500 | | | FILE No. | Kearl Lake | |
|---|---|---|---|---|---|
| DESIGN | FLA | 26/09/07 | SCALE | AS SHOWN | REV. 0 |
| CADD | TRE | 18/10/07 | | | |
| CHECK | FLA | 27/09/07 | FIGURE: 6 | | |
| REVIEW | WES/TC | 28/11/07 | | | |

L:\2006\1344–OIL SANDS\1346\06–1346–022 Shell\9500\9530\CLOSURE DRAINAGE DESIGN\Fig 6_Kearl Lake Drainage System _Plan.dwg Dec 08, 2007 – 12:31pm

## PLAN OF DRAINAGE SYSTEM INTO JACKPINE NORTH PIT LAKE



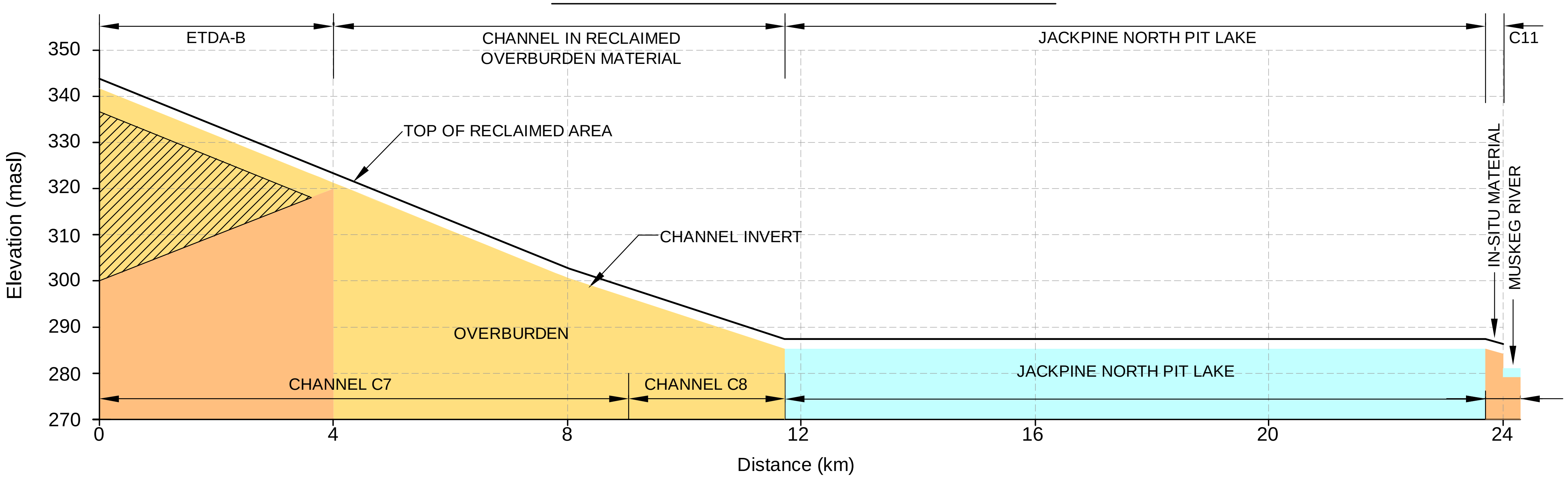

LEGEND

- Existing Contour
- Final Reclaimed Surface Contour
- Main Channel
- Secondary Channel
- Wetlands and Littoral Zone
- Reclaimed Surface
- Lake
- In-Situ Material
- Overburden Sand
- Submerged Dyke
- Tailings

### SUMMARY OF CHANNEL DESIGN PARAMETERS

| Distance [m] | Channel | Drainage Area [km²] | Mean Annual Flow [m³/s] | Return Period [years] | Peak Flow [m³/s] | Assumed Bed Material | Channel Bed Slope | Valley Slope | Channel Side Slope [H:V] | Channel Sinuosity | Recommended Bottom Width Wc [m] | Main Channel Depth [m] | Channel Flow Depth [m] | Channel Flow Velocity [m/s] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9200 | C7 | 11.66 | 0.05 | 2 | 0.33 | Overburden | 0.0038 | 0.0050 | 3 | 1.3 | 1 | 0.3 | 0.30 | 0.59 |
| | | | | 10 | 0.78 | | | | | | | | 0.45 | 0.74 |
| | | | | 100 | 1.98 | | | | | | | | 0.68 | 0.95 |
| | | | | PMF | 20.4 | | | | | | | | 1.19 | 1.71 |
| 6000 | C8 | 104.79 | 0.36 | 2 | 2.37 | Overburden | 0.0045 | 0.0058 | 3 | 1.3 | 3 | 0.7 | 0.52 | 1.00 |
| | | | | 10 | 4.84 | | | | | | | | 0.75 | 1.22 |
| | | | | 100 | 8.24 | | | | | | | | 0.98 | 1.41 |
| | | | | PMF | 84.9 | | | | | | | | 1.85 | 2.58 |
| 1700 | C9 | 231.27 | 0.71 | 2 | 2.23 | Overburden | 0.0029 | 0.0041 | 3 | 1.4 | 4 | 0.5 | 0.38 | 1.15 |
| | | | | 10 | 4.72 | | | | | | | | 0.57 | 1.44 |
| | | | | 100 | 8 | | | | | | | | 0.76 | 1.68 |
| | | | | PMF | 82.4 | | | | | | | | 1.54 | 3.14 |
| 1000 | C10 | 62.68 | 0.17 | 2 | 0.72 | Overburden | 0.0036 | 0.0050 | 3 | 1.4 | 2 | 0.3 | 0.35 | 0.68 |
| | | | | 10 | 1.81 | | | | | | | | 0.56 | 0.88 |
| | | | | 100 | 2.98 | | | | | | | | 0.71 | 1.01 |
| | | | | PMF | 30.7 | | | | | | | | 1.33 | 1.84 |
| 7300 | C11 | 477.67 | 1.17 | 2 | 2.68 | In-Situ | 0.0004 | 0.0010 | 3 | 2.4 | 4 | 0.6 | 0.92 | 0.43 |
| | | | | 10 | 6.14 | | | | | | | | 1.39 | 0.54 |
| | | | | 100 | 10.96 | | | | | | | | 1.84 | 0.63 |
| | | | | PMF | 112.9 | | | | | | | | 3.33 | 1.14 |
| 7700 | C12 | 26.63 | 0.06 | 2 | 0.72 | Overburden and In-Situ | 0.0050 | 0.0070 | 3 | 1.4 | 2 | 0.3 | 0.32 | 0.77 |
| | | | | 10 | 1.42 | | | | | | | | 0.45 | 0.93 |
| | | | | 100 | 2.27 | | | | | | | | 0.58 | 1.06 |
| | | | | PMF | 23.4 | | | | | | | | 1.10 | 1.94 |

## PROFILE OF JACKPINE NORTH PIT LAKE MAIN DRAINAGE CHANNEL




PROJECT
JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE
**JACKPINE NORTH PIT LAKE DRAINAGE SYSTEM**

**Shell Canada Limited**

| PROJECT 06-1346-022.9500 | | | FILE No. Pit Lks 4&5 |
|---|---|---|---|
| DESIGN | FLA | 26/09/07 | SCALE AS SHOWN / REV. 0 |
| CADD | TRE | 08/11/07 | |
| CHECK | FLA | 27/09/07 | **FIGURE: 7** |
| REVIEW | WES/TC | 28/11/07 | |

L:\2006\1346\06-1346-022 Shell\9500\9530\CLOSURE DRAINAGE DESIGN\Fig 7_Drainage System -Pit Lakes 4_5_Plan.dwg Dec 08, 2007 - 12:38pm

Reclaimed drainage areas to the Jackpine North Pit Lake are constrained by the Muskeg River valley to the west and by the outflows from the Kearl Oil Sands Project to the east. The natural gradient of the proposed JEMA development has a northwesterly orientation. These constraints have severely limited the choice of viable alternative routes.

## 4.3 PROPOSED SECONDARY DRAINAGE SYSTEMS

The reclaimed Cells 1 through 8 will have similar microtopography within the secondary drainage system to encourage positive flow toward the primary drainage system. These secondary systems will develop on a network of sand trenches placed between blocks of overburden materials. The sand trenches are needed to provide for release of residual NST porewater during NST consolidation. The secondary drainage channels are expected to form naturally in these trenches as surface runoff flows to these low-lying areas.

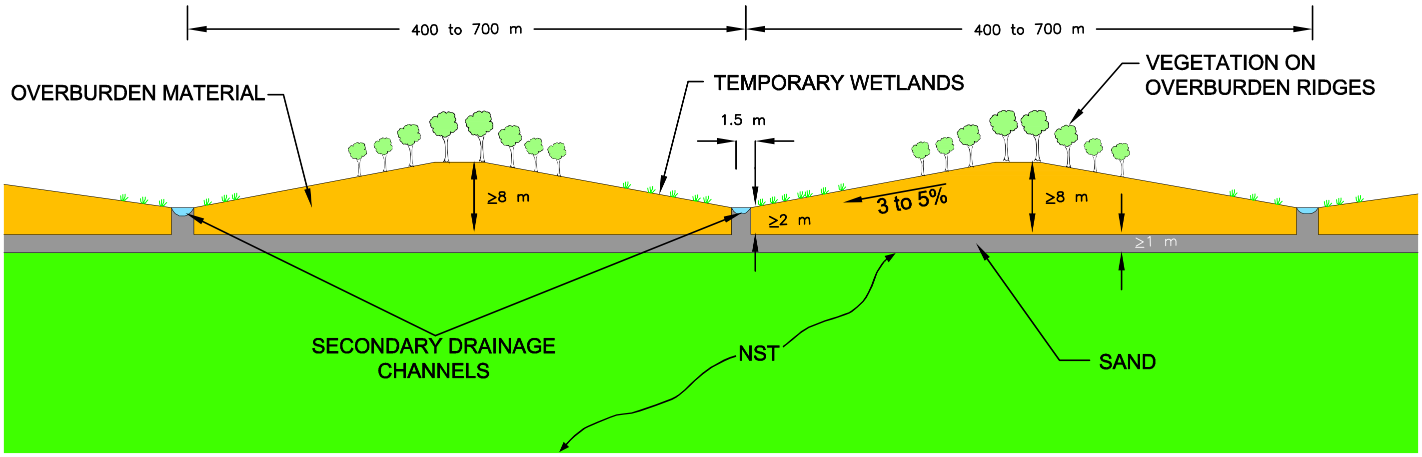
Figure 8 presents a schematic layout of the proposed secondary drainage systems. The systems consist of overburden sand ridges, swales and wetlands. A system of ridges will be developed by controlled placement of the overburden sand materials. This configuration will enhance leaching of the salts from the overburden, which may be naturally present or may result from the upward flux of NST consolidation.

The ridges will be designed to be 8 m high with top widths ranging from 50 to 150 m and side slopes of 3 to 5%. The typical spacing of the ridges ranges from 400 to 700 m. The bottom width of the sand trenches will be about 1.5 m and the side slopes will be 3H:1V.

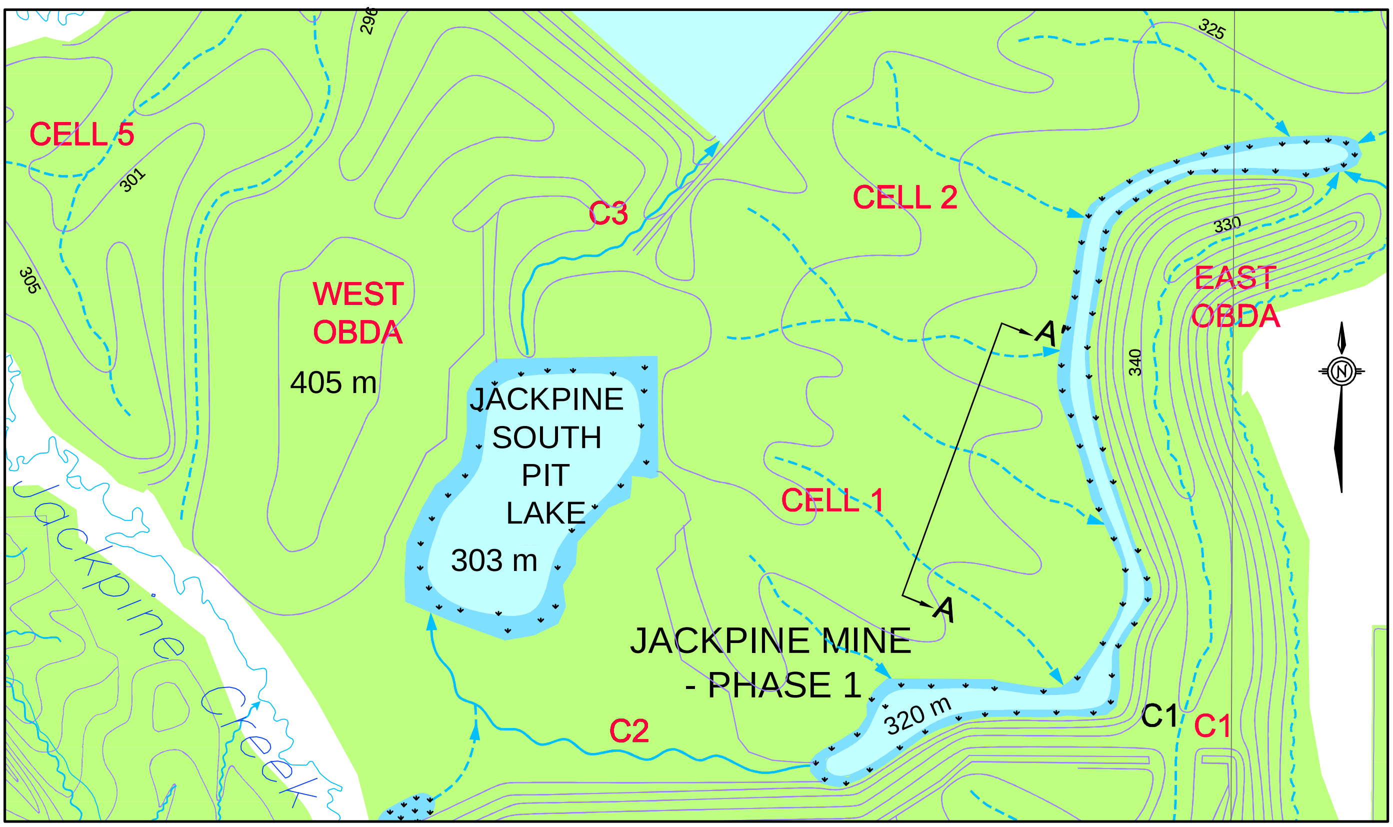
Drainage pathways in the wetlands areas between the ridges are expected to develop naturally after construction of the sand trenches. This natural evolution will facilitate the development of a regime channel pattern and cross-sectional shape. The resulting secondary drainage system is expected to be stable and self-sustaining over the long-term.

## 4.4 SHALLOW WETLANDS

Shallow wetlands will be built into the drainage system to provide hydrological and environmental benefits and attenuate flood peak discharges. By providing storage and some residence time, these wetlands will help improve water quality through biological treatment of the drainage water from the reclaimed areas.




SECTION A-A'
SCHEMATIC ONLY, NOT TO SCALE




1 0 1
SCALE KILOMETRES

## LEGEND

- CONTOURS (318, 316)
- MAIN CHANNEL
- SECONDARY CHANNEL
- LAKE OR POND
- WETLANDS
- RECLAIMED SURFACE
- OPEN WATER

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

**SCHEMATIC LAYOUT OF SECONDARY CHANNELS AT RECLAIMED CONSOLIDATED TAILINGS CELLS**

**Shell Canada Limited**

| | | | | |
|---|---|---|---|---|
| PROJECT 06-1346-022.9500 | | | FILE No. | Schematic Layout |
| DESIGN | FLA | 26/09/07 | SCALE AS SHOWN | REV. 0 |
| CADD | TRE | 27/09/07 | **FIGURE: 8** | |
| CHECK | FLA | 27/09/07 | | |
| REVIEW | WES/TC | 28/11/07 | | |

L:\2006\1344-OIL SANDS\1346\06-1346-022 Shell\9500\9530\CLOSURE DRAINAGE DESIGN\Fig 8_ Schematic Layout of Channels.dwg Dec 07, 2007 - 1:42pm

The shallow wetlands shown on the plans provide a surface area of 5 to 10% of the local contributing drainage area. Each shallow wetlands system will be designed to be evenly divided between vegetated areas and open-water areas. The depths of vegetated area will range from 0 to 1.5 m and the depths of open-water area will range from 1.5 to 3 m. One major wetlands is in the closure drainage plan located at the outlet of Channel C1. It has a surface area of 1.25 $km^2$ and a normal water level of 320 masl. The mean annual inflow to the wetlands is 0.06 $m^3/s$ from a drainage area of 13.74 $km^2$. A schematic of the shallow wetlands system is shown in Figure 9.

# 4.5 PIT LAKES

## 4.5.1 Pit Lake Design Parameters

The closure landscape and drainage systems for the JEMA will include four (2 new and 2 updated) pit lakes, identified in Figure 2. The Jackpine North Pit Lake is separated by a submerged dyke and presented as two cells including an upstream cell and a downstream cell. The downstream cell has no tailings deposit. After closure and in the Far Future, the water balances of these lakes will be maintained by the runoff from natural and reclaimed areas. Table 9 summarizes the relevant design parameters for these lakes.

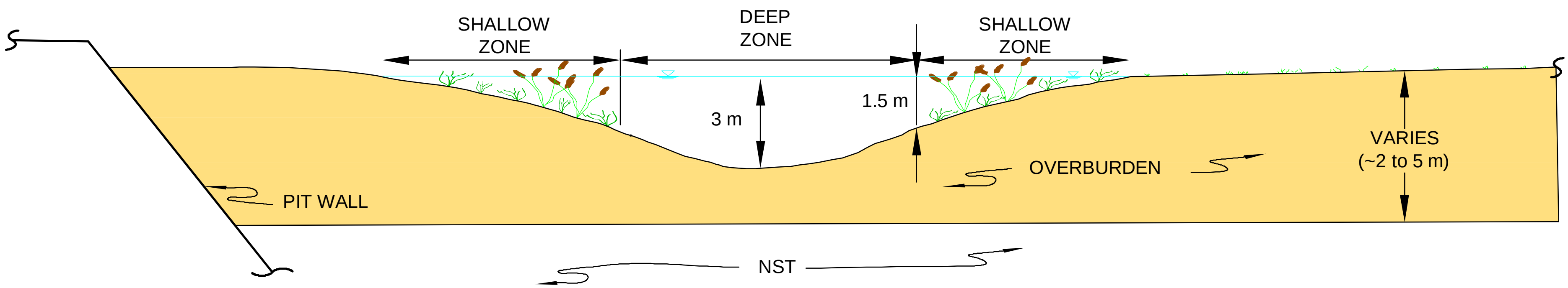
**Table 9 Design Parameters for the Pit Lakes**

| Pit Lake Name | Normal Lake Water Level [masl] | Average Water Depth [m] | Water Volume [$Mm^3$] | Total Lake Surface Area [$km^2$] | Surface Area of Littoral Zone [$km^2$] | Mean Annual Outflow [$m^3/s$] |
|---|---|---|---|---|---|---|
| Jackpine North Central | 290 | 11 | 43 | 5.4 | 1.7 | 0.12 |
| Jackpine North Downstream Cell | 285 | 29 | 79 | 2.5 | 0.58 | 1.2 |
| Jackpine North Upstream Cell | 285 | 12 | 280 | 26 | 4.7 | 1.2 |
| Jackpine South | 303 | 15 | 26 | 1.4 | 0.58 | 0.22 |
| Jackpine South Central | 281 | 11 | 68 | 5.0 | 1.1 | 0.25 |

The pit lakes were sized to be sufficiently large and with sufficient residence times to ensure that water quality objectives are met in the lake outflows.

The lakes have been designed to be self-sustaining over the long-term. They will be equipped with robust features such as breakwater protection, sufficient freeboard and a small overall hydraulic gradient that accommodate natural processes of erosion to minimize the risk of catastrophic failure. The lakes will be fully contained by natural ground or overburden barriers to ensure long-term sustainability.

L:\2006\1344-OIL SANDS\1346\06-1346-022 Shell\9500\9530\CLOSURE DRAINAGE DESIGN\Fig 9 _Shallow wetlands Schematic.dwg Nov 30, 2007 - 4:16pm




DETAIL OF SHALLOW WETLANDS

SCHEMATIC ONLY, NOT TO SCALE

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

**SCHEMATIC LAYOUT OF SHALLOW WETLANDS**

**Shell Canada Limited**

| | | | | |
|---|---|---|---|---|
| PROJECT 06-1346-022.9500 | | | FILE No. Schematic Wetlands | |
| DESIGN | FLA | 27/09/07 | SCALE AS SHOWN | REV. 0 |
| CADD | PSR | 30/10/07 | **FIGURE: 9** | |
| CHECK | FLA | 31/10/07 | | |
| REVIEW | WES/TC | 28/11/07 | | |

## 4.5.2 Design of Littoral Zones and Shoreline Protection

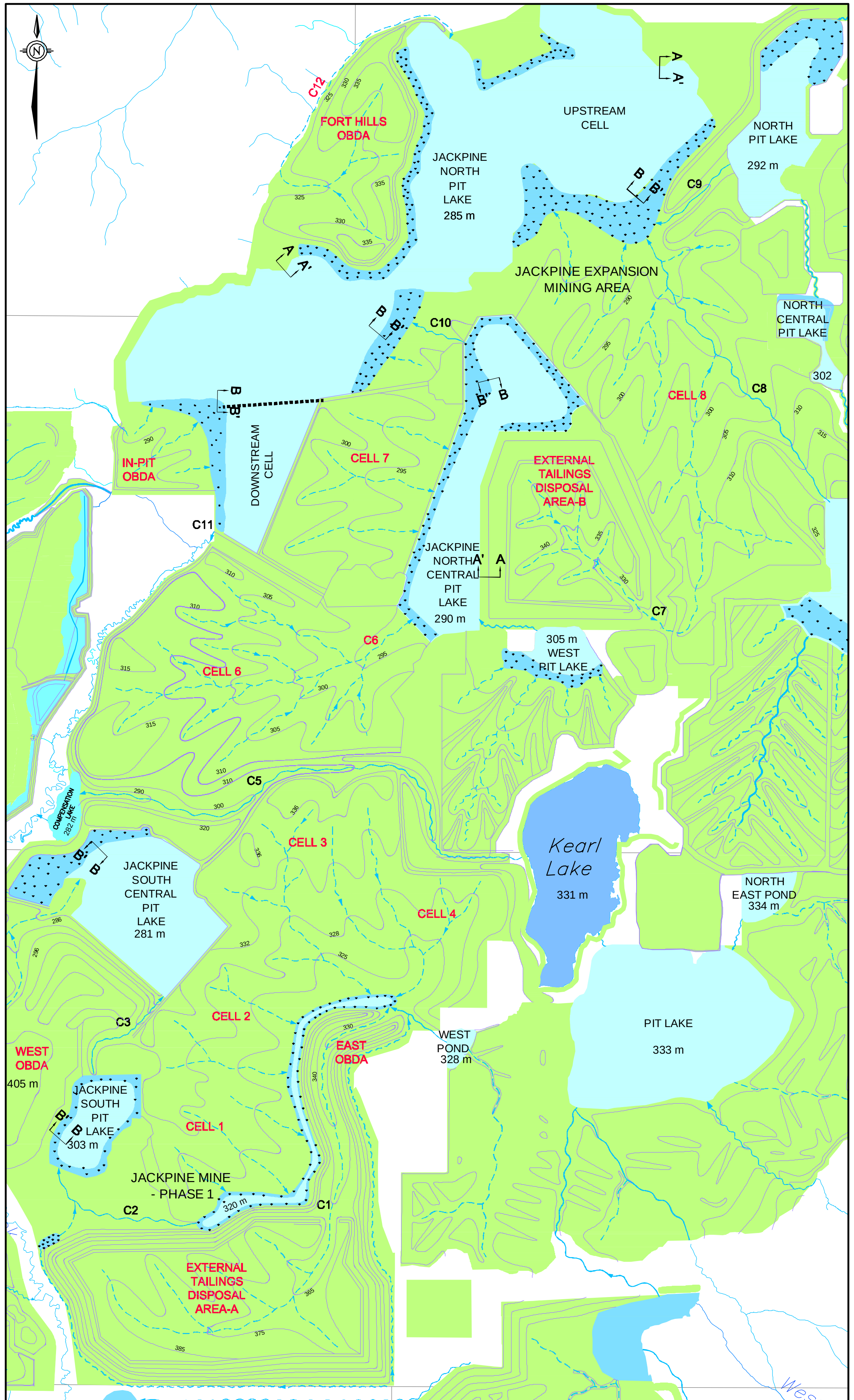
The pit lakes will have littoral zone occupying about 10 to 30% of the total lake surface area. These zones, which will have an average water depth of 1 m, will enhance the biological productivity of the lake and will contribute substantially to the ability of the lake to biodegrade substances. The littoral zone will be constructed along the shorelines of the pit lakes as shown in Figure 10.

The littoral zones will be protected by a breakwater constructed of rip rap material to minimize wave erosion and to support initial growth of wetlands vegetation. The breakwater is designed based on the extreme wind events of a 100-year recurrence interval and the 100-year water level. The estimated wave heights caused by the 100-year westerly hourly wind for the proposed lakes are listed in Figure 10.

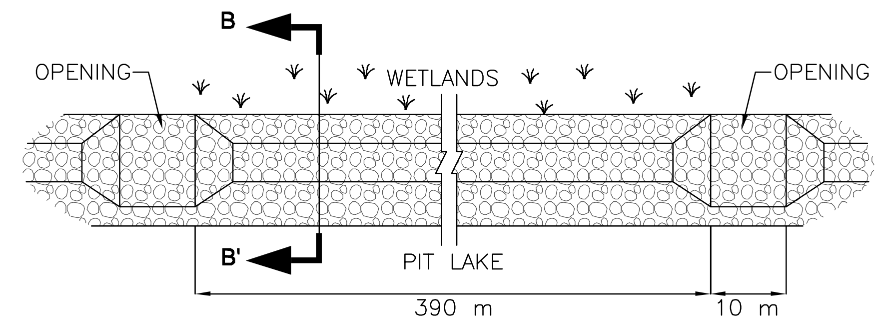
The maximum elevation of the breakwater is designed to be equal to the 100-year flood level plus 100-year wave height for areas that are not protected by a littoral zone. The breakwater that is located by a littoral zone is 0.3 m below the 100-year flood level. The base of the breakwater in Table 10 is designed to be 1 m below the normal water level.

The breakwater is designed to prevent damage from wave erosion by the 100-year extreme hourly wind and 5% damage by the 1,000-year extreme hourly wind. The breakwater is discontinuous, with small openings as shown in Figure 10 (Detail 1) to allow for the circulation of water and the passage of fish between the lakes and the littoral zones for access to food supply and spawning areas.

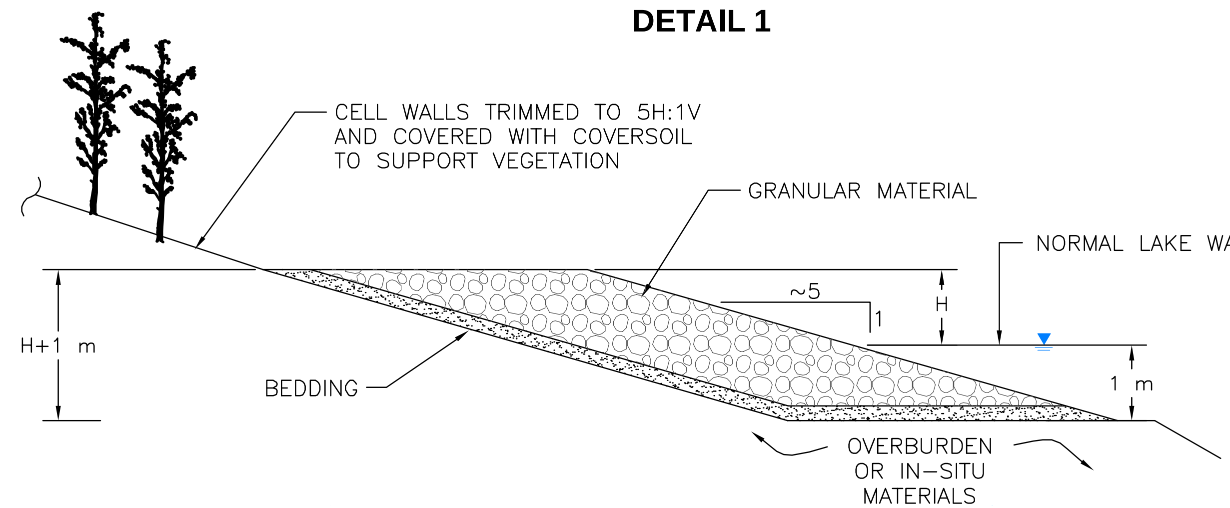
Parts of the shorelines of the pit lakes do not have littoral wetlands. These shorelines can be formed by the mined-out pit walls or in-pit dykes constructed of overburden materials. At the proposed lake water levels, the shoreline materials at the mined-out pit walls may be oil sands or surficial aquifer overburden materials. These sandy soils are easily erodible by wave action. Therefore, a suitable erosion protection measure, such as placement of granular materials similar to those used in the breakwater, is proposed to be used to protect these shorelines and to minimize the shoreline erosion. Similar protection is required for the in-pit dyke. Figure 10 (Section A-A’) presents a typical design of this erosion protection measure.



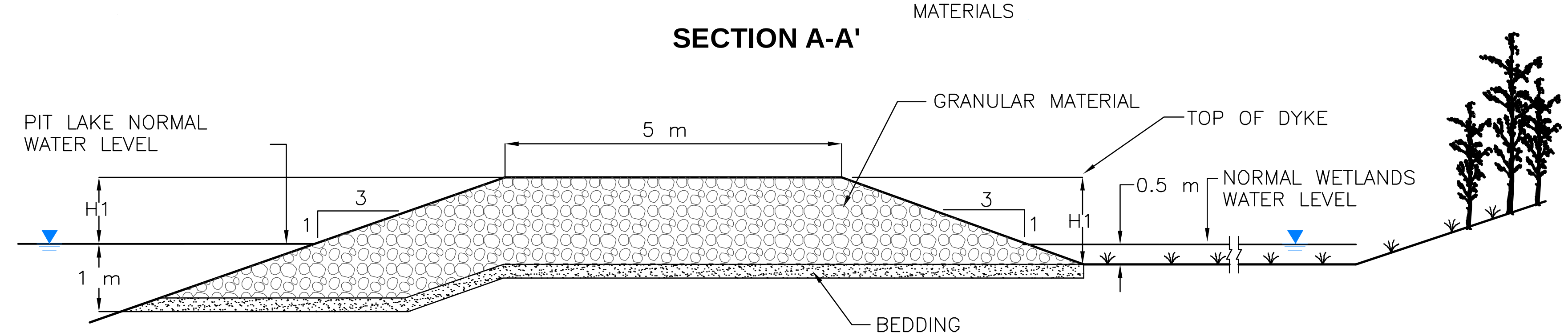

| Pit Lake | Normal Water Level [masl] | Peak Water Level During 100-Year Flood [masl] | Wave Height With 100-Year Return Period [m] | Freeboard Heigh [m] [ H ] A-A' | Freeboard Heigh [m] [ H1 ] B-B' |
|---|---|---|---|---|---|
| Jackpine South Central Pit Lake | 281 | 281.86 | 0.59 | 1.45 | 0.56 |
| Jackpine North Pit Lake (Downstream Cell) | 285 | 286.84 | 0.79 | 2.63 | 1.54 |
| Jackpine North Pit Lake (Upstream Cell) | 285 | 286.84 | 0.82 | 2.66 | 1.54 |
| Jackpine South Pit Lake | 303 | 303.78 | 0.31 | 1.09 | 0.48 |
| Jackpine North Central Pit Lake | 290 | 290.71 | 0.53 | 1.24 | 0.41 |




**DETAIL 1**




**SECTION A-A'**




**SECTION B-B'**

SCALE 2 0 2 KILOMETRES

**LEGEND**

- CONTOURS
- MAIN CHANNEL
- SECONDARY CHANNEL
- LAKE OR POND
- WETLANDS
- RECLAIMED SURFACE
- OPEN WATER
- SUBMERGED DYKE
- LAKE PERIMETER LEVEE

PROJECT

JACKPINE MINE EXPANSION & PIERRE RIVER MINE PROJECT

TITLE

**SHORELINE PROTECTION FOR PIT LAKES**

**Shell Canada Limited**

| | | | | |
|---|---|---|---|---|
| PROJECT 06-1346-022.9500 | | | FILE No. Shoreline Protection | |
| DESIGN | FLA | 26/09/07 | SCALE AS SHOWN | REV. 0 |
| CADD | TRE | 11/10/07 | | |
| CHECK | FLA | 27/09/07 | **FIGURE: 10** | |
| REVIEW | WES/TC | 28/11/07 | | |

L:\2006\1346\06-1346-022 Shell\9500\9530\CLOSURE DRAINAGE DESIGN\Fig 10_ Shoreline Protection for Pit Lakes.dwg Dec 08, 2007 - 12:42pm

**Table 10 Design Parameters of Shoreline Protection**

| Lake Name | 100-Year Flood Level [masl] | Maximum Level of Breakwater [masl] | Minimum Level of Breakwater [masl] |
|---|---|---|---|
| Jackpine South Central | 281.86 | 282.45 | 280.41 |
| Jackpine North Downstream Cell | 286.84 | 287.63 | 284.21 |
| Jackpine North Upstream Cell | 286.84 | 287.66 | 284.18 |
| Jackpine South | 303.78 | 304.09 | 302.69 |
| Jackpine North Central | 290.71 | 291.24 | 289.47 |

The unprotected shoreline on the pit walls consists of competent till materials. This type of material is subject to gradual erosion. Without erosion protection, a stable beach profile would eventually form after a period of gradual wave erosion and occasional slumping of shore materials. This type of shoreline erosion is expected to be very slow because of the presence of gravel and clay in the overburden material.

## 4.6 JACKPINE MINE COMPENSATION LAKE

The proposed Jackpine Mine – Phase 1 compensation plan includes a compensation lake at the downstream end of Channel C5 which handles outflows from the Kearl Lake. This was chosen as the most suitable option for no net loss due to the minimum effects of the proposed development on the Kearl Lake outflows. Consequently, outflows from the Kearl Lake would be used to provide inflow to the Jackpine Mine Compensation Lake.

# 5 CONCLUSION AND CLOSURE

This closure drainage plan shows that it is feasible to develop a self-sustaining closure drainage system for the JEMA. The closure drainage plan will result in self-sustaining landforms after mine closure, maximize beneficial changes and minimize negative impacts. The proposed closure drainage design provides a sound basis for identification and assessment of the environmental impacts of JEMA.

The closure drainage plan for the JEMA will, if designed according to the dynamic system approach, result in a self-sustaining aquatic environment having biodegradation of Project waste. This closure drainage plan will upon closure provide comparable channel characteristics to existing conditions.

# 6 REFERENCES

Bray, D.I. 1972. Generalized Regime-Type Analysis of Alberta Rivers. University of Alberta. Edmonton, AB.

Bretting, A.E. 1946. A set of practical hydraulic formulae based on recent experimental research; comparison with older formulae, Appendix 24, 2d Meeting, International Association of Hydraulic Structures Research, Stockholm. 20 pp.

Clearwater (Clearwater Environmental Consultants Inc.). 2007. Oil Sands End Pit Lakes: A Review to 2007. Submitted to Cumulative Environmental Management Association End Pit Lakes Subgroup.

Golder (Golder Associates Ltd.). 2006. Predicted Water Quality of Oil Sands Reclamation Wetlands: Impact of Physical Design and Hydrology. Submitted to Cumulative Environmental management Association End Pit Lakes Subgroup.

Golder. 2007. Aquatics Environmental Setting Report for the Jackpine Mine Expansion & Pierre River Mine Project. Prepared for Shell Canada Limited. Calgary, AB. Submitted December 2007.

Schumm, S.A. 1977. The Fluvial Systems. John Wiley & Sons. New York, NY.

Shell (Shell Canada Limited). 2002. Jackpine Mine – Phase 1 Application, Environmental Impact Assessment and Socio-Economic Assessment. Volumes 1 to 7. Prepared by Golder Associates Ltd., Komex International Inc., Cantox Environmental Inc. and Nichols Applied Management. Calgary, AB. Submitted May, 2002.

# 7 ABBREVIATIONS

| | |
|---|---|
| % | Percent |
| ≤ | Less than or equal to |
| C,C&R | Closure, Conservation and Reclamation |
| cm | Centimetre |
| CT | Coarse Tailings |
| EIA | Environmental Impact Assessment |
| ESR | Environmental Setting Report |
| ETDA | External Tailing Disposal Area |
| ft | Feet |
| HSPF | Hydrological Simulation Program-Fortran |
| H:V | Ratio of horizontal length (H) to vertical length (V) for a specific slope |
| JEMA | Jackpine Expansion Mining Area |
| km | Kilometre |
| $km^2$ | Square kilometre |
| km/h or km/hr | Kilometres per hour |
| $km/km^2$ | Kilometre per square kilometre |
| m | Metre |
| $m^2$ | Square metres |
| $m^3$ | Cubic metres |
| m/s | Metres per second |
| $m^3/s$ | Cubic metres per second |
| masl | Metres above sea level |
| MFT | Mature Fine Tailings |
| NNLL | No Net Loss Lake |
| NST | Non-Segregating Tailings |
| OBDA | Overburden disposal area |
| PDA | Project Development Area |
| PMF | Probable Maximum Flood |
| PRMA | Pierre River Mining Area |
| Shell | Shell Canada Energy |
| TT | Thickened Tailings |
| U.S. EPA | United States Environmental Protection Agency |

# 8 GLOSSARY

| | |
|---|---|
| **Bankfull Discharge** | The flow rate that fills the channel of an undisturbed stream with a wide floodplain up to the top of its banks prior to flooding. |
| **Biodegrade** | Capable of being decomposed by biological agents. |
| **Bioremediation** | The process of applying corrective action to unbalanced biological systems. |
| **Catchment Area** | The area of land from which water finds its way into a particular watercourse, lake or reservoir (Also termed “river basin” or “watershed.” |
| **Channel Regime** | The morphological characteristics, including cross-section, longitudal slope and sinuosity, of a watercourse that is in long-term equilibrium. |
| **Channel** | The bed of a stream or river. |
| **Coversoil** | Any peat-mineral mix, organic horizon or upland surface soil. |
| **Dendritic Drainage Pattern** | A stream system that branches irregularly in all directions with the tributaries joining with the main stream at all angles. |
| **Drainage Density** | The total length of channels per unit area in a drainage basin. The drainage density characterizes the density of drainage courses in a basin. |
| **Drainage Effectiveness** | The ability to achieve the target land use and soil moisture conditions, avoiding excess water inundation and moisture deficits within the limits that can be tolerated by the target land use and function (i.e. lakes, wetlands, upland vegetation, salt leaching, pre-construction stripping, etc.) |
| **Erosion** | The process by which material, such as rock or soil, is worn away or removed by wind or water. |
| **Evapotranspiration** | A measure of the capability of the atmosphere to remove water from a location through the processes of evaporation and water loss from plants (transpiration). |

| | |
|---|---|
| **Floodplain** | The portion of the river valley, adjacent to the river channel, which is built of sediments during the present regimen of the stream and which is covered with water when the river overflows its banks at flood stages. |
| **Fluvial** | Sediment generally consisting of gravel and sand with a minor fraction of silt and rarely clay. The gravels are typically rounded and contain interstitial sand. Fluvial sediments are commonly moderately to well sorted and display stratification, but massive, non sorted fluvial gravels do occur. These materials have been transported and deposited by streams and rivers. |
| **Geomorphic** | The natural evolution of surface soils and landscape over long periods. |
| **Geomorphology** | The science of surface landforms and their interpretation on the basis of geology and climate. That branch of science that deals with the form of the earth, the general configurations of its surface and the changes that take place in the evolution of landforms. |
| **Glaciofluvial (or Glacio-Fluvial)** | Sediments or landforms produced by melt waters originating from glaciers or ice sheets. Glaciofluvial deposits commonly contain rounded cobbles arranged in bedded layers. |
| **Groundwater** | That part of the subsurface water that occurs beneath the water table, in soils and geologic formations that are fully saturated. |
| **Groundwater Recharge** | Water that enters the saturated zone and contributes to the overall volume of groundwater |
| **Hydrogeology** | The study of the factors that deal with subsurface water (groundwater) and the related geologic aspects of surface water. Groundwater as used here includes all water in the zone of saturation beneath the earth's surface, except water chemically combined in minerals. |

**Hydrologic Simulation Program – Fortran (HSPF)** The Hydrologic Simulation Program – Fortran (HSPF) model is a comprehensive, conceptual, continuous watershed simulation model designed to simulate the water quantity and water quality processes that occur in a watershed. The model can reproduce spatial variability by dividing the basin in hydrologically homogeneous land segments and simulating runoff for each land segment independently, using segment-specific meteorological input data and watershed parameters.

**Lacustrine** Sediment that have been transported or deposited by water or wave action. Generally consisting of stratified sand, silt or clay deposited on a lake bed or moderately well sorted and stratified sand and coarser material.

**Littoral Zone** The zone in a lake that is closest to the shore. It includes the part of the lake bottom, and its overlying water, between the highest water level and the depth where there is enough light (about 1% of the surface light) for rooted aquatic plants and algae to colonize the bottom sediments.

**Lowland Areas** Areas with ground slopes of less than 0.5% and typically poorly drained.

**Mature Fine Tailings (MFT)** Fine tailings that have dewatered to a level of about 30% solids over a period of about three years after deposition. The rate of consolidation beyond this point is substantially reduced. Mature fine tailings behave like a viscous fluid.

**Mixedwood** A terrestrial forest type that is an assemblage of both deciduous and coniferous tree species.

**Muskeg** A soil type comprised primarily of organic matter. Also known as bog peat.

**Non-Segregating Tailings (NST)** Tailings formed from a mixture of cycloned sand tailings and thickened fine tailings in a non-segregating stream. These consolidate relatively rapidly upon placement in tailings disposal areas to form a trafficable surface. Coarse tailings are one type of NST.

**Overburden** Material below the soil profile and above the bituminous sand.

**Piping** — Small leaks in dam or dyke walls that carry away the finer materials, weakening the holding walls and ultimately resulting in failure.

**Pit Lake** — A man-made lake used to fill a mine pit area into which tailings may be discharged. Pit lakes are typically filled with waters pumped from adjacent rivers, or from runoff waters from reclamation areas.

**Porewater** — Water between the grains of a soil or rock.

**Probable Maximum Flood (PMF)** — The most severe flood that may be expected from a combination of the most critical meteorological and hydrological conditions that is reasonably possible in the drainage basin. It is used in designing high-risk flood protection works and siting of structures and facilities that must be subject to almost no risk of flooding. The probable maximum flood is much larger than the 100-year flood.

**Riparian** — Refers to terrain, vegetation or simply a position next to or associated with a stream, floodplain or standing waterbody.

**Runoff** — The portion of water from rain and snow that flows over land to streams, ponds or other surface waterbodies. It is the portion of water from precipitation that does not infiltrate into the ground, or evaporate.

**Sand Ridges on NST** — A ridge that creates hydraulic gradients that will provide well-drained soil conditions necessary for upland vegetation and flushing of saline porewater necessary for salinity control.

**Sinuosity** — The ratio of the thalweg length (i.e., the line connecting the deepest points along a stream) to valley length, for a specific reach of a river or stream system. This is, in essence, a ratio of the stream's actual "running" length to its down-gradient length.

| | |
|---|---|
| **Subsoil** | A stratum that includes one or more of the following:<br>(i) that portion of the B horizon left after salvage of upland surface soil;<br>(ii) the C horizon of an upland soil;<br>(iii) underlying parent material at an upland location that is rated good, fair or poor as described in Table 9, Page 28 of the Soil Quality Criteria Relative to Disturbance and Reclamation,1987, as amended; and<br>(iv) mineral material below an organic layer at a location other than upland, that is rated good, fair or poor as described in Table 9, Page 28 of the Soil Quality Criteria Relative to Disturbance and Reclamation, 1987, as amended. |
| **Surficial Aquifer** | A surficial (at or near the surface of the earth) deposit containing water considered an aquifer. |
| **Suspended Sediments** | Particles of matter suspended in the water. Measured as the oven dry weight of the solids, in mg/L, after filtration through a standard filter paper. Less than 25 mg/L would be considered clean water, while an extremely muddy river might have 200 mg/L of suspended sediments. |
| **Swale** | A natural depression or wide shallow ditch used to convey runoff. |
| **Tailings** | A by-product of oil sands extraction typically comprised of water, sands and clays, with minor amounts of residual bitumen. |
| **Thickened Fine Tailings (TT)** | Thickened fine tailings are produced by increasing the solids content of fine tailings from the Bitumen Cleaning process to 35 to 45% in a large vessel called a thickener by removing water. Thickened tailings are combined with cycloned sand tailings from the Bitumen Recovery process to produce non-segregated tailings (NST). |
| **Till** | Sediments laid down by glacial ice. |
| **Understorey** | Trees or other vegetation in a forest that exist below the main canopy level. |
| **Upland Areas** | Areas that have typical ground slopes of 1 to 3% and are better-drainage. |

**Vegetated Channel/Grass Waterway** Vegetated waterways are broad, intermittent or ephemeral drainage courses, often consisting of the entire valley bottom. They are covered with vegetation and have no defined stream bed or banks.

**Wetlands** Wetlands are land where the water table is at, near or above the surface or which is saturated for a long enough period to promote such features as wet-altered soils and water tolerant vegetation. Wetlands include organic wetlands or "peatlands," and mineral wetlands or mineral soil areas that are influenced by excess water but produce little or no peat.

# APPENDIX 4-4

# CLOSURE DRAINAGE PLAN
# FOR THE
# PIERRE RIVER MINING AREA

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## LIST OF FIGURES

# 1 INTRODUCTION

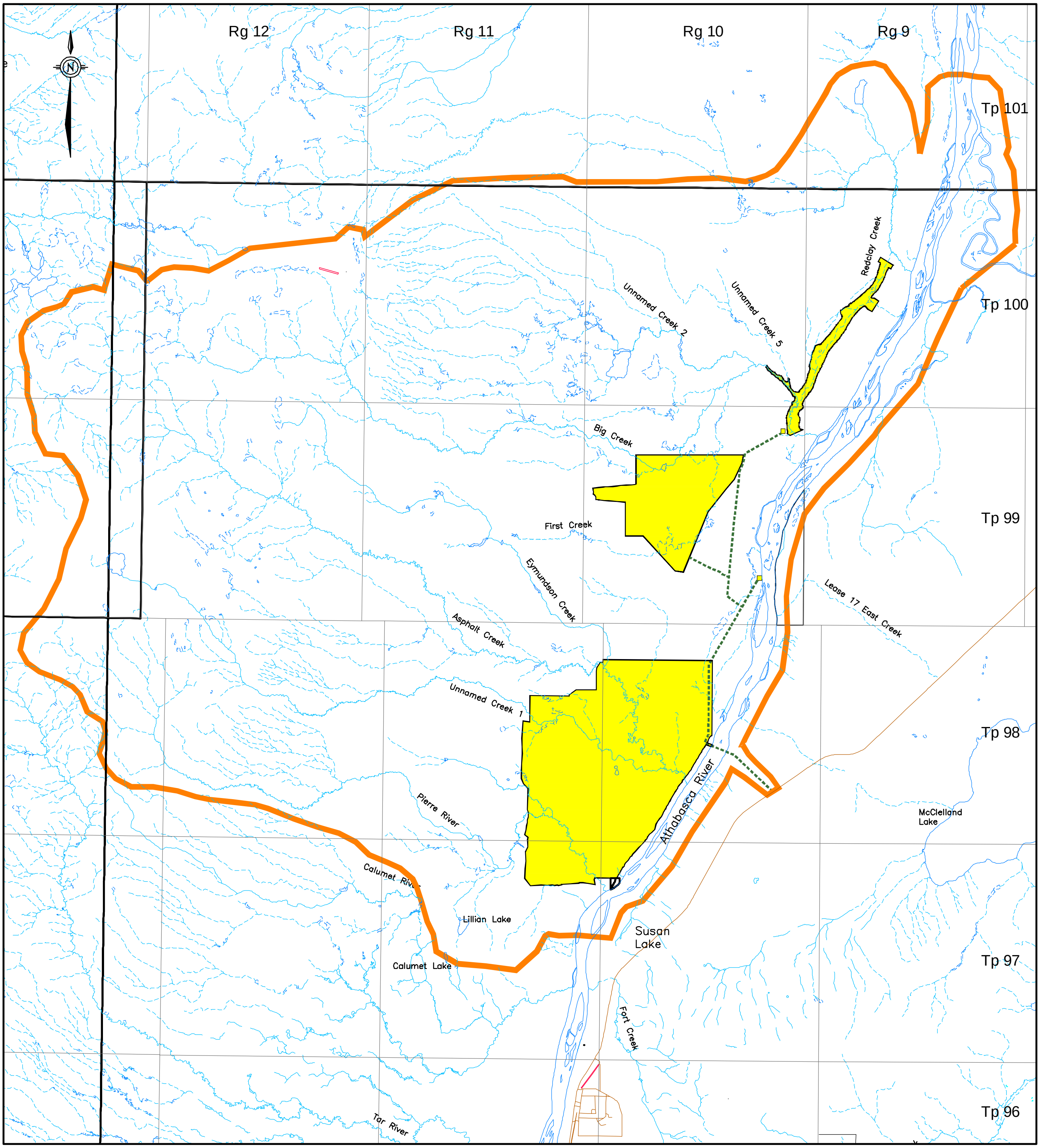
## 1.1 BACKGROUND

Shell Canada Limited (Shell) is applying to develop the Jackpine Mine Expansion & Pierre River Mine Project (the Project). The Pierre River Mine Area (PRMA) is located about 120 km north of Fort McMurray. The development will encompass two distinct areas at closure: an External Tailings Disposal Area (ETDA) located on oil sands Leases 17 and 351, and a reclaimed mining area on Lease 9. In addition, a treatment pond and compensation lake will be located on oil sands Lease 309. Figure 1 shows the pre-development natural drainage. Figure 2 shows the location of the mining area and the ETDA.

At closure, the ETDA will contain sand-capped Thickened Tailings (TT) in its southern cell, and tailings sand only in its northern cell. The Mature Fine Tailings (MFT) contained in the northern cell during operations will be moved to a mine pit lake before closure. At closure, the mine area will be reclaimed to include pit lakes, sand-capped NST terrain, overburden dumps and a reclaimed plant site.

A large lake will be constructed during operation to serve as a fish compensation lake (Redclay Compensation Lake) and a Raw Water Storage Facility. It will be located in a valley northeast of the ETDA and will be partitioned to create a raw water pond in the south and a compensation lake in the north. The design will prevent interflow between the two waterbodies. During mine operation, the Raw Water Storage Facility will supply raw water to the PRMA. At closure, the Raw Water Storage facility will be used as a treatment lake to treat runoff from the ETDA rather than as a source of raw water.

This report presents the closure drainage plan and pre-feasibility design for the PRMA. The objectives of the report, which are a component of the Environmental Impact Assessment (EIA) for the Project, are to demonstrate the feasibility of the proposed mine closure drainage plan and to support Shell's application for the Project. The report describes the design approach, criteria, assumptions and typical plans and cross-sections of the proposed closure landscape and drainage systems.




LEGEND

PIERRE RIVER MINING AREA

LOCAL STUDY AREA

5 0 5

SCALE KILOMETRES

REFERENCE

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USED UNDER LICENSE. PROJECTION: TRANSVERSE MERCATOR
DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 12

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

**PRE-DEVELOPMENT NATURAL DRAINAGE**

**Shell Canada Limited**

| | | |
|---|---|---|
| PROJECT 06-1346-022.9400 | | |
| DESIGN | KM | 21/08/07 |
| CADD | RFM | 21/08/07 |
| CHECK | FLA | 11/10/07 |
| REVIEW | WES/TC | 30/11/07 |

FILE No. Pre-Dev Drainage

SCALE AS SHOWN REV. 0

**FIGURE: 1**

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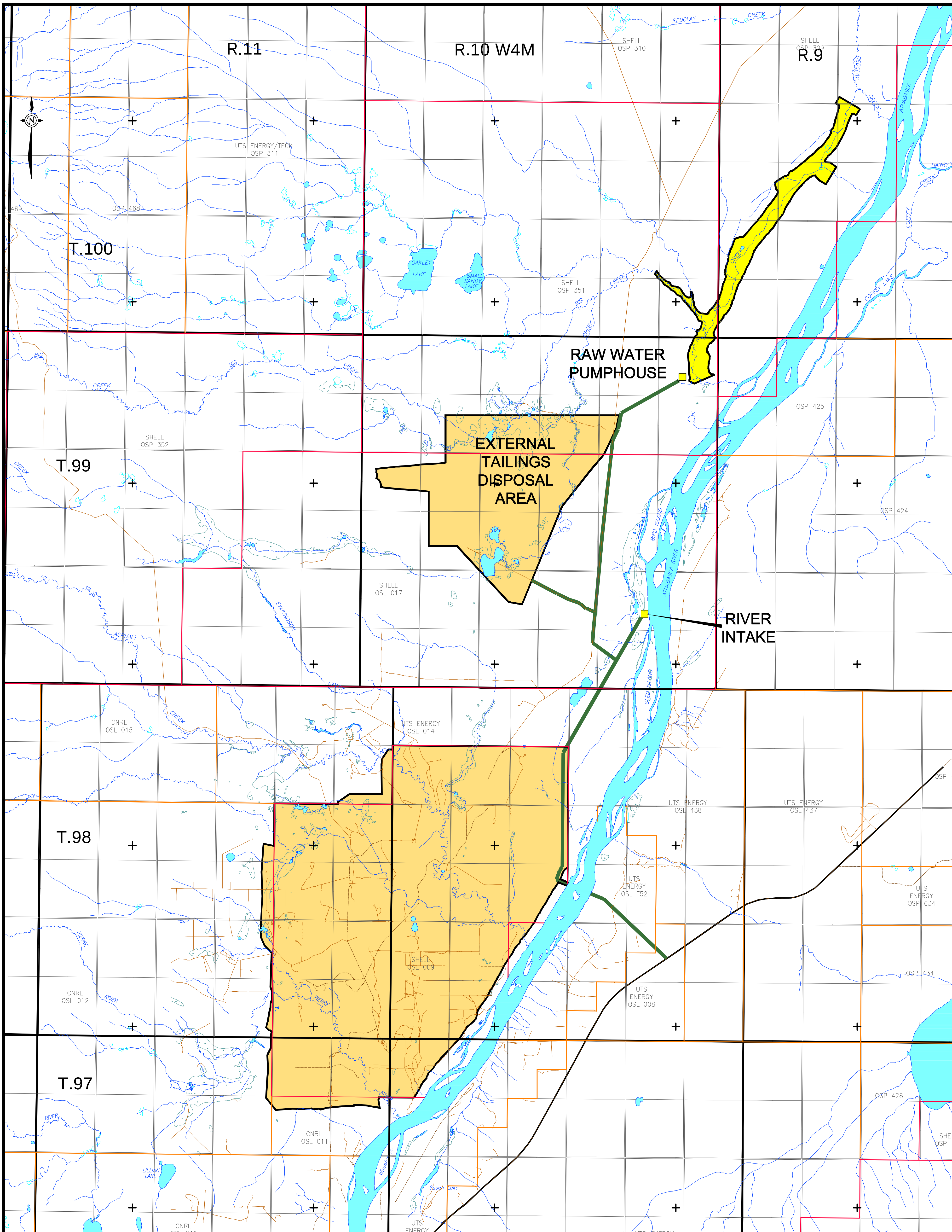


LEGEND

LEASE BOUNDARY

2 0 2

SCALE KILOMETRES

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

PROJECT DEVELOPMENT AREA

| | | | |
|---|---|---|---|
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| CADD | RFM | 23/08/07 | |
| CHECK | FLA | 11/10/07 | FIGURE: 2 |
| REVIEW | WES/TC | 30/11/07 | |

Shell Canada Limited

REFERENCE

ALBERTA DIGITAL DATA OBTAINED FROM ALTALIS LTD. (SEPTEMBER 2004.)
USED UNDER LICENSE. PROJECTION: TRANSVERSE MERCATOR
DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 12

## 1.2 SCOPE OF WORK

The scope of work for the development of the closure drainage plan and the pre-feasibility design of the closure drainage systems included the following tasks:

- identify design criteria for the closure drainage systems;
- analyze flood hydrology and derive flood peak discharges and design parameters of extreme winds;
- identify and evaluate alternative closure reclamation drainage schemes; and
- provide a pre-feasibility design for the proposed closure drainage systems including shoreline protection for the pit lakes.

The scope of work includes the development of a pre-feasibility design that is sufficient to provide a sound basis for assessing the environmental impacts and long-term sustainability of the proposed closure drainage systems. The results of this work include:

- recommended design criteria;
- proposed drainage scheme and drainage system layout; and
- pre-feasibility design of the main drainage facilities, including typical plans, profiles and cross-sections.

## 1.3 PRE-DEVELOPMENT NATURAL DRAINAGE

As shown in Figure 1, several creeks flow through the PRMA development area, including Eymundson Creek, Asphalt Creek, Big Creek and several smaller named and unnamed creeks. These creeks are tributaries of the Athabasca River. The affected tributaries generally convey flows in an easterly direction.

The terrain within the PRMA is relatively flat, with elevations ranging from 250 to 298 metres above sea level (masl) and an average elevation of about 272 masl. The dominant soils in the Project development area are mineral soils developed on glaciofluvial sands. Ground slopes of less than 0.5% are typical of the lowland terrain in the PRMA. Lowland terrain within the PRMA is not as well drained compared to the upland terrain located west of the PRMA. The lowland streams are slow-flowing, meandering streams flowing through an area characterized by a high groundwater table.

The streams in the Project development area have similar geomorphic characteristics, with stream banks composed primarily of varying proportions of silt and sand, and channel beds typically consisting of sand, silt and clay in varying proportions. Many of the channels are vegetated. Slumping of banks and channel down-cutting (degradation) is evident in many of the streams in and adjacent to the Project development area. There is a great deal of beaver activity, with most of the creeks blocked by beaver dams at numerous locations.

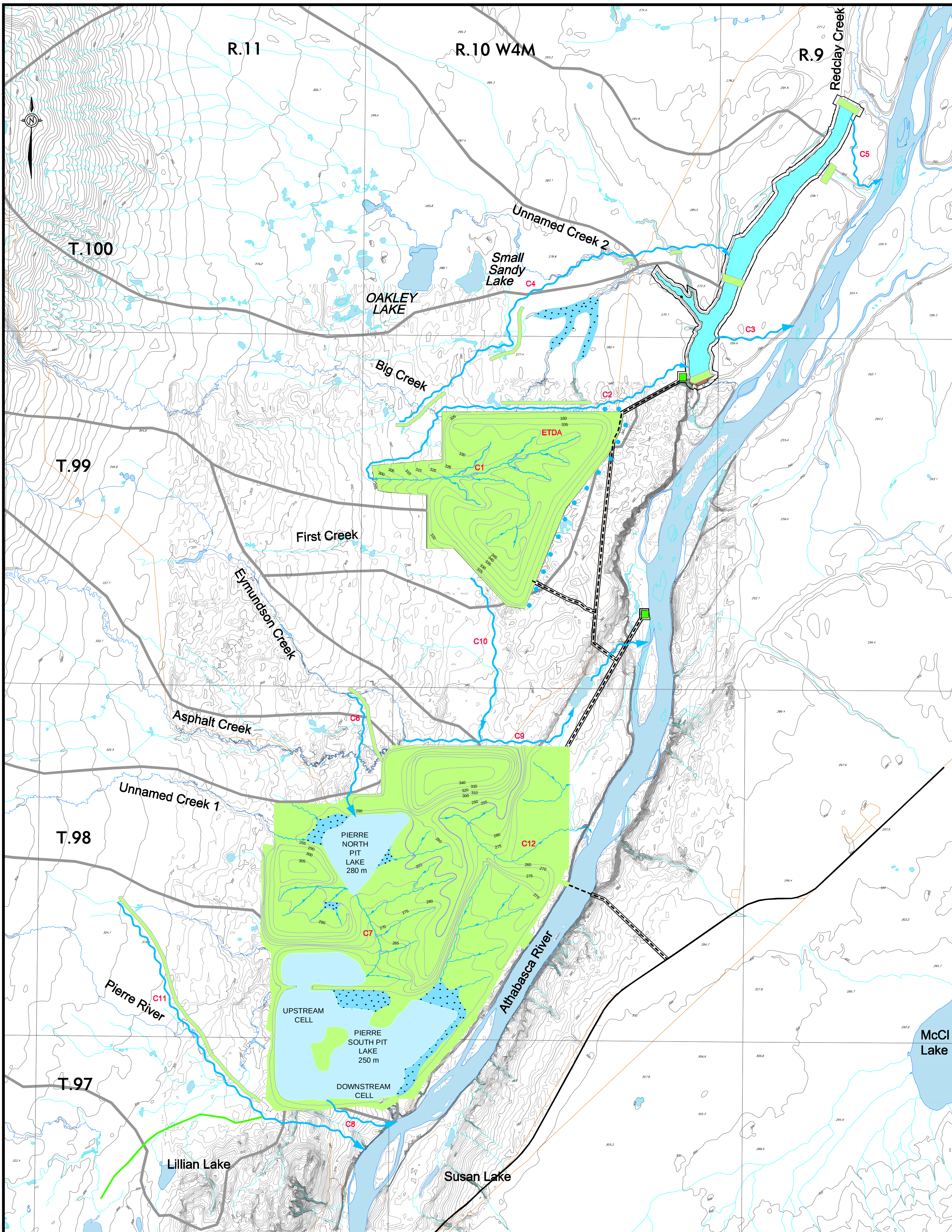
## 1.4 GENERAL LAYOUT OF CLOSURE DRAINAGE SYSTEMS

Figure 3 shows the layout of the proposed closure drainage systems, including main channels, secondary channels, shallow wetlands, lakes and pit lakes. The general layout of the proposed closure drainage systems is described below. The closure drainage plan includes post-disturbance alignment and condition of all ephemeral and permanent streams and waterbodies created as part of the PRMA.

### 1.4.1 External Tailings Disposal Area, the Treatment Lake and Redclay Compensation Lake

At closure, the ETDA will consist entirely of tailings sand. The proposed drainage system on the ETDA will convey runoff through a series of swales to a central drainage channel (C1) excavated into the northern portion of the cell. Channel C1 will direct flow to the west side of the cell and into Channel C2, which will follow the northern edge of the ETDA and discharge into the Treatment Lake (former operational Raw Water Storage Facility) as at closure, this facility will be used to treat runoff rather than as a source of raw water. At closure, an outlet channel (C3) will be constructed from the Treatment Lake to the Athabasca River.

A new creek (C4), to be built on natural ground north of the ETDA, will collect flows from Big Creek and several smaller unnamed creeks and allow for fish passage from the Athabasca River to the watershed. This channel will flow in a northeasterly direction and discharge into the fish compensation lake, also called the Redclay Compensation Lake. The Redclay Compensation Lake will be connected to the Athabasca River through a designed outlet channel (C5).




LEGEND

- MAIN CHANNEL
- SECONDARY CHANNEL
- RECLAIMED SURFACE
- CONTOURS
- WETLANDS
- LAKE OR POND
- CNRL CLOSURE DITCH
- DIVERSION CHANNEL
- WELLS
- WATERSHED BOUNDARY

SCALE 2 0 2 KILOMETRES

REFERENCE

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USED UNDER LICENSE. PROJECTION: TRANSVERSE MERCATOR
DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 12

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

# CONCEPTUAL CLOSURE DRAINAGE PLAN

Shell Canada Limited

| | | | | |
|---|---|---|---|---|
| PROJECT 06-1346-022.9400 | | | FILE No. Closure Plan-PRMA | |
| DESIGN | GB | 17/09/07 | SCALE AS SHOWN | REV. 0 |
| CADD | PSR | 13/11/07 | FIGURE: 3 | |
| CHECK | FLA | 13/11/07 | | |
| REVIEW | WES/TC | 06/12/07 | | |

### 1.4.2 Pierre River Mining Area

At closure, Eymundson Creek and Asphalt Creek will flow into Pierre North Pit Lake by means of a new drainage channel (C6). An unnamed creek also flows into Pierre North Pit Lake. The Pierre River and several small channels will be diverted south around the mining area through Channel C11 and discharged directly to the Athabasca River.

The surface runoff from within the Pierre River mine area will be collected and routed through a drainage system consisting of small drainage channels, wetlands and pit lakes. Channel C7 will connect Pierre North Pit Lake to Pierre South Pit Lake. Several small drainage channels will direct the runoff from the adjacent overburden-capped tailings cells to Pierre North Pit Lake or to Channel C7. Runoff from the eastern in-pit tailings cell will flow directly into Pierre South Pit Lake that will discharge to the Athabasca River through Channel C8.

Runoff from the north Overburden Disposal Area (OBDA) and the reclaimed plant site will be collected by Channel C12 and discharged directly to the Athabasca River. The runoff from the north OBDA will be collected at the toe and flow east across the reclaimed plant site. Two channels between the ETDA and the pit area will divert water around the development area. Channel C9 will follow the north edge of the mine and collect undisturbed water from the surrounding area and some runoff from the North OBDA, discharging to the Athabasca River. Channel C10 will flow in a southerly direction collecting small tributary inflows and will discharge into Channel C9.

At closure, Pierre North Pit Lake will have a water cap with a minimum thickness of 6 m over MFT deposit. This water cap will increase in depth over time as the MFT consolidates. The average water surface elevation of Pierre North Pit Lake will be 280 masl. Pierre South Pit Lake will have a water cap with a minimum thickness of 15 m over TT. The normal water surface elevation of Pierre South Pit Lake will be 250 masl.

The proposed drainage systems include such natural features as floodplains, wetlands and pit lakes for flood flow attenuation and biodegradation of runoff and seepage from reclaimed areas. Littoral zones with shallow wetlands are provided along the shorelines of the pit lakes. Each littoral zone occupies 10 to 30% of the total surface area of each pit lake.

The closure drainage plan of the PRMA was developed to accomplish the objectives of long-term self-sustaining and minimal aquatic impacts on receiving streams. The drainage routes were selected and designed to maximize long-term self-sustaining, minimize the changes in flows in the surrounding creeks and rivers, and to allow for fish migration.

# 2 DESIGN APPROACH, CRITERIA AND ASSUMPTIONS

## 2.1 PERFORMANCE OBJECTIVES

Self-sustaining closure drainage systems are designed to have the same characteristics as pre-development natural drainage systems in terms of dynamic stability, robustness, longevity and self-healing mechanisms. This can be accomplished by designing drainage systems that are patterned after natural analogues subject to similar climatic, topographic and soil conditions. Although it is not possible to recreate the original natural drainage systems of the Project development area, it is possible to replicate the stability, robustness and function of the original natural systems.

In addition, the closure drainage systems will provide a biologically productive landscape and have the capability to handle extreme hydrologic events. This can be accomplished by incorporating drainage features such as shallow wetlands, floodplains and pit lakes for biodegradation of the surface runoff and seepage from the reclaimed surfaces and for attenuating flood peak discharges.

## 2.2 DESIGN APPROACH

Conventional approaches for design of reclamation drainage systems often provide rigid, non-erodible drainage facilities that are designed to handle specific extreme flood events. This results in uniformity of design and construction but does not necessarily accomplish the performance objectives of the closure drainage systems to provide biological productivity and to minimize erosion and achieve long-term sustainability.

A major deficiency of conventional approaches is the absence of a self-healing mechanism. Man-made channels may fail because of overtopping, washout of erosion protection or channel degradation. Such failures often lead to accelerated erosion and/or channel relocation, conditions that typically cause high sediment yields resulting in alteration of aquatic habitats.

The alternative to rigid systems designed for specific extreme events is a dynamic system capable of adjusting to change without accelerated erosion or unacceptable environmental impacts. Such a dynamic system must have robust drainage facilities with several lines of defence and a self-healing capability that can be built into reclamation drainage systems by design. This dynamic system approach was used for the design of closure drainage systems for the PRMA.

This closure approach is based on the recognition that natural drainage systems will change over time. Similar changes are anticipated in closure drainage systems. Anticipation of such natural changes enables the design and construction of robust drainage systems with second and third lines of defence. The types of anticipated changes that could occur to the closure drainage systems over time include the following:

- deposition of sediment that could raise the channel bed and reduce the channel conveyance capacity;
- erosion of the channel bed that could lower the channel bed and result in channel degradation;
- vegetation growth on the channel bed and banks, which would increase the channel roughness, decrease channel velocities and protect against erosion;
- reduction of the width of the channel because of sedimentation on one side of a channel that is built wider than the regime width;
- overtopping and consequent relocation of drainage channels because of excessive sedimentation, beaver dams or icing; and
- bank erosion and subsequent failure because of slope instability or slumping.

Natural channels are in regime and exhibit sediment equilibrium. The existing literature has extensive data collected by fluvial geomorphologists to correlate channel regimes with hydrologic, topographic and soil conditions. These data provide a sound basis for designing channels in regime to replicate the dynamic character of natural channels and to avoid progressive and rapid channel degradation or aggradation.

Closure drainage channels will be capable of handling extreme flood events. Rigid erosion control measures are unnecessary because regime channels will be designed to accommodate erosion. Reduction of flow velocities during extreme flood events will be achieved by building drainage channels in well-defined swales or valleys, similar to natural drainage systems. Floodplains and wetlands provide extra storage to attenuate flood peak discharges.

Natural geomorphic processes are accounted for in the design of the reclamation drainage systems, including self-sustaining pit lake shorelines to accommodate the change processes such as erosion and sedimentation.

## 2.3 DESIGN CRITERIA

Table 1 presents the design criteria developed to achieve the performance objectives of the closure drainage systems by following the fluvial geomorphic approach. These design criteria were adopted for the evaluation of various surface drainage alternatives, selection of the proposed scheme and pre-feasibility design of the drainage systems.

### Table 1 Design Criteria for Developing Closure Drainage Systems

| Design Criteria | Design Considerations or Features Provided for Drainage Systems |
|---|---|
| self-sustaining in geological time frames | Structures such as dams and reservoirs that could cause rapid deterioration of the landscape in the event of an extreme flood event should be excluded from the closure landscape. Channels should be subject to gradual change over geologic time frames and sediment yields from reclaimed surfaces should be similar to those from similar natural systems. |
| drainage effectiveness | Drainage effectiveness and landscape stability should be similar to pre-development conditions. |
| channel in regime | Regime channels should be designed by selecting appropriate channel parameters, including cross-section, longitudinal slope and sinuosity, based on hydrologic and soil conditions and to replicate natural analogues. |
| channel dimensions | Channel dimensions and width-depth ratios should be selected based on regime relationships. Normal channel side slope of the main channel should be a maximum of 2H:1V and vegetated channel side slope should be 3H:1V for all three types of soils (sand, overburden and natural) and minimum channel bed width should be 3 m for major channels and 1 m for minor channels. |
| channel slope | Main and secondary drainage channel slopes should be designed based on regime relationships. Minimum slope of main drainage channels on sandy soils should be 0.08% to allow adequate drainage and to minimize channel erosion. |
| channel sinuosity | Channels should have a sinuous pattern to replicate natural systems and reduce channel bed slopes. |
| floodplains | Main drainage channels should be sized to convey low flows and small frequent flood events. Floodplains should be provided to convey high flows and large flood events with low recurrence intervals. |
| drainage density of secondary drainage channels | Secondary drainage channels should be built on the reclaimed landscape to suit the characteristic drainage density of the terrain. Design drainage densities, defined as length of channels per unit area in a drainage basin, are estimated to be as follows: sand or overburden material at 0.5% slope = 1.0 $km/km^2$. |
| vegetated/grassed waterways on overburden storage areas | Grassed waterways on overburden storage areas should be designed as follows:<br>• width = 10 $A^{0.5}$, where A = drainage area ($km^2$);<br>• organic soil depth = 0.8 m; and<br>• slopes (%) $\leq 0.5 \times \frac{1}{A}$, where A = drainage area ($km^2$). |
| channels on bouldery ground | Where channels cannot meet the erosion control specification indicated below, supply bouldery ground beneath the channel and beside the channel with an initial armour layer on the channel bed. Bouldery ground will consist of select silt/clay overburden material mixed with gravel, cobble or boulder. |

**Table 1 Design Criteria for Developing Closure Drainage Systems (continued)**

| Design Criteria | Design Considerations or Features Provided for Drainage Systems |
|---|---|
| channel erosion protection | Regime channels should be characterized by sediment equilibrium, subject to gradual evolution over geologic time frames and allowable erosion levels for unlined regime channels are as follows:<br>• no erosion during the 10-year flood event;<br>• little erosion during the 100-year flood event; and<br>• moderate erosion during the Probable Maximum Flood (PMF) event.<br>Maximum allowable flow velocities for channels in sandy soils are as follows:<br>• 2-year flood event: 0.5 m/s;<br>• 10-year flood event: 1.0 m/s;<br>• 100-year flood event: 1.5 m/s; and<br>• PMF: 2.0 m/s.<br>Maximum allowable flow velocities for channels in overburden or natural ground (clay/silt/gravel materials) are as follows:<br>• 2-year flood event: 1.0 m/s;<br>• 10-year flood event: 1.5 m/s;<br>• 100-year flood event: 2.0 m/s; and<br>• PMF: 3.0 m/s. |
| shallow wetlands | Shallow wetlands with an average depth of 1 m should be built into the drainage systems to provide for biodegredation and flood attenuation. Shallow wetlands should consist of an open-water area of about 1.5 m deep and a shallow area of about 0.5 m deep with wetlands vegetation. The open-water surface area should be approximately equal to the shallow vegetated area. |
| pit lake | Pit lakes should have a zone of littoral vegetation, occupying between 10 and 30% of the lake surface area to ensure biological productivity. The top layer of the littoral zone substrate should consist of a minimum of 20 cm of low-organic content soil. Average water depth of the littoral zone should be about 0.5 m. The littoral zone should be protected by a breakwater designed to protect against waves associated with the 100-year wind. The breakwater will enable the initial development of the littoral zone and the breakwater should be designed to prevent damage during the 100-year wind and to allow about 5% damage by the 1,000-year wind. Shoreline protection of Pierre South Pit Lake is a major concern because shoreline erosion would threaten the containment of the pit lake. |
| sand ridges on in-pit NST storage area with overburden sand cap | Ridges of sand (underflow sand) should be provided on the in-pit NST storage area with overburden sand cap. Sand ridges are necessary to provide drained soil conditions to ensure access, leach NST porewater residue and support small patches of vegetative cover during initial period of reclamation when consolidation of the NST results in upward flux of tailings porewater. Appropriate reclamation soil material should be placed on the surface of sand to provide the appropriate moisture balance to support deciduous trees or a mixed wood forest cover with dense understorey vegetation, composed mainly of grasses for upland erosion protection. |
| sand trenches on TT storage areas with sand cap | Sand trenches should be provided in TT storage areas with overburden caps to allow release of residual TT porewater. Collector ditches will form naturally on the sand trenches to become the secondary drainage channels. |

There are various types of channel regime relationships governing channel width, depth, width-depth ratio, sinuosity and meander wave length. These parameters are normally a function of mean annual 2-year flood peak or bankfull discharge, soil type and slope, although the regime formulations are not exact. There is a range of acceptable channel parameters as illustrated by the scatter in the original data from which the relationships were used to guide the channel design. Different sets of applicable regime equations were used for channels built in sandy soils and overburden or natural grounds.

The following regime relationships provided by Schumm (1977), were used to guide the designs of channels in sandy soils with mild slopes in natural grounds. The assumed silt/clay content for the sandy bed materials is 30%.

$$W = 37\frac{Q^{0.38}}{M^{0.39}} \qquad \{\text{ft}\}$$

$$D = 0.6M^{0.342} \cdot Q^{0.29} \qquad \{\text{ft}\}$$

$$S = \frac{60}{M^{0.38} \cdot Q^{0.32}} \qquad \{\text{ft/mile}\}$$

$$\lambda = 1890\frac{Q^{0.34}}{M^{0.74}} \qquad \{\text{ft}\}$$

$$P = 0.94M^{0.25}$$

where: Q = mean annual discharge [ft$^3$/s];

M = silt/clay content of the bed material [%];

W = channel bankfull width [ft];

D = channel bankfull depth [ft];

S = channel bed slope;

$\lambda$ = channel wave length; and

P = channel sinuosity.

Channels in overburden soils are to be built out of select overburden materials with dominant gravel material mixed with sand, silt and clay. Channels cut through natural ground are assumed to have bed materials with dominant gravel material mixed with sand, silt and clay. Otherwise, placement of selected overburden materials will be provided to ensure stable channel slopes over geological time frames.

The regime equations for channels with relatively steep slopes to be built in natural ground and overburden soils were based on the Kellerhals equations for gravel rivers in Alberta (Bray 1972), as listed below.

$$Wsm = 1.8Q^{0.5} \qquad \{ft\}$$

$$D = 0.256Q^{0.331} Dg(50)^{-0.025} \qquad \{ft\}$$

$$S = 0.096Q^{-0.344} Dg(50)^{0.586} \qquad \{ft/ft\}$$

where: Q = 2-year flood peak discharge [$ft^3/s$];
Wsm = channel bank-full width [ft];
D = channel bank-full depth [ft];
Dg(50) = median grain size of channel bed material [ft]; and
S = channel bed slope [ft/ft].

Channels built in overburden soils and natural ground were assumed to have similar sinuosity as the natural channels in the upper watershed of the Pierre River basin. The above regime relationship for channel bed slope was used to estimate the equivalent median size of the required bed materials to support the specified channel slopes. The regime relationships were also used as a guideline to estimate the channel bankfull width and depth based on the 2-year flood peak discharge and median grain size of assumed bed materials. The bottom width was then estimated based on the estimates of bankfull width and channel depth.

In addition to the regime equations discussed above, Manning's equation (1889) (Bretting 1946) was used to calculate channel flow based on selected channel geometry. Manning's equation is a function of flow area, channel velocity and slope. Manning's equation is listed below.

$$Q = \frac{1}{n} AR^{2/3} S^{1/2} \qquad \{m^3/s\}$$

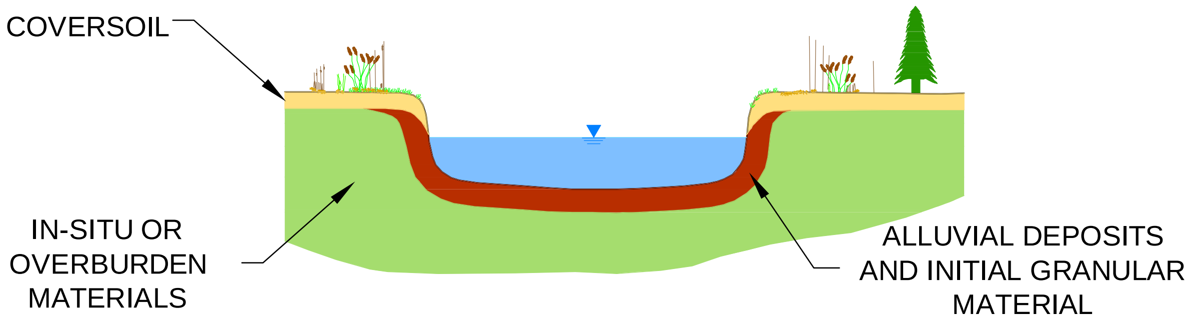
where: Q = flood peak discharge [$m^3/s$];
n = coefficient of roughness [0.039 main channel, 0.15 flood plain];
A = area of flow [$m^2$];
R = hydraulic radius [m]; and
S = channel bed slope [m/m].

As previously stated, the design approach is to create dynamic stability within the closure plan that will allow for the channels to accommodate changes over time. This method allows for the channel to respond to changes in hydrologic or sediment flow through erosion or deposition. A recommended median bed-sediment size ($D_{50}$) for the channels was determined using Kellerhals regime equation as a guideline with a safety factor of two.

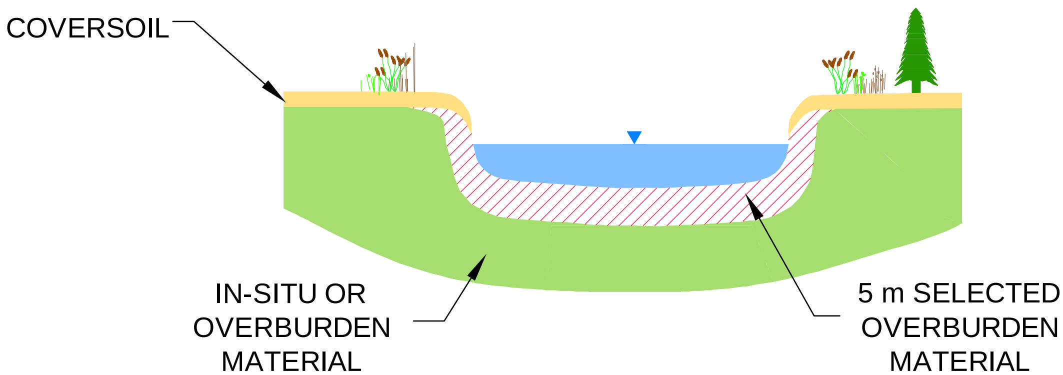
In some cases, specifically Channels C3, C5, C7 and C8, erosion could potentially threatens the sustainability of the system. Therefore these four channels are designed to have little erosion during a 100-year flood event. The recommended $D_{50}$ in the main channel was determined using Simons and Senturk's model (1977). In the event of a large flood, moderate erosion will occur within the channel. Sufficient depth of selected material is required to provide the channel with a self-maintaining supply of appropriate material. This design allows for the channels to be self-healing and gives it the ability to dynamically adapt through erosion and deposition. Figure 4 shows a typical cross-section and profile of channels requiring selected overburden and selected bouldery ground.

Portions of several of the closure diversion channels are aligned across the natural ground slope, and require landforms (very wide, high berms) to ensure that overbank flow during flood events is conveyed along the preferred direction of flow rather than forming a new channel oriented along the natural ground fall line. The landforms are a permanent closure structure that have a crest width of 100 m, 4H:1V side slopes and a height of 4 m above the invert of the closure channel. These landforms will be revegetated in a manner consistent with closure revegetation for the PRMA site (Closure, Conservation and Reclamation Plan in Volume 5, Appendix 5-2).

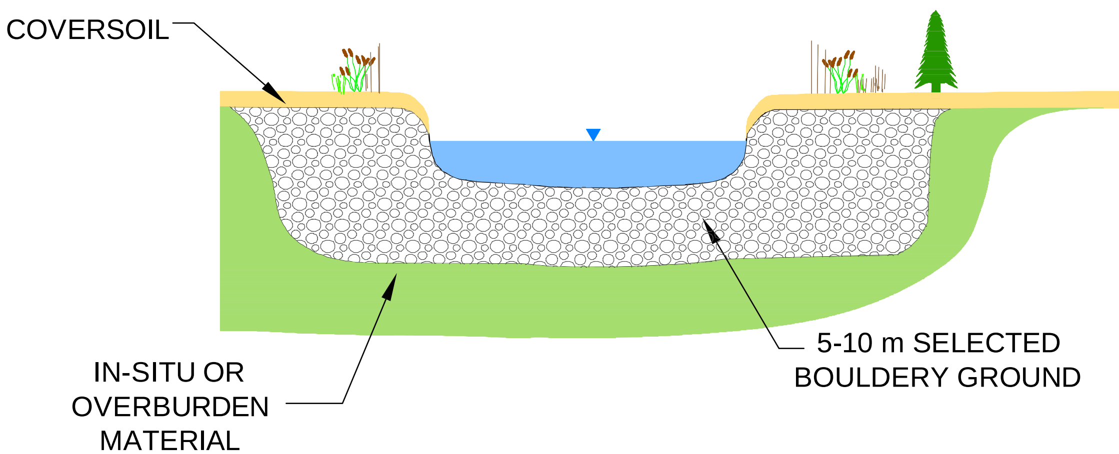
## CHANNELS CONSTRUCTED OF IN SITU MATERIAL




## CHANNELS CONSTRUCTED OF SELECT OVERBURDEN MATERIALS




## CHANNELS CONSTRUCTED OF BOULDERY GROUND




NOTE

CROSS SECTION VARIES AS SHOWN ON FIGURE 6.

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

**DESIGN CONCEPTS OF CLOSURE CHANNELS - TYPICAL CROSS-SECTION**

Shell Canada Limited

PROJECT 06−1346−022.9400
FILE No. Closure−Channels
DESIGN EK 24/09/07
SCALE AS SHOWN
REV. 0
CADD PSR 08/11/07
CHECK FLA 09/11/07
REVIEW WES/TC 30/11/07

**FIGURE: 4**

L:\2006\1344−OIL SANDS\1346\06−1346−022 Shell\9400\Closure Drainage Report\Fig 4 design concepts of closure channels − typical cross−section.dwg Dec 07, 2007 − 1:59pm

## 2.4 DESIGN FEATURES

This pre-feasibility level design of closure reclamation drainage systems was conducted to provide the following desirable features in the reclaimed landscape:

- Provision of Drainage Outlets - The closure landscape will be equipped with surface drainage systems that discharge to natural receiving waters. Closed systems that could result in saline lake areas and reduced flows in the receiving streams will be excluded from the closure landscape.
- No Man-Made Dams - Dams containing large bodies of ponded water are excluded from the closure landscape. Any potentially ponded areas will be limited to shallow wetlands or lakes with depths less than 2 m. Any landmass containing ponded water or liquefiable material will be equipped with a 10 m minimum freeboard and a small overall hydraulic gradient no greater than 20H: 1V.
- Provision for Beaver Dams - The minimum invert of the closure outlet channels from the pit lakes are equal to or greater than 4 m below natural ground. The maximum height of beaver dams found in the Oil Sands Region is about 2.5 m. Therefore, beaver dam blockage would be unable to cause channel overtopping.
- Permanent Walk-Away Mine Closure - The drainage systems and landscape must be permanent walk-away closure systems after a period of monitoring and management.
- Reclamation Surface Soil Cover - Sufficient depth of reclamation surface soil will be placed to provide the necessary soil moisture storage to support a self-sustaining tree cover with a dense understorey. This tree cover and undercover will provide good erosion resistance.
- Consolidation of TT Materials - Consolidation of TT materials and differential settlement will be accommodated by providing managed drainage outlet channels. The invert of a managed drainage channel is lowered during a management period following the end of mining to suit the rate of TT consolidation.
- Topographic Slope - Microtopography will be built into the landscape to create a landform with diverse drainage conditions and local hydraulic gradients that resist soil salinization. A maximum slope of 30% will be provided to support vegetation and a minimum overall slope of about 0.5% will be provided to achieve positive drainage.
- Change in Flow Regime of Receiving Water - The 10-year flood flows of natural receiving waters will not exceed pre-development flows by more than 30%. The 2-year flood flows and mean annual flows of natural receiving waters should not deviate from pre-development flows by more than +100% and -30%.

- Leaching of Salts from Sand Caps - Microtopography will be designed in the form of ridges and swales to provide a mechanism for leaching salts.
- Regime Channel - The drainage systems will be designed to replicate natural channel regime relationships. These regime relationships include various channel parameters such as width, depth, width/depth ratio, meander wavelength, sinuosity, bed material, gradient and bank slope. Channels constructed in accordance with regime relationships based on natural channels will be subject to very slow values of erosion.
- No Side Hill Channels - Side hill channels that run parallel to contours will be excluded from the closure landscape. If a closure channel is aligned across the natural ground slope, a landform will be designed to ensure that overbank flow during flood events is conveyed along the preferred direction of flow rather than forming a new channel oriented along the natural ground fall line.
- Pit Lakes for Biodegredation - All drainage from disturbed areas that contain process-affected water will drain through a pit lake to bioremediate to safe and acceptable discharge standards before release to the natural environment.

# 3 HYDROLOGIC AND WIND DESIGN PARAMETERS

This section summarizes the methodology and results of the analyses related to flood hydrology and extreme wind estimates required for the design of the closure drainage systems. A detailed discussion of the methodology and results of the hydrologic analyses is presented in the Aquatics Environmental Setting Report (ESR) (Golder 2007).

Climatic variables analyzed in the ESR include air temperature, precipitation, evaporation and evapotranspiration, relative humidity, solar radiation and wind speed and direction. Sources of climatic data include historical records of the long-term monitoring stations operated by the Atmospheric Monitoring Division of Environment Canada, seasonal monitoring stations by Alberta Sustainable Resource Development (ASRD), short-term stations by the Regional Aquatics Monitoring Program (RAMP) and oil sands operators, and environmental setting field work conducted for the Project.

Hydrologic variables analyzed in the Aquatics ESR include stream flows, basin water yields, suspended sediments in streams, basin sediment yields and stream geomorphology. Sources of hydrologic data include records of the long-term monitoring stations operated by the Water Survey Division of Environment Canada, short-term monitoring stations by RAMP and environmental setting field work conducted for the Project. Site-specific stream geomorphic data were acquired and analyzed in and around the PRMA.

## 3.1 HYDROLOGIC ANALYSES

Detailed hydrologic analyses were conducted as part of the Surface Water Hydrology Environmental Setting Report (ESR) (Golder 2007). The analyses included a derivation of the climatic and hydrologic parameters to characterize the environmental setting in the study areas. Results from the ESR hydrologic analysis are presented in this section.

The simulated daily flows at various locations in the PRMA watersheds were analyzed to obtain the predevelopment mean and extreme flow parameters. The mean annual water yields of Pierre River, Eymundson Creek, Asphalt Creek, Big Creek and Redclay Creek are estimated to be 68, 68, 81, 49 and 48 mm respectively, corresponding to mean annual discharges of 0.29, 0.67, 0.40, 0.49 and 0.32 $m^3/s$, respectively. The annual water yield depends primarily on the drainage area, precipitation and the ratio of upland area to lowland area. The simulated maximum monthly flows at the river mouth of the Pierre River, Eymundson Creek, Asphalt Creek, Big Creek and Redclay Creek are 3.56, 8.97, 5.42, 6.57 and 4.02 $m^3/s$ (May) respectively, and the simulated minimum mean monthly flows are zero (November to March) for these five streams. These streams are expected to be dry or frozen to the stream bed during extreme low flow conditions.

Hydrologic modelling was conducted to derive simulated flow series for various types of reclaimed surfaces to provide a sound basis for deriving hydrologic parameters that quantify runoff characteristics of the reclaimed surfaces.

## 3.2 TYPES OF RECLAIMED LANDFORMS FOR CLOSURE

### 3.2.1 Landform Types

There are five principal types of reclaimed landforms planned for the Project as listed below:

- reclaimed ETDA, constructed above the original ground, that is constructed of TT, overburden and tailings sands at closure;
- reclaimed tailings capped with overburden materials in the mined-out pits;
- reclaimed plant site;
- reclaimed overburden disposal areas constructed above original ground; and
- pit lakes with MFT stored beneath a water cap.

### 3.2.2 In-Pit Tailings and Overburden Storage Areas

All of the mined-out pit cells, except for those to be used for the creation of pit lakes, will be used to store tailings or overburden. The tailings storage areas will be capped with overburden to raise the elevations of the final topography such that surface runoff will flow to pit lakes. Table 2 lists the average pit bottom and final ground elevations for the pit cells, in-pit dumps and OBDAs.

**Table 2 In-Pit Non-Segregating Tailings and Overburden Disposal Areas**

| Pit Cell | Cell Storage Material | Average Pit Bottom Elevation [masl] | Average Final Surface Elevation [masl] | Average Height of Tailings Cell [m] |
|---|---|---|---|---|
| North OBDA | overburden | 220 | 330 | 110 |
| Cell 1 Tailings | NST with overburden cap | 215 | 285 | 70 |
| Cell 2 Tailings | NST with overburden cap | 210 | 260 | 50 |
| Cell 3 Tailings | NST with overburden cap | 230 | 290 | 60 |
| In-pit Dump 1 | overburden | 230 | 300 | 70 |
| In-pit Dump 2 | overburden | 220 | 250 | 30 |
| In-pit Dump 3 | overburden | 220 | 265 | 45 |

### 3.2.3 Reclaimed Plant Site Area

The plant site will be built at approximately the natural ground surface elevation of 255 masl. At closure, the site will remain relatively flat, with drainage to the east into natural watercourses that discharge to the Athabasca River. The drainage area of these outlet streams was 8.9 $km^2$ before development but it will be raised at closure to about 11.2 $km^2$.

### 3.2.4 Reclaimed External Tailings Disposal Area

The reclaimed ETDA will be built above the original ground level to an average top surface elevation of 330 masl (Table 3). This facility will initially store TT in the southern cell and MFT in the northern cell. The MFT will be moved from the ETDA to Pierre South Pit Lake at closure. The reclaimed surface will range from 345 to 295 masl with an average surface elevation of about 330 masl. The average height will vary from 41 to 63 m. The average overland slope of the reclaimed ETDA surface is 0.3% in the main drainage channel C1 and 0.5% in the secondary drainage systems flowing into the main channel. At closure, an extension to the ETDA will be built with overburden material at a slope of about 1% to connect the ETDA drainage channel to the natural topography.

The surface runoff from this area will flow into Channel C1 and then to Channel C2. Discharge will be directed to the Treatment Lake (former Raw Water Storage Facility) that operates as a treatment pond at closure.

The top surface and side slopes of the ETDA will be capped with a layer of reclamation surface soil composed of organic and mineral soil underlain by TT and sand as specified in the Closure, Conservation and Reclamation Plan (Volume 5, Appendix 5-2). The TT is expected to be fairly impervious, while the sand is expected to be fairly pervious. The reclaimed TT cell inside the perimeter dykes is expected to result in relatively low recharge to the groundwater and relatively high surface runoff potential. The surface of the sand storage cell is expected to have a relatively high groundwater recharge rate but a relatively low potential for gullying after the establishment of mature vegetation.

Drainage swales created on the reclaimed TT cell will be relatively wet while the upland ridges built of sand on the TT cell will be relatively dry with a minimum depth of 1.5 m to the local water table. The sand storage cell will have relatively dry soil conditions capable of supporting upland vegetation. Lowland areas within the ETDA and in seepages zones around its perimeter will be covered with riparian shrublands and wetlands vegetation.

**Table 3 External Tailings Disposal Areas**

| Pit Cell | Average Ground Elevation [masl] | Average Final Surface Elevation [masl] | Average Height of Tailings [m] |
|---|---|---|---|
| ETDA - MFT replaced by sand (northern) Cell | 280 | 330 | 50 |
| ETDA - TT (southern) Cell | 280 | 335 | 55 |

## 3.2.5 Overburden Disposal Area

The North OBDA will be built above original ground level. Sides slopes will range from about 4H:1V to 10H:1V. These structures will be reclaimed with reclamation surface soil and subsoil as specified in the Closure, Conservation and Reclamation Plan (Volume 5, Appendix 5-2). The reclaimed OBDA will be subject to relatively low surface water yield in the summer due to the high porosity of the reclamation soils and well-drained conditions of the sandy subsoil.

## 3.2.6 Pit Lakes

Pit lakes are important features of the mine closure that provide water quality benefits such as biodegradation of surface runoff and seepage waters that potentially include process affected water from tailings materials. Oil sands pit lakes are designed to fulfill two distinct functions in the reclamation landscape. Beginning at the end of operations (2039), through the decommissioning period (2039 to 2049), at closure (2049) and beyond, the pit lakes will provide treatment of runoff from the reclaimed landscape, seepages and tailings flux waters. Over time, these lakes will progress into biologically productive systems. The pit lakes will receive treatment by dilution, biodegradation and settling before waters are released to other watercourses. The pit lakes will be self-sustaining and eventually support a naturally diverse aquatic ecosystem.

Research on pit lakes and wetlands is ongoing, and key findings will continue to be incorporated in the pit lake design process. For example, related wetlands and pit lake work for CEMA (Golder 2006) is assisting in identifying key physical and chemical factors that will control the concentrations of dissolved substances in reclamation wetlands and pit lakes. These factors include surface area, depth, shape, surrounding landscape material, contributing water quantity and quality, as well as climate.

After the initial filling period of the pit lakes, water balance will be governed by surface runoff, direct precipitation, evaporation and groundwater inflows or outflows. The lakes would become highly saline (Oil Sands End Pit Lake Review Document by CEMA End Pit Lakes Subgroup (Clearwater 2007) for effects of salinity on pit lakes) without sufficient surface inflows to compensate for evaporation losses and to provide for throughflow. Therefore, based on hydraulic simulations, sufficient surface runoff will be routed through the pit lakes to provide for productive lakes in the closure landscape. The water level in each of the two pit lakes is above the invert elevation of the outlet channel 80% of the time during the open water season based on hydrologic analysis.

Two waterbodies, Pierre North Pit Lake and Pierre South Pit Lake, are proposed for the Pierre River Mining Area closure drainage systems. Pierre South Pit Lake is divided into two cells by submerged dykes. Table 4 lists the final water surface levels, final water cap depths, and the types of tailings to be stored under the water caps of the pit lakes.

**Table 4 Pit Lakes**

| Pit Lake | Normal Lake Water Level [masl] | Average Water Cap Depth [m] | Materials on Lake Bottom |
|---|---|---|---|
| Pierre North Pit Lake | 280 | 6 | MFT |
| Pierre South Pit Lake | 250 | 15 | MFT |

Note: MFT = Mature Fine Tailings.

## 3.3 HYDROLOGY OF RECLAIMED SURFACES

### 3.3.1 Hydrologic Modelling Analysis

The Hydrologic Simulation Program-Fortran (HSPF) model was used to simulate surface runoff from reclaimed surfaces and to route surface flows through channels and lakes. The HSPF model is a continuous simulation hydrologic model from the United States Environmental Protection Agency (U.S. EPA). It uses a combination of empirical and physically based relationships to predict runoff, evaporation and changes in soil moisture storage. This model can be used to simulate both rainfall runoff and snowmelt runoff.

The HSPF model was validated for natural upland and lowland areas based on the recorded streamflow and water level data in the Pierre River, Asphalt Creek and Unnamed Creek. The calibrated model parameters for the natural basins provided a basis for estimating the model parameters for the reclaimed surfaces. The estimation of these parameters was also based on a good understanding of the runoff processes of the reclaimed surfaces as described below.

**Overburden Disposal Areas:** The OBDAs are expected to have similar hydrologic characteristics as the natural upland areas in the upper Pierre River watershed, because most of the overburden materials are a mixture of till, sands and gravel. However, long-term water yield and flood peak discharges of the OBDAs, following establishment of equilibrium conditions, are expected to be somewhat greater than the natural upland areas because of steeper slopes and reduced surface soil storage capacities.

**In-Pit Non-Segregating Tailings Storage Areas:** The final surface elevations of most of the reclaimed in-pit storage areas will be close to or slightly above original ground levels. The NST storage areas will be capped with overburden to raise the elevations of the final topography such that surface runoff will flow to pit lakes. The relatively well-drained ridges at the overburden-capped tailings areas will have comparable runoff characteristics to the reclaimed overburden storage areas. However, the swales between the ridge areas will be very wet and have similar runoff characteristics as the natural lowland muskeg terrain. The swale areas will be underlain by sand to relieve elevated groundwater pressures and provide an outlet for any residual upward flux of NST porewater.

**External Tailings Disposal Area:** The TT cell in the ETDA will be capped by sand that will be constructed by controlled spigotting to form a final surface consisting of a series of ridges and swales. The reclaimed surface will be characterized by wet conditions in the swales formed between the sand ridges, and drier conditions on the ridge tops. The hydrologic conditions in the swales are expected to be similar to lowland muskeg terrain, while hydrologic conditions on ridge tops are expected to be similar to natural upland areas. The areas at the periphery of the ETDA that are built of sand overburden on pervious foundation soils, are also expected to be relatively dry and supportive of dry upland vegetation. Recharge to the groundwater from the TT cell is expected to be very small.

Tailings pond water from the ETDA has the potential to seep into receiving surface waters due to the hydraulic head between the ETDA and its surroundings. There will be two methods to prevent the interflow and deep percolating water from entering receiving waterbodies without entering a wetlands, pit lake, or treatment lake. During operation, perimeter wells will capture seepages and runoff from the ETDA. These waters will be pumped back into the tailings pond to prevent release of high substance concentrations into receiving surface waters during mine operations. At closure, the wells along the east edge of the ETDA will be modified to direct seepage water to the treatment lake. They will continue to operate until the water quality meets effluent standards.

Large wetlands will be constructed north of the ETDA. The wetlands will provide natural pre-treatment before the water is released to the Treatment Lake. The wetlands and the treatment lake will be of adequate size to ensure that outflow from the reclaimed landscape will be non-toxic prior to release into the Athabasca River.

**Topography:** Sand ridges are needed to provide suitable conditions to support upland vegetation. The high elevation of sand ridges will create hydraulic gradients that will provide well-drained soil conditions necessary for upland vegetation, particularly following initial reclamation when consolidation of tailings results in upward flux of tailings porewater. The ridges will enable early planting of upland vegetation so that the vegetation progression can begin upon mine closure, during a time when the upward flux of tailings porewater would otherwise cause most of the area to perform as wetlands.

The sand ridges and swales will be constructed to form a dendritic pattern of secondary drainage watercourses, with runoff flowing through the swales to main channels and wetlands at the outlet of the tailings area.

The wet areas of the sand cap tailings storage areas will be subject to relatively high evapotranspiration losses because of the greater available soil moisture. Consequently, the annual water yield and flood discharge characteristics of these areas are expected to be similar to the existing lowland muskeg terrain. Annual water yield of the reclaimed tailings storage areas is expected to be greater than the natural lowland because of the smaller soil moisture storage capacity of reclamation soil and the presence of sand ridges that have similar runoff characteristics as natural sandy uplands.

**Shallow Wetlands:** Shallow wetlands will be built into the reclaimed landscape of the in-pit tailings disposal areas and the out-of-pit tailings area. The wetlands will attenuate flood peak discharges and provide for lengthened residence times that will improve drainage water quality through biological treatment and settling of suspended sediments.

**Pit Lakes:** Pit lakes are important features of the closure landscape. They are beneficial for biodegradation of surface runoff from reclaimed areas, including tailings porewater and seepage inflows. They also contribute to the balance of dry and wet landscape in the reclaimed project area. Littoral zones occupying about 10 to 30% of the pit lake areas will be developed along the shores to provide for biological productivity.

The presence of pit lakes in the reclaimed landscape will reduce flood flows by providing lake storage for flow attenuation. However, the lakes will have a small reduction on the net annual water yield from the mine area due to evaporation losses from the lake surfaces.

### 3.3.2 Annual Runoff From Reclaimed Surfaces

The estimated annual water yields from various types of reclaimed and natural surfaces are presented in Table 5 based on the analysis described in Section 3.3.1.

### 3.3.3 Flood Peak Discharges From Reclaimed Surfaces

The simulated flows from the HSPF model were analyzed to determine flood peak discharges from reclaimed surfaces. The resulting flood flow parameters provided a basis for designing the closure reclamation drainage systems. Table 6 presents the derived flood peak discharges for each main channel shown in Figure 3. The Probable Maximum Flood (PMF) peak discharges were derived by using a multiplier of ten times the 100-year flood for purposes of conceptual design of closure facilities at this early stage of development. This approach is consistent with other closure drainage plans produced for the Oil Sands Region.

## Table 5 Estimated Annual Runoff From Natural and Reclaimed Surfaces

| Land Type | Parameter | Annual Water Yields[a][b] [mm] | | | | |
|---|---|---|---|---|---|---|
| | | 100-Year Dry | 10-Year Dry | Mean | 10-Year Wet | 100-Year Wet |
| all land types | precipitation | 221 | 275 | 356 | 442 | 527 |
| natural upland (silt and clay sub-surface soil) | total runoff | 5 | 15 | 48 | 92 | 150 |
| | evapotranspiration | 216 | 260 | 308 | 350 | 377 |
| | surface runoff | 0 | 1 | 3 | 5 | 8 |
| | interflow runoff | 3 | 10 | 33 | 62 | 102 |
| | groundwater flow | 1 | 4 | 13 | 24 | 40 |
| | deep percolation loss | 0 | 0 | 0 | 0 | 0 |
| natural upland (silt, clay and sand sub-surface soil) | total runoff | 0 | 10 | 40 | 77 | 146 |
| | evapotranspiration | 221 | 265 | 316 | 365 | 377 |
| | surface runoff | 0 | 1 | 3 | 6 | 11 |
| | interflow runoff | 0 | 7 | 29 | 57 | 107 |
| | groundwater flow | 0 | 2 | 8 | 15 | 28 |
| | deep percolation loss | 0 | 0 | 0 | 0 | 0 |
| natural upland (sandy sub-surface soil) | total runoff | 20 | 36 | 76 | 125 | 194 |
| | evapotranspiration | 201 | 239 | 280 | 317 | 333 |
| | surface runoff | 0 | 0 | 1 | 1 | 2 |
| | interflow runoff | 4 | 8 | 17 | 27 | 43 |
| | groundwater flow | 16 | 28 | 59 | 97 | 150 |
| | deep percolation loss | 0 | 0 | 0 | 0 | 0 |
| natural lowland (silt and clay sub-surface soil) | total runoff | 0 | 1 | 24 | 50 | 101 |
| | evapotranspiration | 221 | 276 | 332 | 392 | 426 |
| | surface runoff | 0 | 0 | 2 | 3 | 7 |
| | interflow runoff | 0 | 1 | 17 | 37 | 74 |
| | groundwater flow | 0 | 0 | 5 | 10 | 20 |
| | deep percolation loss | 0 | 0 | 0 | 0 | 0 |
| natural lowland (silt, clay and sand sub-surface soil) | total runoff | 0 | 2 | 25 | 53 | 106 |
| | evapotranspiration | 221 | 275 | 331 | 389 | 421 |
| | surface runoff | 0 | 0 | 2 | 4 | 8 |
| | interflow runoff | 0 | 1 | 20 | 41 | 81 |
| | groundwater flow | 0 | 0 | 4 | 8 | 16 |
| | deep percolation loss | 0 | 0 | 0 | 0 | 0 |
| natural lowland (sandy sub-surface soil) | total runoff | 0 | 6 | 27 | 53 | 97 |
| | evapotranspiration | 221 | 269 | 329 | 389 | 430 |
| | surface runoff | 0 | 0 | 1 | 3 | 5 |
| | interflow runoff | 0 | 4 | 15 | 30 | 54 |
| | groundwater flow | 0 | 2 | 11 | 21 | 38 |
| | deep percolation loss | 0 | 0 | 0 | 0 | 0 |
| reclaimed NST with sand capping | total runoff | 20 | 40 | 86 | 143 | 215 |
| | evapotranspiration | 201 | 235 | 270 | 299 | 312 |
| | surface runoff | 1 | 2 | 4 | 6 | 9 |
| | interflow runoff | 8 | 16 | 34 | 57 | 85 |
| | groundwater flow | 11 | 22 | 48 | 80 | 121 |
| | deep percolation loss | 0 | 0 | 0 | 0 | 0 |
| reclaimed NST without sand capping | total runoff | 1 | 10 | 42 | 81 | 107 |
| | evapotranspiration | 220 | 265 | 314 | 361 | 420 |
| | surface runoff | 0 | 3 | 10 | 20 | 27 |
| | interflow runoff | 0 | 5 | 20 | 39 | 51 |
| | groundwater flow | 0 | 3 | 11 | 22 | 29 |
| | deep percolation loss | 0 | 0 | 0 | 0 | 0 |
| reclaimed overburden - silt and clay | total runoff | 3 | 19 | 62 | 115 | 161 |
| | evapotranspiration | 218 | 256 | 294 | 327 | 366 |
| | surface runoff | 1 | 6 | 21 | 38 | 53 |
| | interflow runoff | 1 | 10 | 34 | 62 | 87 |
| | groundwater flow | 0 | 2 | 8 | 15 | 20 |
| | deep percolation loss | 0 | 0 | 0 | 0 | 0 |

## Table 5 Estimated Annual Runoff From Natural and Reclaimed Surfaces (continued)

| Land Type | Parameter | Annual Water Yields[a][b] [mm] | | | | |
|---|---|---|---|---|---|---|
| | | 100-Year Dry | 10-Year Dry | Mean | 10-Year Wet | 100-Year Wet |
| reclaimed overburden - sand | total runoff | 26 | 47 | 94 | 150 | 217 |
| | evapotranspiration | 195 | 228 | 262 | 292 | 310 |
| | surface runoff | 5 | 8 | 16 | 26 | 38 |
| | interflow runoff | 6 | 11 | 22 | 36 | 52 |
| | groundwater flow | 15 | 27 | 55 | 88 | 127 |
| | deep percolation loss | 0 | 0 | 0 | 0 | 0 |
| reclaimed sand storage | total runoff | 33 | 54 | 104 | 164 | 235 |
| | evapotranspiration | 188 | 221 | 252 | 278 | 292 |
| | surface runoff | 1 | 2 | 4 | 6 | 8 |
| | interflow runoff | 11 | 18 | 34 | 54 | 77 |
| | groundwater flow | 21 | 34 | 66 | 104 | 149 |
| | deep percolation loss | 0 | 0 | 0 | 0 | 0 |
| reclaimed plant site | total runoff | 17 | 36 | 84 | 143 | 221 |
| | evapotranspiration | 204 | 239 | 272 | 299 | 306 |
| | surface runoff | 14 | 31 | 71 | 121 | 187 |
| | interflow runoff | 2 | 4 | 10 | 18 | 27 |
| | groundwater flow | 1 | 1 | 3 | 5 | 7 |
| | deep percolation loss | 0 | 0 | 0 | 0 | 0 |
| lake | evaporation | 686 | 645 | 594 | 542 | 498 |

[a] Based on the simulation between 1954 and 2006, assuming precipitation at Ellis, corrected to estimated local elevation (350 masl), was applied to all land types.

[b] Frequency analyses were applied to 53 years of annual precipitations, lake evaporations and simulated runoffs independently.

## Table 6 A Summary of Flood Peak Discharges for Main Drainage Channels

| Channel | Drainage Area [km²] | Flood Peak Discharges [m³/s] | | | |
|---|---|---|---|---|---|
| | | 2-Year Flood | 10-Year Flood | 100-Year Flood | PMF |
| C1 | 2.59 | 0.17 | 0.44 | 1.03 | 10.3 |
| C2 | 24.8 | 0.42 | 1.15 | 3.07 | 30.7 |
| C3 | 48.6 | 0.27 | 0.72 | 1.38 | 13.8 |
| C4 | 223 | 4.73 | 11.8 | 21.0 | 210 |
| C5 | 255 | 3.36 | 9.72 | 21.8 | 218 |
| C6 | 212 | 4.77 | 12.2 | 27.1 | 271 |
| C7 | 303 | 5.10 | 14.4 | 35.3 | 353 |
| C8 | 328 | 2.36 | 5.99 | 11.9 | 119 |
| C9 | 33.6 | 0.26 | 0.78 | 2.21 | 22.1 |
| C10 | 12.4 | 0.10 | 0.33 | 1.07 | 10.7 |
| C11a | 94.4 | 2.75 | 7.04 | 13.5 | 135 |
| C11b[a] | 116 | 10.1 | 24.0 | 46.9 | 469 |
| C12 | 12.0 | 0.77 | 1.49 | 2.38 | 23.8 |

[a] Reach B of Channel C11 will combine with the closure channel from Canadian Natural Horizon Project draining from Horizon Lake. The drainage area for C11b does not include the drainage area from Canadian Natural Horizon Project.

PMF = Probable Maximum Flood.

## 3.4 DESIGN WIND PARAMETERS

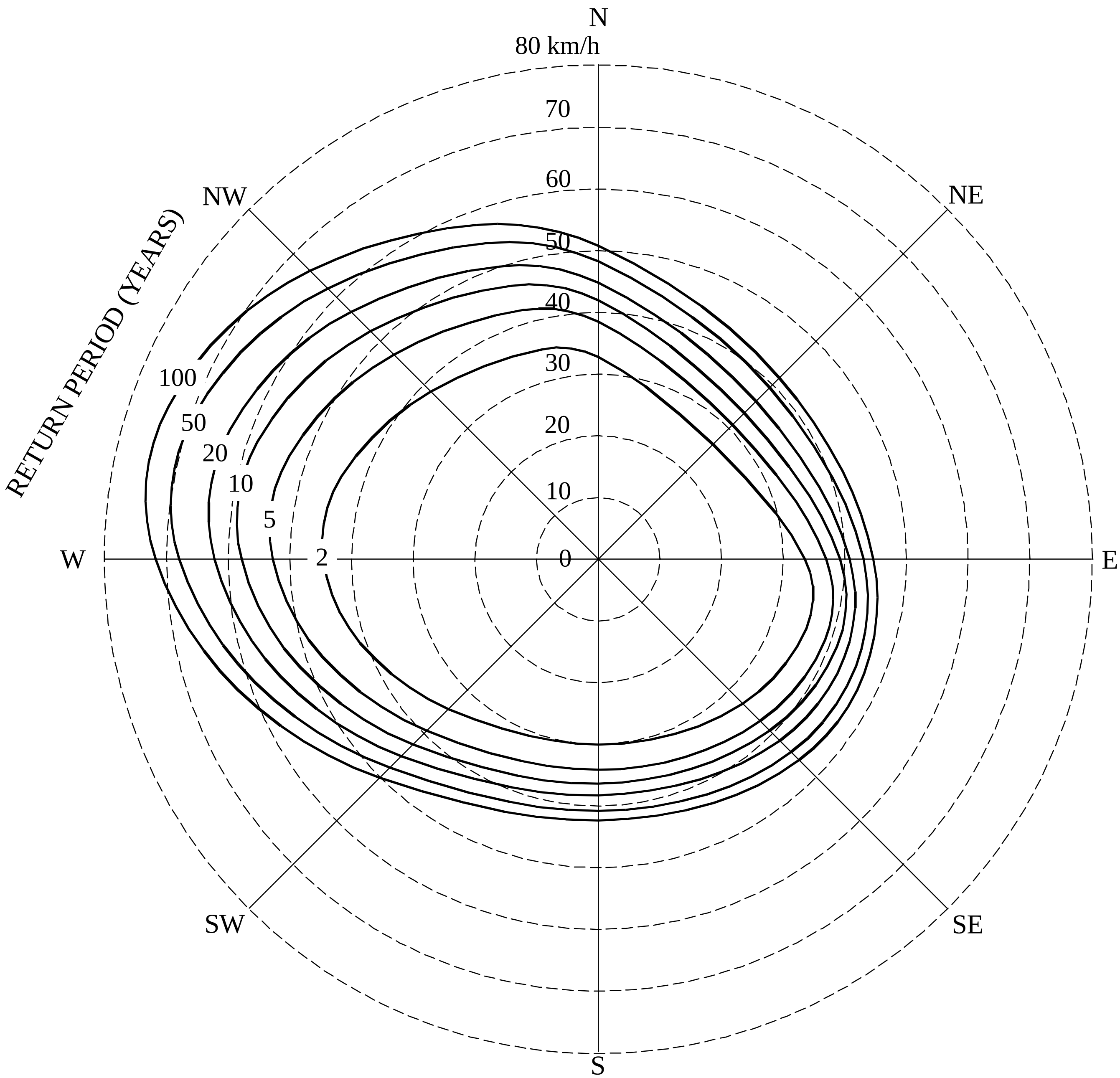
Design wind parameters for the Project development area were required to provide a basis for designing shoreline protection for the pit lakes. The available wind data at the Aurora Climate Station and other nearby climate stations have short periods of record. These data cannot be directly used to derive reliable wind design parameters that require a long period of record for reliable prediction. Therefore, the long-term (1959 to 2006) hourly wind data recorded at the Fort McMurray Airport climate station were used to derive the design wind parameters for the Project development area. However, the long-term wind characteristics at the Fort McMurray Airport climate station are expected to be somewhat different than the Project development area due to the differences in topographic features such as elevation and surrounding landscape. This may introduce some uncertainty to the design wind parameters at the site but the accuracy is considered adequate for this early stage of analysis and concept design.

Table 7 and Figure 5 present the derived design wind parameters for various return periods and directions. They show that the extreme winds from the west and northwest directions are stronger than the extremes from other directions. The extreme hourly 100-year wind speed from the west and northwest directions are 71.6 and 65.7 km/hr, respectively.

**Table 7 Frequency Analysis of Extreme Hourly Wind Speeds at Fort McMurray Airport**

| Wind Direction From | Extreme Hourly Wind Speeds[a] [km/hr] | | |
|---|---|---|---|
| | 2-Year | 10-Year | 100-Year |
| north | 32.9 | 41.8 | 50.8 |
| northeast | 26.0 | 33.4 | 41.6 |
| east | 33.4 | 38.9 | 44.6 |
| southeast | 32.6 | 39.5 | 45.7 |
| south | 30.0 | 36.2 | 42.3 |
| southwest | 34.2 | 42.3 | 49.9 |
| west | 44.6 | 57.6 | 71.6 |
| northwest | 38.2 | 51.8 | 65.7 |

[a] Based on the data recorded at the Fort McMurray Airport from 1959 to 2006.




**NOTES**

1. BASED ON DATA AT THE FORT McMURRAY AIRPORT CLIMATE STATION FROM 1959 TO 2006.

2. INTERPOLATE ALONG MAIN DIRECTIONS.

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

**FREQUENCY ANALYSIS OF EXTREME HOURLY WIND SPEEDS AT FORT McMURRAY AIRPORT CLIMATE STATION**

Shell Canada Limited

| | | | | |
|---|---|---|---|---|
| PRO | 06-1346-022.9400 | | FILE No. | Wind Speeds |
| DESIGN | PW | 10/05/07 | SCALE NA | REV. 0 |
| CADD | RFM | 21/08/07 | | |
| CHECK | FLA | 11/10/07 | **FIGURE: 5** | |
| REVIEW | WES/TC | 30/11/07 | | |

L:\2006\1344-OIL SANDS\1346\06-1346-022 Shell\9400\Closure Drainage Report\ Drawing file: Fig 5 Hourly Wind Speeds.dwg Dec 07, 2007 - 11:31am

# 4 DESIGN OF RECLAMATION DRAINAGE SYSTEMS

## 4.1 GENERAL DRAINAGE SCHEME

The layout of the proposed closure drainage systems in Figure 3 shows the main and secondary drainage systems and the reclamation topography of the Project development area. Figure 3 also shows the integration of the PRMA closure drainage system with Canadian Natural Resources Limited (Canadian Natural) Horizon Project's closure drainage system. The downstream reach of this channel (Channel 11b) has been redesigned to accommodate flows from both the diversion of the Pierre River and from the Canadian Natural Horizon Project.

Figure 6 presents typical cross-sections of closure drainage channels. The proposed channels have relatively small main channels (with the capacity to convey a 2-year flood) and floodplains to accommodate larger flood flows.

## 4.2 MAIN DRAINAGE SYSTEMS

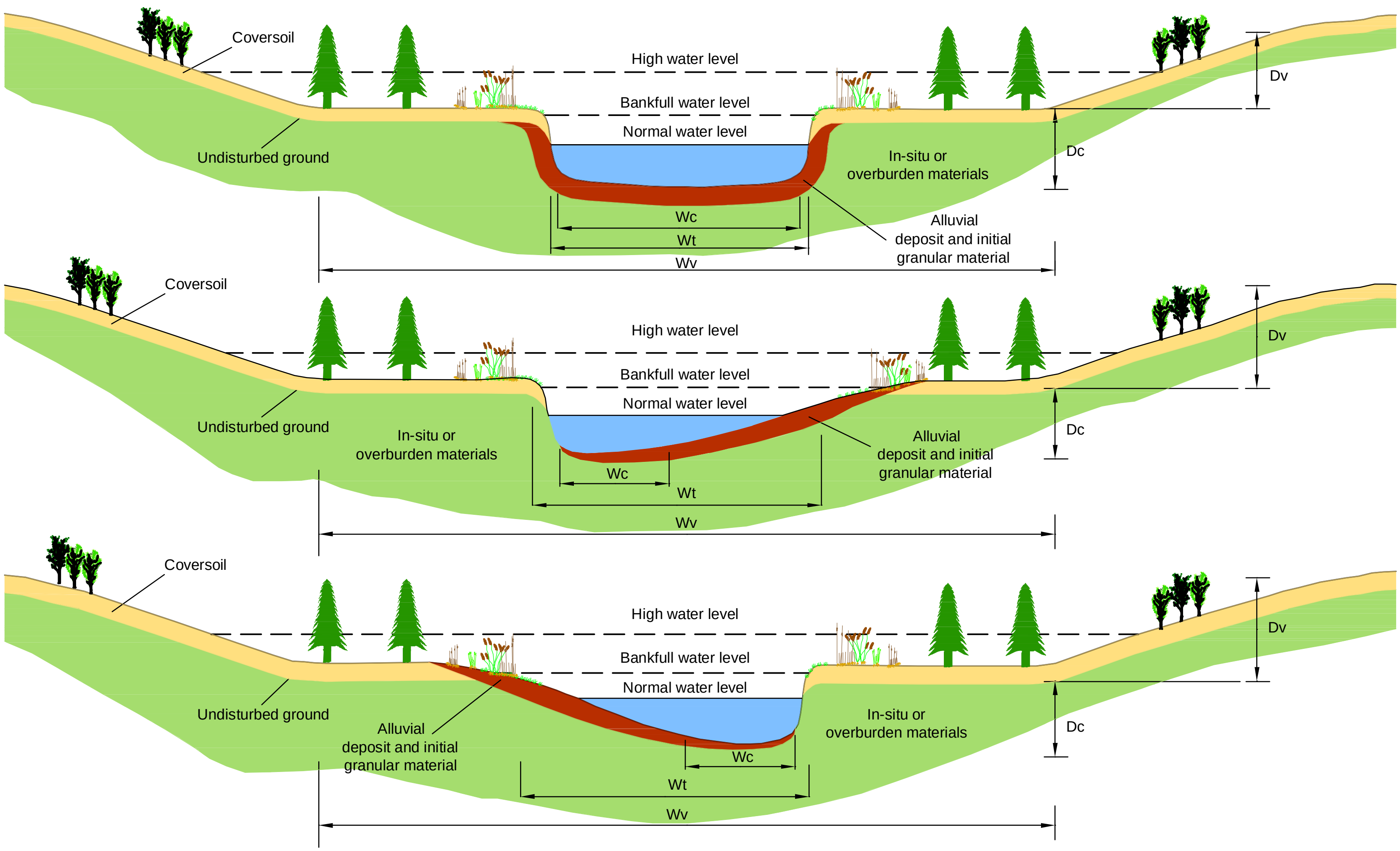
### 4.2.1 Main Drainage Systems to the Treatment Lake and Redclay Compensation Lake

#### 4.2.1.1 Main Drainage System for the External Tailings Disposal Area

***Proposed System***

The proposed main drainage system for the ETDA is shown in Figure 7. The system consists of the main drainage Channel C1 in the former MFT cell and smaller tributaries draining the TT cell. The runoff from the ETDA flows through Channel C2 to the Treatment Lake, which at closure will be used as a treatment pond. The outlet from the Treatment Lake to the Athabasca River (Channel C3) is located to maximize the flowpath through the lake from the inlet channel. This drainage system will collect and convey surface runoff from the entire ETDA and the upward flux of porewater due to TT consolidation from the southern TT cell.

The main drainage channel (C1) to be developed in overburden material will be initially formed by water runoff during sand material placement, possibly by spigotting. The meandering pattern and cross-sectional shape of the sandy channel will naturally evolve by surface runoff during reclamation and after closure to reach a stable regime.




LEGEND

| | |
|---|---|
| Wc | Channel bottom width |
| Wt | Top channel width |
| Wv | Valley width (50 to 100 m) |
| Dc | Channel depth |
| Dv | Valley depth |

PROJECT

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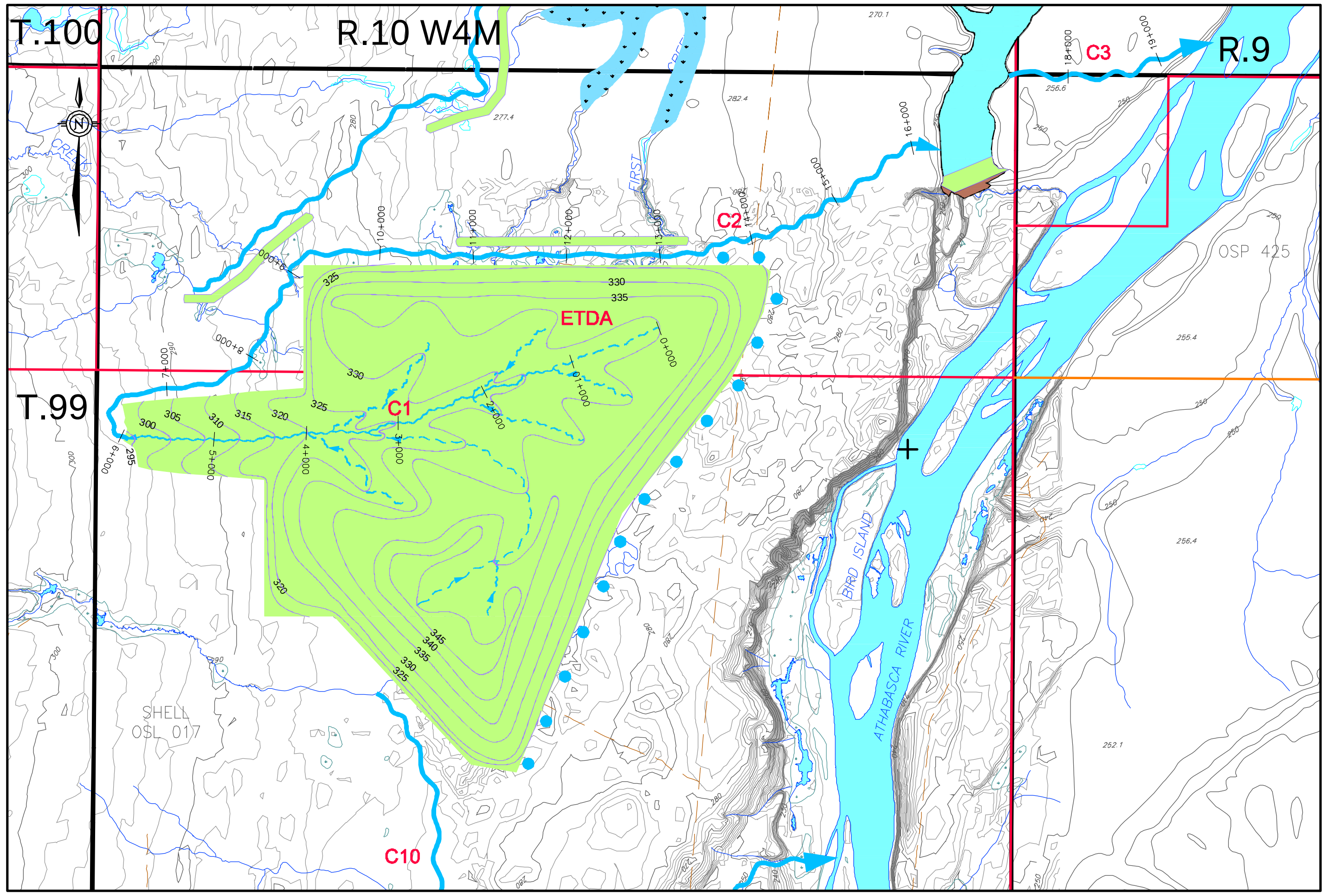
TITLE

# TYPICAL CROSS-SECTIONS OF CLOSURE DRAINAGE CHANNELS

Shell Canada Limited

| PROJECT 06-1346-022.9400 | | | FILE No. Typical X-Section |
|---|---|---|---|
| DESIGN | EK | 24/09/07 | SCALE AS SHOWN REV. 0 |
| CADD | PSR | 11/10/07 | |
| CHECK | FLA | 11/10/07 | FIGURE: 6 |
| REVIEW | WES/TC | 30/11/07 | |

## BASE DRAINAGE SYSTEM OF ETDA




LEGEND

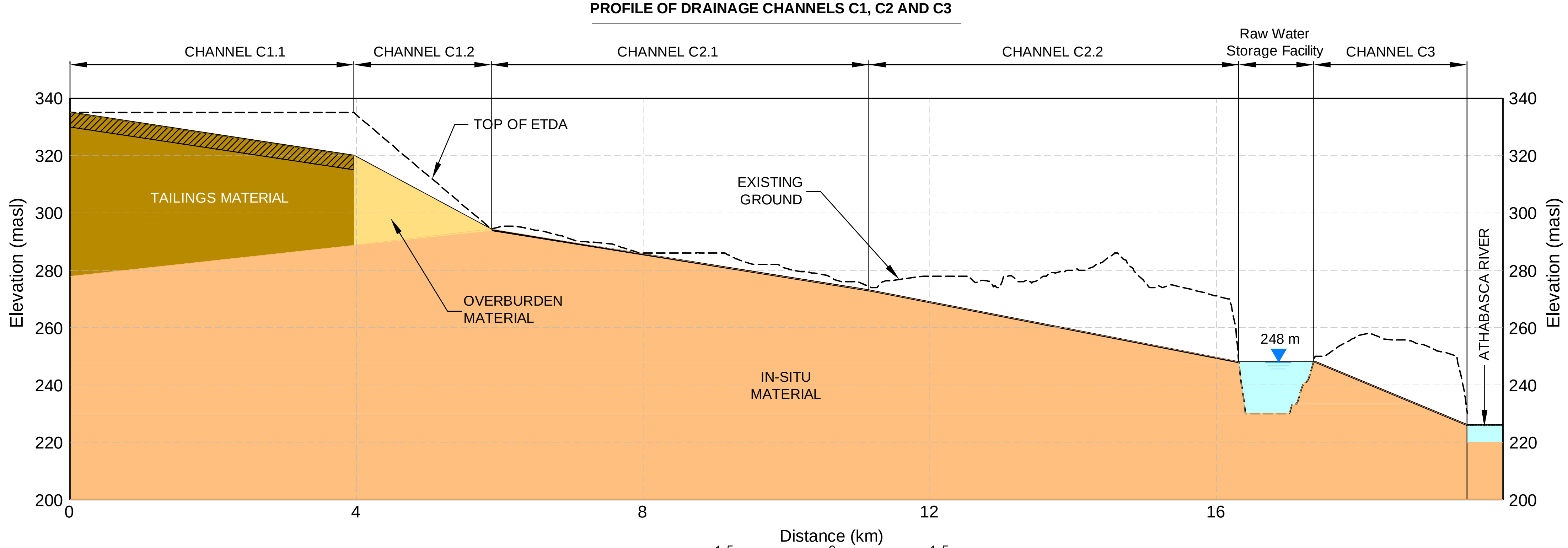
- LEASE BOUNDARY
- MAIN CHANNEL
- SECONDARY CHANNEL
- RECLAIMED SURFACE
- CONTOURS
- WETLANDS
- LAKE OR POND
- DIVERSION CHANNEL
- WELLS
- IN-SITU MATERIAL
- TAILINGS MATERIAL
- SELECT OVERBURDEN MATERIAL
- OVERBURDEN MATERIAL

1.5 0 1.5
SCALE KILOMETRES

## SUMMARY OF CHANNEL DESIGN PARAMETERS

| Channel | Section | Drainage Area [km²] | Mean Annual Flow [m³/s] | Return Period [years] | Peak Flow [m³/s] | Assumed Bed Material | Valley Slope | Channel Slope | Channel Side Slope [n:l] | Channel Sinuosity | Recommended Bottom Width W [m] | Main Channel Depth [m] | Channel Flow Depth [m] | Channel Flow Velocity [m] | Flood Plain Width [m] | D50 of selected material [mm] [Bed/Bank] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C1 Runoff from ETDA | 1 | 24.76 | 0.05 | 2 yr | 0.42 | Selected Overburden | 0.0038 | 0.0032 | 3 | 1.2 | 1 | 0.4 | 0.37 | 0.54 | 5 | 10/13 |
| | | | | 10 yr | 1.15 | | | | | | | | 0.56 | 0.79 | | |
| | | | | 100 yr | 3.06 | | | | | | | | 0.86 | 1.13 | | |
| | | | | PMF | 30.60 | | | | | | | | 2.56 | 2.53 | | |
| C1 Runoff from ETDA | 2 | 24.76 | 0.05 | 2 yr | 0.42 | Selected Overburden | 0.0134 | 0.0096 | 3 | 1.4 | 1 | 0.3 | 0.28 | 0.82 | 25 | 30/40 |
| | | | | 10 yr | 1.15 | | | | | | | | 0.42 | 1.16 | | |
| | | | | 100 yr | 3.06 | | | | | | | | 0.59 | 1.53 | | |
| | | | | PMF | 30.60 | | | | | | | | 1.46 | 3.01 | | |
| C2 Outlet from ETDA to Raw Water Pond | 1 | 24.76 | 0.05 | 2 yr | 0.42 | Sandy | 0.0039 | 0.0030 | 3 | 1.3 | 2 | 0.3 | 0.29 | 0.51 | 20 | N/A |
| | | | | 10 yr | 1.15 | | | | | | | | 0.45 | 0.73 | | |
| | | | | 100 yr | 3.07 | | | | | | | | 0.67 | 0.98 | | |
| | | | | PMF | 30.70 | | | | | | | | 1.93 | 2.10 | | |
| C2 Outlet from ETDA to Raw Water Pond | 2 | 24.76 | 0.05 | 2 yr | 0.42 | Sandy | 0.0049 | 0.0038 | 3 | 1.3 | 3 | 0.3 | 0.22 | 0.51 | 20 | N/A |
| | | | | 10 yr | 1.15 | | | | | | | | 0.38 | 0.73 | | |
| | | | | 100 yr | 3.07 | | | | | | | | 0.58 | 1.01 | | |
| | | | | PMF | 30.70 | | | | | | | | 1.73 | 2.19 | | |
| C3 - Channel from raw water storage into Athabasca River | 1 | 48.57 | 0.04 | 2 yr | 0.27 | OB/Natural | 0.0103 | 0.0085 | 2 | 1.2 | 1 | 0.3 | 0.25 | 0.74 | 5 | N/A |
| | | | | 10 yr | 0.72 | | | | | | | | 0.39 | 1.03 | | |
| | | | | 100 yr | 1.38 | | | | | | | | 0.51 | 1.30 | | |
| | | | | PMF | 13.80 | | | | | | | | 1.51 | 2.88 | | |

## PROFILE OF DRAINAGE CHANNELS C1, C2 AND C3




1.5 0 1.5
SCALE KILOMETRES
VERTICAL EXAGGERATION 40x

L:\2006\1346\06-1346-022 Shell\9400\Closure Drainage Report\Fig 7 Drainage System Channel Design C1 to C3.dwg Dec 07, 2007 - 11:35am

PROJECT
JACKPINE MINE EXPANSION & PIERRE RIVER MINE PROJECT

TITLE
**DRAINAGE SYSTEM - CHANNEL C1, C2 AND C3**

Shell Canada Limited

| | | | | |
|---|---|---|---|---|
| PROJECT 06-1346-022.9400 | | | FILE No. Channels C1, C2-C3 | |
| DESIGN | EK | 24/09/07 | SCALE AS SHOWN | REV. 0 |
| CADD | PSR | 09/10/07 | **FIGURE: 7** | |
| CHECK | FLA | 11/10/07 | | |
| REVIEW | WES/TC | 30/11/07 | | |

Figure 7 presents the designs of the drainage channels around the ETDA (C1, C2 and C3) and shows alignment, profile, typical cross-sections and a summary of the channel design parameters for each channel. The regime equations described in Section 2 were used to configure the channel width, depth, sinuosity (channel length to valley length ratio) and meander wavelength. Manning's equation was used to determine flow conditions and check compliance with the channel design to meet the criteria listed in Table 1.

#### 4.2.1.2 Diversion of Big Creek to Redclay Compensation Lake

Diversion Channel C4 will be constructed through natural ground on the north side of the ETDA to provide conveyance of upstream flows from Big Creek and Unnamed Creek 2 to the Redclay Compensation Lake and the Athabasca River.

Channel C5 provides an outlet from the Redclay Compensation Lake to the Athabasca River. This outlet channel will provide connectivity for fish between the Athabasca River and the upper tributaries of Big Creek and Unnamed Creek 2.

Figure 8 presents the design of the drainage channels north of the ETDA (C4 and C5) and shows for each channel its alignment, profile, typical cross-sections and a summary of the channel design parameters. The channels' width, depth and sinuosity (channel length to valley length ratio) was designed based on the regime equations and Manning's equation described in Section 2.

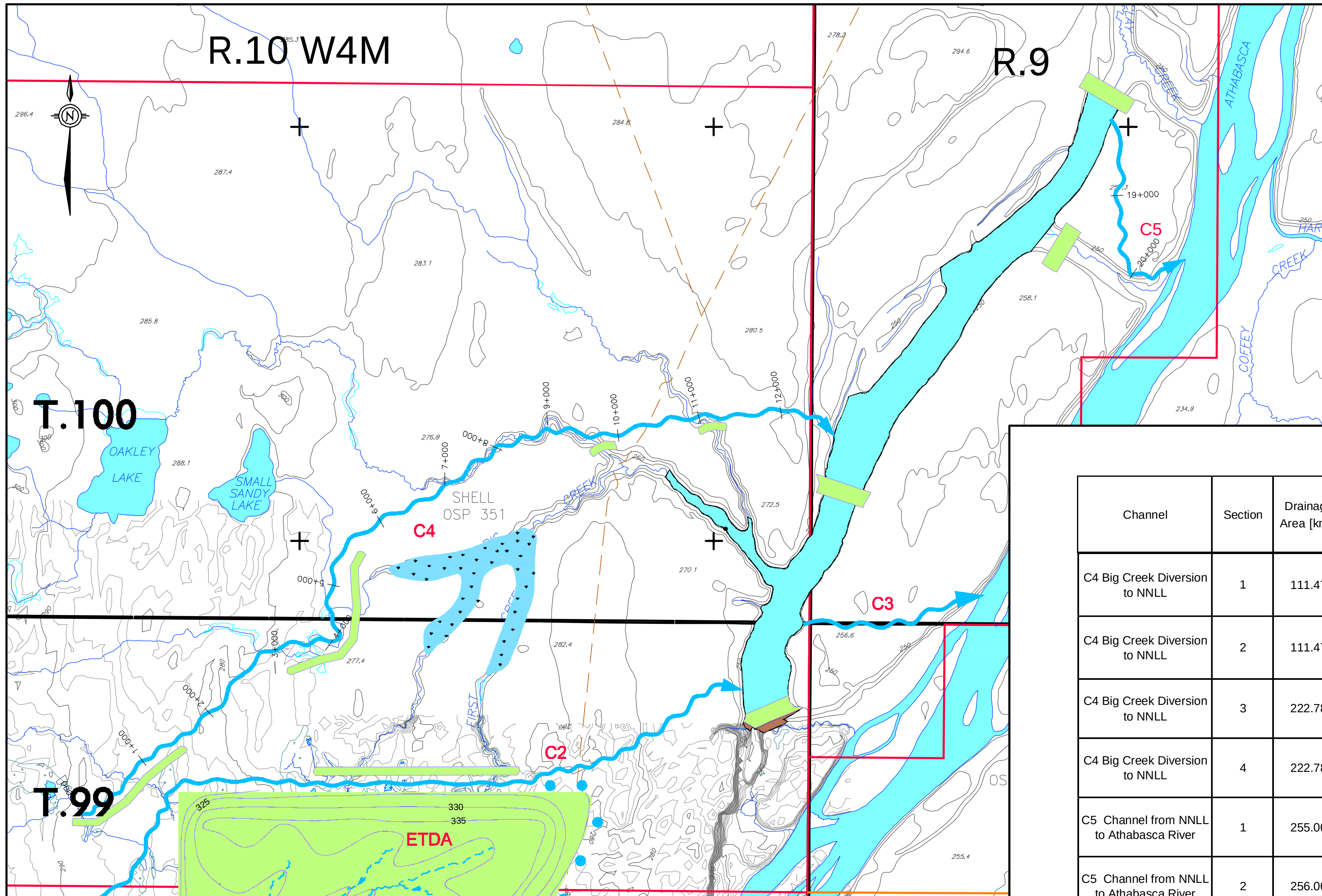
### 4.2.2 Mining Area Drainage System

#### 4.2.2.1 Pit Lake Drainage Systems

##### *Proposed System*

Eymundson Creek and Asphalt Creek will be diverted south through Channel C6 to Pierre North Pit Lake. Channel C6 will be constructed through natural ground south from Eymundson Creek to Asphalt Creek and south from Asphalt Creek to Pierre North Pit Lake. Channel C7 will be constructed on an internal dyke to be built for tailings deposition between Pierre North Pit Lake and Pierre South Pit Lake. A 10-m-thick layer of bouldery ground, consisting of select silt/clay overburden material mixed with gravel, cobbles and boulders will be placed on top of the sand dyke to accommodate the velocities between the two lakes. Outlet Channel C8 will convey flow from Pierre South Pit Lake to the Athabasca River. The outlet will be located in a portion of the lake that contains no MFT. This portion of the South Pit Lake is constructed to provide additional treatment of water prior to release to the Athabasca River.

## BASE DRAINAGE SYSTEM OF CHANNEL C4 AND C5



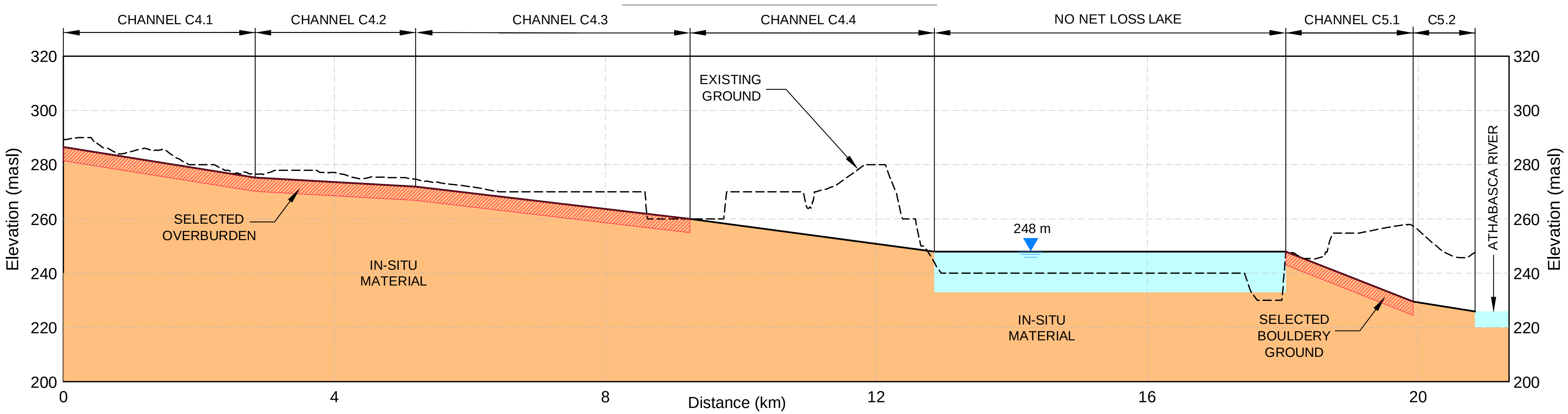

LEGEND
- LEASE BOUNDARY
- MAIN CHANNEL
- SECONDARY CHANNEL
- RECLAIMED SURFACE
- CONTOURS
- WETLANDS
- LAKE OR POND
- DIVERSION CHANNEL
- WELLS
- IN-SITU MATERIAL
- SELECTED BOULDERY GROUND

1.5 0 1.5
SCALE KILOMETRES

## SUMMARY OF CHANNEL DESIGN PARAMETERS

| Channel | Section | Drainage Area [km²] | Mean Annual Flow [m³/s] | Return Period [years] | Peak Flow [m³/s] | Assumed Bed Material | Valley Slope | Channel Slope | Channel Side Slope [n:l] | Channel Sinuosity | Recommended Bottom Width W [m] | Main Channel Depth [m] | Channel Flow Depth [m] | Channel Flow Velocity [m] | Flood Plain Width [m] | D50 of selected material [mm] [Bed/Bank] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C4 Big Creek Diversion to NNLL | 1 | 111.47 | 0.28 | 2 yr | 3.23 | Selected Overburden | 0.0040 | 0.0031 | 2 | 1.3 | 5 | 0.6 | 0.60 | 0.87 | 60 | 50/90 |
| | | | | 10 yr | 8.44 | | | | | | | | 0.94 | 1.24 | | |
| | | | | 100 yr | 16.18 | | | | | | | | 1.21 | 1.49 | | |
| | | | | PMF | 161.80 | | | | | | | | 3.20 | 2.95 | | |
| C4 Big Creek Diversion to NNLL | 2 | 111.47 | 0.28 | 2 yr | 3.23 | Selected Overburden | 0.0014 | 0.0011 | 2 | 1.3 | 7 | 0.7 | 0.68 | 0.57 | 25 | 20/40 |
| | | | | 10 yr | 8.44 | | | | | | | | 1.09 | 0.81 | | |
| | | | | 100 yr | 16.18 | | | | | | | | 1.49 | 1.02 | | |
| | | | | PMF | 161.80 | | | | | | | | 4.77 | 2.29 | | |
| C4 Big Creek Diversion to NNLL | 3 | 222.78 | 0.43 | 2 yr | 4.73 | Selected Overburden | 0.0029 | 0.0023 | 2 | 1.3 | 8 | 0.7 | 0.63 | 0.81 | 60 | 40/70 |
| | | | | 10 yr | 11.78 | | | | | | | | 1.01 | 1.13 | | |
| | | | | 100 yr | 20.95 | | | | | | | | 1.30 | 1.36 | | |
| | | | | PMF | 209.50 | | | | | | | | 3.69 | 2.81 | | |
| C4 Big Creek Diversion to NNLL | 4 | 222.78 | 0.43 | 2 yr | 4.73 | OB/Natural | 0.0033 | 0.0026 | 2 | 1.3 | 8 | 0.7 | 0.61 | 0.84 | 65 | N/A |
| | | | | 10 yr | 11.78 | | | | | | | | 0.98 | 1.18 | | |
| | | | | 100 yr | 20.95 | | | | | | | | 1.27 | 1.42 | | |
| | | | | PMF | 209.50 | | | | | | | | 3.52 | 2.89 | | |
| C5 Channel from NNLL to Athabasca River | 1 | 255.00 | 0.43 | 2 yr | 3.36 | Selected Bouldery Ground | 0.0098 | 0.0082 | 2 | 1.2 | 8 | 0.4 | 0.35 | 1.09 | 50 | 110/200 |
| | | | | 10 yr | 9.72 | | | | | | | | 0.62 | 1.60 | | |
| | | | | 100 yr | 21.75 | | | | | | | | 0.88 | 2.05 | | |
| | | | | PMF | 217.50 | | | | | | | | 2.69 | 4.40 | | |
| C5 Channel from NNLL to Athabasca River | 2 | 256.00 | 0.43 | 2 yr | 3.36 | OB/Natural | 0.0038 | 0.0032 | 2 | 1.2 | 5 | 0.6 | 0.60 | 0.90 | 50 | N/A |
| | | | | 10 yr | 9.72 | | | | | | | | 0.95 | 1.27 | | |
| | | | | 100 yr | 21.75 | | | | | | | | 1.30 | 1.60 | | |
| | | | | PMF | 217.50 | | | | | | | | 3.78 | 3.37 | | |

## PROFILE OF DRAINAGE CHANNEL C4 AND C5




1.5 0 1.5
SCALE KILOMETRES
VERTICAL EXAGGERATION 40x

PROJECT
JACKPINE MINE EXPANSION & PIERRE RIVER MINE PROJECT

TITLE
**DRAINAGE SYSTEM - CHANNEL C4 AND C5**

Shell Canada Limited

| | | | | |
|---|---|---|---|---|
| PROJECT 06-1346-022.9400 | | | FILE No. | Channels C4-C5 |
| DESIGN | EK | 25/09/07 | SCALE AS SHOWN | REV. 0 |
| CADD | TY | 07/10/07 | | |
| CHECK | FLA | 11/10/07 | | |
| REVIEW | WES/TC | 30/11/07 | | |

**FIGURE: 8**

L:\2006\1344-OIL SANDS\1346\06-1346-022 Shell\9400\Closure Drainage Report\Fig 8 Drainage System Channel Design C4 to C5.dwg Dec 07, 2007 - 11:44am

Figure 9 presents the design of the drainage Channels C6, C7 and C8, and shows alignment, profile, typical cross-section and the summary of channel design parameters for each channel. The channels' width, depth, meander wavelength and sinuosity (channel length to valley length ratio) were designed based on the regime equations and Manning's equation described in Section 2.

### *Alternative Pierre South Pit Lake Outlet*

The original Pierre River channel alignment was considered as an alternative drainage outlet for Pierre South Pit Lake. This alternative would have required a very steep outlet channel and considerable fill. The preferred alignment described in the previous section requires substantial excavation, but will have a lower channel slope and is therefore considered to be more self-sustaining and more conducive to fish passage between the pit lake and the Athabasca River.

## 4.2.3 External Diversions

### *Proposed System*

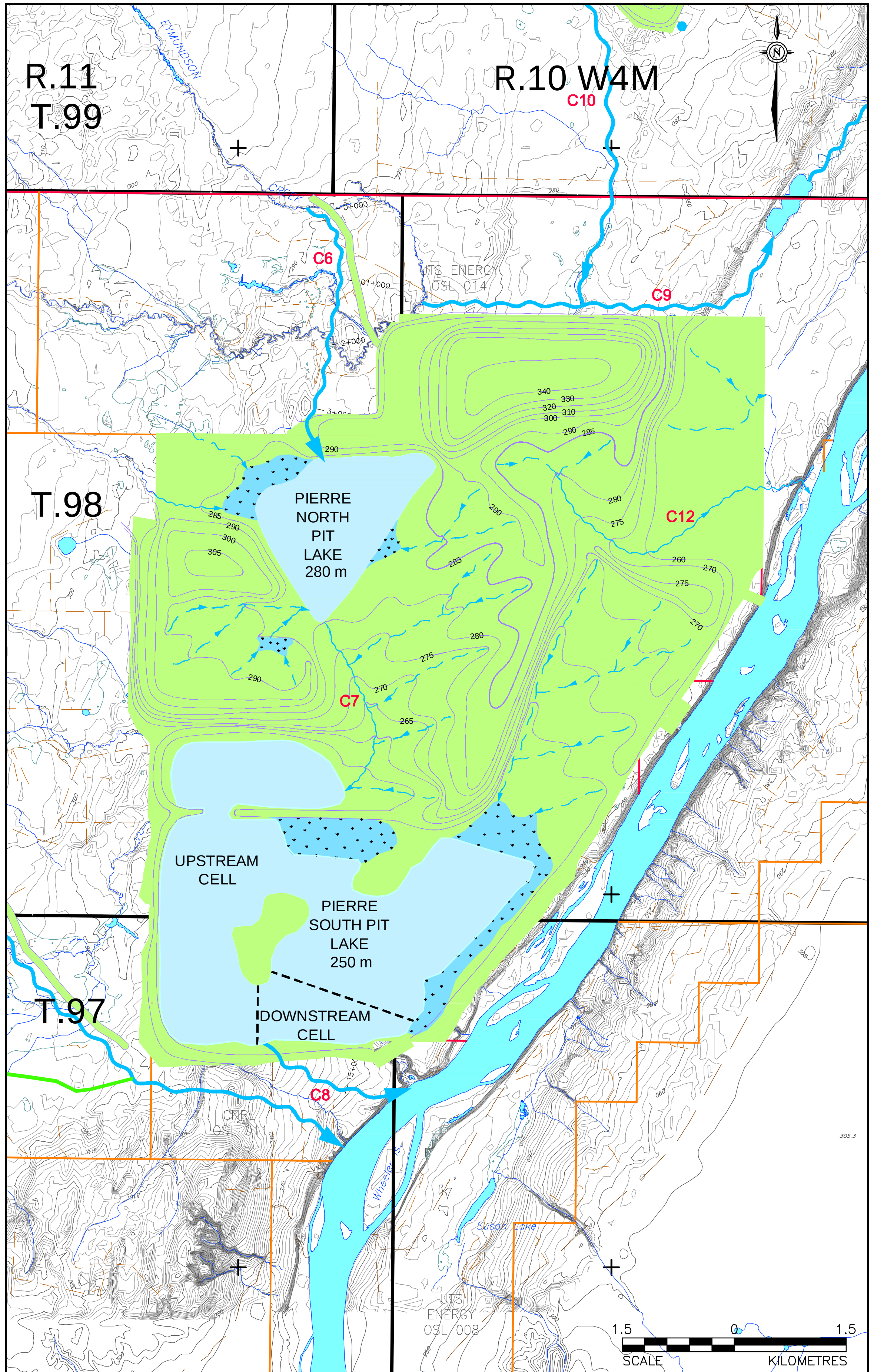
Portions of Channels C9 and C10 will be constructed for operational water management and modified for closure. These channels will collect runoff from small creeks flowing toward the north edge of the mining area and convey the flows to an existing small pond, and then to the Athabasca River.

Figure 10 presents the design of Channels C9 and C10, and shows the alignment, profile, typical cross-sections and the summary of channel design parameters for each channel. The channels' width, depth and sinuosity (channel length to valley length ratio) were designed based on the regime equations and Manning's equation described in Section 2.

Channel C11 will be constructed in natural ground, and will convey flows from the Pierre River to the Athabasca River. It will replace a portion of the closure channel proposed by Canadian Natural Horizon Project and the downstream reach will convey flows both from the Pierre River and Canadian Natural Horizon Project.

Figure 11 presents the design of Channel C11, and shows its alignment, profiles, typical cross-sections and the summary of channel design parameters. The channels' width, depth and sinuosity (channel length to valley length ratio) were designed based on the regime equations and Manning's equation described in Section 2.

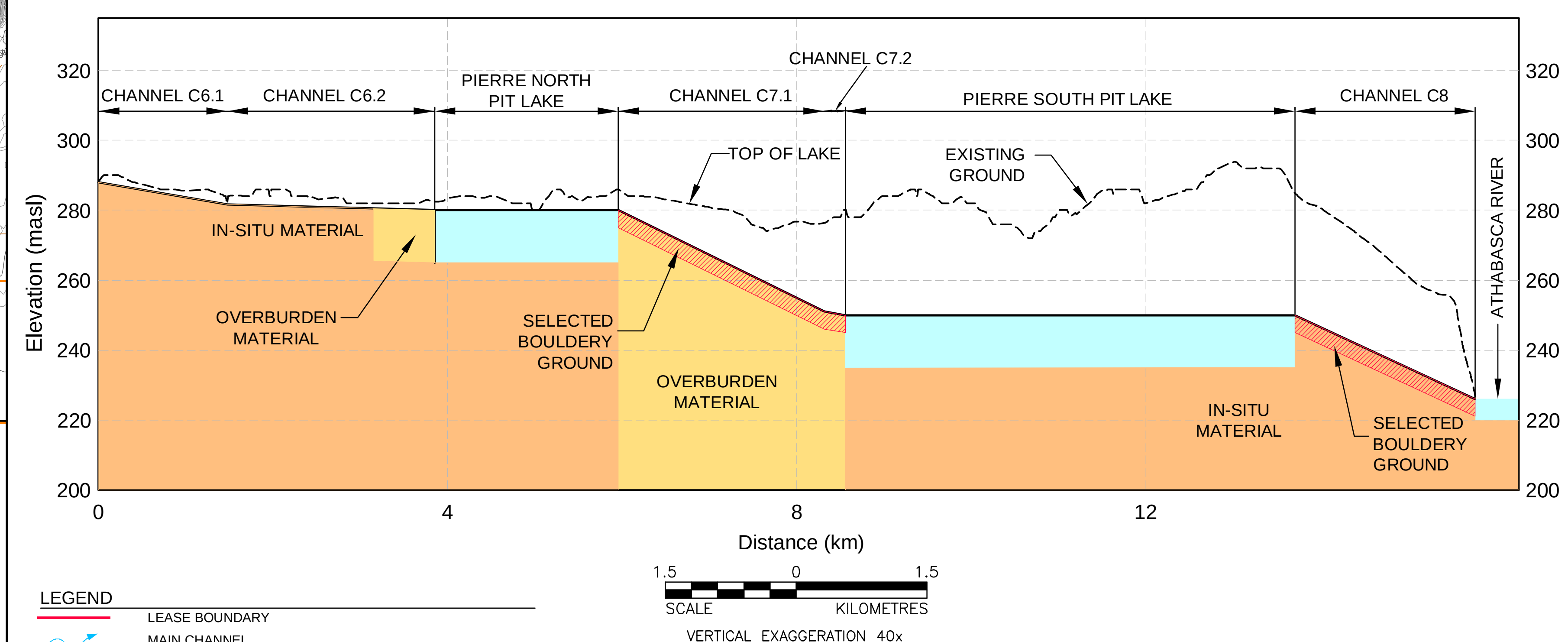
## BASE DRAINAGE SYSTEM OF PIERRE PIT LAKES




## SUMMARY OF CHANNEL DESIGN PARAMETERS

| Channel | Section | Drainage Area [km²] | Mean Annual Flow [m³/s] | Return Period [years] | Peak Flow [m³/s] | Assumed Bed Material | Valley Slope | Channel Slope | Channel Side Slope [n:l] | Channel Sinuosity | Recommended Bottom Width W [m] | Main Channel Depth [m] | Channel Flow Depth [m] | Channel Flow Velocity [m] | Flood Plain Width [m] | D50 of selected material [mm] [Bed/Bank] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C6 - Diversion into the North pit lake | 1 | 4.26 | 0.09 | 2 yr | 0.86 | OB/Natural | 0.0042 | 0.0028 | 2 | 1.5 | 3 | 0.5 | 0.37 | 0.61 | 15 | N/A |
| | | | | 10 yr | 2.69 | | | | | | | | 0.67 | 0.91 | | |
| | | | | 100 yr | 6.83 | | | | | | | | 1.01 | 1.24 | | |
| | | | | PMF | 68.30 | | | | | | | | 3.02 | 2.71 | | |
| C6 - Diversion into the North pit lake | 2 | 90.26 | 0.09 | 2 yr | 0.86 | OB/Natural | 0.0007 | 0.0007 | 2 | 1.1 | 3 | 0.6 | 0.56 | 0.37 | 10 | N/A |
| | | | | 10 yr | 2.69 | | | | | | | | 0.97 | 0.56 | | |
| | | | | 100 yr | 6.83 | | | | | | | | 1.52 | 0.79 | | |
| | | | | PMF | 68.30 | | | | | | | | 4.67 | 1.75 | | |
| C7 - From North Pit Lake to South Pit Lake | 1 | 302.91 | 0.65 | 2 yr | 5.08 | Selected Bouldery Ground | 0.0123 | 0.0102 | 2 | 1.2 | 5 | 0.6 | 0.55 | 1.52 | 50 | 200/330 |
| | | | | 10 yr | 14.04 | | | | | | | | 0.88 | 2.14 | | |
| | | | | 100 yr | 34.94 | | | | | | | | 1.25 | 2.78 | | |
| | | | | PMF | 349.40 | | | | | | | | 3.58 | 5.82 | | |
| C7 - From North Pit Lake to South Pit Lake | 2 | 302.91 | 0.65 | 2 yr | 5.08 | Selected Bouldery Ground | 0.0071 | 0.0060 | 2 | 1.2 | 5 | 0.6 | 0.63 | 1.28 | 50 | 120/215 |
| | | | | 10 yr | 14.04 | | | | | | | | 0.97 | 1.76 | | |
| | | | | 100 yr | 34.94 | | | | | | | | 1.39 | 2.29 | | |
| | | | | PMF | 349.40 | | | | | | | | 4.10 | 4.87 | | |
| C8 Drainage from S Pit Lake to Athabasca | 1 | 328.24 | 0.55 | 2 yr | 2.36 | Selected Bouldery Ground | 0.0116 | 0.0096 | 3 | 1.2 | 4 | 0.5 | 0.39 | 1.16 | 50 | 100/120 |
| | | | | 10 yr | 5.99 | | | | | | | | 0.63 | 1.60 | | |
| | | | | 100 yr | 11.89 | | | | | | | | 0.81 | 1.96 | | |
| | | | | PMF | 118.90 | | | | | | | | 2.12 | 3.95 | | |

## PROFILE OF DRAINAGE CHANNELS C6, C7 AND C8




LEGEND

- LEASE BOUNDARY
- MAIN CHANNEL
- SECONDARY CHANNEL
- RECLAIMED SURFACE
- CONTOURS
- WETLANDS
- LAKE OR POND
- SUBMERGED DYKE
- CLOSURE DITCH CANADIAN NATURAL HORIZON PROJECT
- DIVERSION CHANNEL
- WELLS
- IN-SITU MATERIAL
- OVERBURDEN MATERIAL
- SELECTED BOULDERY GROUND

PROJECT
JACKPINE MINE EXPANSION & PIERRE RIVER MINE PROJECT

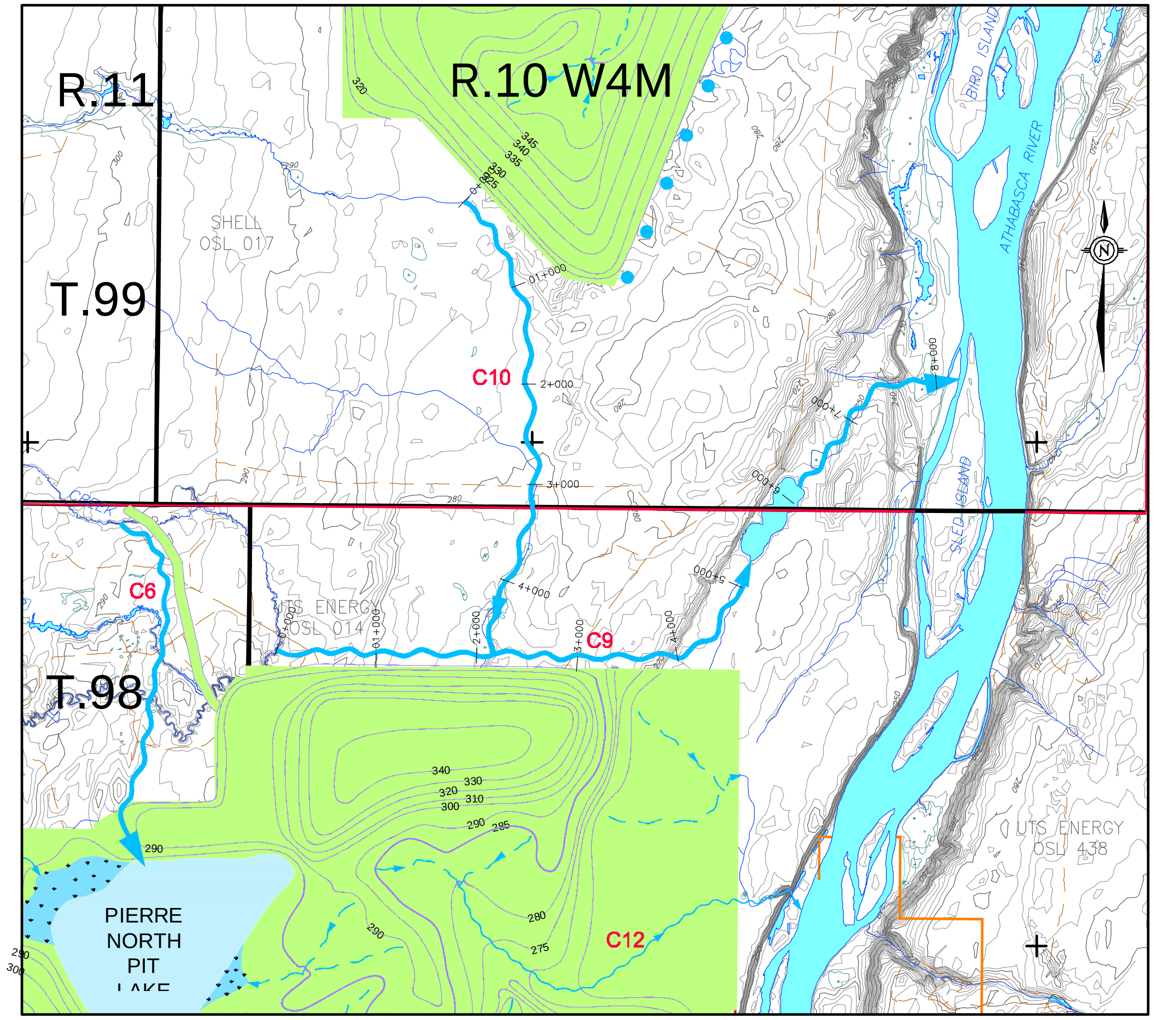
TITLE
**DRAINAGE SYSTEM - CHANNEL C6, C7 AND C8**

Shell Canada Limited

| | | | | |
|---|---|---|---|---|
| PROJECT 06-1346-022.9400 | | | FILE No. | Channels C6,C7-C8 |
| DESIGN | EK | 25/09/07 | SCALE AS SHOWN | REV. 0 |
| CADD | PSR | 11/10/07 | | |
| CHECK | FLA | 11/10/07 | FIGURE: 9 | |
| REVIEW | WES/TC | 30/11/07 | | |

L:\2006\1344-OIL SANDS\1346\06-1346-022 Shell\9400\Closure Drainage Report\Fig 9 Drainage System Channel Design C6 C7 C8.dwg Dec 07, 2007 - 12:00pm

## BASE DRAINAGE SYSTEM OF CHANNEL C9 AND C10




LEGEND

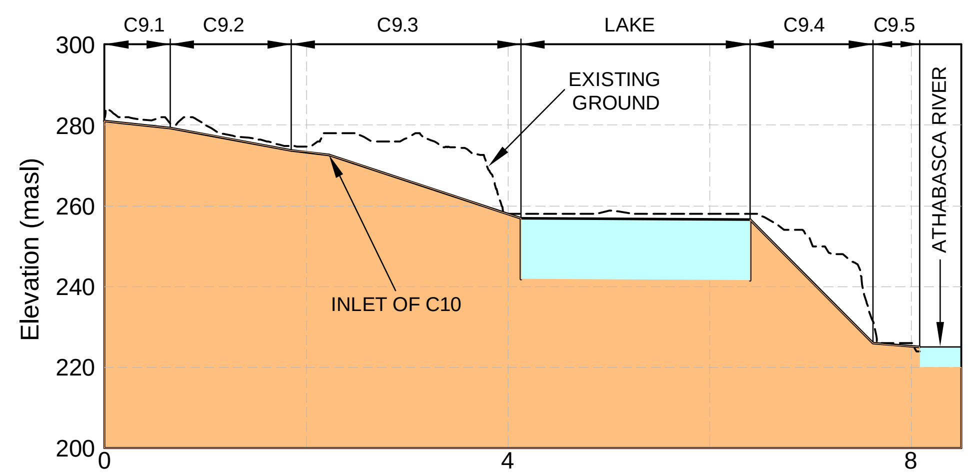
- LEASE BOUNDARY
- MAIN CHANNEL
- SECONDARY CHANNEL
- RECLAIMED SURFACE
- CONTOURS
- WETLANDS
- LAKE OR POND
- DIVERSION CHANNEL
- WELLS
- IN-SITU MATERIAL
- SELECTED OVERBURDEN MATERIAL

1.5 0 1.5
SCALE KILOMETRES

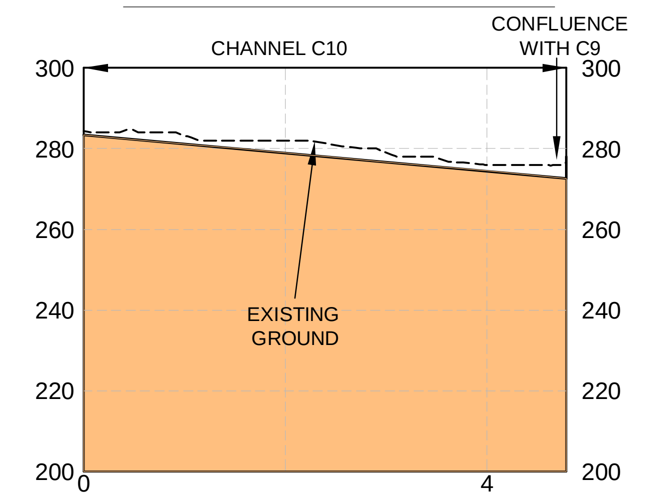
## SUMMARY OF CHANNEL DESIGN PARAMETERS

| Channel | Section | Drainage Area [km²] | Mean Annual Flow [m³/s] | Return Period [years] | Peak Flow [m³/s] | Assumed Bed Material | Valley Slope | Channel Slope | Channel Side Slope [n:l] | Channel Sinuosity | Recommended Bottom Width W [m] | Main Channel Depth [m] | Channel Flow Depth [m] | Channel Flow Velocity [m] | Flood Plain Width [m] | D50 of selected material [mm] [Bed/Bank] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C9 Drainage North of the South Pit | 1 | 33.55 | 0.02 | 2 yr | 0.26 | OB/Natural | 0.0026 | 0.0022 | 2 | 1.2 | 1 | 0.4 | 0.34 | 0.45 | 5 | N/A |
| | | | | 10 yr | 0.78 | | | | | | | | 0.56 | 0.66 | | |
| | | | | 100 yr | 2.21 | | | | | | | | 0.89 | 0.95 | | |
| | | | | PMF | 22.10 | | | | | | | | 2.57 | 2.07 | | |
| C9 Drainage North of the South Pit | 2 | 33.55 | 0.02 | 2 yr | 0.26 | OB/Natural | 0.0046 | 0.0038 | 2 | 1.2 | 2 | 0.3 | 0.21 | 0.50 | 5 | N/A |
| | | | | 10 yr | 0.78 | | | | | | | | 0.38 | 0.73 | | |
| | | | | 100 yr | 2.21 | | | | | | | | 0.64 | 1.08 | | |
| | | | | PMF | 22.10 | | | | | | | | 2.05 | 2.44 | | |
| C9 Drainage North of the South Pit | 3 | 33.55 | 0.02 | 2 yr | 0.26 | OB/Natural | 0.0074 | 0.0049 | 2 | 1.5 | 3 | 0.3 | 0.16 | 0.49 | 10 | N/A |
| | | | | 10 yr | 0.78 | | | | | | | | 0.30 | 0.72 | | |
| | | | | 100 yr | 2.21 | | | | | | | | 0.50 | 1.05 | | |
| | | | | PMF | 22.10 | | | | | | | | 1.59 | 2.36 | | |
| C9 Drainage North of the South Pit | 4 | 33.55 | 0.02 | 2 yr | 0.26 | OB/Natural | 0.0247 | 0.0206 | 3 | 1.2 | 5 | 0.3 | 0.08 | 0.64 | 30 | N/A |
| | | | | 10 yr | 0.78 | | | | | | | | 0.15 | 0.97 | | |
| | | | | 100 yr | 2.21 | | | | | | | | 0.27 | 1.40 | | |
| | | | | PMF | 22.10 | | | | | | | | 0.83 | 3.10 | | |
| C9 Drainage North of the South Pit | 5 | 33.55 | 0.02 | 2 yr | 0.26 | OB/Natural | 0.0051 | 0.0034 | 2 | 1.5 | 2 | 0.3 | 0.22 | 0.48 | 15 | N/A |
| | | | | 10 yr | 0.78 | | | | | | | | 0.39 | 0.70 | | |
| | | | | 100 yr | 2.21 | | | | | | | | 0.60 | 0.97 | | |
| | | | | PMF | 22.10 | | | | | | | | 1.73 | 2.04 | | |
| C10 - Channel running south between mining areas | 1 | 12.44 | 0.01 | 2 yr | 0.10 | OB/Natural | 0.0022 | 0.0019 | 2 | 1.2 | 1 | 0.5 | 0.22 | 0.32 | 5 | N/A |
| | | | | 10 yr | 0.33 | | | | | | | | 0.40 | 0.45 | | |
| | | | | 100 yr | 1.07 | | | | | | | | 0.68 | 0.67 | | |
| | | | | PMF | 10.70 | | | | | | | | 1.90 | 1.52 | | |

## PROFILE OF DRAINAGE CHANNEL C9




## PROFILE OF DRAINAGE CHANNEL C10




1.5 0 1.5
SCALE KILOMETRES
VERTICAL EXAGGERATION 40x

PROJECT
JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

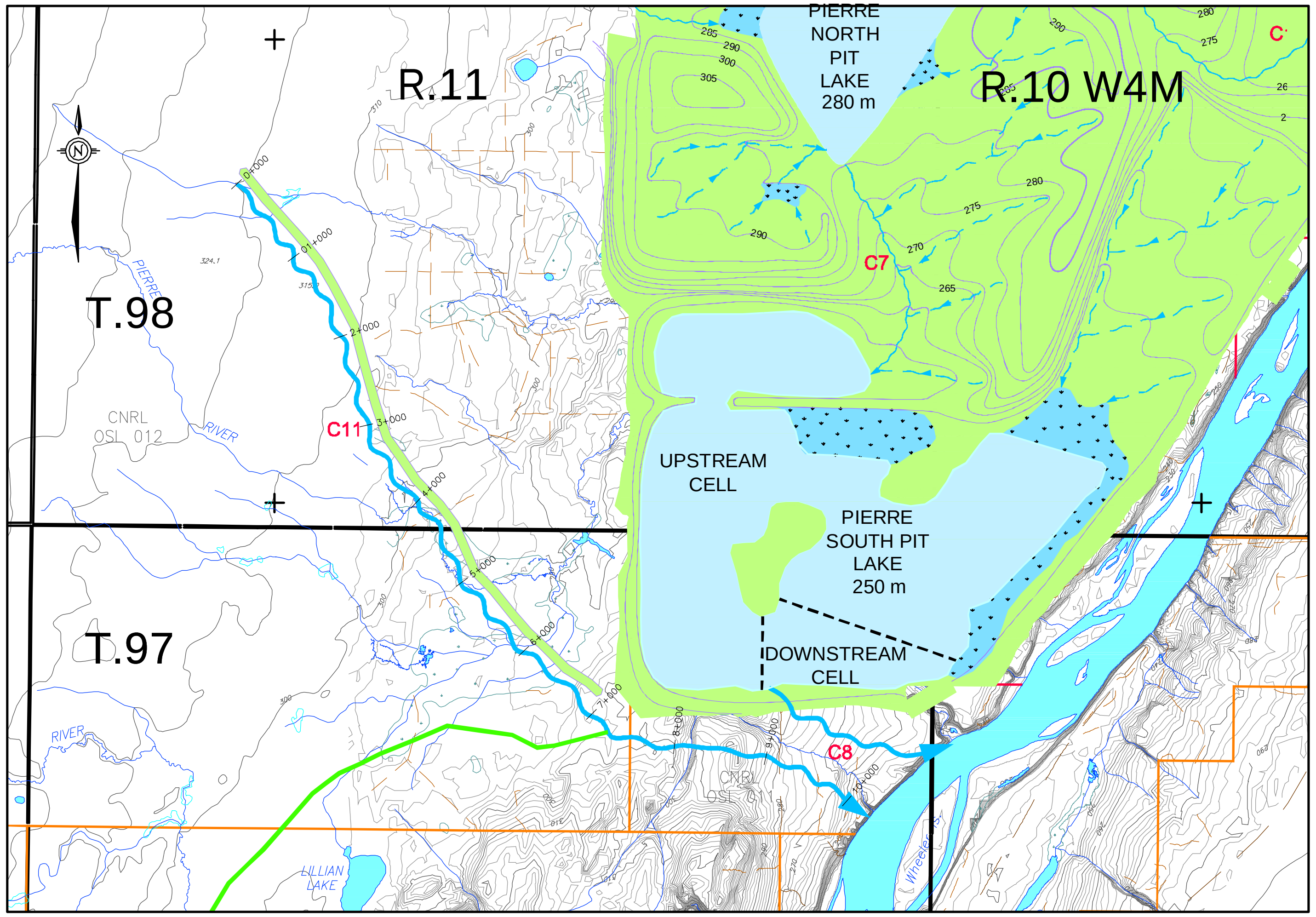
TITLE
DRAINAGE SYSTEM -
CHANNEL C9 AND C10

Shell Canada Limited

| PROJECT 06-1346-022.9400 | | | FILE No. Channels C9-C10 |
|---|---|---|---|
| DESIGN | EK | 24/09/07 | SCALE AS SHOWN REV. 0 |
| CADD | TE | 24/09/07 | |
| CHECK | FLA | 11/10/07 | FIGURE: 10 |
| REVIEW | WES/TC | 30/11/07 | |

L:\2006\1346\06-1346-022 Shell\9400\Closure Drainage Report\Fig 10 Drainage System Channel Design C9 AND 10.dwg Dec 07, 2007 - 1:22pm

## BASE DRAINAGE SYSTEM OF PIERRE RIVER DIVERSION




## SUMMARY OF CHANNEL DESIGN PARAMETERS

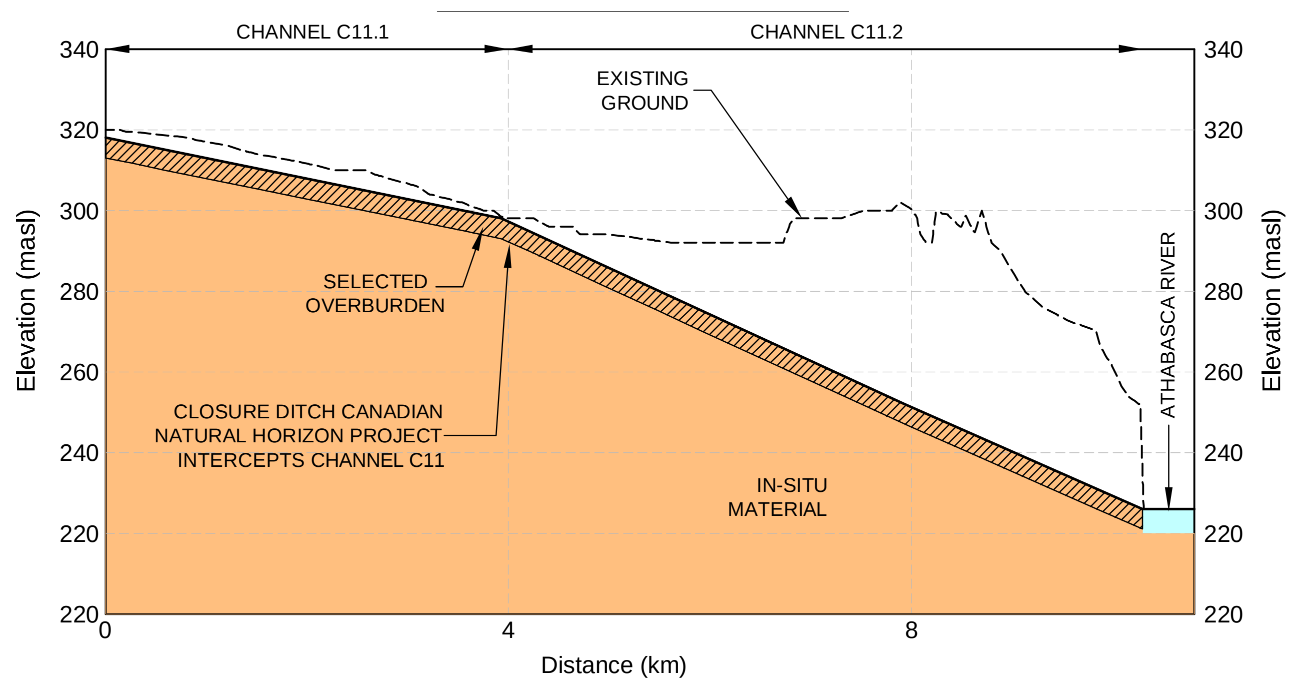
| Channel | Section | Drainage Area [km²] | Mean Annual Flow [m³/s] | Return Period [years] | Peak Flow [m³/s] | Assumed Bed Material | Valley Slope | Channel Slope | Channel Side Slope [n:l] | Channel Sinuosity | Recommended Bottom Width W [m] | Main Channel Depth [m] | Channel Flow Depth [m] | Channel Flow Velocity [m] | Flood Plain Width [m] | D50 of selected material [mm] [Bed/Bank] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C11 - Diversion into Athabasca south of mining area | 1 | 4.26 | 0.06 | 2 yr | 0.69 | Selected Overburden | 0.0051 | 0.0034 | 3 | 1.5 | 5 | 0.3 | 0.23 | 0.52 | 25 | 24/50 |
| | | | | 10 yr | 1.76 | | | | | | | | 0.39 | 0.73 | | |
| | | | | 100 yr | 3.37 | | | | | | | | 0.52 | 0.90 | | |
| | | | | PMF | 33.70 | | | | | | | | 1.57 | 1.97 | | |
| C11 - Diversion into Athabasca south of mining area | 2 | 94.43 | 0.23 | 2 yr | 2.61 | Selected Overburden | 0.0113 | 0.0094 | 3 | 1.2 | 5 | 0.5 | 0.37 | 1.14 | 50 | 40/50 |
| | | | | 10 yr | 6.51 | | | | | | | | 0.60 | 1.57 | | |
| | | | | 100 yr | 14.08 | | | | | | | | 0.83 | 2.00 | | |
| | | | | PMF | 140.80 | | | | | | | | 2.24 | 4.09 | | |

LEGEND

- LEASE BOUNDARY
- MAIN CHANNEL
- SECONDARY CHANNEL
- RECLAIMED SURFACE
- CONTOURS
- WETLANDS
- LAKE OR POND
- SUBMERGED DYKE
- CLOSURE DITCH CANADIAN NATURAL HORIZON PROJECT
- DIVERSION CHANNEL
- IN-SITU MATERIAL
- SELECTED OVERBURDEN

1.5 0 1.5
SCALE KILOMETRES

## PROFILE OF DRAINAGE CHANNEL C11




1.5 0 1.5
SCALE KILOMETRES
VERTICAL EXAGGERATION 40x

PROJECT
JACKPINE MINE EXPANSION & PIERRE RIVER MINE PROJECT

TITLE
**DRAINAGE SYSTEM - CHANNEL C11**

Shell Canada Limited

| | | | | | |
|---|---|---|---|---|---|
| PROJECT 06-1346-022.9400 | | | FILE No. | Drainage Channels | |
| DESIGN | EK | 24/09/07 | SCALE | AS SHOWN | REV. 0 |
| CADD | PSR | 11/10/07 | | | |
| CHECK | FLA | 11/10/07 | | | |
| REVIEW | WES/TC | 30/11/07 | | | |

**FIGURE: 11**

L:\2006\1346-OIL SANDS\1346\06-1346-022 Shell\9400\Closure Drainage Report\Fig 11 Drainage System Channel Design C11.dwg Dec 07, 2007 - 1:24pm

### 4.2.4 Drainage System at Plant Site

Channel C12 conveys outflows from the North OBDA, collects runoff and seepage from the reclaimed overburden-capped tailings area and routes the flow across the reclaimed plant site. The outlet from this channel is an existing creek that flows to the Athabasca River.

Figure 12 shows the proposed main drainage system from the North OBDA and the plant site, consisting of a main drainage channel (C12) and a natural outlet to the Athabasca River.

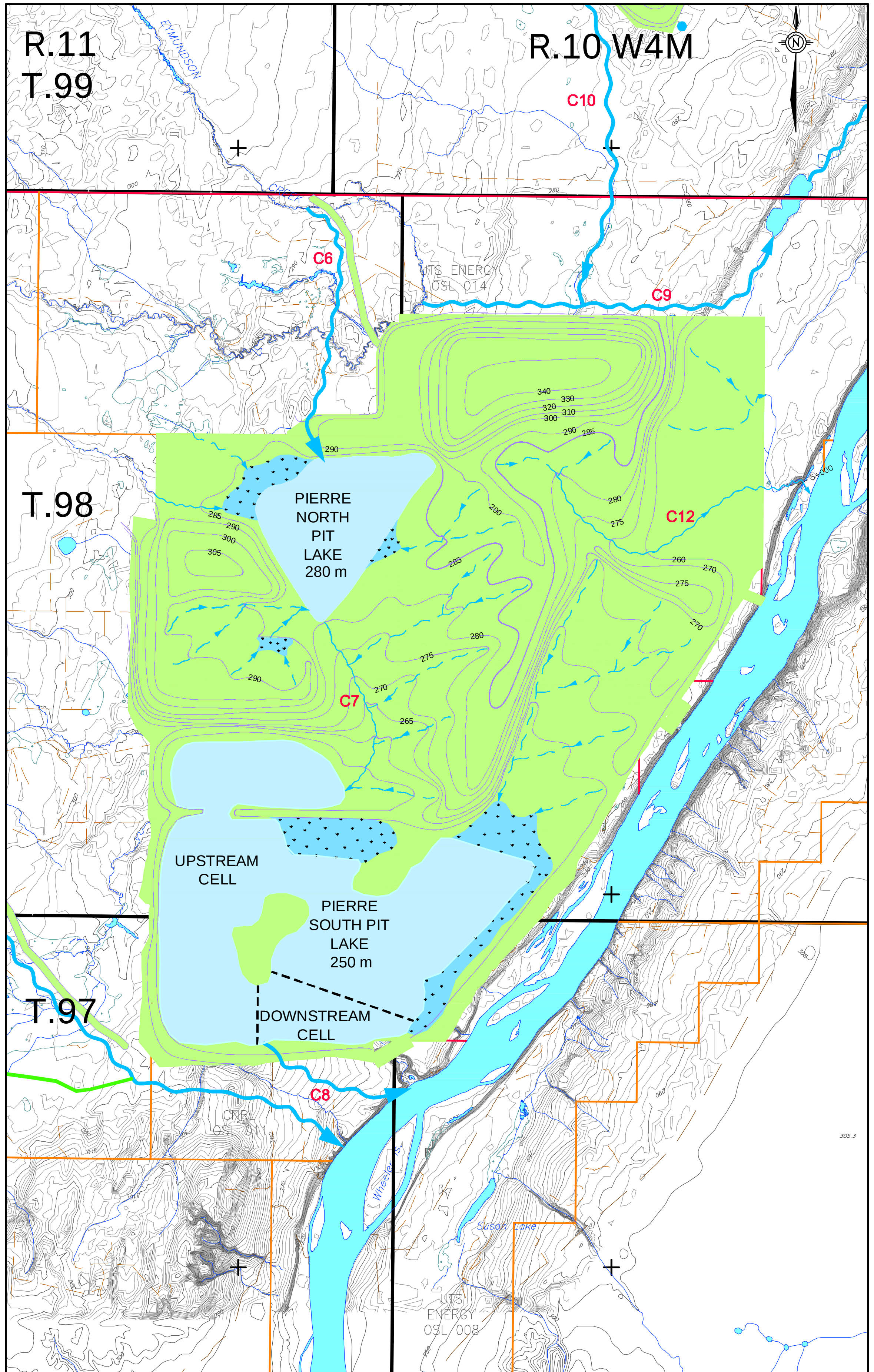
The valley slope of Channel C12 ranges from 0.14 to 5.36% and the channel bed slope ranges from 0.10 to 3.58%, allowing for a channel sinuosity of 1.2 to 1.5. The drainage area of the outlet creek increases by only 2.3 $km^2$ from pre-development conditions, and therefore the natural slope is adequate to accommodate the closure flows.

## 4.3 PROPOSED SECONDARY DRAINAGE SYSTEMS

Microtopography in the form of sand ridges and swales will be built on the relatively flat fine tailings deposition areas. This will form a secondary drainage system to maintain positive flow toward the primary drainage system while allowing flushing of surface soils and suppression of the local groundwater table on ridges. These secondary systems will develop on a network of sand trenches placed between blocks of overburden materials. The sand trenches are needed to provide for release of residual NST porewater during NST consolidation. The secondary drainage channels are expected to form naturally in these trenches as surface runoff flows to these low-lying areas.

Figure 13 presents a schematic layout of the proposed secondary drainage systems. The systems consist of overburden ridges and wetlands swale areas between the ridges. The system of overburden ridges will be developed by controlled placement of overburden materials. This configuration will enhance leaching of salts from the overburden, which may be naturally present or may result from the upward flux of NST consolidation water that is expected to occur upon initial placement of the overburden material.

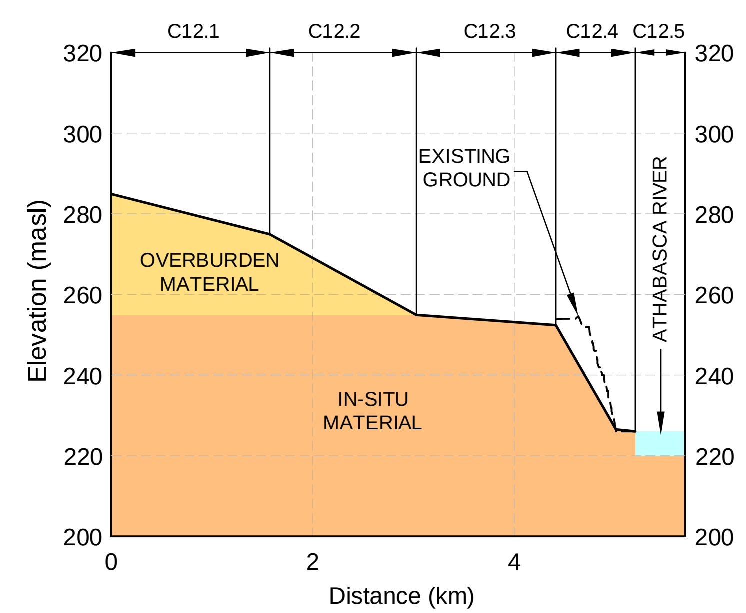
## BASE DRAINAGE SYSTEM OF CHANNEL 12




## SUMMARY OF CHANNEL DESIGN PARAMETERS

| Channel | Section | Drainage Area [km²] | Mean Annual Flow [m³/s] | Return Period [years] | Peak Flow [m³/s] | Assumed Bed Material | Valley Slope | Channel Slope | Channel Side Slope [m] | Channel Sinuosity | Recommended Bottom Width W [m] | Main Channel Depth [n:1] | Channel Flow Depth [m] | Channel Flow Velocity [m] | Flood Plain Width [m] | D50 of selected material [mm] [Bed/Bank] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C12 Runoff from North OBDA and Plant Site | 1 | 11.98 | 0.03 | 2 yr | 0.77 | OB/Natural | 0.0063 | 0.0053 | 3 | 1.2 | 1 | 0.4 | 0.41 | 0.84 | 10 | N/A |
| | | | | 10 yr | 1.49 | | | | | | | | 0.53 | 1.08 | | |
| | | | | 100 yr | 2.38 | | | | | | | | 0.64 | 1.27 | | |
| | | | | PMF | 23.80 | | | | | | | | 1.79 | 2.83 | | |
| C12 Runoff from North OBDA and Plant Site | 2 | 11.98 | 0.03 | 2 yr | 0.77 | OB/Natural | 0.0138 | 0.0099 | 3 | 1.4 | 1 | 0.4 | 0.37 | 0.99 | 15 | N/A |
| | | | | 10 yr | 1.49 | | | | | | | | 0.48 | 1.25 | | |
| | | | | 100 yr | 2.38 | | | | | | | | 0.56 | 1.44 | | |
| | | | | PMF | 23.80 | | | | | | | | 1.46 | 3.02 | | |
| C12 Runoff from North OBDA and Plant Site | 3 | 11.98 | 0.03 | 2 yr | 0.77 | OB/Natural | 0.0018 | 0.0013 | 3 | 1.4 | 1 | 0.6 | 0.59 | 0.47 | 15 | N/A |
| | | | | 10 yr | 1.49 | | | | | | | | 0.75 | 0.59 | | |
| | | | | 100 yr | 2.38 | | | | | | | | 0.89 | 0.69 | | |
| | | | | PMF | 23.80 | | | | | | | | 2.37 | 1.49 | | |
| C12 Runoff from North OBDA and Plant Site | 4 | 11.98 | 0.03 | 2 yr | 0.77 | OB/Natural | 0.0437 | 0.0291 | 3 | 1.5 | 2 | 0.4 | 0.22 | 1.34 | 10 | N/A |
| | | | | 10 yr | 1.49 | | | | | | | | 0.31 | 1.64 | | |
| | | | | 100 yr | 2.38 | | | | | | | | 0.40 | 1.88 | | |
| | | | | PMF | 23.80 | | | | | | | | 1.11 | 4.30 | | |
| C12 Runoff from North OBDA and Plant Site | 5 | 12.98 | 0.03 | 2 yr | 0.77 | OB/Natural | 0.0026 | 0.0022 | 3 | 1.2 | 2 | 0.4 | 0.43 | 0.55 | 10 | N/A |
| | | | | 10 yr | 1.49 | | | | | | | | 0.57 | 0.70 | | |
| | | | | 100 yr | 2.38 | | | | | | | | 0.70 | 0.83 | | |
| | | | | PMF | 23.80 | | | | | | | | 2.11 | 1.88 | | |

## PROFILE OF DRAINAGE CHANNEL C12




1.5 0 1.5
SCALE KILOMETRES
VERTICAL EXAGGERATION 40x

**LEGEND**

- LEASE BOUNDARY
- MAIN CHANNEL
- SECONDARY CHANNEL
- RECLAIMED SURFACE
- CONTOURS
- WETLANDS
- LAKE OR POND
- SUBMERGED DYKE
- CLOSURE DITCH CANADIAN NATURAL HORIZON PROJECT
- DIVERSION CHANNEL
- WELLS
- IN-SITU MATERIAL
- OVERBURDEN MATERIAL

1.5 0 1.5
SCALE KILOMETRES

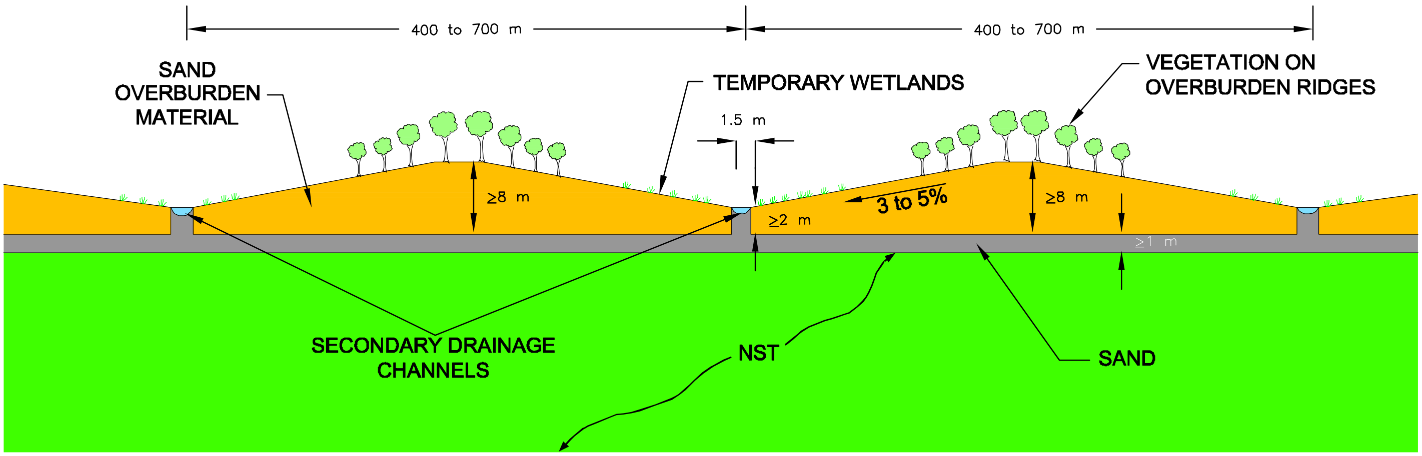
PROJECT
JACKPINE MINE EXPANSION & PIERRE RIVER MINE PROJECT

TITLE
**DRAINAGE SYSTEM - CHANNEL C12**

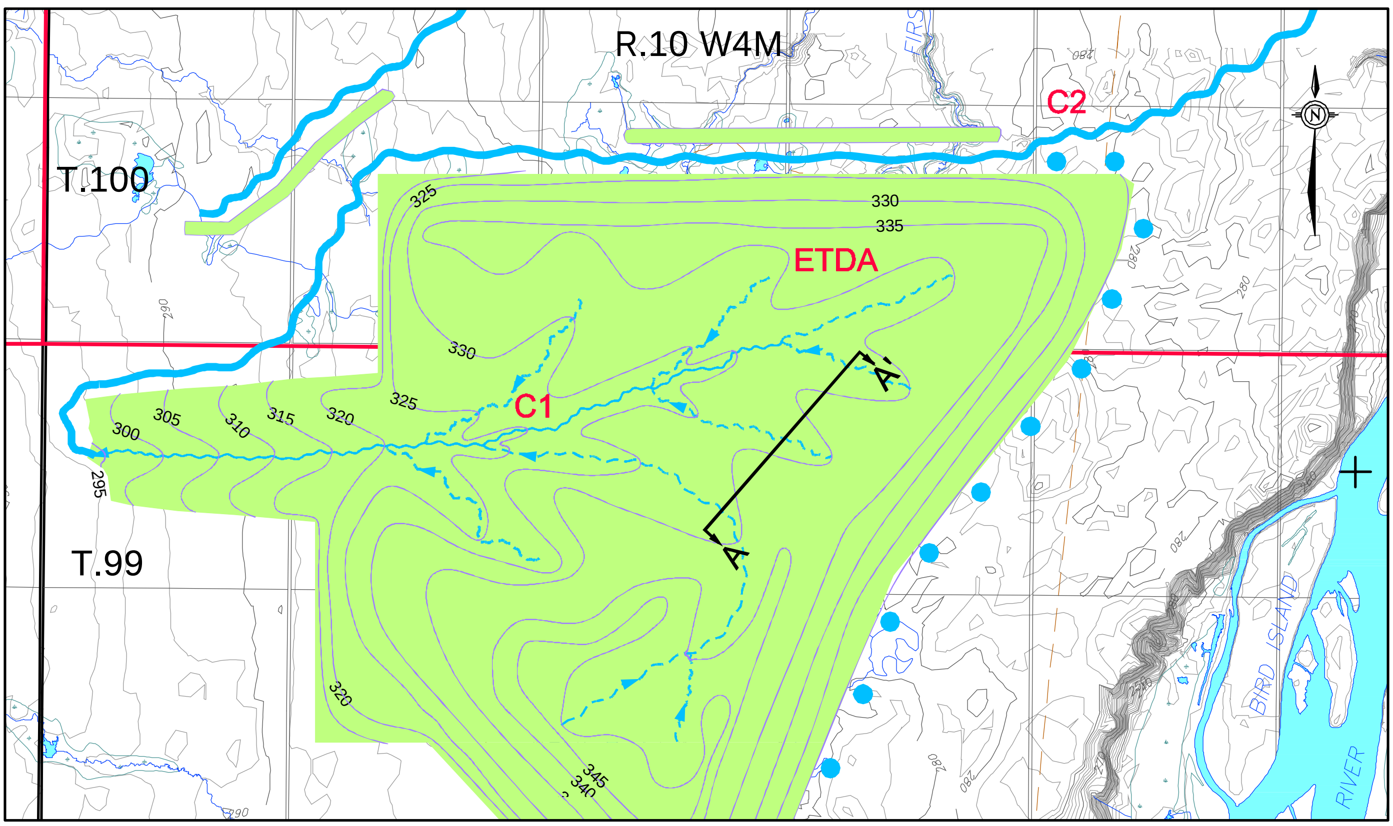
Shell Canada Limited

| | | | | |
|---|---|---|---|---|
| PROJECT 06-1346-022.9400 | | | FILE No. | Channel C12 |
| DESIGN | EK | 24/09/07 | SCALE AS SHOWN | REV. 0 |
| CADD | PSR | 30/10/07 | FIGURE: 12 | |
| CHECK | FLA | 31/10/07 | | |
| REVIEW | WES/TC | 30/11/07 | | |

L:\2006\1346\06-1346-022 Shell\9400\Closure Drainage Report\Fig 12 Drainage System Channel Design C12.dwg Dec 01, 2007 – 3:34pm




SECTION A-A'
SCHEMATIC ONLY, NOT TO SCALE




**LEGEND**

- CONTOURS (318, 316)
- MAIN CHANNEL
- SECONDARY CHANNEL
- LAKE OR POND
- RECLAIMED SURFACE
- OPEN WATER
- WELLS

SCALE 1 0 1 KILOMETRES

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

**SCHEMATIC**
**LAYOUT OF SECONDARY CHANNELS**
**ON RECLAIMED TAILINGS CELLS**

**Shell Canada Limited**

| | | | | |
|---|---|---|---|---|
| PROJECT 06-1346-022.9500 | | | FILE No. | Schematic Layout |
| DESIGN | EK | 24/09/07 | SCALE AS SHOWN | REV. 0 |
| CADD | PSR | 30/10/07 | **FIGURE: 13** | |
| CHECK | FLA | 31/10/07 | | |
| REVIEW | WES/TA | 30/11/07 | | |

The overburden sand ridges will be about 8 m high with 50-m top widths. The typical spacing of the ridges ranges from 400 to 700 m. The bottom width of the sand trenches will be about 1.5 m and the side slopes will be about 3H:1V.

Drainage courses in the wetlands areas between the ridges are expected to develop naturally after construction of the sand trenches. This natural evolution will facilitate the development of a regime channel pattern and cross-sectional shape. The resulting secondary drainage system is expected to be stable over the long-term.

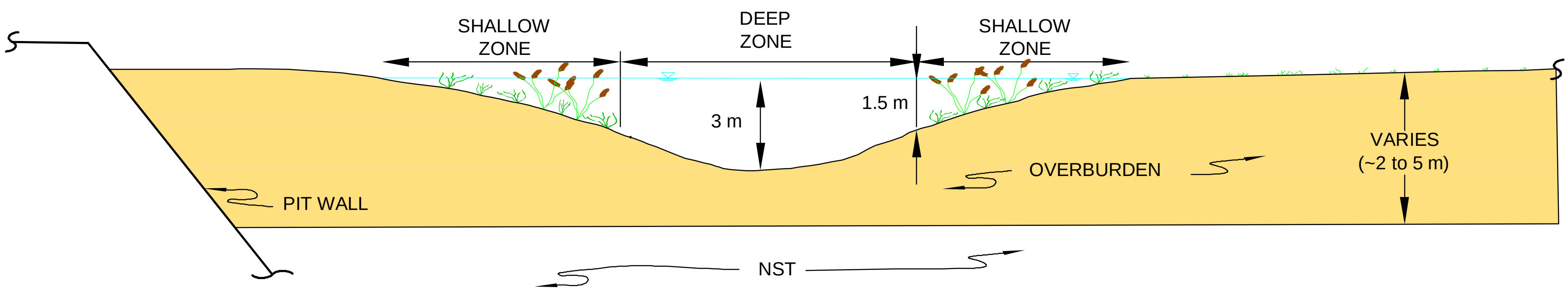
The design concept is that each shallow wetlands system will consist of about 50% vegetated area and about 50% open-water areas. The desired depths of vegetated area will range from 0 to 1.5 m and the depths of open-water area should range from 1.5 to 3 m. Actual conditions are difficult to predict because differential settlement and construction irregularities may result in differences. Some control of actual conditions will be possible by adjusting the depth of outlet channels, after construction, during a monitoring period before certification and custodial transfer. A schematic of the shallow wetlands system is shown in Figure 14. Table 8 summarizes the relevant design parameters of the proposed shallow wetlands.

**Table 8 Relevant Parameters of the Proposed Shallow Wetlands**

| Location | Drainage Area [km²] | Mean Annual Inflow [m³/s] | Normal Water Level [masl] | Surface Area [km²] | Storage Volume [x 1,000 m³] | Residence Time[(a)] [months] |
|---|---|---|---|---|---|---|
| West of Pierre North Pit Lake | 69.0 | 0.16 | 280 | 0.42 | 630 | 1.52 |
| East of Pierre North Pit Lake | 4.13 | 0.01 | 280 | 0.08 | 120 | 4.63 |
| East of Pierre South Pit Lake | 8.35 | 0.01 | 250 | 1.17 | 1,760 | 67.7 |
| North of Pierre South Pit Lake | 303 | 0.65 | 250 | 0.75 | 1,130 | 0.67 |
| East of C7 wetlands | 4.65 | 0.003 | 285 | 0.08 | 120 | 15.4 |

(a) Equivalent to the ratio of storage volume divided by mean annual inflow.

L:\2006\1344-OIL SANDS\1346\06-1346-022 Shell\9400\Closure Drainage Report\Fig 14 Shallow wetlands Schematic.dwg    Dec 01, 2007 - 3:38pm




DETAIL OF SHALLOW WETLANDS

SCHEMATIC ONLY, NOT TO SCALE

PROJECT
JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE
**SCHEMATIC LAYOUT OF SHALLOW WETLANDS**

**Shell Canada Limited**

| | | | | |
|---|---|---|---|---|
| PROJECT 06-1346-022.9400 | | | FILE No. Schematic Wetlands | |
| DESIGN | EK | 17/09/07 | SCALE AS SHOWN | REV. 0 |
| CADD | PSR | 17/09/07 | **FIGURE: 14** | |
| CHECK | EK | 17/09/07 | | |
| REVIEW | WES/TC | 30/11/07 | | |

## 4.4 PIT LAKES

### 4.4.1 Pit Lake Design Parameters

The closure landscape and drainage systems for Pierre River Mining Area will include two lakes: Pierre North Pit Lake and Pierre South Pit Lake. These lakes will be filled by runoff from natural and reclaimed areas during the decommissioning period. After closure and in the Far Future, the water balance in these lakes will be maintained by runoff from natural and reclaimed areas. Table 9 summarizes the relevant design parameters for these lakes.

**Table 9 Design Parameters for the Pit Lakes**

| Pit Lake Name | Normal Lake Water Level [masl] | Average Water Depth [m] | Water Volume [Mm³] | Total Lake Surface Area [km²] | Surface Area of Littoral Zone [km²] | Average Residence Time [years] | Mean Annual Outflow [m³/s] |
|---|---|---|---|---|---|---|---|
| Pierre North Pit Lake | 280 | 6 | 17 | 2.7 | 0.5 | 1 | 0.64 |
| Pierre South Pit Lake | 250 | 12 | 157 | 11.9 | 1.9 | 10 | 0.55 |

Note: Pierre South Pit Lake is divided into two cells by submerged dykes.

Pierre North Pit Lake drains through Channel C7 into Pierre South Pit Lake, and then through Channel C8 into the Athabasca River. The lakes were sized to be sufficiently large and with sufficient residence times to ensure that water quality objectives are met in the lake outflows.

The lakes have been designed to be self-sustaining over the long-term. They will be equipped with robust features that accommodate natural processes of erosion to minimize the risk of catastrophic failure. They will not be subject to uncontrolled spillage or other catastrophic release of water from the lakes by replicating control measures that make natural lakes self-sustaining. Each of the lakes are fully contained by natural ground or in-pit overburden disposal areas with containment at least 10 m in height and outlet capacities that can handle the largest conceivable flood (i.e., the PMF). The Pierre South Pit Lake design calls for the placement of a large in-pit overburden disposal barrier and wide wetlands adjacent to the Athabasca River escarpment. This barrier is high enough to avoid overtopping for any circumstance including beaver dams. It is of sufficient width to accommodate the natural process of shoreline erosion and control the hydraulic gradient between the pit lake and the toe of the escarpment, to avoid piping.

### 4.4.2 Design of Littoral Zones and Shoreline Protection

The pit lakes will have littoral zone occupying about 15% of the total lake surface area. These zones will have an average water depth of about 1 m to enhance the biological productivity of the lake and contribute to the biodegradation of contaminants. The littoral zones will be constructed along the shorelines of the pit lakes as shown in Figure 15.

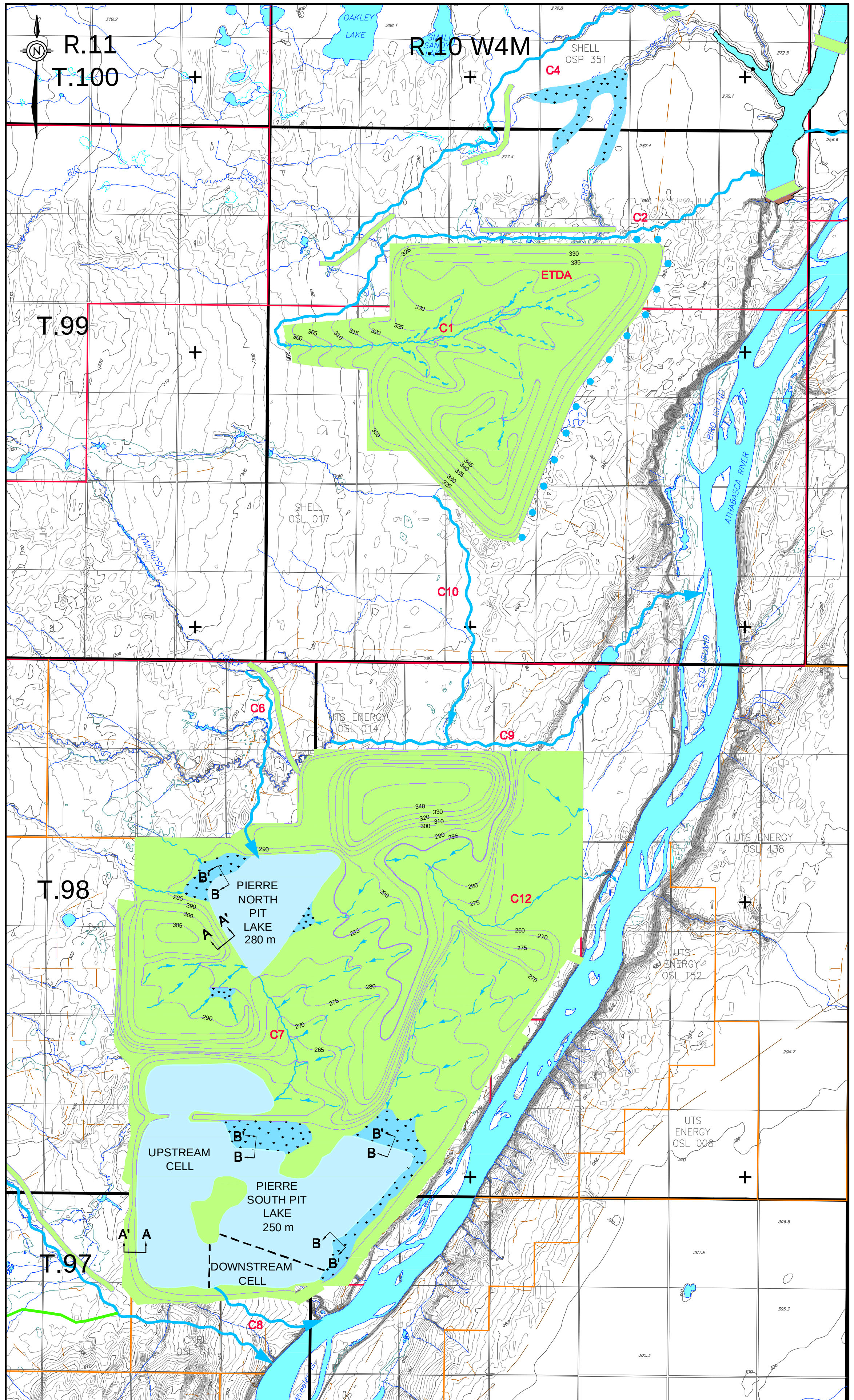
The littoral zones will be protected by a breakwater constructed of rip rap material to avoid excessive wave erosion and to support initial growth of wetlands vegetation. The breakwater is designed based on the extreme wind events of a 100-year recurrence interval. The estimated wave heights caused by the 100-year westerly hourly wind for the proposed lakes are listed in Figure 15.

The maximum elevation of the breakwater is designed to be equal to the 100-year flood level plus 100-year wave height for areas that are not protected by a littoral zone. The breakwater that is located by a littoral zone is 0.3 m below the 100-year flood level. The base of the breakwater in Table 10 is designed to be 1 m below the normal water level.

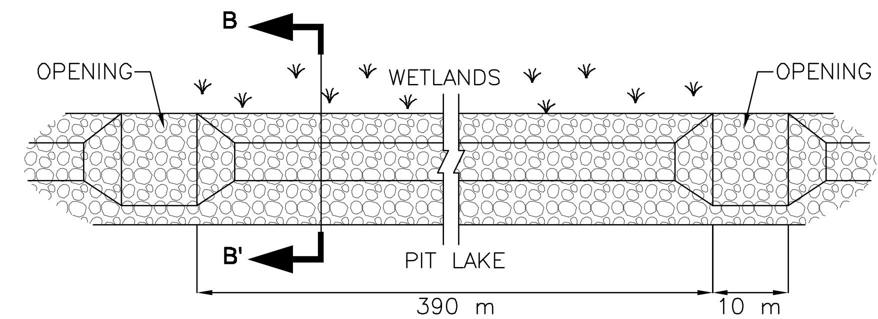
**Table 10 Design Parameters of Shoreline Protection**

| Name | 100-Year Flood Level [masl] | Maximum Level Of Breakwater [masl] | Minimum Level Of Breakwater [masl] |
|---|---|---|---|
| Pierre North Pit Lake | 281.14 | 282.81 | 279.0 |
| Pierre South Pit Lake | 250.88 | 252.54 | 249.0 |

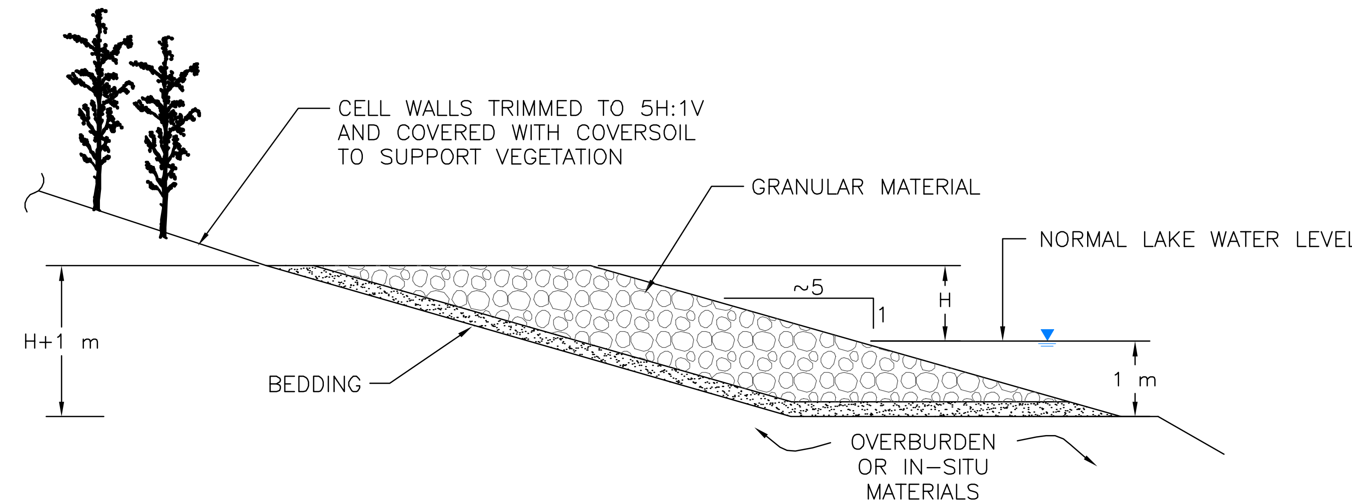
The breakwater is designed to prevent damage from wave erosion by the 100-year extreme hourly wind and 5% damage by the 1,000-year extreme hourly wind. The breakwater is discontinuous, with small openings as shown in Figure 15 to allow for the circulation of water and passage of fish between the lake and the littoral zone for access to food supply and spawning areas.



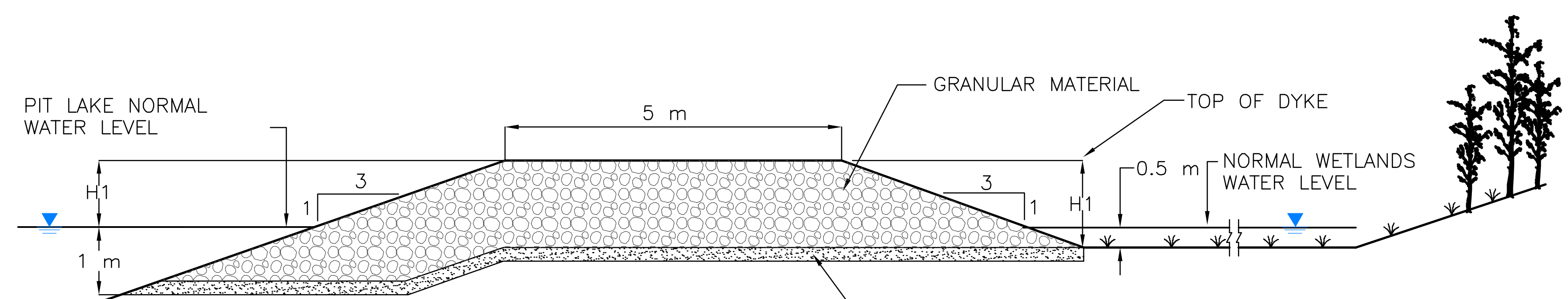

| Pit Lake | Normal Water Level [masl] | Peak Water Level During 100-Year Flood [masl] | Wave Height With 100-Year Return Period [m] | Freeboard Height no littoral zone [(H)] [m] | Freeboard Height with littoral zone $[(H_1)]$ [m] |
|---|---|---|---|---|---|
| South Pit Lake | 250 | 250.88 | 0.78 | 1.66 | 0.58 |
| North Pit Lake | 280 | 281.14 | 0.53 | 1.67 | 0.84 |




**DETAIL 1**




**SECTION A-A'**




**SECTION B-B'**

**LEGEND**

- CONTOURS
- MAIN CHANNEL
- SECONDARY CHANNEL
- LAKE OR POND
- WETLANDS
- RECLAIMED SURFACE
- OPEN WATER
- SUBMERGED DYKE
- WELLS

SCALE 2 0 2 KILOMETRES

PROJECT
JACKPINE MINE EXPANSION & PIERRE RIVER MINE PROJECT

TITLE
**SHORELINE PROTECTION FOR PIT LAKES**

Shell Canada Limited

| | | | | |
|---|---|---|---|---|
| PROJECT 06-1346-022.9400 | | | FILE No. Shoreline Protection | |
| DESIGN | EK | 24/09/07 | SCALE AS SHOWN | REV. 0 |
| CADD | PSR | 30/10/07 | | |
| CHECK | FLA | 31/10/07 | FIGURE: 15 | |
| REVIEW | WES/TC | 30/11/07 | | |

Parts of the shorelines of the pit lakes do not have littoral wetlands. These shorelines will be formed by the mined-out pit walls or in-pit dykes constructed of overburden materials. At the proposed lake water levels, the shoreline materials at the mined-out pit walls may be composed of oil sands or surficial aquifer sands. These sandy soils are easily erodible by wave action. Therefore, a suitable erosion protection measure, such as placement of granular materials similar to those used in the breakwater, is used to protect these shorelines and to minimize the shoreline erosion. Similar protection is required for the in-pit dyke. Figure 15 (Section A-A) presents a typical design of this erosion protection measure.

The unprotected shoreline on the pit walls consists of competent till materials. This type of material is subject to gradual erosion at a very slow rate. Without erosion protection, a stable beach profile would eventually form after a period of gradual wave erosion and occasional slumping of shore materials. This type of shoreline erosion is expected to be very slow because of the presence of some granular and clay materials in the overburden material.

# 5 CONCLUSION AND CLOSURE

This closure drainage plan shows that it is feasible to develop a self-sustaining closure drainage system for the PRMA. The closure drainage plan will result in self-sustaining landforms after mine closure, maximize beneficial changes and minimize negative impacts. The proposed closure drainage design provides a sound basis for identification and assessment of the environmental impacts of PRMA.

The closure drainage plan for the PRMA will, if designed according to the dynamic system approach, result in a self-sustaining aquatic environment having biodegradation of Project waste. This closure drainage plan will upon closure provide comparable channel characteristics, to existing conditions.

# 6 REFERENCES

Bray, D.I. 1972. Generalized Regime-Type Analysis of Alberta Rivers. University of Alberta. Edmonton, AB.

Bretting, A.E. 1946. A set of practical hydraulic formulae based on recent experimental research; comparison with older formulae, Appendix 24, 2d Meeting, International Association of Hydraulic Structures Research, Stockholm. 20 pp.

Clearwater (Clearwater Environmental Consultants Inc.). 2007. Oil Sands End Pit Lakes: A Review to 2007. Submitted to Cumulative Environmental Management Association End Pit Lakes Subgroup.

Golder (Golder Associates Ltd.). 2006. Predicted Water Quality of Oil Sands Reclamation Wetlands: Impact of Physical Design and Hydrology. Submitted to Cumulative Environmental management Association End Pit Lakes Subgroup.

Golder. 2007. Aquatics Environmental Setting Report for the Jackpine Mine Expansion & Pierre River Mine Project. Prepared for Shell Canada Limited. Calgary, AB. Submitted December 2007.

Schumm, S.A. 1977. The Fluvial Systems. John Wiley & Sons. New York, NY.

Simons, D.B. and F. Senturk. 1977. Sediment Transport Technology. Water Resources Publications. 808 pp.

# 7 ABBREVIATIONS

| | |
|---|---|
| % | Percent |
| cm | Centimetre |
| EIA | Environmental Impact Assessment |
| ESR | Environmental Setting Report |
| ETDA | External Tailing Disposal Area |
| ft | Feet |
| ft/ft | Feet per feet |
| ft/mile | Feet per mile |
| $ft^3/s$ | Cubic feet per second |
| H:V | Ratio of horizontal length (H) to vertical length (V) for a specific slope |
| HSPF | Hydrological Simulation Program-Fortran |
| km | Kilometre |
| km/h | Kilometres per hour |
| $Km/km^2$ | Kilometre per square kilometre |
| $km^2$ | Square kilometre |
| m | Metre |
| m/m | Metres per metre |
| m/s | Metres per second |
| $m^2$ | Square metres |
| $m^3$ | Cubic metres |
| $m^3/s$ | Cubic metres per second |
| masl | Metres above sea level |
| MFT | Mature Fine Tailings |
| mm | Millimetre |
| $Mm^3$ | Mega metres (Million cubic metres) |
| NST | Non-Segregating Tailings |
| OBDA | Overburden Disposal Area |
| PDA | Project Development Area |
| PMF | Probable Maximum Flood |
| PRMA | Pierre River Mining Area |
| Shell | Shell Canada Limited |
| TT | Thickened Tailings |
| U.S. EPA | United States Environmental Protection Agency |

# 8 GLOSSARY

| | |
|---|---|
| **Bankfull Discharge** | The flow rate that fills the channel of an undisturbed stream with a wide floodplain up to the top of its banks prior to flooding. |
| **Biodegrade** | Capable of being decomposed by biological agents. |
| **Bioremediation** | The process of applying corrective action to unbalanced biological systems. |
| **Bouldery Ground** | Select fill material consisting of 50:50 silt/clay overburden material mixed with gravel, cobbles and boulders |
| **Channel Regime** | The morphological characteristics, including cross-section, longitudal slope and sinuosity, of a watercourse that is in long-term equilibrium. |
| **Channel** | The bed of a stream or river. |
| **Dendritic Drainage Pattern** | A stream system that branches irregularly in all directions with the tributaries joining with the main stream at all angles. |
| **Drainage Density** | The total length of channels per unit area in a drainage basin. The drainage density characterizes the density of drainage courses in a basin. |
| **Drainage Effectiveness** | The ability to achieve the target land use and soil moisture conditions, avoiding excess water inundation and moisture deficits within the limits that can be tolerated by the target land use and function (i.e., lakes, wetlands, upland vegetation, salt leaching, pre-construction stripping) |
| **Erosion** | The process by which material, such as rock or soil, is worn away or removed by wind or water. |
| **Evapotranspiration** | A measure of the capability of the atmosphere to remove water from a location through the processes of evaporation and water loss from plants (transpiration). |
| **Floodplain** | The portion of the river valley, adjacent to the river channel, which is built of sediments during the present regimen of the stream and which is covered with water when the river overflows its banks at flood stages. |

**Fluvial** Sediment generally consisting of gravel and sand with a minor fraction of silt and rarely clay. The gravels are typically rounded and contain interstitial sand. Fluvial sediments are commonly moderately to well sorted and display stratification, but massive, non sorted fluvial gravels do occur. These materials have been transported and deposited by streams and rivers.

**Geomorphic** The natural evolution of surface soils and landscape over long periods.

**Geomorphology** The science of surface landforms and their interpretation on the basis of geology and climate. That branch of science that deals with the form of the earth, the general configurations of its surface and the changes that take place in the evolution of landforms.

**Glaciofluvial (or Glacio-Fluvial)** Sediments or landforms produced by melt waters originating from glaciers or ice sheets. Glaciofluvial deposits commonly contain rounded cobbles arranged in bedded layers.

**Groundwater** That part of the subsurface water that occurs beneath the water table, in soils and geologic formations that are fully saturated.

**Groundwater Recharge** Water that enters the saturated zone by a downward movement through soil and contributes to the overall volume of groundwater.

**Hydrogeology** The study of the factors that deal with subsurface water (groundwater) and the related geologic aspects of surface water. Groundwater as used here includes all water in the zone of saturation beneath the earth's surface, except water chemically combined in minerals.

**Hydrologic Simulation Program – Fortran (HSPF)** The Hydrologic Simulation Program – Fortran (HSPF) model is a comprehensive, conceptual, continuous watershed simulation model designed to simulate the water quantity and water quality processes that occur in a watershed. The model can reproduce spatial variability by dividing the basin in hydrologically homogeneous land segments and simulating runoff for each land segment independently, using segment-specific meteorological input data and watershed parameters.

| | |
|---|---|
| **Littoral Zone** | The zone in a lake that is closest to the shore. It includes the part of the lake bottom, and its overlying water, between the highest water level and the depth where there is enough light (about 1% of the surface light) for rooted aquatic plants and algae to colonize the bottom sediments. |
| **Lowland Areas** | Areas with ground slopes of less than 0.5% and typically poorly drained. |
| **Mature Fine Tailings (MFT)** | Fine tailings that have dewatered to a level of about 30% solids over a period of about three years after deposition. The rate of consolidation beyond this point is substantially reduced. Mature fine tailings behave like a viscous fluid. |
| **Muskeg** | A soil type comprised primarily of organic matter. Also known as bog peat. |
| **Non-Segregating Tailings (NST)** | Tailings formed from a mixture of cycloned sand tailings and thickened fine tailings in a non-segregating stream. These consolidate relatively rapidly upon placement in tailings disposal areas to form a trafficable surface. Consolidated tailings is one type of NST. |
| **Overburden** | Material below the soil profile and above the bituminous sand. |
| **Piping** | Small leaks in dam or dyke walls that carry away the finer materials, weakening the holding walls and ultimately resulting in failure. |
| **Pit Lake** | A man-made lake used to fill a mine pit area into which tailings may be discharged. Pit Lakes are typically filled with waters pumped from adjacent rivers, or from runoff waters from reclamation areas. |
| **Porewater** | Water between the grains of a soil or rock. |
| **Probable Maximum Flood (PMF)** | The most severe flood that may be expected from a combination of the most critical meteorological and hydrological conditions that is reasonably possible in the drainage basin. It is used in designing high-risk flood protection works and siting of structures and facilities that must be subject to almost no risk of flooding. The probable maximum flood is much larger than the 100-year flood. |
| **Riparian** | Refers to terrain, vegetation or simply a position next to or associated with a stream, floodplain or standing waterbody. |

| | |
|---|---|
| **Runoff** | The portion of water from rain and snow that flows over land to streams, ponds or other surface waterbodies. It is the portion of water from precipitation that does not infiltrate into the ground, or evaporate. |
| **Sand Ridges on NST** | A ridge that creates hydraulic gradients that will provide well-drained soil conditions necessary for upland vegetation and flushing of saline porewater necessary for salinity control. |
| **Sand Trenches on TT** | A depressed watercourse that provides a drainage outlet for groundwater and surface water resulting in drained soil conditions necessary for upland vegetation and flushing of saline pore water necessary for salinity control between watercourses. |
| **Sinuosity** | The ratio of the thalweg length (i.e., the line connecting the deepest points along a stream) to valley length, for a specific reach of a river or stream system. This is, in essence, a ratio of the stream's actual "running" length to its down-gradient length. |
| **Subsoil** | A stratum that includes one or more of the following:<br>(i) that portion of the B horizon left after salvage of upland surface soil;<br>(ii) the C horizon of an upland soil;<br>(iii) underlying parent material at an upland location that is rated good, fair or poor as described in Table 9, Page 28 of the Soil Quality Criteria Relative to Disturbance and Reclamation,1987, as amended; and<br>(iv) mineral material below an organic layer at a location other than upland, that is rated good, fair or poor as described in Table 9, Page 28 of the Soil Quality Criteria Relative to Disturbance and Reclamation,1987, as amended. |
| **Surficial Aquifer** | A surficial (at or near the surface of the earth) deposit containing water considered an aquifer. |
| **Suspended Sediments** | Particles of matter suspended in the water. Measured as the oven dry weight of the solids, in mg/L, after filtration through a standard filter paper. Less than 25 mg/L would be considered clean water, while an extremely muddy river might have 200 mg/L of suspended sediments. |
| **Swale** | A natural depression or wide shallow ditch used to convey runoff. |

**Tailings** A by-product of oil sands extraction typically comprised of water, sands and clays, with minor amounts of residual bitumen.

**Thickened Tailings (TT)** Thickened fine tailings are produced by increasing the solids content of fine tailings from the Bitumen Cleaning process to 35 to 45% in a large vessel called a thickener by removing water. Thickened tailings are combined with cycloned sand tailings from the Bitumen Recovery process to produce non-segregated tailings (NST).

**Till** Sediments laid down by glacial ice.

**Upland Areas** Areas that have typical ground slopes of 1 to 3% and are better-drainage.

**Vegetated Channel/Grass Waterway** Vegetated waterways are broad, intermittent or ephemeral drainage courses, often consisting of the entire valley bottom. They are covered with vegetation and have no defined stream bed or banks.

**Wetlands** Wetlands are land where the water table is at, near or above the surface or which is saturated for a long enough period to promote such features as wet-altered soils and water tolerant vegetation. Wetlands include organic wetlands or "peatlands," and mineral wetlands or mineral soil areas that are influenced by excess water but produce little or no peat.

# APPENDIX 4-6

# CONCEPTUAL COMPENSATION PLAN

## TABLE OF CONTENTS

**SECTION** **PAGE**

## LIST OF TABLES



## LIST OF FIGURES

JPME R1 AENV SIR 022 AND JPME R1 AENV SIR 334

# 1 INTRODUCTION

The Shell Canada Limited (Shell) Jackpine Mine Expansion & Pierre River Mine Project (the Project) consists of an open pit mining operation as described in Volumes 1 and 2 of the Application. Potential impacts on aquatic resources were discussed for the development in Section 6.7 of the Environmental Impact Assessment (EIA).

The Jackpine Expansion Mining Area (JEMA) is located on the east side of the Athabasca River, with the Project development area (Figure 1) occurring within the following drainage systems:

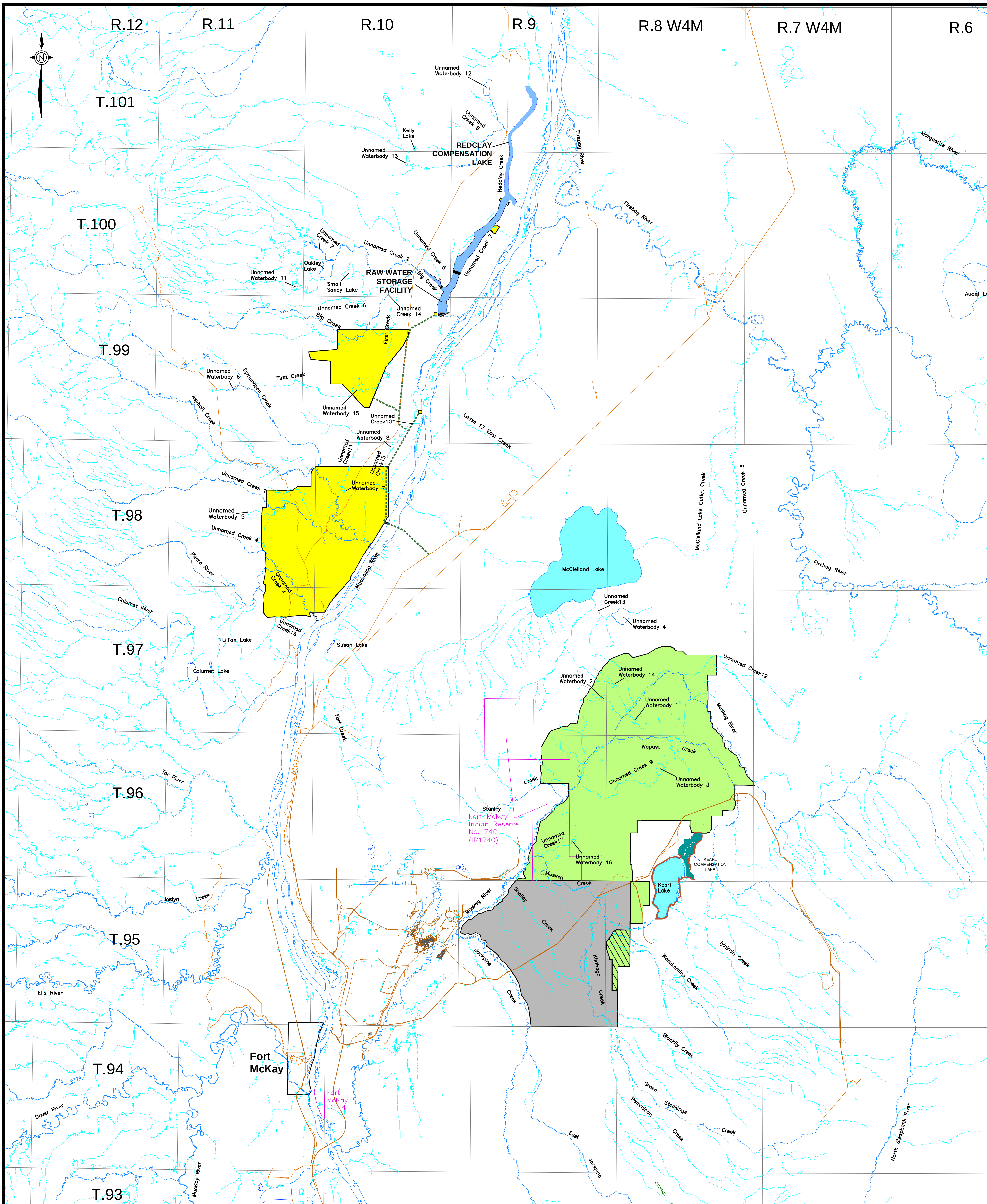
- Upper Muskeg River, including:
  - Wapasu Creek;
  - unnamed tributaries; and
  - unnamed waterbodies.

The Pierre River Mining Area (PRMA) is located on the west side of the Athabasca River, with the Project development area (Figure 1) occurring within the following drainage systems:

- Pierre River;
- Eymundson Creek, including Asphalt Creek;
- Big Creek, including First Creek;
- Redclay Creek;
- unnamed tributaries; and
- unnamed waterbodies.

The development activities associated with the Project were determined to result in changes in fish and fish habitat in the JEMA throughout portions of the upper Muskeg River watershed, including Wapasu Creek, and in the PRMA throughout portions of the Pierre River, Eymundson Creek, Big Creek and Redclay Creek watersheds (Section 6.7 of the EIA). Therefore, a habitat compensation plan was developed to address these specific impacts. In addition, the proposed development in the JEMA will alter some aspects of the previously approved Jackpine Mine – Phase 1 development, including some of the previously planned fish habitat compensation works (i.e., Khahago Lake and the repositioned and reconstructed Muskeg Creek).

L:\2006\1344-OIL SANDS\1346\06-1346-022 Shell\9100\9170\Fig 1 Project Development Area.dwg Dec 04, 2007 - 5:35pm




LEGEND

- PIERRE RIVER MINING AREA
- JACKPINE EXPANSION MINING AREA
- LEASE SWAPPED TO SYNCRUDE
- JACKPINE MINE - PHASE 1
- DYKE
- LAKE PERIMETER LEVEE

5 0 5

SCALE KILOMETRES

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

**PROJECT DEVELOPMENT AREA WITH COMPENSATION LAKE INCLUDED**

Shell Canada Limited

| | | |
|---|---|---|
| PROJECT 06-1346-022.9100 | | |
| DESIGN | MK | 18/09/07 |
| CADD | PSR | 04/12/07 |
| CHECK | GW | 04/12/07 |
| REVIEW | WES/TC | 04/12/07 |

FILE No. Project Dev Area

SCALE AS SHOWN REV. 0

**FIGURE: 1**

REFERENCE

ALBERTA DIGITAL DATA OBTAINED FROM ALTALIS LTD. (SEPTEMBER 2004.)
USED UNDER LICENSE. PROJECTION: TRANSVERSE MERCATOR
DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 12

JPME R1 AENV SIR 502

JPME R1 AENV SIR 504

This appendix provides a fish habitat Conceptual Compensation Plan (CCP) developed with consideration of the "No Net Loss Guiding Principle" for fish habitat, pursuant to seeking approval from Fisheries and Oceans Canada (DFO) for the Project under the federal Fisheries Act. The Practitioners Guide to Compensation (DFO 2002) states that the "requirement for compensation is no net loss in the productive capacity of fish habitat" and that "practitioners should aim for greater than a 1:1 compensation ratio." The CCP was developed to satisfy both this requirement and goal.

The CCP is intended to demonstrate Shell's commitment to compensate for predicted habitat alterations or losses due to development of the Project and to achieving no net loss of the productive capacity of fish habitat. A detailed plan will ultimately be developed through consultation with appropriate regulatory agencies including DFO and Alberta Sustainable Resource Development (ASRD). The final result will be a detailed No Net Loss Plan (NNLP) that will determine habitat losses from the Project and how the offsetting habitat compensation requirements will be achieved. This will be used to satisfy a portion of the requirements for obtaining an Authorization for Works or Undertakings Affecting Fish Habitat for the Project under Section 35(2) of the *Fisheries Act*.

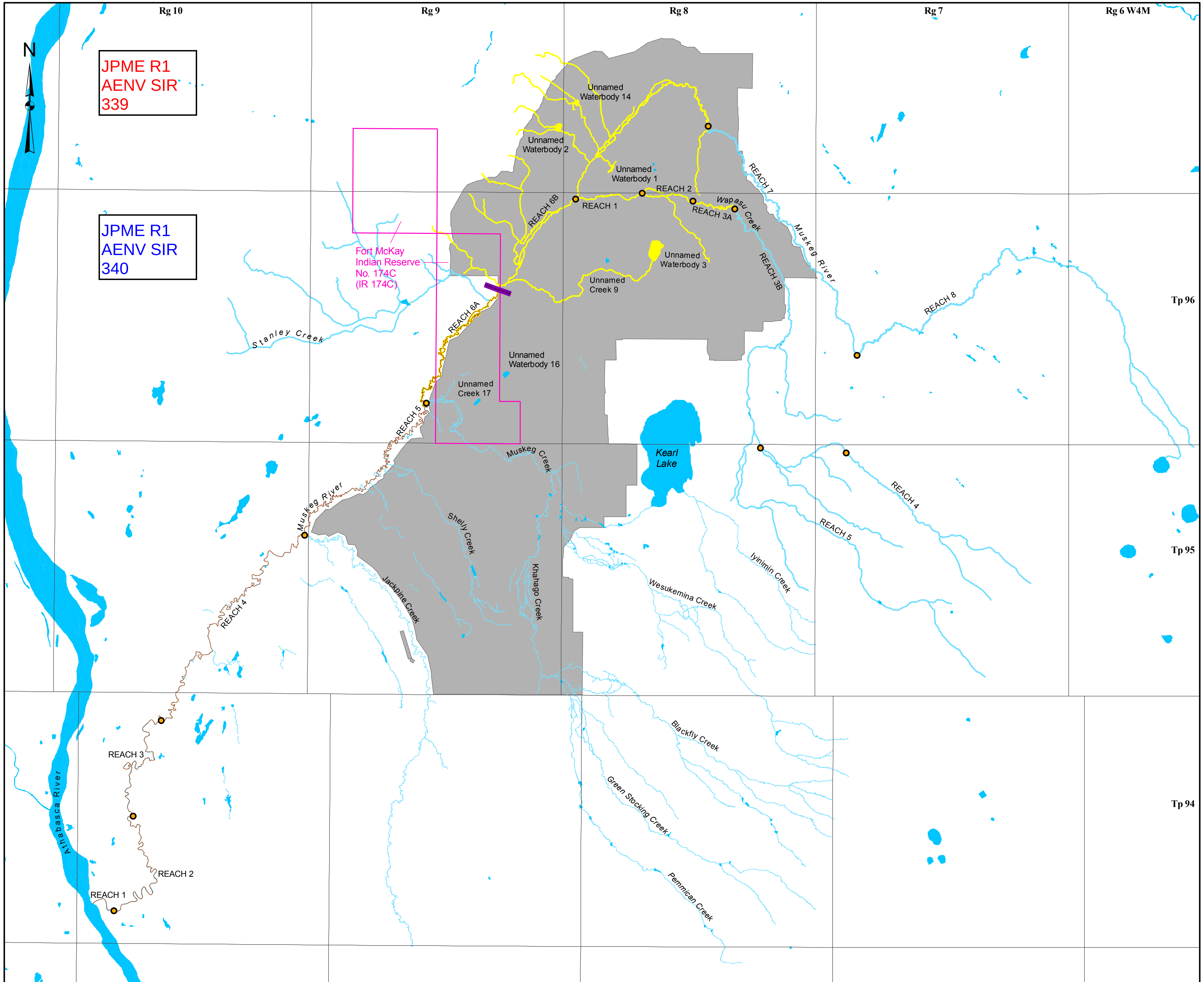
# 2 DESCRIPTION OF PROJECT EFFECTS

The fish and fish habitat EIA (Volume 4, Section 6.7 of the EIA) identified and evaluated the effects of all potential changes predicted to occur due to the development of the Project. The impact assessment was based on the valid linkages and effects pathways between Project activities and predicted changes to surface water hydrology or water quality, as well as linkages assessed specifically for fish and fish habitat. Changes in fish and fish habitat identified in the impact assessment that are relevant to the CCP include those that constitute a Harmful Alteration, Disruption or Destruction (HADD) of fish habitat.

The Project includes the development of mine pits, overburden disposal areas, tailings areas and associated mine facilities within the Project development areas. As a result of these landscape modifications, changes in useable fish habitat area (i.e., habitat quantity) in the watersheds present in the Project development areas were identified by the impact assessment as a potential adverse affect of the Project. These predicted effects represent a reduction in fish habitat productive capacity, and therefore a HADD of fish habitat that will be offset by the proposed compensation described in this appendix.

The Project necessitated integration of approved Syncrude Aurora South, Imperial Oil Kearl Oil Sands Project and Jackpine Mine – Phase 1 operational and closure drainage plans in the Muskeg River watershed, reconciling inconsistencies between the approved facility-specific plans. Conceptual integrated operational and closure surface drainage plans for the Muskeg River watershed are provided in Volume 1, Section 10, and Appendix 4-3, respectively.

Watercourses that occur in any portion of the Project development areas were divided into segments (i.e., reaches), including segments upstream, within, and downstream of the Project development area. Watercourse segments that will result in the HADD of fish habitat due to the JEMA and PRMA are identified in Figures 2 and 3, respectively. However, those waterbodies that are isolated (i.e., not connected to downstream fish habitat areas) are not considered part of the HADD of fish habitat as they do not contribute to the support of subsistence, commercial, or recreational fisheries (DFO 1995). Predicted changes in fish habitat are described in the following sections for the affected watercourses and waterbodies.




**LEGEND**

- INDIAN RESERVE
- JACKPINE EXPANSION MINING AREA AND JACKPINE MINE-PHASE 1
- OPEN WATER
- MUSKEG RIVER REACHES AFFECTED BY FLOW ALTERATIONS
- HABITAT AREAS LOST
- DIVERSION DITCH/PIPELINE LOCATION
- REACH BREAK COORDINATE

**REFERENCE**

Alberta digital data obtained from AltaLIS Ltd. (September 2004), IHS Energy Ltd. (August 2006), Alberta Pacific Ltd. (April 2004), and Alberta SRD, used under license.
Projection: Transverse Mercator Datum: NAD 83 Coordinate System: UTM Zone 12.

4 0 4
SCALE 1:150,000 KILOMETRES

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

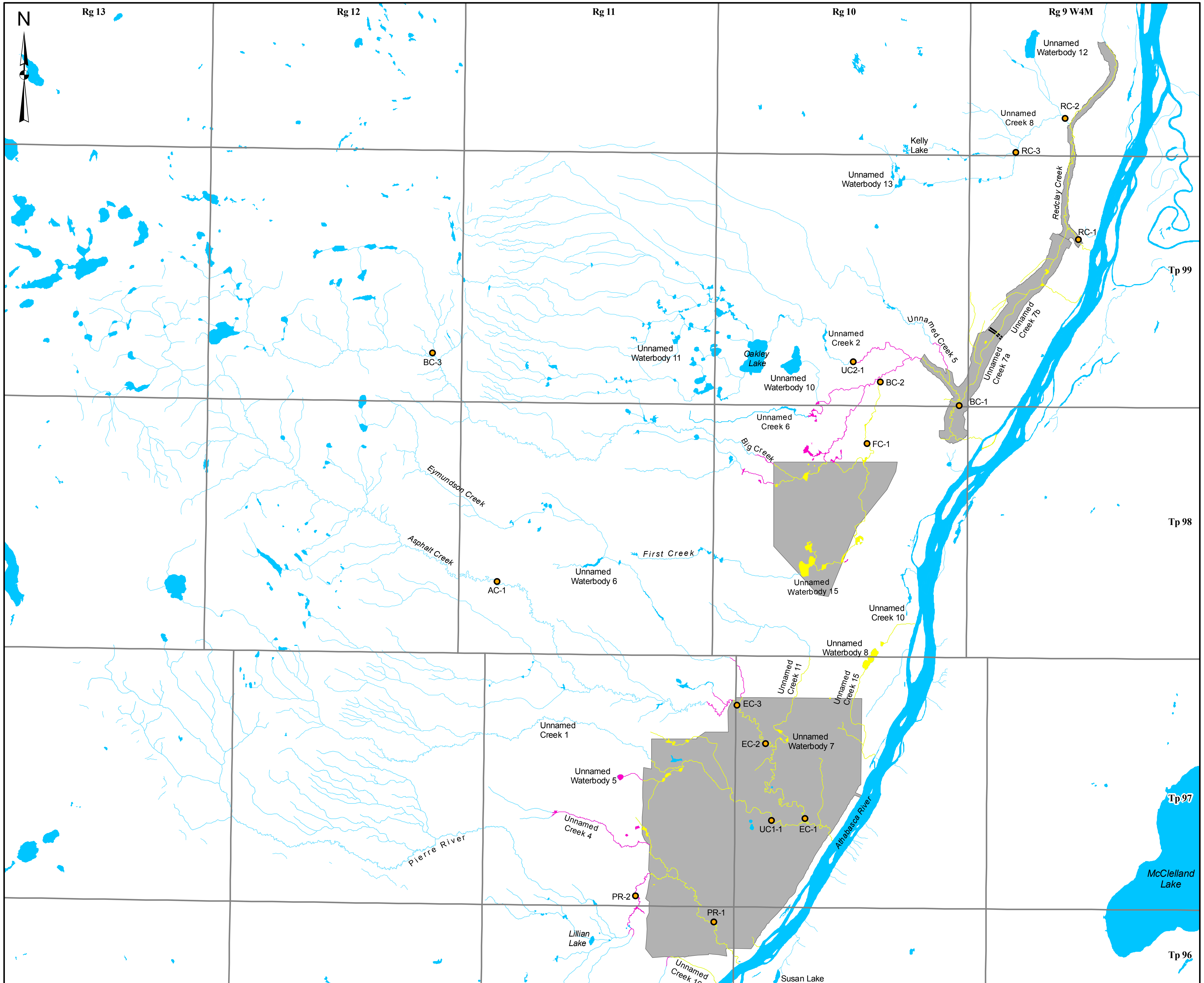
**JACKPINE EXPANSION MINING AREA**
**AFFECTED STREAMS AND WATERBODIES**

Shell Canada Limited

| PROJECT No. 05-1344-027.7600 | | | SCALE AS SHOWN | REV. 0 |
|---|---|---|---|---|
| DESIGN | AA | 27 Aug. 2007 | | |
| GIS | JH | 28 Nov. 2007 | | |
| CHECK | JS | 28 Nov. 2007 | | |
| REVIEW | WES | 28 Nov. 2007 | | |

**FIGURE: 2**

Project: I:\CLIENTS\SHELL\06-1346-022\mapping\mxd\Fisheries\Fig2_JP_Streams_Waterbodies.mxd - Plot: I:\CLIENTS\SHELL\06-1346-022\mapping\pdf\Fisheries\Fig2_JP_Streams_Waterbodies.pdf




**LEGEND**

- HABITAT AREAS LOST DURING OPERATIONS
- ADDITIONAL HABITAT AREAS LOST AT CLOSURE
- PIERRE RIVER MINING AREA
- OPEN WATER
- WATERSHED DIVIDE
- REACH BREAK COORDINATE

**REFERENCE**

Alberta digital data obtained from AltaLIS Ltd. (September 2004), IHS Energy Ltd. (August 2006), Alberta Pacific Ltd. (April 2004), and Alberta SRD, used under license.
Projection: Transverse Mercator Datum: NAD 83 Coordinate System: UTM Zone 12.

4 0 4
SCALE 1:150,000 KILOMETRES

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

**PIERRE RIVER MINING AREA**
**AFFECTED STREAMS AND WATERBODIES**

Shell Canada Limited

| PROJECT No. 06-1346-022.9100 | | | SCALE AS SHOWN | REV. 0 |
|---|---|---|---|---|
| DESIGN | AA | 27 Aug. 2007 | **FIGURE: 3** | |
| GIS | JH | 28 Nov. 2007 | | |
| CHECK | JS | 28 Nov. 2007 | | |
| REVIEW | WES | 28 Nov. 2007 | | |

Project: I:\CLIENTS\SHELL\06-1346-022\mapping\mxd\Fisheries\Fig3_PR_Streams_Waterbodies.mxd- Plot: I:\CLIENTS\SHELL\06-1346-022\mapping\pdf\Fisheries\Fig3_PR_Streams_Waterbodies.pdf

JPME R1
AENV SIR
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## 2.1 JACKPINE EXPANSION MINING AREA

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AENV SIR
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### 2.1.1 Operational Diversions and Closure Drainage System Description

The conceptual integrated operational and closure surface drainage plans for the Muskeg River watershed described in Volume 1, Section 10 and Appendix 4-3, respectively, reflect the discussions held to date between Shell, Syncrude Canada Ltd. (Syncrude) and Imperial Oil Resources Ventures Limited (Imperial Oil), and represent the most viable drainage plans that would function for all integrated operations. Considering the regulatory requirement for functioning integrated drainage, this represents the most conservative set of assumptions against which project impacts can be assessed. The assessment addresses the impacts associated with the Project.

Figure 4 shows the conceptual layout of stream diversions for the JEMA. In 2012, two diversion channels will be constructed as works associated with Syncrude's Aurora South Mine. The first is a 13-km-long diversion channel that will be constructed to convey flows from the west tributaries of Pemmican Creek to Jackpine Creek. The second diversion is a 23-km-long headwater diversion channel that will be constructed to divert the headwaters of Pemmican, Green Stockings, Blackfly, Wesukemina and Iyinimin creeks to Kearl Lake. The channel will follow the natural alignment of Iyinimin Creek. These two diversion channels will facilitate mine development in Aurora South Mine and Jackpine Mine − Phase 1.

In 2012, Kearl Lake will have two outlets, one is the natural outlet to Muskeg Creek and the other feeds a constructed 9-km diversion channel that will discharge to Muskeg River below Stanley Creek as shown in Figure 4. Sufficient flows will be provided in Muskeg Creek to support natural fish habitat in Muskeg Creek and the Jackpine Mine – Phase 1 Compensation Lake. The diversion channel will carry the additional flow associated with the diversion of the headwaters of Pemmican, Green Stockings, Blackfly, Wesukemina and Iyinimin creeks to Kearl Lake from 2012 to 2017 and will also provide fish passage to Kearl Lake. In 2017, Muskeg Creek is cut off by mine progression. From 2017 to 2033, the diversion channel will carry all of the flow from Kearl Lake to the Muskeg River. A pipeline will be constructed to convey flows as required to support the Jackpine Mine Compensation Lake. Also due to mine advance, the 2012 diversion channel to Muskeg River below Stanley Creek will be cut off in 2033 and gravity pipeline(s) will be built across the active mine development area to convey the Kearl Lake outflows to the Muskeg River. The gravity pipeline is not intended to support upstream fish passage from the Muskeg River to Kearl Lake. Consequently, natural levels of fish passage will be maintained to

Kearl Lake through fish transport. The gravity pipeline will be replaced with a reconstructed Muskeg Creek when the landscape is reclaimed. At this point, fish habitat, including passage between Kearl Lake and the Muskeg River, will be restored.

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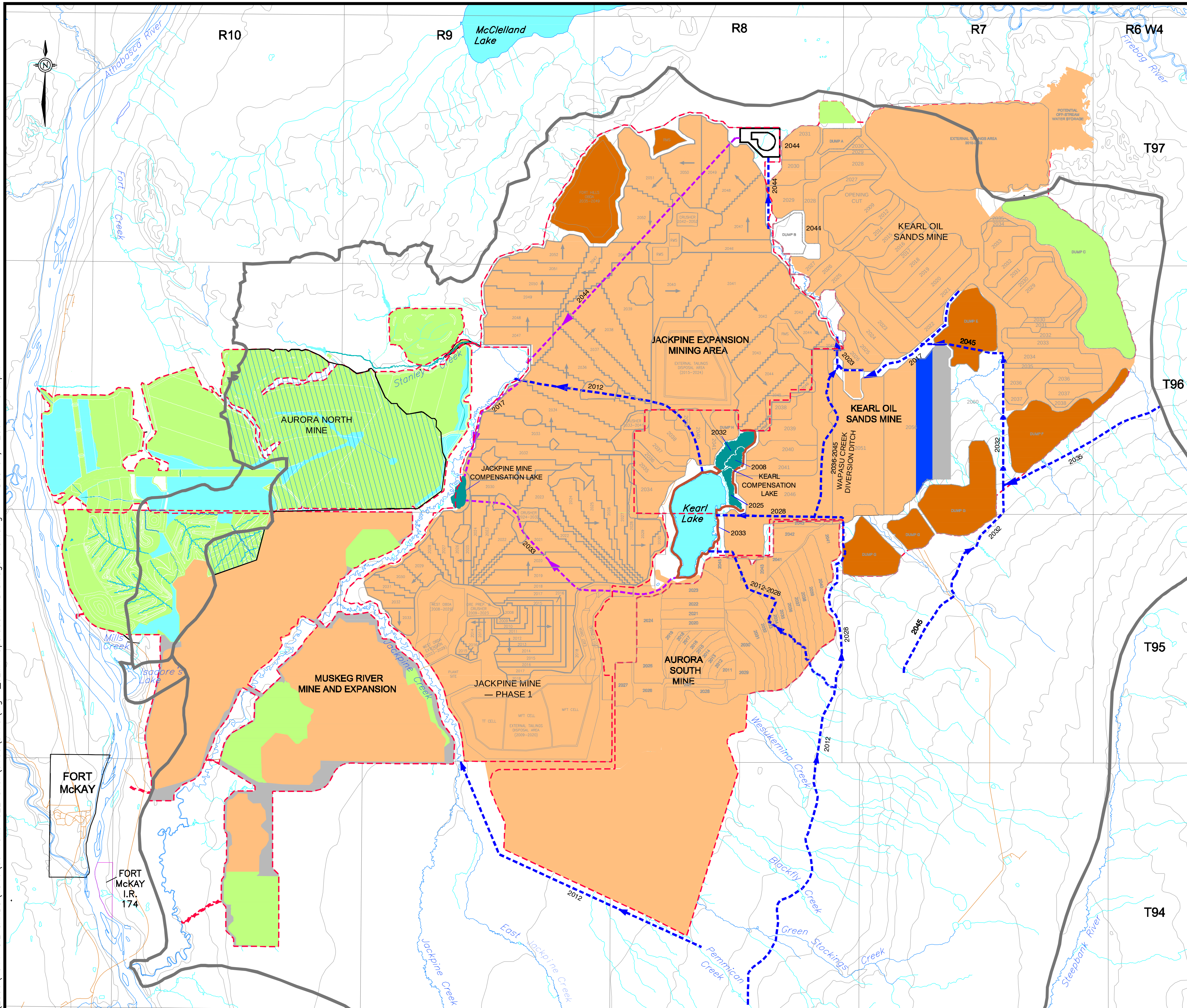
A partial perimeter levee along the periphery of Kearl Lake and the adjacent Imperial Oil Kearl Compensation Lake will be constructed in 2033 to prevent spillage during extreme flood events. An emergency spillway and two operational lake outlet structures will also be built.

In 2028, a 12 km long headwater diversion channel will be constructed to extend the 2012 headwater diversion channel around the Aurora South Mine footprint to discharge to Kearl Lake (Figure 4). This channel extension will also divert Wapasu Creek flows. A side weir and diversion channel will be constructed to divert the Wapasu portion of the diversion flows back to Wapasu Creek and eventually the Muskeg River. Diversion of apportioned flows to Wapasu Creek will begin in 2028 and end in 2036 when Wapasu Creek will be cut off due to JEMA mine advance. The apportioned flows will then be diverted to Muskeg River from 2036 to 2045.

In 2044, a reach of the upper Muskeg River will be cut off due to JEMA mining advance (Figure 4). To maintain flows to the lower Muskeg River, a surge pond with a pump/pipeline system will be constructed to receive flows from the upper Muskeg River for discharge below the mining area (above Stanley Creek confluence).

The closure drainage plan is shown in Figure 5. At closure, runoff from the Aurora South External Tailings Disposal Area (ETDA) will be directed to the Aurora South Mine Pit Lake. This pit lake will discharge to Kearl Lake and also receive runoff from the Aurora South Mine reclaimed pit areas and flows from Iyinimin Creek, Wesukemina Creek and the tributaries of Khahago Creek. The reclaimed areas of JEMA will receive runoff from the five Kearl Oil Sands Project pit lakes and discharge to Muskeg River through the Jackpine North Pit Lake. Runoff from the Aurora South Mine reclaimed areas in the west area will discharge to the Jackpine Mine – Phase 1 closure drainage system and eventually to the Muskeg River through the Jackpine South Central Pit Lake.




## LEGEND

- OPEN-CIRCUIT RECLAIMED AREA
- LAKE OR WETLANDS
- OPEN-CIRCUIT OVERBURDEN DISPOSAL AREA AND RMS
- CLOSE-CIRCUIT MINE DEVELOPMENT AREA
- CLEARED AREA
- MUSKEG DRAINAGE AND OVERBURDEN DEWATERING AREA
- DIVERTED AREA FROM MUSKEG RIVER WATERSHED
- MINE DEVELOPMENT BOUNDARY
- WATERSHED DIVIDE
- PROPOSED COMPENSATION LAKE
- LAKE PERIMETER DYKE
- SURGE POND
- DIVERSION DITCH
- DIVERSION PIPELINE

## NOTES

1 SNAPSHOTS ARE BASED ON THE LATEST MINE ADVANCE PLANS.
2 FIGURE REPRESENTS OPERATIONAL STATE IN 2052.
3 ALIGNMENT OF DIVERSION DITCHES AND PIPELINES ARE APPROXIMATE.

## REFERENCE

ALBERTA DIGITAL DATA OBTAINED FROM ALTALIS LTD. (SEPTEMBER 2004.) USED UNDER LICENSE.
PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83
COORDINATE SYSTEM: UTM ZONE 12

SCALE 3 0 3 KILOMETRES

PROJECT

JACKPINE MINE EXPANSION & PIERRE RIVER MINE PROJECT

TITLE

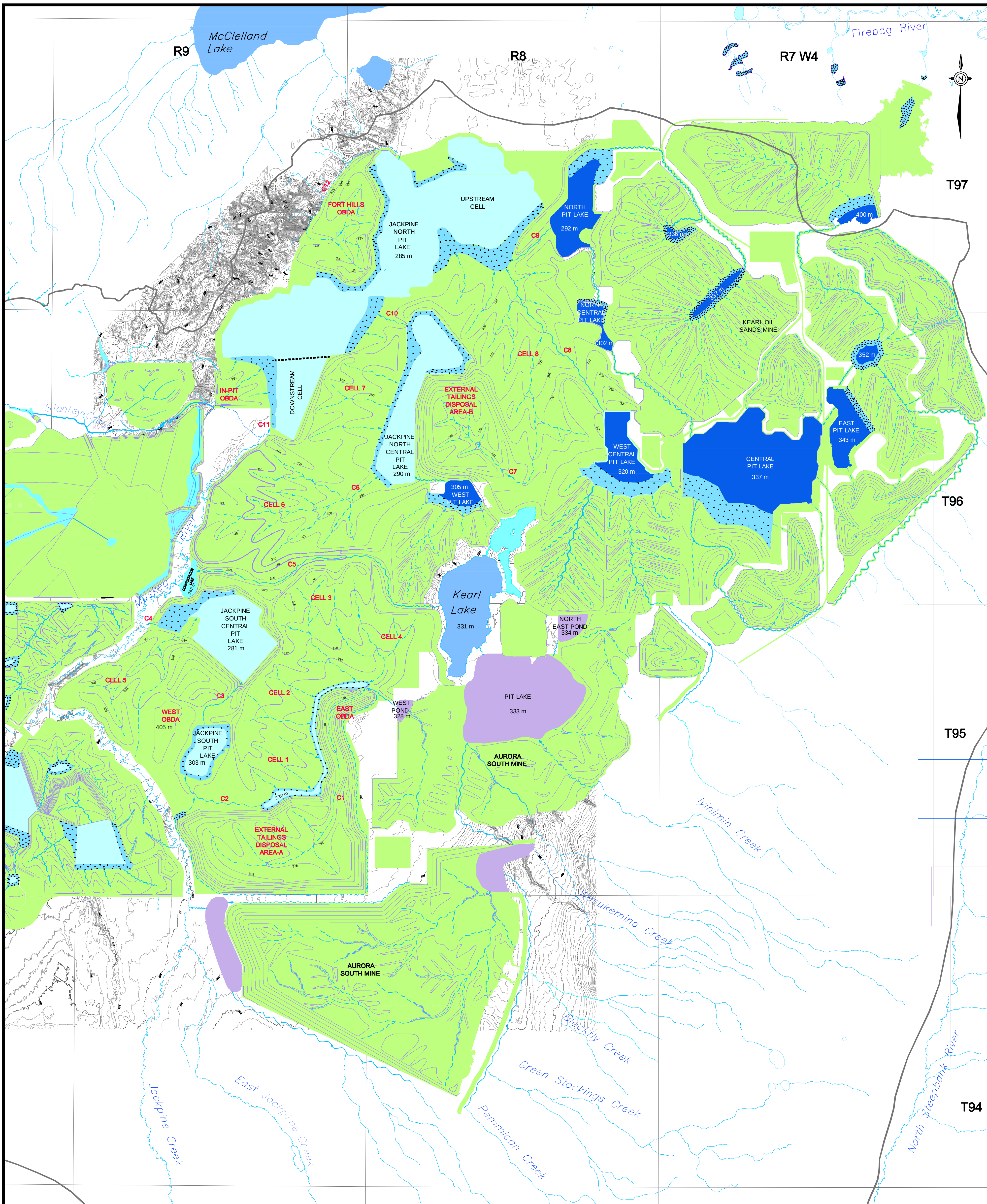
# JACKPINE EXPANSION MINING AREA OPERATIONAL DIVERSION PLAN

Shell Canada Limited

| PROJECT 06–1346–022.9100 | | | FILE No. Operation Diversion | |
|---|---|---|---|---|
| DESIGN | FLA | 05/06/07 | SCALE AS SHOWN | REV. 0 |
| CADD | PSR | 04/12/07 | FIGURE: 4 | |
| CHECK | GW | 04/12/07 | | |
| REVIEW | WES | 04/12/07 | | |

L:\2006\1344–OIL SANDS\1346\06–1346–022 Shell\9100\9170\Fig 4_JEMA–Operational Drainage Plan.dwg Dec 04, 2007 – 5:46pm

L:\2006\1344-OIL SANDS\1346\06-1346-022 Shell\9100\9170\Fig 5_JEMA Closure Drainage Plan.dwg Dec 04, 2007 – 5:16pm




LEGEND

- WATERSHED DIVIDE
- RECLAIMED AREA
- LAKE OR WETLANDS
- KEARL PIT LAKE
- SYNCRUDE PIT LAKE / WETLANDS

2.5 0 2.5
SCALE KILOMETRES

PROJECT
JACKPINE MINE EXPANSION & PIERRE RIVER MINE PROJECT

TITLE
## JACKPINE EXPANSION MINING AREA CLOSURE DRAINAGE PLAN

REFERENCE
ALBERTA DIGITAL DATA OBTAINED FROM ALTALIS LTD. (SEPTEMBER 2004.) USED UNDER LICENSE.
PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83
COORDINATE SYSTEM: UTM ZONE 12

Shell Canada Limited

| | | | | |
|---|---|---|---|---|
| PROJECT 06-1346-022.9100 | | | FILE No. | Closure Plan–JEMA |
| DESIGN | NI | 17/09/07 | SCALE AS SHOWN | REV. 0 |
| CADD | PSR | 01/12/07 | FIGURE: 5 | |
| CHECK | GW | 03/12/07 | | |
| REVIEW | WES/TC | 03/12/07 | | |

For Jackpine Mine – Phase 1, the conceptual integrated operational and closure surface drainage plans for the Muskeg River watershed resulted in the elimination of the Khahago Surge Facility during operation and Khahago Lake on closure. Khahago Lake represented a portion of the fish habitat compensation proposed for the Jackpine Mine – Phase 1 development and was slated to be completed in 2030 (Golder 2005a). Shell will develop this aspect of the required compensation for the Jackpine Mine – Phase 1 at an alternate location. Shell is committed to developing sufficient compensation habitat for the Jackpine Mine – Phase 1 by the required date (2030), as required by the *Fisheries Act* Authorization for that project.

The proposed JEMA development will also change the timing of the HADD of fish habitat in Muskeg Creek and the timing of development of compensation habitat in the reconstructed Muskeg Creek from that specified in the Jackpine Mine – Phase 1 No Net Loss Plan (Golder 2005a). In the Jackpine Mine – Phase 1 compensation plan, the planned reconstruction of Muskeg Creek was to occur over a period of time, with initial reconstruction of a portion of the creek beginning in 2007 to 2008 and completion of the reconstruction during 2030 to 2033 on closure (Golder 2005a). For JEMA, the HADD of fish habitat in Muskeg Creek is delayed and will not occur until 2017, with reconstruction of Muskeg Creek when the landscape is reclaimed, after mining activities have been completed in the Muskeg Creek area.

### 2.1.2 Effects to the Muskeg River Watershed

The upper Muskeg River watershed includes the upper mainstem Muskeg River, Wapasu Creek, several unnamed tributaries and several unnamed waterbodies. The JEMA will result in alteration or direct physical disturbance of the Muskeg River watershed within the Project development area due to drainage alterations, changes in stream flows and the location of the development over a portion of the watershed. All waterbodies and watercourse segments in that portion of the upper Muskeg River watershed within the Project development area will be eliminated or otherwise affected by the Project, and the extent of the affected fish habitat is shown in Figure 2.

The lower portion of the Muskeg River will be affected by flow alterations in varying degrees and at varying times. This includes all reaches of the Muskeg River downstream of the confluence with Unnamed Creek 9 (Figure 2), which is the discharge point of the pump/pipeline. Predicted changes in streamflows and water levels in this portion of the Muskeg River are described and quantified in Volume 4, Section 6.7.5.3. The predicted changes include reductions in the magnitude of spring flows and flood peaks as well as increases in winter flows.

The majority of the habitat loss anticipated with the reduction in peak flows (i.e., 2-year flood flows and greater) will be associated with loss of habitat associated with floodplain inundation. The reduction in magnitude of peak stream flows under the Application Case would suggest there is the potential for the reduction of channel-forming flows required to maintain the channel in its current state and may result in the establishment of a smaller channel over time as vegetation encroaches. Low velocity areas at stream margins will cause sediment and bed material to settle out. The lower flood flows will not be able to clean this material out and over time the channel will narrow, essentially being reset to the new hydrologic regime. As a result of the decrease in peak flows in the Muskeg River downstream of the JEMA development area, there will be a loss of fish habitat resulting from a smaller wetted area during flood flows in the spring, changes to the depth and velocity distribution within the channel, and decreased floodplain inundation.

The predicted changes in stream flow described above have the potential to affect the quantity and quality of fish habitat in the Muskeg River for fish Key Indicator Resources (KIRs), including spring spawning species (i.e., northern pike, Arctic grayling and suckers), juvenile life stages of large-bodied fish species (i.e., sport fish and suckers) and resident fish species (primarily forage fish species. However, it is difficult to determine the overall effect the predicted changes in flow and channel morphology will have on the quality of fish habitat in the Muskeg River during and after the period of channel stabilization to the new flow regime. Some species may benefit from a stabilized flow regime, whereas a loss of habitat area may result for other species.

To help understand the effect of the changes in flow on fish habitat, an assessment of changes to wetted area can be completed for existing surveyed cross sections. The lower Muskeg River near Node M3 is a wide, u-shaped channel, and reductions in peak flow result in a reduction in the average flow depth, but little change to wetted width. Cross-sectional data from the hydrometric monitoring station on the lower Muskeg River (RAMP station S7) have recorded a wetted width of 17.0 m at a discharge of 9.07 $m^3/s$ (RAMP 2004) and a wetted width of 16.2 m at a discharge of 0.45 $m^3/s$ (RAMP 2006), indicating the wetted width varies little with changes in flow for this transect, at least up to bankfull stage.

There are also a number of positive changes to the Muskeg River as a result of Oil Sands development in the Muskeg River watershed, primarily associated with the increase of winter flows in the Far Future snapshot. Increases in winter flows in the Application Case will result in improved overwintering conditions in the Muskeg River relative to natural conditions that are considered limiting. The improved winter conditions would increase survivability for any fish species overwintering in the Muskeg River, including young-of-the-year fish from migratory spawning species such as northern pike, suckers and Arctic grayling. The improved survivability should counter-balance, to some degree, the potential for reduced spawning within the Muskeg River as a result of reduced peak flows.

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Further investigations will be undertaken during development of the detailed NNLP to better quantify effects to fish habitat in the Muskeg River due to flow alterations, to better assess the nature and extent of any HADD of fish habitat, and to determine the amount of compensation that may be required. For the purposes of this CCP, it has been assumed that any HADD to the portion of the Muskeg River affected by flow alterations, that are attributable to JEMA, will be unlikely to exceed a 20% reduction in habitat availability or quality. In quantifying the anticipated habitat losses in this CCP, it has been estimated that the potential HADD to the lower Muskeg River reaches as approximately equivalent to a 20% reduction in habitat area. This is a preliminary estimate, and a more detailed quantification of the potential HADD of fish habitat will be undertaken during development of the detailed NNLP to ensure no net loss in productive capacity of fish habitat is achieved.

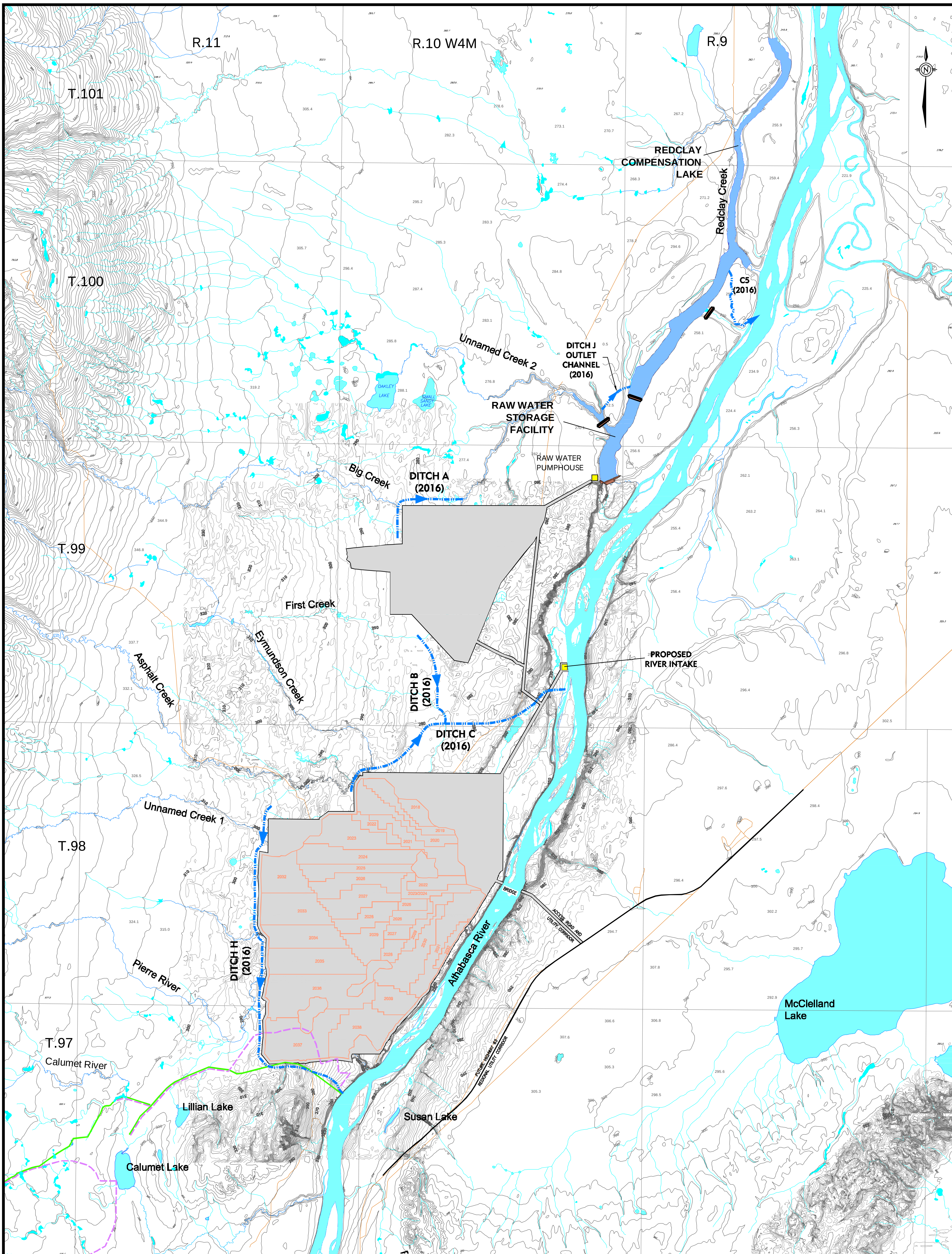
## 2.2 PIERRE RIVER MINING AREA

### 2.2.1 Operational Diversions and Closure Drainage System Description

The conceptual layout of the diversion systems built during the operational phase of the PRMA development is shown in Figure 6. Flows in Pierre River, Unnamed Creek 1 and Unnamed Creek 4 will be diverted south through a drainage channel (Ditch H) in 2016 around the PRMA development area to the Athabasca River. Ditch H will also either intercept Unnamed Creek 16 or be constructed in the channel of that creek. Flows in Eymundson and Asphalt creeks will be diverted north by a drainage channel (Ditch C) to the Athabasca River in 2016. Flows from upper First Creek and Unnamed Creek 11 will be diverted to Ditch C through a drainage channel (Ditch B).

A diversion channel (Ditch A) will be required in 2016 to divert a section of Big Creek to the downstream reach. In addition, Big Creek and Unnamed Creek 2 will be diverted to the Redclay Compensation Lake through a drainage channel (Ditch J) in 2016 as shown in Figure 6.

L:\2006\1344-OIL SANDS\1346\06-1346-022 Shell\9100\9170\Fig 6_PRMA Operational Diversion Plan.dwg Dec 01, 2007 – 10:53am




LEGEND

- CANADIAN NATURAL CLOSURE CHANNEL (2044)
- CANADIAN NATURAL OPERATIONAL DITCH (2021)
- DIVERSION DITCH
- PIERRE RIVER MINING AREA
- DYKE

2.5 0 2.5
SCALE KILOMETRES

NOTE
DRAWING PROVIDED BY SHELL ( PRM-ADVANCE-May 01-2007.dwg)

REFERENCE
ALBERTA DIGITAL DATA OBTAINED FROM ALTALIS LTD. (SEPTEMBER 2004.)
USED UNDER LICENSE. PROJECTION: TRANSVERSE MERCATOR
DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 12

PROJECT
JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE
**PIERRE RIVER MINING AREA OPERATIONAL DIVERSION PLAN WITH COMPENSATION LAKE INCLUDED**

Shell Canada Limited

| PROJECT 06-1346-022.9100 | | | FILE No. Operation-Div-PRMA |
|---|---|---|---|
| DESIGN | FLA | 17/09/07 | SCALE AS SHOWN REV. 0 |
| CADD | PSR | 16/10/07 | |
| CHECK | GW | 16/10/07 | **FIGURE: 6** |
| REVIEW | WES/TC | 30/11/07 | |

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All operational stream channels will be designed to allow fish passage between the Athabasca River and stream locations upstream of the PRMA. The design of any fish passage structures that may be required is not included at this time, in the conceptual design of the diversion channels, but will be included at the preliminary design stage and discussed in the detailed NNLP.

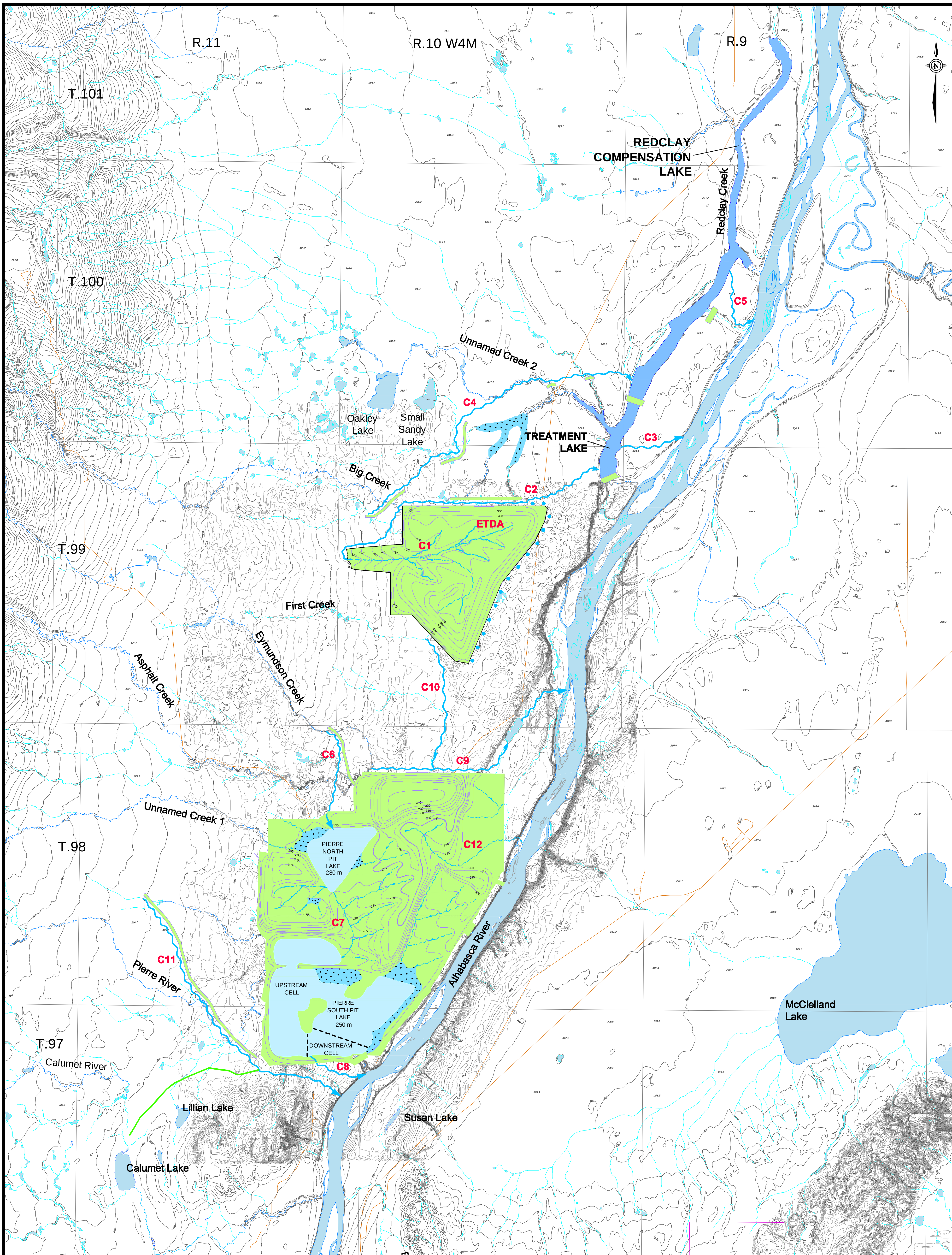
The proposed closure drainage plan for the PRMA is described below and illustrated in Figure 7. At closure, the ETDA will consist entirely of tailings sand. The proposed drainage system on the ETDA will convey runoff through a series of swales to a central drainage channel (C1) excavated into the northern portion of the cell. Channel C1 will direct flow to the west side of the cell and into Channel C2, which will follow the northern edge of the ETDA and discharge into the Treatment Lake (this facility will serve at closure to treat runoff rather than as a source of raw water). At closure, an outlet channel (C3) will be constructed from the Treatment Lake to the Athabasca River.

A new creek (C4), to be built on natural ground north of the ETDA, will collect flows from Big Creek and several smaller unnamed creeks and allow for fish passage from the Athabasca River to the watershed. This channel will flow in a northeasterly direction and discharge into the Redclay Compensation Lake. The Redclay Compensation Lake will be connected to the Athabasca River through a geomorphically designed outlet channel (C5).

During the initial part of the closure period, flows in Pierre River and Unnamed Creek 1 will be continue to be diverted south by a drainage channel (Ditch H) around the mine development area to the Athabasca River (Figure 6). Flows in Eymundson and Asphalt creeks will also continue to be diverted north by a drainage channel (Ditch C) to the Athabasca River. Once water quality in the pit lakes is suitable for discharge, Eymundson Creek and Asphalt Creek will be rerouted to flow into the Pierre North Pit Lake through a new drainage channel (C6) (Figure 7), and Unnamed Creek 1 will also flow directly into Pierre North Pit Lake. At this time, the Pierre River and several small channels will be diverted south around the mining area through Channel C11 and discharged to the Athabasca River through the same outlet as the Canadian Natural Resources Limited (Canadian Natural) Horizon Project closure diversion channel (Figure 7). Inflows to the Pierre North Pit Lake and surface runoff from within the PRMA will be discharged to the Athabasca River through the Pierre South Pit Lake.

The closure drainage plan of the Project was developed to accomplish the objectives of long-term self-sustaining drainage and minimal aquatic impacts on receiving streams. The routes were selected and designed to maximize long-term self-sustaining drainage, minimize the changes in flows in the surrounding creeks and rivers, and to allow for fish passage.

L:\2006\1344-OIL SANDS\1346\06-1346-022 Shell\9100\9170\Fig 7_PRMA Closure Drainage Plan-Compensation Lake Included.dwg Dec 01, 2007 - 11:22am




LEGEND

- SHELL LEASE BOUNDARY
- MAIN CHANNEL
- SECONDARY CHANNEL
- RECLAIMED SURFACE
- CONTOURS
- WETLANDS
- LAKE OR POND
- SUBMERGED DYKE
- CANADIAN NATURAL CLOSURE CHANNEL
- DIVERSION CHANNEL
- WELLS

2.5 0 2.5
SCALE KILOMETRES

REFERENCE

ALBERTA DIGITAL DATA OBTAINED FROM ALTALIS LTD. (SEPTEMBER 2004.)
USED UNDER LICENSE. PROJECTION: TRANSVERSE MERCATOR
DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 12

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

**PIERRE RIVER MINING AREA CLOSURE DRAINAGE PLAN WITH CONCEPTUAL COMPENSATION LAKE INCLUDED**

Shell Canada Limited

| PROJECT 06-1346-022.9100 | | | FILE No. Closure-PRMA | |
|---|---|---|---|---|
| DESIGN | MK | 17/09/07 | SCALE AS SHOWN | REV. 0 |
| CADD | PSR | 16/10/07 | **FIGURE: 7** | |
| CHECK | GW | 16/10/07 | | |
| REVIEW | WES/TC | 30/11/07 | | |

### 2.2.2 Effects to the Pierre River Watershed

The Pierre River watershed includes the mainstem Pierre River as well as several unnamed tributary watercourses and waterbodies. The PRMA will result in alteration or direct physical disturbance of the Pierre River watershed within the Project development area due to drainage alterations, changes in stream flows, and the location of the development over a portion of the watershed (Figure 3). Areas upstream of the Project development area will be maintained through a diversion channel during operations. On closure, a geomorphically designed channel will be constructed that will include fish habitat features and provide fish passage. The extent of affected areas will be greater at closure than during operations, as shown in Figure 3, due to the configuration of channels in the closure drainage plan.

### 2.2.3 Effects to the Eymundson Creek Watershed

The Eymundson Creek watershed includes the Eymundson Creek mainstem, Asphalt Creek, which is the major tributary to Eymundson Creek, and several unnamed tributary watercourses and waterbodies. The PRMA will result in alteration or direct physical disturbance of the portion of the Eymundson Creek watershed within the Project development area during operations due to drainage alterations, changes in stream flows and the location of the development over a portion of the watershed (Figure 3).

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Areas of the watershed upstream of the Project development area will not be directly affected, as connectivity of these areas to the Athabasca River will be maintained through diversion channels during operations. These diversions will continue during the initial part of the closure period. When water quality in the pit lakes is suitable for discharge, Eymundson Creek, Asphalt Creek and Unnamed Creek 1 will be rerouted into the pit lakes, as shown in the closure drainage plan (Figure 7). The extent of affected areas will be slightly greater at closure than during operations, as shown in Figure 3, due to the configuration of channels in the closure drainage plan.

### 2.2.4 Effects to the Big Creek Watershed

The Big Creek watershed includes the Big Creek mainstem, First Creek, as well as several unnamed tributary watercourses and waterbodies. The PRMA will result in alteration or direct physical disturbance of the Big Creek watershed within the Project development area due to drainage alterations and changes in stream flows that are associated with the placement of the external tailings facility and Raw Water Storage Facility over a portion of the watershed

(Figure 3). The extent of affected areas will be greater at closure than during operations, as shown in Figure 3, due to the configuration of channels in the closure drainage plan.

### 2.2.5 Effects to the Redclay Creek Watershed

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The Redclay Creek watershed includes the Redclay Creek mainstem as well as several unnamed tributary watercourses. The PRMA will result in alteration or direct physical disturbance of a portion of the Redclay Creek mainstem and some tributary reaches due to development of the Redclay Compensation Lake, which will inundate these areas. The change from stream habitat to lake habitat as a result of the development of Redclay Compensation Lake is considered an alteration and will be tracked in the detailed accounting of habitat gains to losses at a ratio of 1:1. The extent of watercourses that will be affected by development of the Redclay Compensation Lake in the Redclay Creek watershed is illustrated in Figure 3.

### 2.2.6 Effects to the Athabasca River

A summary of the predicted changes in mean seasonal Athabasca River flows are presented in Tables 6.4-27 and 6.4-28 in Volume 4, Section 6.4.7.3. Changes in Athabasca River flow parameters were evaluated based on maximum allowable total withdrawal specified for each week by the Water Management Framework. As discussed in the Hydrology assessment (Volume 4, Section 6.4.7.3), the reduction in mean seasonal Athabasca River flows due to withdrawals ranges from 2.1% in summer to 14.1% in winter, based on average Athabasca River weekly flows.

Shell has committed to meeting the Water Management Framework for the lower Athabasca River (AENV and DFO 2007). The Framework was developed to manage withdrawals from the Athabasca River and protect the aquatic ecosystem, while allowing industry to operate. The withdrawal restrictions in the Water Management Framework are designed to minimize the duration and frequency of potential habitat effects, and protect the aquatic ecosystem and associated fisheries of the Athabasca River. However, the Water Management Framework recognizes that cumulative water withdrawals, even the restricted withdrawals permitted under the specifications of the Framework, may result in negative effects on fish habitat. Any incremental changes to fish habitat will be addressed through the Phase 2 process of the Water Management Framework. Habitat compensation requirements, if necessary, will be developed for the Project through consultation with DFO.

## 2.3 SUMMARY

Based on the results of the impact analysis, changes to fish and fish habitat were identified for the Project that warrant consideration in the CCP. These changes include habitat alterations or disturbances that would affect the productive capacity of fish habitat and are therefore considered to constitute a HADD that will require habitat compensation measures to achieve no net loss of productive capacity.

The flow regime in the lower reaches of the Muskeg River will be altered, and these alterations have the potential to result in a HADD of fish habitat. For the purpose of the CCP, a preliminary estimate of what is considered the maximum likely potential HADD has been provided (i.e., 20%; see Section 2.1.2). A more detailed quantification of the potential HADD will be undertaken during development of the detailed NNLP.

Under the Water Management Framework for the Athabasca River, there is the potential for a HADD of fish habitat to result from the cumulative withdrawals of all operators during restricted periods. Any changes to fish habitat, and any compensation requirements, will be developed for the project through consultation with DFO.

Summaries of the Project works or undertakings, and the anticipated HADDs are presented in Table 1 (for the JEMA) and Table 2 (for the PRMA).

**Table 1 Summary of the Works or Undertakings Associated with Jackpine Expansion Mining Area Expected to Cause Harmful Alteration, Disruption or Destruction of Fish Habitat**

| Mining Area | Description and Location of Works or Undertakings | Schedule | Description of HADD |
|---|---|---|---|
| Jackpine Expansion Mining Area | Construction of a diversion channel from the north end of Kearl Lake to the Muskeg River below Stanley Creek. | 2012 | Beginning of flow alterations in Muskeg Creek.[a] |
| | Progression of mining and construction of a pipeline from near the outlet of the 2012 diversion to the Jackpine Mine Compensation Lake. | 2017 | Elimination of habitats in Muskeg Creek.[a] |
| | Development of the ETDA. | 2015 to 2024 | Elimination of habitats in the southern end of Unnamed Waterbody 3. |
| | Construction of a pipeline across the active mine area to convey Kearl Lake outflows to the Muskeg River through the Jackpine Mine Compensation Lake. | 2033 | Beginning of flow alterations in the lower Muskeg River. |
| | Progression of mining and diversion of Wapasu Creek flows to the upper Muskeg River. | 2036 | Elimination of habitats in lower Wapasu Creek (Reaches 1, 2 and 3a). |

## Table 1 Summary of the Works or Undertakings Associated with Jackpine Expansion Mining Area Expected to Cause Harmful Alteration, Disruption or Destruction of Fish Habitat (continued)

| Mining Area | Description and Location of Works or Undertakings | Schedule | Description of HADD |
|---|---|---|---|
| Jackpine Expansion Mining Area (continued) | Progression of mining. | 2035 to 2041 | Elimination of habitats in Unnamed Waterbody 3 and Unnamed Creek 9. |
| | Construction of a diversion channel to cut off a reach of the upper Muskeg River and convey flows to a point on the Muskeg River above Stanley Creek. | 2044 | Elimination of habitats in Muskeg River Reach 6b. |

[a] The HADD associated with Muskeg Creek has been authorized by the Fisheries Act Section 35 (2) Authorization for the Jackpine Mine – Phase 1 and will be compensated for by compensation habitat developed for the Jackpine Mine – Phase 1.

## Table 2 Summary of the Works or Undertakings Associated with the Pierre River Mining Area that are Expected to Cause Harmful Alteration, Disruption or Destruction of Fish Habitat

| Mining Area | Description and Location of Works or Undertakings | Schedule | Description of HADD |
|---|---|---|---|
| Pierre River Mining Area | Construction of the Raw Water Storage Facility and the Redclay Compensation Lake. | 2016 | Alteration of habitats in lower Big Creek (Reach 1 and part of Reach 2), lower Redclay Creek (Reaches 1 and 2), Unnamed Creek 7, a lower segment of Unnamed Creek 5, and a portion of an Unnamed tributary to Redclay Creek. |
| | Construction of a diversion channel (Ditch A) to divert a section of Big Creek to the downstream reach. | 2016 | Elimination of habitats in a portion of Big Creek Reach 3. |
| | Construction of a diversion channel (Ditch C) to convey flows from Eymundson and Asphalt creeks to the Athabasca River. | 2016 | Elimination of habitats in lower Eymundson Creek (Reaches 1, 2 and 3, and a small portion of Reach 4), a small portion of lower Asphalt Creek, associated unnamed tributaries and waterbodies, and Unnamed Creek 10 (a tributary to the Athabasca River). |
| | Development of the Plant Site and the North Overburden Disposal Area (OBDA). | 2016 | Elimination of habitats in Unnamed Creek 15 (a tributary to the Athabasca River) and isolation of Unnamed Waterbody 8. |
| | Construction of a diversion channel (Ditch H) to divert flows in the Pierre River and Unnamed Creek 4 around the PRMA development area to the Athabasca River. | 2016 | Elimination of habitats in the lower Pierre River (Reach 1 and most of Reach 2), the lower portions of Unnamed Creek 1, Unnamed Creek 4 and Unnamed Creek 16, and unnamed waterbodies associated with Creeks 1 and 4. |
| | Progression of mining. | 2038 | Elimination of habitats in one small unnamed tributary to the Athabasca River. |
| | Construction of closure drainage channels. | Closure Period | Elimination of some additional habitats in the Pierre River, Eymundson Creek and Big Creek drainages. |

# 3 DESCRIPTION OF AFFECTED WATERBODIES AND WATERCOURSE SEGMENTS

The following provides a description of the fish communities and available fish habitats in the waterbodies and watercourse segments that will be affected by the Project and that are included in the CCP because a HADD of fish habitat in these watercourses and waterbodies is anticipated. The descriptions are based on all historical information, available traditional knowledge and current field data, as presented in the Fish and Fish Habitat Environmental Setting Report (Golder 2007). Locations of study sites at which fish and fish habitat data were collected are shown in Figures 8 and 9.

## 3.1 JACKPINE EXPANSION MINING AREA

Habitats in the upper Muskeg River watershed that will be eliminated by the JEMA development include Reach 6b of the mainstem Muskeg River (i.e., Reach 6 upstream of the confluence with Unnamed Creek 9), and all watercourse segments in the upper Muskeg River watershed located in the Project development area (Figure 2). The effects to fish habitat in the lower reaches of the Muskeg River (Reaches 1 through 5 and Reach 6 downstream of the confluence with Unnamed Creek 9) will not result from physical disturbance or removal of habitat, but habitats may be affected by flow alterations during certain times of the year or in certain years of the mine life as discussed in Section 2.1.2.

### 3.1.1 Muskeg River Watershed

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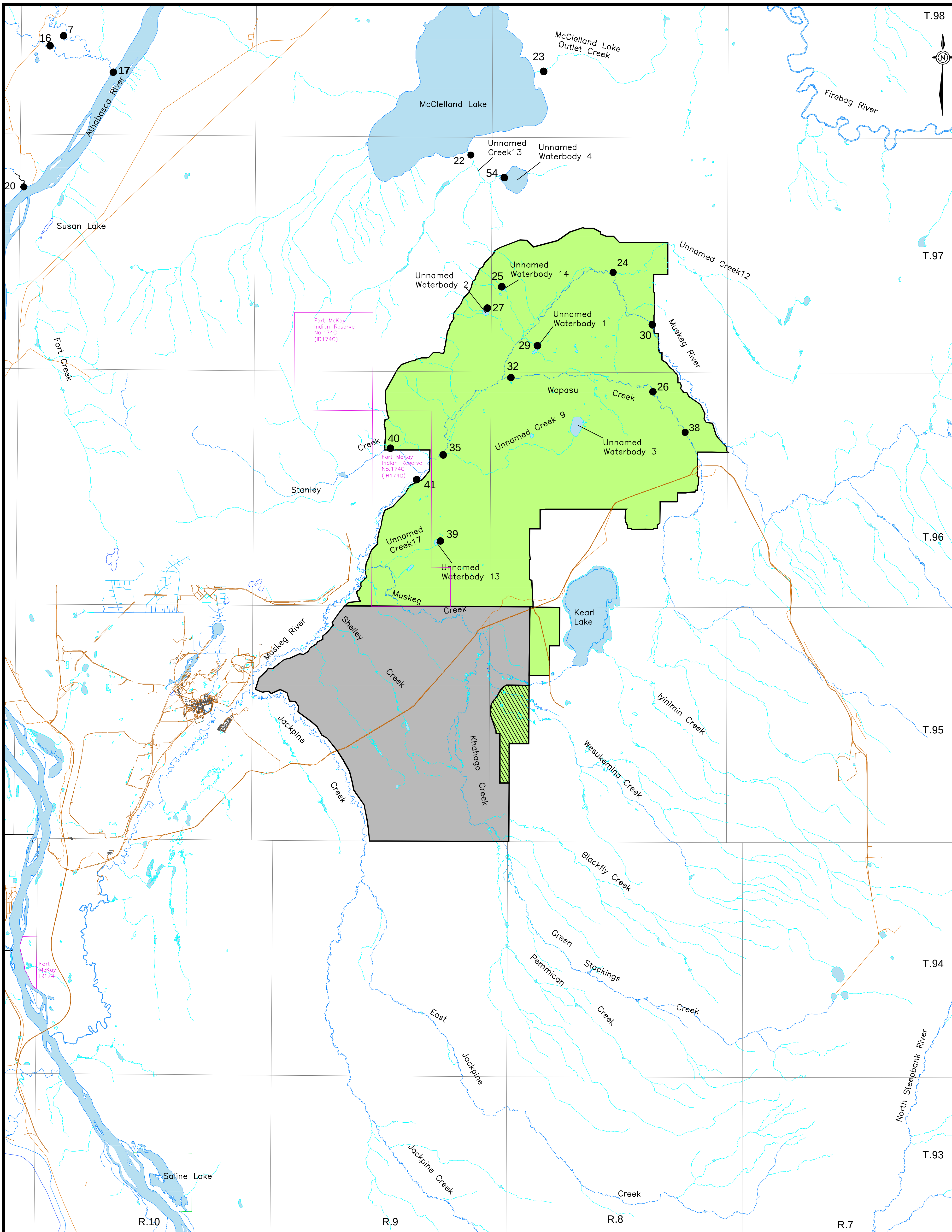
#### 3.1.1.1 Fish Habitat

The Muskeg River watershed has been relatively well studied in the past. In the mainstem, the habitat use potential during the open-water season is generally high for a variety of fish species, although the quality declines in the upper reaches due to depth and Dissolved Oxygen (DO) limitations. In general, the habitat potential of the lower 16.5 km of the mainstem Muskeg River (i.e., Reaches 1, 2 and 3) during the open-water period is high. In contrast, habitat limitations for the remaining 105.5 km of the mainstem river result in poor habitat potential in the middle (Reach 4, 5 and 6) and upper (Reach 7 and 8) reaches of the river (Figure 2) (Imperial Oil 2005). Winter dissolved oxygen conditions are very poor in these reaches upstream of Jackpine Creek (AXYS 2005). Extensive beaver activity likely impedes fish movements in the upper reaches of the river, further reducing the potential for these reaches to support a diverse fish species assemblage (Imperial Oil 2005).

L:\2006\1344-OIL SANDS\1346\06-1346-022 Shell\9100\9170\Fig 8 Fish and fish habitat sites in the RLSA.dwg Dec 01, 2007 - 11:32am




LEGEND

- ROAD
- JACKPINE EXPANSION MINING AREA
- LEASE SWAPPED TO SYNCRUDE
- JACKPINE MINE - PHASE 1
- 7● FISH AND FISH HABITAT SAMPLING SITE

SCALE 3 0 3 KILOMETRES

REFERENCE

ALBERTA DIGITAL DATA OBTAINED FROM ALTALIS LTD. (SEPTEMBER 2004.)
USED UNDER LICENSE. PROJECTION: TRANSVERSE MERCATOR
DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 12

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

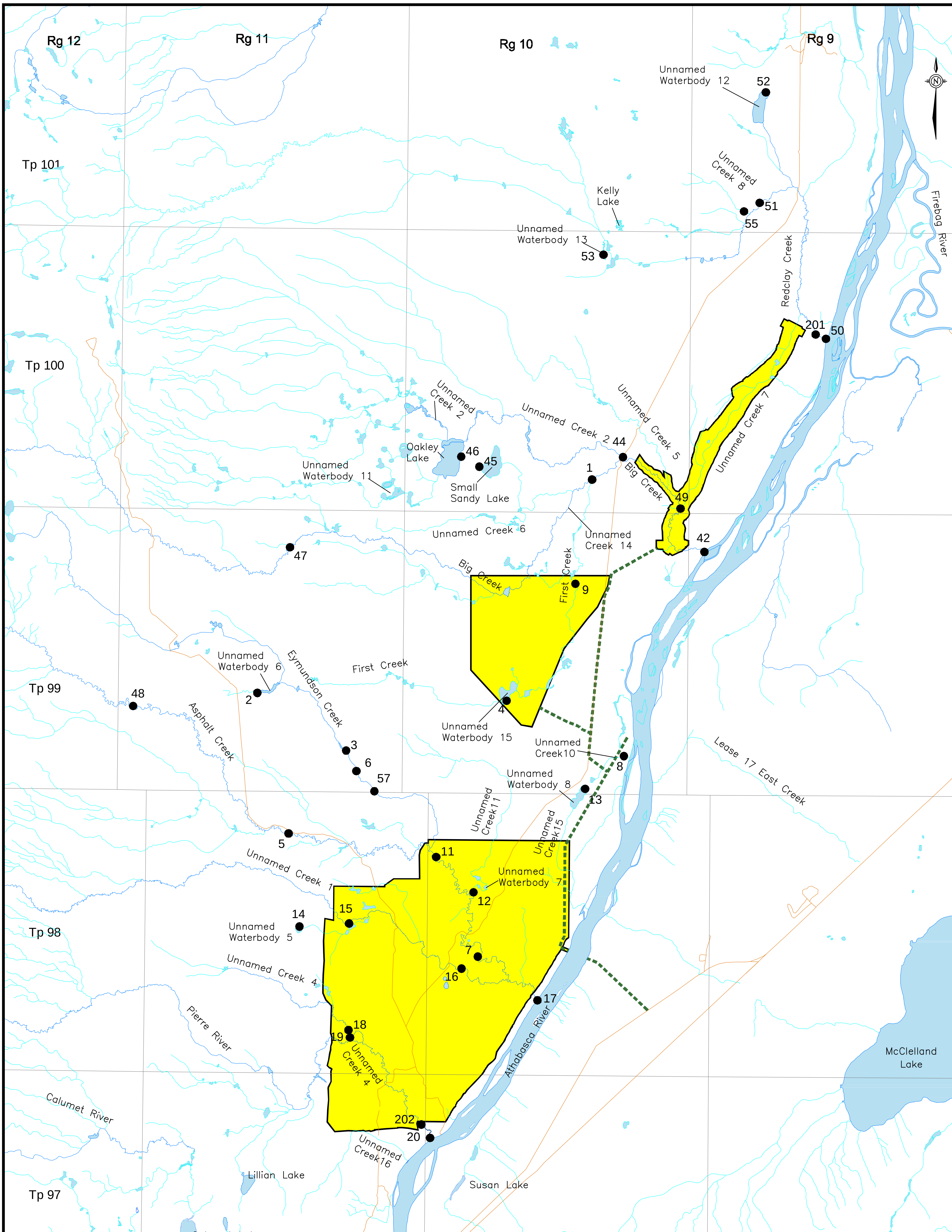
**FISH AND FISH HABITAT SITES IN OR NEAR THE JACKPINE EXPANSION MINING AREA LOCAL STUDY AREA AND REGIONAL STUDY AREA**

Shell Canada Limited

| | | |
|---|---|---|
| PROJECT 06-1346-022.9170 | | FILE No. LSA-RSA |
| DESIGN | MK | 25/09/07 |
| CADD | PSR | 11/10/07 |
| CHECK | GW | 11/10/07 |
| REVIEW | WES/TC | 30/11/07 |
| SCALE | AS SHOWN | REV. 0 |

**FIGURE: 8**

L:\2006\1344-OIL SANDS\1346\06-1346-022 Shell\9100\9170\Fig 9 Fish and fish habitat sites LSA for the pierre river minging area.dwg Dec 01, 2007 - 11:40am




LEGEND

- ROAD
- PROPOSED ACCESS
- PIERRE RIVER MINING AREA
- 7 ● FISH AND FISH HABITAT SAMPLING SITE

2.5 0 2.5
SCALE KM

PROJECT
JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE
# FISH AND FISH HABITAT SITES IN THE PIERRE RIVER MINING AREA LOCAL STUDY AREA

Shell Canada Limited

| | | |
|---|---|---|
| PROJECT 06-1346-022.9100 | | |
| DESIGN | MK | 27/09/07 |
| CADD | PSR | 11/10/07 |
| CHECK | GW | 11/10/07 |
| REVIEW | WES/TC | 30/11/07 |

FILE No. Fish/Habitat -LSA
SCALE AS SHOWN REV. 0

FIGURE: 9

REFERENCE
ALBERTA DIGITAL DATA OBTAINED FROM ALTALIS LTD. (SEPTEMBER 2004.)
USED UNDER LICENSE. PROJECTION: TRANSVERSE MERCATOR
DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 12

Overwintering conditions in the mainstem Muskeg River are variable but limited, with overwintering habitat present in some locations but not others and only in some winters. The DO concentrations are highly variable in winter, with conditions generally better in the lower river compared to further upstream. When present, overwintering habitat is primarily suitable for use only by forage fish due to shallow under-ice depths and/or low DO levels. Lack of reliable overwintering habitat was considered an important limiting factor in the upper river, particularly for resident fish (Imperial Oil 2005).

The tributary watercourses and waterbodies in the upper Muskeg River watershed primarily provide habitats with low to moderate suitability. Habitat limitations include small size, shallow depths, low discharge volume, poor habitat diversity, substrate dominated by fine sediments, poor fish passage and limited overwintering habitat. Jackpine Creek has the highest quality of fish habitat of all Muskeg River tributaries due to increased habitat diversity in the middle reaches, which provide spawning and rearing habitat. However, habitat limitations in the other reaches of Jackpine Creek include low habitat diversity, shallow depths, lack of spawning habitat due to the presence of fine sediments, low winter discharge and extensive beaver activity blocking fish movements.

#### 3.1.1.2 Fish Population

A total of 26 fish species have been reported from the Muskeg River, including 10 sport species, two sucker species and 14 forage fish species (Table 3). These species have been divided into three classes based on their general abundance and distribution, including seven resident species that are typically abundant with wide distributions, five regular migrant species that use the river during the open-water period for part of their life-cycle (Imperial Oil 2005) and 14 restricted species that occur in low abundance with restricted distributions (AXYS 2005). Of the five regular migrant species, three species are primarily migrant but also have a small portion of their populations that are resident (Table 3). In the past, white sucker, longnose sucker, lake chub and Arctic grayling were most frequently reported as the dominant species in the mainstem Muskeg River (AXYS 2005; Shell 2005); however, notable declines have occurred for all five regular migrant species, although the decline has not been as severe for northern pike as it has for the other four species. Reason for the declines was suggested as an increase in beaver activity in the watershed as it relates to impediments to fish passage and changes in spawning habitat for species which prefer swift flowing water with rocky substrate (Golder 2001, 2003). Changes in accessibility and habitat characteristics have been recorded in Jackpine Creek and Muskeg Creek, which contain documented spawning sites for Arctic grayling and/or suckers.

**Table 3 Known Fish Species of the Muskeg River Watershed and Their Distribution Class**

| Classification | Species | | General Distribution Class[(a)] | | |
|---|---|---|---|---|---|
| | Common Name | Scientific Name | Resident | Regular Migrant | Restricted |
| sport fish | Arctic grayling | *Thymallus arcticus* | – | ● | – |
| | bull trout | *Salvelinus confluentus* | – | – | ● |
| | burbot | *Lota lota* | – | – | ● |
| | goldeye | *Hiodon alosoides* | – | – | ● |
| | lake cisco | *Coregonus artedi* | – | – | ● |
| | lake whitefish | *Coregonus clupeaformis* | – | – | ● |
| | mountain whitefish | *Prosopium williamsoni* | – | ● | – |
| | northern pike | *Esox lucius* | ● | ● | – |
| | walleye | *Sander vitreus* | – | – | ● |
| | yellow perch | *Perca flavescens* | – | – | ● |
| non-sport fish | longnose sucker | *Catostomus catostomus* | ● | ● | – |
| | white sucker | *Catostomus commersonii* | ● | ● | – |
| forage fish | brook stickleback | *Culaea inconstans* | ● | – | – |
| | emerald shiner | *Notropis atherinoides* | – | – | ● |
| | fathead minnow | *Pimephales promelas* | ● | – | – |
| | finescale dace | *Phoxinus neogaeus* | – | – | ● |
| | flathead chub | *Platygobio gracilis* | – | – | ● |
| | lake chub | *Couesius plumbeus* | ● | – | – |
| | longnose dace | *Rhinichthys cataractae* | ● | – | – |
| | ninespine stickleback | *Pungitius pungitius* | – | – | ● |
| | northern redbelly dace | *Phoxinus eos* | – | – | ● |
| | pearl dace | *Margariscus margarita* | ● | – | – |
| | slimy sculpin | *Cottus cognatus* | ● | – | – |
| | spoonhead sculpin | *Cottus ricei* | ● | – | – |
| | spottail shiner | *Notropis hudsonius* | – | – | ● |
| | trout-perch | *Percopsis omiscomaycus* | – | – | ● |
| | | *Subtotal of species* | *10* | *5* | *14* |
| **Total species** | | | **26** | | |

[(a)] Distribution Class:

Resident – wide distribution, year-round use by all life stages.

Regular Migrant – moderate to wide distribution, seasonal use by some life stages.

Restricted – limited distribution, rare or irregular use by some life stages.

– = Not applicable.

Fish species diversity declines along the length of the Muskeg River due to habitat changes and increasing distance from the Athabasca River, with the number of species declining in each successive reach moving upstream in the Muskeg River (Table 4). The fish community in Reaches 6, 7 and 8 is considerably less diverse with a notably fewer large bodies species than in the lower watershed.

The fish community in the upper Muskeg River tributaries is primarily dominated by forage fish, but non-sport fish (longnose sucker and white sucker) and occasionally northern pike are also present. Arctic grayling and mountain whitefish have also been recorded in Jackpine Creek (Table 5).

#### 3.1.1.3 Benthic Invertebrates

Mean benthic invertebrate density from four depositional sites in the upper watershed ranged from 12,000 to 44,000 organisms/m² and total taxonomic richness ranged from 28 to 39 taxa/site, indicating rich benthic invertebrate communities of low to moderate density. Simpson's Diversity Index (SDI) indicates a diverse benthic invertebrate community and evenness values indicate that a few taxa accounted for the majority of the total density. The dominant taxa were midges, bristle worms and seed shrimp. The sites sampled during the environmental setting surveys had benthic communities similar to those documented by previous studies in the Muskeg River watershed. Historically, mean benthic invertebrate density ranged from 200 to 116,000 organisms/m² in Muskeg River watercourses and total taxonomic richness ranged from 4 to 59 taxa/site. The dominant taxa have historically been midges, bristle worms and fingernail clams.

#### 3.1.1.4 Watercourses

##### *Muskeg River Mainstem*

Muskeg River mainstem, a tributary to the Athabasca River, has historically been divided into eight reaches. Study sites for this Project were established within Reaches 6 and 7, as they are adjacent to the JEMA. Historically, Reaches 4, 5 and 6 have been described as low gradient, dominated by low stable banks and containing substrates composed of fine sediment. Reaches 4, 5 and 6 are composed of slow, relatively deep meandering runs. Reach 7 contains higher gradients, but habitat types are dominated by runs and pools, a result of the large amount of debris and beaver activity. Reach 7 also contains occasional riffle habitat units, which are absent from Reach 8. For this study, Sites 41 and 30 were located within Reaches 6 and 7, respectively (Figure 8). Both sites were located within an irregularly meandering channel through muskeg bog and consisted of one continuous run habitat unit.

JPME R1 AENV SIR 339 AND JPME R1 AENV SIR 340

## Table 4 Fish Species Distribution in Muskeg River Reaches

| Species | Reach 1 | Reach 2 | Reach 3 | Reach 4 | Reach 5 | Reach 6 | Reach 7 | Reach 8 |
|---|---|---|---|---|---|---|---|---|
| Arctic grayling | ☐● | ◆☐● | ◆☐● | ◆☐● | – | – | – | – |
| brook stickleback | ❖ | ❖ | ❖ | ❖ | ❖ | ❖ | ❖ | ❖ |
| bull trout | ☐❖ | ☐❖ | – | – | – | – | – | – |
| Burbot | ☐● | ☐❖ | – | – | – | – | – | – |
| emerald shiner | ❖ | ❖ | – | – | – | – | – | – |
| fathead minnow | ❖ | ❖ | ❖ | ❖ | ❖ | ❖ | – | – |
| finescale dace[(a)] | – | – | – | – | – | – | – | – |
| flathead chub[(a)] | – | – | – | – | – | – | – | – |
| Goldeye | ❖ | ❖ | – | – | – | – | – | – |
| lake chub | ❖ | ❖ | ❖ | ❖ | ❖ | ❖ | ❖ | ❖ |
| lake cisco | ❖ | ❖ | – | – | – | – | – | – |
| lake whitefish | ☐● | ● | ● | – | – | – | – | – |
| longnose dace | ❖ | ❖ | ❖ | ❖ | – | – | – | – |
| longnose sucker | ◆☐● | ◆☐● | ◆☐● | ◆☐● | ◆☐● | ◆☐● | ◆☐● | – |
| mountain whitefish | ☐● | ☐● | ☐● | ☐● | – | – | – | – |
| ninespine stickleback | ❖ | – | – | – | – | – | – | – |
| northern pike | ☐● | ◆☐● | ◆☐● | ◆☐● | ◆☐● | ☐ | – | – |
| northern redbelly dace | ❖ | ❖ | ❖ | ❖ | – | – | – | – |
| pearl dace | ❖ | ❖ | ❖ | ❖ | ❖ | ❖ | ❖ | ❖ |
| slimy sculpin | ❖ | ❖ | ❖ | ❖ | ❖ | – | – | – |
| spoonhead sculpin | ❖ | ❖ | ❖ | ❖ | ❖ | – | – | – |
| spottail shiner | ❖ | – | – | – | – | – | – | – |
| trout-perch | ❖ | ❖ | ❖ | ❖ | ❖ | – | – | – |
| Walleye | ☐● | ☐● | ☐● | – | – | – | – | – |
| white sucker | ☐● | ◆☐● | ◆☐● | ◆☐● | ◆☐● | ◆☐● | ◆☐● | ☐● |
| yellow perch | ☐❖ | ☐❖ | – | – | – | – | – | – |
| **Number of Species** | **24** | **22** | **16** | **14** | **10** | **7** | **5** | **4** |

(a) Species recorded in tributaries but not in mainstem Muskeg River.

– = Not recorded.

Note: Documented Fish Use:

❖ = Present – life stages unspecified.

◆ = Spawning and incubation.

☐ = Nursery or rearing (fry or juvenile).

● = Adult feeding.

JPME R1 AENV SIR 339 AND JPME R1 AENV SIR 340

## Table 5 Fish Species Distribution in Muskeg River Tributaries

| Species | Unnamed Tributary Drainage[(a)] | Jackpine Creek Drainage[(b)] | Shelley Creek | Muskeg Creek Drainage[(c)] | Kearl Lake | Stanley Creek | Wapasu Creek | Unnamed Tributary Drainage[(d)] | Unnamed Headwater Tributaries[(e)] |
|---|---|---|---|---|---|---|---|---|---|
| Arctic grayling | – | ◆□● | – | – | – | – | – | – | – |
| brook stickleback | ❖ | ❖ | ❖ | ❖ | ❖ | ❖ | ❖ | ❖ | ❖ |
| bull trout | – | – | – | – | – | – | – | – | – |
| Burbot | – | – | – | – | – | – | – | – | – |
| emerald shiner | – | ❖ | – | – | – | – | – | – | – |
| fathead minnow | ❖ | ❖ | – | ❖ | ❖ | – | ❖ | – | – |
| finescale dace[(a)] | ❖ | – | ❖ | ❖ | – | – | – | – | ❖ |
| flathead chub[(a)] | – | ❖ | – | – | – | – | – | – | – |
| Goldeye | – | – | – | – | – | – | – | – | – |
| lake chub | ❖ | ❖ | ❖ | ❖ | ❖ | – | ❖ | – | ❖ |
| lake cisco | – | – | – | – | – | – | – | – | – |
| lake whitefish | – | – | – | – | – | – | – | – | – |
| longnose dace | – | ❖ | – | – | – | – | – | – | – |
| longnose sucker | □● | ◆□● | □ | □● | □ | – | □● | – | – |
| mountain whitefish | – | □● | – | – | – | – | – | – | – |
| ninespine stickleback | – | – | – | – | – | – | – | – | – |
| northern pike | □ | ◆□● | – | ● | □● | – | – | – | – |
| northern redbelly dace | – | ❖ | – | – | – | – | – | – | – |
| pearl dace | ❖ | ❖ | – | ◆❖ | ❖ | – | ❖ | ❖ | ❖ |
| slimy sculpin | ❖ | ❖ | – | ❖ | – | – | – | – | – |
| spoonhead sculpin | – | ❖ | – | ❖ | – | – | – | – | – |
| spottail shiner | – | – | – | ❖ | – | – | – | – | – |
| trout-perch | – | ❖ | – | – | – | – | – | – | – |
| Walleye | – | – | – | – | – | – | – | – | – |
| white sucker | □● | ◆□● | – | ◆□● | □● | – | □● | – | □ |
| yellow perch | – | – | – | – | – | – | – | – | – |
| **Number of Species** | **9** | **16** | **4** | **11** | **7** | **1** | **6** | **2** | **5** |

(a) Tributary to Muskeg River lower Reach 4. Includes three unnamed waterbodies.
(b) Includes East Jackpine Creek.
(c) Includes Khahago, Pemmican, Green Stockings, Blackfly, Wesukemina and Iyinimin creeks.
(d) Tributary to Muskeg River Reach 6. Includes one unnamed waterbody.
(e) Seven tributaries to Muskeg River Reach 8. Species present in one or more of these tributaries.

– = Not recorded

Note: Documented Fish Use:

❖ = Present – life stages unspecified.

◆ = Spawning and incubation.

□ = Nursery or rearing (fry or juvenile).

● = Adult feeding.

Results from this study (Sites 30 and 41), support previous findings regarding habitat use potential, but generally rate the open-water habitat use potential at sites studied as moderate. Water quality parameters were suitable to support all fish species. Instream and overhead cover varied from limited to abundant for both categories.

Lack of reliable overwintering habitat was considered an important limiting factor in the upper river, particularly for resident fish. Within Reach 6, results from this study found adequate under-ice water depths, however, low DO levels may limit the overwintering potential to species tolerant of such conditions. Results from Reach 7 indicate some limiting water depth, but adequate DO levels.

Historically, 26 fish species have been reported to occur in the Muskeg River mainstem; however, only 14 species have been reported in the middle and upper reaches (Reaches 4 to 8). Of these 14 fish species, five were captured during current field investigations. Recent captures include two non-sport fish, longnose sucker and white sucker, as well as three forage fish, brook stickleback, lake chub and pearl dace.

Of the species recorded in the Muskeg River mainstem, three are listed as sensitive (Arctic grayling, bull trout and northern redbelly dace) and one species may be at risk (spoonhead sculpin) (ASRD 2006). Habitat for Arctic grayling and bull trout is not present in the upper five reaches and they have not been documented to inhabit the upper five reaches. Spoonhead sculpin has been documented within Reach 4, 5 and 6 and suitable habitat for this species also has been documented. Suitable habitat for northern redbelly dace is present throughout all reaches and they have been documented within Reaches 4, 5 and 6.

The overall fish and fish habitat diversity for the entire Muskeg River mainstem is rated as high, due to high ratings for all diversity categories (species, habitat and ecosystem diversity).

### *Wapasu Creek*

Wapasu Creek, a tributary to the Muskeg River, has previously been divided into five reaches. Site 32 is located within Reach 1, while both Sites 26 and 38 are located within Reach 3 (Figure 8). All three sites are located within low gradient, irregular meandering channels. The watercourse at Site 32 was composed entirely of flat habitat with organic substrate. Sites 26 and 38 were both composed of run and riffle habitat units and substrate varied from silt/clay to boulders.

The open-water habitat use potential at Site 32, within Reach 1 was generally moderate for sport fish, low for non-sport fish and high for forage fish. The open-water habitat potential within Reach 3 at both Sites 26 and 38 was generally moderate for sport and non-sport fish and moderate to high for forage fish.

Overwintering potential within Reach 1 at Site 32 was low for sport and non-sport fish due to low DO levels, but moderate for more tolerant forage fish. Overwintering habitat use potential at Site 26 was rated as high for sport, non-sport fish, and forage fish. There was limited overwintering potential at Site 38, as the watercourse was frozen to the bottom.

The fish community of Wapasu Creek is dominated by forage fish, with the occurrence of some large bodied, non-sport fish. Historically, six species have been recorded in Wapasu Creek, including longnose sucker, white sucker, brook stickleback, lake chub, pearl dace and fathead minnow. During current field investigations, five of these six species were captured (fathead minnow were not captured).

The overall fish and fish habitat diversity of Wapasu Creek was rated as low. Although both species and ecosystem diversity was very low, habitat diversity was found to be moderate.

### *Unnamed Creek 9*

This unnamed tributary to the Muskeg River mainstem was sampled at Site 35 (Figure 8). The watercourse at this site had an unconfined, straight channel within a muskeg bog and consisted of run habitat. This watercourse was not divided into reaches as it was relatively uniform in channel gradient and morphology.

The open-water season habitat use potential at this site was generally low for sport fish and non-sport fish, but high for forage fish. There was no overwintering habitat use potential at Site 35, as it was frozen through at the time of the survey.

Forage fish species are expected to dominate the fish community within this watercourse, with few to no large-bodied or predator species. Fish sampling at Site 35 resulted in the capture of brook stickleback and lake chub. No sport fish or non-sport fish were captured. There was no historical information for this watercourse.

The overall diversity of fish and fish habitat for Unnamed Creek 9 was considered very low, due to very low ratings for all diversity categories (species, habitat and ecosystem diversity).

### *Unnamed Creek 12*

This unnamed tributary to the upper end of Reach 4 of the Muskeg River mainstem was sampled at Site 24 (Figure 8). The watercourse at this site had an unconfined, meandering channel within a muskeg bog and consisted of run and flat habitat. This watercourse was not divided into reaches as it was relatively uniform in channel gradient and morphology.

The open-water season habitat use potential at Site 24 was generally moderate for both sport and non-sport fish species and high for forage fish species. Overwintering habitat use potential was high for sport, non-sport and forage fish.

The fish community within Unnamed Creek 12 is expected to be dominated by forage fish species with the potential for the occurrence of large bodied and predator species. Fish species captured at this site include one non-sport fish, longnose sucker and three forage fish, brook stickleback, lake chub and pearl dace. No sport fish were captured.

The overall fish and fish habitat diversity rating for Unnamed Creek 12 was assessed as low. This was based on very low ratings for both species and ecosystem diversity (due to the number of forage fish species and lack of predators), but a moderate rating for habitat diversity.

## 3.1.1.5 Waterbodies

### *Unnamed Waterbody 1*

Unnamed Waterbody 1 was located on a tributary to the Muskeg River. Unnamed Waterbody 1 (Site 29) was a relatively uniform waterbody, with a perimeter of approximately 1.3 km and an approximate surface area of 0.05 $km^2$ (Figure 8). A shallow littoral zone surrounded the waterbody, with a deeper pelagic zone in the centre. The average and maximum depths recorded throughout the open-water seasons are 10.6 and 26.1 m, respectively.

Open-water season habitat use potential was generally moderate for both sport and non-sport fish species and high for forage fish. Overwintering habitat use potential was considered low to moderate for sport, non-sport and forage fish.

Although this waterbody was sampled during all seasons, only one fish was captured, a juvenile northern pike, in the summer survey. No existing fish information was available for this waterbody.

Overall fish and fish habitat diversity for Unnamed Waterbody 1 was considered very low, with all diversity categories (species, habitat and ecosystem diversity) rated as very low.

### *Unnamed Waterbody 2*

Unnamed Waterbody 2 (Site 27) was a relatively shallow, uniform waterbody with a perimeter of approximately 1.2 km and an approximate surface area of 0.08 $km^2$ (Figure 8). The average and maximum depths recorded throughout the open-water seasons are 0.76 and 1.0 m, respectively.

Open-water season habitat use potential was rated as low for all fish species, due to limitations such as lack of depth and limited cover. Overwintering habitat use potential was considered low to nil for both sport and non-sport fish and low for forage fish due to DO levels suitable only to low DO tolerant fish species.

No fish species were captured during field investigations at this waterbody. No existing fish information was available.

The overall diversity of fish and fish habitat for Unnamed Waterbody 2 was rated as very low, due to very low ratings for all diversity categories (species, habitat and ecosystem diversity).

### *Unnamed Waterbody 16*

Unnamed Waterbody 16 (Site 39) was located on an unnamed tributary to Muskeg Creek (Figure 8). This waterbody was dominated by shallow littoral habitat, with a perimeter of approximately 0.8 km and with an approximate surface area of 0.05 $km^2$. The average and maximum depths recorded throughout the open-water seasons were 1.0 and 2.2 m, respectively.

Open-water habitat use potential at this waterbody was low to moderate for sport fish and low for non-sport fish. Forage fish habitat use potential during the open-water season was rated as moderate to high, due to their tolerance for high water temperature and the abundance of aquatic vegetation.

Overwintering habitat use potential at Unnamed Waterbody 16 was nil for both sport and non-sport fish and low for forage fish due to recorded low DO levels.

No fish were captured during any of the seasonal surveys and no existing fish information was found for this waterbody.

The overall fish and fish habitat diversity of Unnamed Waterbody 16 was assessed as very low, based on very low ratings for species, habitat and ecosystem diversity.

### *Unnamed Waterbody 17*

Unnamed Waterbody 17 (Site 25) was a relatively shallow, uniform waterbody, dominated by littoral habitat with submergent vegetation (Figure 8). This waterbody had a perimeter of approximately 0.8 km and an approximate surface area of 0.04 $km^2$. The average and maximum depths recorded throughout the open-water seasons are 0.38 and 0.5 m, respectively.

Open-water season habitat use potential was nil to moderate for sport fish, nil to low for non-sport fish and low for forage fish. This was largely based on limitations such as shallow depth and high water temperatures recorded during the summer.

Overwintering habitat use potential within this waterbody was low to nil for both sport and non-sport fish and low for forage fish due to recorded low DO levels.

No fish were captured during any of the seasonal surveys and no existing fish information was found for this waterbody.

The overall diversity of fish and fish habitat in Unnamed Waterbody 17 was rated as very low. This was a result of very low ratings for species, habitat and ecosystem diversity.

## 3.2 PIERRE RIVER MINING AREA

### 3.2.1 Pierre River Watershed

Affected habitats in the Pierre River watershed include the lower reaches of the mainstem Pierre River and several unnamed tributaries and waterbodies.

#### 3.2.1.1 Fish Habitat

The Pierre River mainstem provides suitable open water habitat for several fish species and life stages. This watercourse has a meandering, unconfined channel throughout. At the mouth, the Pierre River is low gradient, depositional and consisting of run habitat with silt and sand substrate. The lower reaches provide spring spawning and summer rearing habitat for species such as northern pike and Arctic grayling from the Athabasca River. Seasonal rearing and feeding habitat may also be present for occasional migrants such as, burbot, mountain whitefish and walleye. Habitat use potential for resident fish species in the Pierre River and its tributaries is limited by poor quality overwintering habitat (i.e., shallow depths and low winter DO), with the exception of occasional beaver ponds potentially suitable for overwintering. The mouth of the Pierre River was frozen to substrate during field surveys, indicating poor overwintering potential. Another site upstream of the mouth was not frozen to the bottom, but had shallow under-ice water depths and low winter DO levels.

### 3.2.1.2 Fish Population

The fish community within the Pierre River is relatively diverse, with a total of 17 species recorded from previous studies combined with fish sampling for the Project. This included five sport, two non-sport and 10 forage fish species (Table 6). The distribution of sport fish species in the Pierre River appears to be primarily limited to the lower reach (0 to 2.9 km) near the confluence with the Athabasca River, The fish community in Pierre River tributaries is dominated by forage fish, with suckers present in some reaches.

### 3.2.1.3 Benthic Invertebrates

Mean benthic invertebrate density at two depositional watercourse sites in the Pierre River was highly variable, ranging from 1,200 to 63,000 organisms/m². Total taxonomic richness ranged from 23 to 40 taxa/site, indicating a rich benthic invertebrate community. The SDI and evenness values indicated a diverse benthic invertebrate community, with a few taxa accounting for the majority of the total density. The dominant taxa were midges and bristle worms.

### 3.2.1.4 Watercourses

#### *Pierre River Mainstem*

The Pierre River was divided into three reaches based on channel gradient and morphology. Two sites were established on the Pierre River to assess seasonal fish habitat potential (Figure 9). Site 20 was located within Reach 1, near the confluence with the Athabasca River and Site 19 was located within Reach 2. The watercourse at both sites exhibited a meandering, unconfined channel. While Site 20 was composed of riffle and run habitat units with variable substrate composition, Site 19 was composed of flat and impoundment habitat and fine substrate.

**Table 6 Fish Species Distribution in Pierre River Mining Area Watercourses and Waterbodies**

| Species | Pierre River Watershed | | | Eymundson Creek Watershed | | | | | Athabasca River Tributary | Big Creek Watershed | | | | | Redclay Creek Watershed | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pierre River | Unnamed Creek 4 | Lillian Lake | Eymundson Creek | Asphalt Creek | Unnamed Creek 1 | Unnamed Creek 11 | Unnamed Waterbody 6 | Unnamed Creek 10 | Big Creek | Unnamed Creek 2 | Unnamed Creek 7 | Oakley Lake | Unnamed Waterbody 15 | Redclay Creek | Unnamed Creek 8 | Unnamed Waterbody 12 | Unnamed Waterbody 13 |
| Arctic grayling | ◆☐● | – | – | ☐ | – | – | – | – | – | – | – | – | – | – | ☐● | – | – | – |
| brassy minnow | ❖ | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| brook stickleback | ❖ | ❖ | ❖ | ❖ | ❖ | – | ❖ | ❖ | ❖ | – | ❖ | ❖ | ❖ | ❖ | ❖ | ❖ | ❖ | ❖ |
| burbot | ☐● | – | – | ☐ | – | – | – | – | – | ❖ | – | – | – | – | ☐ | – | – | – |
| finescale dace | – | – | – | – | – | – | – | – | – | – | – | – | – | – | ❖ | – | – | – |
| flathead chub | ❖ | – | – | ❖ | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| fathead minnow | ❖ | ❖ | – | ❖ | – | – | – | – | – | ❖ | ❖ | – | – | – | ❖ | ❖ | – | – |
| lake chub | ❖ | ❖ | – | ❖ | ❖ | ❖ | ❖ | – | ❖ | ❖ | ❖ | – | ❖ | – | ❖ | ❖ | – | – |
| longnose dace | ❖ | – | – | – | – | – | – | – | – | ❖ | – | – | – | – | ❖ | ❖ | – | – |
| longnose sucker | ❖☐ | ☐ | – | ☐ | – | – | ● | – | – | ❖ | ❖ | ❖ | – | – | ☐● | ❖ | – | – |
| mountain whitefish | ☐● | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – | – |
| northern redbelly dace | ❖ | ❖ | – | ❖ | – | – | – | – | ❖ | – | – | – | – | – | – | ❖ | – | – |
| northern pike | ◆☐● | – | – | – | – | – | – | – | – | – | – | – | – | – | ☐● | – | – | – |
| pearl dace | ❖ | – | – | ❖ | – | ❖ | ❖ | – | ❖ | ❖ | – | – | – | – | ❖ | ❖ | ❖ | ❖ |
| slimy sculpin | ❖ | – | – | – | – | – | – | – | – | ❖ | ❖ | – | – | – | ❖ | ❖ | – | – |
| spoonhead sculpin | – | – | – | – | – | – | – | – | – | ❖ | – | – | – | – | – | – | – | – |
| spottail shiner | – | – | – | – | – | – | – | – | – | ❖ | – | – | – | – | – | – | – | – |
| trout–perch | ❖ | – | – | ❖ | – | – | – | – | – | – | – | – | – | – | ❖ | – | – | – |
| walleye | ☐● | – | – | – | – | – | – | – | – | – | – | – | – | – | ● | – | – | – |
| white sucker | ❖☐ | ● | – | ☐ | – | – | – | – | – | ❖ | – | – | ❖ | – | ● | – | – | – |
| **Number of Species** | **17** | **6** | **1** | **11** | **2** | **2** | **4** | **1** | **4** | **10** | **5** | **2** | **3** | **1** | **14** | **8** | **2** | **2** |

– = Not recorded.

Note: Documented Fish Use:

❖ = Present – life stages unspecified.

◆ = Spawning and incubation.

☐ = Nursery or rearing (fry or juvenile).

● = Adult feeding.

The open-water season habitat use potential at Site 20 was low to moderate for sport and non-sport fish and moderate for forage fish. The open-water season habitat potential at Site 19 ranged from nil to high for sport fish, depending on life history function, and nil to moderate for non-sport fish. Habitat use potential was rated as high overall for forage fish. The increase in open-water habitat use potential from Site 20 to 19 was generally due to an increase in available cover from Site 20 to 19.

Overwintering habitat use potential was nil for all fish species at Site 20, as the watercourse was frozen to the bottom at the time of the winter survey. Site 19, however, was not frozen to the bottom. Overwintering habitat potential was low for sport and non-sport fish due to low DO levels and some limiting water depth, but moderate for the more tolerant forage fish species.

In addition to the two previous sites established on the Pierre River mainstem to assess fish habitat and sample the fish population, a fish fence was established at Site 202, about 350 m upstream from the river mouth. The fish counting fence was constructed and monitored in the spring of 2006. Although seasonal sport-fish migrants were not captured during the fish fence operation, historical information suggests sport fish such as Arctic grayling and northern pike use the Pierre River for spawning and rearing activities.

The Pierre River has two listed sensitive species (Arctic grayling and northern redbelly dace). In addition, brassy minnow and mountain whitefish were determined to be unique species, as neither are found elsewhere in the PRMA LSA.

The overall fish and fish habitat diversity of the Pierre River was considered moderate. This was the result of averaging a low value for species diversity, a moderate value for habitat diversity, and a high value for ecosystem diversity.

### *Unnamed Creek 4*

One survey site (Site 18) was located on Unnamed Creek 4, a tributary to Reach 2 of the Pierre River (Figure 9). The watercourse at Site 18 had an irregular meandering and a frequently confined channel composed of run and flat habitat. This watercourse had only one reach, as channel gradient and channel morphology was relatively unchanged throughout.

The open-water season habitat use potential was rated as moderate for sport fish, low to moderate for non-sport fish and moderate for forage fish. Instream cover was abundant; however, overhead cover was found to be limited. There also was a lack of coarse substrate to fulfill some species spawning requirements.

Overwintering habitat use potential was found to be low for both sport and non-sport fish, due to low DO levels, but moderate for forage species tolerant of such conditions.

Existing fisheries information was not available and sampling at Site 18 resulted in the capture of six fish species. These captured fish included two non-sport fish (longnose sucker and white sucker) and four forage fish species (brook stickleback, fathead minnow, lake chub and northern redbelly dace).

One listed sensitive species, northern redbelly dace, occurred in Unnamed Creek 4 (ASRD 2006).

The overall diversity of fish and fish habitat for Unnamed Creek 4 was rated as very low. This overall rating was based on a low rating for species diversity and very low ratings for both habitat and ecosystem diversity.

### 3.2.2 Eymundson Creek Watershed

Affected habitats in Eymundson Creek watershed include the Eymundson Creek mainstem (Reaches 1 through 3 and a small portion of Reach 4), a small portion of lower Asphalt Creek, and associated unnamed tributaries and waterbodies.

#### 3.2.2.1 Fish Habitat

Overall, Eymundson Creek provides suitable habitat for forage fish and some seasonal habitat use potential in the lower reach for large-bodied fish species from the Athabasca River. Eymundson Creek maintains an irregular meandering channel pattern that is frequently confined within the lower reach and unconfined within the remaining upstream reaches. Habitat was composed of run, flat, riffle and impoundments associated with beaver dams. Asphalt Creek, a major tributary to Eymundson Creek (Figure 3), has an irregular meandering channel and run and riffle habitat. Habitat use potential in Eymundson Creek, Asphalt Creek and unnamed tributaries, is primarily limited by the lack of overwintering habitat. Most of the surveyed sites in the Eymundson Creek watershed were frozen to the substrate; others had shallow under-ice water depths and low DO levels. Habitat limitations in the tributaries in the Eymundson Creek watershed include small channel size, shallow depths, low discharge volume, poor habitat diversity, substrate dominated by fine sediments, poor fish passage and limited overwintering habitat.

One of the waterbodies sampled in the Eymundson Creek watershed provided suitable open water habitat; however, open water habitat in the second waterbody was limited by shallow water depths and high temperatures. Overwintering habitat in both waterbodies was limited due to shallow under-ice water depths and low winter DO levels.

### 3.2.2.2 Fish Population

A total of eleven species of fish have been documented in Eymundson Creek watershed (Table 6). The fish community in Eymundson Creek was dominated by forage fish throughout, with the occurrence of sport fish (Arctic grayling and burbot) and non-sport fish (longnose and white sucker) in the lower reaches (Table 6). The fish community in Asphalt Creek and unnamed tributaries to Eymundson Creek was comprised primarily of forage fish species, with longnose sucker captured in Unnamed Creek 11 (Table 6). Brook stickleback was captured in Unnamed Waterbody 6.

### 3.2.2.3 Benthic Invertebrates

Mean benthic invertebrate density at seven watercourse sites in the Eymundson Creek watershed ranged from 100 to 34,000 organisms/m². Total taxonomic richness ranged from 5 to 33 taxa/site, indicating a range of low to high richness. The SDI values were also indicative of a wide range in diversity. Evenness was generally low, indicating that a few taxa accounted for the majority of the total density. The dominant taxa in were the seed shrimp, midges and bristle worms. Mayflies were also dominant at the erosional site located in Asphalt Creek. Mean benthic invertebrate density at one unnamed waterbody was 30,000 organisms/m² and total taxonomic richness was 33 taxa/site, indicating a rich benthic invertebrate community. The SDI and evenness values indicated a diverse benthic invertebrate community, with a few taxa accounting for the majority of the total density. The benthic invertebrate community was dominated by midges.

### 3.2.2.4 Watercourses

#### *Eymundson Creek Mainstem*

Eymundson Creek was divided into four reaches based on channel gradient and morphology. Six survey sites (17, 7, 11, 57, 6 and 3) were established on this watercourse within Reaches 1, 2, 3 and 4 (Figure 9). Eymundson Creek maintained an irregular, meandering channel pattern throughout its entirety, as was observed at all four sites. However, Site 17 was located in a frequently confined valley, while the remainder of the watercourse was relatively unconfined. The surveyed watercourse was composed of run and flat habitat at

Site 17, run and riffle habitat at Site 7, run habitat at Site 11 and impoundment and flat habitat at Site 6.

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The open-water season habitat potential at Eymundson Creek varied between sites. At Site 17, habitat potential, in general, was low to moderate for sport fish and non-sport fish and high for forage fish. Habitat use potential at Site 7 ranged from low to high for sport fish, depending on life history function, and moderate to high for non-sport fish. Habitat use potential was considered moderate for forage fish. Site 11 was generally rated as low for all fish. Habitat use potential at Site 6 was generally moderate for sport fish, low for non-sport fish and moderate for forage fish.

Overwintering habitat use potential within surveyed sites on Eymundson Creek ranged from nil to low. Sites 17 and 11 had no overwintering potential, as the watercourse was frozen to the bottom during the winter survey. The overwintering habitat potential at Site 7 was rated as low to nil due to shallow water depth and low DO. Site 6 also had a shallow under-ice water depth and low DO unsuitable for sport and non-sport fish, but may be tolerable to some forage fish, resulting in a low overall rating.

Fish species captured during this study included: two sport fish (burbot and Arctic grayling), two non-sport fish (longnose sucker and white sucker) and six forage fish (brook stickleback, fathead minnow, lake chub, northern redbelly dace, pearl dace and trout-perch). Two fish species found in Eymundson Creek are listed as sensitive (Arctic grayling and northern redbelly dace). In addition to listed species, one fish species was considered unique as it does not occur outside of this watercourse in the PRMA LSA. This unique species is the flathead chub, which was captured in a previous study.

The overall fish and fish habitat diversity of Eymundson Creek was considered moderate, due to averaging a low species diversity rating, a high habitat diversity rating and a moderate ecosystem diversity rating.

### *Asphalt Creek*

Asphalt Creek was divided into two reaches, based on channel gradient and morphology. Sites 5 and 48 were situated within Reaches 1 and 2, respectively (Figure 9). Reach 1 at Site 5 had low gradient, irregular meandering, unconfined channel dominated by a single run habitat composition. Although similar, Reach 2 at Site 48 was occasionally confined and was composed of both run and riffle habitat.

Open-water seasonal habitat use potential within Asphalt Creek varied slightly between sites. Site 5 was rated as low to moderate for sport fish and non-sport fish and moderate to high for forage fish. Site 48 was rated as low to moderate for sport fish, moderate for non-sport fish and moderate to high for forage fish.

There was no overwintering habitat use potential within Asphalt Creek at Sites 5 and 48, as both were found to be frozen to the bottom during the winter survey.

The fish community documented in Asphalt Creek was composed of two forage fish species including brook stickleback and lake chub. There was no existing fish information available. There were no listed species found in this watercourse.

The overall diversity of fish and fish habitat in Asphalt Creek was rated as low. This conclusion was based on very low species diversity, moderate habitat diversity and very low ecosystem diversity.

### *Unnamed Creek 1*

Unnamed Creek 1 was divided into three reaches and surveyed at two locations. Site 16 was located within the upper limits of Reach 1 and Site 15 was located within Reach 2 (Figure 9). This watercourse had an irregular meandering and unconfined channel throughout both surveyed sites. Habitat composition also was similar at both sites, with Site 16 composed of run, riffle and flat habitat units and Site 15 was limited to run and riffle units within the surveyed section.

Open-water season habitat use potential differed between the two sites. Site 16 was generally low to moderate for sport fish, low for non-sport fish and moderate for forage fish habitat potential. Site 15 provided low habitat potential for both sport and non-sport fish, while there was low to moderate habitat use potential for forage fish.

There was no overwintering habitat use potential within Unnamed Creek 1 at the surveyed sites, as the watercourse was frozen to the bottom at both sites.

The fish community recorded in Unnamed Creek 1 was composed solely of forage fish. Sampling resulted in the capture of brook stickleback, lake chub and pearl dace. No existing fish information was available.

The overall fish and fish habitat diversity of Unnamed Creek 1 was assessed as low. This conclusion was based on very low species diversity, moderate habitat diversity and very low ecosystem diversity.

### *Unnamed Creek 11*

Unnamed Creek 11, a tributary to Eymundson Creek, is located in the upper limits of Eymundson Creek's Reach 2 (Figure 9). Unnamed Creek 11 consists of one reach as it was relatively uniform in channel gradient and morphology. One survey site (Site 12) was located near its' confluence with Eymundson Creek. The watercourse at this site had an irregular meandering, unconfined channel dominated by run habitat.

Open-water habitat use potential was generally moderate for sport fish, low for non-sport fish and moderate for forage fish. There was no overwintering potential at the surveyed portion of this watercourse, as the watercourse was frozen to the bottom.

Based on sampling results, the fish community at this watercourse was composed mainly of forage fish with the occurrence of non-sport fish. Species captured include one non-sport fish (longnose sucker) and three forage fish (brook stickleback, lake chub and pearl dace).

The overall fish and fish habitat diversity of Unnamed Creek 11 is considered very low, due to very low diversity ratings for all three categories (species, habitat and ecosystem diversity).

## 3.2.2.5 Waterbodies

### *Unnamed Waterbody 5*

Unnamed Waterbody 5 (Site 14) was a relatively shallow, uniform waterbody, dominated by littoral habitat with emergent vegetation (Figure 9). This waterbody had a perimeter of approximately 0.7 km and an approximate surface area of 0.04 $km^2$. The average and maximum depths recorded throughout the open-water seasons are 2.18 and 4.63 m, respectively.

Open-water season habitat use potential was generally moderate for sport fish, low for non-sport fish and moderate for forage fish. This was based on the availability and types of cover, spawning substrate and suitable water quality.

Overwintering habitat use potential within this waterbody was low for both sport and non-sport fish due to low DO levels. However, overwintering potential for forage fish was moderate based on their tolerance for low DO conditions.

No fish were captured during any of the seasonal surveys and no existing fish information was found for this waterbody.

The overall diversity of fish and fish habitat in Unnamed Waterbody 5 was considered very low. This was a result of very low ratings for species, habitat and ecosystem diversity.

### *Unnamed Waterbody 6*

Unnamed Waterbody 6 (Site 2) was a relatively shallow, uniform waterbody, dominated by littoral habitat with submergent and emergent vegetation (Figure 9). This waterbody had a perimeter of approximately 2.2 km and an approximate surface area of 0.07 $km^2$. The average and maximum depths recorded throughout the open-water seasons were 1.22 and 1.55 m, respectively.

Open-water season habitat potential within this waterbody was low for both sport and non-sport fish and moderate to high for forage fish. These ratings were based on shallow depths and high water temperature readings during the summer.

Overwintering habitat potential for sport and non-sport fish was low due to reduced DO levels. Overwintering habitat use potential for forage fish was moderate due to some species tolerance of low DO levels.

The fish community of Unnamed Waterbody 6 is likely composed solely of forage fish. There was no existing fish information for this waterbody. Brook stickleback were captured during surveys of the waterbody. There were no listed species present.

The overall diversity of fish and fish habitat in Unnamed Waterbody 6 was rated as very low. This conclusion was based on very low ratings for species, habitat and ecosystem diversity.

## 3.2.3 Unnamed Tributaries to the Athabasca River

### 3.2.3.1 Watercourses

### *Unnamed Creek 10*

One site was located on Unnamed Creek 10 (Site 8), a tributary to the Athabasca River (Figure 9). This site had no defined channel, lacked flow and was situated within a muskeg bog. This drainage was not divided into reaches as it was relatively uniform in gradient and morphology.

Open-water habitat use potential at this site was generally considered low for sport fish and non-sport fish and moderate for forage fish. This was largely based on the availability and amount of suitable cover and spawning substrate.

Overwintering habitat potential was low to moderate for both sport and non-sport fish due to shallow depth and DO conditions. However, the overwintering habitat use potential for forage fish was high due to their tolerance of these conditions.

The fish community documented within the surveyed site was composed of brook stickleback, lake chub, northern redbelly dace and pearl dace. Northern redbelly dace is listed as sensitive The overall fish and fish habitat diversity was assessed as very low, as all three diversity ratings (species, habitat and ecosystem) were very low.

### 3.2.3.2 Waterbodies

#### *Unnamed Waterbody 8*

Unnamed Waterbody 8 (Site 13) was located at the headwaters of an unnamed tributary to the Athabasca River (Figure 9). This waterbody was relatively uniform and dominated by littoral habitat. This waterbody had a perimeter of approximately 2.4 km and an approximate surface area of 0.20 $km^2$. The average and maximum depths recorded throughout the open-water seasons are 0.86 and 1.40 m, respectively.

Open-water habitat use potential within this waterbody low for sport fish and non-sport fish and moderate for forage fish. This was based on the availability and amount of suitable cover and spawning substrate.

Overwintering habitat use potential was moderate for both sport and non-sport fish due to suitable depths and DO levels. Forage fish overwintering habitat potential was rated as high.

A fish community within Unnamed Waterbody 8 was not detected, as no fish were captured during the seasonal surveys. There was no existing fish information for this waterbody.

The overall fish and fish habitat diversity of Unnamed Waterbody 8 was rated as very low, with very low ratings for species, habitat and ecosystem diversity.

## 3.2.4 Big Creek Watershed

Affected habitats in the Big Creek watershed include the lower reaches of the Big Creek mainstem (Reaches 1 and 2, and a portion of Reach 3 as well as several unnamed tributaries and waterbodies).

### 3.2.4.1 Fish Habitat

Suitable open water habitat is present in the Big Creek mainstem for several fish species and life stages due to the availability of cover, presence of spawning substrate and suitable water quality. Big Creek has an irregular meandering channel, with habitat composed of riffle, run and flat habitat units. Habitat use potential in Big Creek, as well as First Creek and the unnamed tributaries, is limited by the lack of suitable overwintering habitat. Several of the surveyed sites in the Big Creek watershed were frozen to the bottom while others had shallow under-ice water depths and low winter DO levels, with the exception of occasional beaver ponds that may be suitable for overwintering. Habitat limitations in the tributaries in the Big Creek watershed include small channel size, shallow depths, low discharge volume, poor habitat diversity, substrate dominated by fine sediments, poor fish passage and limited overwintering habitat.

Suitable open-water habitat was present in the small waterbodies within the Big Creek watershed, which included Oakley Lake, Small Sandy Lake and several unnamed waterbodies. However, overwintering habitat for large-bodied fish species was considered limited in all of the sampled waterbodies by shallow under-ice water depths and low DO levels.

### 3.2.4.2 Fish Population

Big Creek watershed supports a fish community comprised of eleven species (Table 6). Fish sampling in Big Creek resulted in the capture of one sport fish (burbot), two non-sport fish (longnose sucker and white sucker) and seven forage fish species. In the PRMA, spoonhead sculpin and spottail shiner were only found in Big Creek. Burbot and white sucker were only captured in the lower reach near the confluence with the Athabasca River while longnose sucker were found at both sampling sites in Big Creek as well as in Unnamed creeks 2 and 7. Fish communities in the tributaries and waterbodies within the Big Creek watershed were dominated by forage fish, with longnose or white suckers present in all waterbodies and tributaries except Unnamed Waterbody 15 (Table 6).

#### 3.2.4.3 Benthic Invertebrates

At three erosional sites in the Big Creek watershed, benthic invertebrate density ranged from 250 to 2,600 organisms/m² and total taxonomic richness ranged from 25 to 48 taxa/site, indicating a rich benthic invertebrate community of low density. The SDI and evenness values were indicative of a diverse benthic invertebrate community, with a few taxa accounting for the majority of the total density. The dominant taxa in Big Creek were midges, bristle worms and stoneflies.

At the two depositional sites, benthic invertebrate density ranged from 96,000 to 119,000 organisms/m² and total taxonomic richness ranged from 28 to 37 taxa/site, indicating a rich and abundant benthic invertebrate community. The SDI and evenness values indicated a moderate to highly diverse benthic invertebrate community where a few taxa accounted for the majority of the total density. The dominant taxa at these sites were midges, seed shrimp and bristle worms.

Mean benthic invertebrate density at Small Sandy Lake, Oakley Lake and an unnamed waterbody ranged from 21,000 to 36,000 organisms/m² and total taxonomic richness ranged from 14 to 31 taxa/site, indicating a moderately rich to rich benthic invertebrate community. The SDI and evenness values indicated a diverse benthic invertebrate community, with a few taxa accounting for the majority of the total density. The dominant taxa were midges, bristle worms and seed shrimp.

#### 3.2.4.4 Watercourses

##### *Big Creek Mainstem*

The mainstem of Big Creek consisted of four reaches, based on channel gradient and morphology. Three sites (42, 1 and 47) were situated within Reaches 1, 2 and 3, respectively (Figure 9). Reach 1 at Site 42 had an irregular meandering, occasionally confined channel and Reaches 2 and 3 at each respective site, had an irregular meandering, unconfined channel. Regarding habitat composition, Reach 1 (at Site 42) consisted of run and flat habitat, Reach 2 (at Site 1) consisted of run and riffle, while Reach 3 (at Site 47) was solely composed of run habitat.

Open-water habitat potential was generally moderate for all species within all sites surveyed. This was based on habitat components such as availability and types of cover, spawning substrate and water quality.

Overwintering habitat potential at Site 42 was rated as low for forage fish and low to nil for both sport and non-sport fish. As there was no access to Site 1, overwintering habitat use potential was based on conditions observed at Site 42 and conservatively rated as low for both sport and non-sport fish and moderate for forage fish. There was no overwintering potential within Site 47, as the watercourse was frozen to the bottom.

The fish community of Big Creek was composed of sport fish, non-sport fish and forage fish. Although no known historical information has been documented, fish sampling throughout each of the three survey sites resulted in the capture of one sport fish (burbot), two non-sport fish (longnose sucker and white sucker) and seven forage fish species (fathead minnow, lake chub, longnose dace, pearl dace, slimy sculpin, spoonhead sculpin and spottail shiner).

There are several notable fish species captured within this watercourse. Spoonhead sculpin is listed as may be at risk (ASRD 2006). In addition, spoonhead sculpin and spottail shiner were consider unique species, as they are not present elsewhere in the PRMA LSA.

The overall fish and fish habitat diversity of Big Creek was considered low. This rating was formulated by averaging a low rating for species diversity, a low rating for habitat diversity and a moderate rating for ecosystem diversity.

### *First Creek*

First Creek, a tributary to Big Creek, was divided into two reaches. One survey site (Site 9) was situated within Reach 2 (Figure 9). The watercourse at Site 9 had an irregular meandering, unconfined channel, composed of run and pool habitat.

Open-water habitat potential was generally low to moderate for sport fish, low for non-sport fish and moderate for forage fish. Consideration was given to the suitable cover, spawning conditions and water quality.

Overwintering potential was rated as low to nil for sport and non-sport fish and low for forage fish.

The fish assemblage of Fish Creek has no existing information and no fish were captured during the seasonal surveys.

The overall diversity of fish and fish habitat for First Creek was rated as low, due to very low species diversity, moderate habitat diversity and very low ecosystem diversity.

### Unnamed Creek 2

Unnamed Creek 2, a tributary to Reach 2 of Big Creek, was divided into two reaches. Site 44 was established within Reach 1 (Figure 9). This watercourse had an irregular meandering and unconfined channel and was composed of riffle and run habitat.

Open-water season habitat use potential was generally moderate for all fish species. This was based on habitat requirements for nursery, rearing and feeding, as well as spawning.

Overwintering potential was low for both sport and non-sport fish and moderate for forage fish species. This was based on conditions observed during open-season surveys, as the watercourse was not accessible during the winter survey.

The fish community within Unnamed Creek 2 has been documented in previous studies. In combination with sampling completed at the survey site, longnose sucker, brook stickleback, fathead minnow, lake chub and slimy sculpin have been documented in Unnamed Creek 2.

There are no listed species within this watercourse.

The overall fish and fish habitat diversity of Unnamed Creek 2 was considered very low. Species diversity was very low, habitat diversity was low and ecosystem diversity was very low.

### Unnamed Creek 7

Unnamed Creek 7, a portion of which is a tributary to Big Creek (identified as Unnamed Creek 7a in Figure 3), was surveyed at one site (Site 49), near its confluence with Big Creek (Figure 9). This watercourse at Site 49 was a large marsh with no defined channel and was solely composed of flat habitat. This watercourse was not divided into reaches as it was relatively uniform in channel gradient and morphology.

Open-water habitat use potential within Big Creek at Site 49 was generally low for both sport and non-sport fish, but low to moderate for forage fish. Shallow depth and high water temperatures in the summer season limited to the overall habitat potential.

There was no overwintering habitat use potential within this watercourse at Site 49 as the watercourse was frozen through to the bottom.

No previous studies or historical information was available for this watercourse. However, sampling activities at Site 49 resulted in the capture of one non-sport fish species (longnose sucker) and one forage fish species (brook stickleback).

There were no listed species documented in this watercourse.

The overall fish and fish habitat diversity of Unnamed Creek 7 was assessed as very low, based on very low ratings for all diversity categories (species, habitat and ecosystem diversity).

### 3.2.4.5 Waterbodies

#### *Unnamed Waterbody 15*

Unnamed Waterbody 15 was located within Reach 2 of First Creek (Figure 9). This waterbody had a perimeter of approximately 2.7 km and an approximate surface area of 0.26 $km^2$. A shallow littoral zone with submerged, floating and emerged vegetation was present along the shoreline with a relatively deeper open-water habitat in the centre. The average and maximum depths were 1.05 and 1.32 m, respectively.

Open-water season habitat use potential was low to moderate for both sport and non-sport fish, while forage fish potential was moderate. Habitat considerations included available cover, spawning substrate and water quality.

Overwintering potential was nil for all species due to shallow depth (0.03 m) and low DO levels.

The fish community of Unnamed Waterbody 15 was composed of forage fish. Brook stickleback was the only species captured during the seasonal surveys. No existing fish information was found.

The overall fish and fish habitat diversity at Unnamed Waterbody 15 was considered very low. This was based on very low diversity for species, habitat and ecosystem categories.

## 3.2.5 Redclay Creek Watershed

Affected habitats in the Redclay Creek watershed include the lower reaches of the Redclay Creek mainstem (Reaches 1 and 2) and a portion of an unnamed tributary to Redclay Creek.

### 3.2.5.1 Fish Habitat

Suitable open-water habitat is present in much of the Redclay Creek mainstem, with the middle reaches considered to provide the highest habitat use potential due to the presence of riffles and pools with some rocky substrate. These riffle areas provide potentially suitable spawning habitat for species such as Arctic grayling, walleye and suckers. The watercourse was sinuous, unconfined and predominately consisted of riffle and run habitat, with substrate consisting primarily of organics, clay/silt and sand, with some gravel, cobble and boulder present. The lower reaches of Redclay Creek provide summer rearing and feeding habitat for fish species from the Athabasca River, such as Arctic grayling, walleye and burbot. Overwintering habitats in the Redclay Creek watershed were somewhat limited due to shallow under-ice water depths and low DO levels at some sites, with other sites being frozen to the bottom.

Open-water habitat in the small waterbodies within the Redclay Creek watershed was limited to the forage fish species most tolerant of poor habitat conditions (brook stickleback and pearl dace) due to shallow depths and high water temperatures. Overwintering habitats in these waterbodies were also limited by shallow under-ice water depths and low DO levels.

### 3.2.5.2 Fish Population

Fifteen fish species have been documented in the Redclay Creek watershed. The fish community in Redclay Creek was fairly diverse, consisting of sport fish species, non-sport fish species and forage fish species (Table 6). Previous studies documented Arctic grayling within Redclay Creek. Fish sampling from this Project indicated Redclay Creek is also used by burbot, northern pike and walleye, as well as longnose sucker and white sucker. The distribution of sport fish species in Redclay Creek was limited to the lower reach near the confluence with the Athabasca River. Eight forage fish species were also captured in Redclay Creek (Table 6). Only forage fish species were captured in the unnamed waterbodies in the Redclay Creek watershed.

### 3.2.5.3 Benthic Invertebrates

Mean benthic invertebrate density at two sites in Redclay Creek ranged from 2,100 to 2,800 organisms/m² and total taxonomic richness ranged from 19 to

28 taxa/site, indicating moderately rich to rich benthic invertebrate communities of low density. The SDI and evenness values indicated a diverse benthic invertebrate community, with a few taxa accounting for the majority of the total density. The dominant taxa at the erosional site were mayflies and caddisflies. The depositional site was dominated by midges, bristle worms and caddisflies. Mean benthic invertebrate density at two unnamed waterbodies ranged from 11,000 to 29,000 organisms/m² and total taxonomic richness ranged from 25 to 27 taxa/site, indicating a moderately rich benthic invertebrate community. The SDI and evenness values indicated a diverse benthic invertebrate community, with a few taxa accounting for the majority of the total density. The benthic invertebrate communities of these waterbodies were dominated by midges.

### 3.2.5.4 Watercourses

#### *Redclay Creek Mainstem*

Redclay Creek was separated into four reaches based on channel gradient and morphology. Survey sites were located within Reach 1 (Site 50) and Reach 3 (Site 51) (Figure 9). The watercourse at both sites had a sinuous, unconfined channel and was composed of riffle and run habitat.

Open-water season habitat use potential within Reach 1 (Site 50) was low for sport fish and moderate for both non-sport and forage fish species. Within Reach 3 (Site 51) the open-water season habitat potential was moderate for sport fish, moderate to high for non-sport and generally moderate forage fish species.

Overwintering potential within Redclay Creek was nil for all fish at Site 50, as the watercourse was frozen to the bottom. Site 51 was not entirely frozen, but shallow depth resulted in low overwintering potential for sport and non-sport fish but moderate potential for forage fish species.

In addition to the two previous sites established on Redclay Creek to assess fish habitat and sample the fish population, a fish fence was established at Site 201, about 130 m upstream from the stream mouth. The fish counting fence was constructed and monitored in the spring of 2006 and 2007. Seasonal migrants were captured during the spring of 2007, indicating this watercourse is used for spawning and rearing activities.

Fish species captured during this study included three sport fish species (burbot, northern pike and walleye), two non-sport fish species (longnose sucker and white sucker) and eight forage fish species (brook stickleback, finescale dace, fathead minnow, lake chub, longnose dace, pearl dace, slimy sculpin and trout-perch).

One sensitive species was recorded in Redclay Creek, Arctic grayling (ASRD 2006). In addition, finescale dace is considered a unique species, as it was not found elsewhere in the PRMA LSA.

The overall fish and fish habitat diversity of Redclay Creek was rated as moderate. This resulted from averaging a low species diversity, a moderate habitat diversity and a high ecosystem diversity.

### *Unnamed Creek 7*

One segment of Unnamed Creek 7 appears to flow to Redclay Creek (identified as Unnamed Creek 7b in Figure 3), and another segment is a tributary to Big Creek (identified as Unnamed Creek 7a in Figure 3). A description of Unnamed Creek 7 is provided in the Big Creek watershed section (in Section 3.2.4.4).

# 4 APPROACH FOR ASSESSING HABITAT PRODUCTIVE CAPACITY

## 4.1 SUMMARY OF PRELIMINARY HABITAT QUANTIFICATION

The CCP is based on the principle of achieving no net loss of productive capacity of fish habitat, which is assessed by a comparison of the habitats that will be affected by the Project to habitats that will be developed as part of the Project. The CCP provides preliminary estimates of the area (i.e., quantity) of habitats lost or disturbed by development activities, and habitats that will be newly developed or gained as part of the habitat compensation plan.

Initial habitat quantification for the CCP consisted of estimates of habitat area calculated from existing digital maps of the affected watercourses and waterbodies using a Geographic Information System (GIS) analysis. Although this information is suitable for the conceptual stage of the compensation plan, a more accurate analysis will be conducted for the detailed NNLP, as detailed in the following sections.

Preliminary estimates of watercourse and waterbody areas considered lost due to development of the Project, affected by development of the Redclay Compensation Lake or indirectly affected by Muskeg River flow alterations were calculated based on the surface area of the affected waterbodies and watercourse segments (Table 7). Surface areas were calculated using existing digital maps provided by AltaLis. Further groundtruthing surveys will be conducted as part of development of the detailed NNLP to verify the existence and connectivity of some of the minor tributaries, and to evaluate the connectivity of some of the waterbodies. In addition, the surface areas will be refined using larger scale information to better capture stream sinuosity.

In addition to the habitat losses outlined in Table 7, the proposed development in the JEMA will alter some aspects of the previously approved Jackpine Mine – Phase 1 development, including some of the previously planned fish habitat compensation works as discussed on Section 2.1.1. The proposed JEMA development will affect the planned repositioning and reconstruction of Muskeg Creek whereby the timing of both the HADD of fish habitat in Muskeg Creek and its reconstruction will be delayed. There will also be a loss of some of the planned compensation for Jackpine Mine – Phase 1 as Khahago Lake will not be developed due to the updated integrated drainage plans. On closure, Khahago Lake would have provided 1,650,000 $m^2$ of compensation habitat (Golder 2005a). Shell is committed to developing sufficient compensation habitat for the Jackpine Mine – Phase 1 by the required date (2030), as required by the *Fisheries Act* Authorization for that project.

**Table 7 Preliminary Estimation of Waterbody and Watercourse Habitat Areas Affected due to Development of the Project**

| Mining Area | Watershed Location | Stream Reach or Waterbody Name[a] | Habitat Surface Areas [m²] | | | |
|---|---|---|---|---|---|---|
| | | | Habitat Losses Due to Mining and Diversions | | Habitats Affected by Redclay Compensation Lake Development | Habitats Indirectly Affected by Flow Alterations[b] |
| | | | Losses During Operations | Additional Losses at Closure | | |
| Jackpine Expansion Mining Area | Muskeg River Mainstem Reaches 1 to 5 | Reach 1 | 0 | 0 | 0 | 2,400 |
| | | Reach 2 | 0 | 0 | 0 | 25,269 |
| | | Reach 3 | 0 | 0 | 0 | 20,216 |
| | | Reach 4 | 0 | 0 | 0 | 45,007 |
| | | Reach 5 | 0 | 0 | 0 | 45,986 |
| | | *subtotal* | *0* | *0* | *0* | *138,878* |
| | Muskeg River | Reach 6a[c] mainstem | 0 | 0 | 0 | 17,161 |
| | | *subtotal* | *0* | *0* | *0* | *17,161* |
| | Muskeg River Reach 6b[c] | Reach 6b[c] mainstem | 111,707 | 0 | 0 | 0 |
| | | Unnamed Creek 9 | 10,757 | 0 | 0 | 0 |
| | | other unnamed tributaries | 59,195 | 0 | 0 | 0 |
| | | Unnamed Waterbody 1 | 51,740 | 0 | 0 | 0 |
| | | Unnamed Waterbody 2 | 77,903 | 0 | 0 | 0 |
| | | Unnamed Waterbody 3 | 315,782 | 0 | 0 | 0 |
| | | Unnamed Waterbody 14 | 40,485 | 0 | 0 | 0 |
| | | other unnamed waterbodies | 20,503 | 0 | 0 | 0 |
| | | *subtotal* | *688,072* | *0* | *0* | *0* |
| | Wapasu Creek | Reach 1 | 18,326 | 0 | 0 | 0 |
| | | Reach 2 | 39,205 | 0 | 0 | 0 |
| | | Reach 3a | 16,712 | 0 | 0 | 0 |
| | | unnamed tributaries | 33,032 | 0 | 0 | 0 |
| | | *subtotal* | *107,275* | *0* | *0* | *0* |
| | Khahago Lake[d] | Lake | 0 | 1,650,000 | 0 | 0 |
| | | *subtotal* | *0* | *1,650,000* | *0* | *0* |
| | **Total for JEMA** | | **795,347** | **1,650,000** | **0** | **156,039** |

**Table 7 Preliminary Estimation of Waterbody and Watercourse Habitat Areas Affected due to Development of the Project (continued)**

| Mining Area | Watershed Location | Stream Reach or Waterbody Name[(a)] | Habitat Surface Areas [$m^2$] | | | |
|---|---|---|---|---|---|---|
| | | | Habitat Losses Due to Mining and Diversions | | Habitats Affected by Redclay Compensation Lake Development | Habitats Indirectly Affected by Flow Alterations[(b)] |
| | | | Losses During Operations | Additional Losses at Closure | | |
| Pierre River Mining Area | Pierre River | Reach 1 | 30,511 | 0 | 0 | 0 |
| | | Reach 2 | 52,587 | 13,874 | 0 | 0 |
| | | Reach 3 | 0 | 21,022 | 0 | 0 |
| | | Unnamed Creek 4 | 12,678 | 17,234 | 0 | 0 |
| | | unnamed waterbodies | 40,899 | 58,041 | 0 | 0 |
| | | *subtotal* | *136,675* | *110,171* | *0* | *0* |
| | Eymundson Creek | Reach 1 | 39,524 | 0 | 0 | 0 |
| | | Reach 2 | 97,273 | 0 | 0 | 0 |
| | | Reach 3 | 33,660 | 0 | 0 | 0 |
| | | Reach 4 | 6,246 | 31,814 | 0 | 0 |
| | | Asphalt Creek - Reach 1 | 3,584 | 55,048 | 0 | 0 |
| | | Asphalt Creek - Unnamed Tributary 1 | 0 | 35,022 | 0 | 0 |
| | | Unnamed Creek 1 - Reach 1 | 14,532 | 0 | 0 | 0 |
| | | Unnamed Creek 1 - Reach 2 | 55,041 | 0 | 0 | 0 |
| | | unnamed tributaries to Unnamed Creek 1 | 56,126 | 6,195 | 0 | 0 |
| | | Unnamed Creek 11 | 4,849 | 0 | 0 | 0 |
| | | other unnamed tributaries to Eymundson Creek | 37,036 | 0 | 0 | 0 |
| | | Unnamed Waterbody 5 | 0 | 40,643 | 0 | 0 |
| | | Unnamed Waterbody 7 | 13,163 | 0 | 0 | 0 |
| | | other unnamed waterbodies | 202,785 | 1,351 | 0 | 0 |
| | | *subtotal* | *563,819* | *170,073* | *0* | *0* |

**Table 7 Preliminary Estimation of Waterbody and Watercourse Habitat Areas Affected due to Development of the Project (continued)**

| Mining Area | Watershed Location | Stream Reach or Waterbody Name[a] | Habitat Surface Areas [m²] | | | |
|---|---|---|---|---|---|---|
| | | | Habitat Losses Due to Mining and Diversions | | Habitats Affected by Redclay Compensation Lake Development | Habitats Indirectly Affected by Flow Alterations[b] |
| | | | Losses During Operations | Additional Losses at Closure | | |
| Pierre River Mining Area (continued) | Big Creek | Reach 1 | 35,065 | 0 | 0 | 0 |
| | | Reach 2 | 25,794 | 18,232 | 0 | 0 |
| | | Reach 3 | 20,616 | 48,847 | 0 | 0 |
| | | Unnamed Creek 2 | 0 | 33,250 | 0 | 0 |
| | | Unnamed Creek 5 | 5,548 | 13,405 | 0 | 0 |
| | | Unnamed Creek 6 | 0 | 28,080 | 0 | 0 |
| | | Unnamed Creek 7a | 18,212 | 0 | 54,815 | 0 |
| | | other unnamed tributaries to Big Creek | 18,853 | 25,844 | 0 | 0 |
| | | First Creek - Reach 1 | 13,632 | 0 | 0 | 0 |
| | | First Creek - Reach 2 | 38,617 | 0 | 0 | 0 |
| | | unnamed tributaries to First Creek | 12,583 | 0 | 0 | 0 |
| | | Unnamed Waterbody 15 | 254,914 | 0 | 0 | 0 |
| | | other unnamed waterbodies | 304,496 | 0 | 0 | 0 |
| | | *subtotal* | *748,330* | *167,658* | *54,815* | *0* |
| | Redclay Creek | Redclay Creek mainstem | 0 | 0 | 90,310 | 0 |
| | | Unnamed Creek 7b | 0 | 0 | 99,591 | 0 |
| | | other unnamed tributaries | 0 | 0 | 24,462 | 0 |
| | | unnamed waterbodies | 0 | 0 | 32,274 | 0 |
| | | *subtotal* | *0* | *0* | *246,637* | *0* |

**Table 7 Preliminary Estimation of Waterbody and Watercourse Habitat Areas Affected due to Development of the Project (continued)**

| Mining Area | Watershed Location | Stream Reach or Waterbody Name[a] | Habitat Surface Areas [m$^2$] | | | |
|---|---|---|---|---|---|---|
| | | | Habitat Losses Due to Mining and Diversions | | Habitats Affected by Redclay Compensation Lake Development | Habitats Indirectly Affected by Flow Alterations[b] |
| | | | Losses During Operations | Additional Losses at Closure | | |
| Pierre River Mining Area (continued) | Unnamed Athabasca River Tributaries and Waterbodies | Unnamed Creek 10 | 33,028 | 0 | 0 | 0 |
| | | Unnamed Creek 15 | 125,515 | 0 | 0 | 0 |
| | | Unnamed Creek 16 | 26,773 | 4,567 | 0 | 0 |
| | | other unnamed tributaries | 20,381 | 0 | 0 | 0 |
| | | Unnamed Waterbody 8 | 204,164 | 0 | 0 | 0 |
| | | other unnamed waterbodies | 21,389 | 0 | 0 | 0 |
| | | *subtotal* | *431,250* | *4,567* | *0* | *0* |
| | **Totals for PRMA** | | **1,880,074** | **452,469** | **301,452** | **0** |
| **Total for All Areas** | | | **2,675,421** | **2,102,469** | **301,452** | **156,039** |

(a) Locations of stream reaches and waterbodies are shown in Figure 2 and Figure 3.

(b) Habitat areas given for reaches of the Muskeg River that will be affected by flow alterations are 20% of the total surface areas of those reaches, as it has been estimated that any potential HADD attributable to JEMA, will be unlikely to exceed a 20% reduction in habitat availability or quality (Section 2.1.2)

(c) Reach 6a is that portion of Muskeg River Reach 6 that is downstream of the confluence with Unnamed Creek 9. Reach 6b is that portion of Muskeg River Reach 6 that is upstream of the confluence with Unnamed Creek 9.

(d) There will be a loss of some of the planned compensation for Jackpine Mine – Phase 1 as Khahago Lake will not be developed due to the updated integrated drainage plans (Section 2.1.1). Compensation for the loss of Khahago Lake will be provided for the Project as described in Section 4.1.

## 4.2 PLANNED DETAILED HABITAT QUANTIFICATION

In general, the assessment of the habitat productivity lost or altered by Project development and gained as part of the habitat compensation plan will be based on a Habitat Evaluation Procedures (HEP) type approach (U.S. Fish and Wildlife Service 1980). This system estimates habitat productivity based on a combination of habitat area and habitat suitability on a species-by-species basis. The HEP approach will be used during development of the detailed No Net Loss Plan (NNLP) to refine the appropriate level of compensation habitat needed to offset any losses to the productive capacity of fish habitats from disturbances in the affected watersheds. This system will be used to quantify habitat losses in disturbed areas and habitat gains in any newly created habitats associated with the Project.

Although not done at this conceptual stage in the development of the compensation plan, habitat productivity will be calculated based on a quantified parameter called the Habitat Unit (HU). This method combines the habitat area (i.e., quantity) and habitat suitability (i.e., quality) of a specific fish species to provide a representation of habitat productivity of that fish species. Habitat area refers to the surface area ($m^2$) of the waterbody or watercourse segment being considered. Habitat suitability is evaluated based on Habitat Suitability Index (HSI) models for the relevant fish species. HUs are dimensionless numbers, calculated as the product of habitat area and HSI, representing the overall value of the habitat for the different fish species, and used as a representation of the productive capacity of the habitats. Comparison of the HUs lost in affected habitats as a result of Project activities with HUs gained through compensation activities allows the assessment of the degree to which the Project achieves no net loss of the productive capacity of fish habitat.

Habitat quantity (area) will be calculated for watercourses as stream surface area, determined from channel length and channel width data. Habitat quantity for waterbodies will be determined by measurements of surface area.

Habitat quality will be determined using HSI models to rank the value of the available habitat for specific species and life stages of fish. The HSI models are species-specific models that evaluate the suitability of the habitat in question based on specific variables (i.e., habitat conditions) that are each considered crucial to the development of a self-sustaining population. Each HSI model provides a rating of habitat suitability on a scale of 0.0 (no potential habitat) to 1.0 (optimal habitat conditions). Habitat Units are calculated by multiplying the habitat area ($m^2$) by the HSI rating.

The HSI models to be used for this assessment will be either published models modified for use in the Oil Sands Region or models designed specifically for use in the Oil Sands Region of Alberta. Models modified or developed for use in the Oil Sands Region exist for several fish species that are present in areas affected by the Project (Golder 2005b). The models were developed in a workshop setting by experts from the University of Alberta, DFO, ASRD and Golder and were based on available scientific literature and the experts' experience. Some fish species occur in the Project area for which no specific HSI models for the Oil Sands Region exist. HSI models for these species will be developed as part of the detailed NNLP stage for the Project. These models will be developed in consultation with DFO.

The following sections describe the activities to be conducted for the detailed NNLP to provide a complete assessment of the habitat losses associated with development of the Project. These activities include additional steps to refine the preliminary habitat area estimation, determination of habitat suitability index values, and calculation of habitat units lost as representative of changes in the productive capacity of fish habitats.

### 4.2.1 Habitat Area Determination

This section provides a description of the methods that will be used during the development of the detailed NNLP to measure and calculate the existing habitat area (i.e., surface area) of affected waterbodies and watercourse segments. This includes the lengths, widths, surface areas and gradients of affected watercourse segments, and the surface area of affected waterbodies.

#### 4.2.1.1 Watercourse Segments

Habitat area in a watercourse segment will be calculated by multiplying the length of the watercourse channel in the segment by the average width of the channel. Watercourse segments may consist of one or more of three different types of channel form: defined channel, undefined channel or beaver pond. The quantification of the surface area of each of these channel forms will be calculated in a different manner, as described below.

***Channel Length***

The length of the watercourse channel in each affected watercourse segment will be measured separately and will include all tributary channels in the segment. Channel lengths will be measured using GIS Software (ArcGIS, Version 8.2) and digital aerial photographs. Aerial photos of the watercourse will be orthorectified (geopositioned and distortions due to the camera lens and topography removed) using PCI Geomatica Orthoengine Software (Version 8.2). Specific features (such as roads, cutlines and trails) will be used as ground control as much as possible versus using features like lake margins, stream channels or beaver dams, which can be affected by seasonal variation.

For each watercourse segment, the watercourse channel will be measured by screen digitizing at 2-m intervals (using a screen zoom scale of 1:1,000) to ensure all channel meanders were properly represented in the length calculation. Total channel lengths will be measured for sections of defined channel and sections of undefined channel. Sections of defined channel will be measured as they appear. In areas that appear to be undefined, stereoscopic aerial photo pairs will be examined to check for any possible indication of a channel. Where no channel is apparent and the area appears to be devoid of water, a line will be digitized that repeats the meander pattern of an equal portion of the adjacent section of defined channel.

### *Channel Width*

Stream widths to be used for the habitat area calculations will be derived from all available measurements, including those conducted during the Project environmental setting survey and appropriate historical data. Two types of stream width measurements have been collected: wetted width and channel width. Wetted width refers to the width of the water present in the channel at the time of the survey, which varies with river discharge. Channel width is defined as the portion of the channel that contains river bed substrate, whether wet or dry, and is bordered by rooted terrestrial vegetation. As such, it is associated with the ordinary high water mark that is commonly used by DFO to define the limit of fish habitat in streams. Channel width is independent of river discharge and is the parameter that will be used in the stream habitat area calculations as representing the stream width, and therefore, fish habitat area.

### *Habitat Area*

Habitat area for watercourse segments will be calculated differently for sections of defined and undefined channel in comparison to habitat areas of beaver ponds.

Habitat area for defined and undefined channel sections will be calculated by multiplying the length of each channel type within the watercourse segment by the mean channel width for the segment (exclusive of beaver ponds). In some instances, an undefined channel is truly undefined, even at ground level. In others, it is simply a result of crown cover obscuring the channel. This calculation of habitat area is conservative as it applies the mean channel width measured in sections of defined channel to all areas with no defined channel.

Beaver ponds comprise sections of the watercourse where the channel is flooded and the wetted width is wider than the natural channel width. Therefore, habitat areas of beaver ponds will be determined by direct measurement of area by screen digitizing of aerial photos. The shapes of the beaver ponds will be digitized and areas of the polygons that are delineated will be calculated with the ArcGIS extension 'Xtools'.

The total habitat area for a given watercourse segment will be calculated by summing the area of all channel forms (defined, undefined and beaver ponds) present in the segment.

### *Gradient*

The gradient or slope of each watercourse segment will be calculated using GIS software based on the length of channel in the segment and the change in elevation between the upstream and downstream boundaries of the segment.

### 4.2.1.2 Waterbodies

### *Habitat Area*

Habitat area of each of the affected waterbodies will be determined by direct measurement of area by screen digitizing of aerial photos. The shapes of the waterbodies will be digitized and areas of the polygons that are delineated will be calculated with the ArcGIS extension 'Xtools'.

## 4.2.2 Habitat Suitability Determination

Data concerning habitat conditions and the potential suitability of available habitats for the various fish species, as defined by the relevant species-specific HSI models, will be provided by the available field measurements conducted during the Project environmental setting survey and from historical data. As part of developing the detailed NNLP in consultation with the regulatory agencies, this data and the appropriate HSI models developed from the expert workshop (Golder 2005b) will form the basis for assigning a suitability rating for the available habitat for each of the affected fish species and life stages.

Determining the affected species will be based on assumed fish species distributions, which define the species present (or potentially present) in each waterbody or watercourse segment. Assumed fish distributions will be based on all historical and current fish distribution data and will be developed in consultation with the appropriate regulatory agencies.

## 4.2.3 Determination of Habitat Units

Determination of losses in the productive capacity of fish habitats due to Project development and gains in the productive capacity of habitats to be provided as part of the habitat compensation plan will be based on the calculation of HUs. This will be done as part of the detailed NNLP for the Project. For all habitats lost or gained, selected HSI models will be applied to rank the importance of the habitat, which in turn, will be multiplied by total surface area of the habitats. Comparison of the habitat losses and gains quantified in this manner will allow a detailed assessment of the degree to which the objective of no net loss of productive capacity of fish habitat is achieved. Results will be used in the final configuration and design of the compensation habitats and, if necessary, additional compensation will be developed in consultation with appropriate regulators.

The HU losses and gains will be determined with regard for the appropriate habitat compensation ratio, as determined in consultation with DFO. The compensation ratio specifies the number of compensation HUs to be provided for each HU lost. The compensation ratio is typically greater than 1:1 to account for time delays between loss of fish habitat and the full functioning of the compensation habitat, and uncertainty associated with the models and their predictions of fish habitat losses and gains.

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# 5 PROPOSED HABITAT COMPENSATION

Several habitat compensation options were evaluated with respect to developing the CCP for the Project. The selected option consists of constructing riverine and lacustrine compensation habitats including a compensation lake in the lower Big Creek and lower Redclay Creek watersheds (Redclay Compensation Lake) to provide year-round habitat for a species assemblage similar to those species affected by the Project. As part of the development of the Redclay Compensation Lake and closure drainage plan, riverine habitat also will be constructed. The following sections provide a summary of the process used for developing the compensation plan and a basic description of the compensation habitats.

## 5.1 HABITAT COMPENSATION APPROACH

The selection of the compensation approach included consideration of the hierarchy of compensation preferences for application of the No Net Loss Guiding Principle provided by the DFO Policy for Management of Fish Habitat (DFO 1986). These preferences for compensation are summarized in the following points, in declining order of priority.

- Create or increase the productive capacity of like-for-like habitat in the same ecological unit; that is, replace natural habitat with the same type of habitat at or near the site.
- Create or increase the productive capacity of unlike habitat in the same ecological unit.
- Create or increase the productive capacity of habitat in a different ecological unit.
- Where it is not technically feasible to compensate for the habitat itself (and where deemed appropriate by DFO), use artificial production techniques to maintain a stock of fish, deferred compensation or restoration of chemically contaminated sites.

The CCP attempts to meet the objectives of the hierarchy of compensation preferences by considering these preferences during development and evaluation of compensation alternatives to achieve no net loss of productive capacity of fish habitat. There are a number of opportunities to provide compensation that Shell will pursue in the diversion channels created to provide self-sustaining fish habitat. However, these opportunities do not provide adequate compensation for the Project to meet the DFO No Net Loss Guiding Principle. To meet compensation requirements, one or more large compensation projects are required. The large compensation options considered for the Project include:

- Option 1: Creation of a compensation lake and associated channels in the lower Big Creek and lower Redclay Creek watersheds.
- Option 2: Expansion of the southern boundary of Kearl Lake.
- Option 3: Enhancement of Kearl Lake through deepening.
- Option 4: Enhancement of Lesser Slave Lake.
- Option 5: Rehabilitation of the Athabasca River snye area.
- Option 6: Athabasca River Enhancement.
- Option 7: Off-stream Lake beside the Athabasca River.
- Option 8: Off-stream Lake beside a Major or Minor Tributary.

Option 1 was selected for the proposed compensation plan. This option is on the Shell lease area, has the potential to provide large habitat gains, and has design flexibility in terms of overall size and configuration. As this option will create primarily lacustrine habitat as compensation for primarily riverine habitat losses, and will provide on-site compensation for PRMA and off-site compensation for the JEMA losses, it is consistent with items 2 and 3 in the DFO hierarchy of preferences.

The proposed compensation plan involves building a compensation lake in the lower Big Creek and lower Redclay Creek watersheds. This would include the construction of natural geomorphic channels that incorporate fish habitat features and facilitate fish passage from the Athabasca River to the compensation lake and upper reaches of Big Creek watershed. For this conceptual plan, the lake size is estimated to be approximately 4 $km^2$. The final overall size of the lake may increase or decrease based on the outcome of the detailed assessment of fish habitat lost due to the Project activities and required habitat gains. The final design will be determined for the detailed NNLP in consultation with the appropriate regulators (i.e., DFO and ASRD) and stakeholders. Additional components of the compensation plan to be developed for the detailed NNLP include, but are not necessarily limited to:

- detailed quantification of the surface areas of affected waterbodies and watercourse segments, as described previously;
- determination of assumed fish species distributions for the affected habitats, as described previously;

- development of HSI models for fish species impacted in the Project area for which models for the Oil Sands Region do not currently exist;
- application of HSI models to the affected habitats for all of the selected species based on the assumed distributions, as described previously;
- calculation of HUs lost in affected habitats based on the habitat areas and HSI values, as described previously;
- determination of appropriate habitat compensation ratios through consultation with DFO;
- finalization of the fish species community composition for the compensation habitats;
- determination of designs and HSI values for constructed diversion channels that will be designed to provide fish habitat:
- determination of HSI values for the selected species in the proposed compensation habitats, and calculation of HUs gained based on the proposed lake area;
- final determination of the amount of compensation habitat required to meet the specified compensation ratio (e.g., sizing of the compensation lake, amount of diversion habitat created and provision of additional compensation habitat if necessary);
- additional details of the design of the compensation habitats; and
- verification of water quality and quantity suitability for the compensation habitats.

## 5.2 TIMING OF HABITAT COMPENSATION

Development of compensation lake habitat will occur at the start of the Project. Development of diversion channel compensation habitat is variable, but will generally occur later in the project life as most are closure channels. The first disturbance of habitat due to the Project will occur in 2016, with the initial diversions in the PRMA. Other impacts occur much later in time such as the mining of a portion of the Muskeg River starting in 2046.

## 5.3 DEVELOPMENT OF HABITAT COMPENSATION

The CCP involves the proposed development of riverine and lacustrine compensation habitat. Riverine compensation habitat will occur in the form of channels to be constructed as part of the compensation lake development and channels to be constructed for diversions that will be designed to provide self-sustaining fish habitat. These channels represent an important component of the proposed compensation habitat. Along with riverine compensation habitat, lacustrine compensation habitat will be provided by a compensation lake

(Redclay Compensation Lake) in the lower Big Creek and lower Redclay Creek watersheds to meet the compensation requirements for the Project.

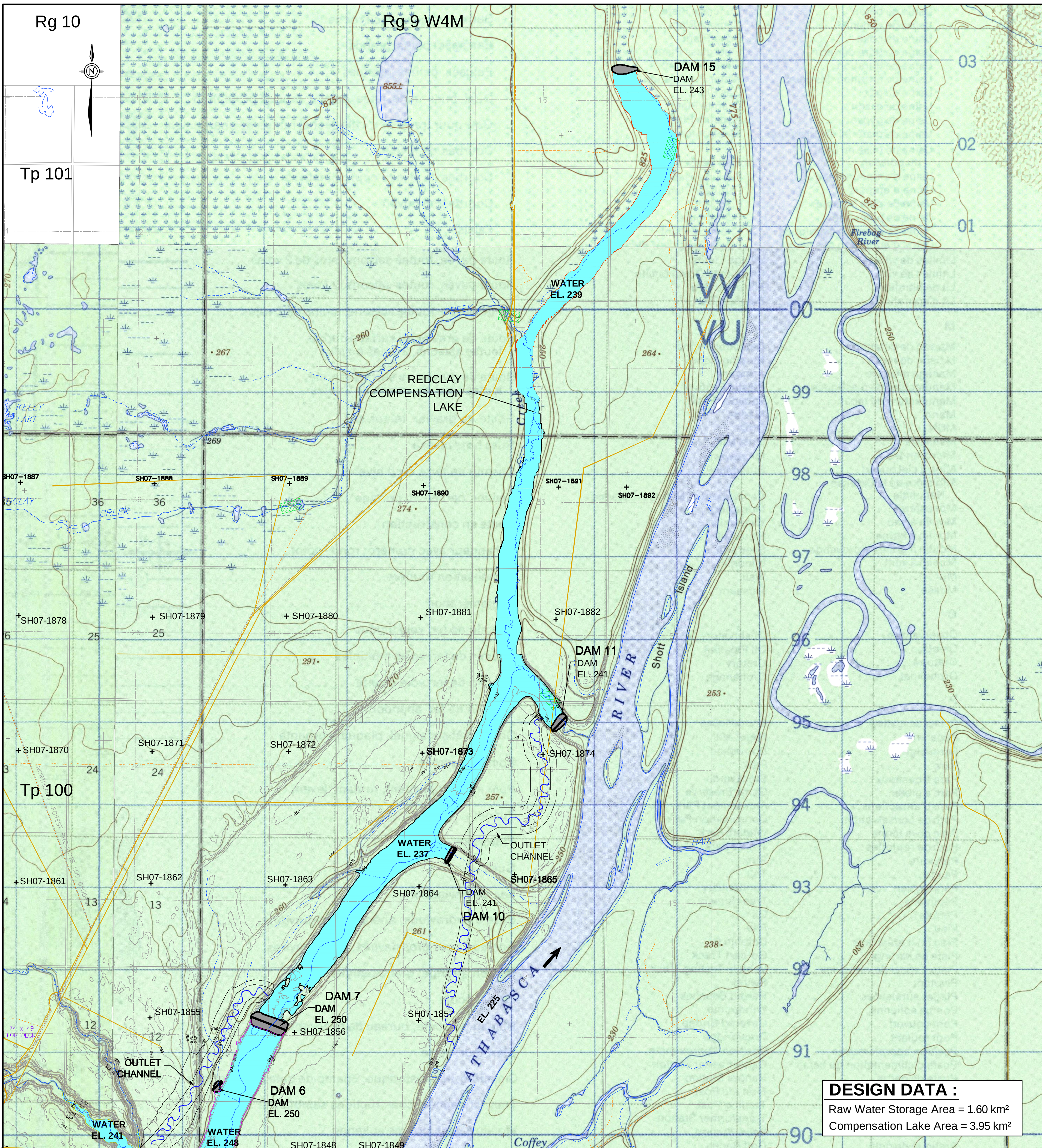
### 5.3.1 Redclay Compensation Lake

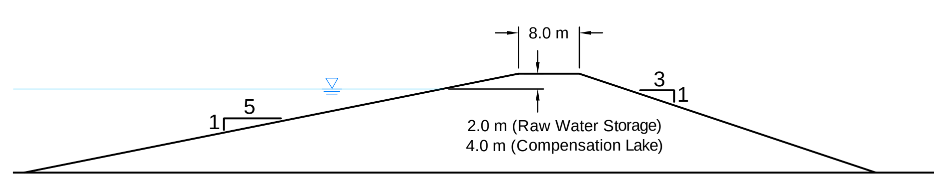
The general location and configuration of the proposed Redclay Compensation Lake is shown in Figure 10. It will be constructed immediately adjacent to the Raw Water Storage Facility that will be constructed as part of the Project. It is intended that the lake will provide the largest portion of the habitat compensation required for the Project. The size of the Compensation Lake is currently proposed to be approximately 4 $km^2$, pending further assessment of changes in productive capacity and continued development of the habitat compensation plan. The lake is designed to provide year-round habitat for a variety of fish species, including sport fish, non-sport fish and forage fish species. Design features will include spawning, nursery, rearing, feeding, and overwintering habitats to support self-sustaining fish populations.

The compensation lake will be constructed to provide habitat diversity in the lake (varying gradients, substrate types, depths.). Circulation of water through the lake would be provided by flow between the inlet stream and a natural geomorphic watercourse outlet that would be designed to provide fish passage. Shoreline protection would be provided as appropriate in areas susceptible to erosion or destabilization due to wind driven wave action or flood events. As part of lake construction, the appropriate mitigations will be undertaken prior to lake filling to reduce the potential for mobilization of methyl mercury into the water or the food chain and the potential for winterkill associated with decomposing organic material.

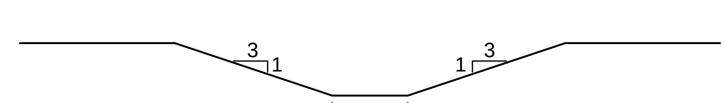
The design of the compensation lake will provide suitable habitat for a proposed fish community consisting of walleye, lake whitefish, cisco, northern pike, yellow perch, burbot, white sucker, longnose sucker and several forage fish species. Suitable habitat for all life stages of all fish species can be provided for within the compensation lake local area. The compensation lake will be connected to upstream and downstream riverine habitat that will provide spawning habitat for some species (see Section 5.3.2). Forage fish species that would be considered for inclusion in the compensation lake fish community include brook stickleback, lake chub, fathead minnow, pearl dace, spottail shiner, emerald shiner and slimy sculpin.

L:\2006\1344-OIL SANDS\1346\06-1346-022 Shell\9100\9170\Fig 10 Proposed Compensation Lake-Raw Water storage Facility.dwg Dec 04, 2007 - 5:58pm




DETAIL - TYPICAL DAM
NTS




DETAIL - TYPICAL OUTLET CHANNEL VALLEY EXCAVATION
NTS

SCALE 1 0 1 KILOMETRES

REFERENCE

BASE DATA OBTAINED FROM CLIENT
DRAWING: SC-DRILLING-2007-rev1.dwg; DATED: 11/23/06
5m CONTOURS OBTAINED FROM AIRBORNE IMAGING, DATED JUNE 10, 2007

TOPOGRAPHIC MAPS 73 E/11 AND E/12 SCANNED BY SoftMap. © 1989
HER MAJESTY THE QUEEN IN RIGHT OF CANADA. DEPARTMENT OF ENERGY, MINES AND RESOURCES. PROJECTION : TRANSVERSE MERCATOR DATUM : NAD83 COORDINATE SYSTEM : UTM ZONE 12

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

**PROPOSED**
**REDCLAY COMPENSATION LAKE AND RAW WATER STORAGE FACILITY**

Shell Canada Limited

| | | | |
|---|---|---|---|
| PROJECT 06-1346-022.9100 | | | FILE No. Propose Compens-Lk |
| DESIGN | WC | 17/09/07 | SCALE AS SHOWN REV. 0 |
| CADD | PSR | 11/10/07 | |
| CHECK | GW | 11/10/07 | **FIGURE: 10** |
| REVIEW | WES/TC | 30/11/07 | |

#### 5.3.1.1 Hydrologic Feasibility

The Redclay Compensation Lake will have a drainage area to surface area ratio of 129:1, which will ensure that it is self-sustaining with no adverse effects due to water level fluctuations. Natural-type water level fluctuations will maximize productivity within the littoral zone. The outflow channel from the lake will consist of a small pilot channel for conveyance of normal outflows from the lake and provide fish passage, with a large floodplain that will provide for conveyance of flood flows similar to a natural channel.

### 5.3.2 Riverine Compensation Habitat

In addition to the above lake design, two channels will be constructed as part of the lake development to provide riverine compensation habitat (Figure 10). The lake outlet channel will be constructed to connect the lake to the Athabasca River and a diversion channel will be constructed to connect the lake to the upper reaches of the Big Creek watershed. Where appropriate, both channels will be designed to provide riverine spawning habitats for select species that prefer flowing water with rocky substrate for spawning (e.g., suckers). Although rocky substrate would be provided in a portion of the lake that could provide potential spawning habitat, providing watercourse spawning habitat for fish species such as suckers is better suited to long-term sustainability of these populations.

Permanent closure channels associated with the Project will be geomorphically designed to provide fish habitat and fish accessibility, and will be included as compensation in the detailed NNLP. Where appropriate, operational diversion channels will be constructed as closure channels. For example, the downstream reach of the Pierre River closure channel will likely be integrated with Canadian Natural's Horizon closure drainage channel and be designed to accommodate the flows from both the diversion of the Pierre River and from the Horizon Project. This geomorphically designed channel will be approximately 13 km in length and contain habitat features, such as cover and velocity shelters, to allow for fish use of the channel by a variety of life stages and fish passage into the upper watershed. The Big Creek closure channel will be approximately 15 km in length. The channel will be designed to allow for fish passage from the Athabasca River to the upper watershed through the Compensation Lake, which will maintain the connection to the Athabasca River through the geomorphically designed outlet channel. Details of the permanent closure channels, with respect to their design and associated fish habitat features, including quantification of habitat gains towards compensation, will be included in the detailed NNLP.

# 6 MONITORING EFFECTIVENESS OF COMPENSATION

## 6.1 MONITORING OBJECTIVES

The proposed habitat compensation measures will be monitored as part of Shell's adaptive management strategy. The results of the monitoring program will provide feedback on the suitability of the compensation measures and identify where adjustments or additional measures are required.

Preliminary details of the proposed monitoring program are presented in Appendix 4-9. It is expected that a more detailed monitoring plan will be developed as part of the detailed lake and closure channel designs, in consultation with regulatory agencies. The detailed monitoring plan will be designed to meet all fish and fish habitat monitoring requirements set forth by DFO in the anticipated Authorization for the Project pursuant to Section 35(2) of the *Fisheries Act.*

# 7 REFERENCES

AENV and DFO (Alberta Environment and Fisheries and Oceans Canada). 2007. Water Management Framework: Instream Flow Needs and Water Management System for the Lower Athabasca River. Edmonton, AB. 37 pp.

ASRD (Alberta Sustainable Resource Development). 2006. The General Status of Alberta Wild Species 2005. Alberta Sustainable Resource Development, Fish and Wildlife Service Division. Edmonton, AB.

AXYS (AXYS Environmental Consulting Ltd.). 2005. Aquatic Environmental Setting Report for the Albian Sands Energy Inc. Muskeg River Mine Expansion Project. Calgary, AB. Submitted April 2005.

DFO (Department of Fisheries and Oceans Canada). 1986. Policy for the Management of Fish Habitat. Department of Fisheries and Oceans. Ottawa, ON.

DFO. 1995. Fish Habitat Conservation and Protection. What the Law Requires: The Directive on the Issuance of Subsection 35(2) Authorizations. Publication DFO/5077. Published by Communications Directorate, Department of Fisheries and Oceans. Ottawa, ON.

DFO. 2002. Practitioners Guide to Compensation for DFO Habitat Staff.

Golder (Golder Associates Ltd.). 2001. Oil Sands Regional Aquatics Monitoring Program (RAMP): 2000 Report. Volume I: Chemical and Biological Monitoring. Prepared for RAMP Steering Committee.

Golder. 2003. Oil Sands Regional Aquatics Monitoring Program (RAMP): Five Year Report. Submitted to the RAMP Steering Committee. Calgary, AB. Submitted May 2003.

Golder. 2005a. Revised No Net Loss Plan for Jackpine Mine- Phase 1. Prepared for Shell Canada Limited. Calgary, AB. 76 pp.

Golder. 2005b. Shell Jackpine Mine – Phase 1 No Net Loss Habitat Compensation Plan: Fish Species Habitat Suitability Index Models Supporting Documentation. Prepared for Shell Canada Limited.

Golder. 2007b. Aquatics Environmental Setting Report for the Jackpine Mine Expansion & Pierre River Mine Project. Prepared for Shell Canada Limited. Calgary, AB. Submitted December 2007.

Imperial Oil (Imperial Oil Resources Ventures Limited). 2005. Kearl Oil Sands Project - Mine Development. Volume 1 to 9. Submitted to Alberta Energy and Utilities Board and Alberta Environment. Prepared by Imperial Oil Resources Ventures Limited in association with Golder Associates Ltd., AXYS Environmental Consulting Ltd., Komex International Inc. and Nichols Applied Management. Calgary, AB. Submitted July 2005.

RAMP (Regional Aquatics Monitoring Program). 2004. Regional Aquatics Monitoring Program (RAMP) 2003 Annual Report. Prepared for the RAMP Steering Committee. Submitted by the RAMP 2003 Implementation Team Consisting of Hatfield Consultants Ltd., Jacques Whitford Environment Ltd., Mack, Slack and Associates Inc. and Western Resource Solutions. Submitted March, 2004. 618 pp.

RAMP. 2006. Regional Aquatics Monitoring Program (RAMP) 2005 Technical Report. Prepared for the RAMP Steering Committee. Submitted by the RAMP 2005 Implementation Team consisting of Hatfield Consultants Ltd., Stantec Consulting Ltd., Mack, Slack and Associates Inc. and Western Resource Solutions. Submitted April 2006.

Shell (Shell Canada Limited). 2005. Muskeg River Mine Expansion Project Application and Environmental Impact Assessment. Submitted to Alberta Energy and Utilities Board and Alberta Environment. Prepared by Golder Associates Ltd. and Nichols Applied Management. Volume 1,2, 3 and 4. Fort McMurray, AB. Submitted April, 2005.

U.S. Fish and Wildlife Service (United States Fish and Wildlife Service). 1980. Habitat Evaluation Procedures (HEP). USFWS, Division of Ecological Services. ESM 102. U.S.D.I.

# 8 ABBREVIATIONS

| | |
|---|---|
| ≤ | Less than or equal to |
| % | Percent |
| AENV | Alberta Environment |
| ASRD | Alberta Sustainable Resource Development |
| Canadian Natural | Canadian Natural Resources Limited |
| CCP | Conceptual Compensation Plan |
| DFO | Fisheries and Oceans Canada (Note: formerly Department of Fisheries and Oceans Canada) |
| DO | Dissolved Oxygen |
| e.g. | For example |
| EIA | Environmental Impact Assessment |
| ETDA | External Tailing Disposal Area |
| GIS | Geographic Information System |
| Golder | Golder Associates Ltd. |
| HADD | Harmful alteration, disruption or destruction |
| HEP | Habitat Evaluation Procedures |
| HSI | Habitat Suitability Index |
| HU | Habitat Unit |
| i.e. | That is |
| Imperial Oil | Imperial Oil Resources Ventures Limited |
| JEMA | Jackpine Expansion Mining Area |
| KIRs | Key Indicator Resources |
| km | Kilometre |
| $km^2$ | Square kilometre |
| LSA | Local Study Area |
| m | Metre |
| m/km | Metre per Kilometre |
| $m^3/s$ | Cubic meter per second |
| mg/L | Milligrams per litre |
| NNLP | No Net Loss Plan |
| organisms/$m^2$ | Organisms per square meter |
| PRMA | Pierre River Mining Area |
| RAMP | Regional Aquatics Monitoring Program |
| RSA | Regional Study Area |
| SDI | Simpson’s Diversity Index |

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|---|---|
| Shell | Shell Canada Limited |
| Syncrude | Syncrude Canada Ltd. |

# 9 GLOSSARY

**Alberta Sustainable Resource Development (ASRD)** — Alberta Sustainable Resource Development (ASRD) is one of the Alberta Ministries whose mission is to encourage balanced and responsible use of Alberta's natural resources through the application of leading practices in management, science and stewardship. ASRD works with Albertans across the province to ensure a balance between the economic, environmental and social values of our province. They fight forest fires, manage fish and wildlife, oversee the development of Alberta's forests, and manage the use of public lands.

**Channel** — The bed of a stream or river.

**Bathymetry** — Measurement of the depth of an ocean or large waterbody.

**Bog** — Sphagnum or forest peat materials formed in an ombrotrophic environment due to the slightly elevated nature of the bog, which tends to disassociate it from the nutrient-rich groundwater or surrounding mineral soils. Characterized by a level, raised or sloping peat surface with hollows and hummocks.

Mineral-poor, acidic and peat-forming wetlands that receives water only from precipitation.

**Channel Regime** — The morphological characteristics, including cross-section, longitudal slope and sinuosity, of a watercourse that is in long-term equilibrium.

**Channel Width** — The horizontal distance along a transect line from stream bank to stream bank (rooted vegetation to rooted vegetation) at the normal high water marks measured at right angles to the direction of flow.

**Compensation (Fisheries)** — The replacement of natural habitat, increase in the productivity of existing habitat or maintenance of fish production by artificial means in circumstances dictated by social and economic conditions, where mitigation techniques and other measures are not adequate to maintain habitat for Canada's fisheries resources.

**Creek** — A branch or small tributary of a river.

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| **Department of Fisheries and Oceans (DFO) (now Fisheries and Oceans Canada)** | Responsible for policies and programs in support of Canada's economic, ecological and scientific interests in oceans and inland waters; for the conservation and sustainable utilization of Canada's fisheries resources in marine and inland waters; for leading and facilitating federal policies and program on oceans; and for safe effective and environmentally sound marine services responsive to the needs of Canadians in a global economy. |
| **Dissolved Oxygen (DO)** | Measurement of the concentration of dissolved (gaseous) oxygen in the water, usually expressed in milligrams per litre (mg/L). |
| **Environmental Impact Assessment (EIA)** | A review of the effects that a proposed development will have on the local and regional environment. |
| **Environmental Setting** | A quantitative level or value from which other data and observations of a comparable nature are referenced. Information accumulated concerning the state of a system, process or activity before the initiation of actions that may result in changes. |
| ***Fisheries Act*** | Federal legislation that protects fish habitat from being altered, disrupted or destroyed by chemical, physical or biological means. Destruction of the habitat could potentially undermine the economic, employment and other benefits that flow from Canada's fisheries resources. Department of Fisheries and Oceans (DFO). 1986. The Department of Fisheries and Oceans Policy for the Management of Fish Habitat. Presented to Parliament by the Minister of Fisheries and Oceans. October 7, 1986. |
| **Fish Habitat (*Fisheries Act*)** | Spawning grounds and nursery, rearing, food supply and migration areas on which fish depend directly or indirectly to carry out their life processes. |
| **Forage Fish** | Small fish (e.g., brook stickleback or fathead minnow) that provide food for larger fish. |
| **Fry** | The early stage of development for the fish from hatching until it is one year old. |

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| **Geomorphic** | The natural evolution of surface soils and landscape over long periods. |
| **Groundtruth or Groundtruthing** | Visiting locations in the field to confirm or correct information produced from remote sources such as interpreted aerial photographs or classified satellite imagery. |
| **Habitat** | The place or environment where a plant or animal naturally or normally lives or occurs. |
| **Habitat Productivity** | Fish productivity is the sum of production rates for all co-occurring fish stocks within a defined area or ecosystem. Habitat productivity integrates the value of primary production, food, cover and other habitat variables needed to produce healthy fish within the habitat area. |
| **Habitat Suitability Index (HSI) Model** | Analytical tools for determining the relative potential of an area to support individuals or populations of a wildlife species. They are frequently used to quantify potential habitat losses and gains for wildlife as a result of various land use activities. |
| **Habitat Unit (HU)** | Generally, used in Habitat Suitability Index models. A habitat is ranked in regards to its suitability for a particular wildlife species. This ranking is then multiplied by the area (ha) of the particular habitat type to give the number of habitat units (HU) available to the wildlife species in question. |
| **Instream Flow Needs** | Amount of water needed in a watercourse for sustaining instream values (such as fisheries or related riverine resources) at an acceptable level based on appropriate study. |
| **Lacustrine** | Sediment that have been transported or deposited by water or wave action. Generally consisting of stratified sand, silt or clay deposited on a lake bed or moderately well sorted and stratified sand and coarser material. |
| **Littoral Zone** | The zone in a lake that is closest to the shore. It includes the part of the lake bottom, and its overlying water, between the highest water level and the depth where there is enough light (about 1% of the surface light) for rooted aquatic plants and algae to colonize the bottom sediments. |
| **Local Study Area (LSA)** | Defines the spatial extent directly or indirectly affected by the Project. |

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| **Mainstem** | The main portion of a watercourse extending continuously upstream from its mouth, but not including any tributary watercourses. |
| **Muskeg** | A soil type comprised primarily of organic matter. Also known as bog peat. |
| **No Net Loss Guiding Principle** | A DFO policy which strives to balance unavoidable habitat losses with habitat replacement on a project by project basis so that reductions to fisheries resources due to habitat loss or damage may be prevented |
| **Non-Sport Fish** | Large fish which is not caught for food or sport (e.g., longnose sucker, white sucker). |
| **Nursery Habitat** | Areas that provide the types of habitat required by fish fry for rearing and feeding after hatching. Typical characteristics of nursery habitat include small food items, cover from predators and velocity shelter. |
| **Oil Sands Region** | The Oil Sands Region includes the Fort McMurray – Athabasca Oil Sands Subregional Integrated Resource Plan (IRP), the Lakeland Subregional IRP and the Cold Lake – Beaver River Subregional IRP. |
| **Overwintering Habitat** | Habitat used during the winter as a refuge and for feeding. |
| **Pool: Run: Riffle Ratio** | The ratio of pool: run: riffle based on the percentage of each stream type in the surveyed section of the stream. These habitat types are described as:<br>• Pool: a deep area of low current velocity;<br>• Run: a moderately deep area within the main current; and<br>• Riffle: a shallow area where the water surface is broken into waves by bed material. |
| **Population** | A collection of individuals of the same species that potentially interbreed. |
| **Reach** | A comparatively short length of river, stream channel or shore. The length of the reach is defined by the purpose of the study. |
| **Rearing Habitat** | Habitat used by young fish for feeding and/or as a refuge from predators. |

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| **Riffle** | A reach of stream that is characterized by shallow, fast-moving water broken by the presence of rocks and boulders. |
| **Riffle Habitat** | Shallow rapids where the water flows swiftly over completely or partially submerged materials to produce surface agitation. |
| **Runoff** | The portion of water from rain and snow that flows over land to streams, ponds or other surface waterbodies. It is the portion of water from precipitation that does not infiltrate into the ground, or evaporate. |
| **Sediment** | Solid material that is transported by, suspended in, or deposited from water. It originates mostly from disintegrated rocks; it also includes chemical and biochemical precipitates and decomposed organic material, such as humus. The quantity, characteristics and cause of the occurrence of sediment in streams are influenced by environmental factors. Some major factors are degree of slope, length of slope soil characteristics, land usage and quantity and intensity of precipitation. |
| **Sensitive** | Any species that is not at risk of extinction or extirpation but may require special attention or protection to prevent it from becoming at risk. |
| **Spawning** | The reproductive stage of adult fish which includes fertilization and deposition of eggs. |
| **Spawning Habitat** | A particular type of area where a fish species chooses to reproduce. Preferred habitat (substrate, water flow, temperature) varies from species to species. |
| **Species** | A group of organisms that actually or potentially interbreed and are reproductively isolated from all other such groups; a taxonomic grouping of genetically and morphologically similar individuals; the category below genus. |
| **Sport / Game Fish** | Large fish caught for food or sport (e.g., northern pike, Arctic grayling). |
| **Stream Diversion** | A change or alteration in the natural course of a watercourse or stream either by removal/redirection of the waterflow or physical alteration to the stream channel. |

**Stream Flow** The movement of surface water in a stream channel, usually measured in cubic metres per second ($m^3/s$). It describes the flow at a specific location along the watercourse. Runoff contributed by the entire land area to the stream can be used to describe flow.

**Substrate** Material in the stream bed. The assemblage of material sizes include:

Organic/Silt: organic material and/or fine material less than 0.006 mm diameter;

Sand: material 0.06 to 2.0 mm diameter;

Small Gravel: material 2 to 8 mm diameter;

Large Gravel: material 8 to 32 mm diameter;

Pebble: material 32 to 64 mm diameter;

Cobble: material 64 to 256 mm diameter; and

Boulder: material more than 256 mm diameter.

**Swale** A natural depression or wide shallow ditch used to convey runoff.

**Tailings** A by-product of oil sands extraction typically comprised of water, sands and clays, with minor amounts of residual bitumen.

**Tributary** A stream that feeds or flows into a larger watercourse or waterbody.

**Waterbody** A standing body of water such as a lake or pond.

**Watercourse** A flowing body of water such as a river, stream or creek.

**Watershed** The entire surface drainage area that contributes water to a lake or river.

# APPENDIX 4-9

# AQUATICS MONITORING PROGRAM

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# 1 INTRODUCTION

This appendix presents a conceptual plan of the Aquatic Resources monitoring that Shell Canada Limited (Shell) will undertake for the Jackpine Mine Expansion & Pierre River Mine Project (the Project). A more detailed monitoring plan will be developed and implemented in consultation with regulators and stakeholders after approval of the Project.

The main objectives of the proposed monitoring plan include the following:

- identify and measure potential effects of the Project on the aquatic environment;
- confirm effectiveness of mitigation measures for the Project;
- identify potential and actual sources of aquatic resources effects so that they can be addressed proactively or mitigated through adaptive management mechanisms;
- confirm predictions of Environmental Impact Assessment (EIA) for the Project;
- satisfy potential regulatory and approval requirements by Alberta Environment (AENV) and the Federal Department of Fisheries and Oceans (DFO) for the Project; and
- evaluate the effectiveness of fish habitats constructed to provide compensation for habitats affected by the Project.

This plan includes monitoring of groundwater and surface water flows, levels and quality, sediment quality, aquatic health and fish and fish habitat during the initial, construction, operational and closure phases of the Project. Specific dates for the various phases and associated monitoring period provided in this appendix are based on the timing of activities identified in the EIA. These dates may change, depending on actual project start-up and resulting sequence of mine activities.

## 1.1 SETTING

The proposed monitoring will occur within the Local Study Areas (LSAs) of the Project (Volume 4, Figure 6.2-3). The LSAs are located in two distinct areas on the east and west sides of the lower Athabasca River. The LSA on the east side of the lower Athabasca River encompasses the Jackpine Expansion Mining Area (JEMA) located within the Muskeg River watershed. The LSA on the west side of the river is the Pierre River Mining Area (PRMA), which covers the

JPME R1 ERRATA

watersheds of Pierre River, Asphalt, Eymundson, First, Big and Redclay creeks. Details of the LSAs are provided in Volume 4, Section 6.2.2.

## 1.2 REGIONAL INITIATIVES

Shell participates in several regional initiative programs that provide monitoring and research information. Shell's monitoring programs will be designed in a manner that can inform these initiatives, as well as use regional information to complement the Project-specific monitoring data collected during these Aquatic Resources monitoring programs. The regional initiatives include:

- The Regional Aquatics Monitoring Program (RAMP), which is a regional program to monitor for potential effects of oil sands developments on aquatic environments.
- Alberta Environment's Regional Groundwater Monitoring Initiative for the Athabasca Oil Sands Area.
- The Cumulative Environmental Management Association (CEMA), which develops environmental objectives and management plans with respect to cumulative effects of projects in the region. Various surface water quality studies are supported by CEMA through its Reclamation Working Group, Surface Water Working Group (SWWG) and the $NO_X/SO_2$ Management Working Group.
- The SWWG has six subgroups: the In-Stream Flow Needs Technical Task Group (IFNTTG); Phase 2 Framework Task Group (P2FTG); Socio-Economics Task Group (SETG); Industry Water Needs and Mitigation Options Task Group (IWNMOTG); Watershed Integrity Task Group (WITG) and Surface Water Quality Task Group (WQTG). The IFNTTG is addressing the question: How does the lower Athabasca River respond to changes in flow? The P2FTG is developing the structured decision-making process for deriving a Phase 2 Water Management Framework recommendation. The SETG is addressing the social, cultural, traditional and economic values of the lower Athabasca River and how they relate to water management alternatives. The IWNMOTG has recently been formed to gather information on oil sands industry water needs, now and in the future. The WITG is developing a watershed management plan for the Muskeg River watershed. The WQTG is addressing water quality objectives and management systems for the lower Athabasca River. Details of these task groups are provided in Appendix 3-2, Section 2.3.3.
  - The Canadian Oil Sands Network for Research and Development (CONRAD), which facilitates collaborative research on environmental issues related to oil sands. Relevant CONRAD

projects include research projects on wetlands, pit lakes, toxicity and tainting potential of tailings waters.

Shell is expecting that the results from the regional monitoring and Project-specific monitoring will be consistent with the predictions presented in the Project Environmental Impact Assessment (EIA). If regional monitoring results are found to be substantially different than EIA predictions, Shell will discuss how to address these differences with regulatory and industry stakeholders.

## 1.3 MONITORING PLAN

The monitoring plans below are a comprehensive summary of the proposed activities to assess changes in aquatic resources in the desired end land uses within the Project LSAs and immediately adjacent areas before and during development as well as after reclamation. The plans integrate protocols developed at a regional scale and monitoring previously and currently conducted by Shell for the Muskeg River Mine and Expansion and Jackpine Mine – Phase 1. Information gathered during Shell's baseline studies for this Project has also been considered in the development of these plans. The plans also consider RAMP and other regional and industry monitoring programs to achieve effective data collection within and near the Project area.

The proposed monitoring will be undertaken to verify and manage changes in aquatic resources, confirm performance of mitigation measures and improve environmental protection strategies. The monitoring data will also assist Shell, regulators and stakeholders to identify, understand and isolate the Project effects from other regional development effects on the aquatic environment. Aquatic resources that will be monitored include groundwater and surface water flows, levels and quality, sediment quality, aquatic health and fish and fish habitat.

To isolate and quantify Project effects on aquatic resources, the proposed monitoring will be done at reference and potential exposure sites as well as major mine-related water release points. The reference sites are monitoring locations upstream or upgradient from the Project development area (i.e., not affected by Project activities). The potential exposure sites are within the Project development area or downstream/downgradient from the Project (i.e., potentially affected by the Project). The mine release points will include outflows of polishing ponds, pit lakes and major seepages to receiving surface waters. The use of reference and exposure sites enables changes in aquatic resources due to the Project to be distinguished from natural conditions and effects from other developments.

Different types of monitoring will be undertaken before the start of the Project, and during each phase of the development as follows:

- Pre-project monitoring: gathering additional baseline data on aquatic resources prior to construction and operation of the mine.
- Construction monitoring: measuring changes in Total Suspended Solids (TSS) during periods when civil works are in progress, and until the construction site is stable and the constructed facilities are operational. Construction monitoring is specific to the water quality component of the monitoring plan.
- Operations monitoring: measuring aquatic resources and water quality of mine-related water releases or seepages from the start of the Project to the end of mining.
- Closure monitoring: measuring aquatic resources and water quality of mine-related water releases or seepages during the decommissioning period.

Monitoring phases may overlap for some monitoring sites. In such cases, monitoring will not be duplicated for the site; rather the monitoring program will shift to the next monitoring period. For example, a pre-project monitoring site will change into an operations monitoring site when water releases from polishing ponds begin to reach the site.

Monitoring will measure aquatic resources that may be affected by the Project through seepage to groundwater aquifers, receiving surface waters and man-made waterbodies in the JEMA, PRMA and in the Athabasca River. The natural receiving surface waters within JEMA are the Muskeg River and its tributaries, including Muskeg and Wapasu creeks and Kearl Lake. Iyinimin Creek will be monitored as part of the activity related to mine plan integration for the Project and nearby developments. Monitoring of natural surface waters within PRMA will cover Pierre River, Asphalt, Eymundson, First, Big and Redclay creeks. The Athabasca River will be monitored by RAMP due to cumulative effects from the Project and other regional developments. Man-made waterbodies to be monitored will include the pit lakes and polishing ponds in JEMA and PRMA. In addition, the Redclay Compensation Lake and a Treatment Lake in PRMA will be monitored.

Regional cumulative aquatic resources issues related to releases from the Project and other developments will be monitored through RAMP, Jackpine Mine – Phase 1 monitoring and this Project's specific monitoring program. The information from existing RAMP aquatic resources monitoring locations within the Project development area and data from Jackpine Mine – Phase 1 monitoring will be considered together with data from the proposed Project-specific monitoring program. The addition of RAMP and Jackpine Mine – Phase 1 data to the Project-specific monitoring data will increase spatial coverage for characterizing changes in aquatic resources due to Project activities. Data collected from RAMP, Jackpine Mine – Phase 1, industry monitoring for nearby oil sands developments, the proposed Project-specific monitoring program and historical sampling programs will be analyzed to achieve the objectives of the proposed monitoring plan.

Aquatic resources of the Athabasca River are monitored by RAMP, Environment Canada, AENV and industry. These aquatic monitoring programs and the proposed Project-specific monitoring of natural groundwater aquifers, receiving surface waters and man-made waterbodies in the JEMA and PRMA are sufficient for characterizing changes in aquatic resources of the Athabasca River due to developments in the region, including this Project.

# 2 HYDROGEOLOGY MONITORING PLAN

A groundwater monitoring program will be developed to monitor changes to groundwater quality, levels and flow patterns due to activities associated with development of the Project.

The approach to the groundwater monitoring program is described in the following sections, followed by an overview of the existing groundwater monitoring network for both the JEMA and PRMA developments.

This plan represents an initial design framework based on professional judgement combined with existing knowledge of hydrogeological conditions. Where appropriate, existing monitoring wells will be retained and incorporated into the groundwater monitoring program.

Currently, Albian Sands Energy Inc. (Albian Sands) maintains a groundwater monitoring network at the Muskeg River Mine, southwest of JEMA. A groundwater monitoring program has been developed for Shell's Jackpine Mine – Phase 1 (WorleyParsons Komex 2007a), immediately south of JEMA. The groundwater monitoring program for JEMA was developed with consideration of these adjacent monitoring programs when siting the monitoring well locations. Monitoring results from all three projects will allow changes in groundwater flow patterns and groundwater quality to be assessed on a larger scale than the JEMA alone. The groundwater monitoring programs will be fully integrated among the three projects.

An adaptive management process to review and refine the groundwater monitoring needs will be included in the groundwater monitoring program. Since mining and reclamation are phased, long-term activities, the groundwater monitoring requirements will evolve during the mine life and through closure. The results of the groundwater monitoring program will be reviewed annually, or as directed by Alberta Environment, and proposed changes to the groundwater monitoring program will be provided through the annual groundwater monitoring report that will be submitted to Alberta Environment.

## 2.1 GROUNDWATER MONITORING PROGRAM OVERVIEW

### 2.1.1 Monitoring Well Installation, Development and Hydraulic Conductivity Testing

The following section describes general installation, development and hydraulic conductivity testing methods which have been employed for existing environmental setting monitoring well installations for the Project. These protocols will also be used for future installations for the ongoing Project-related groundwater monitoring program.

New monitoring wells will be constructed of 51 mm (nominal) diameter threaded Polyvinyl Chloride (PVC) pipe with slotted PVC screen. No glues or solvents will be used. Each monitoring well will be completed with a silica or natural sand pack and bentonite seal throughout the annular space above the sand pack.

Monitoring wells completed in Quaternary deposits will generally be installed using continuous flight augers (solid or hollow stem as required). In very coarse-grained deposits such as those found in the Pleistocene Channel (i.e., coarse gravel), a drilling method suited for installing wells in such material (e.g., rotary drilling with Odex system) will be used. Basal Aquifer monitoring wells will be installed using rotary drilling methods.

After installation, all monitoring wells will be developed to remove drilling fluids and fine materials that might have accumulated in the monitoring wells during installation, as well formation water that might have been affected during drilling and monitoring well installation. Monitoring wells completed in Quaternary deposits (except coarse gravel) will generally be developed by bailing. Monitoring wells installed with rotary drilling methods will be developed using air lift pumping methods.

After development, hydraulic conductivity testing will be completed on all monitoring wells using rising or falling-head single well response tests.

All monitoring wells will be surveyed for location and elevation (geodetic). Monitoring wells will be protected using steel casing well covers with lockable caps.

### 2.1.2 Groundwater Sampling Protocols

All monitoring wells will be sampled with a dedicated polyethylene bailer or dedicated polyethylene Waterra inertial pump and polyethylene tubing. Before sampling, the static groundwater level will be measured manually with a standard electric water level sounder. One to three well casing volumes of standing water will then be purged from the monitoring well.

Electrical Conductivity (EC), pH and temperature will be measured in the field for all wells sampled to ensure representative samples are obtained. Groundwater samples for individual analytical packages will be collected into pre-cleaned sample bottles provided by the analytical laboratory. Samples will be field-filtered where necessary (e.g., for dissolved metals). Appropriate preservatives, supplied by the laboratory, will be used where required. After sampling is completed at each location, all equipment will be thoroughly rinsed with distilled water. New polyethylene bailer, rope and nitrile gloves will be used at each monitoring station.

### 2.1.3 Analytical Parameters for Groundwater Quality

Analytical parameters will be grouped into packages of related constituents, and an appropriate suite of analytical packages will be selected for each monitoring event at each well, as discussed in the following sections.

The following analytical suites are selected to reflect parameters that represent common constituents in groundwater (e.g., major ions, metals, sulphides) and those which are known to be naturally associated with oil sands deposits (e.g., Polycyclic Aromatic Hydrocarbons [PAH], phenols and naphthenic acids) or which may be associated with oil sands extraction process waters or facilities (e.g., Polycyclic Aromatic Nitrogenous Hydrocarbons [PANHs] and Benzene, Toluene, Ethylbenzene and Xylenes [BTEX]).

The analytical packages and corresponding suite of individual parameters for each package are outlined in Table 1.

**Table 1 List of Groundwater Analytical Parameters**

| Parameter Group | Parameters |
|---|---|
| major ions/routine potability | calcium, magnesium, sodium, potassium, chloride, sulphate, carbonate, bicarbonate, fluoride, nitrite-nitrate nitrogen as N, iron, manganese, total alkalinity, total hardness, hydroxide, specific conductance and Total Dissolved Solids (TDS) |
| dissolved sulphide | dissolved sulphide |
| dissolved metals | aluminum, barium, beryllium, boron, cadmium, chromium, cobalt, copper, iron, lead, manganese, molybdenum, nickel, phosphorous, silver, strontium, thallium, tin, titanium, uranium, vanadium, zinc, plus hydride metals: arsenic, mercury and selenium |
| Petroleum Hydrocarbons (PHC) | BTEX, PHC Fraction (F)1 ($C_6$-$C_{10}$), PHC F2 ($C_{>11}$-$C_{16}$), PHC F3 ($C_{>17}$-$C_{34}$) |
| Polycyclic Aromatic Hydrocarbons (PAHs) and alkylated PAHs | naphthalene, acenaphthylene, acenaphthene, fluorene, dibenzothiophene, phenanthrene, anthracene, fluoranthene, pyrene, benzo(a)anthracene, benzo(b&k)fluoranthene, benzo(a)pyrene, indeno(c,d-123)pyrene, dibenzo(a,h)anthracene, benzo(ghi)perylene, methyl naphthalene, C2 substituted naphthalene, C3 substituted naphthalene, C4 substituted naphthalene, biphenyl, methyl biphenyl, C2 substituted biphenyl, methyl acenaphthene, methyl fluorene, C2 substituted fluorene, methyl phenanthrene/anthracene, C2 substituted phenanthrene/anthracene, C3 substituted phenanthrene/anthracene, C4 substituted phenanthrene/anthracene, methyl dibenzothiophene, C2 substituted dibenzothiophene, C3 substituted dibenzothiophene, C4 substituted dibenzothiophene, methyl fluoranthene/pyrene, methyl B(a)A/chrysene, C2 substituted B(a)A/chrysene, methyl B(b&k)F/B(a)P and C2 substituted B(b&k)F/B(a)P |
| Polycyclic Aromatic Nitrogen Heterocycles (PANHs) and Alkylated PANHs | quinoline, 7-methyl quinoline, C2 alkyl substituted quinolines, C3 alkyl substituted quinolines, acridine, methyl acridine, phenanthridine, carbazole, methyl carbazoles and C2 alkyl substituted carbazoles |
| total phenols | total phenols |
| naphthenic acids | naphthenic acids |

## 2.1.4 Groundwater Monitoring Schedule

Groundwater monitoring consists of two general components:

- monitoring of groundwater levels; and
- sampling of groundwater for analysis of groundwater quality.

Groundwater levels will be monitored before groundwater quality sampling. Groundwater quality sampling may not be required at all sites. Groundwater level and quality will be monitored regularly as scheduled in Table 2.

Groundwater quality will be monitored regularly; however, the analytical packages used will vary over time. Initially, detailed characterization will include most, if not all, analytical packages noted in Table 1. After initial characterization sampling is completed, ongoing monitoring will involve a select number of analytical packages. For monitoring wells where groundwater quality is a key component of the monitoring program, the initial characterization will involve a minimum of three sampling events, generally collected semi-annually. For monitoring wells where monitoring of water quality is not the primary focus (e.g., overburden dewatering), a single characterization sampling event will be completed for characterization of groundwater quality.

#### 2.1.4.1 Basal Aquifer Depressurization

Groundwater monitoring associated with the Basal Aquifer depressurization focuses primarily on groundwater levels; however, groundwater quality monitoring will also be completed. Groundwater levels will be monitored semi-annually, however, the initial monitoring may be more frequent depending on the location of the monitoring well and operational requirements. The initial characterization sampling for groundwater quality will consist of a single sampling event. Ongoing groundwater quality will be monitored annually following the schedule outlined in Table 2.

Existing Basal Aquifer monitoring wells will be included in the groundwater monitoring network. Additional monitoring wells will be installed as necessary in advance of mining operations to monitor the effects of Basal Aquifer depressurization.

#### 2.1.4.2 Overburden Dewatering

Monitoring associated with overburden dewatering (including Pleistocene Channel dewatering at JEMA) and mine excavation activities focuses primarily on groundwater levels, which will be monitored semi-annually. Groundwater levels will be monitored before mine pit excavation starts in a given area, and continue until the monitoring wells are removed by overburden stripping or until the mine pit is backfilled. The initial characterization sampling for groundwater quality will consist of a single sampling event to establish baseline conditions for the Quaternary overburden deposits. For those wells installed as part of the environmental setting investigation, environmental setting groundwater quality results will be used as the initial characterization.

Monitoring wells will be installed in advance of mining operations, in both the shallow and deep quaternary deposits. Existing monitoring wells will be incorporated to the extent possible.

#### 2.1.4.3 External Tailings Disposal Area

Monitoring of the External Tailings Disposal Area (ETDA) focuses on groundwater quality and groundwater levels. The initial characterization sampling for groundwater quality will consist of three sampling events. Levels and quality of groundwater will be monitored semi-annually for the analytical packages outlined in Table 2.

Monitoring wells will be installed along the perimeter of the ETDA in both the shallow and deep Quaternary deposits to monitor seepage and the effectiveness of the mitigation measures. In the JEMA, monitoring wells will also be installed within the Pleistocene Channel.

#### 2.1.4.4 Pit Backfilling and Reclamation

Monitoring associated with backfilling of pits and reclamation focuses on both groundwater levels and quality. The initial characterization sampling for groundwater quality will consist of three sampling events. Groundwater levels and quality will be monitored semi-annually for the analytical packages outlined in Table 2.

Monitoring wells installed as part of overburden dewatering monitoring network will be retained for the monitoring of pit backfilling and reclamation. Additional monitoring wells will be installed as required by the hydrogeological conditions at that time.

#### 2.1.4.5 Plant Facilities

The primary objective of groundwater monitoring at the plant sites and the ore processing facilities is groundwater quality monitoring, with monitoring of groundwater levels as a secondary objective. Groundwater levels and quality will be monitored semi-annually and will generally follow the analytical schedule shown in Table 2. However, parameters selected will depend on the nature of the potential source being monitored. For example, for locations with the potential for impacts from process water or tailings, indicator parameters include total phenols and naphthenic acids. At locations where hydrocarbons (solvent or fuel) are expected, indicator parameters will include BTEX+PHC F1 and PHC F2.

Groundwater monitoring wells will be installed in the shallow and deep Quaternary deposits to monitor the effects of the plant activities on groundwater. Target areas will include ponds, storage tanks and processing facilities. Monitoring wells will also be installed upgradient of the facility.

## Table 2 Groundwater Monitoring Schedule

| Program Component | Monitoring Schedule | | | Analytical Parameter Groups[a] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. of Initial Water Quality Sampling Events | Groundwater Quality Frequency | Groundwater Level Frequency | Major Ions | Dissolved Sulphides | Dissolved Metals | BTEX + PHC F1 | PHC F2 and F3 | PAHs | PANHs and Alkylated PANHs | Total Phenols | Naphthenic Acids |
| Basal Aquifer Depressurization | 3 | annual | semi-annual | i, om | i, om | i | i | i | i | i | i | i |
| Overburden Dewatering[b] | 3 | - | semi-annual | i, om | i | i | i | i | i | i | i | i |
| External Tailings Disposal Area | 3 | semi-annual | semi-annual | i, om | - | i, om | i, om | i, om | i | i | i | i |
| Pit Backfill and Reclamation | 3 | semi-annual | semi-annual | i, om | - | i, om | i | i | i | i | i, om | i, om |
| Plant Site and Ore Processing Facilities | 3 | semi-annual | semi-annual | i, om | - | i, om | i, om | i, om | i | i | i, om | i, om |

(a) Refer to Table 1 for a detailed list of parameters in each analytical parameter group.

(b) Includes Pleistocene Channel dewatering for the JEMA development.

Note: i - denotes included in initial sampling characterization; om - denotes included in ongoing monitoring following initial sampling characterization; '-' denotes not included.

### 2.1.5 Groundwater Response

Should significant, unexpected effects on groundwater levels or quality (relative to environmental setting conditions) be detected through the groundwater monitoring program at either the JEMA or PRMA developments, an incident-specific groundwater response plan will be developed and implemented. In general, the plan would include the following elements:

- conduct confirmatory sampling;
- notify Alberta Environment upon confirmation;
- assess monitoring frequency and adjust as required;
- identify the source(s);
- determine the magnitude and extent of effects;
- develop a remediation plan and/or risk management strategy, if necessary;
- isolate or remove the source(s), if possible;
- submit the remediation plan and/or risk management strategy to Alberta Environment for approval; and
- implement the remediation plan and/or risk management strategy.

### 2.1.6 Quality Assurance/Quality Control

The Quality Assurance/Quality Control (QA/QC) program, to be implemented for the groundwater quality program, will be in keeping with the requirements of the Canadian Council of Ministers of the Environment (CCME 1993a). The QA/QC program includes field sampling methods, replicate sampling, specification of level of detection and laboratory QA/QC protocols.

The protocols required for sampling, storage and transportation of groundwater samples will be aimed at obtaining representative samples and maintaining the integrity of those samples between the field and the lab. Complete chain of-custody procedures will be maintained throughout the program; chain-of-custody forms provided by the analytical laboratory will be used for the groundwater sampling program.

The precision and accuracy in the laboratory results will be assessed. In addition to using a laboratory with accredited internal QA/QC standards, Shell will also submit an appropriate number of duplicates to enable external control. From an internal control perspective, the chosen laboratory will participate in national QA/QC programs and score satisfactorily on accuracy.

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The laboratory will have a satisfactory internal QA/QC program. Key factors which will be reviewed for the proposed programs are chain-of-custody, storage and holding times, sample preparation holding times, laboratory QA/QC samples (i.e., method blanks, instrument blanks, duplicates and spikes), instrument calibration, sample analysis influences, validation and reporting and documentation and record keeping. The laboratory will have an internal analytical QA/QC program, and applies data management protocols that meet the requirements of CCME (1993 a,b).

The field component of QA/QC will include about 10% of samples for quality control, which will include field duplicates, travel blanks and/or equipment blanks.

### 2.1.7 Reporting

An annual groundwater monitoring report will be prepared and submitted to Alberta Environment. This report will be prepared as per Alberta Environment requirements. The reporting will review all of the monitoring results for the year, assess trends, describe projects effects and mitigation measures, and any remediation or risk management undertaken. The annual report will also include recommendations for changes to the groundwater monitoring program to make it more effective.

## 2.2 CURRENT MONITORING ACTIVITIES

Albian Sands Energy Inc. maintains a groundwater monitoring program as per the conditions of Alberta *Environmental Protection and Enhancement Act* (EPEA) Approval, Clauses 4.6.1 to 4.6.8. The groundwater monitoring program for the Muskeg River Mine was developed in 1999 (Komex 2004). The Muskeg River Mine Groundwater Monitoring Program meets the terms of AENV Amending Approval Number 20809-00-01, Section 4.6 for Muskeg River (Lease 13) Oil Sands Processing Plant and Mine. WorleyParsons Komex (2007b) presents the 2006 results from the Muskeg River Mine.

The EPEA Approval Number 153125-00-00 was issued to Shell Canada Limited for the construction, operation and reclamation of the Shell Jackpine Oil Sands Project (Oil Sands Processing Plant and Mine) – Phase I. As per the requirements of Section 4.7.1 of the Approval, a groundwater monitoring program was developed and submitted to AENV in April 2006. This program was subsequently approved by AENV in 2007. The implementation of the groundwater monitoring program started in the summer of 2007, with the installation of proposed monitoring wells. Annual groundwater monitoring reports will be submitted to AENV starting in April 2008.

## 2.3 PROJECT MONITORING

The groundwater monitoring program for the JEMA and PRMA will incorporate the existing groundwater monitoring wells installed as part of the environmental setting investigation. Where possible, groundwater monitoring wells will be installed in each area before mining activities begin to allow for sampling to establish baseline conditions at each monitoring location. The groundwater monitoring network will evolve throughout the life of the Project to adequately characterize the effects of the Project on groundwater resources.

### 2.3.1 Pre-Project Monitoring

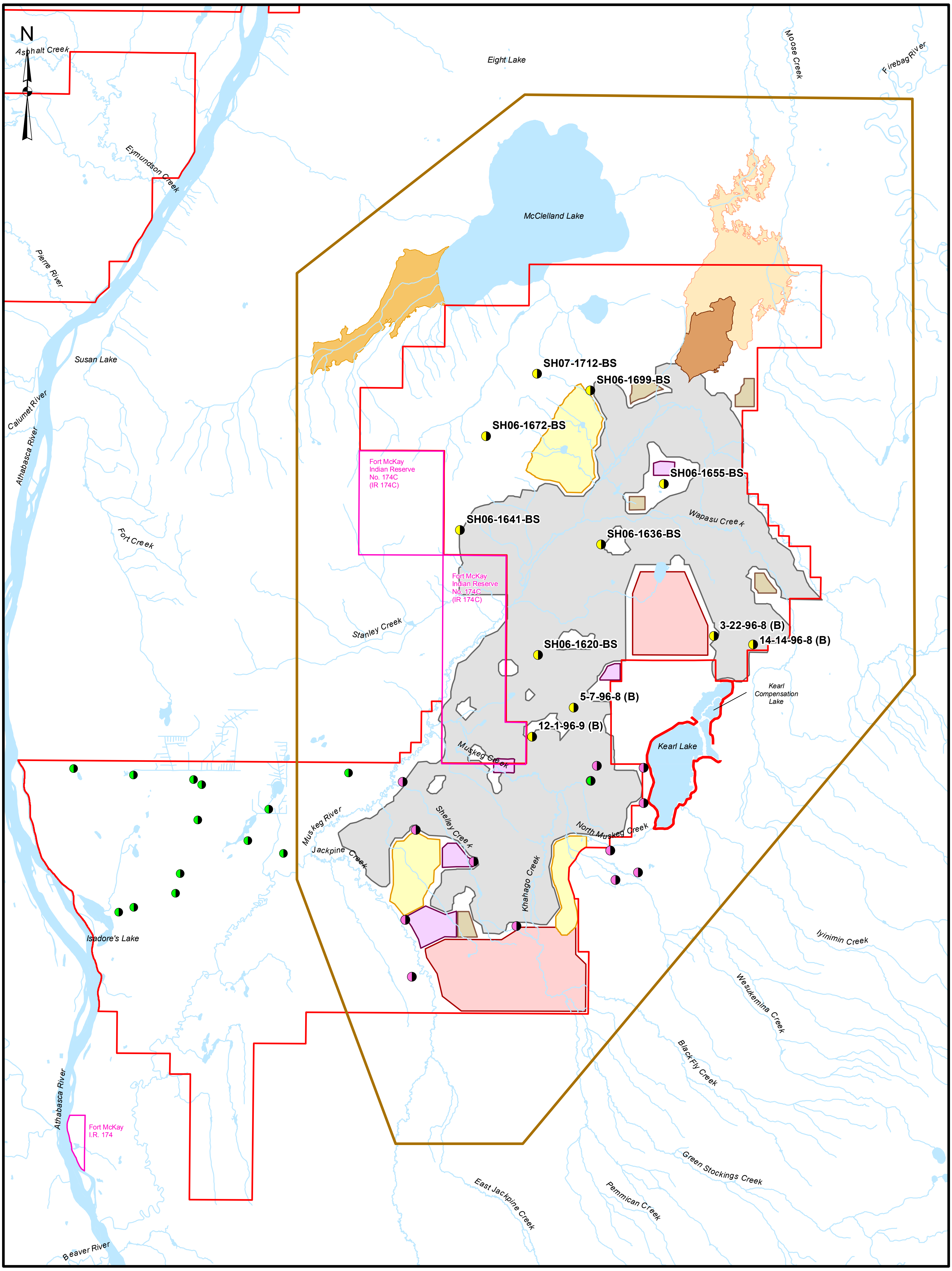
As part of the environmental setting investigation for the Project, a groundwater monitoring network was installed within and around both the JEMA and PRMA development areas, which is briefly described in the following sections. Detailed information on the location and history of the existing networks at each development is provided by WorleyParsons Komex (2007a).

#### 2.3.1.1 Jackpine Expansion Mining Area

For the JEMA development, the groundwater monitoring network installed as part of the environmental setting investigation included:

- seven monitoring wells installed in the McMurray Formation Basal Aquifer;
- four wells installed in the Pleistocene Channel; and
- seventeen wells installed in the shallow and deep Quaternary deposits.

In addition to the above wells, several historical wells are located in the JEMA leases (Leases 15, 31, 36, 88, 89, 631 and 632), including four Basal Aquifer wells, three Pleistocene Channel wells and three Quaternary wells. Figures 1 through 3 illustrate the location of the monitoring wells, both historical and recently installed, in the Basal Aquifer, Pleistocene Channel and Quaternary deposits at the JEMA development.




**LEGEND**

- JACKPINE EXPANSION MINING AREA EXISTING MONITORING WELL
- JACKPINE MINE PHASE 1 EXISTING/APPROVED COMPLIANCE MONITORING WELL
- MUSKEG RIVER MINE EXISTING COMPLIANCE MONITORING WELL
- JACKPINE EXPANSION MINING AREA LOCAL STUDY AREA
- INDIAN RESERVE
- SHELL LEASE
- OPEN WATER
- LAKE PERIMETER LEVEE
- PATTERNED FEN
- LENTICULAR FEN
- McCLELLAND FEN
- PLANT AND ORE PROCESSING FACILITY
- RECLAMATION MATERIAL STOCKPILE
- OVERBURDEN DISPOSAL AREA
- EXTERNAL TAILINGS FACILITY AREA
- MINING AREA

4 0 4

SCALE 1:150,000 KILOMETRES

**REFERENCE**

Alberta digital data obtained from AltaLIS (September 2004) mine areas and lease boundaries obtained from Shell.
Projection: Transverse Mercator Datum: NAD 83 Coordinate System: UTM Zone 12

PROJECT

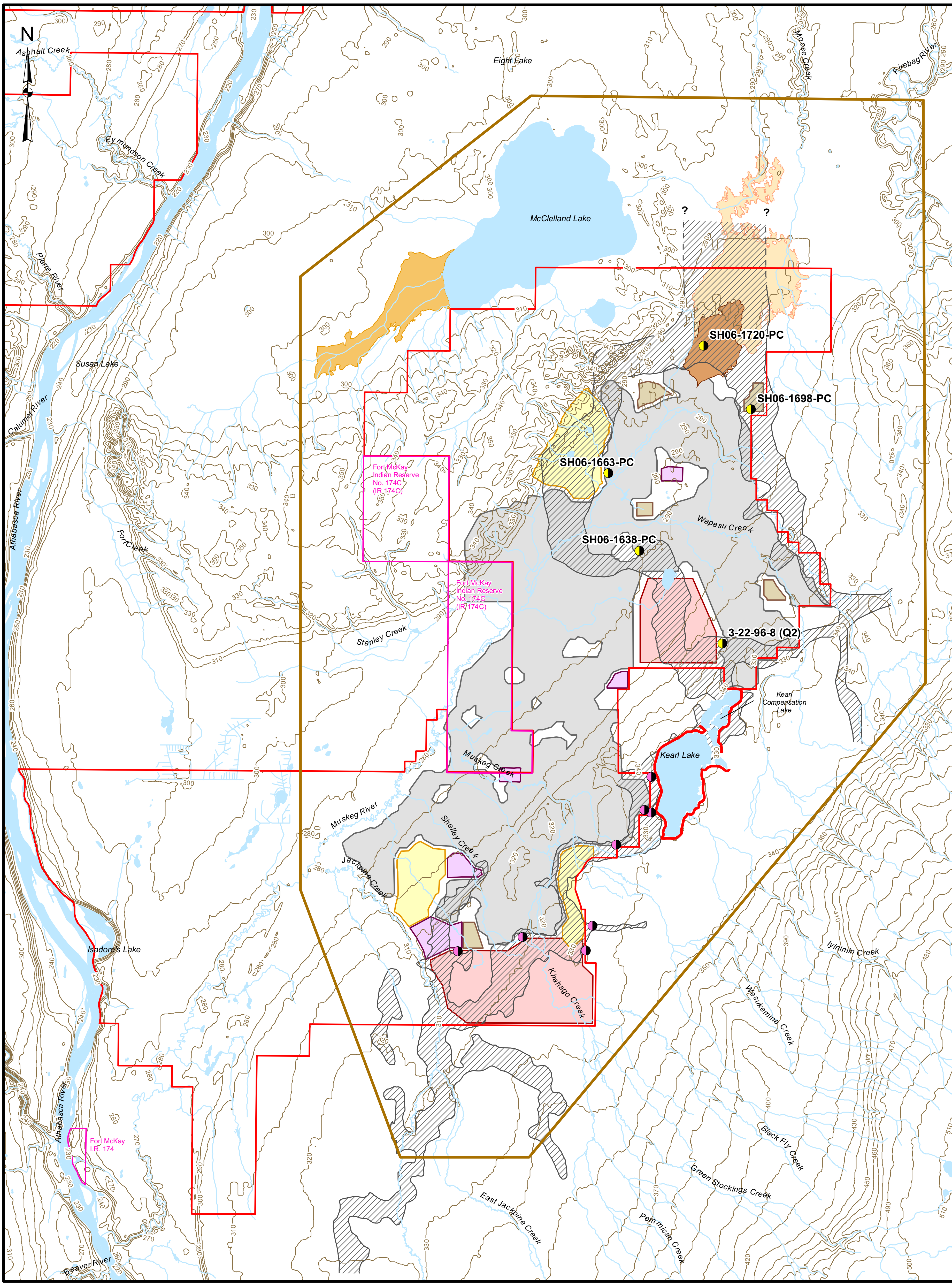
JACKPINE MINE EXPANSION & PIERRE RIVER MINE PROJECT

TITLE

**JACKPINE EXPANSION MINING AREA – EXISTING GROUNDWATER MONITORING NETWORK – BASAL AQUIFER MONITORING WELLS**

Shell Canada Limited

| PROJECT No. 05-1344-027.9000 | | | SCALE AS SHOWN | REV. 0 |
|---|---|---|---|---|
| DESIGN | JH | 25 Jun. 2007 | FIGURE: 1 | |
| GIS | SL | 29 Nov. 2007 | | |
| CHECK | SL | 29 Nov. 2007 | | |
| REVIEW | JK | 30 Nov. 2007 | | |




## LEGEND

- JACKPINE EXPANSION MINING AREA EXISTING MONITORING WELL
- JACKPINE MINE PHASE 1 EXISTING/APPROVED COMPLIANCE MONITORING WELL
- JACKPINE EXPANSION MINING AREA LOCAL STUDY AREA
- INDIAN RESERVE
- SHELL LEASE
- PLEISTOCENE CHANNEL AQUIFER
- ? LIMIT OF DATA
- GROUND SURFACE CONTOUR (masl) CONTOUR INTERVAL = 10 m
- OPEN WATER
- LAKE PERIMETER LEVEE
- PATTERNED FEN
- LENTICULAR FEN
- McCLELLAND FEN
- PLANT AND ORE PROCESSING FACILITY
- RECLAMATION MATERIAL STOCKPILE
- OVERBURDEN DISPOSAL AREA
- EXTERNAL TAILINGS FACILITY AREA
- MINING AREA

4 0 4

SCALE 1:150,000 KILOMETRES

## REFERENCE

Alberta digital data obtained from AltaLIS (September 2004); mine areas and lease boundaries obtained from Shell.
Projection: Transverse Mercator Datum: NAD 83 Coordinate System: UTM Zone 12

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

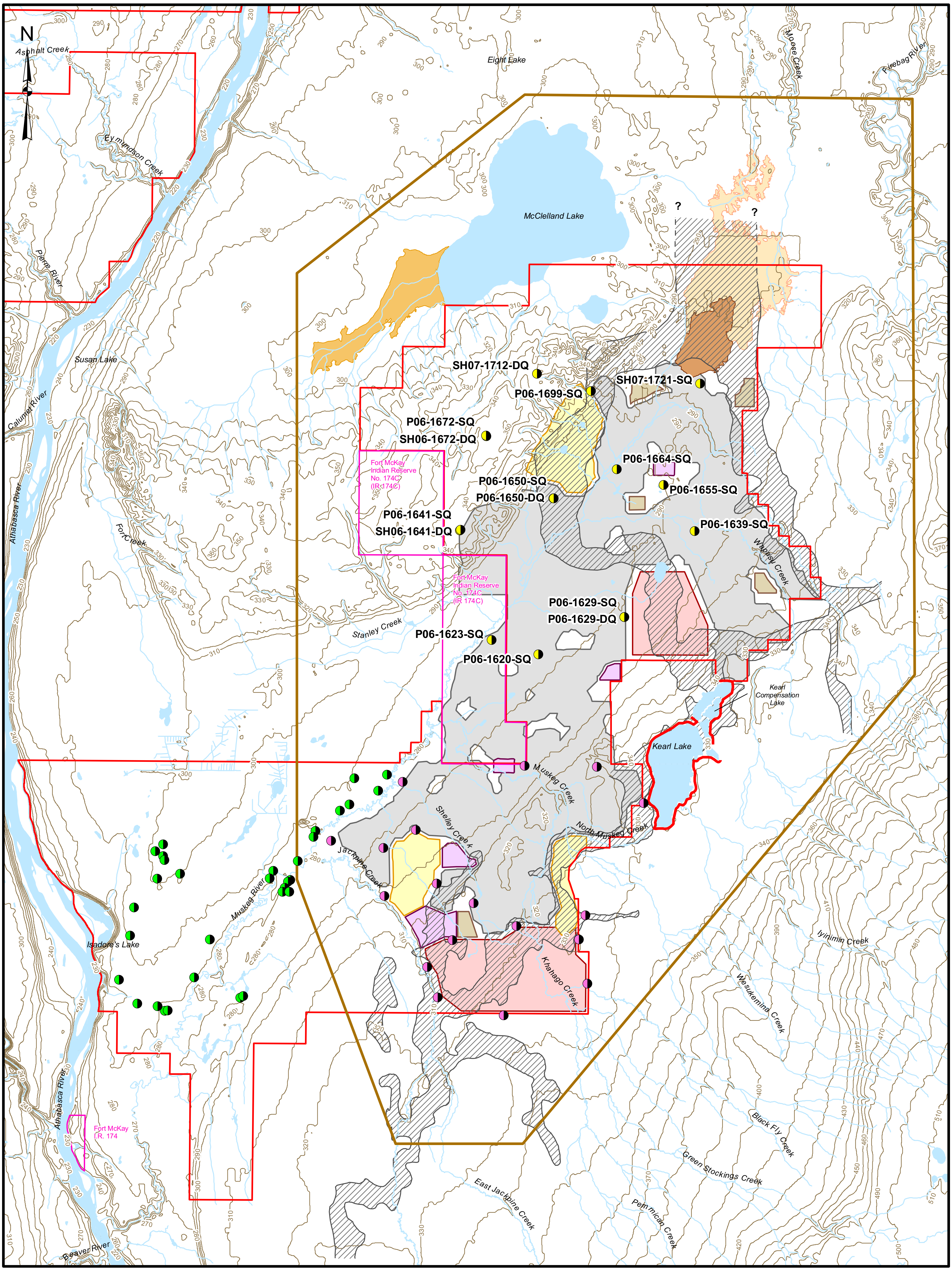
TITLE

**JACKPINE EXPANSION MINING AREA – EXISTING GROUNDWATER MONITORING NETWORK – PLEISTOCENE CHANNEL MONITORING WELLS**

Shell Canada Limited

| PROJECT No. 05-1344-027.9000 | | | SCALE AS SHOWN | REV. 0 |
|---|---|---|---|---|
| DESIGN | JH | 25 Jun. 2007 | **FIGURE: 2** | |
| GIS | SL | 29 Nov. 2007 | | |
| CHECK | SL | 29 Nov. 2007 | | |
| REVIEW | JK | 30 Nov. 2007 | | |

Project: Q:\F3577_Shell\F35772801_Omnibus\EIA_Figures\Monitoring_appendix\Existing_networks\JEMA_PCA.mxd




## LEGEND

- JACKPINE EXPANSION MINING AREA EXISTING MONITORING WELL
- JACKPINE MINE PHASE 1 EXISTING/APPROVED COMPLIANCE MONITORING WELL
- MUSKEG RIVER MINE EXISTING COMPLIANCE MONITORING WELL
- JACKPINE EXPANSION MINING AREA LSA
- INDIAN RESERVE
- SHELL LEASE
- PLEISTOCENE CHANNEL AQUIFER
- – – ? LIMIT OF DATA
- GROUND SURFACE CONTOUR (masl) CONTOUR INTERVAL = 10 m
- OPEN WATER
- LAKE PERIMETER LEVEE
- PATTERNED FEN
- LENTICULAR FEN
- McCLELLAND FEN
- PLANT AND ORE PROCESSING FACILITY
- RECLAMATION MATERIAL STOCKPILE
- OVERBURDEN DISPOSAL AREA
- MINING AREA
- EXTERNAL TAILINGS FACILITY AREA

4 0 4

SCALE 1:150,000 KILOMETRES

## REFERENCE

Alberta digital data obtained from AltaLIS (September 2004); mine areas and lease boundaries obtained from Shell.
Projection: Transverse Mercator Datum: NAD 83 Coordinate System: UTM Zone 12

PROJECT

JACKPINE MINE EXPANSION & PIERRE RIVER MINE PROJECT

TITLE

**JACKPINE EXPANSION MINING AREA – EXISTING GROUNDWATER MONITORING NETWORK – OVERBURDEN MONITORING WELLS**

Shell Canada Limited

| PROJECT No. 05-1344-027.9000 | | | SCALE AS SHOWN | REV. 0 |
|---|---|---|---|---|
| DESIGN | JH | 25 Jun. 2007 | **FIGURE: 3** | |
| GIS | SL | 29 Nov. 2007 | | |
| CHECK | SL | 29 Nov. 2007 | | |
| REVIEW | JK | 30 Nov. 2007 | | |

Project: Q:\F3577_Shell\F35772801_Omnibus\EIA_Figures\Monitoring_appendix\Existing_networks\JEMA_Overburden.mxd

#### 2.3.1.2 Pierre River Mining Area

For the PRMA development, the groundwater monitoring network installed as part of the environmental setting investigation includes:

- nine monitoring wells installed in the McMurray Formation Basal Aquifer; and
- fourteen wells installed in the shallow and deep Quaternary deposits.

Figures 4 and 5 illustrate the location of the monitoring wells currently installed in the Basal Aquifer and Quaternary deposits at the PRMA Project.

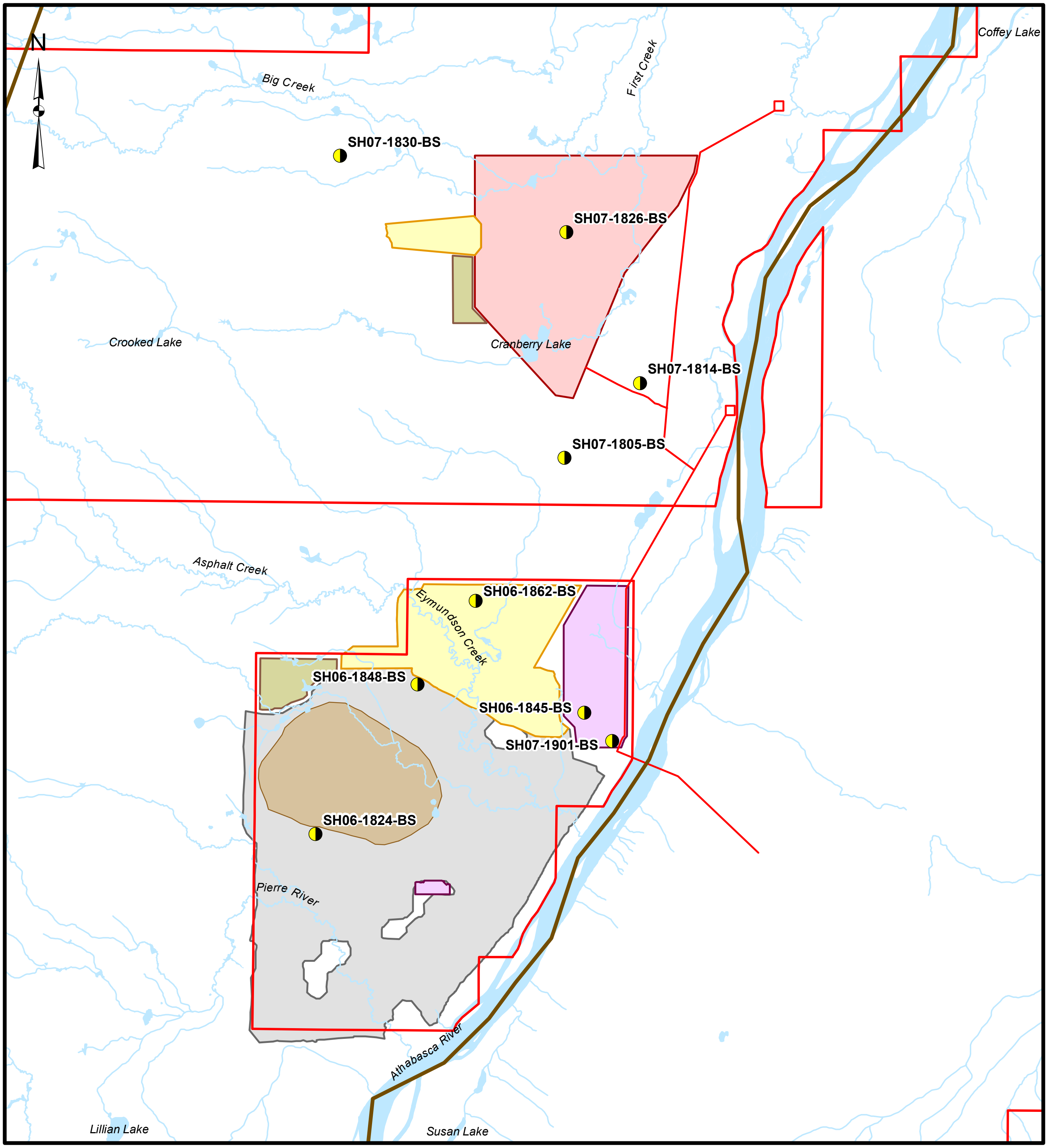
### 2.3.2 Construction Monitoring

No groundwater monitoring activities are anticipated to be required as part of the construction operations at the JEMA and PRMA development areas. Dewatering of overburden deposits and depressurization of the Basal Aquifer are phased, long-term activities that are included under Operations Monitoring.

### 2.3.3 Operations Monitoring

Activities associated with the operations of the Project include Basal Aquifer depressurization, overburden dewatering (including Pleistocene Channel aquifer dewatering in JEMA), operation of the ETDA, pit backfilling and reclamation, and plant operations.

The Groundwater Monitoring Program will monitor potential changes to groundwater quality, levels and flow patterns due to the Project activities. The monitoring program, including the location and number of wells, will be refined and optimized throughout the Project life, taking into account previous monitoring results and the ongoing changes of the development. Project effects will be determined based on the background data collected for each monitoring well before operations begin in the area of the monitoring wells. Monitoring wells may be removed while others are added as the Project evolves and areas are mined and reclaimed.




**LEGEND**

- PIERRE RIVER MINING AREA EXISTING MONITORING WELL
- PIERRE RIVER MINING AREA LOCAL STUDY AREA
- SHELL LEASE
- OPEN WATER
- EYMUNDSON SINKHOLES ESA
- PLANT AND ORE PROCESSING FACILITY
- RECLAMATION MATERIAL STOCKPILE
- OVERBURDEN DISPOSAL AREA
- EXTERNAL TAILINGS FACILITY AREA
- MINING AREA

2.5 0 2.5

SCALE 1:120,000 KILOMETRES

**REFERENCE**

Alberta digital data obtained from AltaLIS (September 2004); ESA from Golder; mining areas and lease boundaries obtained from Shell.

Projection: Transverse Mercator Datum: NAD 83 Coordinate System: UTM Zone 12

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

**PIERRE RIVER MINING AREA – EXISTING GROUNDWATER MONITORING NETWORK – BASAL AQUIFER MONITORING WELLS**

Shell Canada Limited

| PROJECT No. 05-1344-027.9000 | | | SCALE AS SHOWN | REV. 0 |
|---|---|---|---|---|
| DESIGN | JH | 25 Jun. 2007 | **FIGURE: 4** | |
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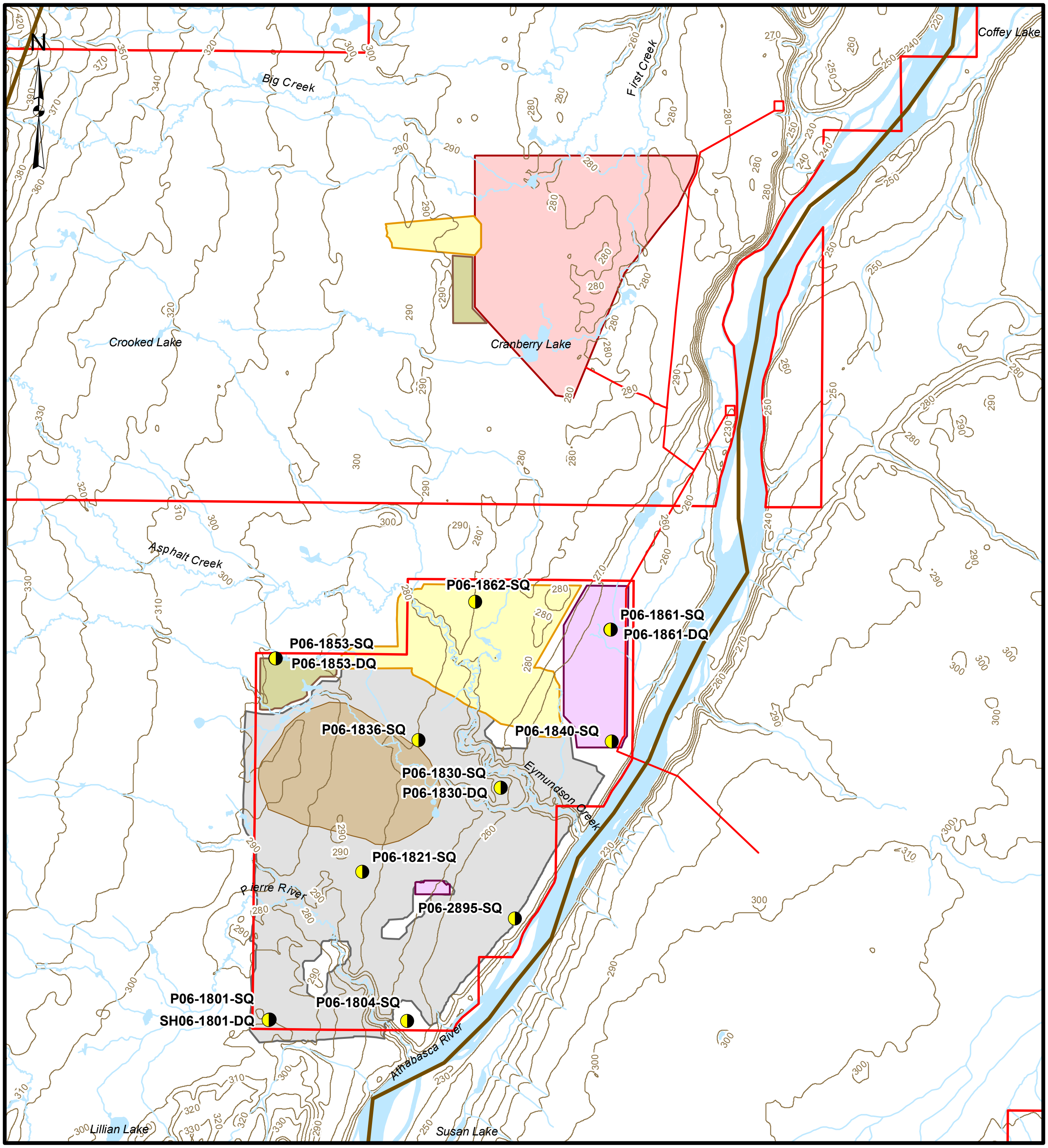
| CHECK | SL | 29 Nov. 2007 | | |
| REVIEW | JK | 30 Nov. 2007 | | |




**LEGEND**

- PIERRE RIVER MINING AREA EXISTING MONITORING WELL
- PIERRE RIVER MINING AREA LOCAL STUDY AREA
- SHELL LEASE
- OPEN WATER
- EYMUNDSON SINKHOLES ESA
- GROUND SURFACE CONTOUR (masl) CONTOUR INTERVAL = 10 m
- PLANT AND ORE PROCESSING FACILITY
- RECLAMATION MATERIAL STOCKPILE
- OVERBURDEN DISPOSAL AREA
- EXTERNAL TAILINGS FACILITY AREA
- MINING AREA

2.5 0 2.5

SCALE 1:120,000 KILOMETRES

**REFERENCE**

Alberta digital data obtained from AltaLIS (September 2004); ESA from Golder; mining areas and lease boundaries obtained from Shell.
Projection: Transverse Mercator Datum: NAD 83 Coordinate System: UTM Zone 12

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

**PIERRE RIVER MINING AREA – EXISTING GROUNDWATER MONITORING NETWORK – QUATERNARY MONITORING WELLS**

Shell Canada Limited

| PROJECT No. 05-1344-027.9000 | | | SCALE AS SHOWN | REV. 0 |
|---|---|---|---|---|
| DESIGN | JH | 25 Jun. 2007 | **FIGURE: 5** | |
| GIS | SL | 29 Nov. 2007 | | |
| CHECK | SL | 29 Nov. 2007 | | |
| REVIEW | JK | 30 Nov. 2007 | | |

Project: Q:\F3577_Shell\F35772801_Omnibus\EIA_Figures\Monitoring_appendix\Existing_networks\PRMA_Quaternary.mxd

### 2.3.4 Closure Monitoring

Closure monitoring for the Project will focus on monitoring groundwater flow and quality in all formations (i.e., Quaternary deposits, Pleistocene Channel, Basal Aquifer) to confirm that hydrogeological and hydrochemical conditions at both the JEMA and PRMA developments are returning to acceptable conditions.

Monitoring of reclaimed areas will occur progressively during the life of the Project and will provide data for the refinement of the groundwater monitoring needs at mine closure. Following mine closure and reclamation, groundwater monitoring will confirm that a shallow groundwater flow system is re-established and that water levels in shallow aquifers and in the Basal Aquifer return to acceptable levels. Should monitoring after closure indicate that groundwater level recovery and groundwater quality are not meeting expected progress, a response plan will be developed and implemented.

It is anticipated that monitoring wells used throughout the life of the Project will continue to be used for closure monitoring. Depending on the results of groundwater monitoring during operations, modifications to the monitoring network may be required to provide adequate closure monitoring. Additional monitoring wells will be progressively installed as mining areas are reclaimed.

# 3 HYDROLOGY MONITORING PLAN

The section addresses the climate and hydrometric monitoring programs before and after the Project begins in the JEMA and PRMA LSAs and RSA.

## 3.1 CURRENT MONITORING ACTIVITIES

### 3.1.1 Climate Data

#### *Jackpine Expansion Mining Area Local Study Area*

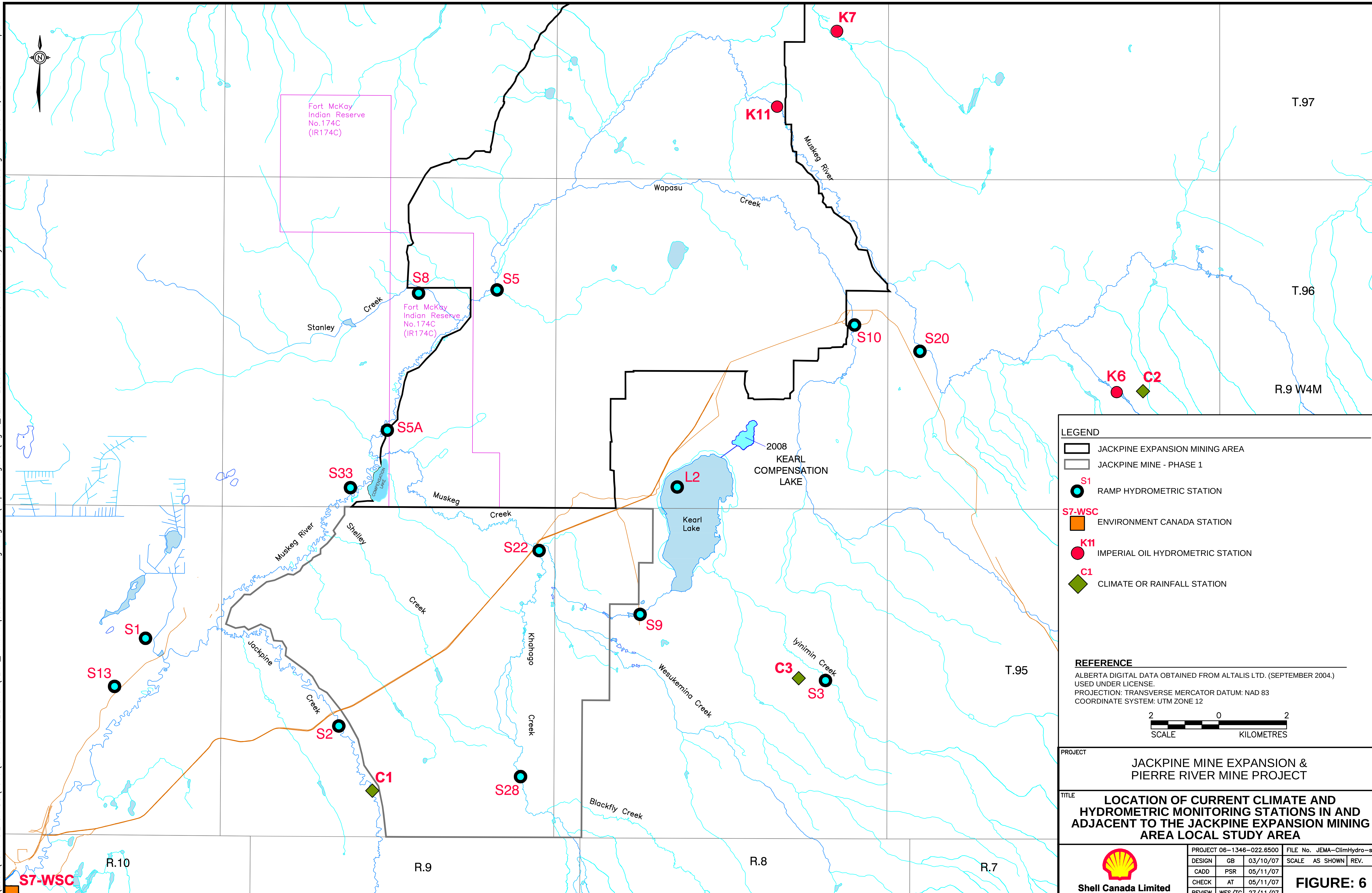
The pre-project climate monitoring programs in the JEMA LSA include RAMP and Imperial Oil Resources Ventures Ltd. (Imperial Oil) monitoring programs. The only year-round climate station (Aurora climate station, C1) in the JEMA LSA is operated by RAMP and has been in operation since 1995. Imperial Oil has operated a summer rainfall station within the Kearl Oil Sands development area since 2002 (C2). A summer rainfall station adjacent to the Iyinimin Creek is also operated by RAMP from May 2004 to October 2005 (C3).

#### *Pierre River Mining Area Local Study Area*

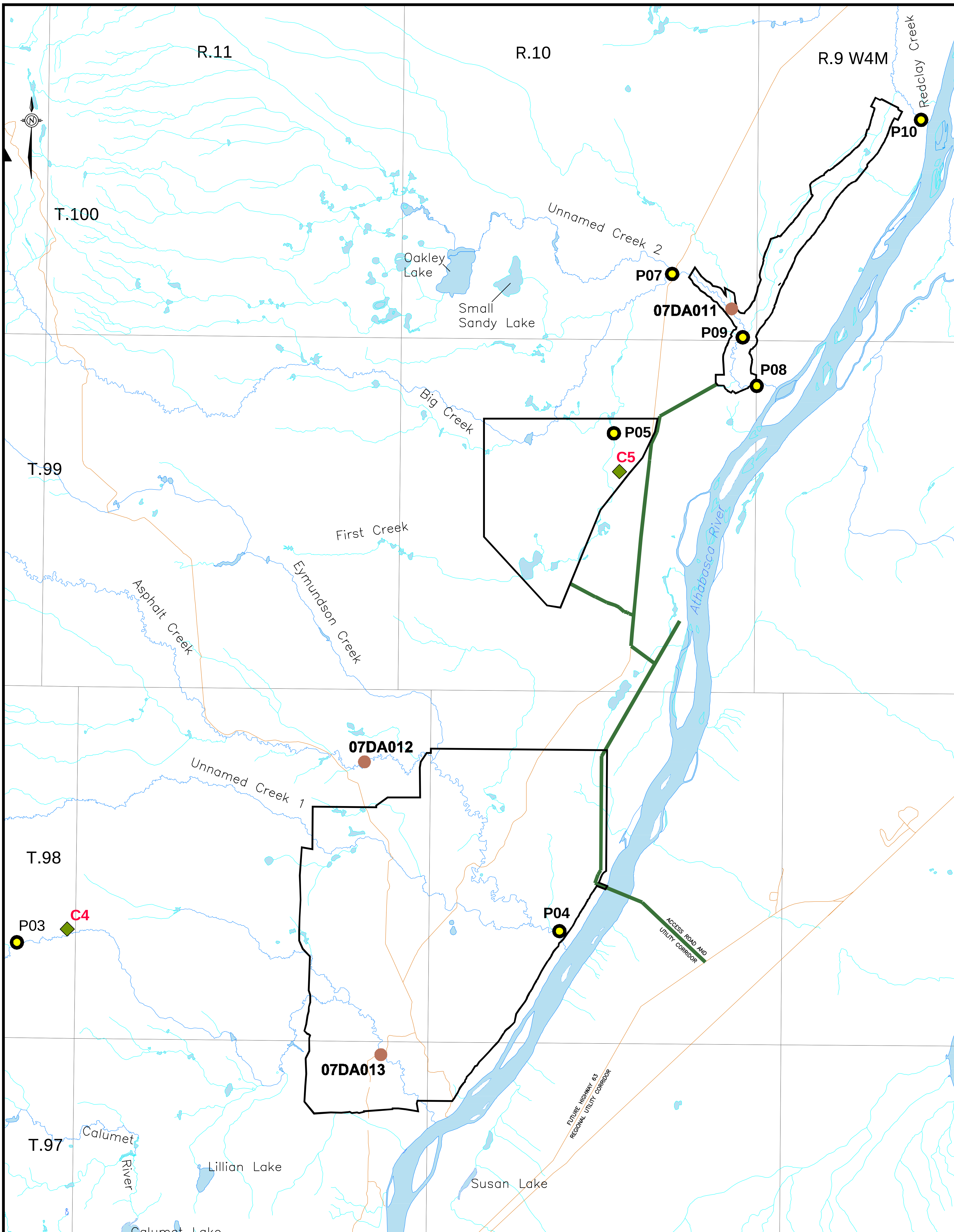
The only pre-project climate monitoring program in the PRMA LSA is the climate monitoring program initiated by Shell in 2005 as part of environmental setting study for the PRMA project. In fall 2005, one precipitation station was installed in the Pierre River watershed (C4) to monitor year-round precipitation and another rainfall station was installed in the First Creek watershed (C5).

Alberta Sustainable Resources Development (ASRD) has also operated seasonal rainfall stations at the Birch Mountain and the Ells lookout stations near the PRMA LSA since the early 1960s. The Birch Mountain Lookout station is located at the boundary of the head watershed of Big Creek and has been recording seasonal rainfall data since 1966. The Ells Lookout station is located southwest of the PRMA LSA in the Ells River watershed and has been recording seasonal rainfall data since 1964. A climate station south of the PRMA LSA (i.e., near the mouth of Calumet River) was also operated by RAMP from January 2003 to October 2005.

The ASRD and RAMP climate stations are equipped with data loggers to store measured data and are downloaded during seasonal field trips. Figures 6 and 7 show the locations of current climate monitoring stations in the JEMA and PRMA LSAs, respectively.




L:\2006\1344-OIL SANDS\1346\06-1346-022 Shell\JEMA_PRMA-Aquatics Monitoring Program\Report Figures\Fig 6_JEMA Location of Current Climate and Hydrometric Stations.dwg Dec 06, 2007 - 1:43pm




LEGEND

PIERRE RIVER MINING AREA

P03 SHELL HYDROMETRIC STATIONS

07DA013 DISCONTINUED ENVIRONMENT CANADA HYDROMETRIC STATIONS

C4 CLIMATE OR RAINFALL STATION

REFERENCE

ALBERTA DIGITAL DATA OBTAINED FROM ALTALIS LTD. (SEPTEMBER 2004.)
USED UNDER LICENSE. PROJECTION: TRANSVERSE MERCATOR
DATUM: NAD 83 COORDINATE SYSTEM: UTM ZONE 12

2 0 2
SCALE KILOMETRES

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

**LOCATION OF CURRENT CLIMATE AND HYDROMETRIC MONITORING STATIONS IN AND ADJACENT TO THE PIERRE RIVER MINING AREA LOCAL STUDY AREA**

**Shell Canada Limited**

| PROJECT 06-1346-022.6500 | | | FILE No. C&H-NODES | | |
|---|---|---|---|---|---|
| DESIGN | GB | 03/10/07 | SCALE | AS SHOWN | REV. 0 |
| CADD | PSR | 05/11/07 | **FIGURE: 7** | | |
| CHECK | AT | 05/11/07 | | | |
| REVIEW | WES/TC | 27/11/07 | | | |

### 3.1.2 Hydrometric Data

The pre-project hydrometric monitoring programs in the JEMA and PRMA LSAs include RAMP, Environment Canada, Shell and Kearl Oil Sands Project monitoring programs. Typically, each hydrometric station is equipped with a pressure transducer to continuously measure water depth and a data logger to store the recorded data. Seasonal visits are made to each station to measure stream flow rate and water level relative to a benchmark. The flow rates and water levels at the station are used to plot a graph for determining the flow rates corresponding to the continuous water depths recorded by the pressure transducer. The pre-project hydrometric monitoring programs in the JEMA and PRMA LSAs are described below.

#### *Jackpine Expansion Mining Area Local Study Area*

Stream flows and water levels in the Oil Sands Region have been monitored by RAMP since 1997 (RAMP 2006). The RAMP programs are partly funded by Shell.

The locations of hydrometric stations in and adjacent to the JEMA LSA are shown in Figure 6. The watercourses and waterbody that are being monitored by RAMP in the JEMA LSA include Muskeg River (S33, S5A, S5 and S20), Jackpine Creek (S2), Muskeg Creek (S22 and S9), Shelley Creek (S21), Stanley Creek (S8), Wapasu Creek (S10), Iyinimin Creek (S3), Khahago Creek (S28) and Kearl Lake (L2). Some of these local, short-term hydrometric stations were active as early as 1995, before RAMP was initiated.

The Water Survey Branch of Environment Canada has only one active monitoring station (Muskeg River, S7) in the JEMA LSA. The station is located close to the mouth of the Muskeg River and monitors flows and water levels. The station has been in operation since 1974. The hydrometric station on Jackpine Creek (S2) was operated by Environment Canada from 1975 to 1993, after which RAMP took over the station operation in 1995.

A one-year monitoring program was conducted as part of JEMA environmental setting study from fall 2005 through fall 2006 for stations P01 and P02.

Three hydrometric stations were installed by Imperial Oil in the Muskeg River watershed between June 2003 and May 2004 to monitor stream flows in and near the proposed Kearl Oil Sands Project Development Area including K6, K7 and K11, as shown in Figure 6.

### *Pierre River Mining Area Local Study Area*

In the PRMA LSA, Environment Canada operated hydrometric stations near the mouth of Pierre River (Station No. 07DA013) from 1975 to 1977, near the mouth of Asphalt Creek (Station No. 07DA012) from 1975 to 1977 and near the mouth of Big Creek (Station No. 07DA011) from 1975 to 1993.

Shell installed seven hydrometric monitoring stations to monitor stream flows as part of the environmental setting study in the PRMA LSA (Figure 7). A one-year monitoring program was completed from fall 2005 through fall 2006 at Station P04. Hydrometric monitoring is on-going at Stations P03, P05, P07, P08, P09 and P010, since sufficient local data is not available in the PRMA LSA.

### *Lower Reach of Athabasca River*

The river flows in the lower Athabasca River below Fort McMurray have been monitored by Environment Canada since 1957 and RAMP has been operating a station at S24 (below Eymundson Creek) since 2001. These stations will continue to be operated by RAMP and Environment Canada. No additional monitoring will be required on the lower Athabasca River to capture hydrologic changes due to regional developments, including this Project.

## 3.2 PROJECT MONITORING PLAN

### 3.2.1 Pre-Project Monitoring

The current climate and hydrometric monitoring programs by Shell in the JEMA and PRMA LSAs will continue until the start of the Project. There is no additional pre-project climate and hydrometric monitoring programs required or planned for the Project.

### 3.2.2 Construction Monitoring

No climate and hydrometric monitoring activities are anticipated to be required as part of the construction operations at the JEMA and PRMA development areas.

### 3.2.3 Operations Monitoring

#### *Jackpine Expansion Mining Area*

The Aurora climate station was moved to a new location on March 7, 2006 due to the Jackpine Mine – Phase 1 development. The new location is about 600 m west of the previous station. The summer rainfall station in the Kearl Oil Sands development area will be unaffected by the Project.

The streams that will be hydrologically affected by the Project and mine plan integration with nearby developments include Jackpine Creek, Iyinimin Creek, Khahago Creek, Muskeg Creek (at Kearl Lake outlet and below Khahago Creek), Wapasu Creek and the Muskeg River (upstream of Stanley Creek, upstream of Muskeg Creek, below Muskeg Creek and at mouth). Kearl Lake water balance will also be affected.

Some of the active hydrometric stations in and adjacent to the Project development area will be discontinued. Station S28 will be discontinued during land clearance of part of the South ETDA. Mine development will require Muskeg Creek to be relocated to a north diversion channel. This will result in relocating Stations S9 and S22. A new station will be located at the new Kearl Lake outlet and a new station will be located where flow will be pumped from a surge pond to the Jackpine Mine – Phase 1 Compensation Lake. Station S3 will be discontinued with construction of headwater diversion channel around Aurora South Mine and replaced by a new station to measure inflow to Kearl Lake.

The north diversion channel from Kearl Lake will be cut off due to advancement of the mine in the area and will be replaced by gravity pipeline(s) across the active mine development area. The hydrometric stations will be moved as appropriate to ensure Kearl Lake outflow will be monitored.

#### *Pierre River Mining Area*

The new climate station (C3) installed by Shell in 2005 will be unaffected by the PRMA project. The summer rainfall station installed in the First Creek watershed (C4) can also be maintained throughout the life of the Project.

The streams that will be hydrologically affected by PRMA project include Pierre River, Eymundson Creek, First Creek, Unnamed Creek 1 and Big Creek.

Flows and water levels at the relevant hydrometric stations will be monitored during the construction period. A monitoring program will be conducted similar to the RAMP and Environment Canada programs.

In addition to monitoring of the hydrometric stations, discharges from all polishing ponds will also be monitored. Outflows from the polishing ponds will be discontinuous in most cases. Pond outflows will be continuously measured whenever there is a release.

Existing stations P03 and P10 will not be affected by PRMA project since it is located outside the PRMA development area.

Unnamed Creek 1 and Pierre River will be directed to a diversion ditch to facilitate mine operations. A new hydrometric monitoring station will be installed near the mouth of this diversion to measure flows to Athabasca River. Asphalt and Eymundson creeks will also be diverted north to a diversion ditch. The existing hydrometric station near the mouth of Eymundson Creek will be relocated to this new diversion ditch.

Existing hydrometric station P05 will also be relocated since the head watershed of First Creek will be diverted south to a diversion ditch. The Big Creek will be diverted to Unnamed Creek 2, and then to North Waterbody. The existing hydrometric station P07 will continue to operate and will be used to monitor inflow to the North Waterbody. The existing hydrometric station near the mouth of Big Creek (i.e., P08) will be relocated to measure outflows from the North Waterbody.

In addition to the monitoring described above, discharges from all polishing ponds will also be monitored. Outflows from the polishing ponds will be discontinuous in most cases. Pond outflows will be continuously measured, whenever there is a release.

### 3.2.4 Closure Monitoring

#### *Jackpine Expansion Mining Area*

At closure, the gravity pipeline(s) from Kearl Lake will be decommissioned and outflows from Kearl Lake will be directed through a closure channel that will be monitored by a new hydrometric station.

Flows from the reclaimed Project development area will be released to Muskeg River through the Jackpine North and Jackpine South Central pit lakes. Closure monitoring will continue beyond the release of outflows from the pit lakes until Shell satisfies the walk-away requirements.

Station S3A is expected to be relocated and installed on the outlet channel of the Aurora South Pit Lake (S3B) by RAMP to monitor inflows to Kearl Lake. The other active hydrometric stations at the end of mine operation will be continued during the closure period. Recorded flow data will be analyzed and reported annually, as described above.

### *Pierre River Mining Area*

At closure, monitoring flows near the mouth of the outlet channel for Pierre South Pit Lake is required to insure the sediment load and water quality is acceptable to discharge to Athabasca River. In addition, outflows from the South Waterbody will be monitored in the closure channel. The other active hydrometric stations at the end of mine operation will be continued during the closure period. Recorded flow data will be analyzed and reported annually, as described above.

## 3.2.5 Reporting

An annual monitoring report for hydrology monitoring in JEMA and PRMA will be prepared early in each year from the start of the Project to end of the decommissioning period. Each annual report will include measured data summary statistics and graphical representations of flows and water levels from the pre-project period to the end of the year preceding the reporting period.

Shell will submit the annual report to both AENV and Fisheries and Oceans Canada (DFO). Raw data will also be provided annually to RAMP.

## 3.2.6 Summary

In general, Shell will monitor climate, water depth, flow rate and water levels during the construction, operation and closure periods to determine Project effects and success of mitigative measures. Hydrometric stations will be placed on hydrologically affected watercourses and diversion ditches. Discharges from polishing ponds will also be monitored as necessary.

Tables 3 and 4 provide a summary of the climate station and hydrometric station locations and monitoring periods for the JEMA and PRMA LSAs, respectively.

## Table 3 Monitoring Periods at Hydrometric Stations Relevant to the Jackpine Expansion Mining Area

| Stream/Lake | Existing or Proposed | Station Operator | Periods When Station Will Be Monitored Under Program | | |
|---|---|---|---|---|---|
| | | | Pre-Project Period[(a)] | Construction and Operation Period[(b)] | Closure Period[(c)] |
| Jackpine Creek | Existing | RAMP | √ | √ | √ |
| Iyinimin Creek above Kearl Lake | Existing | RAMP | √ | √ | – |
| Iyinimin Creek and Diversion to Kearl Lake | Proposed | RAMP | – | √ | – |
| Iyinimin Creek above Kearl Lake | Proposed | RAMP | – | – | √ |
| Muskeg River above Stanley Creek | Existing | RAMP | √ | √ | √ |
| Muskeg River above Muskeg Creek | Existing | RAMP | √ | √ | √ |
| Muskeg River close to the mouth | Existing | Environment Canada | √ | √ | √ |
| Muskeg Creek below Kearl Lake | Existing | RAMP | √ | – | – |
| Muskeg Creek below Kearl Lake | Proposed | Shell | – | √ | – |
| Muskeg Creek below Khahago Creek | Existing | RAMP | √ | – | – |
| Muskeg Creek above Compensation Lake | Proposed | Shell | – | √ | – |
| Jackpine South Central Pit Lake Channel to Muskeg River | Proposed | Shell | – | – | √ |
| Khahago Creek below Black Fly Creek | Existing | RAMP | √ | – | – |
| Muskeg River above Shelley Creek | Existing | RAMP | √ | √ | √ |
| Kearl Lake and its outlets | Existing | RAMP | √ | √ | √ |

(a) Pre-Project period refers to the period before any activities start that may affect the hydrology of a waterbody or stream.

(b) Construction and operation period refers to the period from the start of construction activities (e.g., clearing, civil works, muskeg drainage, dewatering and stream diversion) to the end of mining operations.

(c) Closure refers to the period between end of mine operation and end of mine closure activities (Walk-away Date, [WAD]).

– = Monitoring is not required.

## Table 4 Monitoring Periods at Hydrometric Stations Relevant to the Pierre River Mining Area

| Stream/Lake | Existing or Proposed | Station Operator | Periods When Station Will Be Monitored Under Program | | |
|---|---|---|---|---|---|
| | | | Pre-Project Period[(a)] | Construction and Operation Period[(b)] | Closure Period[(c)] |
| Pierre River | Existing | Shell | √ | √ | √ |
| Mouth of Diversion Ditches | Proposed | Shell | – | √ | √ |
| Eymundson Creek | Existing | Shell | √ | – | – |
| Eymundson Creek before Diversion to Ditch | Proposed | Shell | – | √ | √ |
| First Creek | Existing | Shell | √ | – | – |
| Unnamed Creek 2 | Existing | Shell | √ | √ | √ |
| Big Creek | Existing | Shell | √ | – | – |
| Outlet of North Waterbody | Proposed | Shell | – | √ | √ |
| Big Creek Tributary | Existing | Shell | √ | – | – |
| Outlet from South Waterbody | Proposed | Shell | – | – | √ |
| Redclay Creek | Existing | Shell | √ | √ | √ |
| Pierre South Pit Lake Outlet Channel | Proposed | Shell | – | – | √ |

(a) Pre-Project period refers to the period before any activities start that may affect the hydrology of a waterbody or stream.

(b) Construction and operation period refers to the period from the start of construction activities (e.g., clearing, civil works, muskeg drainage, dewatering and stream diversion) to the end of mining operations.

(c) Closure refers to the period between end of mine operation and end of mine closure activities (Walk-away Date, [WAD]).

– = Monitoring is not required.

# 4 WATER AND SEDIMENT QUALITY MONITORING PLAN

The following describes the monitoring plan that Shell will implement to measure Project-related water releases and their effects on surface water and sediment quality of receiving watercourses and waterbodies from pre-construction to closure of the Project.

The monitoring plan describes sampling parameters, locations, duration, frequency and protocols, as well as data analysis.

The plan consists of monitoring approaches to quantify the following Project influences at different time periods and in different areas within and near the Project development area:

- changes to water quality of receiving waters due to construction activities;
- changes to water and sediment quality of receiving waters from operational and reclamation activities;
- water quality of releases from constructed facilities such as polishing ponds, pit lakes and a Treatment Lake; and
- water quality within the compensation lake.

Civil works that may affect water quality include construction of stream diversions and building of plant site and other infrastructure such as roads, bridges and drainage systems. Operational water releases will be limited to muskeg drainage and overburden dewatering discharge through polishing ponds. Reclamation waters releases will include process-affected waters, such as tailings water seepages and flux waters from external tailings areas and pit lake discharges.

Operational waters (from cooling towers, tailings, mine pit areas, treated sewage effluent and drainage from the plant site) will be continuously recycled or stored in the tailings pond and will not be released to the environment. Therefore, water quality of these operational waters will not be monitored. If it becomes necessary to discharge treated sewage effluent or other operational waters in the future, appropriate assessment will be conducted and the required monitoring program will be designed and implemented.

The monitoring requirements for the Project will evolve with time. For example, monitoring of polishing ponds will be added to the program as these ponds become operational and will be removed once they are decommissioned. Modifications to the monitoring plan will reflect the following:

- changes to the Project design or operations that affect water quality;
- the nature of the surface water releases, and receiving waters and sediment quality;
- analysis of previous monitoring activities; and
- implementation of adaptive management approaches.

However, the program will ensure consistency of core monitoring parameters, sampling locations, frequency and protocols to allow development of continuous records for determining potential spatial and temporal changes in water and sediment quality. To quantify potential Project effects, the monitoring will be done at sites upstream and downstream of the Project development area and mine-related water release points. The monitoring will cover pre-project, construction, operations and closure (decommissioning) periods.

## 4.1 CURRENT MONITORING ACTIVITIES

Water and sediment quality in the Muskeg River watershed are currently monitored at several locations by RAMP, which Shell co-funds. However, RAMP does not monitor water and sediment quality of surface waters within PRMA. Historical water and sediment quality data and environmental setting data collected specifically for the Project are also available at several locations within and near the Project development area, including locations along the Muskeg River and its tributaries, Pierre River, Asphalt, Eymundson, First, Big and Redclay creeks and the Athabasca River. Sampling locations that are currently included in the RAMP program and relevant to the Project are as follows (Figure 8):

- the Muskeg River upstream of Canterra Road Crossing (MUR-2), downstream of Muskeg Creek (MUR-4), and upstream of Muskeg Creek (MUR-5);
- Jackpine Creek at the mouth during all seasons except winter (JAC-1);
- Muskeg Creek about 2 km upstream of the mouth (MUC-1); and
- Kearl Lake (L2).

Sampling locations included in the Jackpine Mine – Phase 1 monitoring program that are relevant to the proposed Project-specific monitoring plan are as follows (Figure 8):

- Muskeg River downstream of Jackpine Creek (MUR-3a);
- Jackpine Creek upstream of Jackpine Mine – Phase 1 (JAC-4);
- Muskeg Creek downstream of Kearl Lake (MUC-2); and
- Compensation Lake (JCL-1).

Water quality parameters vary slightly among sampling locations. The basic parameter list consists of conventional parameters, major ions, nutrients, total and dissolved metals, recoverable hydrocarbons and naphthenic acids (RAMP 2004). Sampling at several locations also include PAH, while water toxicity and/or continuous temperature and dissolved oxygen monitoring occurs at some selected sites (RAMP 2004).

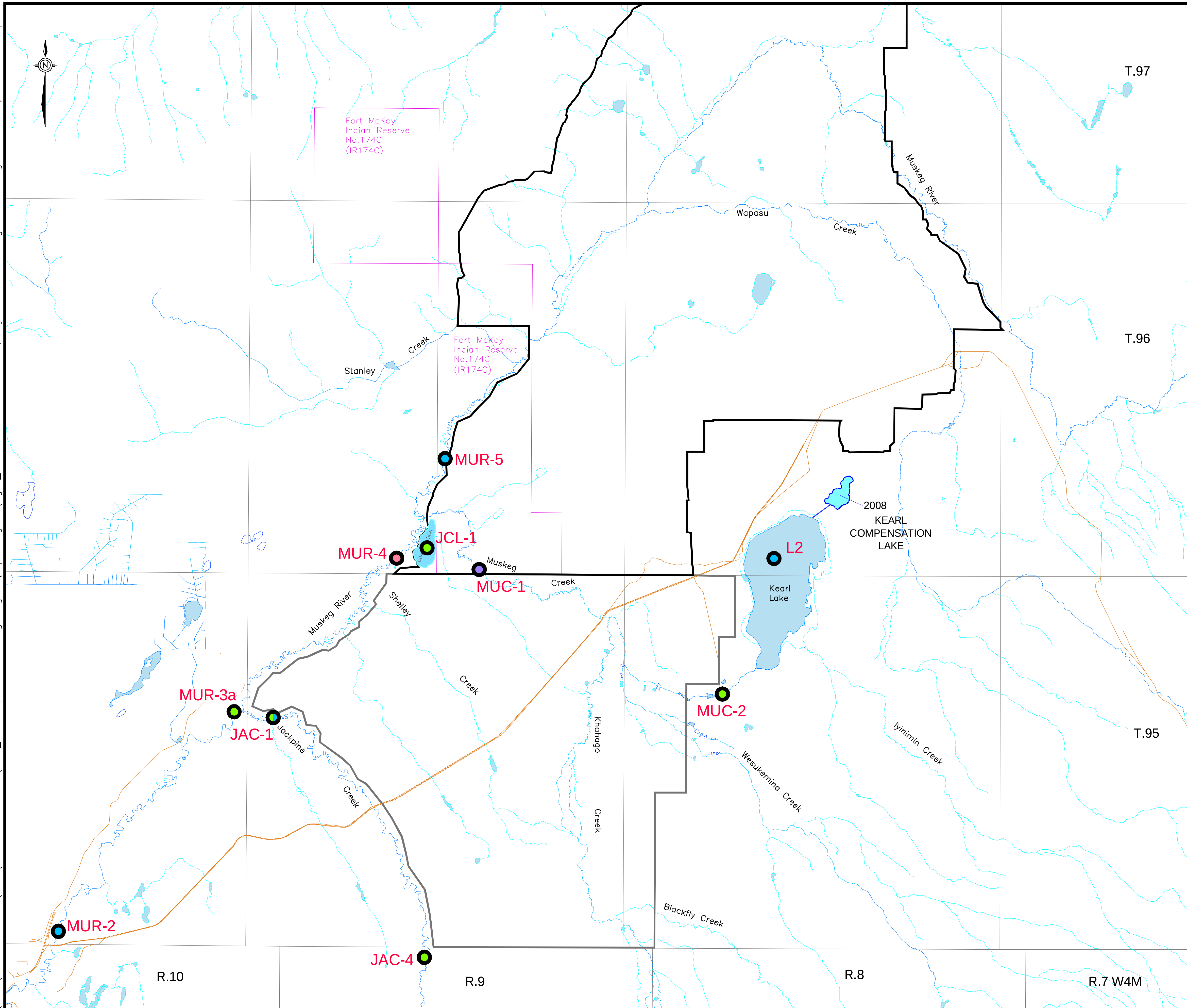
Sediment quality data is also available at several sampling locations on the Muskeg River and some of its tributaries (Figure 8), during the fall season. Existing RAMP sediment quality sampling locations within the Project development area are MUR-2, MUR-4, MUR-5 and JAC-1. There are no RAMP sediment quality stations in PRMA.

Sediment quality parameters vary among sampling locations. The basic parameter list consists of carbon, particle size, total hydrocarbons, metals, PAHs and alkylated PAHs (RAMP 2004). Sediment toxicity is also monitored at MUR-2 and JAC-1.

Shell is involved in regional initiatives on water and sediment quality monitoring and studies listed in Section 1.2. Information for these regional initiatives will complement water and sediment quality data measured under the Project-specific monitoring program presented in this appendix.

## 4.2 PROJECT MONITORING PLAN

Water quality monitoring for the JEMA and PRMA are described in this section for the pre-project, construction, operations and closure periods. The locations monitored during each period are listed in Tables 5 and 6.




LEGEND

- JACKPINE EXPANSION MINING AREA
- JACKPINE MINE - PHASE 1
- JAC-1 JACKPINE MINE - PHASE 1 WATER AND SEDIMENT QUALITY STATION
- MUR-1 RAMP WATER AND SEDIMENT QUALITY STATION
- MUR-4 RELOCATED RAMP WATER AND SEDIMENT QUALITY STATION
- MUC-1 RELOCATED RAMP WATER QUALITY STATION

**REFERENCE**

ALBERTA DIGITAL DATA OBTAINED FROM ALTALIS LTD. (SEPTEMBER 2004.)
USED UNDER LICENSE.
PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83
COORDINATE SYSTEM: UTM ZONE 12

2 0 2
SCALE KILOMETRES

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

**WATER AND SEDIMENT QUALITY CURRENT MONITORING LOCATIONS - JACKPINE EXPANSION MINING AREA**

Shell Canada Energy

| | | | | |
|---|---|---|---|---|
| PROJECT 06-1346-022.6500 | | | FILE No. JEMA-W-SQ Mon-stn | |
| DESIGN | MG | 26/09/07 | SCALE AS SHOWN | REV. 0 |
| CADD | PSR | 05/11/07 | FIGURE: 8 | |
| CHECK | AT | 05/11/07 | | |
| REVIEW | WES/TC | 27/11/07 | | |

L:\2006\1344-OIL SANDS\1346\06-1346-022 Shell\JEMA_PRMA-Aquatics Monitoring Program\Report Figures\Fig 8_JEMA Water and Sediment Quality Current Monitoring Locations.dwg Nov 27, 2007 - 5:27pm

**Table 5 Water and Sediment Quality Monitoring Locations Within Jackpine Expansion Mining Area**

| Stream/Lake | Sampling Location Type | Pre-Project | Construction and Operation | Closure |
|---|---|---|---|---|
| Muskeg River upstream of Muskeg Creek, Muskeg River adjacent the Muskeg River Mine and Expansion ETDA; Jackpine Creek at the mouth and Kearl Lake | RAMP (WQ & SQ) | √ | √ | √ |
| Muskeg Creek near the mouth | Relocated RAMP (WQ) | √ | √ | – |
| Muskeg Creek diversion at closure | Relocated RAMP (WQ) | – | – | √ |
| Muskeg River downstream of Muskeg Creek | Relocated RAMP (WQ & SQ) | √ | √ | √ |
| Muskeg Creek just downstream of Kearl Lake | JPM1 (WQ & SQ) | √ | √ | – |
| Kearl Lake outlet diversion at closure | JPM1 (WQ & SQ) | – | – | √ |
| Jackpine Mine Compensation Lake, Jackpine Creek at the mouth[a], Jackpine Creek upstream of Jackpine Mine – Phase 1, Muskeg River downstream of Jackpine Creek | JPM1 (WQ & SQ) | √ | √ | √ |
| Muskeg River upstream of Wapasu Creek, Wapasu Creek at the mouth, Iyinimin Creek at the mouth | JEMA (WQ & SQ) | √ | √ | – |
| Kearl Lake, Muskeg River headwaters downstream of diversion channel, Wapasu Creek downstream of diversion channel, Muskeg River headwaters upstream of diversion channel, Iyinimin Creek upstream of diversion channel, Muskeg River downstream of Muskeg Creek diversion | JEMA (TSS) | – | √ | – |
| Polishing pond outflows | JEMA polishing pond (WQ) | – | √ | – |
| Pit lakes | JEMA pit lake (WQ & SQ) | – | – | √ |
| Iyinimin Creek at the mouth | Mine plan integration (WQ & SQ) | – | – | √ |

[a] Only winter WQ monitoring.

– = Monitoring is not required.

Notes:

√ = Location monitored during indicated period.

WQ = Water Quality.

SQ = Sediment Quality.

ETDA = External Tailings Disposal Area.

TSS = Total suspended solids.

RAMP = Regional Aquatics Monitoring Program.

JPM1 = Jackpine Mine – Phase 1.

JEMA = Jackpine Expansion Mining Area.

**Table 6 Water and Sediment Quality Monitoring Locations Within Pierre River Mining Area**

| Stream/Lake | Sampling Location Type | Pre-Project | Constuction and Operation | Closure |
|---|---|---|---|---|
| Asphalt Creek upstream of Project development area, First Creek upstream of Project development area | PRMA (WQ & SQ) | √ | √ | √ |
| Pierre River upstream of Project development area, Big Creek upstream of Project development area | PRMA (WQ & SQ) | √ | √ | – |
| Pierre River diversion channel upstream of Horizon Project diversion channel | Relocated PRMA (WQ & SQ) | – | – | √ |
| Pierre River at the mouth, Eymundson Creek at the mouth, Big Creek at the mouth, Redclay Creek at the mouth | PRMA (WQ & SQ) | √ | – | – |
| Pierre River diversion channel at the mouth, Redclay Compensation Lake, Asphalt and Eymundson Creek diversion channel at the mouth | Relocated PRMA (WQ & SQ) | – | √ | √ |
| Polishing pond outflow | Polishing pond | – | √ | – |
| Pierre River diversion channel at the mouth, Pierre River upstream of Project development area, Asphalt Creek upstream of Project development area, First Creek upstream of Project development area, Asphalt and Eymundson Creek diversion channel at the mouth, Big Creek downstream and upstream of diversion channel | TSS sampling location | – | √ | – |
| Pit lakes and Treatment Lake | Pit lake (WQ & SQ) | – | – | √ |

Notes:
– = Monitoring is not required.
√ = Location monitored during indicated period.
WQ = Water Quality.
SQ = Sediment Quality.
TSS = Total Suspended Solids.
PRMA = Pierre River Mining Area.

## 4.2.1 Pre-Project Monitoring

### *Jackpine Expansion Mining Area*

Pre-project monitoring will be undertaken to characterize water and sediment quality in receiving waters that may be affected by Project activities. Sampling locations for pre-project monitoring include current RAMP and Jackpine Mine – Phase 1 sites in addition to Project-specific sampling locations immediately upstream and downstream of the Project development area and future pit lake release points. The Project-specific sampling locations are located on Muskeg River upstream of Wapasu Creek, Wapasu Creek at the mouth. Monitoring of Iyinimin Creek at the mouth will be part of the activities to integrate mine plans for the Project and other nearby developments. To characterize changes in water and sediment quality due to future releases from the West Pit Lake, RAMP sampling location MUR-4 will be relocated on Muskeg River downstream of Muskeg Creek. Also, RAMP sampling location MUC-1 will be relocated to about 2 km upstream of the mouth of Muskeg Creek to measure Project effects on water and sediment quality in the creek. Data from the pre-project monitoring will be complemented with environmental setting information collected in support of the Project application and historical data within the Project development area.

Pre-project monitoring locations, duration and frequency are described below.

### *Pierre River Mining Area*

Pre-project monitoring will be undertaken to characterize water and sediment quality in receiving waters that may be affected by development activities within PRMA. Sampling locations for pre-project monitoring will provide benchmark information upstream and downstream of the Project development area and at key future process-water release points. There are no RAMP sampling locations within PRMA. Pre-project sampling for water and sediment quality will be undertaken for the Pierre River, Eymundson Creek, Asphalt Creek upstream of the Project development area, First Creek, Big Creek and Redclay Creek.

Pre-project monitoring locations, duration and frequency are described below.

### 4.2.1.1 Parameters

Water quality parameters in JEMA and PRMA will include RAMP standard parameters (RAMP 2004), PAHs and toxicity, as required. Sediment quality parameters will include RAMP standard parameters (RAMP 2004) and toxicity (Table 7). The RAMP parameter list has been developed and refined since 1997 to meet the following objectives with respect to key substances in the Oil Sands Region:

- to provide regulatory requirements;
- to measure suitability of a waterbody to support aquatic life;
- to determine potential substance inputs from point and non-point sources;
- to compare measured substance concentrations with guidelines and objectives designed to protect aquatic life;
- to provide supporting data for biological surveys; and
- to estimate overland and sub-surface sources of streamflow.

**Table 7 Water and Sediment Quality Parameters for the Project Monitoring Plan**

| Description | Individual Constituents | Reason for Monitoring |
|---|---|---|
| **Water Quality** | | |
| oil and grease | oil and grease (only in sedimentation pond outflow) | EPEA |
| pH and temperature | pH, temperature | EPEA |
| total suspended solids | total suspended solids | EPEA and *Fisheries Act* |
| acute toxicity | 96-hour acute lethality test using rainbow trout (*Oncorhynchus mykiss*), 48-hour static acute lethality test using *Daphnia magna* | EPEA and *Fisheries Act* |
| chronic toxicity | chronic lethality test using *Ceriodaphnia* and fathead minnows | EPEA and *Fisheries Act* |
| organic carbon | dissolved organic carbon, total organic carbon | EPEA and *Fisheries Act* |
| conventional | specific conductance, alkalinity, total dissolved solids, hardness | EPEA and *Fisheries Act* |
| major ions | bicarbonate, calcium, carbonate, chloride, magnesium, potassium, sodium , sulphate, sulphide | EPEA and *Fisheries Act*, constituents in process-affected water |
| total and dissolved metals | aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, copper, iron, lead, lithium, manganese, mercury, molybdenum, nickel, selenium, silver, strontium, thallium, titanium, uranium, vanadium, zinc | EPEA and *Fisheries Act*, constituents in process-affected water |
| oxygen-related | biochemical and chemical oxygen demand, dissolved oxygen | EPEA and *Fisheries Act* |
| organics | naphthenic acids, total phenolics, total recoverable hydrocarbons, benzene, toluene, ethylbenzene, xylene (BTEX), phenols | EPEA and *Fisheries Act*, constituents in process-affected water |
| nutrients and ammonia | total and dissolved phosphorus, nitrate/nitrite, total Kjeldahl nitrogen, ammonia | EPEA and *Fisheries Act*, constituents in process-affected water |
| target PAHs | see RAMP (2004) for list | EPEA and *Fisheries Act* |
| alkylated PAHs | see RAMP (2004) for list | EPEA and *Fisheries Act* |
| **Sediment Quality** | | |
| particle size | percent sand, percent silt, percent clay, moisture content | characterize potential change in bottom sediment composition |
| carbon content | total inorganic carbon, total organic carbon, total carbon | affects toxicity and bioavailability of some substances |
| organics | total recoverable hydrocarbons, total volatile hydrocarbons ($C_5$-$C_{10}$), total extractable hydrocarbons ($C_{11}$-$C_{30}$) | aggregate indicators of process-affected sediments |
| total metals | aluminum, arsenic, barium, beryllium, boron, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, mercury, molybdenum, nickel, potassium, selenium, silver, sodium, strontium, thallium, uranium, vanadium, zinc | constituents that may affect fish, aquatic health |
| target PAHs | see RAMP (2004) for list | constituents that may affect fish, aquatic health |
| alkylated PAHs | see RAMP (2004) for list | constituents that may affect fish, aquatic health |
| chronic toxicity | *Hyalella azteca*, *Chironomus tentans*, *Lumbriculus variegatus* | indicator of sediment quality and potential effect on aquatic health |

#### 4.2.1.2 Locations

### *Jackpine Expansion Mining Area Sampling Locations*

In addition to existing and relocated RAMP sampling locations (MUR-2, MUR-4, MUR-5, JAC-1, MUC-1 and L2) and Jackpine Mine – Phase 1 sampling locations (MUR-3a, JAC-4, MUC-2, JAC-1 during winter, JCL-1), the Project-specific program will monitor water and sediment quality at the following locations:

- Muskeg River upstream of Wapasu Creek; and
- Wapasu Creek at the mouth.

Effects on Iyinimin Creek at the mouth will be monitored as part of the mine plan integration activity for the Project and other nearby developments.

### *Pierre River Mining Area Sampling Locations*

Water and sediment quality will be measured at the following sampling locations:

- Pierre River at the mouth and upstream of the Project development area;
- Eymundson Creek at the mouth;
- Asphalt Creek upstream of the Project development area;
- First Creek upstream of the Project development area;
- Big Creek at the mouth (BIC-1) and upstream of the Project development area; and
- Redclay Creek at the mouth.

#### 4.2.1.3 Duration

Monitoring of the proposed JEMA and PRMA sample locations during the pre-project period will commence upon regulatory approval of the Project and the proposed monitoring plan. These sites will also be monitored during operation and decommissioning period, if corresponding surface water still exists.

#### 4.2.1.4 Frequency

Water quality samples will be collected once during each season in JEMA and PRMA. Seasonal sampling will be conducted to coincide with RAMP seasons, defined as follows:

- winter: November to March;
- spring: April to May;
- summer: June to August; and
- fall: September to October.

Winter monitoring will occur only at sites with sufficient flow to allow sampling. Thus, winter monitoring at individual sites will be revised, if it is determined to be not needed due to consistent absence of adequate flow to allow sampling. Sediment quality samples will be collected once per year during the fall season.

#### 4.2.1.5 Protocols

Water sampling methods and laboratory analyses for samples collected in the JEMA and PRMA will follow Standard Methods for the Examination of Water and Wastewater (APHA 1999). Appropriate RAMP field sampling protocols (RAMP 2004) will also be followed. Whole effluent toxicity testing will adhere to the appropriate Environment Canada Biological Test Methods that are expected to be listed in the EPEA Approval for the Project.

#### 4.2.1.6 Data Analysis

Spatial and temporal variability of pre-project data for JEMA and PRMA will be analyzed using statistical and graphical methods, such as those used in RAMP (2004). Results of these analyses will form the basis for measuring changes in water and sediment quality due to Project activities.

#### 4.2.1.7 Reporting

An annual monitoring report for water quality monitoring in JEMA and PRMA will be prepared early in the year following the start of the Project. The report will include measured data summary statistics and graphical representations of water and sediment quality for the pre-project period.

Shell will submit the annual report to both AENV and Fisheries and Oceans Canada (DFO). Raw data will also be provided annually to RAMP.

### 4.2.2 Construction Monitoring

Construction monitoring in JEMA and PRMA is specific to the water quality component of the aquatic resources monitoring plan. The objective of construction monitoring is to measure TSS concentrations in receiving waters during civil works. Civil works include construction of stream diversions and building of plant site and other infrastructure such as roads, bridges and drainage systems. Construction monitoring generally occurs during short periods of time from the start of Project to the decommissioning period. The measured TSS concentrations will be compared to limits prescribed by regulators.

Construction-related monitoring locations, duration, frequency, protocols and data analysis for the JEMA and PRMA are described below.

#### 4.2.2.1 Parameters

Initially, water samples collected in JEMA and PRMA will be analyzed for TSS and turbidity. Grab water samples will be collected from each monitoring site and delivered to an accredited laboratory for TSS analyses. Turbidity will be measured in-situ using a turbidity meter. The collected TSS and turbidity data will be used to establish a TSS-turbidity curve for each watercourse or waterbody affected by construction. The purpose of the TSS-turbidity curves will be to provide continuous TSS prediction based on turbidity measurements. Continuous measurement of TSS concentrations during civil works is necessary to ensure compliance with regulatory requirements.

#### 4.2.2.2 Locations

##### *Jackpine Expansion Mining Area Sampling Locations*

Turbidity and TSS in the JEMA will be monitored at locations on the Muskeg River, (headwaters downstream of diversion channel and downstream of Muskeg Creek diversion), Iyinimin Creek upstream of diversion channel, Wapasu Creek downstream of diversion channel and Kearl Lake.

##### *Pierre River Mining Area*

Turbidity and TSS in the PRMA will be monitored at locations on the Pierre River diversion channel at the mouth, Pierre River upstream of Project development area, Asphalt Creek upstream of Project development area, First Creek upstream of Project development area, Asphalt and Eymundson Creek diversion channel at the mouth and Big Creek downstream and upstream of the diversion channel.

#### 4.2.2.3 Duration

Sampling locations in JEMA and PRMA will be monitored during each specific instream construction activity and continue until the concentrations are either consistently at background levels or below appropriate guideline values. Background levels will be based on TSS values recorded at the upstream site for each release point.

#### 4.2.2.4 Frequency

In both the JEMA and PRMA, TSS and turbidity will be measured four times per day at each monitoring site. The sampling interval during each day will be co-ordinated to cover the effects of specific construction processes or stages. Once adequate data has been measured to establish a TSS-turbidity relationship, turbidity will be measured hourly during times of construction activity until turbidity (and TSS) levels at the downstream site are consistently at or near background levels (i.e., turbidity and TSS levels measured at the upstream site).

#### 4.2.2.5 Protocols

Water sampling methods and laboratory analyses will follow Standard Methods for the Examination of Water and Wastewater (APHA 1999). Appropriate RAMP field sampling protocols (RAMP 2004) will also be followed. Turbidity meters will be calibrated and checked regularly.

#### 4.2.2.6 Data Analysis

Within the first week after the start of construction activities on a given watercourse, water samples containing different concentrations of TSS from the monitoring sites will be analyzed and used to establish a regression relationship between TSS and turbidity. The regression relationship will be used to predict TSS concentration at the monitoring sites based on measured turbidity. The measured turbidity values will be converted to TSS.

#### 4.2.2.7 Reporting

Readings for TSS that exceed the prescribed regulatory limits will be immediately reported to applicable construction personnel so appropriate mitigation activities are promptly performed. The exceedance will also be reported to AENV and DFO verbally within 24 hours and with a letter within seven days of an exceedence.

A monitoring report will be prepared early in the year following the start of construction activities as part of the annual water quality reporting to regulators. The report will include measured data summary statistics and graphical representations of TSS concentrations for the year. It will also highlight the TSS concentrations measured during each specific construction activity. All exceedances of prescribed limits will also be summarized in the report. The data in this report will be provided to RAMP.

### 4.2.3 Operations Monitoring

The specific objectives of the operations phase water quality monitoring for JEMA and PRMA include the following:

- To ensure that polishing ponds are monitored as specified in Table 7 and in EPEA approval for the Jackpine Mine – Phase 1.
- To assess changes in water and sediment quality due to Project-related water releases into receiving waters.

Operational monitoring of water quality in JEMA and PRMA will be conducted from the start of the Project until the end of mine operations and plant decommissioning. The monitoring locations, monitoring parameters, general sampling locations, sampling durations, frequencies and protocols, and data analyses requirements for water and sediment quality monitoring of different facilities and receiving waters are described below. Ongoing assessment of monitoring results and use of an adaptive management process will identify where changes in elements of the program may be required to meet the objectives of the monitoring plan.

#### 4.2.3.1 Parameters

Monitoring in the JEMA and PRMA will include parameters listed in Table 7. These parameters are based on typical EPEA authorization requirements for monitoring sedimentation ponds (Table 7). The EPEA and the *Fisheries Act* authorizations also require monitoring of these parameters to determine the Project's contribution to potential aquatic environmental effects on receiving surface waters.

#### 4.2.3.2 Locations

##### *Jackpine Expansion Mining Area*

In addition to existing and relocated RAMP monitoring locations and Jackpine Mine – Phase 1 monitoring locations, watercourses and waterbodies within the Muskeg River watershed will be monitored upstream and downstream of the Project footprint. Based on current Project sequencing of mine plans, the facilities and waters that will require monitoring during operations under this Project include:

- outflows of polishing ponds receiving muskeg drainage and overburden dewatering waters, and runoff from muskeg and overburden storage areas;
- Muskeg River upstream of Wapasu Creek; and
- Wapasu Creek at the mouth.

Effects on Iyinimin Creek at the mouth will be monitored as part of the mine plan integration activity for the Project and other nearby developments.

### *Pierre River Mining Area*

Sampling locations in PRMA watercourses and waterbodies will be monitored upstream and downstream of the Project footprint to determine the combined developments effects. Based on current Project sequencing of mine plans, the facilities and waters that will require monitoring during operations include:

- outflows of polishing ponds receiving muskeg drainage and overburden dewatering waters, and runoff from muskeg and overburden storage areas;
- Pierre River diversion channel at the mouth and upstream of the Project development area;
- Asphalt Creek upstream of Project development area and Asphalt and Eymundson Creek diversion channel at the mouth;
- First Creek upstream of Project development area;
- Big Creek upstream of Project development area; and
- Redclay Compensation Lake.

## 4.2.3.3 Duration

In-stream sites will be monitored throughout operation during periods when polishing ponds discharge water. Polishing ponds will be monitored during periods when they release flow into receiving waters.

## 4.2.3.4 Frequency

Monitoring will be conducted once every season for water quality and once during each fall for sediment quality in receiving streams and the compensation lake. Water quality monitoring in polishing ponds will be scheduled according to the EPEA Approval requirements for the Project.

#### 4.2.3.5 Protocols

Water sampling methods and laboratory analyses will follow Standard Methods for the Examination of Water and Wastewater (APHA 1999). Appropriate RAMP field sampling protocols (RAMP 2004) will also be followed. Toxicity testing will follow the analytical methodology in the EPEA Approval requirements for Jackpine Mine – Phase 1. Sediment sampling and analyses will follow protocols in Environment Canada (1994), RAMP (2004) and the potential EPEA Approval requirements for the Project.

Each water quality sampling event for the Compensation Lake will include field depth-profile measurements of temperature, dissolved oxygen, conductivity and pH. If the field measurements show stratification in the lake at the time of sampling, separate water quality samples will be collected from the top and bottom layers to represent the epilimnion and hypolimnion, respectively.

#### 4.2.3.6 Data Analysis

Data analyses will include the following assessments:

- statistical summary and (seasonal/annual) trend analysis of measured data, and comparison with environmental setting or pre-project data and relevant guideline values;
- performance of polishing ponds;
- compliance with the EPEA and/or DFO approval requirements; and
- need for adjustments in monitoring.

#### 4.2.3.7 Reporting

An annual monitoring report will be prepared early in the year following the sampling for the previous year. The report will include measured data summary statistics and graphical representations of water and sediment quality of receiving stream monitoring locations collected during the previous year. Given that construction activities will continue throughout the operations period, it will also include the TSS concentrations measured during each specific construction activity.

### 4.2.4 Closure Monitoring

The specific objectives of the closure water quality monitoring for the JEMA and PRMA include the following:

- to measure water and sediment quality changes in receiving waters due to water releases from the reclamation landscape;
- to monitor the water quality of pit lake and determine if it meets discharge criteria or is within the natural range of variability for local waters, prior to their discharge to the environment. In addition, monitoring will determine the natural remediation efficiency of the pit lakes; and
- to determine major sources of substance loading from the Project to receiving surface waters.

Water and sediment quality will be monitored during the decommissioning period. The ongoing assessment of monitoring results and use of an adaptive management process will identify where changes are required to meet the objectives of the monitoring plan. The monitoring parameters, sampling locations, durations, frequency and protocols and data analyses requirements for different facilities and receiving surface waters are described below.

Pit Lake sampling locations are identified in the Project-specific monitoring plan; however, details of water and sediment quality monitoring for pit lakes is not included in this plan. Pit lake monitoring will be incorporated in future after Project approval and when details of pit lake design, operation and monitoring requirements are available. The pit lake monitoring will adhere to standards or recommendations of the CEMA Reclamation Working Group End Pit Lake Task Group or the applicable regulatory requirements.

### 4.2.4.1 Parameters

Water and sediment quality monitoring parameters are described in Table 7.

### 4.2.4.2 Locations

#### *Jackpine Expansion Mining Area*

In addition to the existing and relocated RAMP monitoring locations (MUR-2, MUR-5, JAC-1, MCR-1, L2) and Jackpine Mine – Phase 1 monitoring locations (MUR-3a, JAC-4, JCL-1), the Project-specific monitoring plan will include the following sampling locations:

- pit lakes within JEMA; and
- Kearl Lake outlet diversion at closure.

Effects on Iyinimin Creek at the mouth will be monitored as part of the mine plan integration activity for the Project and other nearby developments.

### *Pierre River Mining Area*

Water and sediment quality will be monitored at the following sampling locations:

- pit lakes and treatment lake in PRMA;
- Pierre River diversion channel at the mouth and upstream of the Canadian Natural Resources Limited Horizon Project diversion channel;
- Asphalt Creek upstream of the Project development area and Asphalt and Eymundson Creek diversion channel at the mouth;
- First Creek upstream of the Project development area; and
- Redclay Compensation Lake.

These water and sediment monitoring sites and data from existing and relocated RAMP sites will represent conditions within the Project development area and will provide data for determining water and sediment quality changes due to the Project.

## 4.2.4.3 Duration

Each of the sites listed in Section 4.2.4.2 will be monitored during the decommissioning period.

## 4.2.4.4 Frequency

Grab water quality samples will be collected during each of the four seasons. Winter water quality monitoring will be undertaken only at locations with sufficient flow to allow sampling. Sediment quality samples will be collected once per year during fall.

## 4.2.4.5 Protocols

Water sampling methods and laboratory analyses will follow Standard Methods for the Examination of Water and Wastewater (APHA 1999). Appropriate RAMP field sampling protocols (RAMP 2004) will also be followed. Whole effluent toxicity testing will adhere to the appropriate Environment Canada Biological Test Methods listed in the EPEA approval for the Jackpine Mine – Phase 1.

Each water quality sampling event for the compensation lake sampling will be preceded by field measurements of temperature, dissolved oxygen, conductivity and pH at different depths of the waterbody. If the field measurements show stratification in the lake at the time of sampling, separate water quality samples will be collected from the top and bottom layers to represent the epilimnion and hypolimnion, respectively.

#### 4.2.4.6 Data Analysis

Spatial and temporal trend analyses will be undertaken to determine changes in water and sediment quality due to the Project. Water and sediment quality guideline attainment will also be calculated.

#### 4.2.4.7 Reporting

Annual data reports will be submitted to AENV and DFO. The report will include summary statistics that compare water and sediment quality in receiving waters to corresponding data at reference locations or under environmental setting conditions.

# 5 FISH AND FISH HABITAT MONITORING PLAN

## 5.1 CURRENT MONITORING ACTIVITIES

Fish and benthic invertebrates are currently monitored by RAMP in the Oil Sands Region. The RAMP monitoring activities of fish populations and benthic invertebrates in or around the Project development areas include:

- fish inventory on the Athabasca River (spring and fall sampling), the Muskeg River and Jackpine Creek (summer/fall);
- tissue collection and analysis for target fish species in the Athabasca River, the Muskeg River and Jackpine River;
- sentinel fish species program on the Muskeg River; and
- benthic invertebrate sampling in the Muskeg River, Jackpine Creek and Kearl Lake.

Several stations in the Muskeg River watershed are monitored by RAMP, and their activities include a fish inventory (conducted in 2004), sentinel species monitoring (conducted in 2004 and 2006) a fish counting fence near the mouth of the Muskeg River (operated in 2003 and 2006) and fish tissue tainting studies (last conducted in 2001). The current RAMP benthic invertebrate monitoring activities in the Muskeg River watershed include sampling in the lower reach of the Muskeg River near the mouth, in the lower to middle reach of the Muskeg River, in the upper reach of Muskeg River (upstream of Stanley Creek), in the lower reach of Jackpine Creek near the mouth, in the upper reach of Jackpine Creek and in Kearl Lake.

Shell is currently conducting monitoring activities in the Muskeg River watershed for the Jackpine Mine – Phase 1. Monitoring sites currently include the Muskeg River, Muskeg Creek, Wesukemina Creek, Khahago Creek and Jackpine Creek. The monitoring program for that project also includes monitoring of the proposed Jackpine Mine Compensation Lake. Locations of watercourse sites currently being sampled for the Jackpine Mine – Phase 1 monitoring program, as well as the proposed compensation lake site, are shown in Figure 9 and summarized in Table 8. This table also presents the Project monitoring for the pre-project, operations and closure periods. Details of the Jackpine Mine – Phase 1 monitoring program are provided in Shell (2007).

No monitoring activities are currently being carried out by Shell or RAMP in watercourses and waterbodies in PRMA, including the Pierre River, Eymundson Creek, Big Creek and Redclay Creek watersheds.

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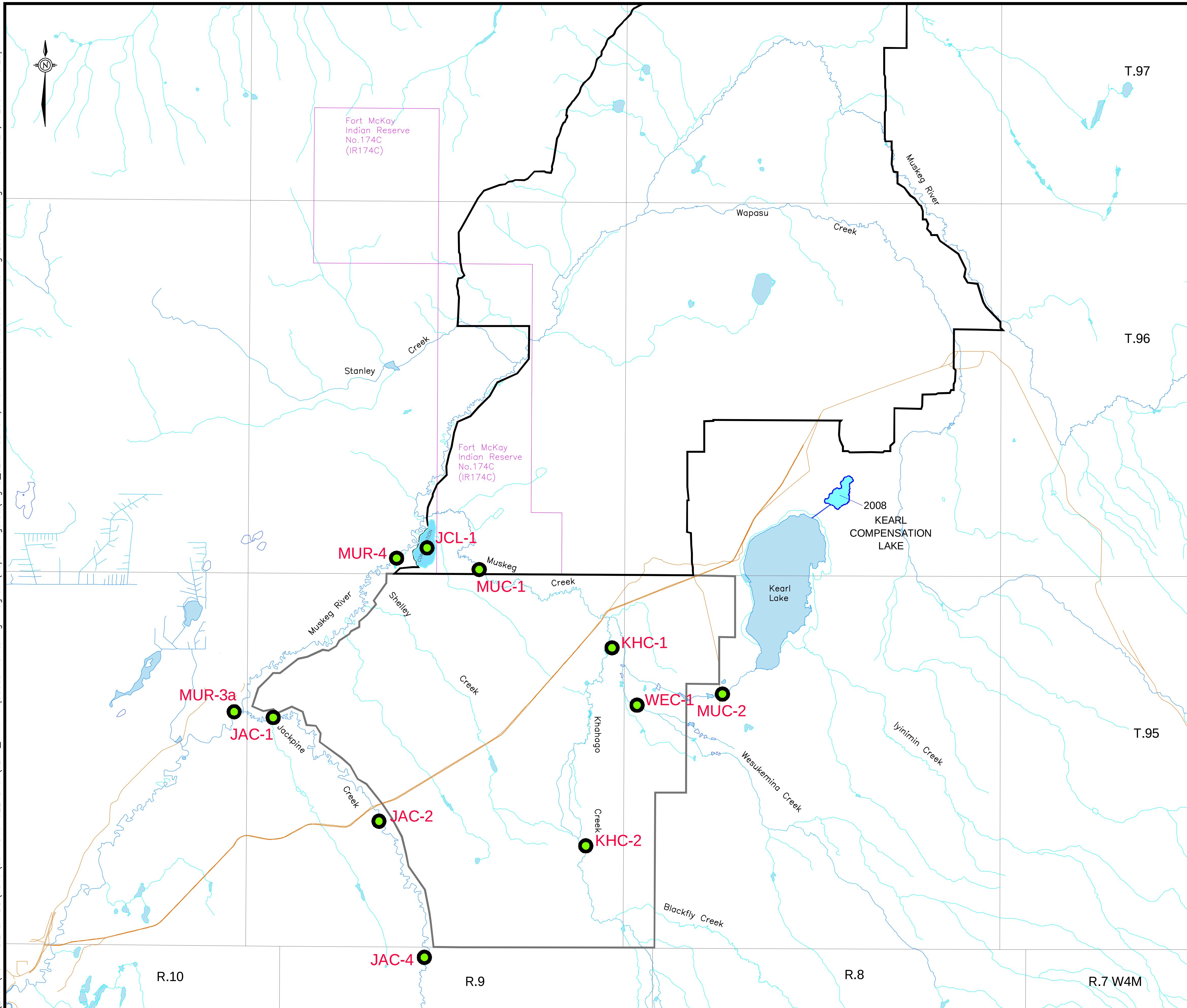


LEGEND

- JACKPINE EXPANSION MINING AREA
- JACKPINE MINE - PHASE 1
- MUR-1 JACKPINE MINE - PHASE 1 FISH AND FISH HABITAT SITES

REFERENCE

ALBERTA DIGITAL DATA OBTAINED FROM ALTALIS LTD. (SEPTEMBER 2004.)
USED UNDER LICENSE.
PROJECTION: TRANSVERSE MERCATOR DATUM: NAD 83
COORDINATE SYSTEM: UTM ZONE 12

2 0 2
SCALE KILOMETRES

PROJECT

JACKPINE MINE EXPANSION &
PIERRE RIVER MINE PROJECT

TITLE

# CURRENT FISH AND FISH HABITAT MONITORING LOCATIONS FOR THE JACKPINE EXPANSION MINING AREA

Shell Canada Energy

| | | | |
|---|---|---|---|
| PROJECT 06-1346-022.6500 | | | FILE No. JEMA-Current-FFH |
| DESIGN | MG | 26/09/07 | SCALE AS SHOWN REV. 0 |
| CADD | PSR | 05/11/07 | |
| CHECK | AT | 05/11/07 | |
| REVIEW | WES/TC | 27/11/07 | |

FIGURE: 9

**Table 8 Fish and Fish Habitat Monitoring Locations, Including Watercourses Currently Being Sampled and the Proposed Compensation Lake, for the Jackpine Mine – Phase 1 Monitoring Program**

| Stream/Lake | Habitat Type (Natural or Compensation) | Station Operator | Pre-Project Period[(a)] | Construction and Operation Period[(b)] | Closure Period[(c)] | Monitoring Objectives |
|---|---|---|---|---|---|---|
| Muskeg River downstream of Jackpine Creek and upstream of Muskeg Creek | Natural | Albian Sands | ✓ | ✓ | ✓ | Potential environmental effects |
| Jackpine Creek at the mouth, at Canterra Road and upstream of Project development area | Natural | Albian Sands | ✓ | ✓ | ✓ | Potential environmental effects |
| Muskeg Creek near mouth | Natural | Albian Sands | ✓ | ✓ | – | Characterization of habitats to be lost<br>Fish passage |
| Muskeg Creek at outlet of Kearl Lake | Natural | Albian Sands | ✓ | ✓ | – | Characterization of habitats to be lost<br>Fish passage |
| Khahago Creek at the mouth and at the surge facility | Natural | Albian Sands | ✓ | – | – | Characterization of habitats to be lost |
| Wesukemina Creek near the mouth | Natural | Albian Sands | ✓ | – | – | Characterization of habitats to be lost |
| Jackpine Mine Compensation Lake[(d)] | Compensation | Albian Sands | – | ✓ | – | Assessment of Compensation Habitat |

(a) Pre-project period refers to the period before any activities start that may affect the fish and fish habitat of a waterbody or watercourse.

(b) Construction and operation period refers to the period where construction activities (e.g., clearing, civil works, muskeg drainage, dewatering and stream diversion) begin and mining operations end.

(c) Closure refers to the period between end of mine operation and end of mine closure activities.

(d) The compensation lake site, formerly referred to as Site NNL-1 (Shell 2007).

– = Monitoring is not required.

Note: ✓ = Location monitored during indicated period.

## 5.2 PROJECT MONITORING PLAN

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The fish and fish habitat monitoring program is designed to monitor the effectiveness of the development of compensation habitats, to obtain additional environmental setting information on watercourses and waterbodies that will be directly affected by the Project, and to determine if any effects occur in watercourses and waterbodies indirectly affected by the Project. The monitoring program is also designed to ensure that diversion structures do not affect fish passage or migration. The monitoring plan described herein is conceptual. A more detailed version of the plan will be prepared during development of the "No Net Loss Plan" for the Project.

There are three distinct periods during which monitoring will be conducted, and the sampling program will vary among those periods. A pre-project period of monitoring will be undertaken very early in development of the Project, before the watercourses are affected, to collect environmental setting information. Monitoring will continue during the construction and operational period, and additional monitoring will be undertaken during the decommissioning period.

The monitoring objectives differ among monitoring locations as well as the Project periods. Sites located on waterbodies or watercourses that will be directly affected by the Project, resulting in habitat losses, will be monitored for fish habitat on a seasonal basis and for fish presence and abundance (during the fall) for a period of up to five years, depending on the construction schedule. Sites indirectly affected by the Project (e.g., by flow alterations) will be monitored for potential environmental effects, including fish habitat (each season), fish presence and abundance (during the fall), benthic invertebrate abundance and community structure, and periphyton (benthic algae, bacteria, fungi and organic material on the surfaces of bottom substrates). Duration of monitoring at indirectly affected sites will depend on the Project development schedule, timing of anticipated effects, and the nature of any effects detected during monitoring.

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Sites located within compensation habitats will be monitored for fish habitat (each seasonal) and for fish presence and abundance (during the fall) for the first five years after construction, and once every three years thereafter, until effectiveness of compensation has been demonstrated. Sites located within diversion structures will be monitored to evaluate fish passage until successful fish passage through the structures has been demonstrated. Sites may be monitored for the purpose of meeting one or all of the objectives described above. Adaptive management procedures will be used to ensure the success of the compensation measures. If the anticipated effectiveness of compensation is not achieved initially, additional measures to be undertaken could include modifications of the compensation works, construction of additional compensation works, and fish stocking programs. Additional monitoring would also be conducted to evaluate the effectiveness of any modified or new compensation works.

### 5.2.1 Pre-Project Monitoring

The pre-project monitoring will be undertaken in the JEMA and the PRMA before the watercourses become affected by development of the Project. As compensation habitats will not be constructed until after this period, the initial period monitoring includes only natural habitats. The monitoring sites and objectives for the JEMA and the PRMA are described in Tables 9 and 10, respectively.

**Table 9 Proposed Fish and Fish Habitat Monitoring Locations in the Jackpine Expansion Mining Area During Each Stage of the Project**

| Watercourse or Waterbody | Habitat Type (Natural or Compensation) | Station Operator | Pre-Project Period[(a)] | Construction and Operation Period[(b)] | Closure Period[(c)] | Monitoring Objectives |
|---|---|---|---|---|---|---|
| Muskeg River Reach 1 | natural | proposed | ✓ | ✓ | ✓ | potential environmental effects |
| Muskeg River Reach 2 | natural | proposed | ✓ | ✓ | ✓ | potential environmental effects |
| Muskeg River Reach 3 | natural | proposed | ✓ | ✓ | ✓ | potential environmental effects |
| Muskeg River Reach 6 | natural | proposed | ✓ | ✓ | ✓ | potential environmental effects |
| Muskeg River Reach 6 | natural | proposed | ✓ | ✓ | – | characterization of habitats to be lost |
| Wapasu Creek | natural | proposed | ✓ | ✓ | – | characterization of habitats to be lost |
| Kearl Lake | natural | proposed | ✓ | ✓ | ✓ | potential environmental effects |
| 2012 Kearl Lake Diversion Channel (downstream) | constructed | proposed | – | ✓ | – | fish passage |
| 2012 Kearl Lake Diversion Channel (upstream) | constructed | proposed | – | ✓ | – | fish passage |
| Muskeg Creek | natural | proposed | ✓ | ✓ | – | fish passage |
| Muskeg Creek Replacement Channel | compensation | proposed | – | – | ✓ | assessment of compensation habitat |

(a) Pre-Project period refers to the period before any activities start that may affect the fish and fish habitat of a waterbody or watercourse.

(b) Construction and operation period refers to the period where construction activities (e.g., clearing, civil works, muskeg drainage, dewatering and stream diversion) begin and mining operations end.

(c) Closure refers to the period between end of mine operation and end of mine closure activities.

– = Monitoring is not required.

Note: ✓ = Location monitored during indicated period.

**Table 10 Proposed Fish and Fish Habitat Monitoring Locations in the Pierre River Mining Area During Each Stage of the Project**

| Waterbody | Habitat Type | Station Operator | Pre-Project Period[(a)] | Construction and Operation Period[(b)] | Closure Period[(c)] | Monitoring Objectives |
|---|---|---|---|---|---|---|
| Pierre River at the mouth | natural | proposed | ✓ | ✓ | – | characterization of habitats to be lost; fish passage |
| Pierre River upstream of Project development area | natural | proposed | ✓ | ✓ | – | characterization of habitats to be lost |
| Eymundson Creek at the mouth | natural | proposed | ✓ | ✓ | – | characterization of habitats to be lost |
| Eymundson Creek downstream of Asphalt Creek | natural | proposed | ✓ | ✓ | – | characterization of habitats to be lost |
| Eymundson Creek upstream of Project development area | natural | proposed | ✓ | ✓ | – | characterization of habitats to be lost |
| Unnamed Creek 1 | natural | proposed | ✓ | ✓ | – | characterization of habitats to be lost |
| Asphalt Creek upstream of Project development area | natural | proposed | ✓ | ✓ | – | characterization of habitats to be lost |
| Unnamed Waterbody 12 | natural | proposed | ✓ | ✓ | – | characterization of habitats to be lost |
| First Creek downstream of ETDA | natural | proposed | ✓ | ✓ | – | characterization of habitats to be lost |
| Big Creek at the mouth | natural | proposed | ✓ | ✓ | – | characterization of habitats to be lost |
| Big Creek upstream of the Redclay Compensation Lake | natural | proposed | ✓ | ✓ | – | characterization of habitats to be lost; fish passage |
| Unnamed Creek 2 | natural | proposed | ✓ | ✓ | – | characterization of habitats to be lost |
| Redclay Creek at the mouth | natural | proposed | ✓ | ✓ | – | characterization of habitats to be lost |
| Redclay Creek upstream of compensation lake | natural | proposed | ✓ | ✓ | – | characterization of habitats to be lost |
| Pierre River upstream of the mouth | natural | proposed | ✓ | – | – | fish passage |
| Pierre River Diversion upstream of the mouth | operational channel | proposed | – | ✓ | ✓ | fish passage |
| Eymundson Creek upstream of the mouth | natural | proposed | ✓ | – | – | fish passage |
| Asphalt Creek and Eymundson Creek Diversion upstream of the mouth | operational channel | proposed | – | ✓ | – | fish passage |
| Redclay Compensation Lake | compensation | proposed | – | ✓ | ✓ | assessment of compensation habitat |
| Compensation Lake Outlet | compensation | proposed | – | ✓ | ✓ | fish passage; assessment of compensation habitat |
| Big Creek Closure Diversion (downstream reach near Redclay Compensation Lake) | compensation | proposed | – | – | ✓ | fish passage; assessment of compensation habitat |
| Big Creek Closure Diversion (upstream reach) | compensation | proposed | – | – | ✓ | fish passage; assessment of compensation habitat |
| Pierre River Closure Channel upstream of the mouth | compensation | proposed | – | – | ✓ | fish passage; assessment of compensation habitat |
| Pierre River Closure Channel upstream of the Horizon Project diversion channel | compensation | proposed | – | – | ✓ | fish passage; assessment of compensation habitat |

(a) Pre-Project period refers to the period before any activities start that may affect the fish and fish habitat of a waterbody or watercourse.
(b) Construction and operation period refers to the period where construction activities (e.g., clearing, civil works, muskeg drainage, dewatering and stream diversion) begin and mining operations end.
(c) Closure refers to the period between end of mine operation and end of mine closure activities.
– = Monitoring is not required.
Note: ✓ = Location monitored during indicated period.

### 5.2.2 Construction Monitoring

No fish and benthic invertebrates monitoring activities that are directly related to specific construction activities are anticipated to be required as part of the construction operations at the JEMA and PRMA development areas. However, fish and fish habitat monitoring will be continued during the construction phase of the Project, and these monitoring activities will be the same as described under Operations Monitoring (Section 5.2.3).

### 5.2.3 Operations Monitoring

During construction and operations of the Project, fish and fish habitat monitoring will continue at some of the same locations as during the pre-development period (Tables 9 and 10).

Monitoring locations will be located on the 2012 Kearl Lake diversion channel and will be used to evaluate fish passage through the diversion from Muskeg River to Kearl Lake. Four monitoring locations will be added to the PRMA program during the operations period. Pierre River Diversion upstream of the mouth and Asphalt Creek and Eymundson Creek Diversion upstream of the mouth will be monitored to evaluate fish passage from the Athabasca River into the diversion channels.

During the operations period, it is expected that the Redclay Compensation Lake and an outlet channel to the Athabasca River will be constructed. Monitoring sites will be established in the lake and in the outlet channel. Monitoring of the Redclay Compensation Lake and the outlet channel will begin after construction and will continue until the effectiveness of compensation has been demonstrated. The monitoring at Big Creek upstream of the Redclay Compensation Lake will additionally include monitoring to evaluate fish passage from the Athabasca River, through the Redclay Compensation Lake, and into the upper watershed of Big Creek.

### 5.2.4 Closure Monitoring

The fish and fish habitat study sites to be monitored during and after closure are described in Tables 9 and 10. During the decommissioning period of the Project, fish and fish habitat monitoring will continue in some of the same study sites as during the operations period.

Two monitoring locations will be added to the JEMA program during the decommissioning period. Two sites will be located on the Muskeg Creek

Replacement Channel, which will convey flows from Kearl Lake to the Athabasca River through the Jackpine Mine Compensation Lake. One site will be located at the outlet of Kearl Lake, to monitor fish passage, and one other site will be selected to evaluate the effectiveness of compensation habitat constructed in that channel. Four monitoring locations will be added to the PRMA program during the decommissioning period. Monitoring sites will be selected to evaluate the effectiveness of compensation habitat in the Pierre River Closure Channel and the ability of that channel to provide fish passage. The Big Creek Closure Diversion will be monitored to evaluate the effectiveness of compensation habitat in the diversion channel and the ability of the channel to provide fish passage.

It is anticipated that effectiveness of the Redclay Compensation Lake and outlet channel at meeting habitat compensation targets will be demonstrated before the end of the decommissioning period. Therefore, no post-closure monitoring of these locations is planned.

## 5.2.5 Monitoring Methods

### 5.2.5.1 Natural and Constructed Watercourse Habitats

Representative stream study reaches will be established in natural and constructed watercourses to collect population data on fish species and information on fish habitat use, physical habitat characteristics, aquatic vegetation, thermal regime, water quality and stream discharges. For the monitoring sites at indirectly affected locations that will be monitored for potential environmental effects (i.e., the Muskeg River sites affected by flow alterations), data will also be collected on benthic invertebrates and periphyton. The representative study reaches will consist of segments of watercourses selected as representative of a longer portion of a specific watercourse, and will typically have a length of approximately 40 times the bankfull width of the channel, as recommended by Harrelson et al. (1994).

#### *Fish Habitat*

Fish habitat sampling will occur seasonally (spring, summer and fall) during the open-water seasons. Various habitat characteristics will be recorded from monitoring locations including mesohabitat type (e.g., riffle, run, pool) depth, velocity, substrate characteristics, cover characteristics, aquatic vegetation, temperature, dissolved oxygen and pH. In addition, water temperature will be monitored continuously by installalled data-logging thermographs at one location in each of the representative study reaches, during the open-water period. Discharge measurements will be recorded in each representative reach during each sampling session. Discharge, dissolved oxygen and overwintering

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capabilities will be evaluated during the ice-covered season. Habitat measures associated with the fish Habitat Suitability Index (HSI) models being used at the time will all be measured for the appropriate species.

### *Fish Sampling*

Fish sampling (other than for fish passage studies) in the representative study reaches will be conducted once each year, during fall. Fall is the season that typically has the highest biomass and has stream conditions conducive to effective sampling. Within each representative reach, a stratified sampling approach will be used to ensure that the various mesohabitat types present are all sampled and that each mesohabitat type receives the appropriate sampling effort.

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While a variety of sampling methods may be used, it is anticipated that the primary method for sampling the representative stream study reaches will be electrofishing. In general, about 20 channel widths will be sampled by electrofishing. However, longer reaches may be sampled, where necessary (i.e., in very small streams or where fish densities appear to be particularly low). Where appropriate, minnow trapping will be used as a supplemental sampling method and, where used, the number of traps set at any one location will be determined based on site-specific conditions. Where site conditions allow, fyke nets may also be used as an additional supplemental sampling method. When minnow traps or fyke nets are used, they will be set for overnight periods at each sampling location.

Fish sampling will be conducted within all mesohabitat types present in the representative reaches to collect relevant fish population data (lengths, weights, age classes), relative abundance information based on Catch-Per-Unit-Effort (CPUE) data and, within any reaches where fish biomass data may be required, to estimate densities (number per unit area) and biomass per unit area for each species and age-class.

The density and biomass estimates will be extrapolated to the total area within a watercourse using the fish distribution information and stream length and width data measured during collection of habitat mapping data as part of this monitoring program.

### *Benthic Invertebrates, Periphyton and Aquatic Macrophytes*

The representative reaches will be measured for benthic invertebrates, periphyton and macrophytes on one occasion each year, at the time of maximum annual development (i.e., late summer or fall) or as indicated in the HSI models. Sampling protocols will be consistent with those used in the RAMP sampling or the HSI models, as appropriate. As the distribution and composition of benthic invertebrate, periphyton and macrophyte communities is dependent upon physical habitat characteristics, stratified sampling designs will be developed for these to ensure appropriate representation of different habitat types.

Benthic invertebrates and periphyton sampling will be conducted only at the Muskeg River sites that will be monitored for potential environmental effects due to flow alterations. These sites are MUR-1, MUR-1a, MUR-3 and MUR-5.

Benthic invertebrate samples from representative study reaches of streams will be collected from selected sites within each reach (i.e., sites selected to represent the different habitats present in the study reach). At each selected benthic sampling site, samples will be collected from the predominant habitat type in the area of each site. Depositional habitats will be sampled using an Ekman grab, and a Neill cylinder or Surber sampler will be used to sample erosional habitats. Three to five replicate samples will be collected at each site, ensuring that habitats within each selected site, including depths and steam flows, are kept similar. Additional supporting data collected at each stream site will include field water quality measurements (pH, conductivity, dissolved oxygen and water temperature), bankfull and wetted channel widths aquatic macrophyte cover, current velocity and water depth. All Ekman samples will be field sieved using a 250 µm sieve box to remove fine sediments. An additional sediment grab will collected from depositional stream sites for analysis of Total Organic Carbon (TOC) and particle size.

Periphyton samples from representative study reaches of streams will be collected from the same sites selected for benthic invertebrate sampling. At each selected benthic sampling site, samples will be collected from the predominant habitat type in the area of each site. A total of five replicate samples will be collected per site and analyzed for chlorophyll a concentration. Additional sets of five replicate samples will be collected for taxonomic analyses. Each replicate sample will consist of a scrape from measured areas on the top of two cobbles.

Aquatic macrophytes will be sampled as appropriate for the HSI models.

#### 5.2.5.2 Natural Waterbody Habitats and Redclay Compensation Lake

Natural and constructed waterbodies will be monitored to collect population data on fish species and information on fish habitat use, physical habitat characteristics, aquatic vegetation, thermal regime and water quality. Sampling will occur in littoral and pelagic zones, as prescribed in the HSI models. For the

Redclay Compensation Lake, monitoring will also include collection of information on benthic invertebrates, phytoplankton and zooplankton.

The Redclay Compensation Lake will be designed to provide compensation habitat for the JEMA and PRMA. The fish and fish habitat monitoring program is designed to monitor the development of biological communities in the compensation lakes and to evaluate the effectiveness of achieving the compensation objectives for the Project. The purpose of the auxiliary sampling is simply to understand any problems that may occur and allow appropriate adaptive measures to be undertaken. If fish community development is proceeding well, the auxiliary sampling may be reduced.

## *Fish Habitat*

This monitoring program will include the collection of data on fish habitat characteristics including temperature, dissolved oxygen, conductivity, pH, depths, substrate characteristics, cover characteristics and aquatic macrophytes. Sampling will be conducted seasonally (spring, summer and fall), during the open-water period, with some additional data collected during the ice-covered period to evaluate overwintering capabilities and as prescribed in the HSI models.

Temperature and dissolved oxygen monitoring will include measurement of vertical profiles at various locations within the waterbody during each of the open-water sampling sessions. In addition, dissolved oxygen profiles will also be measured in winter. Water temperatures will be monitored continuously by installed data-logging thermographs, during the open-water period.

## *Fish Sampling*

### Redclay Compensation Lake

Large fish species will be sampled once each year, during fall, throughout Redclay Compensation Lake (including littoral zone and pelagic zone areas) to document spatial distribution and to obtain relevant fish population data (lengths, weights, age-classes). Several littoral zone and pelagic zone sampling areas will be monitored in the lake. Sampling methods will focus on non-lethal approaches such as electrofishing, fyke nets and imaging systems, with selection of methods depending on the characteristics of the locations and species being sampled.

Forage fish species are expected to colonize primarily the littoral zones of the lake, although some species may also use the pelagic zone. Therefore, sampling of these species will be primarily within the littoral zone sampling areas, with some sampling within the pelagic zone to determine the extent species utilize that area. Forage fish species will be sampled once each year, during fall. Sampling methods may include electrofishing, fyke nets, gill nets, trawls, minnow traps, seining, imaging systems and observation by snorkelling. While a variety of sampling methods may be used, it is anticipated that the primary method of sampling the littoral zone areas, for the purpose of obtaining fish density and biomass per unit area data, will be electrofishing. Where practical, seining may also be used for collecting data on a per unit area basis.

Fish population data to be collected will include lengths, weights and age-classes. Estimates of density (number per unit area) and biomass per unit area for forage fish species will be based on habitat-specific density and biomass estimates from sampling in the various mesohabitat types present within each of the littoral zone sampling areas. These habitat-specific estimates will be based on a stratified sampling design (i.e., stratified by mesohabitat type) and will require habitat mapping of the littoral zone of the lake. These density and biomass estimates will be extrapolated, based on the amount of each habitat type in the lake, to obtain estimates of the total biomass of each forage fish species present in the lake.

### *Water Quality*

Monitoring of water quality in Redclay Compensation Lake will be done at three deep water sites (one of which will be at the deepest location in the lake) and at three littoral zone sites. Water quality sampling will be conducted on a seasonal basis (spring, summer, fall and late winter), and parameters measured will include temperature, dissolved oxygen, conductivity, major ions, total dissolved solids, nitrogen, phosphorus and chlorophyll. Vertical profile measurements of temperature, dissolved oxygen and conductivity will be taken at each location.

### *Benthic Invertebrates, Aquatic Macrophytes, Phytoplankton and Zooplankton*

Benthic invertebrates, aquatic macrophytes, phytoplankton and zooplankton will be monitored once a year, at the time of maximum annual development (i.e., late summer or fall). Sampling protocols will be consistent with those used in RAMP. As the distribution and composition of benthic invertebrate and macrophyte communities are dependent upon physical habitat characteristics, stratified sampling designs will be developed for these to ensure appropriate representation of different habitat types. Only information on aquatic macrophytes will be collected from natural waterbodies, while benthic invertebrates, aquatic macrophytes, phytoplankton and zooplankton will all be monitored in Redclay Compensation Lake.

Benthic invertebrate samples will be collected at randomly selected locations in open-water areas, outside heavy macrophyte growth and in water at least 1 m deep, in the littoral zone sampling areas in Redclay Compensation Lake. Samples will be collected at locations with fine sediments using an Ekman grab with a bottom area of 0.023 $m^2$. At locations with coarse substrate materials, other sampling methods (e.g., kick sampling or airlift sampling) will be used. Additional supporting data collected at each sampling location will include field water quality measurements (pH, conductivity, dissolved oxygen and water temperature), aquatic macrophyte cover and species composition at each sample site (by visual assessment), water depth and secchi depth.

Aquatic vegetation (macrophytes) in the littoral zone of natural waterbodies and Redclay Compensation Lake will be monitored, at the same locations where benthic invertebrates are sampled, with sampling in late summer each year. Aquatic macrophyte abundance will be estimated within 1 x 1 m floating quadrats, placed randomly in emergent and submergent macrophyte zones within each of the six littoral zone sampling areas. At each plot, the quadrat will also be used to estimate percent cover for each plant species observed as rooted within the sampling plot. Additional information recorded at each sampling plot will include a photograph of the plot, water depth, substrate characteristics and macrophyte vigour.

Phytoplankton and zooplankton samples will be collected from the pelagic zone sampling areas in Redclay Compensation Lake, at the same locations where water quality samples are taken. Phytoplankton will be sampled with a depth integrated composite sampler (hose or bottle) and zooplankton will be sampled using a 25-cm-diameter Wisconsin plankton net. At each location, one composite water sample will be taken for phytoplankton. Each composite sample will consist of five depth integrated samples, collected using a depth integrating bottle. Phytoplankton samples will be preserved in a bottle with Lugol's solution. At each location, a composite zooplankton sample, consisting of three vertical hauls collected using the plankton net, will be taken. The depth sampled from (i.e., length of each haul) will be recorded to allow estimation of the volume of water filtered. Zooplankton samples will be preserved in plastic sample bottles using 5% buffered formalin.

#### 5.2.5.3 Evaluation of Compensation Effectiveness

The effectiveness of constructed compensation habitats will be evaluated based on several performance measures including:

- measured habitat characteristics and application of HSI models;
- fish biomass per unit area data;

- fish population data (e.g., age structure, growth); and
- fish community species composition.

Habitat Suitability Index (HSI) models will be applied, using measured habitat data from the compensation habitats, to compare the number of habitat units created in the compensation habitats with those predicted for compensation habitats in the No Net Loss Plan and with the number of habitat units lost in affected watercourses and waterbodies.

A major objective of the fish and fish habitat monitoring program is to validate the HSI models using fish biomass and habitat measurements. This model validation will include plotting the model suitability indices for various representative habitats against fish biomass estimates for those habitats. Where results of the model validation procedure indicate the potential for improvement of the models, and when DFO requires changes to the models, the HSI models will be revised by adjusting the model suitability indices to provide a better correlation with biomass, removal of spurious variables, and addition of relevant variables. Where appropriate, revision of the HSI models also will incorporate knowledge generated by other studies in the Oil Sands Region. The revised models will then be applied to re-evaluate habitat losses in affected watercourses and to evaluate compensation habitat gains based on actual habitat data collected from the compensation habitats. The HSI models will be used to calculate the performance end-points in habitat units to evaluate whether compensation objectives have been achieved.

#### 5.2.5.4 Evaluation of Fish Passage

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Spring monitoring will be conducted in Muskeg Creek, the outlet diversion channel of Kearl Lake, the Muskeg Creek Replacement Channel, the Pierre River operational and closure diversion channels, the Eymundson Creek diversion channel, and the outlet from the Redclay Compensation Lake to evaluate the effectiveness of fish passage into and through these facilities. Evaluation of the effectiveness of passage will be based, in part, on environmental setting fish sampling information collected during the pre-development period using fish counting stations located in natural habitats. During the construction and operations period and the closure period (when necessary), fish counting stations will be used to ensure fish are moving into and through the constructed habitats as required.

#### 5.2.5.5 Fish Salvage Activities

*Fisheries Act* authorizations typically outline specific requirements for fish salvage activities and for data collection to be conducted during the fish salvages.

While the fish salvage activities are one-time events at each location, rather than ongoing monitoring activities, the data collected during fish salvages can be used to complement monitoring data collected under the monitoring plan activities, and will be useful for validation of HSI models and verifying fish density and biomass per unit area estimates made as part of the EIA and the monitoring program. Sampling procedures for fish salvages will generally include multiple-pass electrofishing of watercourses to be dewatered and minnow trapping. Fish salvage under ice-covered conditions has proven to be ineffective; therefore, fish salvages will be conducted under open-water conditions.

Data collection and analyses conducted as part of fish salvage operations typically include:

- location of capture;
- mesohabitat type and average wetted width at the capture site;
- electrofishing pass, trapping effort;
- number of fish captured;
- population and biomass estimates by fish species;
- measured fork length and weight for the first 100 fish of each species and estimated fork length for the remaining fish of each species;
- length frequency histograms for the measured sample for each fish species;
- lifestage (fry, juvenile, adult) and lifestage definitions using fork length for each species;
- type of electrofisher used;
- length of channel shocked and area shocked for each reach sampled; and
- detailed maps indicating the fish salvaged area.

### 5.2.5.6 Reporting

The Alberta EPEA Approval reporting requirements related to fish and fish habitat monitoring typically include reporting the results of the fish monitoring program annually, to be included as part of an annual Conservation and Reclamation Report that is generally required as specified in the EPEA Approval. An annual report on the environmental effects monitoring is a typical additional EPEA reporting requirement that includes, as a component, some of the results of the fish and fish habitat monitoring program.

Reporting requirements under conditions of the *Fisheries Act* authorizations typically include annual reports on the results of the fish and fish habitat monitoring program, and reports on the results of fish salvage activities. The annual monitoring report will provide the results of the fish and fish habitat monitoring program as outlined above. Each annual monitoring report will incorporate all previous years' results, as required to present the entire monitoring program in a single coherent annual report.

Shell will submit the annual report to both AENV and Fisheries and Oceans Canada (DFO). Raw data will also be provided annually to RAMP.

# 6 REFERENCES

APHA (American Public Health Association). 1999. Standard Methods for the Examination of Waste and Wastewater. 20th Edition. American Public Health Association. Washington, D.C.

CCME (Canadian Council of Ministers of the Environment). 1993a. Guidance manual on Sampling, Analysis, and Data Management for Contaminated Sites. Volume I: Main Report. Report CCME EPC-NCS62E, Winnipeg, Manitoba, December, 1993.

CCME. 1993b. Guidance manual on Sampling, Analysis, and Data Management for Contaminated Sites. Volume II: Analytical Method Summaries. Report CCME EPC-NCS66E, Winnipeg, Manitoba, December, 1993.

Environment Canada. 1994. Guidance Document on Collection and Preparation of Sediments for Physiochemical Characterization and Biological Testing. Report EPS 1/RM/29. December, 1994.

Harrelson, C.C., C. L. Rawlins and J. P. Potyondy. 1994. Stream channel reference sites: an illustrated guide to field technique. Gen. Tech. Rep. RM-245. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 61 p.

Komex (Komex International Ltd.). 2004. 2003 Groundwater Monitoring Program for the Muskeg River Oil Sands Project. Unpublished report prepared for Albian Sands Energy Inc. March 2004. Internal File No. E35776503.

RAMP (RAMP 2003 Implementation Team). 2004. Regional Aquatics Monitoring Program (RAMP) 2003 Annual Report. Prepared for: RAMP Steering Committee. Submitted by the RAMP 2003 Implementation Team consisting of: Hatfield Consultants Ltd., Jacques Whitford Environment Ltd., Mack, Slack & Associates Inc., and Western Resource Solution. March 2004.

RAMP (Regional Aquatics Monitoring Program). 2006. Regional Aquatics Monitoring Program (RAMP) 2005 Technical Report. Prepared for the RAMP Steering Committee. Submitted by the RAMP 2005 Implementation Team consisting of Hatfield Consultants Ltd., Stantec Consulting Ltd., Mack, Slack and Associates Inc. and Western Resource Solutions. Submitted April, 2006.

Shell (Shell Canada Limited). 2007. Jackpine Mine – Phase 1 Surface Water and Fish Monitoring Plan. May 2007.

WorleyParsons Komex. 2007a. Proposed Groundwater Monitoring Program for Jackpine Mine – Phase 1. Report prepared for Shell Canada Limited. Calgary. April 2006.

WorleyParsons Komex. 2007b. 2006 Groundwater Monitoring Program Muskeg River Mine. Report prepared for Albian Sands Energy Inc. Edmonton. March 2007.

# 7 ABBREVIATIONS

| | |
|---|---|
| % | Percent |
| < | Less than |
| AENV | Alberta Environment |
| ASRD | Alberta Sustainable Resource Development |
| BTEX | Benzene, Toluene, Ethylbenzene, Xylene |
| CEMA | Cumulative Environmental Management Association |
| CONRAD | Canadian Oil Sands Network for Research and Development |
| CPUE | Catch per unit of effort |
| DFO | Fisheries and Oceans Canada (Note: formerly Department of Fisheries and Oceans Canada) |
| EC | Electrical Conductivity |
| e.g. | For example |
| EPEA | Alberta *Environmental Protection and Enhancement Act* |
| ETDA | External Tailing Disposal Area |
| HSI | Habitat Suitability Index |
| i.e. | That is |
| IFNTG | Instram Flow Needs Task Group |
| JEMA | Jackpine Expansion Mining Area |
| m | Metre |
| $m^2$ | Square metres |
| mg/l | Milligrams per litre |
| mm | Millimetre |
| PAH | Polycyclic aromatic hydrocarbons |
| PANH | Polycyclic aromatic nitrogen heterocycles |
| PHCs | Petroleum Hydrocarbons |
| PRMA | Pierre River Mining Area |
| PVC | Polyvinyl chloride |
| QA/QC | Quality Assurance/Quality Control |
| RAMP | Regional Aquatics Monitoring Program |
| RSA | Regional Study Area |
| SWWG | Surface Water Working Group of CEMA |
| TDS | Total Dissolved Solids |
| TOC | Total Organic Carbon |
| TSS | Total Suspended Solids |
| WITG | Watershed Integrity Task Group |
| µm | Micron or Micrometre |

# 8 GLOSSARY

**Acute** A stimulus severe enough to rapidly induce an effect; in aquatic toxicity tests, an effect observed in 96 hours or less is typically considered acute. When referring to aquatic toxicology or human health, an acute effect is not always measured in terms of lethality.

**Alkalinity** A measure of water's capacity to neutralize an acid. It indicates the presence of carbonates, bicarbonates and hydroxides, and less significantly, borates, silicates, phosphates and organic substances. Alkalinity is expressed as an equivalent of calcium carbonate. Its composition is affected by pH, mineral composition, temperature and ionic strength. However, alkalinity is normally interpreted as a function of carbonates, bicarbonates and hydroxides. The sum of these three components is called total alkalinity.

**Anoxia** Little to no dissolved oxygen in the water sample. Waters with less than 2 mg/L of dissolved oxygen experience anoxia.

**Aquifer Depressurization** The process of reducing the natural hydrostatic pressure in an aquifer.

**Bankfull Width** The width of the stream, measured at the water surface elevation corresponding to the bankfull discharge. For undisturbed streams with a wide floodplain, this is equivalent to channel width.

**Basal Aquifer** A water-bearing strata located at the lowest portion of a stratigraphic unit.

**Benthic Invertebrates** Invertebrate organisms living at, in or in association with the bottom (benthic) substrate of lakes, ponds and streams. Examples of benthic invertebrates include some aquatic insect species (such as caddisfly larvae) that spend at least part of their lifestages dwelling on bottom sediments in the waterbody. These organisms play several important roles in the aquatic community. They are involved in the mineralization and recycling of organic matter produced in the water above, or brought in from external sources, and they are important second and third links in the trophic sequence of aquatic communities. Many benthic invertebrates are major food sources for fish.

| | |
|---|---|
| **Conductivity** | A measure of the capacity of water to conduct an electrical current. It is the reciprocal of resistance. This measurement provides an estimate of the total concentration of dissolved ions in the water. |
| **Dissolved Oxygen (DO)** | Measurement of the concentration of dissolved (gaseous) oxygen in the water, usually expressed in milligrams per litre (mg/L). |
| **Ekman Grab** | Cube-shaped mechanical device with a spring-loaded opening that is lowered to the bottom of a waterbody and triggered to close as to collect a sample of the bottom substrate. |
| **Electrical Conductivity** | The capability of a solution to transmit an electrical current. A capability closely related to the concentration of salts in soils. |
| **Electrofishing** | A ‘live’ fish capture technique in which negative (anode) and positive (cathode) electrodes are placed in the water and an electrical current is passed between the electrodes. Fish are attracted (galvano-taxis) to the anode and become stunned (galvano-narcosis) by the current, allowing fish to be collected, measured and released. |
| **Fen** | Sedge peat materials derived primarily from sedges with inclusions of partially decayed stems of shrubs formed in a eutrophic environment due to the close association of the material with mineral rich waters. Minerotropic peat-forming wetlands that receive surface moisture from precipitation and groundwater. Fens are less acidic than bogs, deriving most of their water from groundwater rich in calcium and magnesium. |
| **Fork Length** | The length of a fish measured from the most anterior portion of the head to the tip of the shortest rays in the caudal fin (i.e., to the fork in the tail). |
| **Groundwater** | That part of the subsurface water that occurs beneath the water table, in soils and geologic formations that are fully saturated. |
| **Habitat Suitability Index (HSI) Model** | Analytical tools for determining the relative potential of an area to support individuals or populations of a wildlife species. They are frequently used to quantify potential habitat losses and gains for wildlife as a result of various land use activities. |

**Hydraulic Conductivity** The permeability of soil or rock to water.

A coefficient "k" depends on the physical properties of formation and fluid. It describes the "ease" with which a fluid will flow through a porous material. "k" is the rate of flow per unit cross-sectional area under the influence of a unit gradient, and has the dimension of:

$Length^3/Length^2$ x Time or Length/Time (e.g., m/s), but should not be confused with velocity.

**Littoral Zone** The zone in a lake that is closest to the shore. It includes the part of the lake bottom, and its overlying water, between the highest water level and the depth where there is enough light (about 1% of the surface light) for rooted aquatic plants and algae to colonize the bottom sediments.

**Mesohabitat** General habitat characteristics of a watercourses or waterbody, as assessed on a large scale.

**Oil Sands Region** The Oil Sands Region includes the Fort McMurray – Athabasca Oil Sands Subregional Integrated Resource Plan (IRP), the Lakeland Subregional IRP and the Cold Lake – Beaver River Subregional IRP.

**Pelagic** Inhabiting open water, typically well off the bottom. Sometimes used synonymously with limnetic to describe the open water zone (e.g., large lake environments).

**pH** The degree of acidity (or alkalinity) of soil or solution. The pH scale is generally presented from 1 (most acidic) to 14 (most alkaline). A difference of one pH unit represents a ten-fold change in hydrogen ion concentration.

**Polycyclic Aromatic Hydrocarbon (PAH)** A chemical by-product of petroleum-related industry. Aromatics are considered to be highly toxic components of petroleum products. PAHs, many of which are potential carcinogens, are composed of at least two fused benzene rings. Toxicity increases along with molecular size and degree of alkylation of the aromatic nucleus.

**Regional Aquatics Monitoring Program (RAMP)** RAMP was established to determine, evaluate and communicate the state of the aquatic environment in the Athabasca Oil Sands Region.

**Riffle-Run-Pool** A mixture of flows and depth and providing a variety of habitats. Pools are deep with slow water. Riffles are shallow with fast, turbulent water running over rocks. Runs are deep with fast water and little or no turbulence.

**Secchi Depth** A parameter used to determine the clarity of surface waters. The measurement is made with a "Secchi" disk, a black and white disk that is lowered into the water and the depth is recorded at which it is no longer visible. A secchi depth recording of 5 ft indicates that the device was last visible at 5 ft below the surface.

High secchi depth readings indicate clearer water that allows sunlight to penetrate to greater depths. Low readings indicate turbid water which can reduce the passage of sunlight to bottom depths. Limited light penetration can be a factor in diminished aquatic plant growth beneath the surface, thus reducing the biological reaeration at lower depths.

**Sediment** Solid material that is transported by, suspended in, or deposited from water. It originates mostly from disintegrated rocks; it also includes chemical and biochemical precipitates and decomposed organic material, such as humus. The quantity, characteristics and cause of the occurrence of sediment in streams are influenced by environmental factors. Some major factors are degree of slope, length of slope soil characteristics, land usage and quantity and intensity of precipitation.