NORMAN WELLS OPERATIONS
INTERIM CLOSURE AND RECLAMATION PLAN
SUBMITTED FOR APPROVAL MARCH 2016

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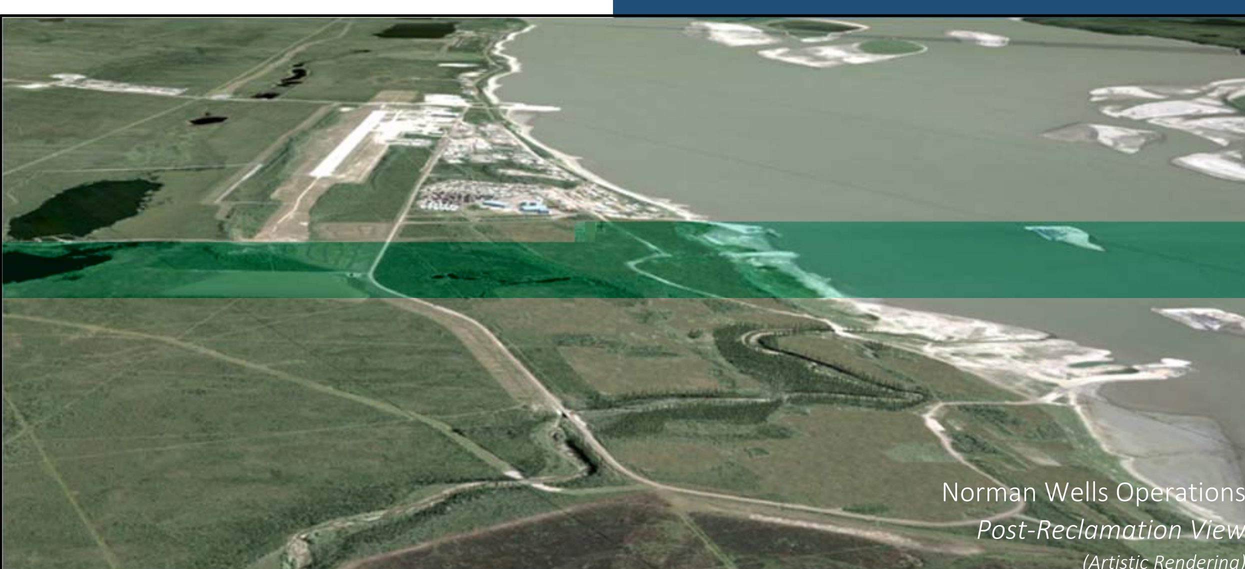
Norman Wells Operations
Current View



Norman Wells Operations
Post-Reclamation View
(Artistic Rendering)

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ACRONYMS

AEMP	Aquatic Effects Monitoring Program
BIT	Bear Island Terminal
C&R	Closure and Reclamation
CCME	Canadian Council of Ministers of the Environment
CPF	Central Processing Facility
D&D	Dismantling and Demolition
DPE	Dual Phase Extraction
GIT	Goose Island Terminal
LTMA	Long Term Management Area
LTMF	Long Term Management Facility
MPE	Multi-Phase Extraction
MVLWB	Mackenzie Valley Land and Water Board
MVRMA	*Mackenzie Valley Resource Management Act*
NTPC	Northwest Territories Power Corporation
NWT	Northwest Territories
SLWB	Sahtu Land and Water Board
SSA	Sahtu Settlement Area

1.1 INTRODUCTION

This Plain Language Summary describes the current Closure and Reclamation (C&R) Plan for Imperial's Norman Wells Operations (referred to from here on as "Operations").

The Operations C&R Plan deals with concepts that hold value for different groups of stakeholders, including regulators, communities, Aboriginal governments/organizations, and other interested parties. This summary aims to communicate the C&R planning process and key features of the plan in a clear, direct manner that speaks to all stakeholder groups.

The C&R Plan itself is a detailed technical document. It is referred to in this summary and is available as a resource for more details and technical information (see Section 17).

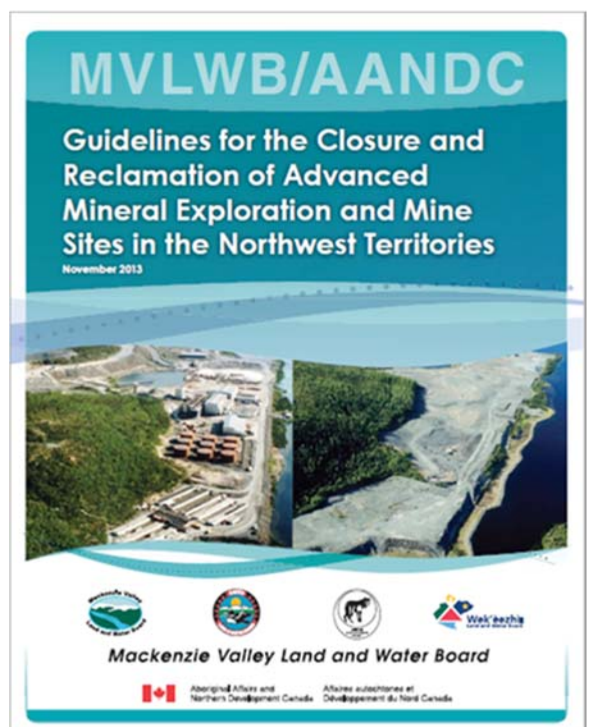
Why is a C&R Plan Required?

Imperial is committed to conducting its operations in compliance with regulatory requirements that apply to its Operations. There are a number of licences and permits that regulate activities for the Operations. A primary one is the Water Licence issued by the Sahtu Land and Water Board (SLWB) under the *Mackenzie Valley Resource Management Act* (MVRMA). The current version of the Water Licence requires that Imperial submit a Closure and Reclamation (C&R) Plan for the Operations to the SLWB by 5 March 2016.

Because the Water Licence itself does not specifically say what the C&R Plan should cover or what it should look like, Imperial consulted with regulators early in the process on the best source of guidance for planning and a general template.

General guidance for the C&R Plan has been adopted from the Mackenzie Valley Land and Water Board's (MVLWB's) "*Guidelines for the Closure and Reclamation of Advanced Mineral Exploration and Mine Sites in the Northwest Territories*" (MVLWB 2013).

The guidelines were not developed for oil and gas facilities. However, they provide a coordinated and consistent approach to closure planning that reflects the regional and community setting and can be adapted well to the Operations.



What is a C&R Plan?

A C&R Plan describes activities to be planned and completed prior to and following the end of the operational life of a facility to make sure that it is closed and reclaimed in a manner that matches up with goals for closure.

For the Operations, the C&R Plan describes the coordinated actions planned to return the site and affected areas to established settings that are compatible with a healthy environment and with safe human activities.

What's in the C&R Plan?

The C&R Plan lines up with the template provided in the MVLWB Guidelines. Because the guidelines have been developed for mineral exploration and mine sites (versus oil and gas operations), there are a few areas where the template has been adapted, with the input of regulators, to reflect the nature and scale of the Operations.

Norman Wells Operations
Interim C&R Plan
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- Introduction
- Project Environment
- Project Description
- Permanent Closure and Reclamation
- Progressive Reclamation
- Temporary Closure
- Integrated Schedule of Activities
- Post Closure Site Assessment
- Financial Security
- Closure
- References
- Appendices (e.g., Record of Engagement)

The C&R Plan is an *Interim* plan which will be reviewed during the remaining life of the Operations (see Section 16). Interim status notwithstanding, the plan describes the C&R activities that Imperial expects to implement for the Operations.

A more defined version of this plan will be developed closer to the scheduled closure of the Operations. This final plan will reflect ongoing stakeholder engagement as well as the technical, community, environmental and economic conditions that exist at that time. This final plan will also reflect the continuous improvement processes that will be applied to the definition of specific closure activities between now and closure.

The Working Group

The Interim C&R Plan has been developed by Imperial along with local community stakeholders, the regulatory community and with the technical assistance of Imperial's consulting partners.

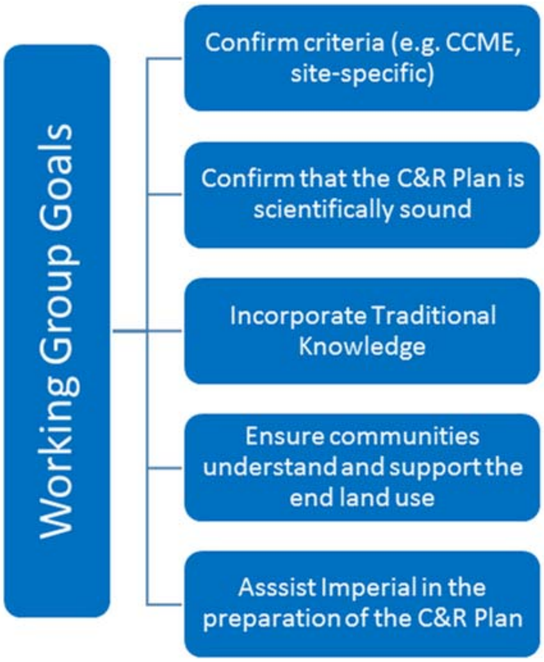
In 2014, the SLWB requested that a Working Group come together to provide a formal way for meeting with stakeholders interested in the development of Imperial's C&R Plan for the Operations.

The Working Group represents a chance to engage with regulators, communities, Aboriginal governments/organizations, and other interested parties. Imperial has participated in the Working Group to obtain guidance and feedback, and to resolve issues before the review of the C&R Plan for approval by the SLWB.

Imperial's participation in the Working Group is consistent with the company's Sahtu Settlement Area (SSA) Community Engagement Plan for the Operations.

Working Group Goals

Goals for the Working Group, as set out by the SLWB are:



Community Engagement

The Working Group has been the primary vehicle for ensuring that community perspectives are reflected in the C&R Plan. As a member of the local and regional communities, Imperial also routinely communicates with local stakeholders that may not have a formal involvement in the Working Group. Imperial will continue to consult with regulatory and community stakeholders following the submission of this Interim C&R Plan.

Local Opportunities

The C&R Plan includes some facilities and processes that will be in place over a long period of time to ensure that the closed site remains compatible with a healthy environment and with human activities.

These facilities and processes will require people and equipment to manage and monitor their operation; and there is also work involved in putting these requirements in place.

There is a variety of possible commercial arrangements that could be developed using local or regional businesses and skills to address these, and potentially other, C&R requirements. Imperial anticipates that the scope of these potential opportunities, along with prospective training and capacity building opportunities, will be an important part of the discussions and engagements that will occur as the C&R Plan evolves in the years leading up to facility closure.

For more information, see Section 2.4 of the *Interim Norman Wells Operations Closure and Reclamation Plan*.

1.2 NORMAN WELLS OPERATIONS

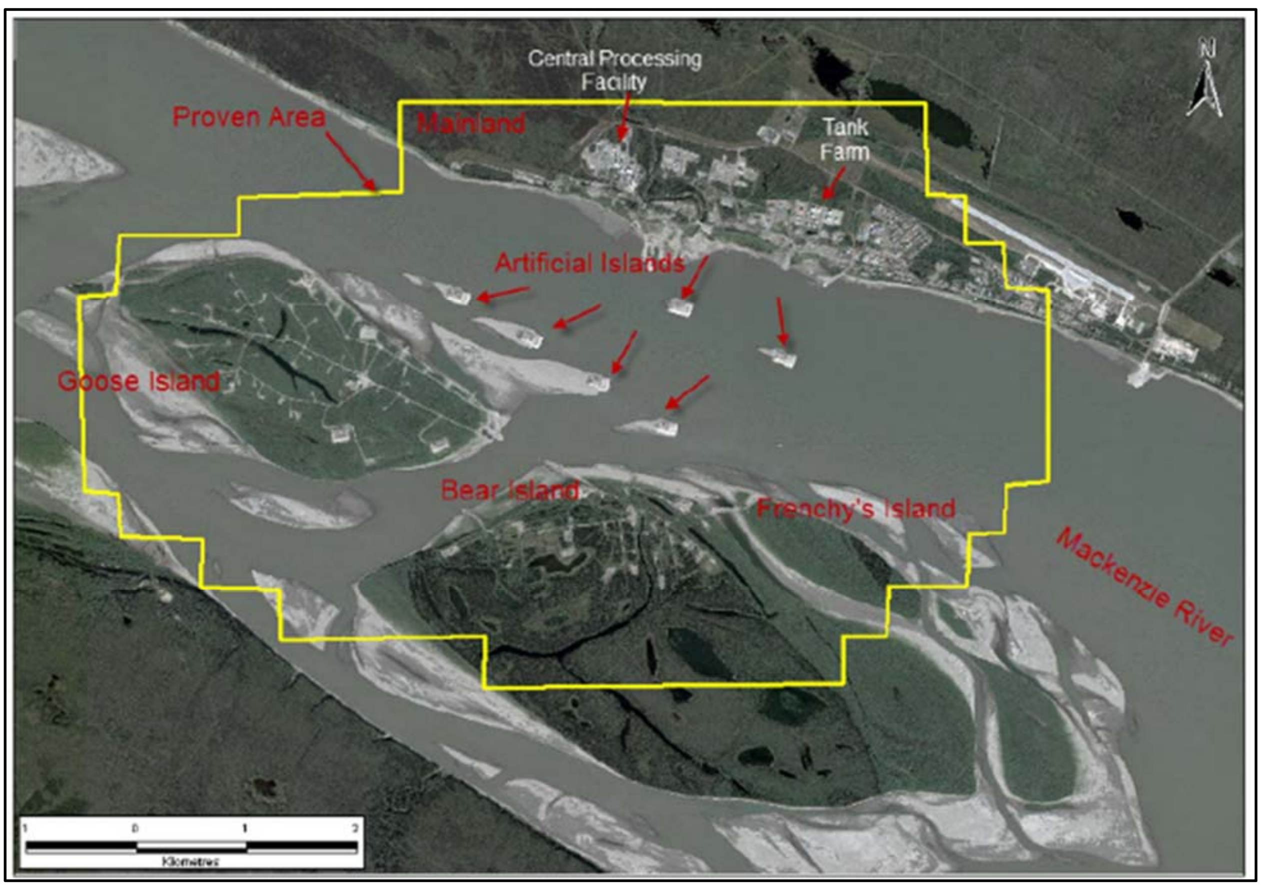
Imperial has been conducting operations at Norman Wells since the 1920s when the first well on the banks of the Mackenzie River east of the Bosworth Creek delta was drilled.

Imperial's Operations are located within the municipal boundary of the Town of Norman Wells and within an area called the Proven Area. The Proven Area is situated on Federal Crown Lands, Territorial Lands and lands owned by Imperial and other private landowners, and covers an area of 7,939 acres or 32 km^2. The actual size of the geographical footprint of the Operations is approximately 11 km^2.

Oil and gas production facilities (collectively called "the Field") include operations on the Mainland, the three Natural Islands (Bear, Goose and Frenchy's), and six Artificial Islands (1-Rayuka, 2-Rampart, 3-Dehcho, 4-Ekwe, 5-Iteh K'ee and 6-Little Bear). A Central Processing Facility (CPF) is also located on the Mainland. Collectively, the Field and CPF are referred to as the Operations (see figure below).

Currently, the Operations produce approximately 1,900 m^3 (12,000 bbl or barrels) of oil per day from 353 operating wells. These include oil producers and water injectors. In addition to producing oil, Imperial generates electricity for internal use and for the Northwest Territories Power Corporation (NTPC) to supply the Town of Norman Wells.

For more information, see Section 4.0 of the *Interim Norman Wells Operations Closure and Reclamation Plan*.



Local Environment

The Norman Wells Operations is located along the Mackenzie River ("the River") - the largest and longest river system in Canada.

The soil and water in the Sahtu region are unique because they contain naturally occurring metals, salts and oils. The area is also known to have natural oil and gas seeps along the River.

The Operations lies in a zone of discontinuous permafrost. Discontinuous means that permafrost in the area is common but it isn't found everywhere; or at the same thickness or depth. The layer of soil above the bedrock at the Operations is typically shallow. Groundwater on the north side of the River generally flows toward the south.

There are various terrestrial (land) and aquatic (water) wildlife species in the Norman Wells area which are important local resources.

For more information, see Section 3.0 of the *Interim Norman Wells Operations Closure and Reclamation Plan*.

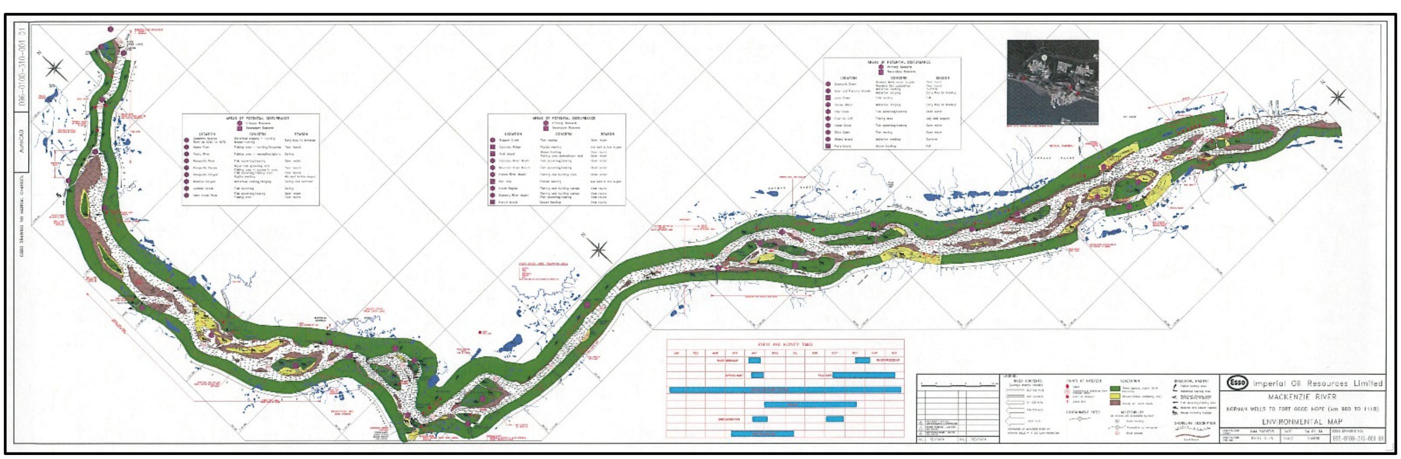
Community Setting

Norman Wells is located within the boundaries of the Sahtu Settlement Area (SSA). There are five communities in the SSA. These are Colville Lake, Déline, Fort Good Hope, Norman Wells, and Tulita.

The Operations is located within the limits of the Town of Norman Wells. The Town is the transportation hub for the SSA. Norman Wells' establishment and growth closely followed the exploration and development of hydrocarbons in the area. However, Norman Wells features a wide variety of businesses and economic development opportunities in addition to major oil and gas production and operating facilities.

Traditional Knowledge

Imperial hosted Traditional Knowledge workshops in Fort Good Hope and Norman Wells in 2013 as part of the Water Licence Renewal Application process, and to build on the knowledge base assembled during previous studies in the communities. Local Elders who regularly use the River were asked to share their knowledge of the River and the surrounding area, and to update the River map that was made in 1993 (below).

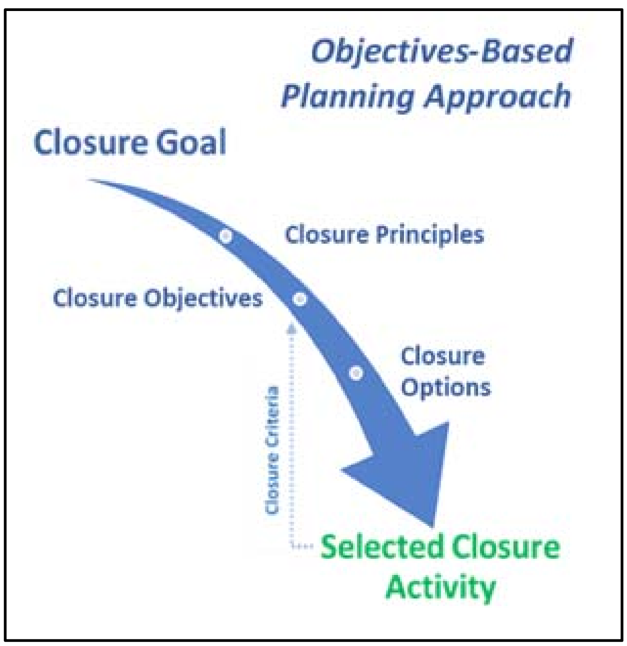


1.3 C&R PLANNING APPROACH

Imperial has followed the Objectives-Based approach that is recommended in the MVLWB guidelines to develop the C&R Plan.

Imperial, along with the Working Group, agreed to adopt the overall closure goal from the guidelines for the Operations. Closure principles, also adopted from the guidelines, were used to guide the selection of clear and measurable closure objectives.

Next, the specific actions and measures (activities) required to meet each closure objective were selected from a set of options. Criteria were identified to measure the success of selected closure activities in meeting the objectives.

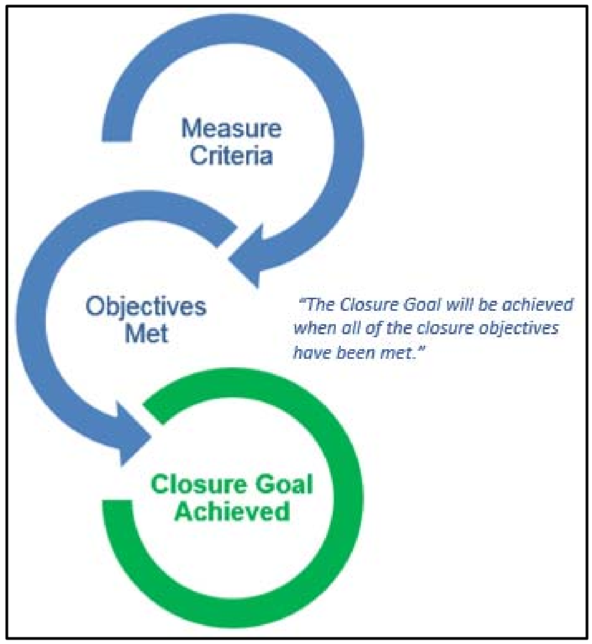


Closure Goal & Principles

The overall closure goal establishes overall vision and purpose of closure for the Operations.

> ***Closure Goal:*** *"To return the site and affected areas to viable and wherever practicable, self-sustaining ecosystems that are compatible with a healthy environment and with human activities."*

As a general statement, the closure goal can't be measured directly. It is considered achieved when all of the closure objectives have been met.



The Working Group also agreed on a set of guiding closure principles that are specified in the MVLWB guidelines and that support the closure goal. The principles were considered in the selection of closure objectives and include: Physical Stability, Chemical Stability, No Long Term Active Care, and Future Use. Imperial has accommodated the "No Long Term Active Care" principle in the Interim C&R Plan by limiting post closure management activities to those required to sustain the property in its reclaimed state. Post closure management will not involve activities that indefinitely defer the closure and reclamation of facilities or lands on the Proven Area.

Closure Objectives

Closure Objectives were developed to describe what the selected closure activities should aim to achieve. The objectives set measureable, achievable targets to guide the selection of what activities will be implemented to achieve closure.

Site-Wide Objectives

Site-wide Closure Objectives apply property-wide and set the stage for the next planning steps.

These objectives address overarching values as established by the Working Group; as well as key environmental components or 'media', including air, land, water and wildlife.

- Landscape closed and reclaimed in a manner that reflects consultation with community members and associated Traditional Knowledge and use.
- Removal or mitigation of physical and chemical hazards.
- Incremental disturbance of land required to support closure and reclamation activity minimized.
- Compliance with legal, regulatory and corporate obligations.
- Archaeological and historically significant sites identified by entities such as the Prince of Wales Northern Heritage Centre, Norman Wells Historical Society, regional Land Corporations and Secretariat are protected and preserved.

Site-Wide Objectives
Overarching Values

- Dust levels at the closed and reclaimed site safe for people, vegetation, wildlife, and aquatic life.
- Soil that is safe for people and the environment.
- Closed and reclaimed landscape that is physically stable, safe, and consistent and compatible with the surrounding natural area.
- Below ground facilities and infrastructure are abandoned or removed as appropriate for safe utilization of the defined future land use.
- Above-ground facilities, infrastructure and debris are removed.
- Water quality that is safe for humans, wildlife and aquatic life; and does not compromise the ecology of natural watercourses such as the Mackenzie River and Bosworth Creek.
- Hydrology and drainage of the reclaimed land surface generally consistent with the character of the local watershed and appropriate to the defined land use.
- Terrain restoration to allow safe utilization and passage by terrestrial wildlife.

Site-Wide Objectives
Air, Land, Water, and Wildlife

Component-Specific Objectives

As a next level of detail, Component-Specific Closure Objectives were developed for smaller, more manageable sections of the Operations, called Closure Components.

Some of these component-specific objectives match the site-wide objectives. This overlap, where it exists, lines up with the MVLWB Guidelines.

Many of the site-wide closure objectives also apply to individual project closure components – so they have been adopted at that level.

In some cases, there are closure factors that are unique to a project component. In these cases, distinct component closure objectives were developed.

These distinct objectives, where they exist, are described in the component-specific sections later in this summary. They are also described in detail in Section 5.0 of the C&R Plan.

Component Objectives – Common Themes

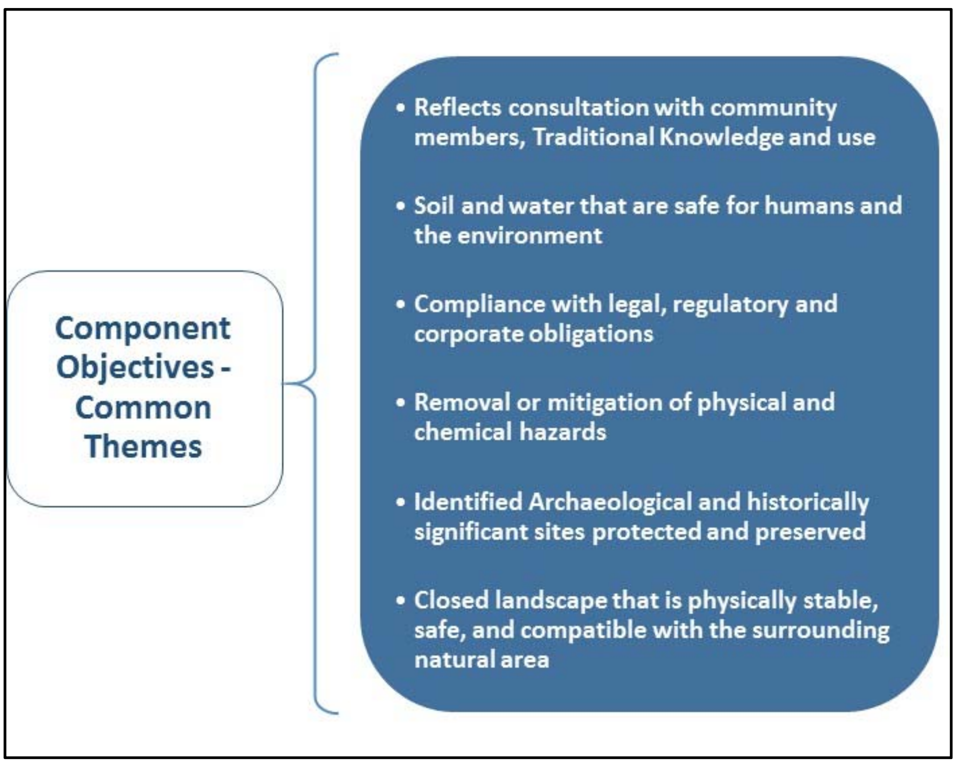
There is a common set of themes in the component-specific objectives. These common themes mirror the overarching site-wide objective values and are highlighted in the figure below.

Closure Components

Closure Components were selected to provide a coordinated and consistent approach to closure planning. Project components include the following, which are illustrated on the next page:

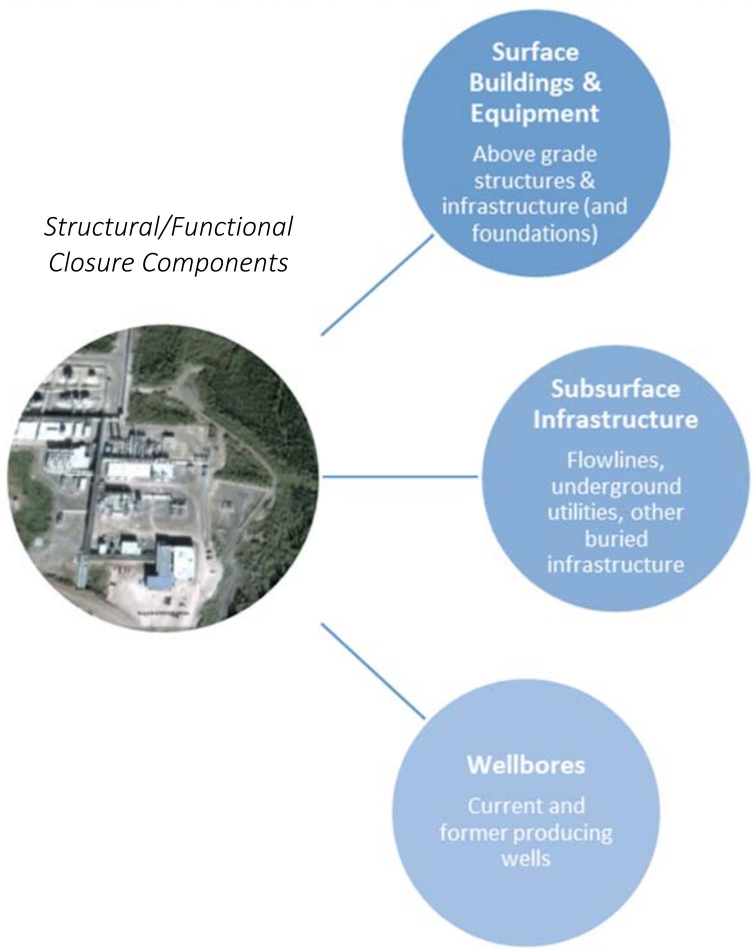
- four distinct geographic areas (Mainland, Natural Islands, Artificial Islands and Natural Watercourses); and
- three different types of major infrastructure/functional features (Surface Buildings & Equipment, Subsurface Infrastructure, Wellbores).

For more information, see Section 5.2.3 of the *Interim Norman Wells Operations Closure and Reclamation Plan*.



Geographic Closure Components

Structural/Functional Closure Components



1.4 CLOSURE ACTIVITIES

Closure Activities are specific actions and measurements that are planned and completed to meet closure objectives. At an operations-wide level, the order of closure activities for the Operations will follow the sequence shown in the figure on the right.

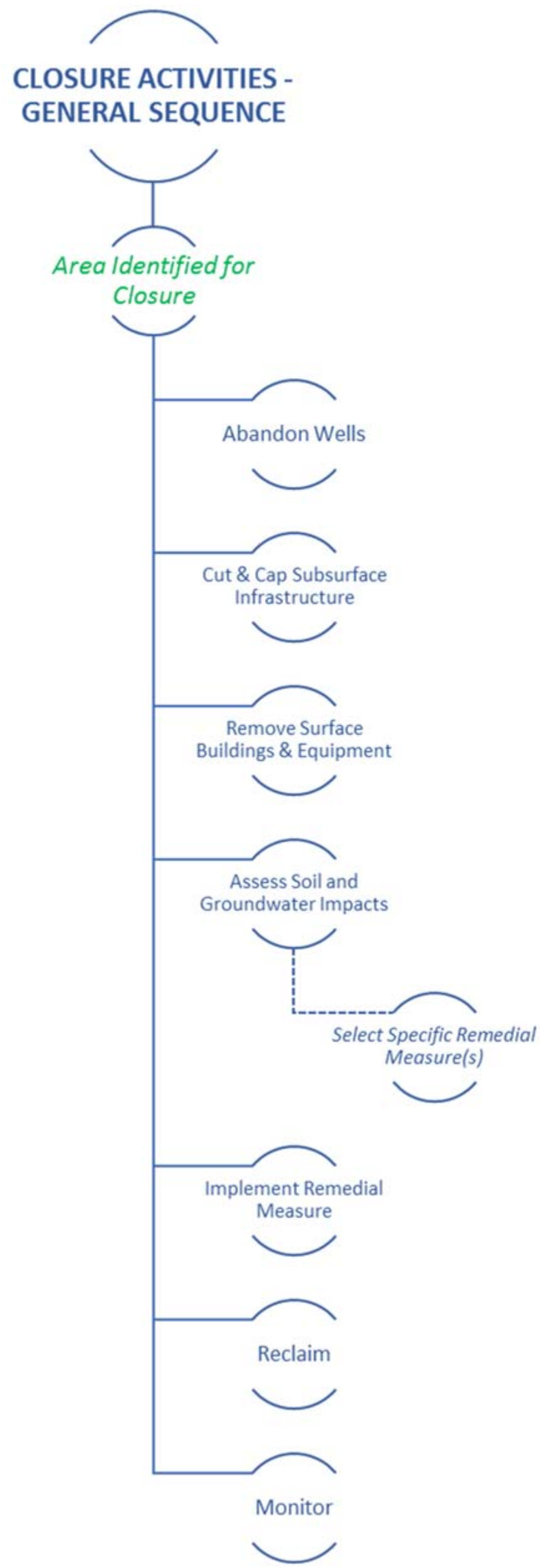
When an area is scheduled for closure, the Wellbores and below ground (subsurface) infrastructure are either cleaned and abandoned in place following proven protocols, or removed. Surface buildings, equipment and infrastructure are then decommissioned, dismantled and removed.

The quality of groundwater and soil in the area(s) are assessed to determine the nature and scale of any remaining impacts. This information is used to determine the best strategies (or remedial measures) to neutralize, reduce or remove impacted soil and groundwater. Once the remedial measure(s) are complete, the area is reclaimed and monitored according to the C&R Plan.

Closure Options

Closure options are a set of proposed alternatives for closing each project component. Closure options for the Operations were evaluated to determine the selected closure activity for the component. Evaluation was based on how well each option will meet the closure objective(s).

Options were also reviewed based on how well each is expected to perform and how well each addresses potential safety and environmental risks associated with putting the option in place. Options were also reviewed for possible benefits to the community (e.g., commercial benefits).



Property-Wide/Central Closure Activities

Due to a significant link to the closure objectives, property-wide level closure options focused on strategies to remediate the impacted soil materials that are present across the Proven Area. Remedial strategies assessed included removing and gathering impacted soils together for disposal (on-site and off-site were considered), in situ (in place) containment, as well as options for soil treatment.

The primary option selected involves the removal of soils that cannot practically be treated and consolidation in a central on-site Long Term Management Facility (LTMF). This option was selected because:

1. It is expected to meet closure objectives (i.e., to limit post closure land use restrictions by keeping materials in one central place);
2. It can be predicted to perform well (i.e., there is certainty that it will function as expected and required);
3. There are associated local employment and commercial opportunities; and
4. It is economically possible.

For more information, see Section 5.0 (Table 5-4: Comparative Rankings of C&R Remedial Strategy Alternatives) of the *Interim Norman Wells Operations Closure and Reclamation Plan*.

Long Term Management Facilities (LTMF)

Long Term Management Facilities (LTMF) are enclosed earthen structures - similar to secure landfills and are designed to contain impacted materials over open-ended timeframes. They are typically the most practical and adaptable options, particularly for relatively remote locations like Norman Wells. As the preferred alternative for the Operations, an LTMF will be used for the impacted soils and structure dismantling/demolition debris produced during remediation.

Impacted soils throughout the Proven Area will be removed and treated, or consolidated into a single LTMF. The LTMF will have features in place to ensure proper containment of these materials. These features will be similar to those used in modern secure landfills.

The LTMF will be sited in a dedicated portion of the Mainland Central area and is described in detail in Section 5 (*Mainland Component)*.

Long Term Management Areas (LTMAs)

The proposed C&R approach also includes Long Term Management Areas (or LTMAs). LTMAs are sources or zones of impacted materials which will require long term management in their current location.

There will be a few LTMAs for the Operations. LTMAs will be limited to a small number of source areas located primarily in the Mainland Central/ East areas and are described in Section 5 (*Mainland Component*).

Component Closure Activities

The following sections provide a summary of the closure activities that have been selected from options for each project component. These are specific actions and measurements that have been selected to meet closure objectives for each component.

1.5 MAINLAND COMPONENT

The Mainland component of the Operations is one of the primary focus areas for closure activity because of its scale and because of its location at the centre of both the Proven Area and Imperial's historical operations. Component objectives for the Mainland are aligned with the site-wide closure options.

The Mainland component contains much of the Proven Area's inventory of impacted soil. In addition, the Long Term Management Areas (LTMAs) that have been identified on the Proven Area to date are located in this component. The central location of the Mainland also makes it the best location for the Long Term Management Facility (LTMF) which is a key element of the C&R Plan.

Long Term Management Areas (LTMAs)

LTMAs are sources or zones of impacted materials which will require long term management in their current location. This is because they can't be reliably or permanently remediated using currently available technology and/or at a realistic cost.

Candidate LTMAs are identified, and their status regularly reviewed, on the basis of the monitoring and site characterization data that is routinely compiled during site operations. The final schedule of LTMAs at closure will be dependent on site conditions and technology capabilities relevant at the time. Current information suggests that impacts identified in the Refinery Bank area and the former Flare Pit north of Battery 3 could be designated as LTMAs following closure.

Refinery Bank: A groundwater containment and hydrocarbon recovery system is in place on the Refinery Bank to mitigate hydrocarbon impacts from previous operations of the old refinery. The nature and location of these impacts is such that product recovery efforts may require long term management.

Former Flare Pit: The former Flare Pit north of Battery 3 contains salt from previous operations which extends into the underlying fractured bedrock. Removing the salt impacted soil above the rock would still leave a significant portion of the total salt in the area. Therefore, the former Flare Pit area may be identified as an LTMA.

LTMA - Refinery Bank Gathering System

For more information, see Section 5 of the *Interim Norman Wells Operations Closure and Reclamation Plan*.

Long Term Management Facility (LTMF)

The Mainland component area was considered as the location for a Long Term Management Facility (LTMF) because of its central location on the Proven Area and because it contains the largest proportion of the Proven Area's impacted soil inventory.

Impacted soil volumes on the Mainland that do not meet CCME Industrial criteria will be excavated and treated, or consolidated within the LTMF.
See Section 12 for discussion on CCME Criteria.

LTMF Description

The LTMF will be used to contain impacted soil that cannot practically be treated and reused, as well as waste and debris from the dismantling of buildings, equipment and infrastructure. It is currently anticipated that only a limited portion of the soil inventory will be treatable, and that most of the soils will be directed to the LTMF.

The completed LTMF footprint area will be a little over 10 ha and has a design capacity of 720,000 m^3. Completion of the LTMF will be staged to support the sequence of closure and align with progressive reclamation activities for the Operations (see Section 13).

The shape of the final LTMF is rounded with slight curves so that it appears similar to a natural landform. The top and the side slopes have also been designed with a natural landform in mind. The LTMF cap will be seeded with grass similar to those on the surrounding lands.

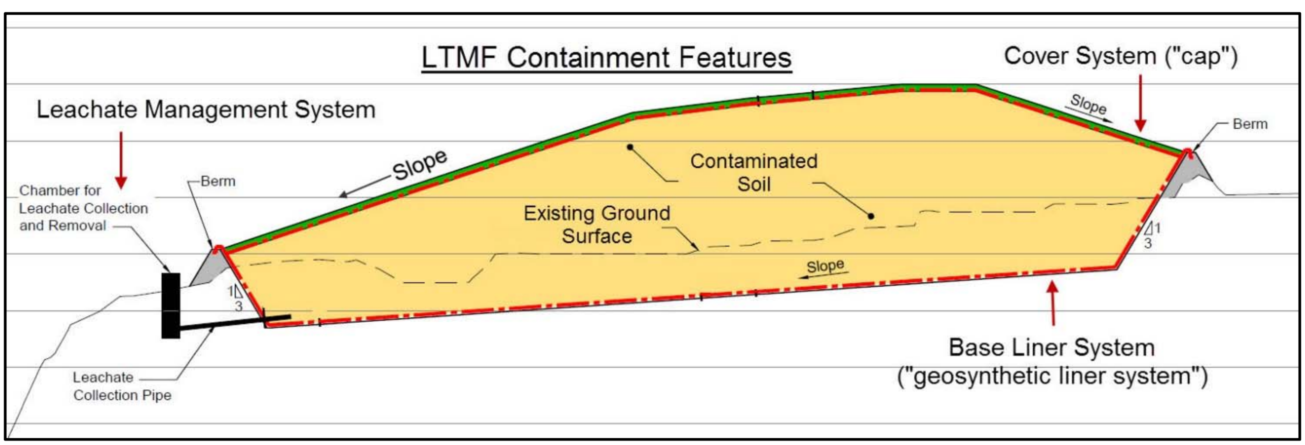
LTMF Containment Features

To provide reliable containment, the LTMF will include key features specifically designed for the proposed use to northern conditions. These are proven containment features similar to those used in modern secure landfills including:

- A “geosynthetic” base liner system – the bottom and sides of the LTMF will be a barrier comprised of a flexible plastic geomembrane over a manufactured soil bentonite material. Together these function to prevent liquid seeping out of the structure.
- A cover system – an LTMF ‘cap’ made from geomembrane materials similar to those used in the base liner system.
- Leachate Management System – a system to collect, remove, and treat or dispose of any excess liquids in the LTMF and to prevent any liquids from leaving the structure.

An important component of LTMF development will be the operational monitoring capabilities to be implemented and maintained, to ensure proper performance of the LTMF containment system.

For more information, see Section 5.5.1 of the *Interim Norman Wells Operations Closure and Reclamation Plan*.



LTMF Location

Different locations were considered for a Mainland LTMF. The preferred (selected) site is the current location of the Mainland Drilling Sumps.

The reasons for choosing this site included:

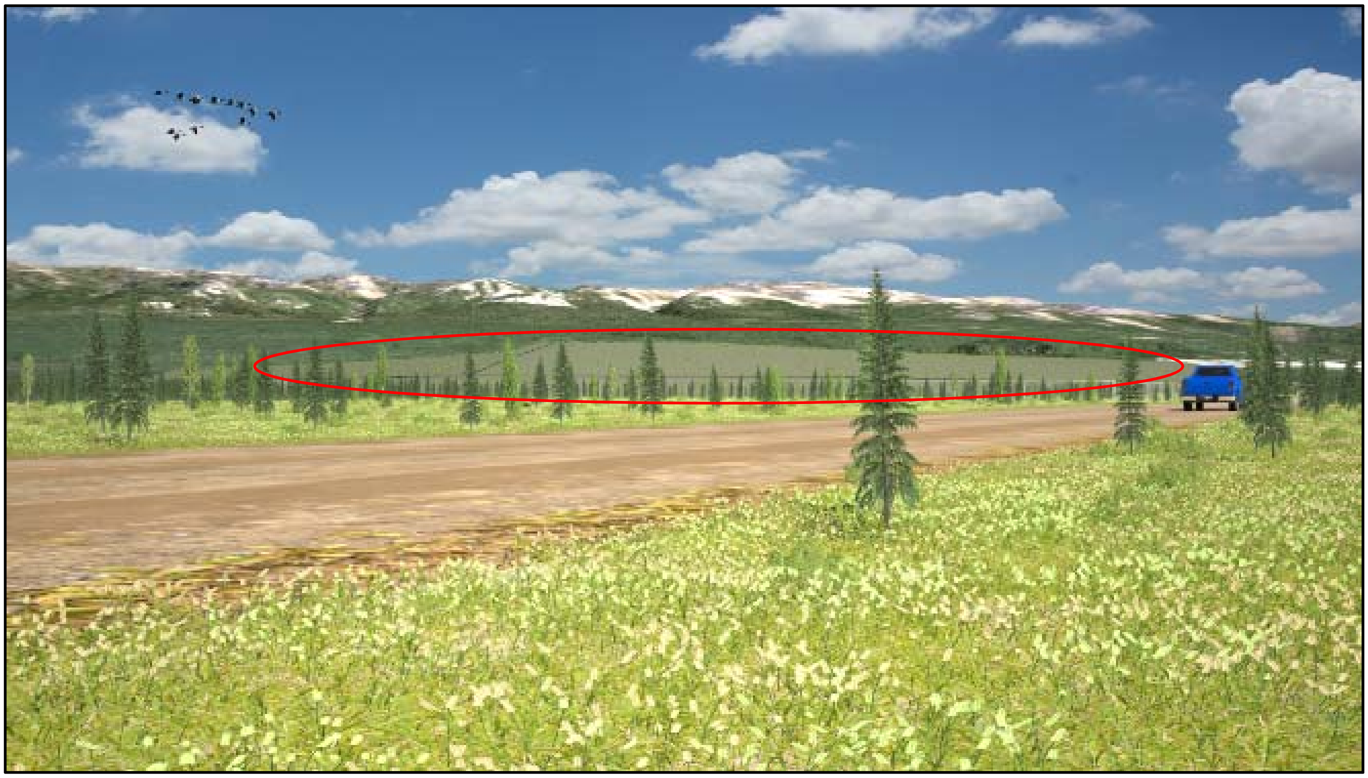
- The site is an existing impacted area;
- Early LTMF development will not interfere with pre-closure operations, or the operation of existing soil treatment facilities (see Section 13);
- The site provides extended physical and visual buffers between the LTMF and the Mackenzie River and Bosworth Creek;
- LTMF development in this area matches an existing local land use (i.e., for waste management) that is accepted by the community; and
- The site footprint avoids overlaps with existing Operations facilities and well sites.

For more information, see Section 5.5.1 of the *Interim Norman Wells Operations Closure and Reclamation Plan*.

What will the LTMF Look Like?

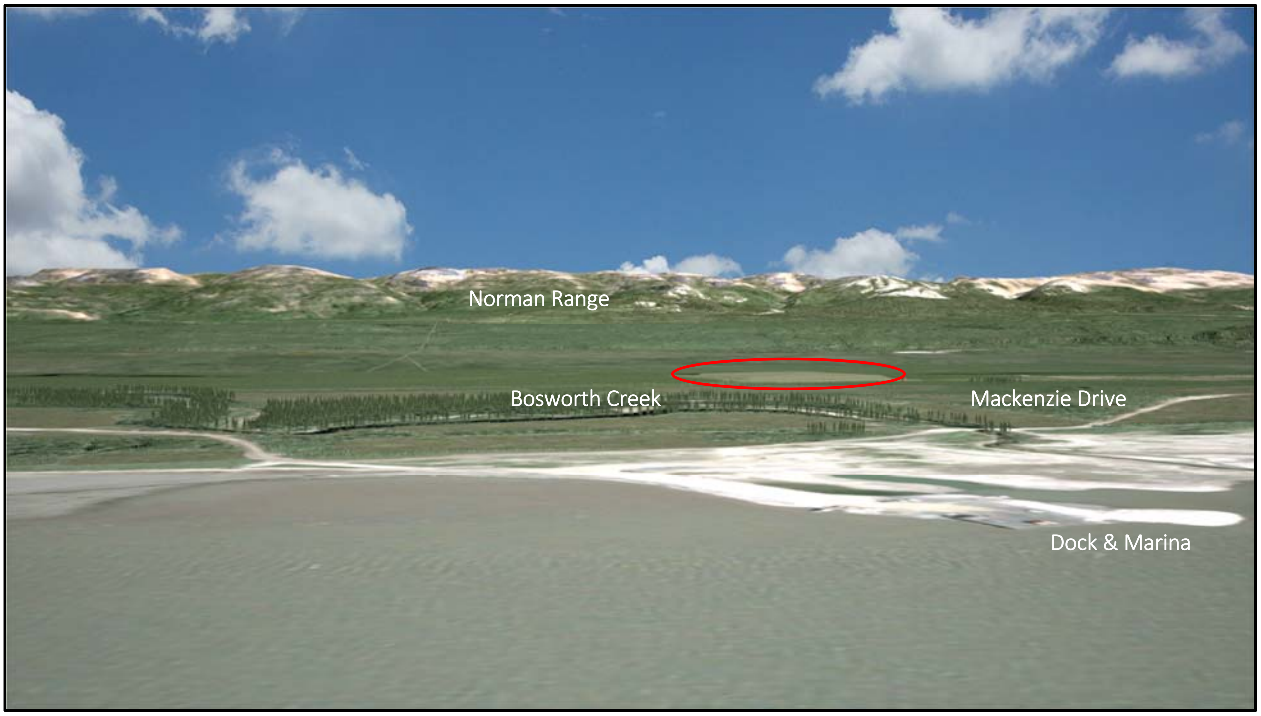
Artistic representations of the completed LTMF are provided on the following pages. These include views of the LTMF from the air, road and River.

See the following pages for views of the final LTMF from the air, road and River.



Completed LTMF looking Northeast: Driving east along Canol Drive with a view of the south side of the proposed LTMF (circled) and Discovery Ridge on the south slopes of the Norman Range.

Completed LTMF looking northwest: Driving west along Canol Drive with a view of the east side of the proposed LTMF and water treatment facility.



Completed LTMF view from River: Approaching the reclaimed Mainland from the Mackenzie River with a view of the proposed LTMF (circled) located between Bosworth Creek and the Norman Range on the horizon. The dock and marina are visible in the foreground. Mackenzie Drive meanders over Bosworth Creek towards the marina and the reclaimed former Central Processing Facility on the left.

Completed LTMF aerial view: Approaching the proposed LTMF and water treatment facility (circled) in the foreground with a view towards the Town of Norman Wells and the airport. The reclaimed former tank farm and refinery area is visible on the right. (Note that this figure assumes the entire Mainland tank farm is removed following closure. In practice, there may be some tanks retained to support community requirements after facility shutdown.)

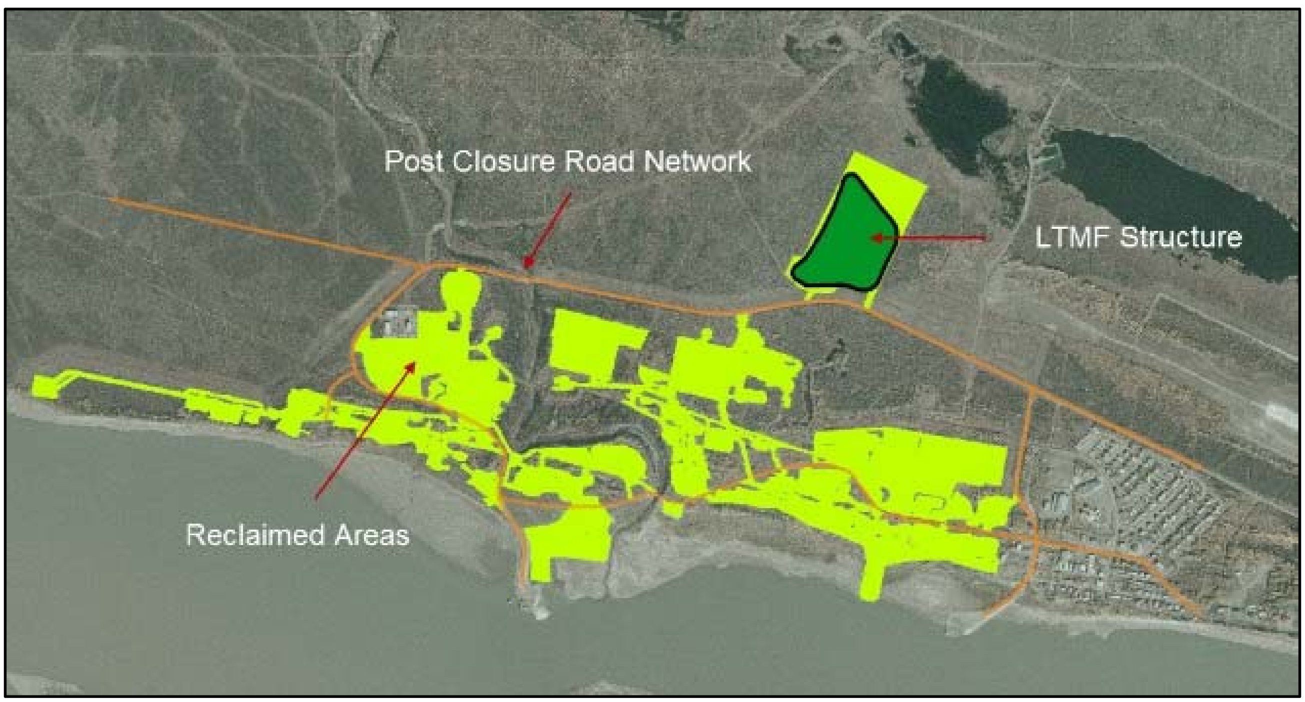
Reclamation Elements

Reclamation elements for the Mainland will involve backfilling the areas where impacted soil materials have been removed with locally available soils. This is described in more detail in Section 5.6 of the Interim Norman Wells Operations C&R Plan (*Materials Management Plan*). A general arrangement of the post reclamation Mainland land surface is shown below.

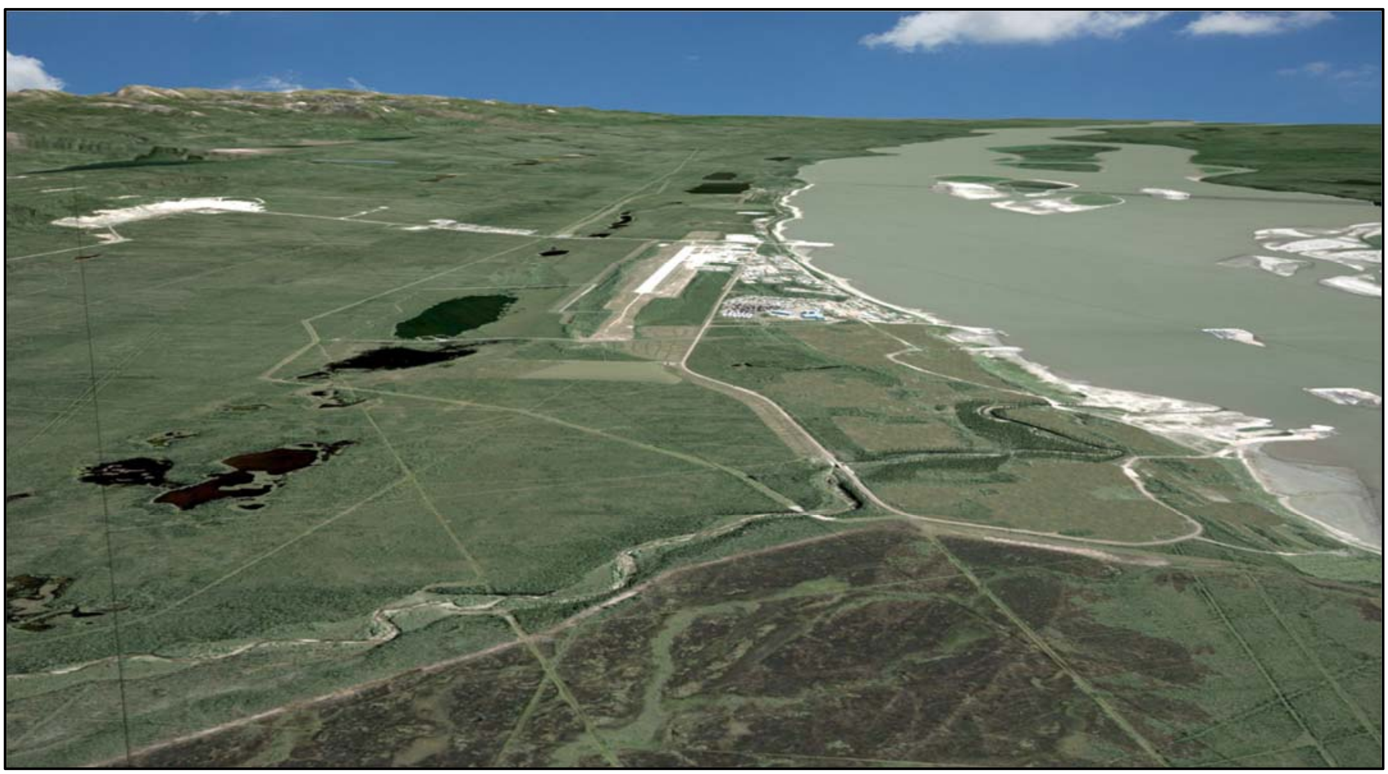
Land surfaces and capabilities will be re-established to meet applicable reclamation objectives. Most disturbed areas will be revegetated. Some areas will have shaped and contoured accumulations of shale areas that, based on observations of natural vegetation regrowth on the Operations to date, are expected to revegetate naturally over time.

An artistic representation of the post reclamation Mainland component is provided on the next page.

For more information, see Section 5.5.1 of the *Interim Norman Wells Operations Closure and Reclamation Plan*.



Current Norman Wells Operations Mainland



Mainland Component Post-Reclamation (Artistic Rendering)

(Note that this figure assumes the entire Mainland tank farm is removed following closure. In practice, there may be some tanks retained to support community requirements after facility shutdown.)

1.6 NATURAL ISLANDS

This component focusses on the remediation and reclamation activities proposed for Bear, Goose and Frenchy's Islands. Closure activities related to the Buildings and Equipment, Wellbores and Subsurface Infrastructure on these islands is described in Sections 9, 10 and 11.

Remediation

The main closure activity for the Natural Islands component is focused on remediation of impacted soil materials.

> *Impacted soils on the Natural Islands that do not meet CCME Parkland Criteria will be removed, relocated and treated, or consolidated within the Mainland LTMF.*
> *See Section 12 for discussion on CCME Criteria.*

The additional component specific option that was considered was the possibility of developing a separate LTMF for impacted soils from the Natural Islands, most likely in the general vicinity of the Bear Island drilling sumps. This approach was not adopted because:

- It does not fit with the general closure planning principle to limit the footprint of a post-closure landscape; and
- It would create separate requirement for post closure operations and maintenance.

For more information, see Sections 5.6 (Materials Management Plan) and Section 8.0 (Integrated Schedule of C&R Activities) of the *Interim Norman Wells Operations Closure and Reclamation Plan.*

Reclamation Elements

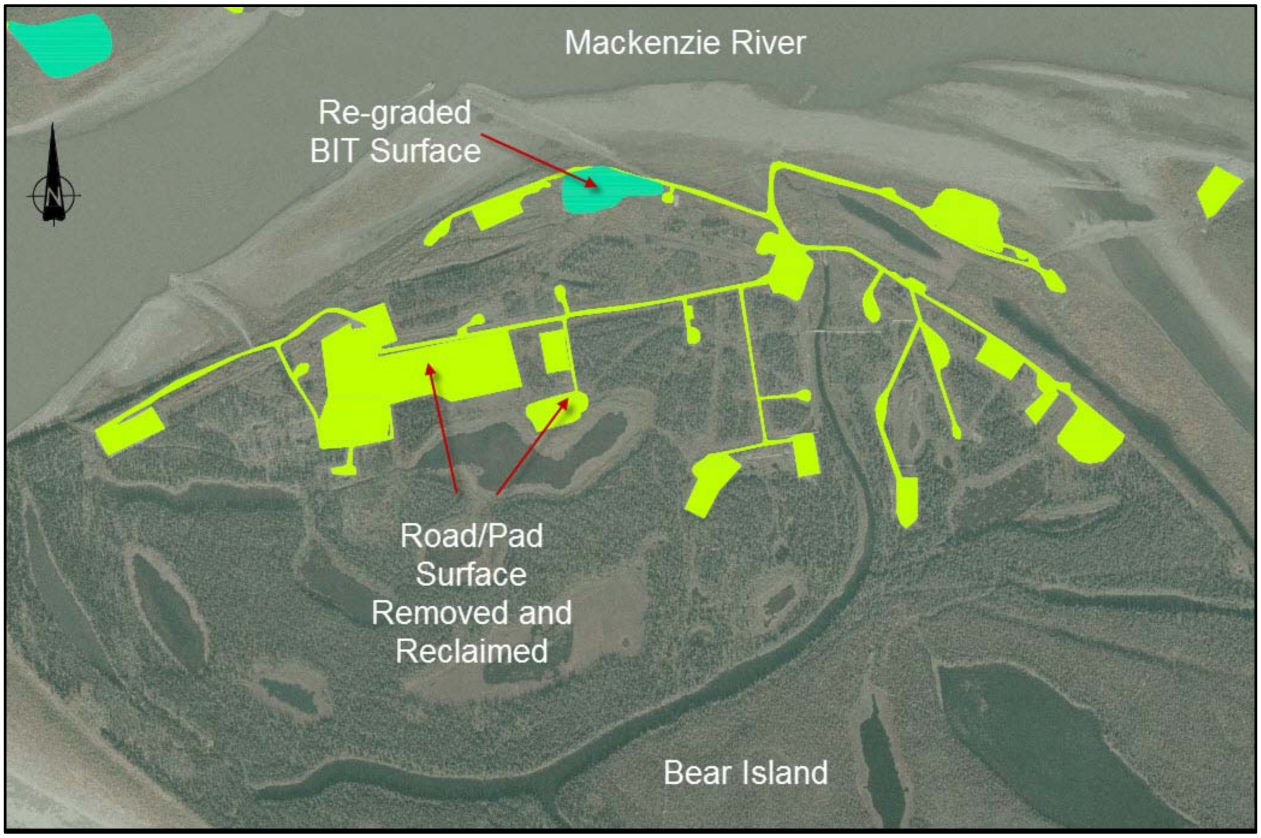
The main elements of the proposed reclamation activity for the Natural Islands are:

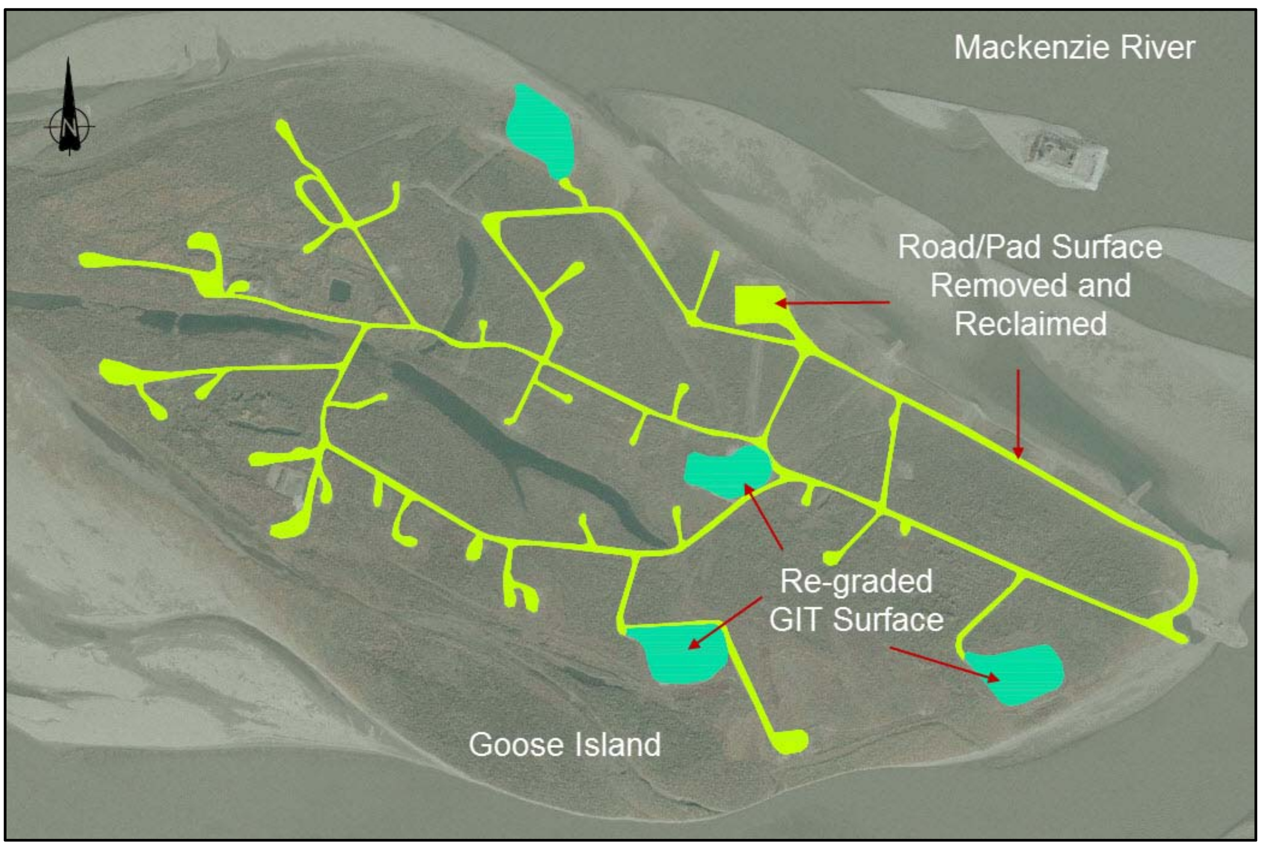
1. The areas where impacted soil materials have been removed (i.e., for relocation to the Mainland LTMF) will be filled in with shales taken from existing island roadways and terminal sites;
2. This layer of shales will then be covered with a layer of locally sourced soil;
3. The remaining shale on island roads will be removed to grade level, gathered together and relocated to respective Goose Island Terminal (GIT) and Bear Island Terminal (BIT) sites;
4. These gatherings of shale at the GITs/ BITs will be contoured (shaped) so that final land slopes and features will be physically stable and compatible with the surrounding landscape;
5. Finished land surfaces (i.e., on backfilled soil excavations and reclaimed roads) will be seeded (or left to revegetate where this is expected to be more effective); and
6. Select areas around the GITs/BITs and some road alignments will receive tree or shrub plantings to provide an aesthetic transition between reclaimed grass areas and the surrounding lands.

The general arrangements of reclaimed landscapes on Goose and Bear Islands are illustrated on the next page.

For more information, see Section 5.5.2 of the *Interim Norman Wells Operations Closure and Reclamation Plan.*

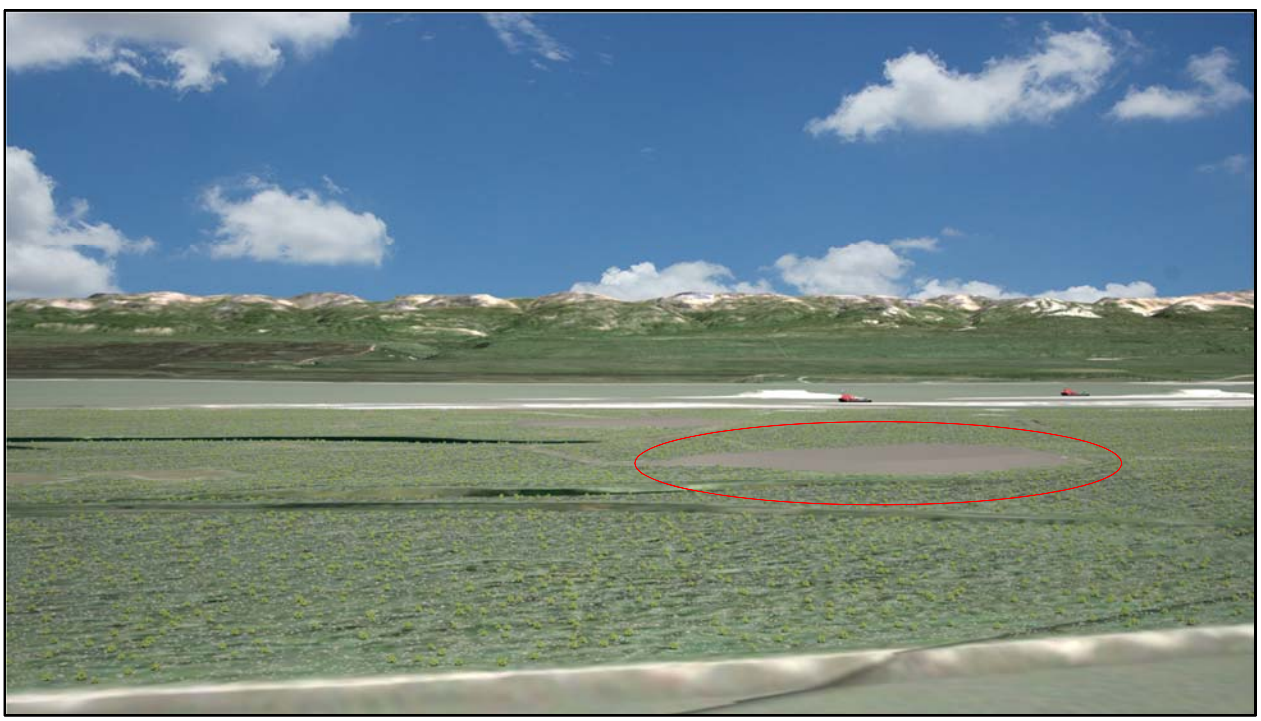
> *On the following page are artistic representations of a reclaimed terminal (GIT) at Goose Island as seen from the Mainland and as seen from the River.*





Natural Islands – General Reclamation Arrangements

GIT view from Mainland: Approaching Goose Island from the north with the Mackenzie River in the foreground & Mackenzie Mountains on horizon. Reclaimed access roads & contoured former Terminal pads are visible on the island (circled).



GIT view from River: Goose Island in the foreground with a view towards the Mackenzie River and the Norman Range on the horizon. The contoured former Goose Island Terminal pads are visible on the island (circled).

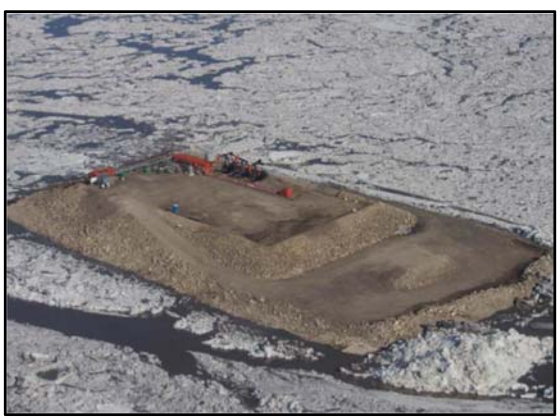
1.7 ARTIFICIAL ISLANDS

This component focusses on the remediation and reclamation activities proposed for the six Artificial Islands in the Mackenzie River Channel ((1 (Rayuka), 2 (Rampart), 3 (Dehcho), 4 (Ekwe), 5 (Iteh K'ee), and 6 (Little Bear)).

Closure activities related to the Buildings and Equipment, Wellbores and Subsurface Infrastructure on these islands is described in Sections 9, 10 and 11.

The islands were constructed between 1983 and 1984 and are located in relatively shallow water near the edge of the main river channel. The islands are constructed with a sand core dredged from the river channel contained with a rock berm sourced from the local quarry.

The rock berm is protected by "armour" comprised of riprap (rubble), stone and/or gabions (cages containing rocks). The slope of the islands that faces upstream is constructed with a shallow sloped ledge, called an ice pile-up storage berm.



Artificial Island 6

Remediation

Similar to the Natural Islands, the main closure activity for the Artificial Islands is focused on remediation of impacted soil materials.

Impacted soils on the Artificial Islands that do not meet CCME Parkland Criteria or background will be removed, relocated and treated, or consolidated within the Mainland LTMF. See Section 12 for discussion on CCME Criteria.

For more information on the Artificial Islands, see Sections 5.6 & 8.0 of the *Interim Norman Wells Operations Closure and Reclamation Plan.*

Reclamation Elements

Imperial is examining various alternatives for the post closure fate of the Artificial Islands. One approach is to let the natural erosion processes and movement of the Mackenzie River return the sands in the core of the islands to the riverbed after all or portions of the existing island armour is removed.

The armour material (i.e., riprap, gabions, and large gravels) would be returned to the Mainland at closure and incorporated into surface reclamation plans or returned to the source quarry owned by the Town of Norman Wells. The island berms below the armour would be left in place once confirmed to be free of impact and displaced over time by the combined actions of ice and river flows.

Decisions on the effectiveness of this and other possible reclamation approaches will be made following the outcomes of upcoming technical studies and stakeholder engagement and consultations. These studies will examine the nature and scale of natural soil relocation processes and the long term impacts on local fish habitat and navigation on the Mackenzie River.

For more information, see Section 5.5.3 of the *Interim Norman Wells Operations Closure and Reclamation Plan.*

1.8 NATURAL WATERCOURSES

The Natural Watercourses component is made up mainly of the surface waters and sediments in the Mackenzie River and Bosworth Creek, but consideration is also given to smaller, local waterbodies on the Natural Islands and other areas across the Proven Area.

The conditions of surface waters and sediments in the Mackenzie River and Bosworth Creek were described in the discussion of baseline conditions provided in Section 3.3.1 of the C&R Plan. These conditions are routinely monitored and reviewed with community stakeholders under the Aquatic Effects Monitoring Program (AEMP) that Imperial undertakes and manages.

The water and sediment quality data compiled over the years for local watercourses provides no indication of any significant human-caused impact that can be associated with the Operations.

For more information, see Section 3.0 of the *Interim Norman Wells Operations Closure and Reclamation Plan.*

C&R Scope & Activities

Given the lack of human-caused impact, there are no C&R activities proposed that focus specifically on objectives under the Natural Watercourses Component. That said, it is important to note that a number of the C&R activities proposed for other components are ultimately intended to reduce long term risks to surface water and sediment quality, in line with component objectives related to:

- Stable River and creek banks that are compatible with surrounding lands
- River water sediment quality that is safe for humans, aquatic life, and fish habitat

This includes a central element of the C&R Plan, that being removal followed by treatment or containment of all impacted soils in a centralized Long Term Management Facility (LTMF) and the designation of Long Term Management Areas (LTMAs). A primary feature of these is the long term protection of downstream environmental media.

For more information, see Section 5.5.4 of the *Interim Norman Wells Operations Closure and Reclamation Plan.*

Mackenzie River at the Norman Wells Operations

1.9 BUILDINGS, EQUIPMENT & SURFACE INFRASTRUCTURE

This component focusses on all of the above grade buildings and equipment on the Proven Area, and their subsurface foundations. C&R activities related to the downhole portion of production and injection wells and other subsurface (underground) infrastructure are described in Sections 10 and 11.

Above grade buildings and equipment are present on the Mainland, the Natural Islands, and includes the infrastructure on the Artificial Islands.

The Central Processing Facility (CPF) is the primary functional area on the Mainland. The CPF is made up of various facilities, buildings and surface infrastructure and also includes a flare stack and tank farm.

Other related above grade Mainland infrastructure includes terminals, facilities, storage areas, tank farms, as well as a road network, helicopter pad and two docks.

Above grade facilities on Bear and Goose Islands include terminals, production terminals, fuel and methanol storage areas, as well as helicopter pads and docks. There are no facilities, apart from production wells and their associated flow lines, present on Frenchy's Island. Buildings and equipment on the Artificial Islands are included in the Natural Islands inventory. This is consistent with the definitions of project components.

For more information on the buildings and equipment inventory, see Section 5.5.5 of the *Interim Norman Wells Operations Closure and Reclamation Plan.*

Mainland Surface Buildings, Infrastructure

C&R Scope & Activities

The scope of C&R activity for the buildings and equipment component consists of decommissioning, dismantling and/or demolition of facilities following shut-down, and the management and final disposition of all associated materials and wastes.

Decommissioning

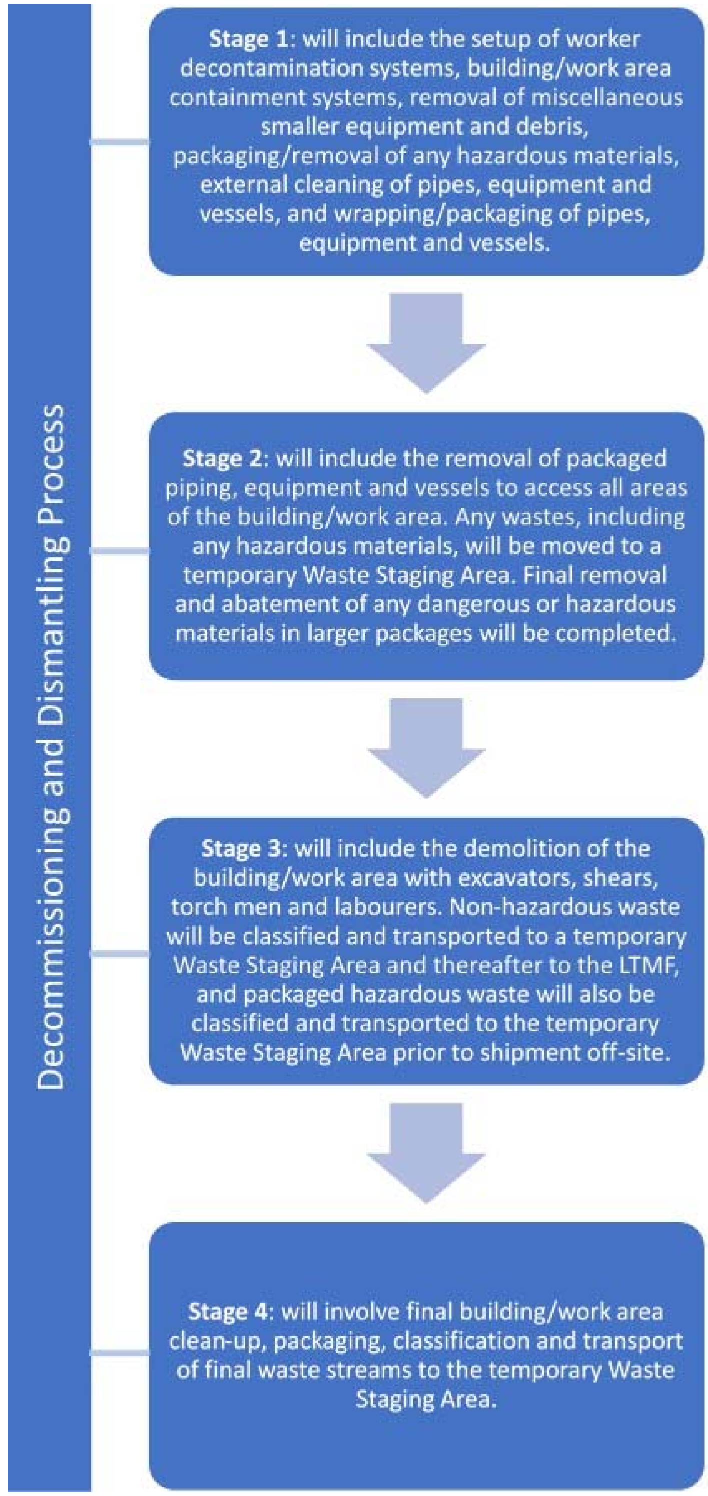
Decommissioning refers to taking processes and their associated equipment permanently out of service at closure. It includes the removal (or purging) of process chemicals. These equipment shut-downs are typically required from time to time during operations, and the proven operational protocols for these shut-downs in place at the time of closure will be applied.

The chemicals, residuals and/or wastes generated during these activities will be managed in accordance with the approved facility waste management plan in place at the time.

Dismantling and Demolition (D&D)

<u>Above Grade Structures and Equipment</u>

D&D of above grade structures and equipment will follow detailed plans developed at the time of closure. Individual plans will be structure or area specific, but will likely include general stages similar to the one on the right:



Foundation Elements

Uncontaminated foundation elements (e.g., concrete slabs, pedestals, grade beams and/or footings, and steel pipe piles) will be cut and removed to depths established on an area specific basis.

Foundation elements with surfaces known or suspected to have contaminants (e.g., oiled concrete slabs), will be excavated and removed entirely, and managed thereafter as contaminated rubble (i.e., directed to the LTMF).

What will happen with the Materials?

Dismantling and Demolition (D&D) activities for buildings and equipment at the Operations will generate several general material categories.

Disposition strategies for these materials (i.e., reuse, recycling or disposal) will be different depending on the material category (see below).

The one significant alternative considered for this component was the option of directing D&D waste and rubble to third party commercial waste management facilities outside the community (most likely in northern BC or Alberta). This approach was discounted due to potential safety risks, environmental (emissions) considerations and cost.

For more information, see Section 5.5.5 of the Interim Norman Wells Operations Closure and Reclamation Plan.

1.10 WELLBORES

The Wellbores Component includes C&R activity related to the downhole abandonment of production and injection wells to prevent the possibility of oil coming to the surface; as well as the reclamation of local excavations or disturbances that might be made in order to complete abandonment activity. There are 353 wells at the Operations. These are located throughout the Proven Area and include:

- 179 wells used for production;
- 168 wells used for injection;
- five suspended wells; and
- one well is listed as ‘other’.

Norman Wells Operations Wellsite Equipped with a Pumpjack

C&R Scope & Activities

There are three primary C&R activities that will be associated with the Wellbores component. These are described in the figure to the right.

For more information, see Section 5.5.6 of the Interim Norman Wells Operations Closure and Reclamation Plan.

1 - Downhole Abandonment

- Follow proven protocols and methods to permanently separate the underground layer that the wellbores went into from the reclaimed surface of the land.
- *Downhole abandonment is conducted to prevent the possibility of oil coming to the surface; it will be guided by well-defined and proven regulatory procedures that are routinely updated on the basis of both facility specific and corporate experience.*

2 - Cutting & Capping

- Remove all wellbore hardware above a certain underground depth and put a physical cap on the wellbores at that depth (i.e., permanently close the wellbore underground).
- *Standard regulatory procedures for cutting and capping wells following Alberta Energy Regulatory Directive 20.*

3 - Backfilling & Reclamation

- Fill in, shape and revegetate the land surface directly around of the former wellbore.
- *Following capping, the excavations will be filled in by pushing in locally available soil (grading). If the excavations do not meet criteria, they will go to the LTMF. Backfilled excavations will be revegetated using the seed mix for the area, or left to revegetate naturally if this is expected to be more effective. Deeper cut and caps (i.e., on the Artificial Islands) will use drilling processes that will not cause major surface disturbances. So post capping will generally be followed by local grading and contouring followed by seeding.*

1.11 SUBSURFACE INFRASTRUCTURE

This component includes flowlines (both overland and under the Mackenzie River); and various utilities (i.e., electrical lines, communications lines and potable water and septic service).

C&R Scope & Activities

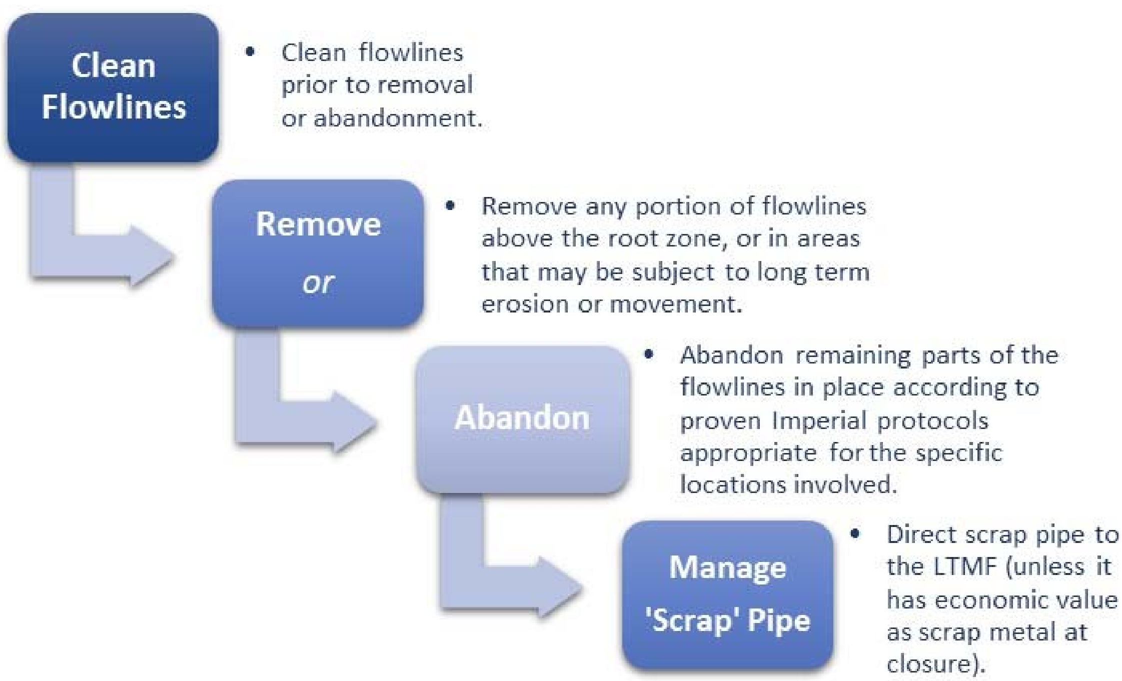
Flowlines

The network of flowlines that service the Operations facilities are the most significant element of the subsurface component.

Flowlines are used to connect the Field Operations with the CPF. A number of flowlines (oil, water and gas) run under the Mackenzie River. Flowlines between the Field and CPF are used for:

- Production (oil, produced water and gas) from the producing wells in the Field to the CPF;
- Injection (fresh water, produced water and propane) from the CPF to injection wells in the field; and
- Natural gas (fuel gas, artificial lift) from the CPF to gas lift wells and field facilities.

The sequence of closure activity for flowlines is illustrated below:



Flowline Abatement and Management

All flowlines will be cleaned prior to removal or abandonment. Imperial's operational flowline cleaning protocols will be updated to include cleaning procedures specific to the features and conditions of each of the flowlines.

"Pigging" technologies will be used to remove wax deposits in flowlines. Pigging involves inserting a full line-size ball or scraper into the flowline at the wellhead or facility. As the "pig" blocks the flow in the line, backpressure behind the pig increases, and the pigging device is pushed down the flowline. Waxy deposits are scraped off of the inside walls by the pig as it is 'squeezed' down the flowline. The pigs are launched into the line by pig senders and retrieved by pig receivers.

Management of wastes from cleaning processes will follow Imperial flowline integrity and facility waste management plans.

Flowline Abandonment

Flowline ends will be removed to below the root zone (the specific depths involved may vary by area) and the rest of the flowline will be capped. Flowline sections will be completely removed in areas where post-closure erosion or movement may occur. These will be capped in the spot that they have been removed.

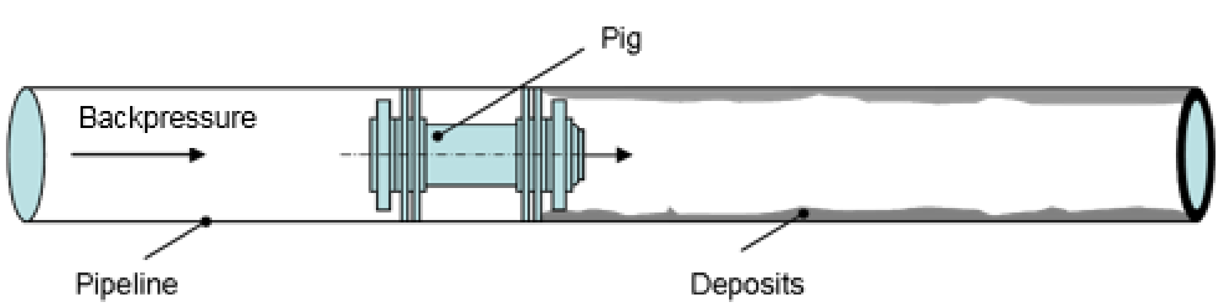
Most cleaned and capped flowlines will be left, unfilled in place. If they cross significant roadways or other transportation routes, they will be filled with material such as sand or grout to make them structurally stable.

Flowline sections left under the Mackenzie River will be filled with water or grout (specialized concrete) to prevent them from moving or floating.

Subsurface Utilities

Utilities within the root zone of the surface will be removed and directed to the LTMF. Removal schedules will be area and utility specific. Utilities that contain or may contain leftover impacts will be excavated and removed entirely, and directed to the LTMF.

For more information, see Section 5.5.7 of the *Interim Norman Wells Operations Closure and Reclamation Plan.*



Flowline Cleaning with "Pigging" Technology

1.12 CLOSURE CRITERIA

The MVLWB guidelines define closure criteria as:

"…standards that measure the success of selected closure activities in meeting closure objectives…"

Depending on the closure objective, criteria can be numerical values (e.g., soil or water quality parameters) or statements that describe a standard to measure against (e.g., …"compliance with applicable regulatory requirements…"). The Interim Norman Wells Operations C&R Plan includes both types of criteria.

Closure criteria can be site-specific or adopted from territorial/federal or other standards.

Closure criteria have been expanded upon for each closure objective during the development of the Interim C&R Plan and will be finalized in the final C&R Plan.

For more information on closure criteria, see Section 5.2.4 of the *Interim Norman Wells Operations Closure and Reclamation Plan.*

CCME Criteria

The C&R Plan includes specific closure objectives related to the safety of soils and water for people and the environment.

Environmental assessments of soil and water quality will be completed to demonstrate that these objectives have been met. The soil and water test results will be compared with specific criteria. These will include established Canada-wide standards as defined by the Canadian Council of Ministers of the Environment (CCME) – called "CCME criteria" from here on. Where available, criteria will also include background conditions (i.e., samples obtained from nearby areas that have not been impacted).

The CCME is made up of the environment ministers from the federal, provincial and territorial governments. The CCME has developed a set of Canadian Environmental Quality Guidelines (CEQG) to provide specific tools for reliable and scientifically defensible remediation of contaminated sites. These include:

- *Water Quality Guidelines for the Protection of Freshwater Aquatic Life;*
- *Soil Quality Guidelines for the Protection of Environmental and Human Health; and*
- *Canada-Wide Standards for Petroleum Hydrocarbons (PHC) in Soil.*

Soil Quality Guidelines

The Government of the Northwest Territories has adopted the soil criteria established by the CCME. The CEQG Soil Quality Guidelines include concentration limits for various substances typically produced by oilfield operations (e.g., petroleum hydrocarbons, salts).

For each of these parameters, the guidelines outline what levels are safe for the environment and for people under several different land use categories. This is because the definition of safe levels depends on what the land will be used for, how, and for how long. The Soil Quality Guidelines include criteria under four land use categories:

1. Agricultural
2. Residential/Parkland
3. Commercial
4. Industrial

CCME Land Use Criteria for the Operations

The Mainland and Natural Island components of the Operations have been zoned as "Industrial Lands" by the Town of Norman Wells.

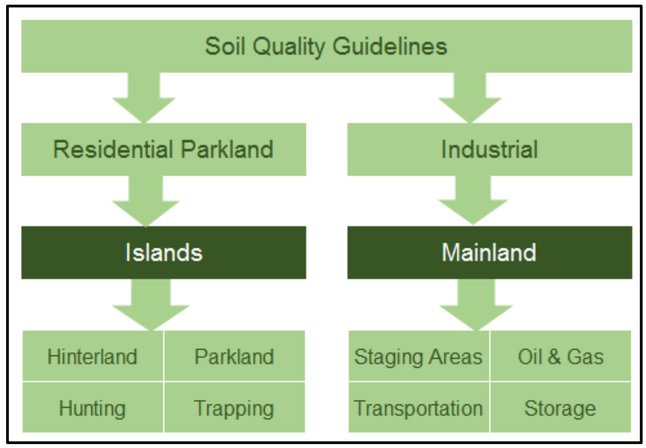
According to the *Community Plan Bylaw (#13-01)* (the Bylaw), this means these lands are intended for hydrocarbon, light and heavy industrial uses. Examples of permitted uses in the Bylaw include processing of hydrocarbons, as well as construction operations, trucking companies and manufacturing or warehousing and equipment storage.

The Operations Mainland and Natural Island areas have been zoned as "Industrial Lands" by the Town of Norman Wells (Community Plan Bylaw (#13-01).
The C&R Plan proposes Mainland closure criteria for land use (CCME) that lines up with this zoning. For the Natural and Artificial Islands the C&R Plan provides for land use above and beyond this industrial definition.

The current C&R Plan proposes closure criteria for the Mainland that is consistent with the zoning in the Bylaw. For the Natural Islands and Artificial Islands, the C&R Plan provides for additional potential land use above and beyond the industrial definition.

Specifically:

- Mainland – CCME Industrial criteria: This means that soil analyses at the Mainland will be compared with CCME Industrial criteria to demonstrate the safety of soils for that designated land use. This will be used to demonstrate that the objective of soils safe for the environment and people has been met.
- Natural Islands and Artificial Islands – CCME Parkland criteria: This means that soil analysis at the Natural and Artificial Islands will be compared with CCME Parkland criteria to demonstrate the safety of soils for that designated land use, which includes uses such as hinterland, natural parkland and hunting and trapping.



What does Industrial vs. Parkland Look Like?

Reclaimed landscapes on top of soils remediated to Industrial or Parkland will not necessarily look different. This is because, from an environmental and human safety standpoint, the criteria (CCME) are related to the quality of the soil underneath the surface, not the shape or vegetation planted on the top.

In fact, an area remediated to Industrial criteria may look exactly the same as an area remediated to Parkland once reclamation is complete – even though they are not zoned for the same land uses.

1.13 PROGRESSIVE RECLAMATION

Imperial has undertaken various C&R initiatives and activities over the years and will continue to do so in the lead up to facility closure. These *Progressive Reclamation* activities are described and reported in annual progress reports submitted to the SLWB.

> *"**Progressive reclamation** takes place prior to permanent closure to reclaim components and/or decommission facilities that no longer serve a purpose. These activities can be completed during operations with the available resources to reduce future reclamation costs, minimize the duration of environmental exposure and enhance environmental protection. Progressive reclamation may shorten the time for achieving closure objectives and may provide valuable experience on the effectiveness of certain measures that might be implemented during permanent closure." (MVLWB 2013)*

Generally, progressive reclamation activities for the Operations have focused on:

1. Site assessments to identify and define impacted source areas;
2. Monitoring activities (particularly for ground and surface waters);
3. Soil remediation (i.e., excavation & treatment on-site, in-situ vapour extraction, ex-situ bioremediation, or interim containment and capping in place);
4. Groundwater remediation in high priority areas;
5. Surface restoration and revegetation in select areas; and
6. Completion of downhole abandonment activities for decommissioned production wells and groundwater wells no longer needed.

Current Facilities for Progressive Reclamation

Imperial maintains, or is in the process of developing, treatment facilities that are used to manage the impacted soils generated by progressive reclamation efforts. These include:

- A biological treatment facility ("biocell") located in the Mainland area north of the former Battery 3 site. Soils are directed to the biocells from various locations across the Proven Area, after they have been characterized and deemed suitable for bioremediation; and
- A soil washing facility that is currently being constructed in the area south of the biocells, immediately northeast of the former Battery 3. The facility is designed to treat salt impacted soils resulting from progressive reclamation efforts on the Operations.

Biocell in Operation

One key focus of Imperial's progressive reclamation efforts in the period before closure will be to use these existing treatment facilities to better understand how much of the soil inventory can practically be treated and reused after the facility shuts down. Efforts will be made to quantify treatable soil volumes and to understand the required features and operating characteristics of treatment facilities required after closure to support the final C&R Plan.

Pre-Closure LTMF Development

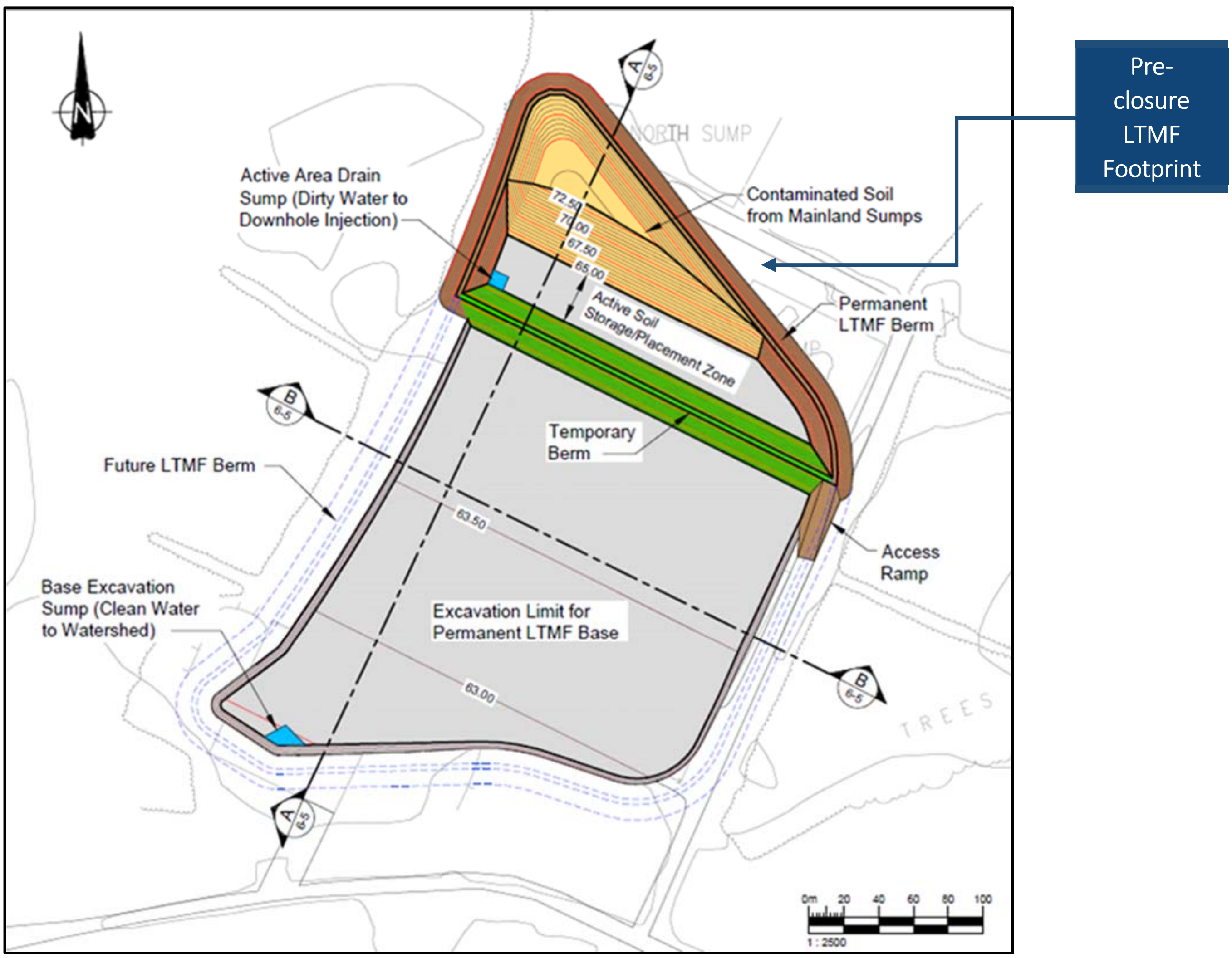
Imperial anticipates that some LTMF capacity will be required to support remediation and reclamation activities prior to closure.

The pre-closure LTMF will be developed as the initial stage of the permanent LTMF described in Section 5 (*Mainland Component*). The specific features, shape and size of this LTMF will be determined during closure planning.

The pre-closure LTMF will be developed within the footprint of the permanent LTMF. The first stage will be sized for all of the contaminated soils in the Mainland sumps area.

The pre-closure LTMF will start with a smaller portion of the full permanent LTMF base footprint and will grow within the permanent footprint as needed to accommodate contaminated material volumes generated prior to Operations closure.

The following figure shows the potential pre-closure LTMF configuration:



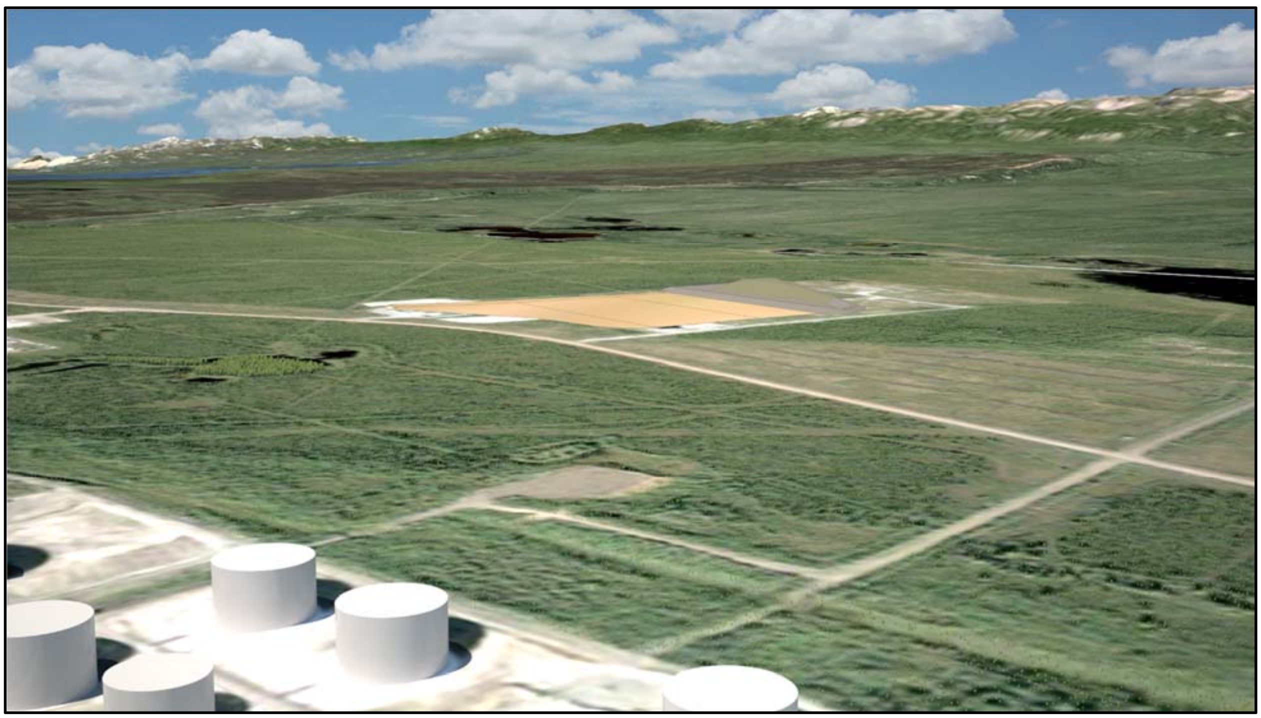
Pre-Closure LTMF Features

At the start, the pre-closure facility will take up a minor piece of the full LTMF footprint. It will be built up to the full permanent height, then the footprint will be expanded. This will minimize the operating LTMF footprint at any given time, reducing water management requirements. The pre-closure LTMF will have an interim cover structure.

Removing all of the existing sump materials as part of the first stage of LTMF development will create a low spot between the pre-closure LTMF footprint and the edge of the permanent LTMF which will capture clean rain/snow. Drainage from active areas of the pre-closure LTMF will be contained and kept out of this depression and directed to existing wastewater management systems as part of regular operations prior to closure.

An artistic rendering of the pre-closure LTMF is provided below

For more information, see Section 6.0 of the *Interim Norman Wells Operations Closure and Reclamation Plan*.



Pre-Closure LTMF aerial view: Approaching the proposed LTMF from the southeast with a view of the Imperial Oil tank farm on the lower left. The proposed LTMF is visible on the north side of Canol Drive in the centre of this image. Seepage Lake is visible north and east of the LTMF.

1.14 CLOSURE SEQUENCE & SCHEDULE

Completing all of the activities that have been outlined in this plan will involve two distinct time periods - before and after the Norman Wells Operation shuts down.

Final planning of the work will be undertaken during the three years prior to shut down. Over this period, the field investigations needed to support detailed plans and designs will be completed, and the associated detailed engineering and work packages will be developed. This work will essentially involve taking the general plans outlined in the version of this C&R Plan available at shut down, and refining and detailing them to the degree needed to complete the work.

The actual remediation and reclamation work called for in the C&R Plan will be completed over an approximately ten year period after the facility ceases operations. This time will be needed because the capacity of the specialized equipment to abandon the wells will be limited by the physical challenges associated with the Operations' configuration and size. In addition, it will not be efficient or effective to complete the excavation of contaminated soils until this well infrastructure has been dealt with, and this will extend the timelines required for final site reclamation.

The current estimates of timelines for all of the activities proposed for C&R planning and execution will be reviewed with each update of this interim plan. The resulting schedule updates will reflect the influence of any new developments in well abandonment processes and technology, and in the predictions of contracting resources likely to be available at facility shut down.

For more information, see Section 8.0 of the *Interim Norman Wells Operations Closure and Reclamation Plan*.

1.15 POST CLOSURE ASSESSMENT

There will be a variety of initiatives and activities undertaken before, during and after execution of a final C&R Plan focused on confirming that the objectives set for the Plan have been met.

Pre-execution Review of Final C&R Plan

This review refers to the technical and stakeholder reviews of the Final C&R Plan applicable at the time of facility closure and immediately prior to C&R Plan execution.

Testing & Monitoring During C&R Plan Execution

Various testing and monitoring activities will be undertaken during C&R Plan execution to evaluate criteria which directly relate to the scope, duration and scale of C&R activities (e.g., confirmatory sampling in excavations).

Ongoing Post Closure Monitoring

These are the testing and monitoring activities that will continue, at least in some form, indefinitely following completion of the C&R Plan.

One Time Post Closure Assessment

This program will be a dedicated, point in time assessment undertaken at the conclusion of C&R Plan execution to evaluate conditions relating to the remediated and reclaimed landscape that are not subject to change or variation post closure.

For more information, see Section 9.0 of the *Interim Norman Wells Operations Closure and Reclamation Plan.*

1.16 NEXT STEPS

Ongoing Community Engagement

Imperial will continue to proactively engage with local stakeholders and regulatory agencies as this interim plan is refined.

As discussed in Section 1, the Interim C&R Plan includes some facilities and processes that will be in place over a long period of time. These facilities and processes will require people and equipment to manage and monitor their operation; and there is also work involved in putting them in place.

There is a variety of possible commercial arrangements that could be developed using local or regional businesses and skills to address these, and potentially other, C&R requirements. Imperial anticipates that the scope of these potential opportunities will be an important part of the discussions and engagements that will occur as the C&R Plan evolves in the years leading up to facility closure.

Interim C&R Plan Review and Update

This is the first of an expected series of interim C&R Plans for the Operations. These will be reviewed and updated in the operational period prior to closure at a frequency and through a process determined in conjunction with the SLWB.

1.17 FOR MORE INFORMATION

A complete copy of the Norman Wells Operations Closure and Reclamation Plan can be found on the Sahtu Land and Water Board Public Registry Website (www.slwb.com).

The registry also includes other publicly available information related to the closure and reclamation planning process, as well as documentation associated with the Imperial Water Licence (S03L1-001) for the Norman Wells Operations.

Additional information on the Imperial Norman Wells Operations can be found at: www.imperialoil.ca.

DEFINITIONS

Term	Definition
Abandonment	The permanent dismantlement of a facility so it is permanently incapable of its intended use. This includes the removal of associated equipment and structures. For wellbores, downhole abandonment is conducted to prevent the possibility of oil coming to the surface.
Background	An area near the site under evaluation not influenced by chemicals released from the site, or other impacts created by on-site activity.
Closure	Is the process of returning the Norman Wells Operations site and affected areas to conditions that prevent or minimize any adverse effects on the environment or threats to human health and safety.
Closure Criteria	Standards that measure the success of selected closure activities in meeting closure objectives.
Closure Goal	The guiding statement that provides the vision and purpose of reclamation. Attainment of the closure goal happens when the proponent has satisfied all closure objectives. By its nature, the closure goal is a broad, high-level statement and not directly measurable.
Closure Objectives	Statements that describe what the selected closure activities are aiming to achieve; they are guided by the closure principles. Closure objectives are typically specific to project components, are measurable and achievable, and allow for the development of closure criteria.
Closure Options	A set of proposed alternatives for closing and reclaiming each mine component. The closure options are evaluated to determine the selected closure activity, which must be approved by the Board.
Contamination	See “Impact”.
Decommissioning	Taking out of service/closure and preliminary cleanup of a facility or a portion thereof, such as a pit or pond, during or following operations, taking into account long-term protection of human health and the environment, with no intent to obtain a release from the surface lease agreement. Decommissioning includes activities such as purging flowlines and disconnecting electrical supplies.
Dismantling	Downhole and surface abandonment of a well or dismantling of a facility in a manner that meets or exceeds regulatory requirements.
End Land Use	The allowable use of disturbed land following reclamation. Municipal zoning and/or approval may be required for specific land uses.
Impact	Any chemical concentration (in soil or water) which exceeds applicable cleanup criteria. The term “impact” as used is not intended to suggest resultant adverse effects, which are to be determined by formal risk assessment.
In Situ	“In place”.
Reclamation	Returning the ability of the land to support land uses that are similar, but not necessarily identical, to that which existed before development of the site (i.e., stabilization, contouring, revegetation).
Remediation	Treating or removing soil or groundwater affected by potential contaminants of concern that result from former oil and gas operations and exceed regulatory criteria.

2.0 INTRODUCTION

Imperial Oil Limited's (Imperial's) Norman Wells Operations (Operations) are located within the municipal boundary of the Town of Norman Wells in Canada's Northwest Territories (NWT). The regional location and setting of the Operations are shown on Figure 2-1. One of the primary instruments regulating activities on the Operations is the Water Licence issued by the Sahtu Land and Water Board (SLWB) under the *Mackenzie Valley Resource Management Act* (MVRMA). The Water Licence defines:

- allowable water withdrawals and sources;
- the required qualities of waters returned to the environment;
- conditions applying to operations, maintenance, waste management, contingency planning, and aquatic effects monitoring; and
- requirements for facility closure and reclamation.

The current version of the Water Licence requires that Imperial submit a Closure and Reclamation (C&R) Plan for the Operations to the SLWB by 5 March 2016 (SLWB 2015). The Water Licence does not provide specific direction for the form and content of the C&R Plan. Consultations with regulatory stakeholders have concluded that general guidance for plan development can be taken from the Mackenzie Valley Land and Water Board's (MVLWB's) "Guidelines for the Closure and Reclamation of Advanced Mineral Exploration and Mine Sites in the Northwest Territories" (MVLWB 2013). It has been acknowledged that this document does not relate specifically to oil and gas facilities, but nonetheless outlines processes and content that apply generally to resource sector C&R planning.

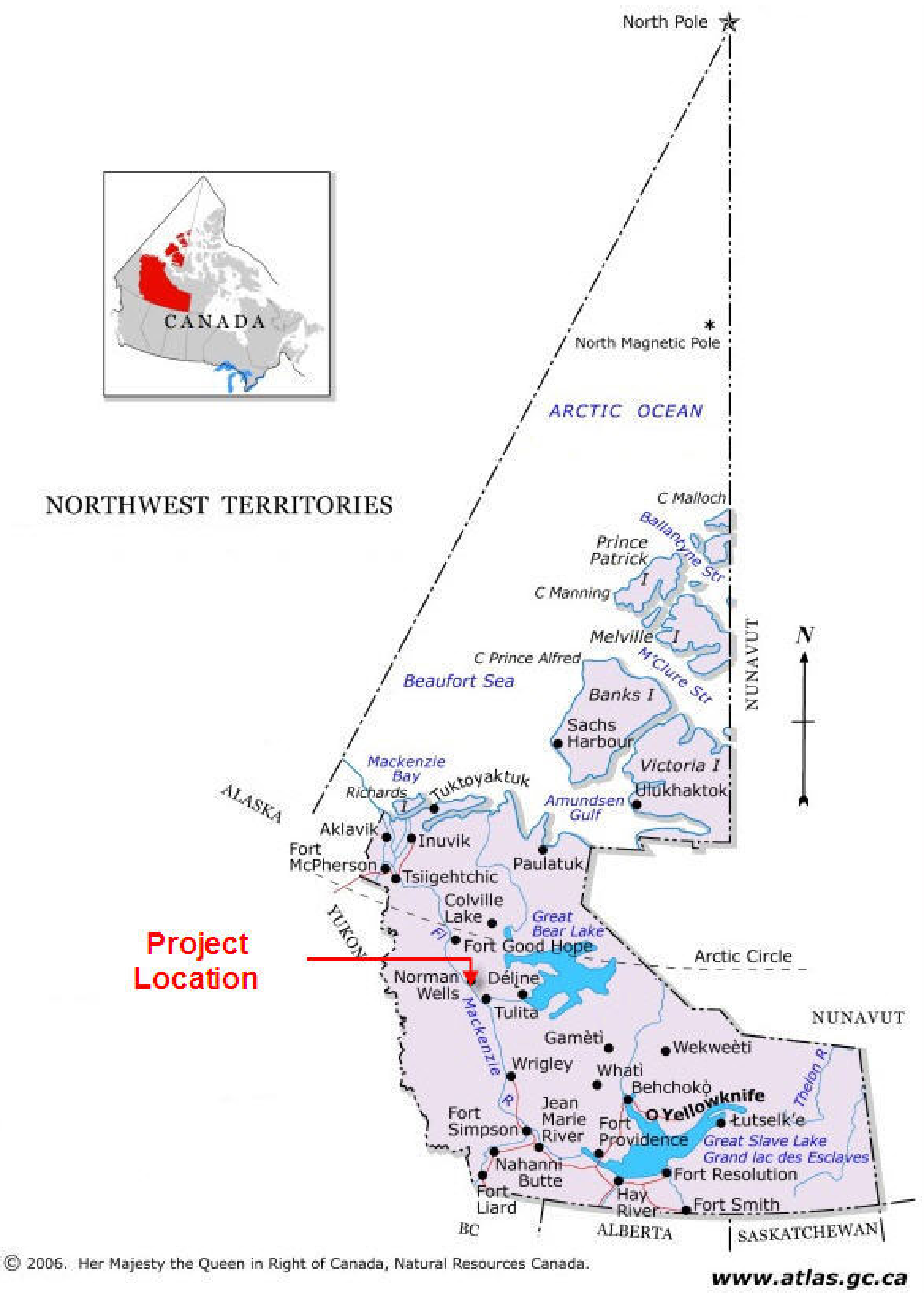
This document responds to the Water Licence requirements by presenting Imperial's current C&R Plan for the Operations.

2.1 Purpose and Scope of the C&R Plan

2.1.1 Project Overview

Imperial's Operations are located within the Proven Area. The Proven Area covers all of Goose Island, most of Bear Island, a portion of Frenchy's Island, the six artificial islands, and the Mainland area including the Central Processing Facility (CPF). The Proven Area covers about 7,939 acres or 32 km^2. The actual size of Imperial's Operations is about 11 km^2 or about one third of the Proven Area (see Figure 2-2).

Imperial's presence in the Norman Wells area dates back to the early 1900s. In the late summer of 1919, six members of an exploration crew reached the north bank of the Mackenzie River after a two month journey from northern Alberta. Their target was an oil seep that had first been documented in 1789 by the explorer, Alexander Mackenzie. Local populations had always been aware of these seeps. In August 1920, Imperial encountered an oil reservoir. Unknown at the time, they had discovered one of the largest oil fields in Canadian history. Imperial operated a refinery at the site from 1921 to 1996. In the early 1980s, Imperial carried out a major expansion of its production facilities. Today, Norman Wells ranks as one of the largest sources of conventional oil in Canada.



NORMAN WELLS OPERATIONS
INTERIM CLOSURE AND RECLAMATION PLAN

Project Location

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Figure 2-1

December 2015 | CC4058

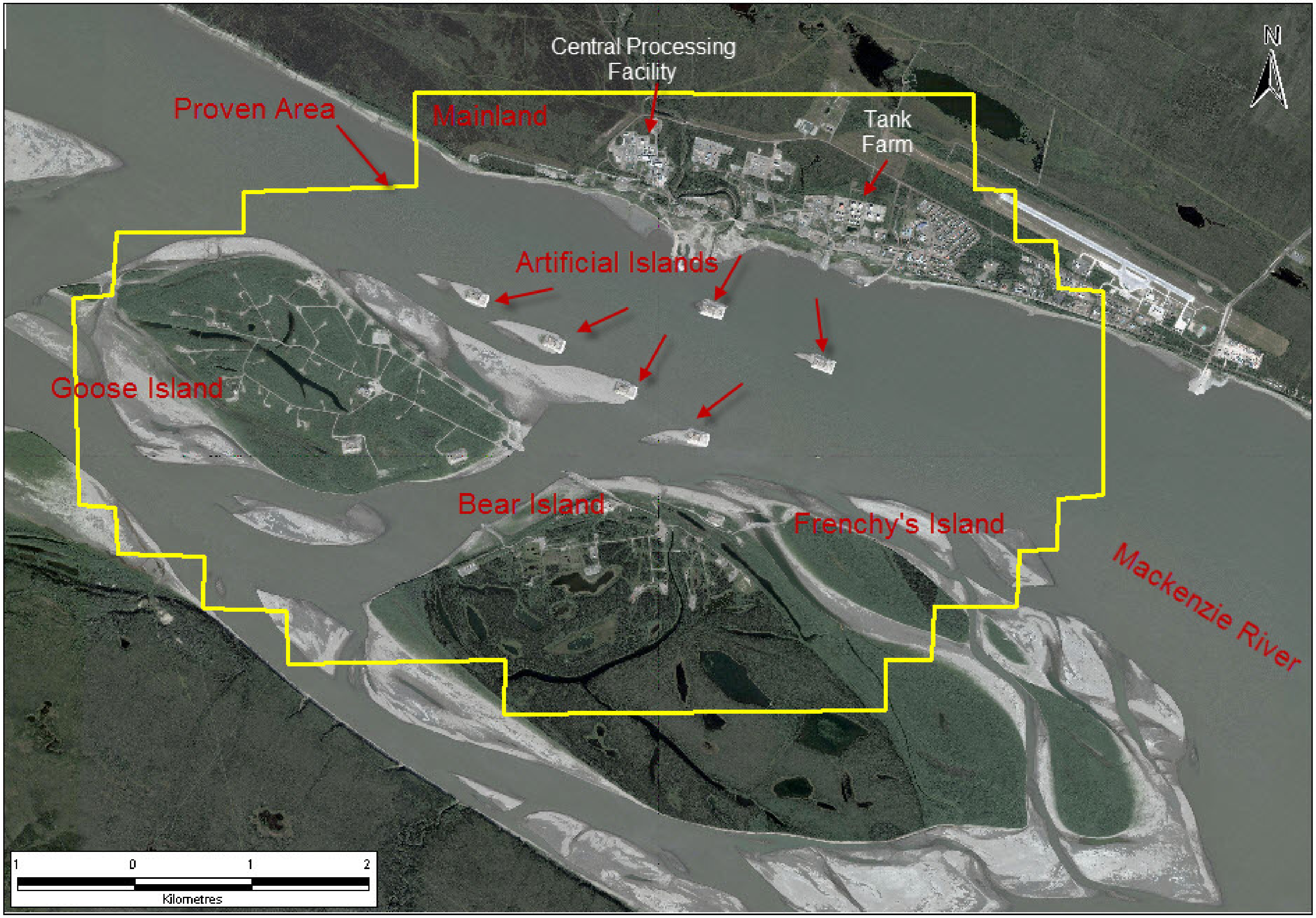

Image: Google Earth, November 2007. Proven Area boundary: interpreted from Beaufort-Mackenzie Mineral Development Area (BMMDA) web site (www.bmmda.nt.ca).

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NORMAN WELLS OPERATIONS INTERIM CLOSURE AND RECLAMATION PLAN

General Arrangement

Date: December, 2015	Project No.: CC4058	**Figure: 2-2**

Imperial's Operations produce approximately 2,100 m^3 (12,000 bbl) of oil per day with operations on the natural and artificial islands, and on the Mainland including the CPF. There are 347 active wells split about evenly between injectors and producers. In addition to producing oil, Imperial generates electricity for internal use and for the Northwest Territories Power Corporation (NTPC) to supply the Town of Norman Wells (Imperial 2014e).

Additional detail on the nature and scale of the Operations is provided in Section 4.0.

2.1.2 C&R Plan Status

This document is an interim C&R Plan that, pursuant to the requirements of the Water Licence, will be reviewed and, if necessary, updated on an annual basis. It builds on C&R concepts and initiatives that Imperial has developed and submitted over the year (for example, Imperial (2015)) in a structure that responds more directly to the Water Licence and MVLWB requirements. A more defined version of this plan capturing additional detail relating to plan execution will be developed in the period immediately prior to closure, on the basis of the technical, social and market conditions operative at the time.

Continuous improvement processes will be applied to the updates of this plan that are developed over the period prior to closure. These processes will consider, among other things, technological improvements that can be adopted for the remediation and containment systems applied for the management of contaminant issues on the Proven Area. This continuous improvement effort and the regular plan reviews that are integral elements of the Water Licence C&R planning mechanism, mean that the final C&R Plan will be the product of an iterative process of developing, reviewing and refining closure options in conjunction with local and regulatory stakeholders.

2.2 Document Structure

This C&R Plan document has been structured and organized to respond to the format specified or recommended in MVLWB (2013). The contents of the report sections and appendices are as follows:

Section 1.0 (Plan Language Summary)

An Executive Summary of the C&R document, including associated visual representations of key plan elements, structured and written as a standalone overview for a wide range of stakeholder groups.

Section 2.0 (Introduction)

Describes the purpose and scope of the C&R Plan, its current development status, introduces the general goal of the plan, identifies the plan development organization and team, outlines the approach taken to engaging the community in plan development, and lists the applicable regulatory instruments.

Section 3.0 (Project Environment)

Describes the current and pre-development nature and condition of the lands included in the Proven Area, and the local and regional environmental settings.

Section 4.0 (Project Description)

Describes the nature, scale, scope and history of the Imperial facilities and operations that make up the Operations.

Section 5.0 (Permanent Closure and Reclamation)

This is the document section that describes the key elements of the proposed C&R Plan. Detailed objectives are presented by major project component, and the proposed C&R activities are outlined both for the Proven Area as a whole, and details specific to individual components. The post closure monitoring, maintenance and Adaptive Management scopes are also described.

Section 6.0 (Progressive Reclamation)

Describes Imperial's past and present C&R activities on the Operations, and the proposal for expanding these progressive reclamation activities over the remaining operational phase prior to closure.

Section 7.0 (Temporary Closure)

This section is prescribed by the MVLWB format, but not applicable to the Operations because there is no expectation that the facility will resume operations following closure.

Section 8.0 (Integrated Schedule of Activities)

This section provides a schedule of major planning and execution activities related to C&R at facility closure for each project component, and for Progressive Reclamation activities undertaken prior to closure.

Section 9.0 (Post Closure Site Assessment)

Describes the various programs of review, assessment and monitoring that will be undertaken at various junctures to ensure that the prescribed C&R objectives are met.

Section 10.0 (Financial Security)

This section notes that an update to the Security Deposit and associated Reclamation Liability estimate that currently exists for the Operations will be prepared following review and acceptance of the interim C&R Plan.

<u>Appendix A</u>: Glossary of Terms and Definitions.

<u>Appendix B</u>: List of Acronyms, Units and Symbols.

Appendix C: Record of Engagement.

Appendix D: Lessons Learned from Other Projects

Appendix E: Reclamation Research

Appendices A through E have been included and structured to respond to the document content recommended in MVLWB (2013). In addition to these, Appendices F through Q provide support to content in specific sections of the document.

2.3 Goal of the C&R Plan

Imperial has applied the Objectives Based approach to developing the Operations' C&R Plan that is recommended in the Mackenzie Valley Land and Water Board guidelines (MVLWB 2013). The basic elements of this approach are illustrated in the MVLWB figure that is reproduced herein as Figure 2-3. The primary goal of the C&R Plan has been adopted from the guideline recommendations and is as follows:

The closure goal for the Norman Wells Operations is to return the site and affected areas to viable and, wherever practicable, self-sustaining ecosystems that are compatible with a healthy environment and with human activities.

Further, the four core closure principles, again adopted from the guidelines, are applicable to the Operations and were adopted by Imperial; these relate to:

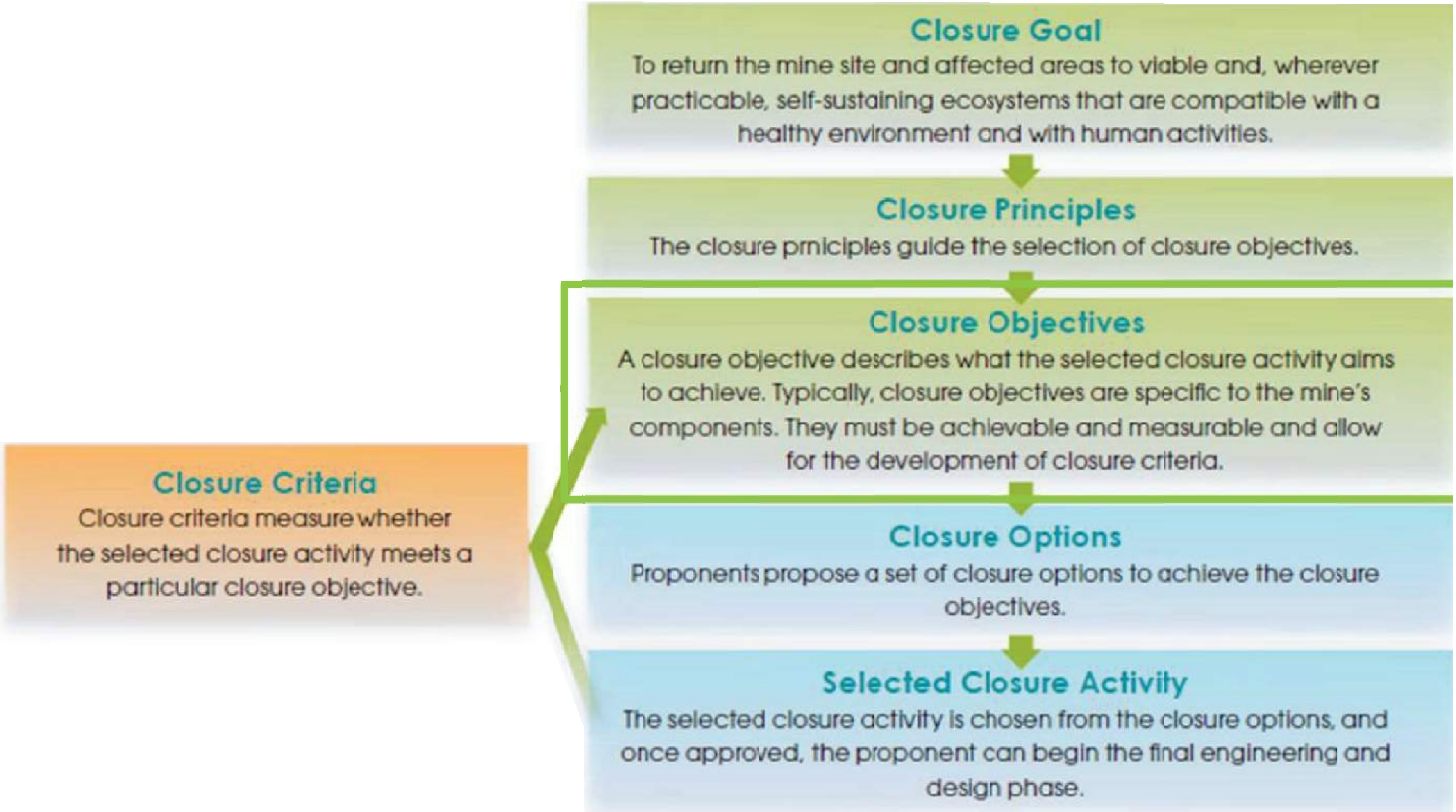
- physical stability;
- chemical stability;
- no long term active care; and
- future use.

The Closure Objectives and Criteria that form critical elements of the Figure 2-3 approach were developed on the basis of discussions and engagements with community and regulatory stakeholders, and are included in the detailed descriptions of proposed C&R activity that are provided in Section 5.0.

2.4 The C&R Planning Team

2.4.1 Planning Organization

This interim C&R Plan has been developed by Imperial in concert with local community stakeholders, the regulatory community and with the technical assistance of Imperial's consulting partners. An organization chart for the team involved in developing this interim plan is provided on Figure 2-4. This organization will be reviewed and revised in concert with future C&R Plan updates, and will expand to reflect Imperial's execution resources in the lead-up to facility closure and the associated development of a final C&R Plan.



REFERENCE DRAWING SOURCE: FROM MVLWB (2013)

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CLIENT: IMPERIAL OIL LIMITED

PROJECT NAME: NORMAN WELLS OPERATIONS

SHEET TITLE: CLOSURE AND RECLAMATION PLAN OBJECTIVE BASED APPROACH TO C&R PLAN DEVELOPMENT

PROJECT NUMBER: CC4058

FIGURE NUMBER: 2-3

ISSUE/REVISION: A

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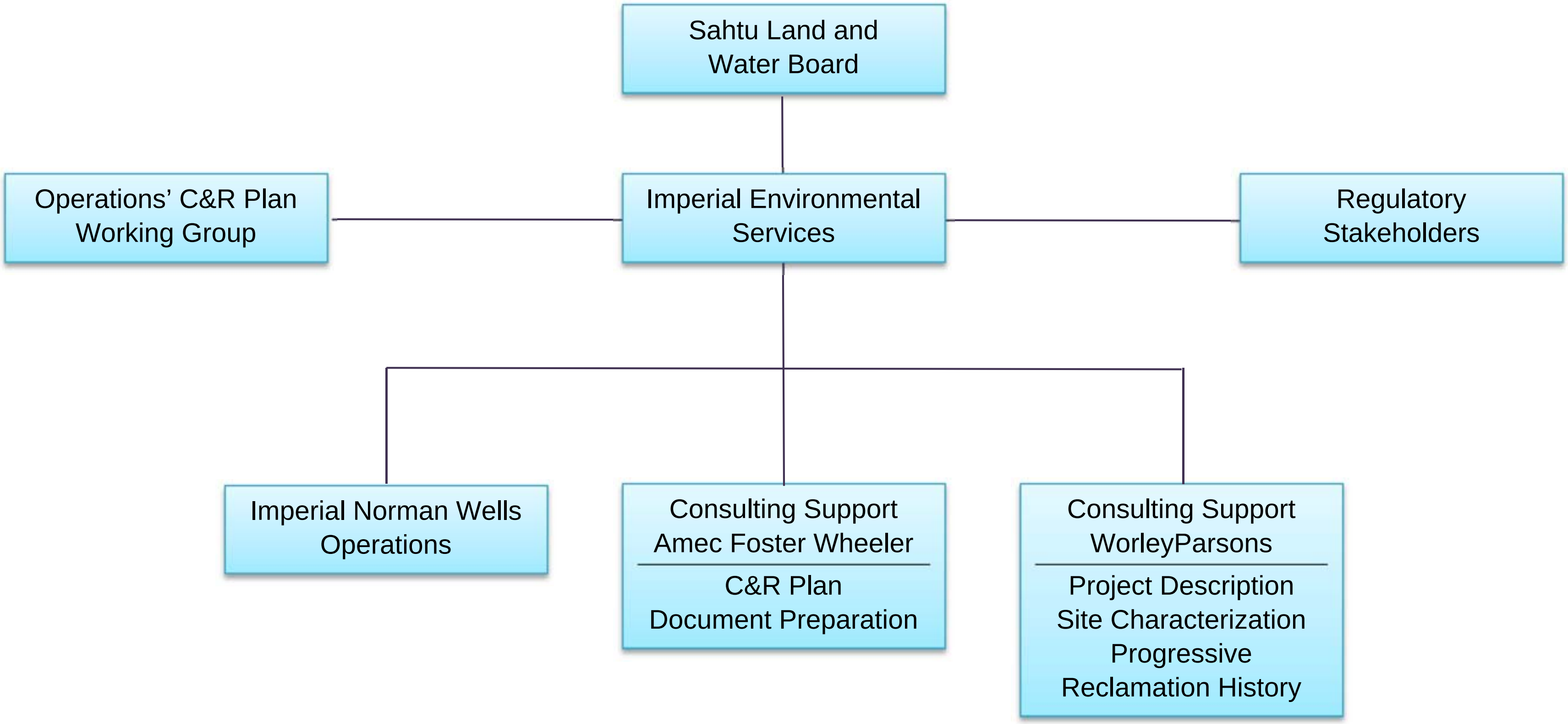


Figure 2-4: C&R Planning Team Organization

2.4.2 The Working Group

In 2014, the SLWB requested establishment of a Working Group to provide a formal mechanism for meeting with stakeholders interested in development of Imperial Oil's C&R Plan for the Operations. The goals outlined for the Working Group by the SLWB included the following (SLWB 2014):

- to confirm closure criteria (e.g., CCME, site specific);
- to confirm that Imperial Oil's Closure and Reclamation Plan is scientifically rigorous;
- to incorporate traditional knowledge;
- to ensure that communities understand and support the planned end land use; and
- to assist Imperial in the preparation of its C&R Plan.

Collectively, the Working Group provided Imperial with suggestions and advice on the contents of its C&R Plan for the Operations. The Working Group represented an opportunity to address concerns held by regulators, communities, Land Claim organizations, and individuals. Imperial participated in the Working Group to obtain guidance and feedback, and to resolve issues before the review of the Plan for approval by the SLWB.

The working group was comprised of representatives from aboriginal governments or organizations, federal and territorial governments, regulatory boards, and members of the public with a particular interest in the project. Organizations/entities represented on the Working Group included:

- the SLWB;
- the Sahtu Renewable Resource Board (SRRB);
- the Department of Environment and Natural Resources (ENR) of the Government of the Northwest Territories (GNWT);
- Aboriginal Affairs and Northern Development Canada (AANDC);
- the National Energy Board (NEB);
- Transport Canada;
- Environment Canada;
- Fisheries and Oceans Canada;
- the Déline Land Corporation (DLC);
- the Déline Renewable Resources Council (DRRC);
- Fort Good Hope Renewable Resources Council (RRC);
- the Tulita Land Corporation;
- the Town of Norman Wells;

- the Norman Wells Renewable Resource Commission (NWRRC);
- Imperial Oil Limited; and
- Amec Foster Wheeler.

The SLWB prepared a Terms of Reference for the Working Group which outlined the group's mandate, its make-up and guidelines for its operation (SLWB 2014).

2.5 Community Engagement

2.5.1 During C&R Plan Development

The Working Group was the primary vehicle for ensuring that community perspectives and requirements are reflected in the Operations' Interim C&R Plan. In addition, Imperial, as a member of the local and regional communities, routinely interacts with local stakeholders that may not have a formal involvement in the Working Group. Imperial will continue to consider inputs from these contacts as the Interim C&R Plan is refined in the future.

Imperial's participation in the Operations' C&R Plan Working Group was undertaken within the broader community engagement process that is reflected in the company's Community Engagement Plan for the Operations. This plan is maintained as one of the company's commitments under the SLWB Water Licence and sets forth the following engagement objectives:

- gather concerns, insights and ideas from the members of the Sahtu Settlement Area (SSA) that can be used to improve project designs and operational plans by providing:
  - timely information on project activities and longer tem operations; and
  - a meaningful and timely process for providing input on project descriptions and resolving issues.
- be respectful, attentive and responsive to the concerns of affected parties;
- actively engage affected communities, research organizations and northern businesses to understand their environmental concerns and explain potential development benefits;
- maintain high safety, business and ethical standards; and
- respect northern culture.

The current version of Imperial's Community engagement Plan for the SSA is provided in Appendix F.

As part of its mandate, the Working Group met at regular intervals to review the status of C&R Plan development activities. Three of these meetings were held during development of the Interim C&R Plan: one in November 2014, a second in September 2015 and a third in January 2016, all in Norman Wells. Minutes and Action Items for the meetings are provided in Appendix G, along with Imperial correspondence providing updates to action items status. In addition, the broad range of community interactions (i.e., including those outside of the Working Group) relevant to C&R planning were recorded in a dedicated Engagement Log for the C&R

planning effort. The Engagement Log developed during C&R Plan preparation, which was consistent with the formats prescribed in the general SSA Engagement Plan, is also provided in Appendix G.

2.5.2 During and After C&R Plan Execution

One of the features of the proposed C&R Plan outlined herein is the development of facilities, structures and processes to provide for the effective containment and long term management of the environmental liabilities present on the Operations' Proven Area at closure. The nature and scale of these facilities will be such that various technical, regulatory and management obligations will survive closure and require active involvement from Imperial and/or from local or regional stakeholders. As the C&R Plan evolves in the period leading up to closure, the community may wish to consider how post closure commercial opportunities could factor into local economic development plans. These opportunities could include:

- contracting for C&R activities (e.g., heavy civil works);
- environmental monitoring and management;
- development, operation and/or management of the containment structures incorporated into the plan (involvements could potentially include ownership, in whole or in part, supported by some form of risk/reward partnership with Imperial); and
- maintenance and monitoring of both the management facilities and the reclaimed Proven Area post closure.

There are a variety of possible commercial structures that could be developed using local or regional capabilities to address these, and potentially other, C&R requirements. Imperial anticipates that the nature, scope and scale of these potential structures will be an important element of the discussions and engagements that will occur as the C&R Plan evolves in the years leading up to facility closure. As these discussions develop, Imperial is open to various possibilities for the partitioning of responsibilities post closure from those in which Imperial retains full and direct control to arrangements under which responsibilities are delegated to community stakeholders/entities as potential business opportunities.

2.6 Regulatory Instruments for C&R

2.6.1 Regulatory Framework

Site reclamation activities at the Operations are primarily under the jurisdiction of two regulatory agencies. The SLWB approves and administers the Water Licence with associated terms and conditions. Through this instrument, the SLWB regulates and monitors environmental impacts associated with historical activities at the Norman Wells site. The National Energy Board (NEB) regulates activities related to oil production and gathering, as well as transport of hydrocarbon product across provincial and territorial boundaries. Current/recent spills and cleanup activities are, therefore, under NEB jurisdiction.

Other regulatory agencies which will likely have input into or jurisdiction over specific portions of the final C&R Plan include:

- Department of Fisheries and Oceans (DFO);
- Northwest Territories Department of Environment and Natural Resources (ENR);
- Municipal and Community Affairs (MACA);
- Aboriginal Affairs and Northern Development Canada (AANDC); and
- Mackenzie Valley Land and Water Board.

The specific instruments by which these agencies may be involved in C&R activity will be defined as a function of the elements of the final C&R Plan approval prior to closure.

2.6.2 Water Licence Requirement

Part J of the type A Water Licence that regulates operations on the Operations (i.e., S13L-007) specifies those requirements relating to closure and reclamation. Those conditions are as follows (SLWB 2015):

1. The Licencee shall submit within one year of the Licence being issued a C&R Plan for approval by the Board.
2. The Licencee shall adhere to the approved C&R Plan and shall annually review the Plan and make any necessary revisions to reflect changes in operations, technology, chemicals or fuels, or as directed by the Board. Revisions to the Plan shall be submitted to the Board for approval.
3. The Licencee shall carry out Progressive Reclamation of areas affected by Licenced operations as soon as is reasonably practicable.
4. The Licencee shall provide an Annual C&R Plan Progress Report no later than 31 May following the calendar year being reported. The report shall contain the information set out in Schedule 7, Item 1.
5. A minimum of 24 months prior to the end of Commercial Operations, the Licencee shall submit a Final C&R Plan to the Board for approval.

This document responds to the requirement defined by Item 1 above and initiates the development of the document that will respond to Item 5 eventually.

3.0 PROJECT ENVIRONMENT

The following sections describe pre-disturbance environmental conditions for the Operations. Where relevant, changes from pre-disturbance conditions are also described as they relate to current development status of the Operations. Environmental conditions or characteristics that are unique to individual Closure Components in the context of this Plan are further described in Section 5.

As it was not the practice to collect environmental baseline data in the early 1920s when the Operations started, detailed reports on pre-disturbance environmental conditions specific to the area are limited. As such, efforts have been made to derive information from various references in order to present a level of information sufficient to understand pre-development (baseline) conditions for the Operations. These references include reports, studies and literature reviews prepared by Imperial and submitted to the Sahtu Land and Water Board under various Water Licence conditions for the Operations as well as reports and historical data produced by applicable government and regulatory agencies, regional working groups and, in some cases, the scientific community. Traditional Knowledge made available by local communities has provided valuable context and information for the following sections.

Where studies commissioned by Imperial since the start of the Operations have produced information inferred to represent pre-development conditions, this information is referenced; particularly in the descriptions of physical and chemical environments.

3.1 Atmospheric Environment

3.1.1 Regional Overview

Imperial's Operations are located in the Sahtu Settlement Area (SSA) of the Northwest Territories (NWT). The SSA is located the Canadian sub-arctic climate zone. The Canadian sub-arctic climate zone covers the majority of the Mackenzie Valley and is characterized by long cold winters, short cool summers, and extreme annual temperature variations (INAC 2001).

Rainfall in the region usually occurs as prolonged, low-intensity events. Normal annual total precipitation in the area around Norman Wells averages 290 mm (SLUPB 2010), with about half of that falling seasonally as snow. Snow and ice cover generally persists between October and May and snowmelt runoff in spring is a dominant feature of regional stream hydrographs (INAC 2001).

Bright sunshine reaches a maximum of approximately 18.5 hours per day during the month of June, diminishing to a minimum of 5.3 hours per day during the month of December (Environment Canada 2015c). Air quality in the NWT is generally good (ENR 2011). With respect to climate change, the Canadian sub-arctic climate region is documented to be experiencing general warming trends that are in addition to normal large annual and decadal fluctuations in weather (ENR 2011).

Following is an overview of the climate setting for the Operations. As the Operations do not have a dedicated weather station, information on climate and air quality conditions has been largely derived from local stations within Environment Canada and Northwest Territories

Environment and Natural Resources (ENR) monitoring networks. Temperature and precipitation statistics and trends provided are based on data collected from the Environment Canada Norman Wells Station A between 1981 and 2010 (Environment Canada 2015, 2015b). Information on wind is based on data collected between 2009-2015 at the Northwest Territories Environment and Natural Resources (NWT ENR) Air Quality Monitoring Network Norman Wells Station (ENR 2015).

Climate change is also discussed, at a settlement area/regional level, consistent with applicable reports and data.

3.1.2 Temperature

Temperature data collected at the Environment Canada Norman Wells A Station between 1981 and 2010 indicates daily temperatures which range seasonally from extremely low (e.g., -50.0°C) to very warm (e.g., 35°C). Temperature data are summarized in Table 3-1, presented in Figure 3-1, and described in further detail below (Environment Canada 2015, 2015b).

January is typically the coldest month of the year with a mean daily air temperature of -26.1°C. The minimum (extreme) daily air temperature recorded during the period was -54.4°C recorded in February 1990. A more representative daily minimum temperature for January during the period was -29.9°C (Environment Canada 2015). These cold temperatures result in the presence of discontinuous permafrost in the Norman Wells area, which affects subsurface soil temperatures and groundwater flow (Imperial 2003a).

July is typically the warmest month with a mean daily air temperature of 17.1°C. The maximum (extreme) daily air temperature recorded during the period was 35.0°C recorded in July 1989. A more representative daily maximum temperature for July during the period was 22.5°C. The average air temperature during the 1981-2010 period was approximately -5.1°C (Environment Canada 2015).

Table 3-1: Mean, Minimum and Maximum Daily Temperatures (1981-2010) – Norman Wells Station A

Daily Values	Lowest (°C)	Average (°C)	Highest (°C)
Mean	-26.1	-5.1	17
Minimum	-29.9* (-54.4**)	-9.9	11.5
Maximum	0.6	4.7	22.5* (35.0**)

* *Representative temperature*
** *Extreme temperature*

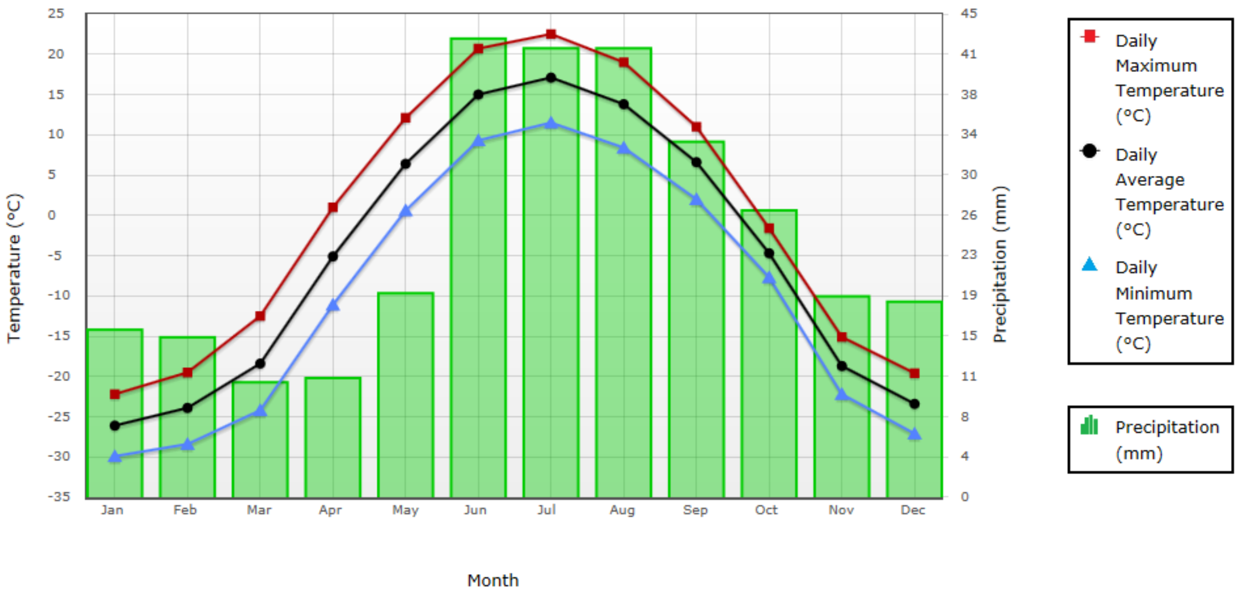


Figure 3-1: Temperature and Precipitation Chart for 1981 to 2010 - Canadian Climate Normals - Norman Wells Station A

3.1.3 Precipitation and Wind

Precipitation data collected at the Environment Canada Norman Wells A Station between 1981 and 2010 indicates a mean annual precipitation of 294.4 mm with mean annual rainfall of 171.7 mm and mean annual snowfall of 161.5 mm (Environment Canada 2015).

Precipitation at Norman Wells occurs to some extent as rainfall year round, with mean monthly rainfall peaking between June and August, inclusive. The average annual snow depth during the 1981-2010 period was 12 cm. Average monthly and yearly precipitation for Norman Wells is provided in Table 3-2 and presented in Figure 3-1 (Environment Canada 2015, 2015b).

Table 3-2: Average Monthly and Yearly Precipitation (1981-2010) - Norman Wells Station A

Period	Snowfall (cm)	Precipitation (mm)	Rainfall (mm)
January	0.2	21.1	15.6
February	0.0	19.9	14.9
March	0.1	14.4	10.7
April	1.2	12.8	11.1
May	13.3	6.4	19.0
June	42.4	0.4	42.7
July	41.8	0.0	41.8
August	41.1	0.7	41.8
September	26.7	6.9	33.1
October	4.6	27.3	26.7
November	0.0	26.0	18.7
December	0.2	25.9	18.2
Year	171.7	161.5	294.4

Wind speed at Norman Wells averages 2.6 metres per second (m/s) and ranges from 0 m/s to 21.1 m/s. Wind direction averages 285.9 degrees.

3.1.4 Air Quality

Air quality conditions at Norman Wells are subject to influences from road, river and air traffic, burning of various fuels for electricity and heat, and oil and gas operations. These influences notwithstanding, average air quality at Norman Wells is good when compared to the *Guideline for Ambient Air Quality Standards in the Northwest Territories* (ENR 2014). Average air quality conditions recorded at the NWT ENR Norman Wells Air Quality Monitoring Station are provided in Table 3-3. Comparative standards per the Guideline are also provided.

Table 3-3: Average Air Quality (2009-2015)

Air Quality Parameter	Norman Wells Average	*NWT Guideline Standard
Sulphur Dioxide (SO_2)	0.5 ppb_v	11 ppb_v
Ground Ozone (O_3)	22.2 ppb_v	63 ppb_v
Nitrogen Dioxide (NO_2)	1.6 ppb_v	32 ppb_v
Total Suspended Particulate (TSP)	3.9 ug/m^3	60 ug/m^3

* *Annual Arithmetic Mean*

3.1.4.1 Climate Change

Temperature and precipitation normally fluctuate between years in the Northwest Territories. However, both arctic and sub-arctic climate regions are showing warming trends which are occurring in addition to these normal large annual and decadal fluctuations in weather (ENR 2011). Climate change in the Mackenzie Valley is notable with average annual temperatures increasing about 2°C since record keeping started in the 1940s (ENR 2008).

Table 3-4 provides predicted mean rises in seasonal air temperatures in the SSA. These have been derived from computer models used to determine seasonal air temperature rises across the Canadian Arctic (SLUPB 2010).

Table 3-4: Mean Rises in Seasonal Air Temperatures in the SSA (Latitude 65-70)

Seasonal Temperature Values (°C)		Period (Years)		
		2011 - 2040	2041 - 2070	2071 - 2100
Winter	Moderate	1.4	3.8	6.6
	High	1.8	4.2	7.8
Spring	Moderate	1.0	2.5	3.7
	High	1.2	2.5	4.7
Summer	Moderate	0.5	1.6	2.7
	High	0.9	1.7	3.1
Fall	Moderate	1.4	4.0	5.3
	High	2.1	4.1	6.3

3.2 Physical (Terrestrial) Environment

3.2.1 Overview

Imperial's Operations are located within the Tulita District of the Sahtu Settlement Area at Latitude +65°17' and Longitude 126°50', about 140 km south of the Arctic Circle. The Operations are located predominantly along the north shore of the Mackenzie River, and produces oil from wells drilled within the Norman Wells Proven Area (Figure 3-2) (Imperial 2013). The Norman Wells PA falls within the municipal boundaries of the Town of Norman Wells.

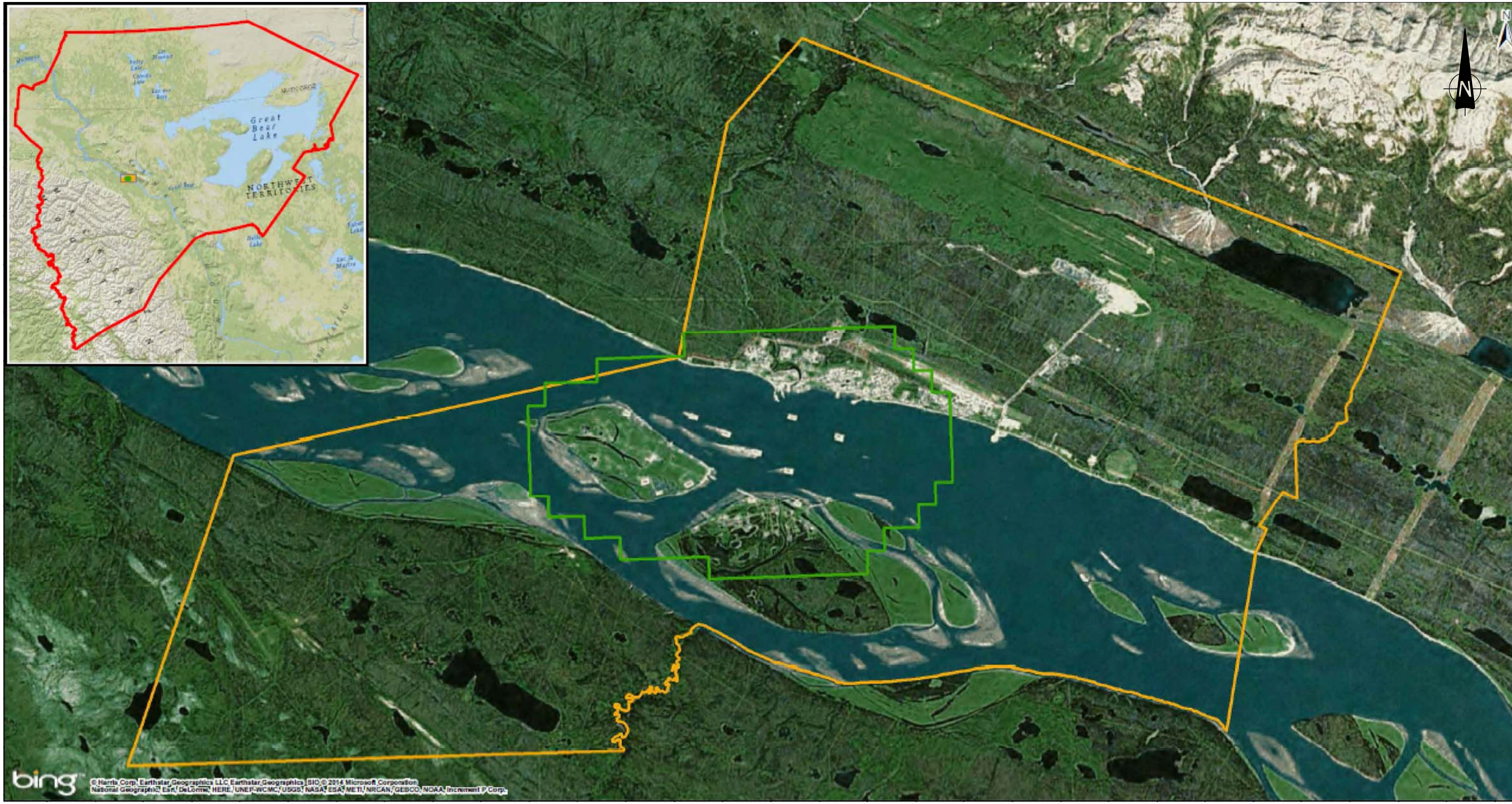
Producing wells in the PA are located on the mainland as well as several natural islands (Bear Island, Goose Island and Frenchy's Island) and Artificial Islands (1-Rayuka, 2-Rampart, 3-Dehcho, 4-Ekwe, 5-Iteh K'ee and 6-Little Bear) (Figure 3-3) (Imperial 2014b, 2014c).

The Norman Wells area falls within the Taiga Plains Ecoregion (Taiga Plains), one of the two predominant Ecoregions in the SSA (Imperial 2013).

3.2.2 Topography

The Taiga Plains Ecoregion is an area of low lying plains centred along the Mackenzie River. Topography is characterized by subdued relief with a few significant hill systems. The nearly level to gently rolling plains are occasionally interrupted by larger river valleys, including the Mackenzie Valley, which can be hundreds of metres deep (ENR 2009). Sedimentary bedrock underlies most of the Ecoregion.

Glaciation events have produced deposits of sand, gravel, and boulders in the Ecoregion. These glacial moraine areas predominate and occur in various forms and thicknesses, resulting in undulating and low-relief hills and various elongated ridges. Alluvial deposits are common along the Mackenzie River (ENR 2009). Figure 3-4 provides an overview subsection of the Taiga Plains Ecoregion, along with major physiographic elements including the plains and lowlands around Norman Wells (ENR 2009).



LEGEND:

- SAHTU SETTLEMENT AREA
- PROVEN AREA
- NORMAN WELLS MUNICIPAL BOUNDARY

amec foster wheeler	PROJECT NAME: NORMAN WELLS		PROJECT NUMBER: CC4058
CLIENT: IMPERIAL OIL LIMITED	SHEET TITLE: CLOSURE AND RECLAMATION PLAN NORMAN WELLS AREA		FIGURE NUMBER: 3-2
			ISSUE/REVISION: A

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CLIENT
IMPERIAL OIL LIMITED

PROJECT NAME
NORMAN WELLS

SHEET TITLE
CLOSURE AND RECLAMATION PLAN
NORMAN WELLS OPERATIONS

PROJECT NUMBER
CC4058

FIGURE NUMBER
3-3

ISSUE/REVISION
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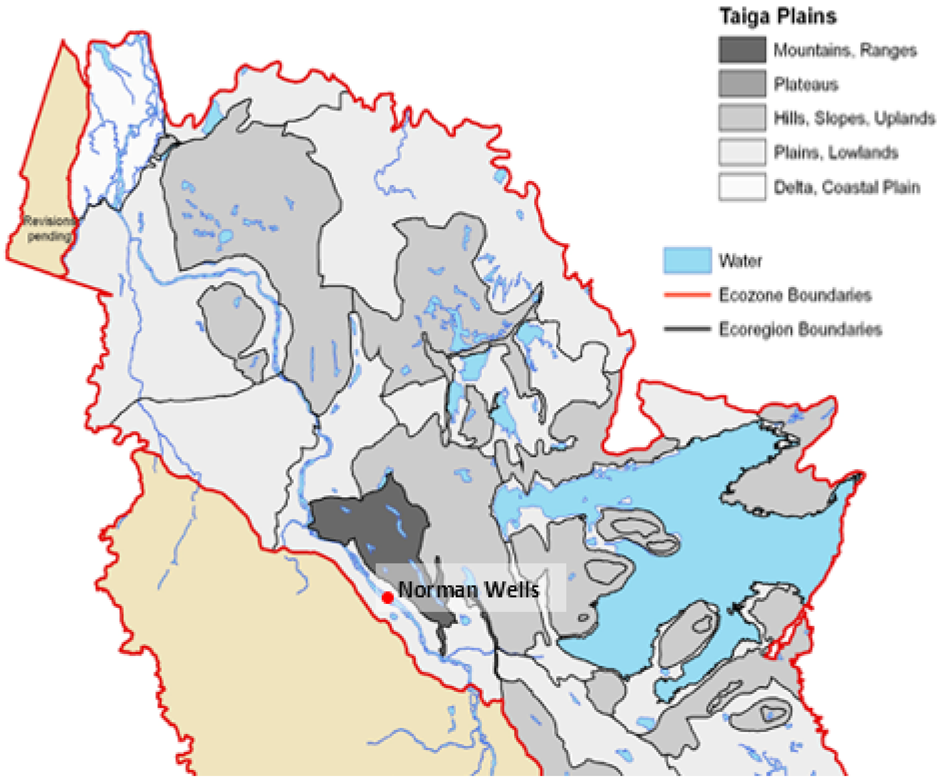


Figure 3-4: Taiga Plains Ecological Region - Subsection

Cold temperatures in the Ecoregion are linked to the presence of discontinuous permafrost. This permafrost affects local subsurface soil temperatures and groundwater flow around Norman Wells (Imperial 2003a).

Landforms known as karst topography are present in the Sahtu Settlement Area around Norman Wells. Karst landscapes form where rock dissolves in water (e.g., limestone), creating features like sinkholes, caves, dry valleys and gorges, turloughs and poljes (large depressions drained underground by inner sinkholes) (Ford 2008).

The Operations itself are located along the northern Mackenzie River riverbank, which rises steeply from the lower flood plain to a relatively flat terrace about 65 metres above sea level (masl). Site elevations at Operations range from approximately 50-70 masl (Imperial 2003). The mainland site itself is situated on an upper terrace of the Mackenzie River approximately 15 metres above average water level (Imperial 2003a). The site is dissected by Bosworth Creek, a steep-banked drainage feature that is confined to a relatively narrow valley. The eastern slope of the Bosworth Creek valley is quite steep, having an angle of roughly 35°.

3.2.3 Watershed and Hydrology

Much of the Taiga Plains Ecoregion drains to the Arctic Ocean via the Mackenzie River and its main tributaries. Approximately 18 percent of the Taiga Plains in the NWT is covered by water. The Taiga Plains includes two of Canada's largest freshwater bodies, Great Slave Lake and Great Bear Lake, along with numerous smaller lakes and ponds (< 10 ha in size) (Imperial 2013a).

Within the SSA, the majority of streams fall within the Mackenzie River drainage basin (Figure 3-5) (INAC 2013). The total Mackenzie River basin is 1.8 million km^2 making it the largest of any river in Canada. It has the second highest mean discharge in Canada at 9,700 m^3/s (Kokelj 2001). The Mackenzie River system flows roughly 4,200 km from the headwaters of the Athabasca River in the Columbia ice field in Jasper National Park, Alberta, and the snowfields of the upper Peace River headlands in northeastern British Columbia to its final drainage into the Northwest Territories Beaufort Sea (Imperial 2013a). The volume of Mackenzie River drainage to the Beaufort Sea accounts for 60% of the freshwater that flows into the Arctic Ocean from Canada (MRBB 2003).

Figure 3-5: Mackenzie River Basin

Surface runoff in the Mackenzie River drainage basin occurs during spring freshet and as a result of summer rain events. The region follows a zone of discontinuous and intermediate discontinuous permafrost which affects the hydrological cycle. Ice rich permafrost conditions can act as a barrier to water infiltration, leaving more water available for surface runoff to streams. For example, most of the spring snowmelt and rainfall runs off quickly because of impermeable ground conditions; this can result in rapid rises in local stream water levels (Kokelj 2001).

As a whole, the Mackenzie River system does not generally respond rapidly to runoff events, given its extremely large size, the number of inflows, and the volume of storage capacity within the basin (Kokelj 2001). However, hydrological data from the Water Survey of Canada demonstrates large seasonal variability in local river flow and water levels around Norman Wells (Kokelj 2001).

3.2.3.1 Mackenzie River at Norman Wells

Monthly mean discharge data from Water Survey of Canada Mackenzie River Station at Norman Wells (10KA001) is provided in Table 3-5. The mean annual hydrograph is characterized by a relatively steep rise in May with a mean peak occurring in late May/early June (Figure 3-6) (Kokelj 2001). There is generally a gradual recession of flow volumes during the rest of the year, with a slightly steeper decline during freeze-up in November. Following freeze-up, there is a small increase in flow, after which there is a very gradual winter flow decrease. This decreased flow continues until just before spring melt (Kokelj 2001). The range of flows in any given month can vary significantly, especially during the spring melt. The 1975 hydrograph in Figure 3-6 demonstrates that flow can also be influenced by rainfall events (see correlating peaks on Julian Days).

The 1:10, 1:100 and 1:500 year flood discharges for the Mackenzie River at Norman Wells have been estimated at 29,300 cubic metres per second (m^3/s), 34,800 m^3/s and 38,100 m^3/s, respectively, by Environment Canada (Westermann 1990).

Table 3-5: Monthly Mean Discharge (1943-2013)

Period	Mean (m^3/s)	Maximum (m^3/s)	Minimum (m^3/s)
January	3,810	6,680	2,260
February	3,430	4,960	2,130
March	3,240	4,670	2,190
April	3,550	4,920	2,430
May	13,500	18,700	6,680
June	17,400	24,400	10,000
July	15,600	24,700	8,540
August	12,500	18,100	6,920
September	10,600	13,700	6,590
October	8,890	13,400	6,270
November	5,140	10,000	2,340
December	4,270	18,100	2,250
Mean	8,540	9,920	5,990

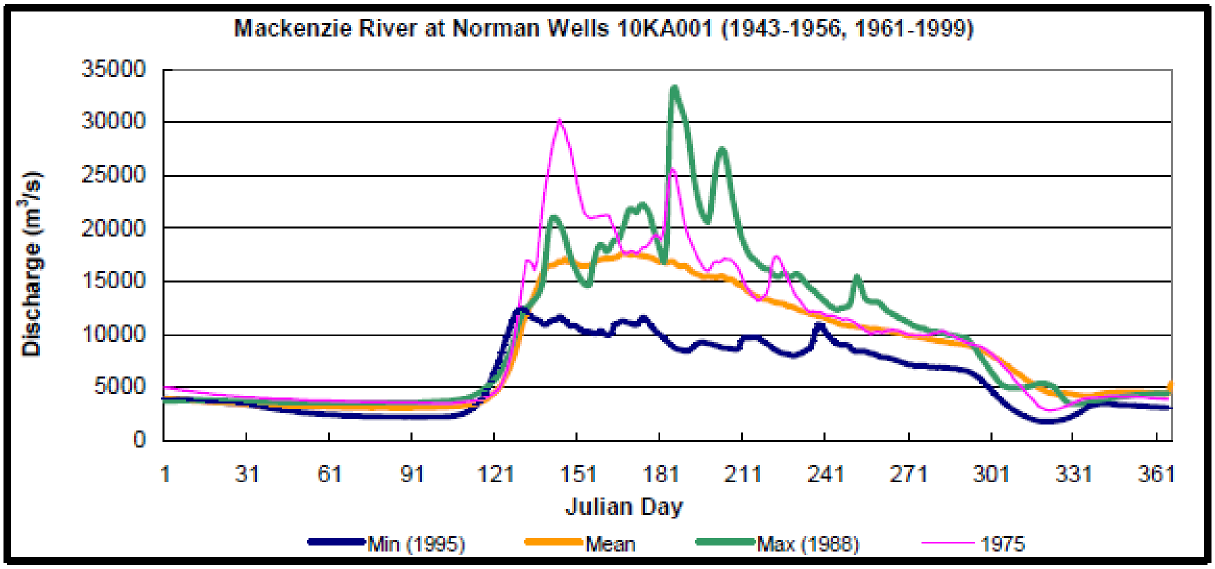


Figure 3-6: Hydrograph - Mackenzie River at Norman Wells Hydrometric Station

The seasonal range in water levels during the open water period is in the order of 5 m (Rescan 1998). Monthly mean water level data from the Water Survey of Canada Mackenzie River Station at Norman Wells (10KA001) is provided in Table 3-6. Water levels during break-up have reached 11 m above low water and consistently exceed summer high water. Typical water levels are approximately 4-5 m in the winter with late spring/summer levels rising to 7-9 m in May and June (Figure 3-7).

Table 3-6: Monthly Mean Water Level (2000-2013)

Period	Mean (m)	Maximum (m)	Minimum (m)
January	5.380	5.974	4.840
February	5.127	5.691	4.820
March	4.866	5.535	4.579
April	4.853	5.276	4.561
May	7.009	8.080	6.217
June	6.229	7.005	5.277
July	5.718	6.466	4.986
August	5.039	5.601	4.359
September	4.731	5.097	4.080
October	4.398	4.727	4.179
November	4.946	5.568	4.244
December	5.365	5.714	4.994
Year	5.288	5.495	5.101

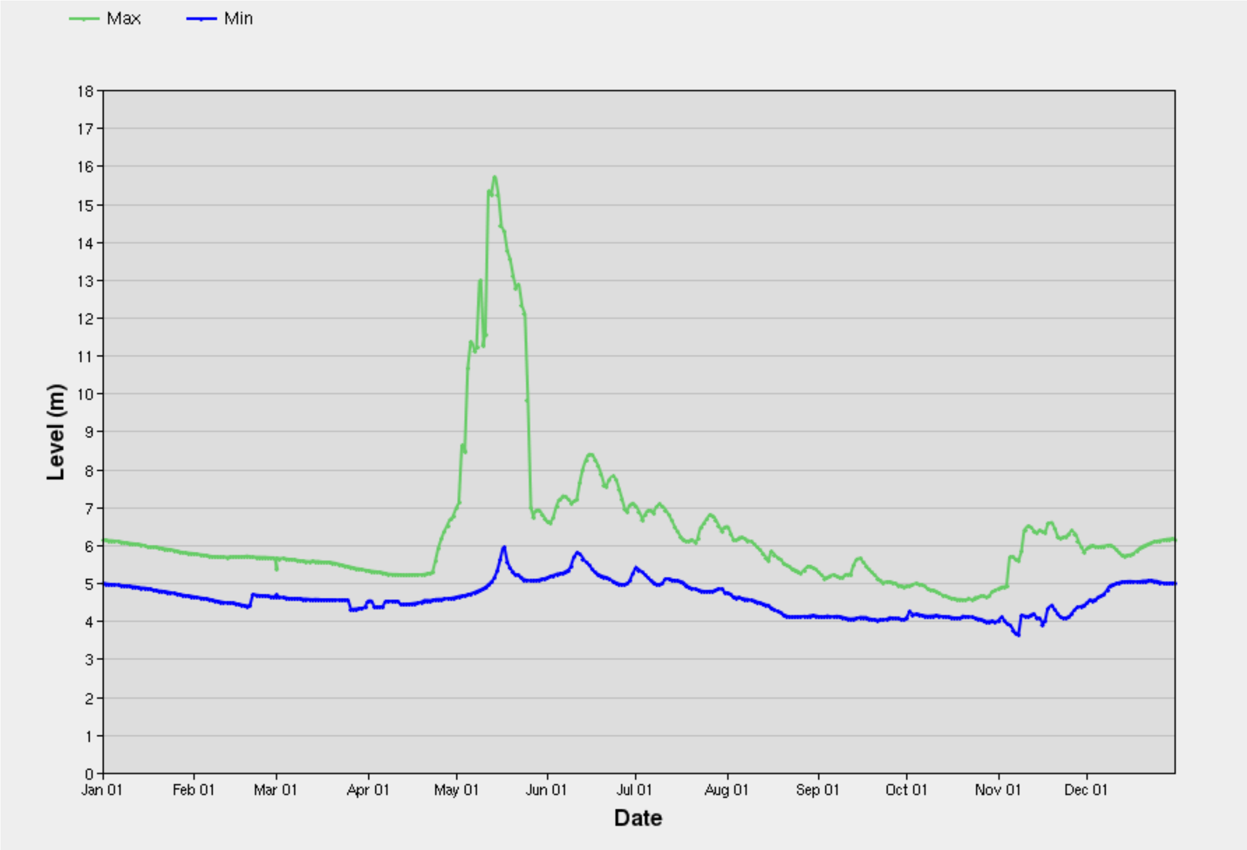


Figure 3-7: Water Level Graph for Mackenzie River at Norman Wells (10KA001) (2000-2013)

3.2.3.2 Bosworth Creek

Flow data from the Water Survey of Canada (WSC) HYDAT station (10KA007) on Bosworth Creek shows a mean annual hydrograph characterized by a relatively steep rise in May with a mean peak occurring in late May/early June, primarily associated with spring melt (Figure 3-8) (WSC 2001).

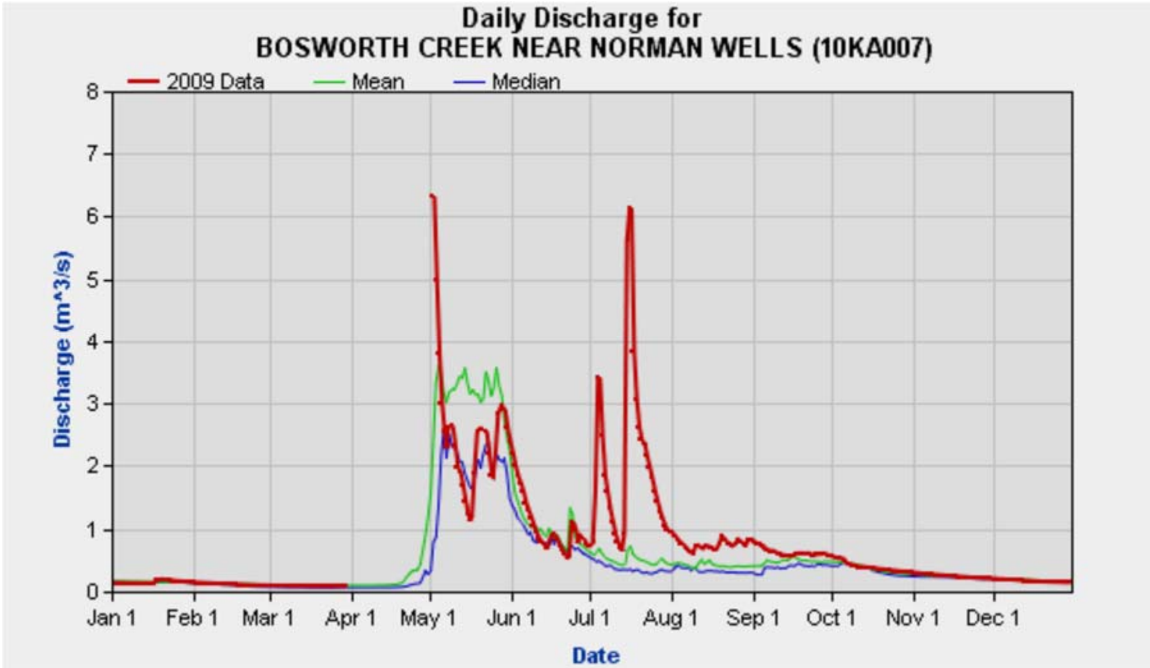


Figure 3-8: Hydrograph - WSC HYDAT Station (10KA007) on Bosworth Creek

3.2.4 River and Littoral Zone Characteristics

The Mackenzie River flows in a west-northwesterly direction through the Mackenzie Valley past Norman Wells. The Mackenzie Valley is bounded on the south by the Canyon Ranges of the Mackenzie Mountains and on the north by the Norman Range of the Franklin Mountains (Imperial 2014). The River is joined by the Great Bear River over a shallow gravel bar upstream of Norman Wells and continues downstream through channels (some braided) eventually widening up to 5 km.

At Norman Wells, the River is approximately 4.65 km wide and contains a number of natural and artificial islands. The Mackenzie River bottom is primarily silt and sand (Imperial 2003). The riparian zone along the Mackenzie River consists of seasonal mudflats backed by a band of scrub which extends from the edge of the mudflats up the river bank (Imperial 2005).

The Mackenzie River is the largest source of sediment to the Arctic with an annual load of 2.2×10^{11} kg (Macdonald and Thomas 1991; Yunker and MacDonald 1995). Both the river discharge and suspended particulate matter (SPM) concentrations are relatively low from November to May (3,500 m^3/s and 3-4 mg/L, respectively), but they increase dramatically in late June during the spring freshet (to 25,000 m^3/s and >250 mg/L). River flow and SPM levels remain high during the summer with only a slight decrease in October (Macdonald and Thomas 1991, Yunker and MacDonald 1995).

Break-up of the Mackenzie River ice at Norman Wells usually occurs over a two-week period in May, and freeze-up typically occurs during a three-week period in October-November. Ice thickness of the Mackenzie River usually ranges from 1 to 1.5 m (Imperial 2008). The Norman Wells natural islands, particularly on Goose Island, are heavily influenced by ice scouring during spring break-up on the Mackenzie River.

3.2.4.1 Bosworth Creek

Bosworth Creek is the primary tributary to the Mackenzie River at Norman Wells. It originates at Hodgson (Jackfish) Lake (65°18'N 126°41'W) in the Tulita District of the Sahtu Settlement Area and parallels the base of Discovery Ridge before a course change where it joins the Mackenzie River immediately to the west of the Town of Norman Wells (ESRF 2009). Bosworth Creek is a small, high-energy creek with a gravel bottom (Imperial 2003a). The riparian zone along Bosworth Creek consists of a band of mostly coniferous forest (Imperial 2005).

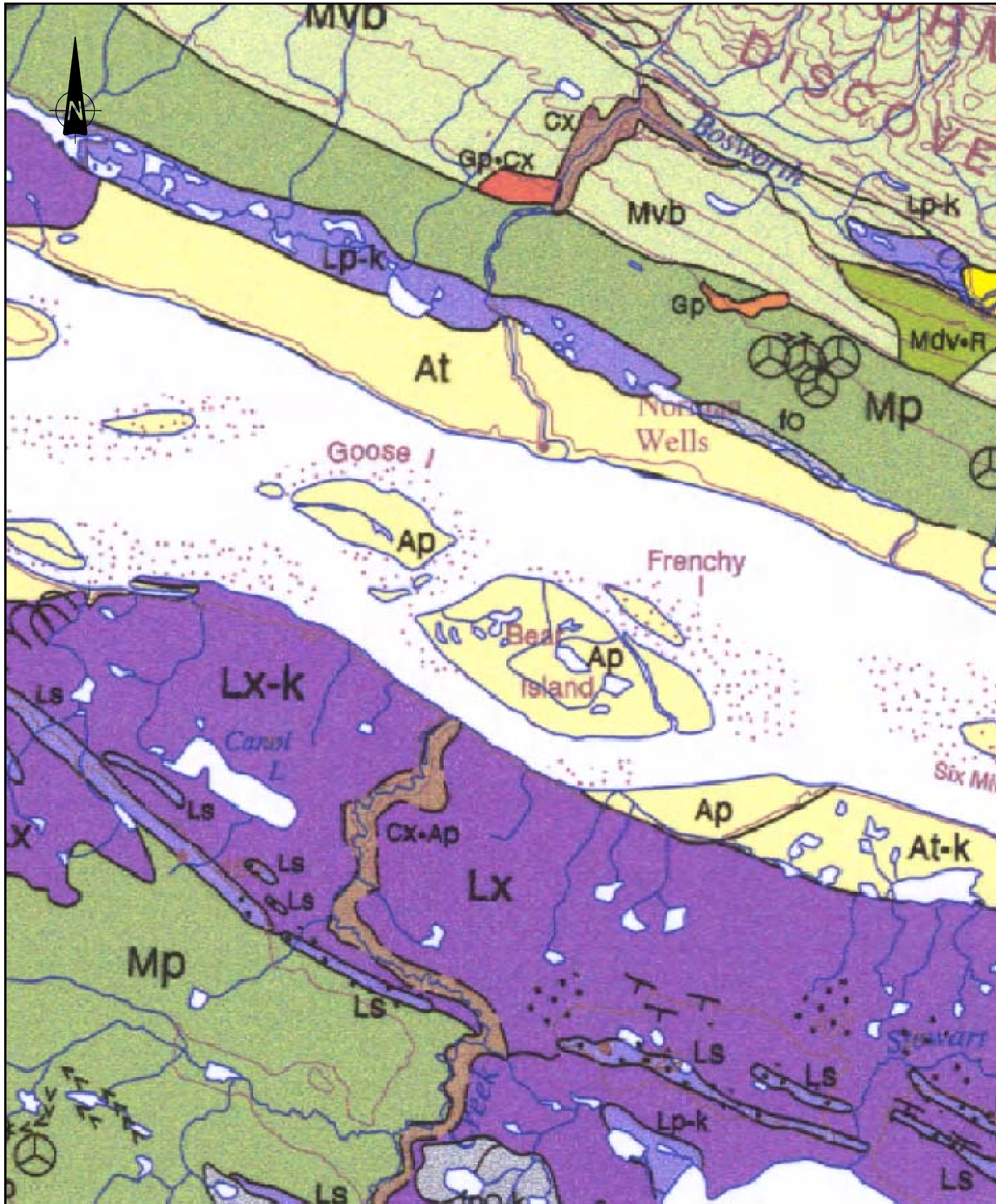
A weir was constructed on Bosworth Creek in 1960 by Imperial Oil Resources to create a small impoundment supplying drinking water to the Town of Norman Wells and to process water to the nearby Operations (ESRF 2009). When the Town no longer needed the impoundment as a water supply and following closure of the Operations' refinery, the Government of the Northwest Territories requested the removal of the weir and completion of stream rehabilitation measures. The weir removal, completed in 2005, also included stream bed reclamation work under Imperial's Reclamation and Restoration Plan to improve fish habitat and spawning bed access as well as restoration of riparian vegetation (ESRF 2009).

3.2.5 Surficial Geology

Surficial materials in the Taiga Plains Ecoregion are primarily the result of deposition during Quaternary glaciation. Glacial till is the most common surficial material followed by glacio-lacustrine and glacio-fluvial deposits. The majority of the Ecoregion is covered with a till blanket, with some large areas of till veneer in the north. There tends to be a mix of coarse and fine grained glacio-lacustrine sediments in river drainages, including the Mackenzie River (Biodivcanada 2015).

Remnants of associated glacio-lacustrine sediments are present in the vicinity of Norman Wells. These glacial deposits have been reworked by fluvial processes, slope processes and the development of organic layers and may be quite variable in texture, ranging from silt and clay sized particles, to coarser sand and gravel lenses deposited during more active meltwater drainage episodes (Imperial 2014b). Figure 3-9 provides a detailed illustration of the surficial geology around Norman Wells (NRCAN 1989).

The most dominant soils identified in the area of Norman Wells are Static and Turbic Crysols which have developed on either alluvial or moraine materials (Hardy Associates (1978) Ltd. 1980). Localized areas of Organic Crysols have also been noted overlying lacustrine deposits in low areas or around fens and wetland areas.



GLACIAL LACUSTRINE DEPOSITS: *silt and clay with minor sand, in many places overlain by a discontinuous veneer of organic deposits and locally overlain by sand; sediments laid down in a glacial lake*

Lp,Lp-k, Lb,Ls	*Lp – thick sediments occurring as a flat to gently sloping plain, 2–15 m thick, Lp-k – lacustrine plain containing thermokarst depressions, Lb – blanket of lacustrine sediments occurring as gently to moderately sloping plain, 2–8 m thick, Ls – sand and less gravel occurring as shoreline deposits, up to 10 m thick*
Lx,Lx-k	*Lx – lacustrine complex or transitional between glaciofluvial and lacustrine deposits, with upper 0–3 m consisting of sand; 3–20 m thick, Lx-k – lacustrine complex containing thermokarst depressions, 3–20 m thick*

GLACIOFLUVIAL DEPOSITS: *sand and gravel, locally with a veneer of eolian silt or sand; deposited as proglacial or ice contact sediments by glacial meltwater*

Gp,Gt, Gv,Gd	***Outwash deposits**: Gp – flat to gently sloping plain, 2–30 m thick, Gt – underlying a terrace, 2–30 m thick, Gv – underlying a terrace,<3 m thick, Gd – gentle sloping fan 2–30 m thick*

ALLUVIAL DEPOSITS: *sand, silt, and minor gravel in association with modern drainage regime*

Ap,Ap-k, At,At-k	*Ap – floodplain sediments, coarse sand and gravel with silt and fine sand occurring as channel and overbank floodplain sediments, 3–5 m thick, Ap-k – floodplain sediments containing thermokarst depressions, At – sand and silt, in places underlain by gravel; occurs as terraces, 2–5 m thick, At-k – sand and silt, occurring as terraces containing thermokarst depressions*

GLACIAL DEPOSITS: *nonsorted silt, sand, and clay with some coarser clasts (till); till of mountainous areas has abundant pebbles, cobbles, and boulders in silty sand matrix; deposited by glacial ice and occurring in a variety of different landforms.*

Mp,Mpv	***Moraine plain**: till occurring as: Mp – flat to gently sloping plain, 3–20 m thick, Mpv – variable area of thick and thin till, 1–3 m thick*
Mv,Mb	***Till veneer and till blanket**: Mv – veneer of till with slopes conforming to underlying bedrock topography, <2 m thick, Mb – gently to moderately sloping plain controlled by bedrock, 3–6 m thick*
Md	***Drumlinoid and hilly plain**: plain with individual drumlins or extensively fluted, 2–30 m thick,*

COLLUVIAL AND SHEETWASH DEPOSITS: *diamicton, rubble, and organic-rich silt and sand derived from bedrock and surficial materials by a variety of colluvial and sheetwash processes*

Cv,Cb,Ca	*Cv – veneer deposit that conforms to bedrock topography, <2 m thick, Cb – blanket deposit that conforms to bedrock topography, >3m thick, Ca – organic-rich silt and sand developed on glacial lacustrine sediments or soft bedrock, 1–2 m thick*
Cz	***Landslide deposits**: rubble and/or diamicton occurring as stepped or fan-shaped deposits; formed by rotational slumping or retrogressive-thaw flow failure of glacial lacustrine sediments or shale*
Cx	*Complex consisting of two or more of Cv, Cb, Ca, Cz, and Af, undivided*

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The active soil layer (seasonally unfrozen layer above permafrost) is generally between 0.3 and 1.0 m thick (Imperial 2003a). The thickness of this layer is highly dependent on seasonal aspects, proximity to buried infrastructure (e.g., underground flowlines), or degree of surface disturbance (e.g., vegetation clearing, open excavations, etc.) (Imperial 2003a).

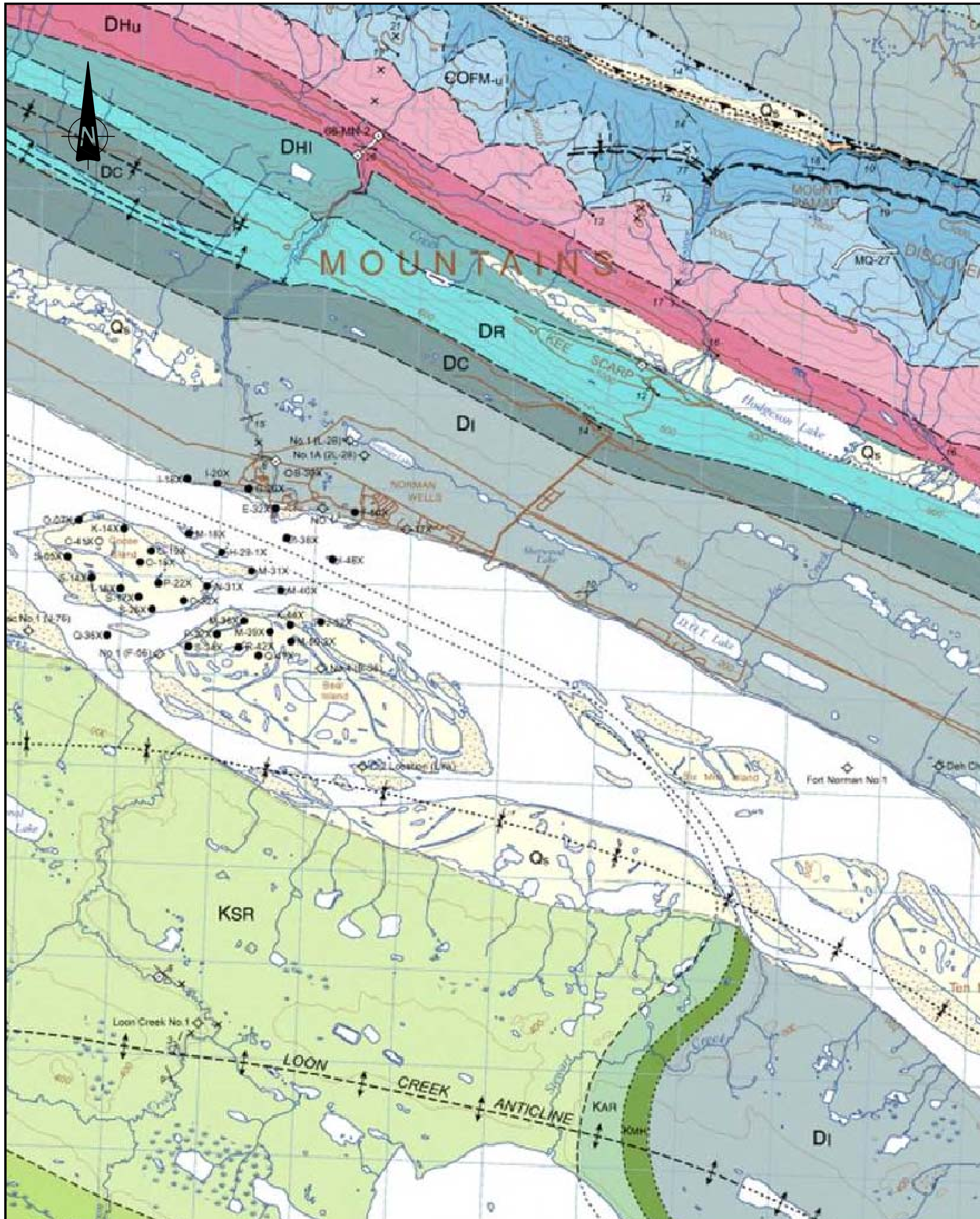
3.2.6 Bedrock Geology

Bedrock geology in the vicinity of Norman Wells has been studied and described in detail (Hume 1954). The site is located on a monoclinal structure on the southwest flank of the Discovery Range, and on the northeast limb of the Carcajou. The general dip of the bedrock strata is 4 to 5° to the southwest (Imperial 2003a). Recent glacial and post-glacial sediments in the Mackenzie River valley are underlain by Cretaceous and Devonian-aged Imperial and Canol Formations, respectively (Link 1920; Hume 1954). Figure 3-10 provides a detailed illustration of the geology around Norman Wells (NRCAN 2012).

The Cretaceous beds have eroded north of Bear Island and the Canol Formation sub-crops in the area. Depth to bedrock is estimated to be 0 to 10 m at the Norman Wells site, based on information obtained during previous groundwater quality investigations. This estimate is confirmed by the presence of small outcrops along the shore of the Mackenzie River and within the Bosworth Creek valley (Imperial 2003a).

The Imperial Formation thickness beneath the Norman Wells area varies from approximately 80 m at the northern bank of the Mackenzie River, to less than 10 m under the northern edge of the site (Link 1920). The Imperial Formation is comprised of interbedded sandstones, siltstones and shales and is underlain by the Canol Formations (250 m to 370 m thick). These fractured marine shales are highly bituminous, and are the interval within which the original oil discovery was made (Imperial 2014b). Underlying these shales is up to 100 m of oil saturated reef limestone known as the Kee Scarp Formation. The contact between the surrounding Canol Formation and Devonian-aged limestone reef forms a stratigraphic trap reservoir (Figure 3-11) (Imperial 2014b), currently being produced by the Operations (Williams 1986).

Local folding and fracturing of the shales, siltstones and sandstones overlying the oil saturated Kee Scarp limestone has resulted in numerous naturally-occurring oil and gas seepage zones at ground surface (Imperial 2003a). These naturally occurring hydrocarbon seeps are discussed in more detail in Section 3.3.1.1.



QUATERNARY

Qs	**Quaternary sediment:** mud, sand, and gravel: unconsolidated.

LATE CRETACEOUS

KLB	**Little Bear Formation:** sandstone: lithic wacke to quartz arenite and chert arenite, mottled grey, greenish-grey, brown, or rusty, thin- to thick-bedded, typically friable and porous, crossbedded, laminated, ripple marks, graded bedding, locally bioturbated; interbedded with mudstone and shale: somewhat silty, dark grey to brown or black, crumbly and soft, minor sideritic concretions; and minor coal.
KSR	**Slater River Formation:** shale and mudstone: dark brown to dark grey, black, or rusty-brown, soft, crumbly, and fissile, sideritic concretions common, rare fish scales; minor bentonite and ash tuff: white to yellow, pale green, or orange-brown; and minor sandstone: lithic wacke, brown, grey, or rusty, very thin- to thin-bedded, crosslaminated, and bioturbated.

DEVONIAN

DI	**Imperial Formation:** shale: locally silty, dark grey to greenish-grey, fissile; interbedded with siltstone: locally micaceous or calcareous, greenish-grey to purplish-brown, laminated, bioturbated; and sandstone: lithic wacke to quartz arenite, micaceous, locally calcareous or glauconitic, grey to greenish-grey or brown, very thin- to medium-bedded, laminated and crosslaminated, abundant and diverse trace fossils; and minor limestone: bioclastic, grey to brown or orange, diverse fossil assemblage. Includes Jungle Ridge Member, comprising limestone: lime mudstone, silty, grey, weathers light yellow, very thin- to thin-bedded, laminated, shale partings, and rare fossils.

Horn River Group (Hare Indian, Ramparts, and Canol formations)

DHR	**Horn River Group:** shale: carbonaceous or petroliferous, calcareous to siliceous, locally silty, dark grey or black, weathers grey, black, brown, or rusty, locally fossiliferous; minor limestone: dark grey with tentaculitids, interbedded with shale at base of unit; cream to light grey stromatoporoid limestone (Ramparts Formation) may be present in the middle of the unit.
DC	**Canol Formation:** shale: siliceous, sulphurous, petroliferous, dark grey to dark brown or black, weathers grey, brown, or yellow, with pink or red patches where burnt and/or oxidized, laminated to very thin-bedded, platy, locally semiresistant.
DR	**Ramparts Formation:** limestone: wackestone to grainstone or rudstone, petroliferous, cream, beige, or light grey, weathers to light shades of grey, brown, yellow, and orange, medium- to very thick-bedded, very fossiliferous (stromatoporoids dominate).
DHI	**Hare Indian Formation:** shale: carbonaceous, calcareous, black, fissile, may contain tentaculitids or other fossils; interbedded with minor limestone: dark grey to black, thin-bedded, tentaculitids common. Basal Bluefish Member is calcareous and fossiliferous, unit becomes less carbonaceous, less calcareous, less fossiliferous, and increasingly silty upsection.
DHu	**Hume Formation:** limestone: wackestone to grainstone, floatstone, medium to dark grey or brownish-grey, typically weathers light grey, thin- to very thick-bedded, parallel to irregular or nodular bedded, fossiliferous with abundant and diverse assemblage. Unit is thicker bedded and cliff-forming in upper part.
DBR	**Bear Rock Formation:** limestone breccia: variably dolomitic and petroliferous, angular clasts range from granule- to boulder-sized, greyish-brown to grey, weathers light grey, vuggy, massive and rubbly with rare bedded intervals of laminated carbonate, tends to form hoodoos.

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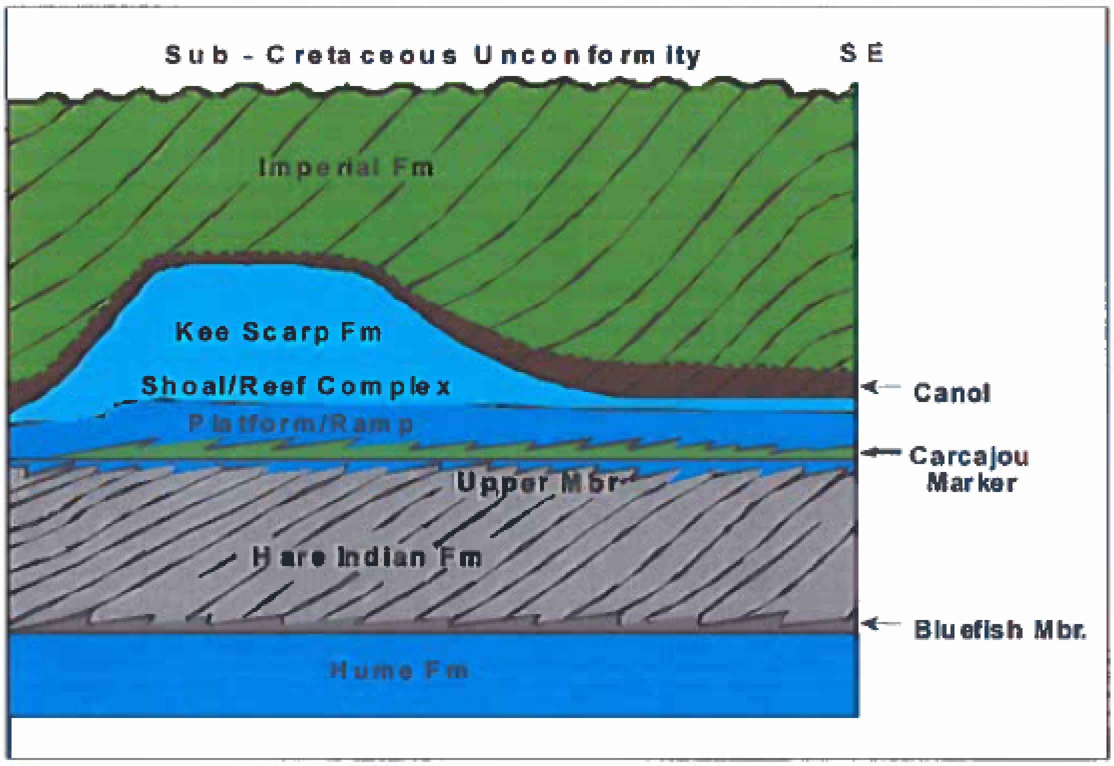


Figure 3-11: Detail of the Stratigraphic Trap (Hydrocarbon) Reservoir

3.2.7 Hydrogeology

No known regional hydrogeologic studies specific to the Norman Wells area have been identified for the period prior to development of the Operations (Imperial 2003a). As such, the basis for understanding the local hydrogeologic setting is formed from work commissioned by Imperial at the Operations (Imperial 2003a).

The regional terrain slopes from the Norman Range of the Franklin Mountains (located north of the site) towards the Mackenzie River. Based on the premise that shallow, unconfined groundwater flow is generally controlled by topography, the inferred direction of shallow groundwater flow on the north side of the Mackenzie River is to the south, with discharge presumably occurring to the Mackenzie River (Imperial 2003a). However, there is no apparent evidence of springs originating from the terrace along the Mackenzie River. Smaller creek valleys, such as Bosworth Creek, would also exert some control on local groundwater flow patterns, and could serve as discharge areas as well (Imperial 2003a).

Groundwater surface elevations do not indicate a consistent groundwater flow direction for the Operations' Mainland area. Flow is inferred as mainly in the direction of the Mackenzie River, with some localized flow toward Bosworth Creek (Imperial 2014b).

Bear Island and Goose Island groundwater surface elevations align with surface topography with local flow directions inferred to be from higher ground toward the nearest body of water (in most cases the Mackenzie River) (Imperial 2014b). Figure 3-12 shows inferred groundwater flow direction for the Mainland, Bear Island, and Goose Island (Imperial 2014b).

Groundwater monitoring wells have been installed on the Operations' Mainland, Bear Island and Goose Island at various times in the history of the Operations. These have been sampled since the late 1990s and early 2000s to characterize groundwater quality and for the early detection of groundwater changes across the site (Imperial 2014b).

Two groundwater-bearing intervals have been identified at the site as a result of these investigations. The average depth to groundwater is 2 to 4 metres below grade in most areas of both the Mainland and Island(s) facilities. This is a shallow, discontinuous groundwater interval which occurs in the overburden. It is a seasonally unfrozen layer that overlies permafrost and its distribution is highly dependent on the permafrost (Imperial 2014b). A deeper, unconfined, groundwater interval has been identified in the bedrock interval. This interval has more lateral continuity than the shallow interval; however, permafrost plays a significant role in groundwater distribution (Imperial 2003a).

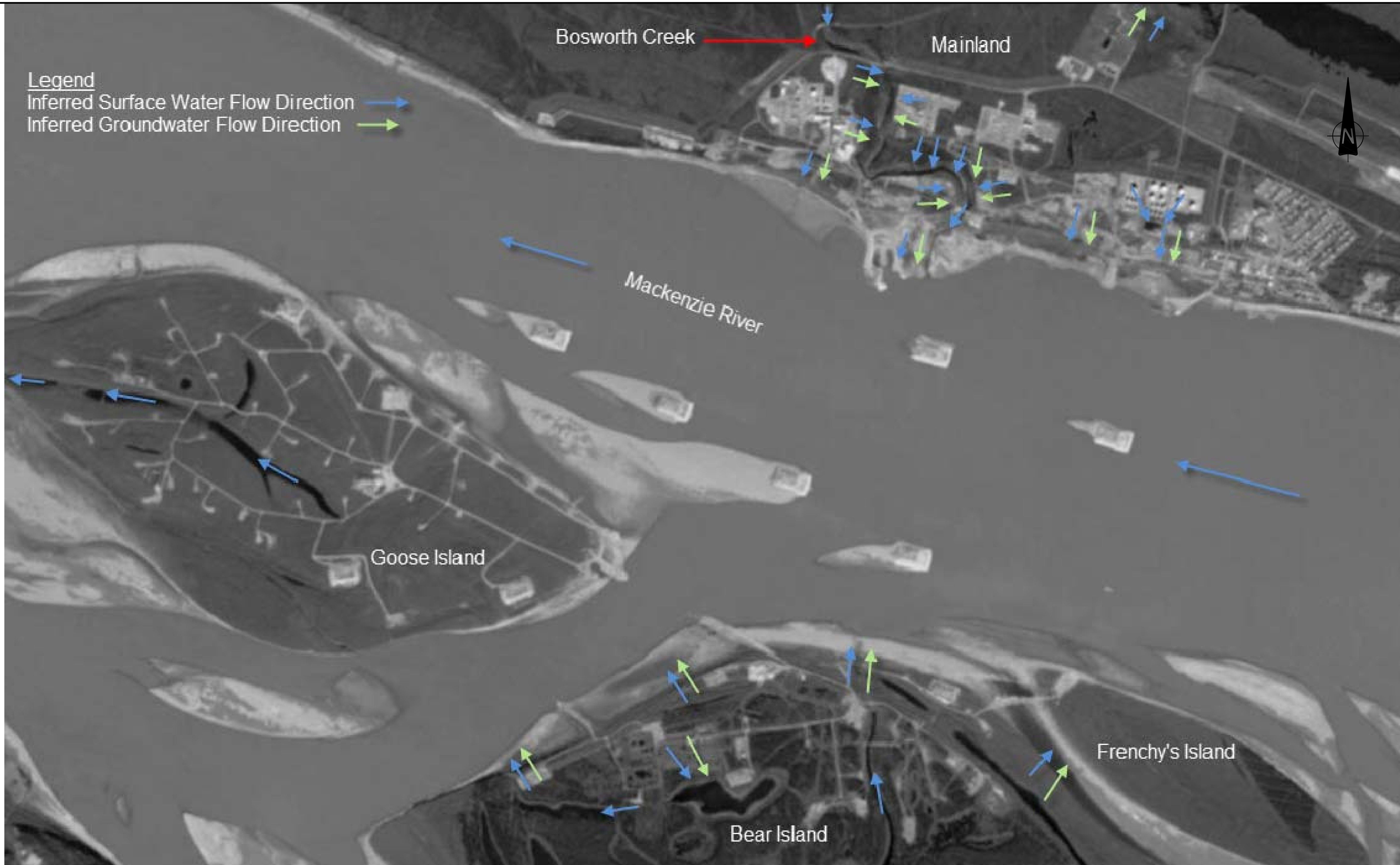
The presence of discontinuous permafrost exerts a strong control on local groundwater flow patterns, both lateral and vertical. Ice lenses in the subsurface act as barriers to groundwater movement based on the comparatively low hydraulic conductivity associated with frozen soil. As a result, complex groundwater flow patterns are expected beneath the area (Imperial 2003a).

3.2.8 Permafrost

Permafrost is defined as ground that remains below 0°C continuously for at least two consecutive years (NRC 1988). The Norman Wells area lies in a zone of discontinuous permafrost (Geological Survey of Canada 1969), where typical maximum permafrost thickness ranges from 50 to 65 m. In the vicinity of the Mackenzie River and around some facilities at Operations, permafrost is absent.

Depth to permafrost at the Operations varies locally and is influenced by temperature, soil conditions and vegetative cover. In some places, extensive unfrozen zones (taliks) within the permafrost have developed, separating the permafrost into lenses (Imperial 2014b). Based on the results of previous environmental investigations, permafrost is interpreted to be discontinuous across the Operations' Refinery and Battery #3 sites (Imperial 2003a).

The discontinuous permafrost has a strong influence on groundwater flow patterns in the Norman Wells area, with frozen soil and ice lenses acting as barriers to groundwater flow and affecting contaminant mobility in certain areas (Imperial 2003a).



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PROJECT NAME
NORMAN WELLS

SHEET TITLE
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INFERRED SURFACE/GROUNDWATER
FLOW DIRECTION

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3.2.9 Geological Hazards and Seismicity

There are significant karst sites in the Sahtu Settlement Area (Ford 2008); these include the Norman Range Sinkholes which exist within 50 km of the Town of Norman Wells. Karst topography forms where rock (limestone) dissolves in water creating features which typically include sinkholes, caves, dry valleys and gorges, turloughs and poljes (Ford 2008). Karst landscapes in the area sometimes contain ‘disappearing’ streams or underground rivers. Norman Wells is situated in a region of low seismicity (NRCAN 2010).

3.3 Chemical Environment

3.3.1 Background or Pre-Development Conditions

3.3.1.1 Natural Hydrocarbon Seeps

A natural seep occurs when oil and/or gas rise to the surface from natural underground sources and through natural pathways and conditions. The seeps can appear on land or in rivers and streams. Most oil and gas seeps are produced by natural geologic processes that take place over millions of years. The presence of naturally occurring hydrocarbon seeps in the SSA, including around the Town of Norman Wells, predates Operations (Imperial 2013b). These oil seepages gave rise to the Dene name of the area, "Le Gohlini," meaning "where the oil is" (SLUPB 2010).

A review of information regarding the history, location and productivity of these seeps in the Norman Wells operations area is presented in the *Renewal Application for Water Licence S03L1-001 - Natural Seeps* that is publically available on the SLWB registry (Imperial 2013b). The review is based on historical records relating to natural seeps, previous attempts to calculate seep productivity, and environmental investigations of several seeps within the Operations area. Excerpts of the Natural Seeps report are provided here as context for subsequent sections on the background (pre-development) chemical environment for the Operations, specifically:

- Concentrations of hydrocarbons, salts and metals in certain stratigraphic soil and bedrock units that have been found to be naturally elevated above generic federal environmental quality guidelines (described in Section 3.3.1.2).
- Efforts to effectively evaluate the origin of groundwater parameters which may exceed regulatory guidelines (described in Section 3.3.1.5).

.1 <u>Historical Identification of Seeps</u>

Alexander Mackenzie reported encountering bituminous substances during his exploration of the Mackenzie River in the late 1700s (Hume and Link 1945). There is also an 1889 record of R.G. McConnell noting bituminous limestone at Bear Rock near the confluence of the Bear and Mackenzie Rivers (GNWT 2013).

The presence of oil saturated dark shale along the banks of the Mackenzie River near Fort Good Hope is also noted in early geological reports. These reports are supported by trading post records tracking trade in tar, with specific mention of a large oil seep (i.e., source) at Rond Lake near Fort Good Hope (GNWT 2013).

Seeps in the present day location of Norman Wells were confirmed in 1911 by Cornwall. The interest in oil exploration in the area during this period prompted a geological expedition to the area lead by T.O. Bosworth who staked several areas around the delta of a creek (Bosworth Creek) for a consortium of investors located in Calgary (Hume and Link 1945).

The 1914 geological report prepared by Bosworth noted that principal seepage of oil occurred along approximately 75 miles (120 km) of the Mackenzie River, between what is now known as Tulita and Bosworth Creek. This section of the River was known as the “Long Reach” (Imperial 2014a). The Fort Creek Shale (now included in the Canol Formation) protrude along the River’s edge for most of this section. Bosworth reported that when digging in the river gravel, the outcrops of green oil sands are exposed and the oil could be collected in considerable amount. Imperial purchased the claims from the Calgary based consortium and began development of the Norman Wells area in 1919 (Imperial 2014a).

Additional mapping of the area in 1919 and 1920 by Link led to the identification of oil and gas seeps at Oil Creek (Bosworth Creek), Seepage Lake, and Joe Creek (Golder 2007). Link also observed that oil could be seen rising to the surface of the Mackenzie River in summer and pooling under ice in the winter. Sulphur rich springs were also identified in the general area. A series of detailed maps and cross sections documenting these findings were prepared by Link and include documentation of seeps in the Norman Wells area (Golder 2007).

Following the mapping expedition of 1919, a second program in 1920 involved drilling a well at the seep locations at Bosworth Creek. This well, referred to as Discovery Well No. 1, was located approximately 100 metres inland from the bank of the Mackenzie River and approximately 10 metres above the river level. Drilling results from Discovery Well No. 1 were issued by Link in a 1920 report (Imperial 2014). The lithological log indicates that oil was first encountered at a depth of 83 feet (25 metres) within the Norman Sandstone (now included in the Imperial Formation). The Hope Shale (now referred to as the Canol Shale) was intercepted at a depth of 225 feet (78 metres) and a major oil strike is recorded to have occurred at 783 feet (239 metres) (Imperial 2014a).

Following the success of Discovery Well No. 1, the field was expanded gradually over the next 10 years. During the 1940s, a major expansion of the Norman Wells field coincided with the construction of the CANOL pipeline (Imperial 2014). More extensive mapping during this time mapped oil seeps at Bluefish Creek and Bear Rock (Link 1943; Stelek et al. 1944). Other oil and gas seeps in the Mackenzie River Valley were noted during subsequent exploration in the 1970s.

.2 Location of Historically Identified Seeps

The locations of natural seeps in the broader lower Mackenzie Valley area, SSA, and Norman Wells are documented in the *Renewal Application for Water Licence S03L1-001 - Natural Seeps* (Imperial 2013b). Specific to the Operations area, natural oil and gas seepage continues to occur along the Mackenzie River shoreline and below the riverbed in several locations within the Proven Area. Surficial on-shore seeps are most apparent at the following locations (Imperial 2014a):

- along the Mackenzie River shoreline upstream and downstream of the former Operations Refinery area;
- the Bosworth Creek and Bosworth Creek Delta area;
- along the Mackenzie River shoreline below the F-28X well;
- at Joe Creek located approximately 7 km upstream of Norman Wells; and
- at Seepage Lake located north of Operations and within the Proven Area

Since 1998, Imperial has commissioned a number of field and laboratory investigations of the oil and gas seepage zones around the mainland portion of the Operations (Komex 1999, 2001, 2002, 2003; Worley Parsons 2008). Figure 3-13 illustrates recently identified natural seeps around the mainland portion of the Operations, as well as historically recorded natural seeps, primarily in the above areas (Imperial 2014a).

Figure 3-13: Historical and Recently Identified Natural Seeps in the Vicinity of Operations' Mainland

The presence of these natural seeps may lead to a natural source of hydrocarbons in soils, bedrock and groundwater at the Operations. Soil and bedrock analytical results from several Phase 2 Environmental Site Assessments within the Operations area have indicated that there are concentrations of hydrocarbons, salts and metals in certain stratigraphic units that are naturally elevated (Imperial 2013). Groundwater monitoring records maintained by Imperial show that natural occurring hydrocarbons and/or naturally occurring saline groundwater tend to dominate the deeper monitoring locations (i.e., monitoring wells greater than 15 m in depth) (Imperial 2014).

3.3.1.2 Soils

The assessment of background environmental conditions at the Operations has been an important part of characterization activities since 1997 (Imperial 2013). As it was not the practice to collect baseline data in the early 1920s when the Operations started, efforts have been made to establish appropriate background sample locations for soils and groundwater (Imperial 2013).

Soil and bedrock analytical results from several Phase 2 Environmental Site Assessments within the Norman Wells operations area have indicated that there are concentrations of hydrocarbons, salts and metals in certain stratigraphic units that are naturally elevated above generic federal environmental quality guidelines (Imperial 2013). Understanding background (or pre-development) soil quality is required to determine appropriate site remediation criteria for the Operations.

Shale material from the Town of Norman Wells quarry has been crushed to varying degrees and used as fill material across the Operations, to allow construction on the unstable muskeg areas. Further, the underlying siltstone bedrock is at or very close to the surface along the lower terrace of the Mackenzie River on the Mainland portion of the Operations (Imperial 2013). Given the potential for the shale and siltstone to be influencing soil chemistry at the Operations, bedrock chemical conditions have also been investigated (Imperial 2013).

The majority of the background soils/bedrock data for the Operations were collected in 1998, 2003, 2010 and 2012 (Imperial 2013). Data were collected for a range of environmental projects and it is possible that a location suitable for background purposes for a surface soils investigation may not necessarily provide suitable background surface soils data due to disturbance of surface soil, or due to presence of shale fill material (Imperial 2013). Only data from those background locations considered to have minimal or no potential industrial impact have been included in background soils/bedrock data for the Operations.

The available data for background Operations soil and bedrock chemistry collected between 1998 and 2012 have been compiled and assessed to confirm maximum reported values, as well as 95th percentile values where sufficient data existed within a specific stratigraphic unit. The data (summarized in Appendix H) have been screened against generic contaminated sites guidelines for fine-grained soils that were selected to be a conservative screening tool for the likely post-closure use of the Operations area (Imperial 2013). For the purposes of Operations' environmental assessment programs, soil and bedrock data in Appendix H have been compiled by geographic area (Mainland versus Islands) and by the following general stratigraphic units (Imperial 2013):

- surface organic soil;
- surface mineral soil;
- subsurface mineral soil; and
- bedrock.

Some general trends are apparent from the review of the available background soils/bedrock data (Imperial 2013):

- Concentrations of one or more metals/trace elements (As, Mo, Ni, Se, Tl and Zn) exceeding CCME guidelines have been confirmed in background organic surface soil, mineral subsurface soil, and underlying siltstone bedrock on the Mainland.
- Concentrations of As, Mo, Se and Tl exceeding CCME guidelines have also been confirmed in shale bedrock samples collected from the Town of Norman Wells quarry. This shale material is used as fill throughout the Norman Wells Operations site and the adjacent Town.
- Above guideline SAR values have been measured/calculated for a limited number of mineral subsurface soil samples on the Mainland, as well as the siltstone bedrock.
- In the Island soils, background metals concentrations in surface mineral soil are typically below CCME Parkland use guidelines. However, several metals (As, Mo, Se, Tl) may be present at concentrations above guidelines in the subsurface soil.
- EC levels above CCME Parkland guidelines (2 dS/m) may be present in both organic and mineral soil on both the Islands and the Mainland. The few locations with EC values above CCME Parkland guidelines are not associated with chloride, a typical indicator of industrial impact. Based on the available data set, it is considered likely that the above listed parameters and concentrations are naturally occurring.
- One or more BTEX and PHC F1 through F4 parameter concentrations above detection limits but generally below CCME guidelines have been reported in all strata and may be associated with organic matter and/or hydrocarbon seeps at the bedrock / soil interface, particularly in the vicinity of the Mackenzie River.
- Background data sets for the organic and mineral surface soil on the Islands, as well as the underlying bedrock are very limited and should be interpreted/referenced with caution.

3.3.1.3 Sediment

Studies have shown that naturally occurring levels of heavy metals are generally associated with the sediments along the Mackenzie River Valley (Reid et. at 1974). These studies also noted that hydrocarbons present in the water column or sediments of the Mackenzie River (which was only sampled upstream of Norman Wells) were present at concentrations below 1 ppm (Reid et. at 1974).

Mackenzie River sediments have been sampled as part of Imperial's Aquatic Effects Monitoring Program (AEMP) to assess the effects of the Operations on the river. Sediments were collected over a two year period (2003/2004) from sites located upstream of the Town of Norman Wells, downstream of a naturally occurring hydrocarbon seep, and downstream of the Operations. Samples were analyzed for Polycyclic Aromatic Hydrocarbons (PAHs). Small concentrations of PAHs (below levels harmful to fish and other aquatic life) were present in all of the sediment samples collected from the Mackenzie River.

Concentrations of PAHs downstream of the Operations were the same as that measured upstream; which suggests that the Operations are not adding more PAHs to the river sediments than what is naturally occurring. Sediment samples taken in proximity to the natural hydrocarbon seep did show small increases in PAHs as compared to upstream samples; which indicates these natural seeps are a source of PAHs entering the river and suggests that contamination of sediments, where it might be observed, is linked to naturally occurring seepage.

3.3.1.4 Surface Water

Mackenzie River water may be classified as nutrient-rich due to relatively high levels of total organic carbon, total nitrogen, total phosphorous and iron (Rescan 1998). High naturally occurring levels of heavy metals are generally associated with the sediments along the Mackenzie River Valley (Reid et. at 1974). As stated above, these studies also noted that any hydrocarbons present in the water column of the Mackenzie River (which was only sampled upstream of Norman Wells) were present at concentrations below 1 ppm (Reid et. at 1974).

Several in-depth water quality studies focused on hydrocarbons in the Mackenzie River at Norman Wells were conducted in the 1980s and 1990s (EVS 1985, 1986; Nagy et al. 1987; Hrudey and Associates 1988; Indian and Northern Affairs Canada 1997; Environment Canada 1998). In general, levels of anthropogenic contaminants and petroleum hydrocarbons downstream of Norman Wells have been found to be similar to levels observed upstream in the Mackenzie River or in other northern rivers. In summary, the main findings have been previously summarized as follows (Imperial 2003):

- Analysis of water samples collected upstream and downstream of the Operations refinery showed very low concentrations of alkanes and polynuclear aromatic hydrocarbons (PAHs), despite the presence of natural hydrocarbon seepage at Norman Wells.
- Slightly higher concentrations of polychlorinated biphenyls (PCBs) were found in both the east and west portions of the Mackenzie River compared to other northern rivers studied.
- Concentrations of hexachlorocyclohcxane (HCH) were lower in the Mackenzie River than in other rivers flowing to either the Arctic Ocean or Hudson's Bay.
- Dinitrodimethyl toluene (DDT) concentrations were roughly similar among rivers flowing to the Arctic Ocean, but they were higher than those in rivers draining into Hudson's Bay.

- Concentrations of chlorobornancs (CI-Ms) were too close to the limit of detection to be interpreted.

A more recent quality study took place from just prior to the decommissioning and dismantling of the Operations' Refinery (Imperial 2003). Environment Canada (1998) analyzed six samples from the Mackenzie River at Norman Wells for 16 PAHs over the study period (June 1995 to June 1996). The majority of the PAHs were at or near the limit of detection (i.e., 10 to 30 ng/L) in all samples. The only exception was one sample (from of a total of 96) with detectable concentrations of 2-methylnaphthalene (2-MTNPH) (20 ng/L) and l-methylnaphthalcne (1-MTNPH) (13 ng/L). These results were consistent with those obtained in the previous studies highlighted above, which found low levels of PAHs in all segments of the Mackenzie River examined.

.1 Bosworth Creek

Water quality information for Bosworth Creek appears to be limited prior to dismantling of the weir (Collins et al. 2011). A water quality data report, produced in 2011 through an initiative funded and administered by Natural Resources Canada summarizes the existing water quality data that has been gathered on Bosworth Creek intermittently from 1953 to 2009, as well as the results of surface water quality sampling programs conducted as part of the overall study (Collins et al. 2011). The report indicates that through most of the Bosworth Creek watershed, the measured parameters for water quality fall within the acceptable standards for CCME Guidelines for the Protection of Aquatic Life. The report also notes the following regarding Bosworth Creek water quality:

- Documented naturally occurring oil seeps are prevalent near the mouth of Bosworth Creek (Esso Resources Canada Ltd. 1980). However, existing water quality data reviewed as part of the study do not show exceedances for hydrocarbon parameters and the report suggests that hydrocarbon impacts are not presently of concern for Bosworth Creek (Collins et al. 2011).
- While the pH of Bosworth Creek is heavily influenced by surrounding geology, pH for the creek is considered normal for freshwater ecosystems; where the average pH is usually in the range of 6-8 (Collins et al. 2011).
- Several of the samples in the existing database show exceedances in metals at a few locations below the confluence of Bosworth Creek and the unnamed major tributary entering from Discovery Ridge. It is suggested that groundwater inputs below this confluence account for the higher values in these metals as compared to upstream values. Results from the sampling program itself did not allow for any conclusions about the overall impact of metals impact on water quality in the Creek ecosystem (Collins et al. 2011).
- Water velocities measured during the study varied from 0.55 to 0.88 m/s, pH averaged 8.3, and dissolved oxygen averaged 6.2 mg/L (Collins et al. 2011).

3.3.1.5 Groundwater

As stated in Section 3.3.1.2, the assessment of background environmental conditions at the Operations has been an important part of characterization activities since 1997 (Imperial 2013). As it was not the practice to collect baseline data in the early 1920s when the operation started, efforts have been made to establish appropriate background sample locations for soils and groundwater. It is important to defensibly determine naturally occurring background concentrations for parameters of interest, in order to effectively evaluate the origin of groundwater parameters which may exceed regulatory guidelines (Imperial 2013). This evaluation is also required to determine appropriate remediation criteria, as background may be selected as suitable criteria, particularly where it is greater than regulatory guidelines.

Background monitoring wells would ideally be installed in an undisturbed, up-gradient area, isolated from any potential sources of anthropogenic impact. However, these locations tend to be heavily influenced by permafrost in the vicinity of Norman Wells. Previous attempts to install background wells in up-gradient areas of the lease, removed from the Operations facilities and in areas of natural vegetation, have resulted in rapidly frozen groundwater monitoring wells that consistently remain frozen (Imperial 2014a). As such, the use of the term “background” in this section does not necessarily mean the groundwater monitoring well is installed in an undisturbed, up-gradient area (i.e., upstream). Rather, the term is used for locations inferred to be removed from site facilities and free of facility related impacts (Imperial 2013).

In order to improve characterization of background soil and groundwater conditions, Phase II Environmental Site Assessment (ESA) programs in 2010 and 2012 focused on installation of new potential background wells in surficial sediments (Imperial 2014a). This included six new wells on the Natural Islands and five wells distributed throughout the Mainland East, Central and West areas in recent years (Imperial 2013). As a result of the wells installed during the 2010 and 2012 ESA programs, supplemented by annual groundwater sampling from 1997 to 2012, a sufficient database has been compiled to determine a statistical background for key parameters in a range of hydrogeological units (Imperial 2014a). As summarized in Appendix I, 24 wells within the monitoring network have been identified as background locations. These wells are separated into four groups, based on the hydrogeological zone where the well screen is completed:

- surficial sediments on Mainland;
- surficial sediments of Natural Islands;
- shallow bedrock on Mainland; and
- deeper bedrock on Mainland.

Statistical background analyses concentrated on the first three of these hydrogeological zones as the primary interest. The deep bedrock category was not characterized to the same extent as water quality in the deep bedrock as it is less important for comparison in groundwater and environmental monitoring programs. A geometric mean, minimum, maximum and 95th percentile value was determined for each of the three hydrogeological units of interest for the parameters listed in Table 3-7. Results of the statistical analyses are provided in tables attached to Appendix I.

Table 3-7: Indicator Parameters and Dissolved Metals/Trace Elements

Indicator Parameters		Dissolved Metals and Trace Elements		
pH	Sulphate	Aluminium	Cadmium	Nickel
Chloride	TDS	Antimony	Chromium	Selenium
DOC	Nitrite as N	Arsenic	Copper	Thallium
Fluoride	Nitrate as N	Barium	Lead	Titanium
Hardness	Phenols	Beryllium	Mercury	Uranium
Iron		Boron	Molybdenum	Zinc

Of note, the 95th percentile analysis indicates that the following parameters may naturally exceed applied CCME criteria in groundwater at the Operations (Imperial 2013):

- Groundwater from surficial sediments on Mainland sites – iron, phenols, cadmium, copper, selenium, uranium and zinc. Chloride and petroleum hydrocarbons can also occur above the applied guideline in natural seepage zones.
- Groundwater for surficial sediments on Natural Islands sites - iron, phenols, cadmium, copper, selenium, uranium and zinc.
- Groundwater from shallow bedrock – chloride, iron, phenols, aluminum, arsenic, copper and selenium. As noted previously, petroleum hydrocarbons would also be expected within areas of natural seepage in the upper bedrock.

3.3.2 Overview of Contaminant Impacts

3.3.2.1 Soil

Imperial Oil has conducted environmental investigations that address soil contamination resulting from historic operations at the Operations for over 15 years. Characterization data for areas of the Operations exhibiting soil conditions exceeding criteria were provided by Imperial Oil via data developed by WorleyParsons (WorleyParsons 2014a). The methodology utilized to characterize areas of potential environment concern (APECs) and estimate volumes of soil which exceed current regulatory guidelines are described below.

The APECs were characterized in terms of the following (WorleyParsons 2014b):

- geographic area;
- closest infrastructure / reference point;
- environmental concerns;
- depth of impact;
- information source;
- associated contaminant; and
- status (e.g., potential or proven).

Geographic areas were classified as Mainland (East, Central or West), Goose Island, Bear and Frenchy's Islands or Artificial Islands. APECs were associated with sites such as well sites, terminals, batteries, tank farms or the Central Processing Facility (CPF). Environmental concerns were described according to the substance spilled (e.g., hydrocarbons, salt water, metals). The depth of impact was described as occurring in the upper 2 metres or in subsurface soils. Information sources included documentation such as environmental assessment reports, interviews, observations, air photographs and/or spill reports.

Soil contaminants were classified as follows:

- hydrocarbons;
- hydrocarbons + salts;
- hydrocarbons + salts + metals;
- salts; and
- metals.

Other potential categories (e.g., hydrocarbons and metals) were not described because they did not capture significant, distinct soil volumes.

WorleyParsons described each APEC as proven or potential using the following definitions:

- a "proven" impact resulted when sufficient Phase II Environmental Site Assessment (ESA) data indicated an impact exceeding the applicable guideline was present; and
- a "potential" impact resulted when contamination was inferred through Phase I ESA activities, but a reasonable quantity of Phase II ESA data were not available to confirm the type of impact or provide an estimate of its magnitude or extent.

APECs were updated in 2014 (Imperial 2014d). At the time, a total of 97 APECs had been identified. The status of each APEC had been established through review of environmental assessment programs that were completed by the end of 2013. Approximately 63 percent of the APECs at the Operations were classified as proven impacts while 18 percent were classified as potential impacts that have not been proven. Nineteen of the APECs (20 percent) were investigated and found to be free of impacts or had been remediated (Imperial 2014d).

.1 <u>Soil Assessment Criteria</u>

WorleyParsons assessed soil impacts within each APEC against the following guidelines:

- Canadian Environmental Quality Guidelines (CCME 2007) and updates; and
- Canada-Wide Standard for Petroleum Hydrocarbons (PHC) in Soil (CCME 2008).

The applicable guidelines were assumed to be industrial land use, fine-grained surface soil for the mainland areas, and residential/parkland land use, fine-grained surface soil for the natural and artificial islands.

.2 Estimated Soil Volumes

Background Conditions

WorleyParsons considered several unique characteristics of the Norman Wells oilfield when quantifying soil impacts at the site:

- shallow depth to bedrock, limiting the practical excavation/remediation depths;
- naturally occurring hydrocarbon seeps and hydrocarbons in the shallow subsurface;
- naturally occurring elevated sodium and select trace elements in the near surface bedrock underlying the Mainland area;
- several naturally occurring metals in soil which are above guidelines; and
- the presence of intermittent permafrost and ice lenses.

Depth to bedrock is generally 5 to 10 m on the Mainland and the general dip of the bedrock is 4 to 5 degrees to the southwest. Glacial and post-glacial sediments in the Mackenzie River valley are underlain by the Imperial and Canol formations. The Imperial formation comprises interbedded sandstones, siltstones and shales. The original oil discovery in 1920 was in the highly bituminous Canol formation marine shales. The oil-saturated Knee Scarp formation underlies these shales.

Folding and fracturing of the bedrock above the Knee Scarp formation has resulted in naturally occurring oil and gas seepage at several locations within the Proven Area. The naturally occurring hydrocarbons are present in groundwater that is in hydraulic continuity with hydrocarbon seeps that are present along the Mackenzie River (WorleyParsons 2008).

Elevated sodium adsorption ratios (SAR) have been reported for shallow bedrock at several Mainland Operations' locations. The elevated SAR values were interpreted to be characteristic of the native bedrock material (WorleyParsons 2008).

Trace metal concentrations exceeding CCME industrial and Parkland criteria occur in shallow fill materials used across the Operations (WorleyParsons 2008). These trace metals include arsenic, molybdenum, nickel, selenium and zinc which are naturally present in shale fill, subsoil, peat and/or organic soil. The naturally occurring concentrations of these metals established from quarry shale, borrow area and peat stockpile samples are similar to the following:

- Arsenic to 43 mg/kg;
- Molybdenum to 55 mg/kg;
- Nickel to 239 mg/kg;
- Selenium to 82 mg/kg; and
- Zinc to 435 mg/kg.

Details regarding geochemical background for soil are provided in Imperial 2014d. A summary of the available background soil data is provided in Section 3.3.1.2.

Estimating Assumptions

The impacted soil volume for each APEC was estimated with consideration of the following parameters (WorleyParsons 2014d):

- likely source of impact;
- mobility of the chemicals in question;
- distance from likely source;
- concentration of the contaminants;
- experience with similar issues at similar sites; and
- density of Phase I and Phase II ESA data points to represent the area/zone of impact.

The extent of impact was estimated using analytical data, borehole logs, spill data and/or terrain conductivity/resistivity mapping. The depth of impact was determined from the minimum value of the following (WorleyParsons 2014d):

- depth to groundwater, permafrost, and/or bedrock;
- depth of practical excavation;
- depth of likely contaminant penetration; and/or
- depth of guideline exceedances shown in other data (e.g., Phase II ESA data).

Where environmental assessment or spill history documentation was not available, WorleyParsons assumed the following:

- 50 m^3 of soil impact for every 1 m^3 fluid released on each spill site;
- 100 m^3 of soil impacted at all operating well sites located on the Mainland;
- 50 m^3 of soil impacted at all operating well sites on the islands; and
- 250 m^3 of impacted soil on each Artificial Island.

Results

Table 3-8 summarizes the (WorleyParsons 2014b) APEC soil quantity results for each geographic area.

Table 3-8: Estimated Impacted Soil Volumes

Geographic Area of Potential Environmental Concern		Estimated Impacted Soil Volume (m^3)		
		Upper 2 m Soils	Subsurface Soils	Total
Mainland	Roads	3,780	-	**3,780**
	Well Sites	14,426	-	**14,426**
	West	45,462	14,500	**59,962**
	Central	75,448	21,450	**96,898**
	East	186,500	44,935	**231,435**
	Sumps	29,775	46,750	**76,525**
Artificial Islands	Artificial Islands	7,583	-	**7,583**
Goose Island	Goose Island	9,209	1,250	**10,459**
Bear and Frenchy's Islands	Sumps	31,375	99,400	**130,775**
	Bear and Frenchy's Islands	32,000	5,575	**37,575**
	Total	**435,558**	**233,860**	**669,418**

The environmental concerns were categorized according to the type of impact present (WorleyParsons 2014b). Table 3-9 shows that light end (F1 (C6 to C10 and F2 (C10 to C16)) hydrocarbons account for approximately 47 percent of the impacted volume. Heavier hydrocarbons (F3 (C16 to C34) and F4 (C34 to C50)) account for 11 percent of the soils and mixed impacts occur in 42 percent of the soils. Approximately 65 percent of the impacted soil volume is located in the upper 2 m while 35% is present in the subsurface or below 2 m in depth.

Table 3-9: Estimated Impacted Soil Volumes by Impact Type

Area	Soil Depth	Light Hydrocarbons	Heavy Hydrocarbons	Mixed Hydrocarbons, Metals and/or Salts	Total
Artificial Islands	Upper 2 m	1,987	2,030	3,566	**7,583**
	Subsurface	-	-	-	**-**
Bear and Frenchy's Islands	Upper 2 m	17,300	2,475	12,225	**32,000**
	Subsurface	5,575	-	-	**5,575**
Bear Island Sumps	Upper 2 m	-	-	31,375	**31,375**
	Subsurface	-	-	99,400	**99,400**
Mainland Roads	Upper 2 m	-	3,780	-	**3,780**
	Subsurface	-	-	-	**-**
Goose Island	Upper 2 m	4,712	1,338	3,159	**9,209**
	Subsurface	1,250	-	-	**1,250**
Mainland Central	Upper 2 m	51,967	15,375	8,106	**75,448**
	Subsurface	9,400	4,550	7,500	**21,450**
Mainland East	Upper 2 m	169,939	14,086	2,475	**186,500**
	Subsurface	35,060	6,750	3,125	**44,935**
Mainland Sumps	Upper 2 m	-	-	29,775	**29,775**
	Subsurface	-	-	46,750	**46,750**
Mainland Wells	Upper 2 m	1,912	1,550	10,964	**14,426**
	Subsurface	-	-	-	**-**
Mainland West	Upper 2 m	13,663	18,304	13,495	**45,462**
	Subsurface	-	6,100	8,400	**14,500**
Totals	**Upper 2 m**	**261,480**	**58,938**	**115,140**	**435,558**
	Subsurface	**51,285**	**17,400**	**165,175**	**233,860**
	Grand Total	**312,765**	**76,338**	**280,315**	**669,418**

Table 3-9 shows that the 72 percent of impacted soil is located on the Mainland while 27 percent of the impacted soil volumes occur on the Natural Islands. A total of 7,583 m^3 or 1% of the total impacted soil is located on the Artificial Islands.

3.3.2.2 Surface Waters

Imperial maintains a Surveillance Network Program (SNP) as part of its Operations (Imperial 2013c). The SNP is operated under the terms and conditions of the Water Licence (S03L1-001 as amended). As part of the SNP, Imperial undertakes surface water management activities which include the collection of representative samples for field testing and/or laboratory analysis (Imperial 2013c).

A review of field results from all surface water releases at the Operations indicates no recorded values above the guideline limits set out in the Water Licence. Review of laboratory results for all surface water releases at the Operations indicates that oil, grease and pH values did not exceed guideline limits as set out in the Water Licence (Imperial 2013c).

Between 2004 and 2006, phenol concentrations were observed to exceed the limit set out in the original 2004 Water Licence. Naturally occurring concentrations of phenols were not considered in the original guideline limits and an amendment to the Water Licence in 2006 included an adjustment to the limit to account for naturally occurring phenols. All phenol results since that time have been recorded as below the guideline limit (Imperial 2013c).

3.3.2.3 Groundwater

.1 Monitoring Program

The purpose of the groundwater monitoring program is to characterize groundwater and to detect any changes in water quality (Imperial 2014a) resulting from historic operations. Table 3-10 shows the distribution of groundwater monitoring wells located within the Operations current to May 2015 (Imperial 2015).

Table 3-10: Summary of Monitoring Wells

Monitoring Area	Actively Monitored Wells		
	Overburden	Bedrock	Total
Mainland East - Former Refinery	24	28	**52**
Mainland East (excluding Refinery)	112	1	**113**
Mainland Central	48	8	**56**
Mainland West	24	6	**30**
Mainland Sumps	18	14	**32**
Bear Island	53	0	**53**
Goose Island	16	0	**16**
Total	**295**	**57**	**352**

The monitoring wells in Table 3-10 constitute part of the monitoring program for areas where abandonment and restoration activities have occurred, are occurring or are anticipated to occur (Imperial 2014d). The monitoring network covers two groundwater bearing zones that have been identified in the Operations; a shallow discontinuous interval and a deeper unconfined interval (Imperial 2014). The depth to groundwater in the shallow zone is typically 2 to 4 metres in most areas of the Operations. This shallow groundwater zone is a seasonally unfrozen layer overlying permafrost (Imperial 2014).

.2 Groundwater Assessment Criteria

Water quality is compared to the Canadian Council of Ministers of the Environment (CCME) Canadian Environmental Quality Guidelines (CEQG) for the Protection of Freshwater Aquatic Life (FWAL) (note that CCME's groundwater drinking guidelines are generally less conservative than the FWAL criteria and in any case, would not be applicable over most of the Proven Area post closure - CONFIRM). Exceedances of the FWAL values do not necessarily indicate a facility-related source and may reflect natural conditions (Imperial 2014d). The parameters that may naturally exceed the FWAL criteria include (Imperial 2014d):

- groundwater from surficial sediments on Mainland sites – iron, phenols, cadmium, copper, selenium, uranium and zinc. Chloride and petroleum hydrocarbons can also occur above the FWAL guideline in natural hydrocarbon seepage zones;
- groundwater from surficial sediments on the Natural Islands – iron, phenols, cadmium, copper, selenium, uranium and zinc; and
- groundwater from shallow bedrock – chloride, iron, phenols, aluminum, arsenic, copper, and selenium. Petroleum hydrocarbons would also be expected within areas of natural hydrocarbon seepage in the upper bedrock.

Details regarding background geochemical statistics for groundwater are provided in Imperial 2015b.

.3 Groundwater Quality

Groundwater monitoring wells have been installed at various locations within the Norman Wells Operations and have been sampled and tested for over 15 years. Groundwater monitoring results were most recently reported to the SLWB by Imperial Oil in their 2014 Annual Closure and Reclamation Progress Report (Imperial 2015). These 2014 results, reported for each Geographic Area and associated Site, are summarized in Table 3-11 and provide a representation of the current understanding of groundwater qualities across the Proven Area. As noted in Section 3.3.1.5, some parameters, including metals, salts and petroleum hydrocarbons, may naturally exceed the applied CCME criteria at the Operations. Where known, exceedances that may be partly attributed to natural conditions (i.e., hydrocarbon and/or saline water seepage) are identified.

Table 3-11: Groundwater Quality Overview

Geographic Area	Site	Notes / Parameters Exceeding the FWAL Guideline
Mainland East	Former Refinery	Refined and light-end free product. Naturally-occurring crude oil and saline water seepage are present. Containment and remediation systems were initiated in 2003. Approximately 43,000 kg of hydrocarbon have been recovered by the pumping system and 56 m^3 have been removed by the extraction system.
	B-38X Well Site	Free-phase hydrocarbons, metals, phenols, chloride. Naturally-occurring crude oil and saline water seepage are present. A groundwater treatment system was installed in 2004. Approximately 58,500 kg of hydrocarbon have been recovered.
Mainland Central	Former Battery # 3	Free-phase hydrocarbons, metals, chloride, nitrate, phenols and trace elements.
	Bosworth Creek and Delta Areas	Chloride and iron. Natural seeps are known to occur in this area.
	B-30X Well Site	Metals and trace elements, benzene, toluene and phenols.
	Tank 401 Area	On-site soil treatment was completed from 2010 to 2013. Potential naturally-occurring free-phase hydrocarbons are present in one monitoring well.
	Operation Biocell and A&R Biocell Areas	Metals, toluene, nitrate and phenols. Petroleum hydrocarbon impacts including benzene, ethylbenzene, xylenes and PHC F1 pre-date construction of the biocells.
Mainland West	E-27X Well Site	Chloride.
	F-28X Well Site	Free-phase hydrocarbons.
Mainland Sumps	Mainland Sump	Chloride and metals.
	Well Services Sump	Chloride, phenols, metals and trace elements.
	Sumps 1 through 6	Chloride, metals, trace elements and phenols.
	Cemetery Sump	All sampled parameters remain below the applicable FWAL guidelines.
	C-27X Sump	Chloride, phenols, metals. Naturally-occurring free-phase hydrocarbons were present in one well.
Bear Island	Sumps 1 to 5	Chloride, metals, toluene, ethylbenzene, benzene, pH and phenols.
	Sump 6	Chloride, metals and phenols.
	Bear Island West	Metals, trace elements and phenols.
	Bear Island East	Monitoring wells were found to be destroyed in 2014, Sampling could not be conducted.

3.4 Biological Environment

3.4.1 Regional Ecosystem Overview

The NWT has an ecological landscape classification system, based on the 1996 Ecological Framework for Canada, which recognizes four regions (ENR 2009):

- Taiga Plains;
- Taiga Shield;
- Taiga/Boreal Cordillera; and
- Southern Arctic.

All four of these Ecoregions are present in the Sahtu Settlement Area; however, two Ecoregions predominate:

- Taiga Plains, which runs north-south and is principally located east of the Mackenzie River; and
- Taiga/Boreal Cordillera, which extends west of the Mackenzie River to the Yukon border

Norman Wells falls within the level II Taiga Plains Ecoregion which is an area of low lying plains centred along the Mackenzie River. Topography is characterized by subdued relief with a few significant hill systems (ENR 2009).

The hierarchical ecological classification system also allows for increasingly small ecoregions to be described (ENR 2009). Level III ecoregions are identified primarily by differences in regional climate that can be observed in vegetation and soils unique to each ecoregion (ENR 2009). Norman Wells is within the level III Taiga Plains Low Subarctic (LS) Ecoregion, which contains 14 smaller ecoregions that cover the central 160,000 km^2 of the Taiga Plains. The Ecoregion encompasses the central third of the Taiga Plains (ENR 2009).

3.4.2 Vegetation

The level II Taiga Plains Ecoregion is heavily dominated by forest, with notable shrublands in the Mackenzie River Delta and south of Great Slave Lake. Fire scars appear on the land cover and are concentrated near the shrubland areas in the Mackenzie Delta, and south and west of Great Slave Lake. A minimal amount of low vegetation and barren ground is found in the west-central part of the Ecoregion (Biodivcanada 2015a).

The level III Taiga Plains Low Subarctic (LS) Ecoregion contains level to undulating till plains. Recent fires have affected many area of this Ecoregion. Upland areas typically contain white or black spruce stands and/or regenerating shrub and young regenerating forest communities. Peatlands with discontinuous permafrost features are typical of lower, wet areas (ENR 2009).

Within the Taiga Plains Low Subarctic Ecoregion Norman Wells is located in the level IV North Mackenzie Plain Low Subarctic Ecoregion. The ecoregion occupies a narrow, gently sloped valley 15 to 30 km between the Norman Range Low Subarctic and the eastern boundary of the level II Taiga Cordillera Ecoregion and parallels the Mackenzie River for over 300 km (ENR 2009). The ecoregion is transitional between the level II Taiga Plains and the Taiga Cordillera Ecoregion and includes three main landform types:

- fluvial or glacio-fluvial terraces;
- lacustrine plains; and
- undulating to hummocky morainal shallow to deep terrain

Native vegetation within the Mackenzie Plain Low Subarctic Ecoregion consists predominantly of closed stands of black spruce (*Picea mariana*) and jack pine (*Pinus banksiana*) with an understory of mosses, bog cranberry (*Vaccinium vitis-idaea*), blueberry (*Vaccinium caespitosa*), Labrador tea (*Leturn groendlandicum*), and lichens. White spruce (*Picea glance*), balsam fir (*Abies balsamifera*), and trembling aspen (*Populus tremuloides*) occur in the warm, moist sites in the southern section of the region. Drier sites have relatively open stands of black spruce and jack pine (Imperial 2008).

Fires have influenced the vegetation communities in the Mackenzie Plain Low Subarctic Ecoregion. The moraine areas, which have had recent fires are now dominated by bog birch (*Betula glandulosa*), green alder (*Alnus viridis*) - white spruce (*Picea glauca)* and Alaska paper birch communities (ENR 2009).

Wetlands cover 25-50% of the Ecoregion, and are characteristically peat plateau bogs, and ribbed and horizontal fens (Ecoregions Working Group 1989). Low, closed and open stands of black spruce, ericaceous shrubs, and sphagnum (*Sphagnum spp*.) mosses dominate poorly drained, peat-filled depressions.

Vegetation characteristics of the Operations' Natural Islands are described as:

- Bear Island - dominated by willows (*Sala spp.*). Part of the island may be covered by river ice during spring break-up which keeps the willow flats in an early successional stage (Imperial 2008). Upland areas have small stands of large, mature spruce. Bear Island has an extensive history of resource exploration and extraction. There is an existing intensive exploration footprint in the form of seismic lines across both Bear and Frenchy's Island. The northern portion of Bear Island is well developed with numerous existing well pads, access roads, borrows and sumps (Imperial 2008).
- Goose Island - located downstream of Bear Island and is frequently scoured by ice. Vegetation on Goose Island is therefore dominated by willows and alder (*Alnus sp.*). Numerous roads, well pads and gathering terminals are present on Goose Island (Imperial 2008).

3.4.2.1 Endangered or Threatened Plant Species

Previous searches of the *Species at Risk Act* Public Registry have been conducted for plants that are listed as Endangered, Threatened or Special Concern and occur in the Northwest Territories (Imperial 2008). These searches indicated that species classified as Endangered, Threatened, or Special Concern under the *Species at Risk Act* are not currently recorded in the NWT (Imperial 2008). However, the NWT ENR Wildlife Division lists hairy rockcress (*Braya pilosa*), Nahanni aster (*Symphyoirichum nahanniense*), Raup's willow (*Sally raupii*), and Drummond bluebell (*ilertensia drurnmondii*) as rare species that occur in the Northwest Territories. None of these identified rare species are identified as occurring in the local Norman Wells area.

3.4.3 Terrestrial Wildlife and Avifauna

Large mammals, raptors, and waterfowl are abundant in the Norman Wells area (Rescan 1998). Large mammals in the Norman Wells area include bear, caribou, moose, wolverine, lynx, and fox. Furbearing animals include beaver, marten, muskrat, and mink. Moose represent a species important for food, economy, and the culture of the area. Marten is the economically most important furbearing animal in the Northwest Territories (Rescan 1998 and references therein).

Moose in the area are of particular significance because they are a major source of food (Bayha and Snortland 2002, 2003, 2004). Moose occur on the Mainland and on natural islands on the Mackenzie River. The poplar stands on the islands provide thermal and visual cover and the riparian vegetation (*willow spp.*) of the alluvial areas provide winter browse (Imperial 2008). The moose population in the Norman Wells area is historically stable in numbers and composition, with continued high productivity (Latour 1992, Veitch et al. 1996).

Common bird species in the area include the American crow (*Corvus brachyrhynchos*), gray jay (*Perisoreus canadensis*), common raven (*Corvus cortex*), ruffed grouse (*Bonasa umbellus*), sharptailed grouse (*Tympanuchus phasianellus*), spruce grouse (*Dendragapus canadensis*), and ptarmigan (*Lagopus lagopus*) (Bayha and Snortland 2002, 2003, 2004).

Waterfowl are abundant in the Mackenzie River Valley, which serves as a major migration corridor for swans, geese, ducks, and shore birds. Nesting and staging habitat is provided by the small lakes and rivers in the Norman Wells area. Islands in the Mackenzie River are particularly important staging areas for migrating geese and swans (see Rescan 1998 and references therein).

Upland game birds and waterfowl are also an important food resource, these food resources include grouse, ptarmigan, mallard (*Anas platyrhynchos*), northern pintail (*Anus acuta*), Canada goose (*Branta canadensis*), and snow goose (*Chen caerulescens*) (Bayha and Snortland 2002, 2003, 2004).

Raptor habitat is found in the rocky outcrops of the Mackenzie Plain and cliffs along the Mackenzie River. Commonly identified raptors in the Norman Wells area include peregrine falcons, golden eagle, and red-tail hawks (Matthews 1989). Bald eagles nest in lowland areas near lakes or rivers.

The Mackenzie Valley forms one of North America's most travelled migratory corridors (Western Central Flyway) for waterfowl that breed along the Arctic coast. The islands of the Mackenzie River are Important Bird Areas (IBA sites NT081 and NT082) (IBA Canada 2015). An Important Bird Area is a site providing essential habitat for one or more species of breeding or non-breeding birds. These sites may contain threatened species, endemic species, species representative of a biome, or highly exceptional concentrations of birds (IBA Canada 2015). The NT082 site is located northeast of Fort Norman while NTO8 I consists of a 250 km reach of the Mackenzie River and includes the Islands at Norman Wells.

3.4.3.1 Wildlife Species at Risk

Lists of endangered and threatened species produced by the Committee on the Status of Rare and Endangered Wildlife Species in Canada (COSEWIC) have been previously reviewed to determine the status of wildlife potentially existing in the Norman Wells area (Imperial 2008). Four species with natural ranges surrounding the area were listed. These are described in Table 3-12.

Table 3-12: Wildlife Species at Risk in the Norman Wells Area

Species	Status	Description
Woodland Caribou	▶ SARA: Threatened, schedule I ▶ COSEWIC: Threatened, May 2002 ▶ NWT: Sensitive	Woodland caribou inhabit the forests east of the Mackenzie Mountains. In winter, woodland caribou use uplands, bogs and south facing slopes where the snow is not too deep. Limiting factors to the Woodland caribou population include natural predation, habitat fragmentation or loss, human disturbance (road and pipeline construction etc.), and hunting (COSEWIC 2002). Woodland caribou are an important food source for both the Norman Wells and Fort Norman communities. Woodland caribou in the Sahtu region are considered secure.
Peregrine Falcon (sub sp. anatum)	▶ SARA: Threatened, schedule 1 ▶ COSEWIC: Threatened, May 2000 ▶ NWT: Sensitive	The Peregrine falcon subspecies, Falco peregrinus anatum, is found below the treeline, with a large population located along the Mackenzie River Valley. Peregrine falcons require proper nesting sites, usually located on cliff ledges near water. The home range, where peregrines hunt other birds in the air, overlaps the nesting range and can extend up to 27 kilometres from the nest. Pesticides were the major contributors to the drop in Peregrine Falcon numbers between the 1950s and 1970s. However, numbers have been slowly increasing since the mid-1970s due to the North American ban on organochloride pesticides (Environment Canada 2006).
Grizzly Bear	▶ COSEWIC: Special Concern, May 2002 ▶ NWT: Sensitive	In North America, the northwestern population of grizzly bears (all existing populations) are designated Special Concern (Ross 2002). Grizzly bears occur through much of the Northwest Territories with the highest concentrations being found in the Mackenzie Mountains. Characteristics of project facilities such as food sources and wastes, and some industrial materials (e.g., lubricating oils) can attract bears to the project area. The life history characteristics of Grizzly bears make them particularly sensitive to human-caused mortality (unregulated hunting, poaching, accidental or defensive kills).
Wolverine	▶ COSEWIC: Special Concern, May 2003 ▶ NWT: Sensitive	Wolverine show less variation in habitat selection patterns relying more on an adequate, year-round food supply rather than a particular landscape or plant association (COSEWIC 2003). The COSEWIC lists the western Canadian population as a Special Concern. Wolverine numbers are considered stable but their life history characteristics (low population densities, low reproductive rates, and low juvenile survival) make them sensitive to human activities (COSEWIC 2003).

3.4.3.2 Important Wildlife Areas

A report released in 2012 by the GNWT describes Important Wildlife Areas (IWA) in the western Northwest Territories (Haas and Wilson 2012). IWA in this context are ecologically important wildlife species which meet one of several conditions primarily linked to socio-economic importance and protected status and areas where these species consistently gather, take refuge, are areas with source populations or are unique areas used by different species. In the area of Norman Wells, two IWAs have been identified for moose and Muskox (NWT Centre for Geomatics 2012); these are identified on Figure 3-14 and include:

- Three Day Lake (figure reference 33) - known for having consistently high moose densities, some of the highest in the SSA (SLUPB 2009).
- Norman Wells to Fort Good Hope Winter Road (figure reference 42) - moose also tend to concentrate along the winter road between Norman Wells and Fort Good Hope.
- Sahtu Muskox Areas (figure reference 50) - these are places in the Sahtu region where one can consistently find large numbers of muskoxen

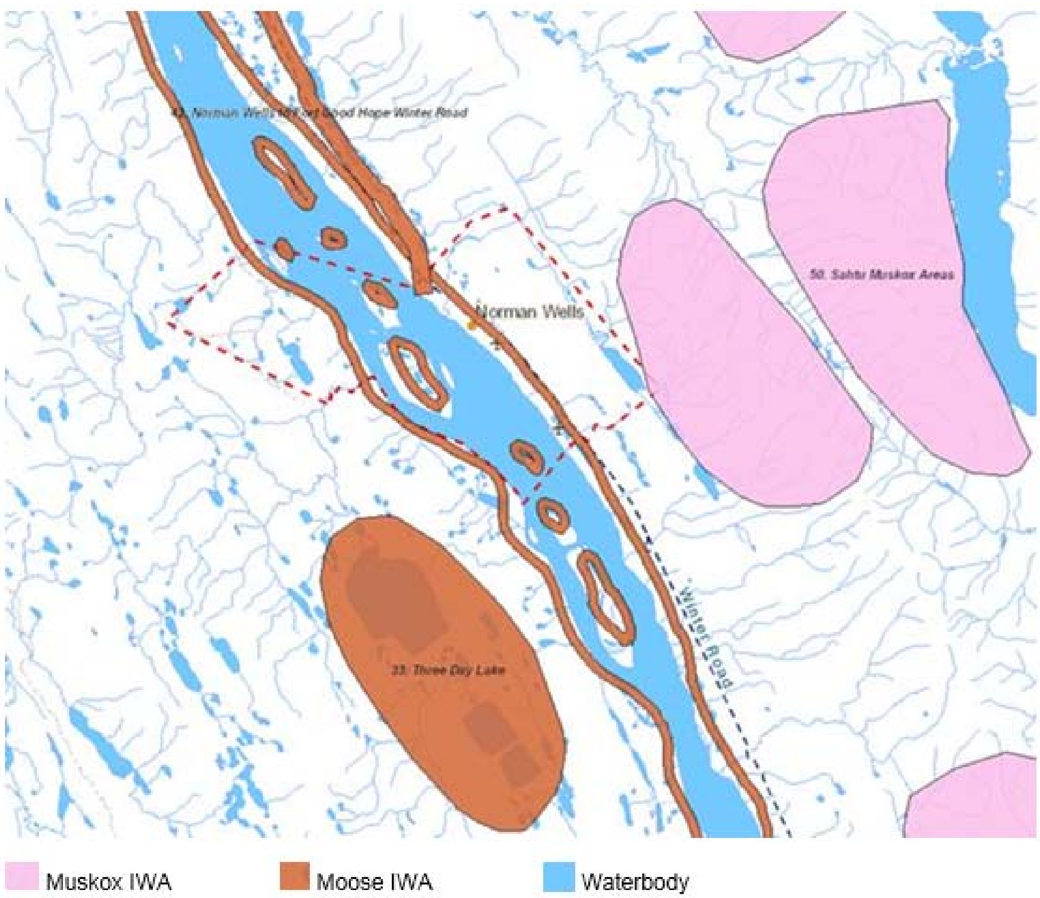


Figure 3-14: Important Wildlife Areas near Norman Wells

3.4.4 Aquatic Life

Aquatic biota in the Mackenzie River at Norman Wells were the focus of several studies during the 1980s (M/S 1985, 1986; ESL 1987; Lockhart et al. 1987a; Hrudey and Associates 1988; RMC 1992). The fish resources in the Mackenzie River and two local tributaries, Bosworth and Loon Creeks, identified in these studies were summarized by Rescan (1998). A total of 34 fish species have been identified, and most species have been observed in the Norman Wells area (Imperial 2008).

Many of the fish species are only seasonally abundant as they move past Norman Wells to and from spawning, rearing and overwintering areas, either in the Mackenzie River mainstream or in tributary streams and lakes (Rescan 1998). The Mackenzie River itself is used for spawning as well as access to spawning sites that include Bosworth Creek (Senes Consultants Ltd., Guthrie 2009).

Species of importance to local resource use are (Rescan 1998):

- Arctic Grayling (*Thymallus urcticus*);
- Broad Whitefish *(Coregonus nasus*);
- Inconnu (Stenodus leueichthvs); and
- Burbot (*Low Iota*).

Other fish species in the Mackenzie River in the vicinity of Norman Wells include (Senes Consultants Ltd., Guthrie 2009):

- Bull Trout (*Salvelinus confluentus*);
- Dolly Varden (*Salvelinus malma*);
- Arctic Cisco (*Coregonus atumnali*);
- Least Cisco (*Coregonus sardinella*);
- Walleye (*Stizostedion vitreum*); and
- Lake Whitefish (*Coregonus clupeaformis*).

Major taxonomic groups of aquatic invertebrates in the Mackenzie River include midges, oligochaete worms, caddisflies, mayflies, stoneflies, and other true flies (Imperial 2005).

3.4.4.1 Bosworth Creek

A literature review on Bosworth Creek, produced in 2011 through an initiative funded and administered by Natural Resources Canada (Senes Consultants Ltd., Guthrie 2009), summarizes survey and study results on Bosworth Creek in the 1970s and late 1990s which report the presence of Arctic Grayling, Burbot, Flathead Chub (*Platygobio gracilis*), Inconnu (*Stenodus leucichthys*), Lake Chub (*Couesius plumbeus*), Lake Whitefish, Longnose Dace (*Rhinichthys cataractae*), Longnose Sucker (*Catostomus catostomus*), Ninespine Stickleback (*Pungitius pungitius*), Northern Pike (*Esox Lucius*), Slimy Sculpin (*Cottus cognatus*), and Trout-perch (Percopsis omiscomaycus) (Senes Consultants Ltd., Guthrie 2009).

From a recreational and food harvesting perspective, Jackfish Lake on Bosworth Creek has been reported as a popular Northern Pike fishing recreation area for local residents and records indicate that Burbot is harvested from the creek for subsistence during fall and winter (Senes Consultants Ltd., Guthrie 2009).

Preliminary analysis has been completed on benthic invertebrates in Bosworth Creek as part of the initiative and has identified 31 Families (Senes Consultants Ltd., Guthrie 2009). Taxonomic groups represented include midges, oligochaete worms, caddisflies, mayflies, stoneflies, and other true flies. Amphipods, snails, and fingernail clams are also present in Bosworth Creek.

Bosworth Creek has a minor spawning and rearing area for Arctic grayling and suckers at its mouth Bosworth Creek and has been suggested to provide summer fish feeding habitat. The creek has flowing water year-round and provides a probable over-wintering habitat. During the winter, Bosworth Creek had a water depth of 0.32 m, discharge rate of 1.01 m^3/s, temperature of 1.0°C and dissolved oxygen of 10.2 mg/L (Senes Consultants Ltd., Guthrie 2009).

3.4.4.2 Aquatic Effects Monitoring Program

As a requirement of the current Water Licence (S03L-001 as amended), Imperial has completed an Aquatic Effects Monitoring Program (AEMP) in connection with its operations at Norman Wells. The main goal of the AEMP was to “determine whether Imperial’s operation is having an effect on the Mackenzie River adjacent to Norman Wells” (Golder 2007). In the context of aquatic life, the AEMP focus was on fish quality, specifically the condition of Loche and Whitefish as valued local food sources. Work conducted under the AEMP has established that fish quality concerns with both loche (dark, small livers), and whitefish (‘watery’ flesh) appears to be related to the natural cycles of the fish.

The AEMP looked at several approaches to see if the quality of fish and water of the Mackenzie River is being affected by the Operations, and to determine a cause for any effects that may be found. For fish, the AEMP was primarily interested in assessing Loche liver quality and Whitefish flesh quality. The results of the approaches taken through the AEMP aligned with each other, in that they all indicate that the Operations are not having an effect on the quality of Mackenzie River fish and water (Imperial 2013).

3.5 Human Environment and Community Setting

Norman Wells is located within the boundaries of the Sahtu Settlement Area (SSA). The SSA covers one quarter, approximately 283,000 km^2 of the Northwest Territories. It represents 6% of the total population of the territory, and is home to an estimated 2,680 people (GNWT 2013).

3.5.1 Local Communities

There are five communities in the Sahtu Settlement Area (SLUPB 2010):

- Colville Lake;
- Déline;
- Fort Good Hope;

- Norman Wells; and
- Tulita.

3.5.1.1 Norman Wells

Norman Wells is located on the east bank of the Mackenzie River at +65º15'N and 126º50'W. In 2011, the population was 727. Records of petroleum in the area date back to the Alexander Mackenzie expeditions in the late 1700s (Hume and Link 1945). Establishment of the Town of Norman Wells, along with its growth, closely followed the exploration and development of hydrocarbons in the area (GNWT 2013).

Norman Wells features a wide variety of businesses and economic development opportunities in addition to major oil and gas production and operating facilities. The Town supports local and regional tourism and is home to both Federal and regional government offices (Norman Wells 2015). As a regional transportation hub, Norman Wells features an 1,800 metre asphalt airstrip, with daily scheduled flights from Calgary/Edmonton/Yellowknife and Inuvik. Norman Wells is also the hub for regional airline flights to other local communities. The Mackenzie River, which passes by Norman Wells, serves as the major barge route for freight in the NWT during summer months. In the winter, the Mackenzie ice highway provides an overland road connection to the NWT's year-round highway system (Town of Norman Wells 2010).

A brief description of the upstream and downstream neighboring communities of Tulita and Fort Good Hope is provided below:

- Tulita is located upstream of Norman Wells, at the confluence of the Great Bear and Mackenzie Rivers, at +64º54'N and 125º35'W. The population was 478 in 2011. The community was founded circa 1805 by the Northwest Company, with the establishment of an Anglican Church in 1860 (GNWT 2013)
- Fort Good Hope is located downstream of Norman Wells, along the east bank of the Mackenzie River at +66º15'N and 128º37'W. The population was 515 in 2011. Fort Good Hope is the oldest community in the lower Mackenzie Valley (established in 1805) (GNWT 2013)

3.5.2 Heritage

The Prince of Whales Northern Heritage Center has advised of one known heritage site within a 500 m buffer of the Norman Wells town boundaries (location undisclosed) (Prince of Whales 2013).

In addition, three gravesites have been identified during Traditional Knowledge workshops including the Town of Norman Wells cemetery on the upper bank of the Mackenzie River south of E-25X and two single grave sites (one along the west side of Bosworth Creek and east of historic Tanks 53 and 401; and a second located south of D-36X on the bank of the Mackenzie River). The location of these gravesites is marked on Traditional Knowledge mapping to facilitate ongoing avoidance of these areas.

4.0 PROJECT DESCRIPTION

4.1 Location

Imperial's Operations are located at latitude +65°17' and longitude -126°51', within the boundaries of the Town of Norman Wells which is, in turn, located within the Tulita district of the Sahtu Settlement Area (SSA). The Tulita district is one of three districts in the SSA. The remaining two districts are the Déline and K'asho Gotine. Figure 4-1 shows the location of Norman Wells within the SSA (Imperial 2013).

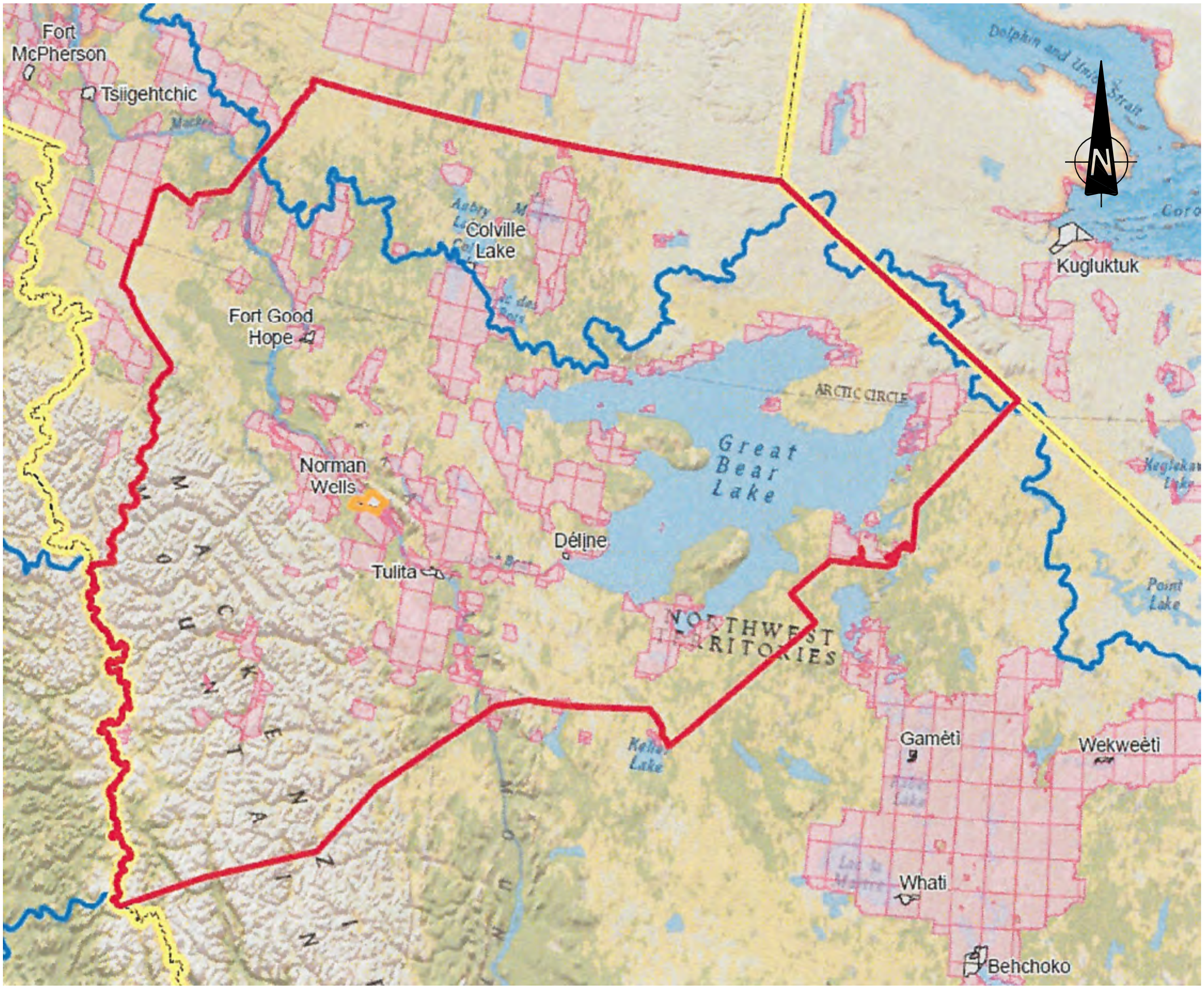
An estimated 2,680 people or 6% of the total population of the NWT live in the SSA (GNWT 2013, as cited in Imperial 2013). The SSA covers approximately 283,000 km^2 or one quarter of Canada's NWT. The five largest communities in the SSA are (GNWT 2013, as cited in Imperial 2013):

- Colville Lake: located at 67°02'N, 126°07'W with a population in 2011 of 149. Colville Lake is a traditional community whose economy is primarily based on hunting, fishing and trapping.
- Déline: is situated on Great Bear Lake at +65°10'N and -123°25'W and in 2011, the population was 472. Déline became a Charter Community on 1 April 1993, and officially changed its name from Fort Franklin on 1 June 1993.
- Fort Good Hope: is located along the east bank of the Mackenzie River at 66°15'N and had a 2011 population of 515. Established in 1805, Fort Good Hope is the oldest settlement in the lower Mackenzie Valley.
- Norman Wells: is located on the east bank of the Mackenzie River at +65°17'N and -126°50'W and the 2011 population was 727. Establishment and growth of the Town closely followed the exploration and development of hydrocarbons in the area (GNWT 2013).
- Tulita: is located at the confluence of the Great Bear and Mackenzie Rivers at 64°54'N and 125°35'W, and in 2011, the population was 478. The community was established circa 1805 by the Northwest Company.

4.2 Access

There is no all-weather road access to the Operations. During the summer, heavy barge access is available via the Mackenzie River. Commercial services with individual barge capacities up to 14,000 tonnes (equivalent to about 10,000 m^3 of bulk excavated soil) are available to transfer materials from the Operations to a hub at Hay River, NWT (NTCL 2015).

The Mackenzie Highway provides all weather access to Wrigley, NWT. From there, an ice road of about 330 km provides winter access to the Operations. This ice road is typically open from early January to later March (GNWT 2015c).



REFERENCE DRAWING SOURCE: FROM IOR (2013)

amec foster wheeler	PROJECT NAME: NORMAN WELLS OPERATIONS	PROJECT NUMBER: CC4058
CLIENT: IMPERIAL OIL LIMITED	SHEET TITLE: CLOSURE AND RECLAMATION PLAN THE SAHTU SETTLEMENT AREA (FROM IOR 2013)	FIGURE NUMBER: 4-1
		ISSUE/REVISION: A

Scheduled air service is available to Norman Wells from Edmonton, Alberta, and Yellowknife and Inuvik, NWT. Charter air transport and cargo services are also available.

The Artificial Islands that form part of Imperial's operations are accessed via a company barge in the summer and a winter ice road constructed and maintained by Imperial.

4.3 Facility and Process Description

The descriptions of both the Operations' operational history and its current configuration that are provided in this section have been reproduced or paraphrased from Imperial's most recent Water Licence renewal application, specifically Imperial (2013b).

4.3.1 Overview

Imperial's oil and gas production facilities at Norman Wells include operations on the Mainland, the Natural and Artificial Islands (the Field), and a Central Processing Facility (CPF) located on the Mainland. Collectively, they are referred to as Operations. Production from the Field is collected through a gathering system and directed to the CPF. The CPF separates production from the Field into gas, oil and produced water. The gas is used to run equipment and inject into the gas lift system (a type of artificial lift used to assist in oil production). Imperial supplies electricity to the NTPC, who, in turn, supplies electricity to the Town of Norman Wells. Produced water is reinjected to maintain reservoir pressure and the oil is transported south via the Enbridge Pipeline.

4.3.2 Site and Operational History

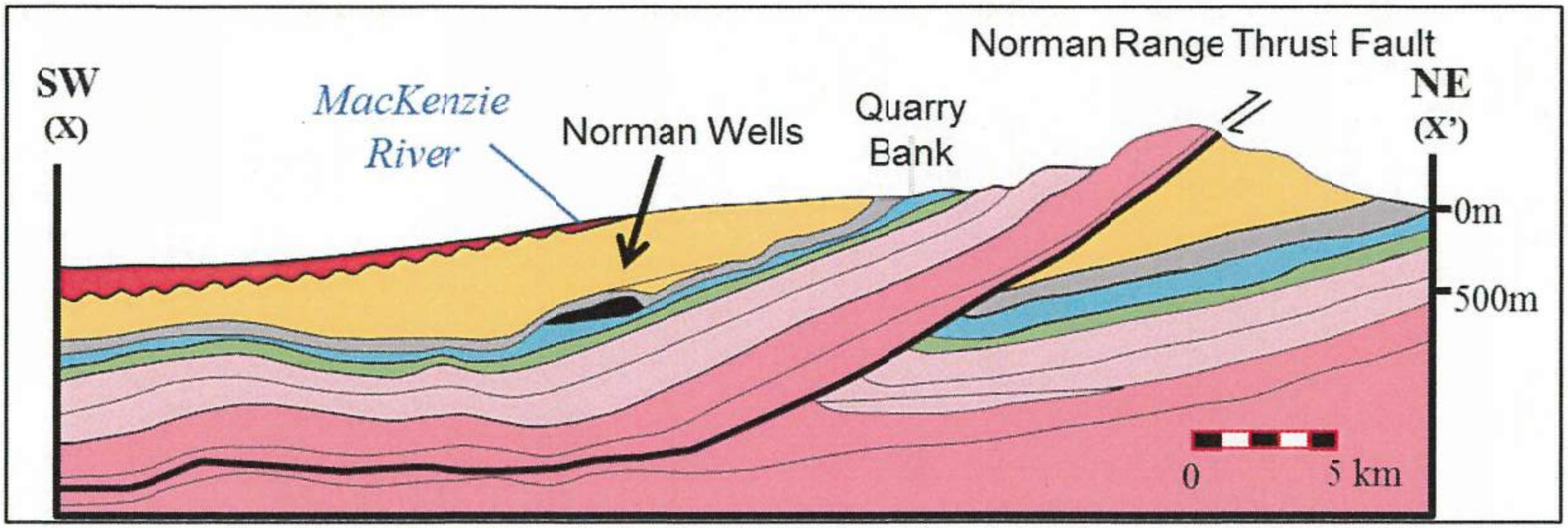
Imperial has been conducting operations at Norman Wells since the 1920s when the first well on the banks of the Mackenzie River east of the Bosworth Creek delta was drilled. This discovery well was drilled to test a series of oil seeps previously observed on the banks and shoreline of the Mackenzie River (Link, as cited in Imperial 2013b). A producing horizon was found at a depth of approximately 150 m.

4.3.2.1 Early Development of the Reservoir

Drilling in the 1920s and 1930s led to the discovery of the main reservoir, a carbonate reef at a depth of approximately 400 m (Kee Scarp Formation). Details on the geologic setting and cross sections depicting the geology in the Norman Wells area and Imperial's main reservoir are shown on Figure 4-2 and Figure 3-11 (as presented previously in Section 3.0). A description of the geology is as follows:

- Stratigraphy: structurally tilted isolated carbonate buildup assigned to Kee Scarp Formation (the arrow labelled Norman Wells on Figure 4-2 is pointing at the Kee Scarp Formation reef buildup and oil accumulation).

Cross-Section Depicting the Geology in the Norman Wells Area



REFERENCE DRAWING SOURCE: FROM: YOSE, L.A., BROWN, S., DAVIS, T.L., EIBEN, T., KOMPANIK, G.S. AND MAXWELL, S.R. 3D GEOLOGIC MODEL OF A FRACTURED CARBONATE RESERVOIR, NORMAN WELLS FIELD, NWT, CANADA. p 90, AS CITED IN (IOR, 2013b)

amec foster wheeler	PROJECT NAME: NORMAN WELLS OPERATIONS
CLIENT: IMPERIAL OIL LIMITED	SHEET TITLE: CLOSURE AND RECLAMATION PLAN CROSS-SECTION DEPICTING THE GEOLOGY IN THE NORMAN WELLS AREA
PROJECT NUMBER	CC4058
FIGURE NUMBER	4-2
ISSUE/REVISION	A

- Reservoir: predominantly recrystallized limestone; depth to top reef varies from approximately 320 metres below ground surface (mbgs) (Mainland portion of the reservoir) to approximately 625 mbgs (reservoir depth on the far side of Goose Island); average thickness of the reservoir is approximately 100 m (325 ft); average porosity 8%, oil gravity 38.5 API (American Petroleum Institute), and reservoir temperature of approximately 25°C.
- Source and Seal: Canol Formation (Figure 3-11), up to 6.7% total organic carbon (TOC). The trap and seal occur as a result of the porous Kee Scarp reservoir thinning and terminating against impermeable Canol shale.

4.3.2.2 Refinery Operation

Between 1921 and 1925, a small refinery was built and operated to process hydrocarbons from the reservoir. Around 1935, the refinery was reopened and expanded. The refinery remained operational until 1996 when it was shut down, decommissioned and dismantled (Canadian Encyclopedia 2013, as cited in Imperial 2013b).

4.3.2.3 World War II Expansion and US Army Canol Project

Between 1944 and 1945, the Field was further developed in response to the need for petroleum during and after to the Second World War. As part of this expansion, the 1,000 km long Canol Pipeline was constructed by the US Army between 1942 and 1944. Petroleum produced from the Norman Wells field was shipped to Whitehorse via the Canol Pipeline over a 13 month period before being abandoned in March 1945 (Canadian Encyclopedia 2013, as cited in Imperial 2013b).

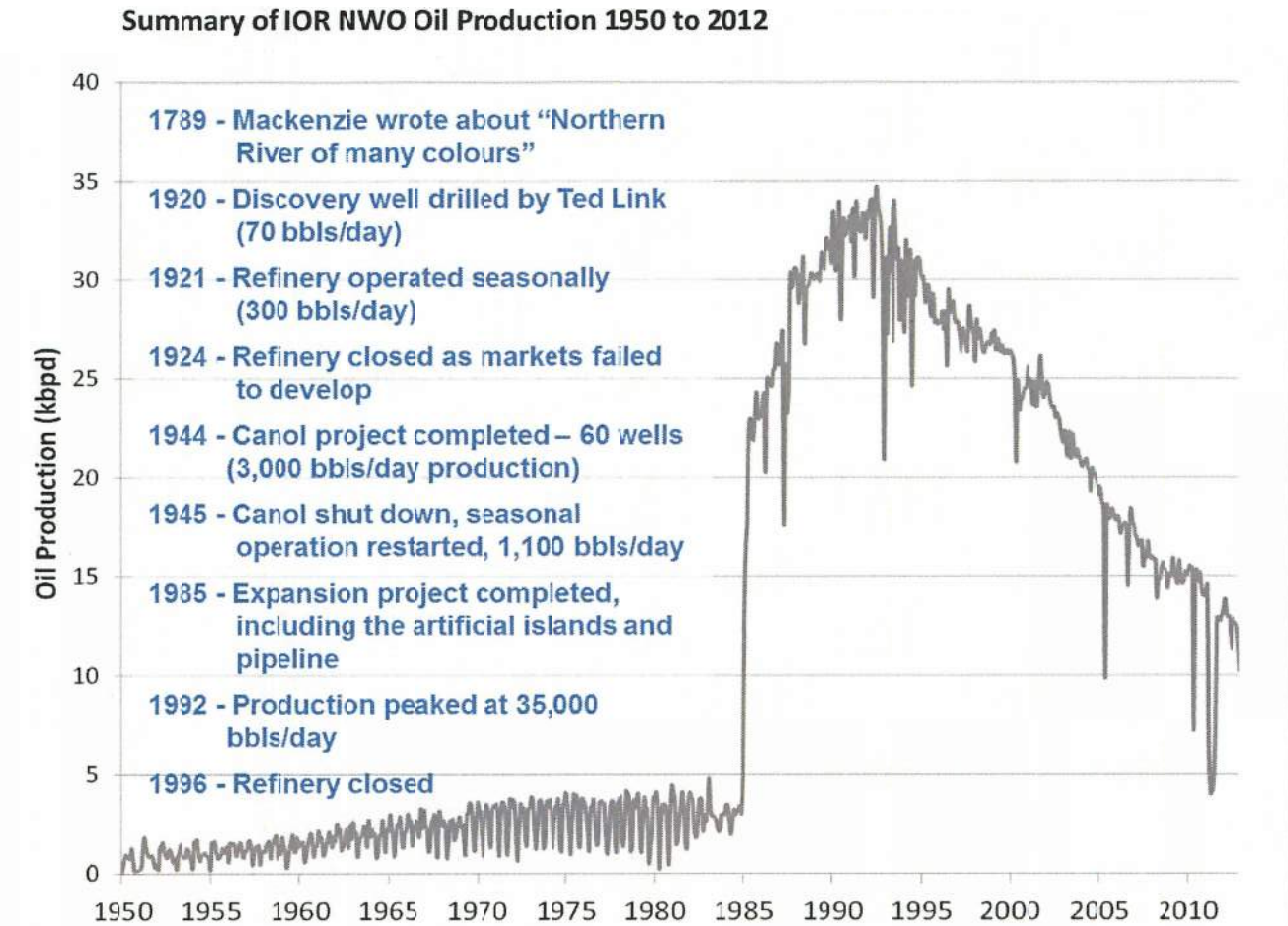
Other major infrastructure constructed around this time included Batteries #1 and #3 (both located on the Mainland), and the Bear Island Battery. Battery #1 was operational from approximately 1950 to 1983; Battery #3 was operational from the 1940s until 1990 when it was decommissioned. The Bear Island Battery was operational from approximately 1950 to 1983.

4.3.2.4 Development of Operations to Present Day

In the early 1980s, Imperial's Operations underwent a major expansion, which included the construction of the CPF and the six Artificial Islands in the Mackenzie River. A number of additional wells were drilled as part of this expansion to increase field production. The construction of the Enbridge Pipeline began in 1983 and was finished in 1985. Enbridge ships stabilized crude through a 12 inch diameter, 870 km long pipeline that starts in Norman Wells, NWT, and ends at Zama, Alberta (Enbridge 2013, as cited in Imperial 2013b).

4.3.2.5 Historical Production Summary

A summary of oil production from the Operations is presented in Figure 4-3. This figure shows the seasonal nature of production increases and decreases between the 1950s and early 1980s, and the major expansion in production which occurred in the mid-1980s. Since the mid-1980s, oil production has been declining.



Note: Dip shown in 1995, 2000, 2005 and 2010 is from a turnaround. Dip in 2011 is from the Plains Pipeline failure causing extended downturn in production.

REFERENCE DRAWING SOURCE: FROM IOR (2013b)

amec foster wheeler	PROJECT NAME: NORMAN WELLS OPERATIONS
PROJECT NUMBER: CC4058	
CLIENT: IMPERIAL OIL LIMITED	SHEET TITLE: CLOSURE AND RECLAMATION PLAN SUMMARY OF IOR NWO OIL PRODUCTION 1950 TO 2012
FIGURE NUMBER: 4-3	ISSUE/REVISION: A

4.3.3 Current Norman Wells Operation

Imperial's Operations are located within the boundaries of the Proven Area, which covers all of Goose Island, most of Bear Island and a portion of Frenchy's Island, the six Artificial Islands, and the Mainland including the CPF. The Proven Area covers an area of 7,939 acres or 32 km^2. The actual size of the Operations' geographical footprint is approximately 11 km^2.

As noted previously, Imperial's Operations include the Field and CPF. The Field is generally comprised of the production facilities outside of the CPF, but within the Proven Area. A description of the major infrastructure and functional areas for the Field and CPF are described below.

4.3.3.1 The Field

The main operational areas in the Field include both permanent and temporary seasonal infrastructure. These operational areas include the following infrastructure:

<u>Permanent Infrastructure</u>

- Goose Island Terminals (GIT) 4, 7, 8, and 9;
- Mainland Terminals (LT) 2, 3, 7, and 11;
- Land Pipeline Terminal (LPT) 1;
- Bear Island Terminals (BIT) 2, 3, 4, and 5;
- Bear Island Production Terminals (BPT) 1 and 2;
- 386 wells located on the Mainland, Artificial Islands and Natural Islands of which:
  - 179 are production wells;
  - 170 are injection wells;
  - seven are suspended;
  - 29 are abandoned; and
  - one is an observation well.
- other miscellaneous infrastructure associated with the gathering, testing and transport of production from Goose, Bear and Frenchy's Islands, as well as the six Artificial Islands (1 (Rayuka), 2 (Rampart), 3 (Dehcho), 4 (Ekwe), 5 (Iteh K'ee), and 6 (Little Bear));
- other miscellaneous infrastructure to support transportation around the site such as helicopter pads and barge and boat landings; and
- other miscellaneous bermed areas for the storage of hazardous waste, chemicals, methanol, diesel, and gasoline.

<u>Temporary Infrastructure</u>

- ice roads are constructed seasonally after freeze up to access the islands from the Mainland.

4.3.3.2 The CPF

The main functional areas of the CPF are presented on Figure 4-4. The main functional areas of the CPF include:

- flare stack;
- tank farm;
- produced water handling;
- fresh water handling;
- crude oil pumping;
- storage;
- settling pond;
- retention area (CPF Impound);
- waste heat recovery;
- glycol heaters;
- gas processing, drying and refrigeration;
- crude oil chilling;
- MCC power generation;
- gas compression;
- crude oil handling;
- office; and
- miscellaneous skids and mechanical buildings.

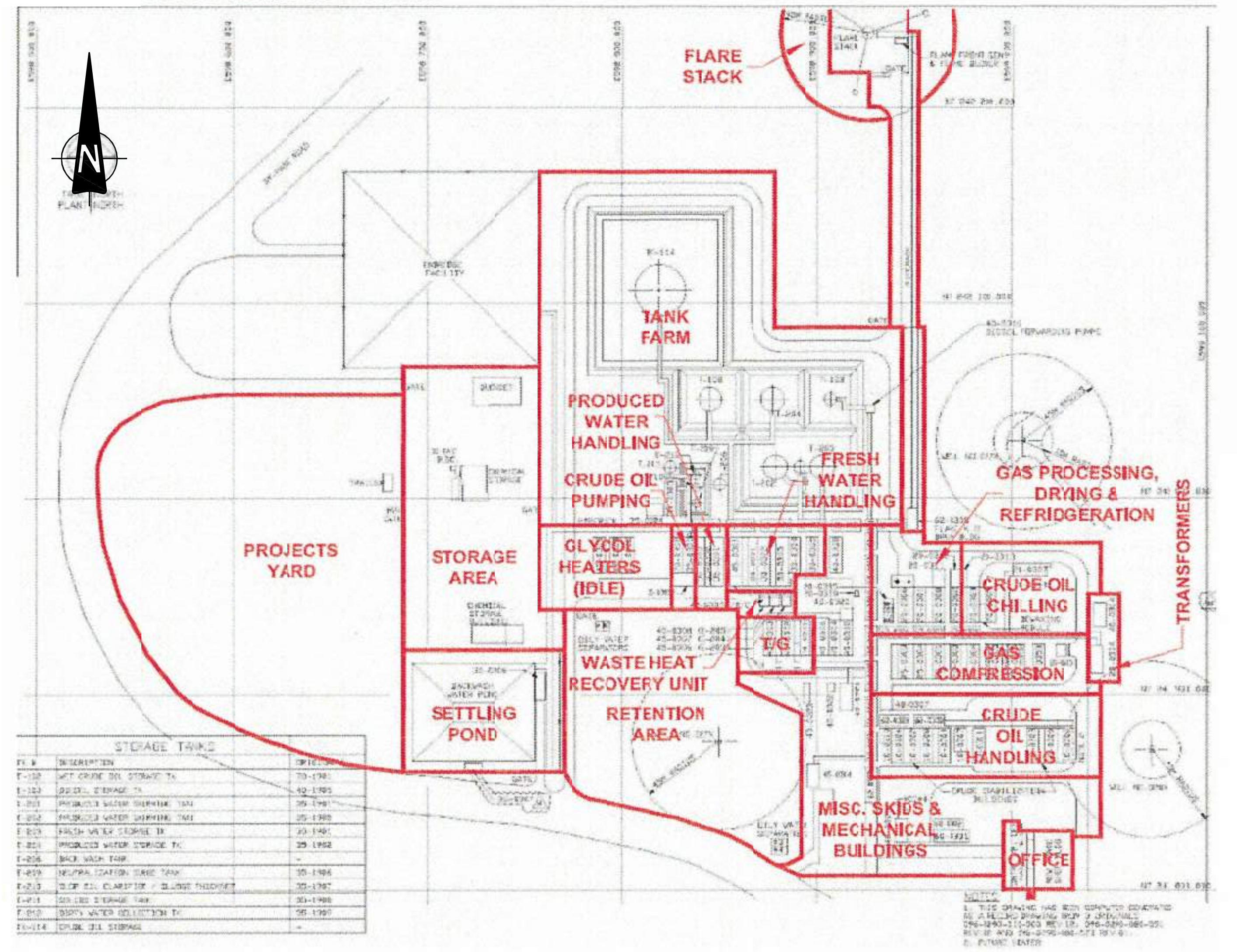
4.3.4 Surrounding Area

The mainland portion of the Operations is bounded by the following land uses:

- the Enbridge facility is located to the northwest of the CPF;
- a bulk fuel storage/loading facility and the Town of Norman Wells is located to the east;
- a recreational/parkland area is located to the south, west, and north; and
- the Mackenzie River is located to the south.

In addition to the above, the sewage lagoons and the local airport for the Town of Norman Wells are located to the northeast of the Operations.

IOR's Main CPF Areas



REFERENCE DRAWING SOURCE: FROM IOR (2013b)

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CLIENT
IMPERIAL OIL LIMITED

PROJECT NAME
NORMAN WELLS OPERATIONS

SHEET TITLE
CLOSURE AND RECLAMATION PLAN
IMPERIAL OIL RESOURCES
MAIN CPF AREAS

PROJECT NUMBER
CC4058

FIGURE NUMBER
4-4

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4.3.5 Field Operations

4.3.5.1 Mainland

Field infrastructure located on the Mainland includes:

- wells (production and injection) and associated flowlines;
- four land terminals (LT) 2, 3, 7, and 11;
- one Land Pipeline Terminal (LPT) 1;
- bermed area for storage of methanol;
- a road network (with two bridges crossing Bosworth Creek), helicopter pad and two docks;
- waste storage yard;
- F-31X Treatment and Injection Facility;
- well servicing yard;
- warehouse, various other buildings for equipment storage and laydown yards; and
- soil treatment facilities (biocells for hydrocarbon remediation and a soil washing facility for salt removal).

4.3.5.2 Bear Island

Infrastructure located on Bear Island includes:

- wells (production and injection) and associated flowlines;
- four terminals BIT 2, 3, 4, and 5;
- two production terminals BPT 1 and 2;
- six backfilled sumps associated with historical drilling operations;
- a fuel and methanol storage area;
- two reclaimed borrow pits;
- a road network; and
- helicopter pads and causeway/barge loading and unloading area.

Multi-phase product (containing crude oil, produced water, and gas) from Frenchy's Island, Bear Island and Islands 5 and 6 flows into BIT 4; from BIT 4, product flows to GIT 4 (Goose Island) in two flowlines under the River (6" and a 10").

4.3.5.3 Goose Island

Infrastructure located on Goose Island includes:

- wells (production and injection) and associated flowlines;

- four terminals GIT 4, 7, 8 and 9;
- two former sumps;
- two former borrow pits;
- a fuel and methanol storage area;
- a road network; and
- helicopter pads and a causeway/barge loading and unloading area.

Multi-phase product from Goose Island, BIT 4 and Island 4 comes into GIT 4, where the produced gas is separated from the crude oil and produced water (together it is called emulsion). The produced gas from GIT 4 is sent to the CPF in a 14” flowline under the river. The emulsion is sent to the CPF in a 10” flowline under the river.

4.3.5.4 Frenchy’s Island

Frenchy’s Island is accessed by a causeway which connects seasonally to Bear Island. Frenchy’s Island has both production and injection wells located on one well pad. As mentioned above, production from Frenchy’s Island flows into BIT 4 on Bear Island.

4.3.5.5 Artificial Island 1 (RAYUKA)

Both injection and production wells are located on Island 1. A flowline corridor connects Island 1 to the LPT located on the east shore of the Mackenzie River (Mainland).

4.3.5.6 Artificial Island 2 (RAMPART)

Both injection and production wells are located on Island 2. A flowline corridor connects Island 2 to the LPT located on the east shore of the Mackenzie River (Mainland).

4.3.5.7 Artificial Island 3 (DEHCHO)

Both injection and production wells are located on Island 3. Island 3 is connected to the Mainland by a flowline corridor originating from Goose Island, extending beneath Island 3, and terminating at the CPF.

4.3.5.8 Artificial Island 4 (EKWE)

Both injection and production wells are located on Island 4. A flowline corridor connects Island 4 to Goose Island.

4.3.5.9 Artificial Island 5 (ITEH K’EE)

Both injection and production wells are located on Island 5. A flowline corridor connects Island 5 to Bear Island.

4.3.5.10 Artificial Island 6 (LITTLE BEAR)

Both injection and production wells are located on Island 6. A flowline corridor connects Island 6 to Bear Island.

4.3.6 Field Equipment

4.3.6.1 Flowline Summary

A network of flowlines is used at the Operations. These flowlines are used to connect the Field Operations with the CPF. The major uses for the flowlines between the Field and CPF are as follows:

- production (oil, produced water, and gas) from the producing wells in the Field to the CPF;
- injection (fresh water, produced water, and propane) from the CPF to injection wells in the field; and
- natural gas (fuel gas, artificial lift) from the CPF to gas lift wells and field facilities.

A total of 27 flowlines (oil, water and gas) are buried and encased in concrete under the Mackenzie River.

Flowlines are maintained according to all applicable regulatory standards and codes. Flowline integrity is maintained using a combination of corrosion mitigation activities. Depending on the flowline, maintenance pigging, chemical inhibition and biocide applications are completed to maintain the flowline. Inline inspection and direct assessments are completed to assess flowline condition, remaining life, and operating risk.

Flowlines which pass through environmentally sensitive areas are deemed to be ‘critical’. All flowlines that are buried under the Mackenzie River are deemed critical. Planned maintenance associated with these flowlines is tracked for schedule adherence and completion quarterly. Deviations require a risk assessment, mitigation plan and management approval. Not all planned maintenance activities are applicable to every flowline.

All buried flowlines have cathodic protection to prevent external corrosion. Corrosion rates are tracked and monitored using a combination of corrosion coupons (a monitoring tool), inspection results and fluid analysis.

4.3.6.2 F-31X Treatment and Injection Facility

The F-31X Treatment and Injection Facility is a solid/liquid separation system. The purpose of the facility is to accommodate material containing a higher content of liquids than solids. The F-31X Treatment and Injection Facility is not a disposal facility; only fluid containing solids that easily settle are accepted and treated in this facility.

In the F-31X treatment and injection process, impacted fluid containing solids enter the system through a Grizzly Tank. The weir system in the Grizzly Tank separates the liquid-solid mixture, allowing the solids to settle to the bottom of the tank. The remaining liquids pass through into Tank 001. Straight fluid containing no solids can be pumped from the truck directly into Tank 001. A skimmer in Tank 001 separates hydrocarbons from water; the remaining treated water is injected into the F-31X injection well. The hydrocarbons are recycled into the CPF.

4.3.7 Central Processing Facility (CPF) Operations

The purpose of the CPF is to supply:

- chilled, stabilized crude oil to the Enbridge Pipeline for transmission to Zama, Alberta;
- treated, fresh water to the field for injection;
- treated, produced water to the field for injection;
- high pressure lift gas to the field; and
- electricity to Imperial facilities and the NTPC.

An input-output block diagram is presented on Figure 4-5. As part of the CPF operation, the following inputs are accepted from the field gathering system:

- emulsion from Goose Island, Bear Island, the Artificial Islands 3, 4, 5, and 6, and Land Terminal (LT) 2 is gathered via the 10” cross-river line;
- separated gas from Goose Island, Bear Island, and the Artificial Islands 3, 4, 5, and 6 is gathered via the 14” cross river line; and
- multi-phase from Mainland Land Terminals (LT) 2, 3, 7, 11, and the Artificial Islands 1 and 2 is gathered via the 12” multi-phase line.

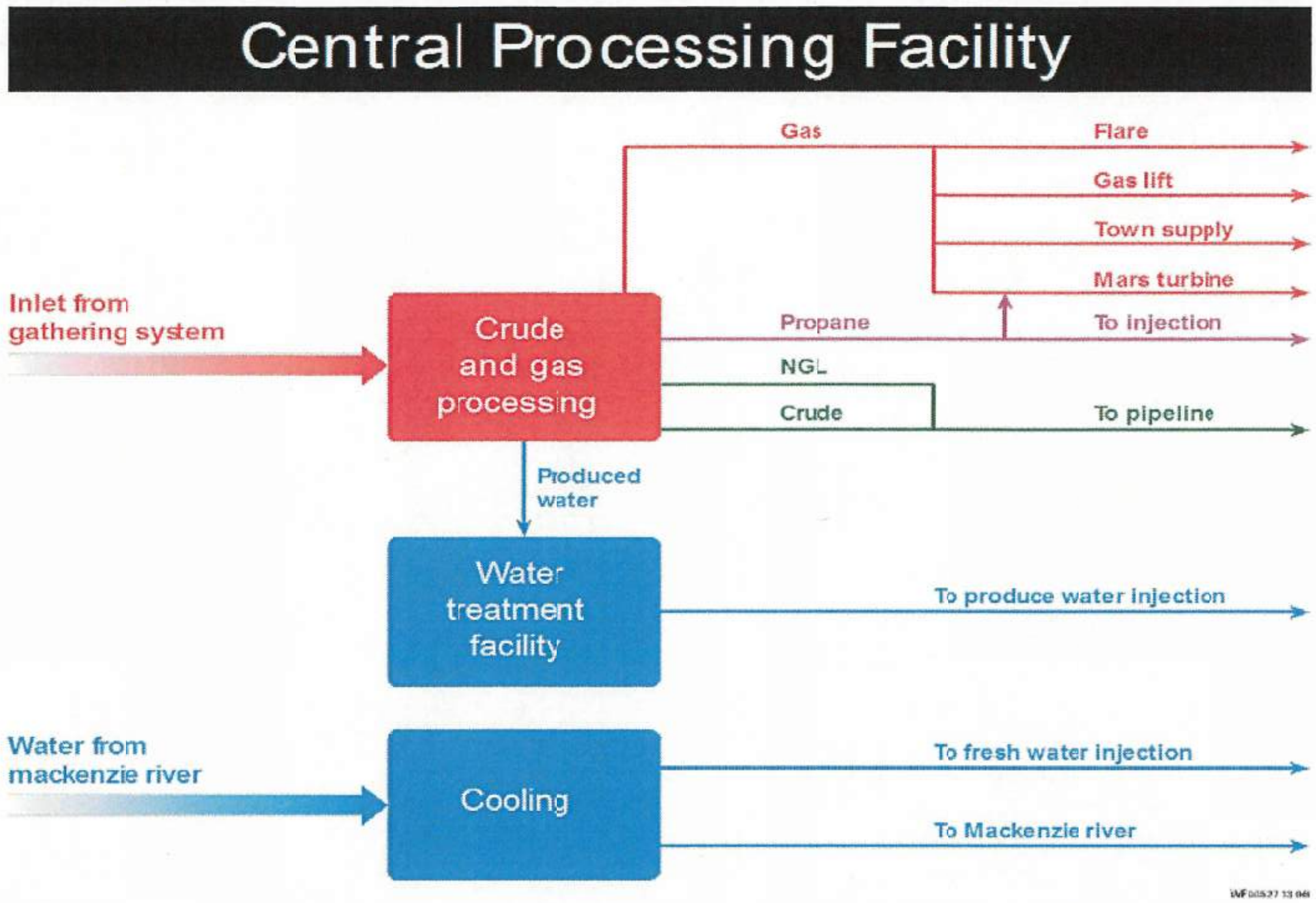
In addition to these inputs, fresh water from the Mackenzie River is also pumped to the CPF for cooling and injection. Similar to municipal drinking water systems, the fresh water withdrawn at the CPF is treated with chlorine to prevent bio-fouling. Additional details about the performance of the fresh water system are presented in Section 13 of the Renewal Application.

From these inputs, the CPF produces the following outputs:

- gas to flare;
- gas to Mars Turbine;
- lift gas to the field (to support oil production);
- propane to injection;
- Natural Gas Liquids (NGL) to Enbridge Pipeline;
- crude oil to Enbridge Pipeline;
- produced and fresh water to the field for injection; and
- fresh water used for cooling returned to the river.

In addition to these outputs, the CPF also produces electrical power for Imperial and NTPC.

CPF Input-Output Block Diagram



REFERENCE DRAWING SOURCE: FROM IOR (2013b)

amec foster wheeler	PROJECT NAME: NORMAN WELLS OPERATIONS	PROJECT NUMBER: CC4058
CLIENT: IMPERIAL OIL LIMITED	SHEET TITLE: CLOSURE AND RECLAMATION PLAN CPF INPUT-OUTPUT BLOCK DIAGRAM	FIGURE NUMBER: 4-5
		ISSUE/REVISION: A

4.3.8 CPF Processes and Utilities

A number of major processes and associated utilities are undertaken at the CPF. Table 4-1 presents a summary of these.

Table 4-1: Process and Utility Systems of the CPF

Processes	Utilities
Inlet Separation and Crude Stabilization	Glycol/Water Heating and Distribution
Main Gas Compression	Power Generating and Distribution
Crude Storage and Chilling	Instrument/Service Air Compressing
Gas Boosting	Flaring and Closed Drain System
Refrigeration	Fresh Water Treatment and Injection
Gas Dehydration	Produced Water Treating and Injection
Liquid Dehydration	Shop Oil Recovery
Regeneration Gas	Fuel Gas Chilling and Distribution
Fuel Gas Chilling	Waste Heat Recovery Unit
De-ethanizing and De-propanizing	

4.3.8.1 Processes

Inlet Separation and Crude Stabilization

The Inlet Separation and Crude Stabilization system removes produced water and gas from the crude oil being received from the field. The produced water and gas must be removed from the crude oil to meet specifications prior to the oil entering the Enbridge Pipeline.

Main Gas Compression

The Main Gas Compressors provide energy to push the gas through the Gas Handling and Refrigeration Processes. The compressing of the gas along with the subsequent cooling, allows the liquids to drop out of the gas. The liquids are later processed in the De-ethanizing and De-propanizing system.

Crude Storage and Chilling

The purpose of the Crude Storage and Chilling process is to produce chilled and stabilized crude for shipping. This system is important because portions of the Enbridge Pipeline are buried in permafrost and are susceptible to melting. Chilling the oil before it enters the Enbridge Pipeline helps ensure the permafrost does not melt. Temperature restrictions, which vary during the year, are placed on the shipping line.

The crude is cooled by liquid propane on the shell side of the chillers. From the chillers, the oil goes to Enbridge to be shipped south via the pipeline.

Gas Boosting

The Gas Boosting process recovers low pressure gas from the treater and the stabilizer.

Refrigeration

The Refrigeration process supplies propane refrigerant for the feed gas chillers, crude chillers, and the overhead condenser. Refrigeration is important because it allows heavier hydrocarbons to be recovered from gas before it is used for fuel gas and gas lift purposes. The refrigerant is also used in the Crude Storage and Chilling process to make sure the oil is cooled before entering the Enbridge Pipeline.

Gas Dehydration

The Gas Dehydration process removes moisture from the gas so that the gas can be chilled without causing condensation.

Liquid Dehydration

The Liquid Dehydration process removes water moisture from natural gas liquids (NGL) so that the liquids can be processed.

Regeneration Gas

The Regeneration Gas process is used to provide hot regeneration gas for the dryers in the Gas and Liquid Dehydration processes. The Gas and Liquid Dehydration dryers become saturated with water, and the Regeneration Gas process is used to regenerate the dryers by removing the moisture.

Fuel Gas Chilling

The Fuel Gas Chilling process is used to lower the propane content of the dehydrated gas and to recover NGL for use in the De-ethanizing and De-propanizing process.

From the Fuel Gas Chilling section, the gas supplies most of the gas for gas lift.

De-ethanizing and De-propanizing

The purpose of the De-ethanizing and De-propanizing process is to separate low pressure fuel gas, propane, and NGL. Propane is used for injection to the wells, for turbine fuel enrichment and for use in the Refrigeration System.

The NGL is added to the stabilized crude and is a component in the chilled crude that is sold to Enbridge Pipeline for pumping to the south.

4.3.8.2 Utilities

Glycol Heating and Distribution

Heated glycol is used as a medium for building heat, heat tracing and for process use. After supplying the loads, the glycol returns to the heat recovery system, or the boilers to be reheated.

Power Generation and Distribution

Turbine driven generators in the CPF generate power. The turbines can burn three different types of fuel:

- fuel gas;
- enriched gas (with propane); and
- diesel.

The power generation supplies 4,160 V power to the power distribution. The emergency power generation provides power for essential services in the event there is a shutdown of the power generation. This includes supplying power to start the power generation after a power failure.

The power distribution distributes the electrical power to the various users throughout the Operations and to NTPC at the required voltages.

Instrument/Service Air Compressing

The Instrument/Service Air Compressor supplies instrument air and service air for use in the CPF to operate the controls, control valves, and transmitters necessary for operating and maintaining the CPF.

Flaring and Closed Drain System

The purpose of the Flaring and Closed Drain System is to burn vapours prior to release to atmosphere. This provides a safe and effective means of collecting and disposing of vapours during CPF upset conditions.

Fresh Water Cooling

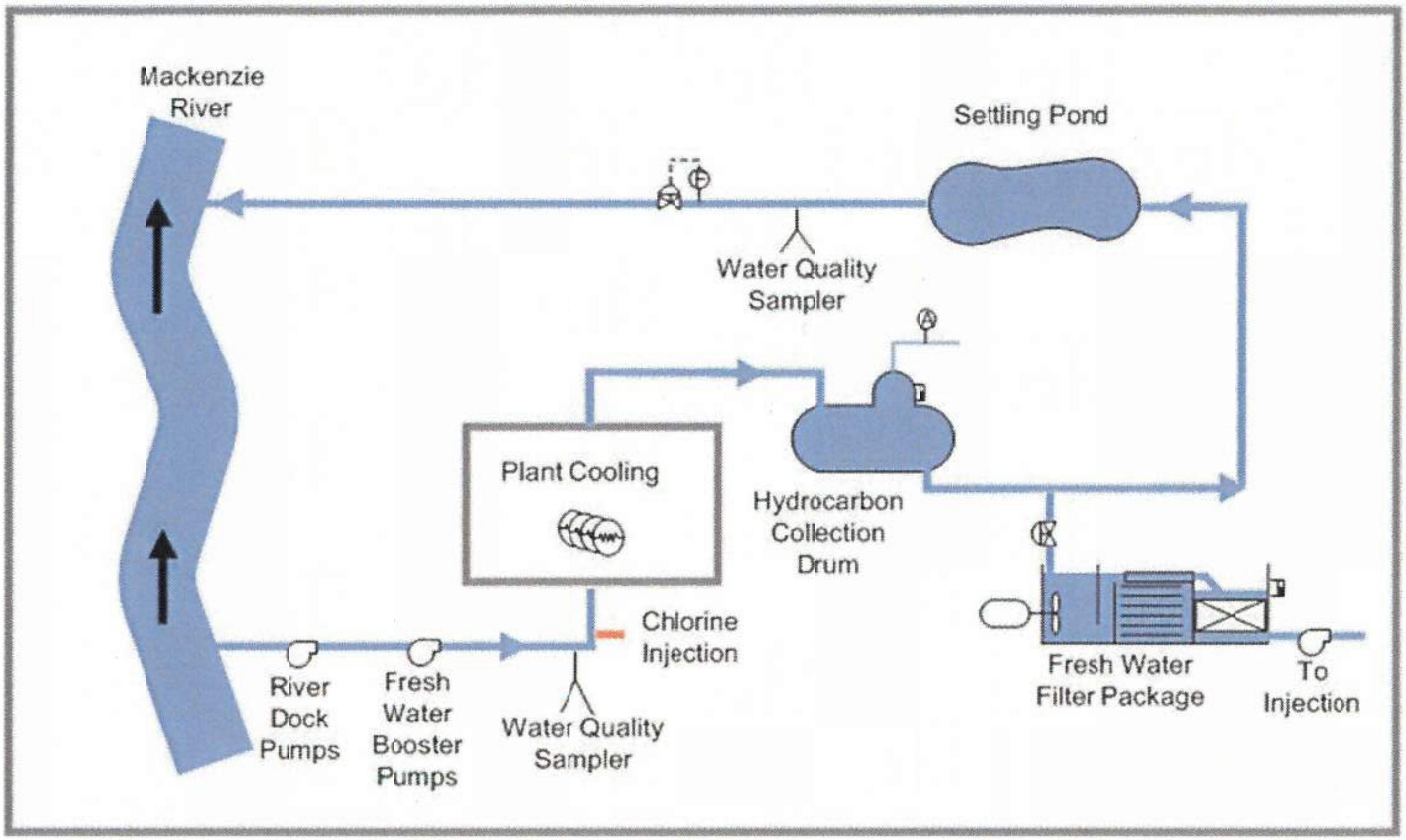
Fresh water is pumped from the Mackenzie River into the CPF to be used for cooling. The three submerged water pumps are housed in a closed bunker on the Imperial dock. After the water quality sampling, but prior to being used for plant cooling, the water is treated with chlorine. The water must be treated with chlorine to kill bacteria in the piping and related equipment as the water is moved through the CPF. A schematic of this system is presented in Figure 4-6.

Water used for cooling is carried in tubes or pipes, which keeps the water from not contacting other substances within the CPF. Figure 4-7 presents a schematic of how the water is passed through the tubes for cooling while remaining separated from the process fluids. Cooling water supplies the following equipment:

- E-111 (de-propanizer condenser);
- E-125 (K-103 after cooler); and
- E-113 (propane refrigerant condenser).

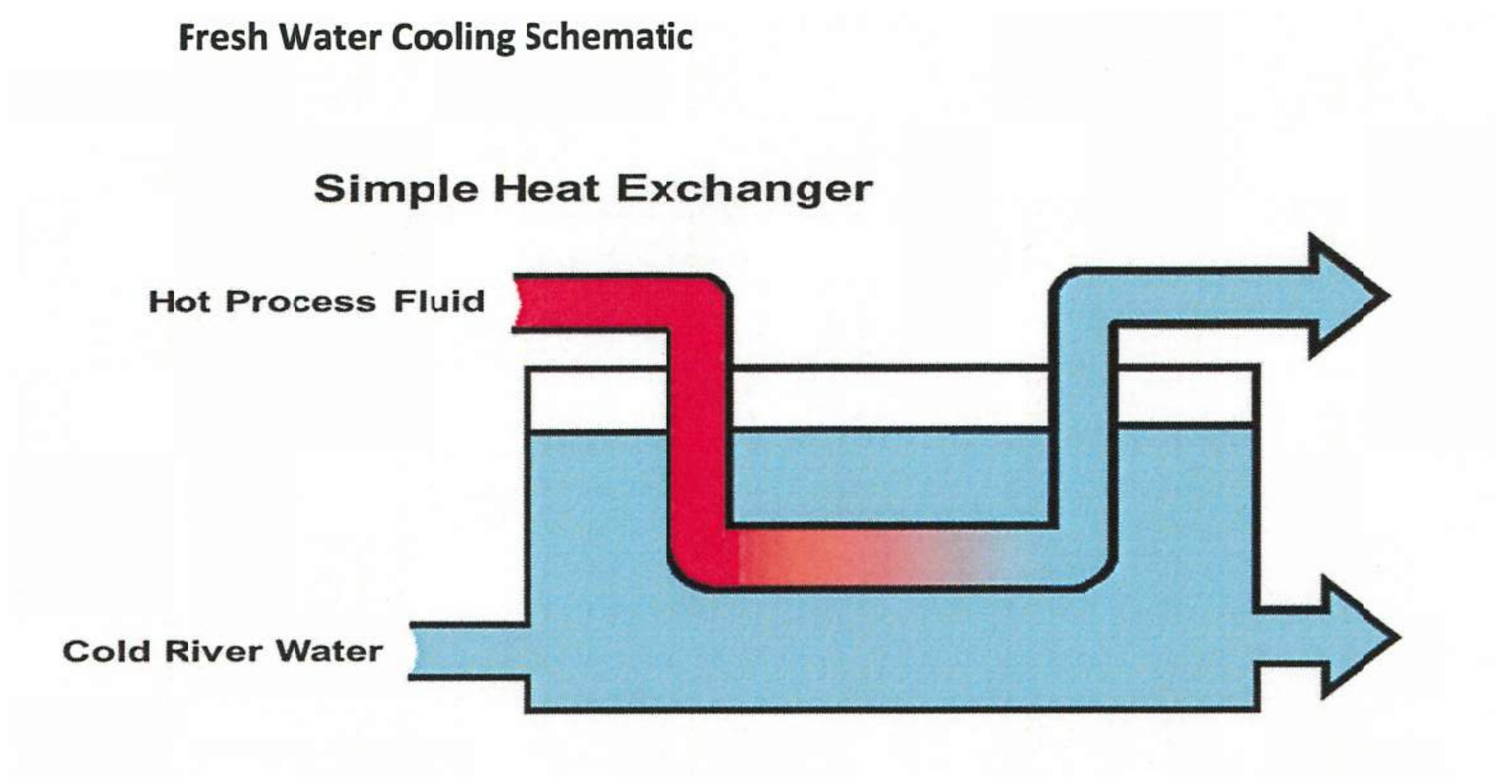
The cooling water from E-113 is used as secondary cooling water and supplies the motor and oil cooling for compressors K-101, K-102, K-104, K-105, K-106, and K-107. Water from the primary and secondary cooling water returns through the hydrocarbon collection drum (V-201).

Fresh Water Process Schematic



REFERENCE DRAWING SOURCE: FROM IOR (2013b)

amec foster wheeler	PROJECT NAME NORMAN WELLS OPERATIONS		PROJECT NUMBER CC4058
CLIENT IMPERIAL OIL LIMITED	SHEET TITLE CLOSURE AND RECLAMATION PLAN FRESH WATER PROCESS SCHEMATIC		FIGURE NUMBER 4-6
			ISSUE/REVISION A



REFERENCE DRAWING SOURCE: FROM IOR (2013b)

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CLIENT
IMPERIAL OIL LIMITED

PROJECT NAME
NORMAN WELLS OPERATIONS

SHEET TITLE
CLOSURE AND RECLAMATION PLAN
FRESH WATER
COOLING SCHEMATIC

PROJECT NUMBER
CC4058

FIGURE NUMBER
4-7

ISSUE/REVISION
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File Name: P:\CC4058\1 Deliverables\2 Figures\CC4058_FIG 4-7_E-1027.dwg Saved By: Layte , Christopher Plot Date: 151113 2:25 PM
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Water flows through the hydrocarbon collection drum (V-201), which has sensors that can detect hydrocarbons in the water. If any hydrocarbons are detected, the outlet valves on the settling pond automatically shut in, and water return to the river will cease.

Once the fresh water has passed through the hydrocarbon collection drum, it will either be diverted:

- to the settling pond for discharge back to the Mackenzie River; or
- for fresh water injection.

Discharge Back to the Mackenzie River

The settling pond allows for natural settling of any sand/silt in the water prior to being returned to the Mackenzie River. As the water is released from the settling pond, there is an outlet water quality sampler that collects water for analysis. Upon confirmation that the water meets discharge criteria listed in the Water Licence, it is discharged over riprap onto the bank of the Mackenzie River. The discharge water from the settling pond stays close to shore as it moves with the river current downstream. The movement towards the middle of the river is very slow.

Fresh water not returned to the Mackenzie River is injected into the reservoir for voidage replacement. This maintains pressure in the reservoir and enhances recovery of oil. Once the fresh water for injection is directed to the injection system, a chemical flocculant is injected into the water stream. The flocculant enables the suspended solids to be removed from the water. Additionally, prior to entering the fresh water filters, a polymer is injected into the water, which helps to bind the solids. In the fresh water filters, the suspended solids are removed. Prior to the water going out to the field, it also goes through deaerating. In this step, the deaerator removes dissolved oxygen and other dissolved gases from the water, to help prevent corrosion. Before injection water leaves the plant for the field, chlorine and corrosion inhibitors may be added to the water, if necessary, to prevent corrosion in the fresh water injection system.

Produced Water Treating and Injection

The Produced Water Treating and Injection utility takes produced water that has been separated from the oil in the Crude Stabilization process, treats it, and reinjects it into the reservoir (all produced water is reinjected into the reservoir). This helps maintain pressure in the reservoir thus providing an efficient means for using this water.

Slop Oil Recovery

The Slop Oil Recovery utility recycles liquids from the open drain system in the CPF to the Produced Water Treating and Injection utility.

The sumps throughout the CPF collect liquids from equipment open drains and floor drains. These liquids are then pumped to produced water skim tank T-201 in the Produced Water Treating and Injection utility.

Fuel Gas Chilling and Distribution

The purpose of the Fuel Gas Distribution utility is to supply high pressure gas to the Field for gas lift, fuel gas for use by Enbridge, fuel gas for power generating, and low pressure fuel gas for CPF use. The gas is chilled to lower its dew point thus lowering the propane content so that it can be used as fuel gas. This utility then distributes the fuel gas at the required pressures.

Waste Heat Recovery Unit

The Waste Heat Recovery Unit captures waste heat from the turbines exhaust stacks to reduce the amount of natural gas needed to meet current CPF process heating requirements.

4.3.8.3 CPF Operations

Flaring

In addition to the major processes and utility operations noted in Sections 4.3.8.1 and 4.3.8.2 above, flaring is also an integral part of operations at the CPF. A flare stack is located north of the CPR.

The flare has a continuous pilot in case an unforeseen upset or emergency shutdown (ESD) of the CPF occurs. In this circumstance, the CPF is depressurized (vessels, lines, etc.) and all gases directed to flare to be combusted and released in a safe manner. In addition to providing for the safe release of incoming gas production from the Field during periods of upset or ESD, flaring is also used during CPF turnarounds and planned maintenance activities. All of these flaring operations are managed within the context of comprehensive monitoring and regulatory reporting requirements and protocols.

Routine Operations Support and Maintenance Activities

Imperial is required to conduct inspections of the islands and carry out maintenance work as a condition of the Water Licence and/or NEB requirements. Imperial conducts inspections of the artificial islands and natural islands including bathymetric surveys of associated underwater infrastructure (i.e., flowlines). These surveys provide information on the depth of the flowline corridors relative to the river bottom.

Based on the inspection work completed, Imperial prepares evaluations for the repair and maintenance work required to maintain the structural integrity of its islands. This information is submitted with a schedule for completing the work to the SLWB on an annual basis. Details of Imperial's assessment and maintenance activities related to the integrity of the mainland dock, natural islands, and artificial islands are included in the Annual Break Up records submitted to the SLWB.

In addition to the regular inspection and maintenance work completed on the islands, Imperial also conducts a variety of other support and maintenance activities on a regular basis. These activities include:

- pre and post break-up maintenance;

- dock and landing repairs;
- Artificial Island, Goose Island Terminal, Bear Island Terminal repairs;
- bunker repairs;
- road and ditch maintenance;
- ongoing helicopter support;
- construction and maintenance of winter ice roads to the islands;
- maintenance and use of boats in support of field activities;
- maintenance around bridges, culverts and banks near watercourses;
- maintenance on equipment and flowlines (above and below ground);
- refuelling operations via the refuelling dock; and
- plant cooling water Settling Pond cleaning.

Periodic maintenance of the Settling Pond requires cooling water to be diverted to the retention area so the pond can be cleaned.

4.3.8.4 Imperial Wells and Drilling Waste Management (2004 - 2012)

As noted previously, Imperial completed a major expansion of its Operations in the 1980s. Over the past 10 years, there has been less drilling activity. Table 4-2 summarizes the drilling activity that has occurred since.

Table 4-2: Summary of Drilling Activity

Well Name	Spud (Drilling Start) Date	Rig Release Date	NAD 27 Latitude	NAD 27 Longitude
Norman Wells M-50-1X	4 July 2008	28 August 2008	+65°15’24.1”	-126°51’56.4”
Norman Wells N-13X	15 September 2008	28 September 2008	+65°16’33.4”	-126°56’26.6”
Norman Wells N-50X	3 August 2009	21 September 2009	+65°15’24.1”	-126°51’56.4”
Norman Wells O-42X	26 August 2009	28 September 2009	+65°15’24.4”	-126°51’57.4”
Norman Wells M-50-2X	8 July 2009	22 October 2009	+65°15’24.1”	-126°51’56.4”

Since 2007, the management of drilling waste no longer uses sumps for the final disposal of spent drilling muds. During the last drilling program in 2009, fluids were tested and transported to the F-31X Treatment and Injection Facility, and spent drilling muds were shipped south for disposal at a Licenced waste management facility.

4.4 Land Description and Ownership

The Proven Area was formed through an agreement between Imperial and His Majesty the King in the right of Canada on 21 July 1944. The Proven Area is situated on Federal Crown Lands, Territorial Lands and lands owned by Imperial. The distribution of the Proven Area lands amongst these categories is shown on Figure 4-8 and a description of the leased parcels is provided in Table 4-3. Territorial land is administered by MACA. Federal Crown lands are administered by AANDC (Imperial 2013e).

1 : 50000

Source: GNWT Community on-line Atlas (http://atlas.lands.gov.nt.ca)
(Note: Modified to show the four Southernmost artificial islands as Federal Parcels)

CLIENT IMPERIAL OIL LIMITED	DWN BY: MDDS CHK'D BY: BG/CW	PROJECT NORMAN WELLS CLOSURE AND RECLAMATION PLAN	REV. NO.: A DATE: NOV. 2015
amec foster wheeler	DATUM: - PROJECTION: - SCALE: AS SHOWN	TITLE PA LAND OWNERSHIP	PROJECT NO: CC4058.300 FIGURE No. FIGURE 4-8

Table 4-3: Norman Wells Leases

Location	Lessor	Date	Term	Imperial SNT File #	Type
Mainland Plant Site	Commissioner of the NWT	13 August 2009	30 years	0043	Mainland Lease
Artificial Island 1	INAC	15 November 1982	30 years	00091	Note: new lease currently being negotiated for 30 year term
Artificial Island 2	INAC	15 November 1982	30 years	00092	Note: new lease currently being negotiated for 30 year term
Artificial Island 3	INAC	15 November 1982	30 years	00093	Note: new lease currently being negotiated for 30 year term
Artificial Island 4	INAC	15 November 1982	30 years	00094	Note: new lease currently being negotiated for 30 year term
Artificial Island 5	INAC	15 November 1982	30 years	00095	Note: new lease currently being negotiated for 30 year term
Artificial Island 6	INAC	15 November 1982	30 years	00096	Note: new lease currently being negotiated for 30 year term
West Marina Dock	INAC	16 December 2009	30 years	00135	Water Lot Dock

4.5 Current Approvals and Permits

A land use permit from the SLWB is not required for the Operations as the majority of the Norman Wells Proven Area lies within the Town of Norman Wells community boundary, which is exempt from the requirements of the Mackenzie Valley Land Use Regulations (Section 4 [b]).

In addition to its Water Licence, Imperial also holds a variety of other Licences, permits and permissions from other regulators with jurisdiction over various aspects of the Operations. These regulators include the NEB, DFO, Transport Canada and GNWT. The approvals issued by these regulators include permits and Licences regulating water use, waste management, operation of wells and facilities, and maintenance of docks, amongst others. Imperial also holds a number of other comparatively minor permits, Licences and registrations (e.g., transportation of dangerous goods permits, boat registrations, electrical permits) relating to regular day to day operations of the facility (Imperial 2013e).

5.0 PERMANENT CLOSURE AND RECLAMATION

The C&R Plan that has been developed for the Operations' Proven Area is outlined in this section. This section provides:

- a discussion of the Project Closure objectives and criteria, and the general planning principles that they were grounded in;
- a general overview of the C&R Strategy and Plan presented in an integrated fashion for the Proven Area as a whole;
- a summary of the soil material quantities that drove development of key plan components and a discussion of their basis and derivation;
- an assessment of the C&R strategic alternatives at the Proven Area level that outlines the basic rationales for selecting the proposed C&R strategy;
- more focused, component specific descriptions of proposed C&R activity;
- a discussion of the general earth materials management plan that is a core component of the general C&R strategy; and
- a presentation, again at the Proven Area level, of the monitoring, maintenance, reporting and Adaptive Management requirements that are anticipated following execution of the proposed C&R activity.

5.1 Definition of Permanent Closure and Reclamation

Permanent closure refers to the final closure of the Operations with no foreseeable intent by Imperial to return to production of oil and gas on the Proven Area. Addressing the post closure objectives that have been established for the Proven Area will require the development of management facilities or protocols that will be operated or applied indefinitely following initial execution of the C&R Plan. Imperial intends to address these requirements, either directly or through community and/or commercial partners, for as long as they are required post closure.

5.2 Closure Objectives and Criteria

5.2.1 General Planning Principles

Early in the C&R planning process, Imperial outlined a set of general principles that described the philosophies and boundary conditions that were anticipated to influence subsequent planning activities. The following statements of general principles guided the development of project objectives and criteria, and the selection of strategies, methods and technologies forming the basis of an integrated C&R Plan for the Norman Wells Proven Area. These principles, or driving criteria, were selected with a view to supporting the development of the best value C&R strategy that could be defended as satisfying those technical and social outcomes that stakeholders will expect the Plan to deliver.

- Minimizing Post Remediation Land Use Restrictions: The intent here is to mitigate environmental liabilities in ways that maximize the long term utility of the lands involved. In practice, this means removing or mitigating environmental contaminants to levels compatible with the anticipated future land use.
- Consolidation of Environmental Liabilities: Minimizing land use restrictions at a site as large and complex as the Norman Wells Proven Area will require the consolidation of environmental liabilities. Restrictions related to disparate contaminant sources can be mitigated most cost effectively by consolidating them within dedicated management areas that limit the overall footprint of impact.
- Commitment to Long Term Management: The Norman Wells Proven Area includes some contaminant areas that, by their nature, will require long term in-situ management. These are areas with contaminant sources for which a reliable, permanent, point in time remediation technology is not available, or for which the costs of short term, permanent remediation greatly exceed long term in-situ management. It is recognized that managing liabilities in-situ over the long term requires the development and application of management and financial structures that must survive closure of the Operations. Imperial will reconcile this planning principle with the "no long term active care" principle specified in the MVLWB Guidelines (see Section 2.3) by limiting post closure management requirements to those linked inherently with sustaining the property in its reclaimed state. Long term management will not involve activities that indefinitely defer the closure and reclamation of facilities or lands on the Proven Area.
- Commitment to Adaptive Management: Adaptive Management refers to the application of mitigation strategies in response to the observed performance outcomes provided by a remediation plan and/or management system. It is particularly relevant in the context of complex remediation plans/systems for which reliable predictions of long term performance are difficult, unreliable or inconclusive. Rather than relying entirely on prediction, the proponent commits to adjusting the elements of a remedial system on the basis of the performance actually delivered. Committing to Adaptive Management is similar to, and often integrated with, commitments to long term liability management areas in that a requirement to develop and maintain management systems that survive a proponent's tenancy on the site is created. Again, given the scale and complexity of the environmental liability portfolio at Norman Wells, Adaptive Management proposals may be preferred over comprehensive, costly and potentially inconclusive efforts at predicting C&R outcomes.
- Soil Treatment Philosophy: Contaminated soils should be treated only if it can be reliably predicted that the material produced can be used without further monitoring, or without restrictions beyond those associated with the land use prescribed for the area in question. If these outcomes cannot be assured by the performance limits of the technology, it will likely be more cost effective to manage these soils as part of the non-treatable component of the contaminated soil inventory.

- Free Product and Groundwater Recovery Philosophy: Free hydrocarbon liquids and/or contaminated groundwaters will be recovered if the effort can be reliably predicted to completely and permanently mitigate the associated environmental liabilities. In any case, liquids requiring capture during the operation of a hydrodynamic containment system will be recovered.
- Dismantling and Demolition (D&D) Materials Disposition Philosophy: Materials produced (i.e. Industrial on the Mainland) by the dismantling and/or demolition of facility structures will be recycled or reused when and where the materials have a market value sufficient to cover the costs of cleaning, preparation, handling and off-site disposition (i.e., where there are natural market drivers to safely relocate the materials off-site). In all other circumstances, D&D materials will be included with the inventory of materials on-site requiring long term management.
- Hazardous Materials Disposition Philosophy: Soils and other materials categorized as hazardous by applicable regulation will be directed to dedicated long term management facilities on-site that are integrated appropriately with the broader site management plan, unless the costs of developing and operating these dedicated facilities is greater than the costs of disposition to existing, third party waste management facilities.
- Land Restoration Philosophy: Reclamation guidelines will be interpreted to provide general equivalency in the aesthetics and utility of reclaimed lands, not necessarily restoration to pre-development conditions or direct equivalency with adjacent land uses. Soil profile restoration concepts will be constrained by the local availability of organic materials and/or amendments (e.g., topsoils) and desired performance and/or aesthetic outcomes may require the adoption of Adaptive Management philosophies in the development of surface reclamation plans.
- Application of Proven Methods: This refers to the application of methods that are known, or are judged likely, to be feasible at the Norman Wells Proven Area. In short, this means that there needs to be confidence that the combination of methods and equipment proposed to execute a C&R Plan are appropriate for this setting.
- The Safety Criterion: This refers to the application of methods consistent with recognized standards of construction health and safety. This criterion acknowledges that it must be possible to execute the proposed plan safely. This may be self-evident, but could have a significant influence on the detailed development of specific methods for key scope areas (e.g., the excavation of contaminated materials in geotechnically unstable areas).

5.2.2 Project Component Descriptions

The starting point for Component-Specific Closure Objective determination was the selection of appropriate Closure Components. In consideration of the Closure Objective definition provided in the MVLWB/AANDC Guidelines (i.e., *"…describe what the selected closure activity aims to achieve…and allow for the development of closure criteria*"), selection of Closure Components was based on two primary criteria:

1. Closure Components that are broad enough to accommodate further assessment of preferred closure activities throughout the closure and reclamation planning and engagement process; and
2. Closure Components that are detailed enough to allow for some interim refinement of closure criteria.

It is pertinent to note that the Guidelines do not provide an explicit definition of 'Closure Component'. Section 3.3 suggests individual Closure Components for Mine Sites which, as defined, do not necessarily align well with the Operations' setting. However, the Closure Components selected for the Operations do align with the suggested mine site Closure Components when the mine site components are more broadly grouped, for example:

- surface vs. subsurface '*workings*';
- activity/geographic-specific areas, features; and
- facility, infrastructure and material types.

Following is an overview of the Closure Components selected for the Operations' C&R Plan:

- Mainland: the developed areas on the north side of the Mackenzie River that include the Central Processing Facility, the former refinery and Tank Farm areas, the sumps and all of the associated ancillary facilities and infrastructure;
- Natural Islands: specifically, Goose, Bear and Frenchy's Islands;
- Artificial Islands: the production platforms constructed within the Mackenzie River channel by Imperial;
- Natural Watercourses: the river itself as well as Bosworth Creek;
- Surface Buildings and Equipment: includes all of the above grade equipment, buildings and other structures throughout the Proven Area and their associated foundations;
- Subsurface Infrastructure: includes all of the utilities, pipelines and/or other infrastructure below grade; and
- Wellbores: refers specifically to the current and former Imperial producing wells that will need to be abandoned prior to, or during, closure.

5.2.3 Component Objectives

The component specific objectives developed for the Operations' C&R Plan on the basis of the general planning principles described above are outlined in Table 5-1. This table provides individual objectives for each of the media relevant for the component in question. Each objective is accompanied by a description of the criteria proposed to define if the objective has been met, and an overview of the actions and measurements that will be completed to assess compliance with criteria.

Table 5-1
Imperial Norman Wells Operations - Interim Closure and Reclamation Plan
Component-Specific Objectives and Criteria

Component	Media	Objective	Criteria	Actions-Measurements
All Components	*Overarching Values*	Landscape closed and reclaimed in a manner that reflects consultation with community members and associated traditional knowledge and use	Traditional knowledge and use information consistently updated through consultation with community members and incorporated in project schedule, and footprint	Documentation of how traditional knowledge and use has been considered in project planning and scheduling
All Components	Overarching Values	Removal or mitigation of physical and chemical hazards	Inspection by a qualified professional to ensure no unmitigated risks on reclaimed land	Documentation and sign-off by qualified professional(s)
All Components	Overarching Values	Incremental disturbance of land required to support closure and reclamation activity is minimized	Closed and reclaimed footprint contained to existing Proven Area, unless otherwise approved	Post-closure assessment by qualified professionals
All Components	Overarching Values	Compliance with legal, regulatory and corporate obligations pertaining to post-closure and reclamation conditions	Adhere to post-closure and reclamation assessment and monitoring plans	Post-closure and reclamation reporting and documented regulatory reviews
		Closed and reclaimed sites that are compatible with requirements for safe navigation of the Mackenzie River	Compliance with applicable Transport Canada regulations and other appropriate regulatory standards and guidelines for safe navigability	Inspection and documentation by qualified professional(s) of final artificial island status for adherence to applicable Transport Canada and other appropriate regulatory standards and guidelines
All Components	Overarching Values	Archaeological and historically significant sites identified by entities such as the Prince of Wales Northern Heritage Centre, Norman Wells Historical Society, regional Land Corporations and Secretariat are protected and preserved	No significant impact on archaeological or historical resources	Inspection of archaeological and historically significant sites by qualified professionals, with input from community members as appropriate, to verify and document avoidance and/or protection
Mainland	*Air*	Dust levels at the closed and reclaimed site safe for people, vegetation, wildlife, and aquatic life	Dust/total suspended particulate levels that meet appropriate *NWT ENR Guideline for Ambient Air Quality Standards in the Northwest Territories*	Monitoring of dust levels by qualified professionals
	Land	Soil that is safe for people and the environment and compatible with the defined future land use	Remediated soils that meet: 1. CCME criteria suitable for Industrial Land Use, or site-specific risk based criteria (as appropriate for future land and water use and protection of site-specific human and ecological receptors); or 2. If greater, background conditions	Confirmatory sampling by qualified professionals
		Landscape that is physically stable, safe and generally compatible with the surrounding natural area	Satisfactory final inspection by qualified professional engineers	Post-closure assessment and documentation by qualified professionals
	Water	Water quality that is safe for humans, wildlife and aquatic life	Surface water and groundwater quality (at the final receptor or point of use) that meets: 1. CCME guidelines, or site-specific risk based criteria (as appropriate for future water use and protection of site-specific human and ecological receptors); or 2. If greater, background water quality	Surface water and groundwater quality monitoring, at final receptor and/or point of use locations, by qualified professionals
		Hydrology and drainage of the reclaimed land surface consistent with the character of the local watershed and appropriate to the defined land use	Surface contours that promote drainage consistent with natural drainage patterns	Post-reclamation monitoring of surface water drainage by qualified professionals
	Wildlife	Terrain restoration to allow safe utilization and passage by terrestrial wildlife	Safe use of formerly disturbed areas by wildlife within the defined future land use	Wildlife monitoring by qualified individuals
Natural Islands	*Air*	Dust levels at the closed and reclaimed site safe for people, vegetation, wildlife, and aquatic life	Dust/total suspended particulate levels that meet appropriate *NWT ENR Guideline for Ambient Air Quality Standards in the Northwest Territories*	Monitoring of dust levels by qualified professionals
Natural Islands	*Land*	Soil that is safe for people and the environment and compatible with the defined future land use	Remediated soils that meet: 1. CCME criteria suitable for Parkland Land Use, or site-specific risk based criteria (as appropriate for future land and water use and protection of site-specific human and ecological receptors); or 2. If greater, background conditions	Confirmatory sampling by qualified professionals
Natural Islands	Land	Closed and reclaimed landscape that is physically stable, safe and generally compatible with the surrounding natural area	Satisfactory final inspection by qualified professional engineers	Post-closure assessment and documentation by qualified professionals
Natural Islands	*Water*	Water quality that is safe for humans, wildlife and aquatic life	Surface water and groundwater quality (at the final receptor or point of use) that meets: 1. CCME guidelines, or site-specific risk based criteria (as appropriate for future water use and protection of site-specific human and ecological receptors); or 2. If greater, background water quality	Surface water and groundwater quality monitoring, at final receptor and/or point of use locations, by qualified professionals
Natural Islands	Water	Hydrology and drainage of the reclaimed land surface consistent with the character of the local watershed and appropriate to the defined land use	Surface contours and substrate types that promote drainage generally consistent with pre-development drainage patterns	Post-reclamation monitoring of surface water drainage by qualified professionals
Natural Islands	*Wildlife*	Terrain restoration to allow safe utilization and passage by terrestrial wildlife	Safe use of formerly disturbed areas by wildlife within the defined future land use	Wildlife monitoring by qualified individuals
Artificial Islands	*Air*	Dust levels at the closed and reclaimed site safe for people, vegetation, wildlife, and aquatic life	Dust/total suspended particulate levels that meet appropriate *NWT ENR Guideline for Ambient Air Quality Standards in the Northwest Territories*	Monitoring of dust levels by qualified professionals
	Land	Soil that is safe for people and the environment and compatible with the defined future land use	Remediated soils that meet: 1. CCME criteria suitable for Parkland Land Use, or site-specific risk based criteria (as appropriate for future land and water use and protection of site-specific human and ecological receptors); or 2. If greater, background conditions	Confirmatory sampling by qualified professionals
		Closed and reclaimed landscape that is physically stable, safe and generally compatible with the surrounding natural area	Satisfactory final inspection by qualified professional engineers	Post-closure assessment and documentation by qualified professionals
	Water	Closed and reclaimed artificial islands that do not cause an adverse effect to Mackenzie River water quality	Surface water and groundwater quality (at representative downstream locations) that meets: 1. CCME guidelines, or site-specific risk based criteria (as appropriate for future water use and protection of site-specific human and ecological receptors); or 2. If greater, background water quality	Surface water quality monitoring, at representative downstream locations, by qualified professionals

Table 5-1
Imperial Norman Wells Operations - Interim Closure and Reclamation Plan
Component-Specific Objectives and Criteria

Component	Media	Objective	Criteria	Actions-Measurements
Natural Watercourses	*Land*	River and creek banks that are stable and compatible with surrounding lands	Satisfactory final inspection by qualified professional engineers and representative project stakeholders	Post-closure assessment and documentation by qualified professionals
	Sediment	River sediment quality that is safe for humans, aquatic life, and fish habitat	Sediment quality downstream of the closed and reclaimed site that meets: 1. CCME criteria , or site-specific risk based criteria (as appropriate for future land and water use and protection of site-specific human and ecological receptors); or 2. If greater, background conditions	Removal of source area contaminants to levels that address criteria for both the source areas and downstream watercourses.
	Water	Water quality that is safe for humans, wildlife, aquatic life, and fish habitat	Surface water quality (at the final receptor or point of use) that meets: 1. CCME guidelines, or site-specific risk based criteria (as appropriate for future water use and protection of site-specific human and ecological receptors); or 2. If greater, background water quality	Surface water and groundwater quality monitoring, at final receptor and/or point of use locations, by qualified professionals
Surface Buildings, Infrastructure and Equipment	*Land*	Above-ground facilities, infrastructure and debris are removed	Facilities, infrastructure and debris are removed at surface	Post-dismantling visual surface inspections and documentation by qualified professionals
	Materials Management	Re-utilization of materials and equipment that retain economic value	Value of materials and equipment (as benefits to the community) demonstrated to be net positive	Monitoring of materials disposal process by qualified professionals
Subsurface Infrastructure	*Land*	Subsurface infrastructure (e.g. flowlines, utilities) is abandoned or removed as appropriate for safe utilization of the defined future land use	Compliance with Canadian Oil and Gas Drilling and Production Regulations and other appropriate regulatory standards and practices for the abandonment of below-ground oil and gas infrastructure	Monitoring and documentation of facility demolition for adherence to materials management plans and environmental and OHS standards
Wellbores	*Land*	Wellbores are abandoned as appropriate for safe utilization of the defined future land use	Compliance with applicable oil & gas production regulations and other appropriate regulatory guidance for the abandonment of below-ground oil and gas infrastructure	Monitoring and documentation of facility demolition for adherence to materials management plans and environmental and OHS standards

A number of these Site-Wide Closure Objectives also apply at the Closure Component level. This overlap with Site-Wide Objectives, where it exists, remains in overall alignment with the definition of Closure Objective in the MVLWB/AANDC Guidelines. There are, however, exceptions where closure and reclamation considerations are unique to a Closure Component. In these cases, distinct Closure Objectives are proposed. These include specific objectives in the following Closure Components and topic areas:

- Artificial Islands: Mackenzie River navigability;
- Natural Watercourses: river/creek banks, and navigability;
- Surface Buildings and Equipment: reutilization of materials and equipment; and
- Wellbores: wellbore abandonment.

5.2.4 Closure Criteria

The MVLWB/AANDC Guidelines define Closure Criteria as "*…standards that measure the success of the selected closure activities in meeting closure objectives…*". In this context, there are Site-Wide Closure Criteria that also apply at a Closure Component level. This overlap with Site-Wide Criteria, where it exists, remains in overall alignment with the definition of Closure Criteria in the Guidelines.

There are exceptions where decisions on final Land Use are unique to a Closure Component or Components and distinct Closure Criteria apply. This is the case for Criteria for Mainland soils (includes reference to *CCME Industrial Land Use criteria*), and Criteria for Natural and Artificial Islands soils (includes reference to *CCME Parkland* criteria). There are also distinct Closure Criteria in other areas linked to the Components in Table 5-1.

Component Criteria include standards/guidelines (e.g., CCME), regulations, and site-specific, risk-based criteria, as well as consideration of background conditions. It is expected that these Component Criteria will be further refined during the closure and reclamation planning process as specific Closure Activities are selected to meet Closure Objectives.

5.3 Impacted Soil Quantities

Amec Foster Wheeler calculated the aerial extent of soil impacts using volume and depth data from the information provided in WorleyParsons (2014a and 2014b). WorleyParsons applied the following CCME Guidelines in these documents:

- Canadian Environmental Quality Guidelines (CCME 2007 and updates); and
- Canada-Wide Standard for Petroleum Hydrocarbons (PHC) in Soil (CCME 2008).

WorleyParsons excluded the protection of potable groundwater exposure pathway because the shallow groundwater beneath the site may contain naturally-occurring hydrocarbons and salts and because of the presence of discontinuous permafrost. For each area of impact identified, WorleyParsons selected the minimum value from the following parameters to estimate the depth of impact:

- depth to groundwater, permafrost, and/or bedrock;
- depth of practical excavation;
- depth of likely contaminant penetration; and/or
- depth of guideline exceedances shown in other data (Phase II information).

WorleyParsons estimated the aerial extent of impact by assuming a clean boundary based on approximately half the distance between locations of confirmed or suspected impact and adjacent clean locations. Table 5-2 summarizes the impacted soil volumes generated by these criteria and assumptions.

The distribution of these volumes is illustrated on Figures 5-1 and 5-2. The aerial extent of impacted soils is shown as circles of various diameters and colours with larger soil volumes represented by progressively larger circles and depth represented by colour. Red circles are indicative of relatively shallow impacts and represent the total source area volume as a circular perimeter extending to 2 m. Similarly, blue circles are indicative of relatively deep impacts and represent source area volumes within circular perimeters extending to 4 m. It is important to note that these figures are rough constructs developed to illustrate the general distribution of contaminant impacts and to support preliminary facility planning and siting. The actual distribution of contamination for any individual source can vary significantly from this representation.

5.4 Overview of the C&R Strategy Plan

This section provides an integrated presentation of the proposed C&R Plan for the entire Operations' Proven Area. The section provides both a summary of proposed C&R activity and context for subsequent discussions of C&R activity by component. This plan summary is accompanied by some of the technical background that went into developing key elements of the proposal. Finally, the section provides a review of alternatives that were considered at an integrated Proven Area level. This high level discussion supplements the more focused, component specific considerations of alternatives that are provided later.

5.4.1 Plan Description

The central elements of the proposed C&R Plan for the Operations are as follows:

- Impacted soils remaining on the Proven Area at closure will be treated and reused on-site or consolidated into a single Long Term Management Facility or LTMF.
- Impacted soils remediated prior to closure as part of Progressive Reclamation efforts will be managed on-site via treatment and/or containment.
- The LTMF will be sited in a dedicated portion of the Mainland Central area.
- The LTMF will incorporate containment features similar to those used in contemporary secure landfills (i.e., geosynthetically based liner and cover systems; leachate collection, management and disposition capabilities).

Table 5-2: Norman Wells 2014 Soil Quantity Summary (from AMEC, 2014)

Area	CCME Industrial on Mainland Parkland on Islands			Total Volume (m3)
	UPPER 2 m	UPPER 2 m	UPPER 2 m	
	Light Hydrocarbon Volumes	Heavy Hydrocarbons Volumes	Mixed Hydrocarbons, Metal and/or Salt Volumes	
Entire Site	-	3,780	-	**3,780**
Mainland Wells	1,912	1,550	10,964	**14,426**
Mainland West	13,663	18,304	13,495	**45,462**
Mainland Central	51,967	15,375	8,106	**75,448**
Mainland East	169,939	14,086	2,475	**186,500**
Mainland Sumps	-	-	29,775	**29,775**
Artificial Islands	1,987	2,030	3,566	**7,583**
Goose Island	4,712	1,338	3,159	**9,209**
Bear Island Sumps	-	-	31,375	**31,375**
Bear and Frenchy's Islands	17,300	2,475	12,225	**32,000**
Total	**261,480**	**58,938**	**115,140**	**435,558**

Area	Industrial on Mainland Parkland on Islands			Total
	SUBSURFACE SOILS	SUBSURFACE SOILS	SUBSURFACE SOILS	
	Light Hydrocarbon Volumes	Heavy Hydrocarbons Volumes	Mixed Hydrocarbons, Metal and/or Salt Volumes	
Entire Site	-	-	-	**-**
Mainland Wells	-	-	-	**-**
Mainland West	-	6,100	8,400	**14,500**
Mainland Central	9,400	4,550	7,500	**21,450**
Mainland East	35,060	6,750	3,125	**44,935**
Mainland Sumps	-	-	46,750	**46,750**
Artificial Islands	-	-	-	**-**
Goose Island	1,250	-	-	**1,250**
Bear Island Sumps	-	-	99,400	**99,400**
Bear and Frenchy's Islands	5,575	-	-	**5,575**
Total	**51,285**	**17,400**	**165,175**	**233,860**

Total Upper 2 m and Subsurface	**312,765**	**76,338**	**280,315**	**669,418**

0m 200 400 600 800 1000

1 : 25000

CLIENT: IMPERIAL OIL LIMITED	DWN BY: MDDS	PROJECT: NORMAN WELLS INTERIM CLOSURE AND RECLAMATION PLAN	DATE: DEC. 2015
amec foster wheeler	CHK'D BY: BG		PROJECT No.: CC4058.300
	DATUM: NAD 27	TITLE: QUANTITY DISTRIBUTION MAP NWO PA INDUSTRIAL ON THE MAINLAND / PARKLAND ON THE ISLANDS	REV. No.: A
	PROJECTION: ZONE 99		FIGURE No.: FIGURE 5-1
	SCALE: AS SHOWN		

CLIENT:

IMPERIAL OIL LIMITED

amec foster wheeler

DWN BY:	MDDS
CHK'D BY:	BG
DATUM:	NAD 27
PROJECTION:	ZONE 99
SCALE:	AS SHOWN

PROJECT:

NORMAN WELLS INTERIM CLOSURE AND RECLAMATION PLAN

TITLE:

QUANTITY DISTRIBUTION MAP MAINLAND INDUSTRIAL ON THE MAINLAND / PARKLAND ON THE ISLANDS

DATE:	DEC. 2015
PROJECT No.:	CC4058.300
REV. No.:	A
FIGURE No.:	FIGURE 5-2

- Following LTMF completion, leachate that accumulates within the structure will be treated in a dedicated plant to meet prescribed surface water quality criteria prior to discharge to the local watershed.
- There will be a small number of Long Term Management Areas, or LTMAs as defined below. These LTMAs will be geographically and operationally distinct from the LTMF. The small number of LTMAs makes geographic separation between LTMAs and the LTMF technically and economically viable.
- Impacted source areas will be remediated to CCME criteria (Industrial for the Mainland; Parkland for the balance of the Proven Area) or site specific, risk based alternates.
- Treatment will be limited to that proportion of soils for which proven and available technologies can reliably produce soils meeting CCME Industrial criteria at costs that are competitive with LTMF disposition.
- Off-site disposition of significant proportions of the impacted soil inventory at closure will not form part of the plan because the associated unit costs are much higher than LTMF disposition.
- Materials will be relocated to the LTMF, and the source areas backfilled, over an execution schedule that will likely extend over a period of years to accommodate the associated wellbore abandonment scope. Materials from the islands will be relocated to the Mainland via an ice road.
- C&R activity for the artificial islands (apart from downhole abandonment and above grade facilities dismantling and/or demolition) will be comprised of the removal of impacted soils and potentially, the physical island armour. The scope and impact of armour removal will be assessed and further defined on the basis of a pending study of the river’s erosional dynamics.
- Impacted soil excavations (apart from the artificial islands) will be backfilled using the most cost effective source of clean overburden and/or shale available and appropriate for the area in question. In most cases, this means excavations will be backfilled with locally available shales. In some areas, it will be more cost effective to use locally borrowed, clean overburdens.
- Residual shale volumes that are dispersed geographically will be consolidated locally into landforms shaped to meet the aesthetic objectives and criteria established for reclamation.
- Exposed overburden surfaces within the disturbed footprint will be contoured and prepared appropriately and then left to revegetate naturally, or actively revegetated with suitable combinations of seeding, fertilizers and plantings (the selection of natural re-establishment or active revegetation will be made on an area specific basis).
- Above grade facilities will be removed using conventional methods of decommissioning, dismantling and/or demolition. The disposition of dismantling and demolition materials and wastes will be market driven. Materials or wastes with no net market value will be directed to the LTMF.

- Subsurface infrastructure will be removed to an elevation below the root zone or the lower limit of anticipated erosion, with the remaining portions of the infrastructure cleaned (to levels consistent with the proposed future land use and applicable laws, regulations and guidelines), capped (where applicable), and left in place.

The above elements are reflected in the illustration of the Operations' Proven Area post closure that is provided on Figure 5-3. This figure shows:

- the proposed LTMF in the current Mainland Sumps area;
- the outlines of currently disturbed areas that will be remediated by relocating impacted soils to the LTMF and then revegetating (by natural invasion or active means) exposed backfill or overburden surfaces to grass, or by planting native tree saplings in select areas (typically at the edge of the reclaimed areas to provide an aesthetic transition between grassed areas and adjacent wooded lands); and
- the locations of island GIT and BIT structures that will be recontoured into landformed features accommodating the shale volumes removed from local road alignments.

5.4.2 Basis of Key Plan Elements

The following sections outline some of the key design issues and criteria considered in the development of the C&R Plan's central features.

5.4.2.1 Long Term Management Areas (LTMAs)

.1 Definition and Significance

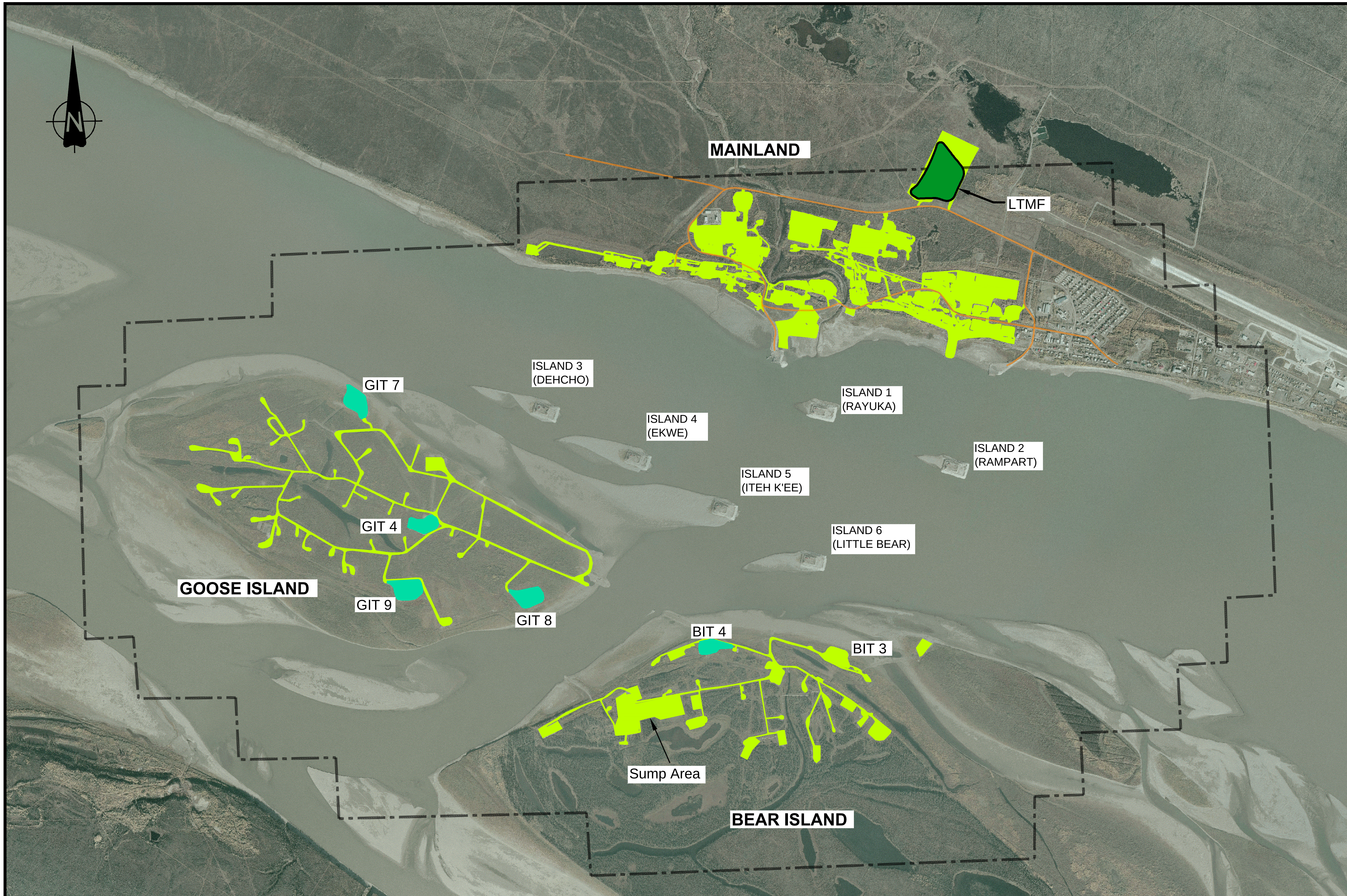
For the purposes of this C&R Plan, Long Term Management Areas (or LTMAs) are contaminant sources or zones exhibiting liabilities that, by their nature, will likely require long term, or indefinite, in-situ management. An LTMA is a source for which reliable, permanent, point in time remediation technology is not available, or for which the remediation costs significantly exceed those for indefinite in-situ management. LTMAs are important because they could influence the location, and potentially the design, of containment structures that may feature in the C&R Plan, particularly in light of the "Consolidation of Environmental Liabilities" principle that is also outlined in Section 5.2.1. LTMA locations become starting points for the consideration of sites appropriate for the consolidation of other liabilities within the Imperial Proven Area.

.2 Identification of LTMAs

Site Characterization Review

A prerequisite for identifying LTMAs was a comprehensive understanding of the characterization data that is available for the property. The C&R team ensured this understanding was applied to the effort by:

- reviewing the large body of characterization documents that have been compiled for the site over the years (particularly Worley Parsons 2014a, 2014b, and 2014c);



LEGEND

- Proven Area Boundary
- Post-Closure Road Network
- LTMF Structure
- Re-graded GIT and BIT Surfaces
- Reclaimed Areas

0m 300 600 900 1200

1 : 30000

CLIENT: IMPERIAL OIL LIMITED	DWN BY: MDDS	PROJECT: NORMAN WELLS INTERIM CLOSURE AND RECLAMATION PLAN	DATE: OCT. 2015
amec foster wheeler	CHK'D BY: BG		PROJECT No.: CC4058.300
	DATUM: -	TITLE: MAINLAND, GOOSE AND BEAR ISLAND OVERALL RECLAMATION PLAN	REV. No.: A
	PROJECTION: -		FIGURE No.: FIGURE 5-3
	SCALE: AS SHOWN		

- compiling inputs from Amec Foster Wheeler staff familiar with site conditions via ongoing involvement with environmental liability assessments for the property; and
- facilitating Amec Foster Wheeler team interactions and discussions around characterization data and the associated implications for liability mitigation and/or management.

In addition, Amec Foster Wheeler solicited inputs from WorleyParsons staff who have had long involvements in site characterization activities and interim soil treatment and/or remediation efforts. These inputs were received via meetings and supplementary communications among Amec Foster Wheeler and WorleyParsons staff.

LTMA Attributes

LTMA identification efforts focused on liabilities that are known, or have the potential to be technically and/or economically impractical to permanently remediate with certainty. Candidate sites or liabilities were areas that:

- involved contaminants that have migrated into bedrock fractures and that cannot be completely and reliably removed over any predictable timelines; or
- involved contaminants that cannot be physically excavated and relocated using either conventional earth moving equipment, or specialized equipment for which mobilization to Norman Wells is feasible.

Outcomes

Broadly speaking, the number of LTMAs identified are limited because of the following basic characteristics of the Imperial Proven Area and its associated operations:

- bedrock and, intermittently, permafrost occur at relatively shallow depths that have limited the vertical migration of contaminants;
- the limited overburden depths make relocation of impacted materials using conventional earth moving equipment feasible;
- high volume and/or concentrated zones of impacted material are limited to a comparatively small number of source areas located primarily in the Mainland Central and East areas; and
- there are many additional, discrete contaminant source areas across the Proven Area, but they tend to be limited aerially and comparatively shallow (i.e., amenable to relocation).

Note that natural hydrocarbon and salt seep/discharge areas have not been considered as potential LTMAs. This assumes that technical efforts to distinguish between natural and anthropogenic impacts are successful and that these distinctions can be effectively communicated to stakeholders. It is acknowledged that there are technical complexities associated with making these distinctions that may not be fully addressed before or during closure operations. It may be necessary to adjust later iterations of the C&R Plan, in some instances, should this be the case.

The review of site characterization data identified only two areas that would likely be described as LTMAs and the footprint of these areas is comparatively small (in the range of 3,000 m^2) (see Section 5.5.1.3.1). This assessment may change as the technical and economic elements of the Plan are developed (both during and after initial C&R Plan preparation), but the current review suggests that LTMA footprints will not be large enough to have a major influence on the location or design of the consolidation and containment structure (LTMF) that features prominently in the C&R Plan. The relatively small LTMA footprints identified to date mean that LTMF designs are driven primarily by requirements for contaminated material excavation, consolidation and containment. These LTMF designs will be more like conventional secure landfills than the hybrid of landfill and in-situ management systems that might have been supported by larger LTMA footprints.

5.4.2.2 Long Term Management Facilities (LTMF)

.1 <u>Concepts</u>

Long Term Management Facilities (LTMFs) are earth based structures engineered to provide for the containment of impacted materials over indefinite timeframes. In the Norman Wells context, an LTMF would be used to manage the proportion of the impacted soil inventory that is not treatable (as defined in Section 6.3.2), and structure dismantling/demolition debris produced during remediation. LTMFs are typically the most viable and flexible of remedial technologies, particularly for relatively remote locations like Norman Wells.

Design Philosophy

Physically, LTMFs are similar to what have been traditionally referred to as secure landfills. The reasons for applying the LTMF descriptor are as follows:

- it reinforces the notion that Imperial's involvement in managing residual liabilities will extend beyond the point in time remedial effort;
- it reinforces the position that differences in facility scope and concept between LTMFs and traditional landfills do exist (primarily that LTMFs are designed to meet the particular containment requirements of the site, project and materials in question) and that prescriptive landfill regulations may, therefore, not always be appropriate and/or necessary given the particulars of the site and project; and
- describing secure landfills as LTMFs is becoming more common, particularly for projects involving large and complex source sites, and there are now relevant precedents in Canada (e.g., the routine development of engineered containment structures in the upstream oil and gas and mining sectors, and the use of landfills as part of DEW Line remediation programs).

Note that the phrase, "Long Term" in LTMF has no specific definition. Practically, and by precedent, it refers to some form of indefinite oversight and management. It is not intended to convey or imply that an alternate approach to remediation and/or management will be considered at some point in the future (although it is worth noting that, as storage structures, LTMFs are relatively compatible with the future application of breakthrough technologies, because the stored materials are retrievable).

Containment Specifications and Features

The LTMF concepts described herein apply geosynthetically based containment designs. This assumption separates the designs from uncertainties related to the availability, performance and cost of locally available, earth materials. In addition, geosynthetically based designs are proven, and unlikely to introduce a material cost penalty, even if future project development activity identifies attractive local earth alternates.

The general LTMF containment concept is comprised of a base liner system, a cover system, and a leachate collection and management system. The assumed components and configurations of the liner, cover and leachate collection systems are shown on Figure 5-4. The leachate management system is a typical requirement of LTMF designs and is required to collect and remove any excess moisture contents in the materials placed (i.e., beyond the field holding capacities of the soils involved), and to reduce the head or driving force of liquid that would otherwise migrate through any flaws or holes in the base and side slope lining geosynthetics.

The LTMF concept proposed as part of the Operations' C&R Plan assumes that following construction of the LTMF, the leachate collection system would be serviced by a small water treatment plant. The relatively high leachate and runoff volumes generated during LTMF construction would be directed to Imperial's existing wastewater management infrastructure (provided that the LTMF development schedule can be integrated appropriately with the wastewater management system decommissioning schedule). This avoids having to size the ongoing post closure leachate treatment capability to handle volumes that will peak during construction and drop substantially following placement of the LTMF cover. Imperial's obligation to operate and maintain this water treatment capacity would extend indefinitely.

Geometry

The LTMF geometries presented in this section are intended to be representative of technically defensible, industry consistent/compliant and economically viable approaches to facility development. It is useful to note however, that a wide variety of geometries and configurations including developments reflecting contemporary landform concepts could be considered. The associated unit facility costs would likely increase from those described herein (costs generally increase as slopes decline and base footprints expand), but not materially so.

.2 <u>Siting</u>

The LTMAs that have been identified are located, along with a large proportion of the Proven Area's impacted material inventory, in the Mainland Central area bounded by:

- the Bypass Road and Mainland Sumps perimeter to the north;
- Bosworth Creek to the west;
- the Mackenzie River to the south; and
- the Public Works dock to the east.