ABANDONMENT AND RECLAMATION COST ESTIMATE FOR NORMAN WELLS OPERATIONS

Submitted to:

Imperial Oil Environmental Services
Calgary, Alberta

Submitted by:

AMEC Environment & Infrastructure
Calgary, Alberta

September 2014

CE04494

25 September 2014
CE04494

Ms. Melissa Wade
Senior Advisor, Environmental Services
Imperial
237 – 4 Avenue SW
Calgary, AB T2P 3M9

Dear Ms. Wade:

Re: 2014 Abandonment and Reclamation Cost Estimate for Norman Wells Operations

We are pleased to submit our final report presenting abandonment and reclamation (A&R) cost estimates for the Norman Wells Operation. The report describes the data sources, the asset management assumptions and the unit prices that form the basis of the estimate.

We have enjoyed working with you on this project and look forward to assisting you with future assignments. Please feel free to contact the undersigned at 403-387-1798 (chris.wenzel@amec.com) or Mike Panek at 403-387-1666 (mike.panek@amec.com) if you have any questions or comments on the document.

Yours truly,

AMEC Environment & Infrastructure

E. Chris Wenzel, P.L. (Eng.)
Project Manager

ECW/jm

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AMEC is committed to achieving sustainability through balancing economic growth, social responsibility and environmental protection. Learn more at: http://amec.com/aboutus/sustainability.htm.

1.0 INTRODUCTION

1.1 Site Description

Imperial Oil Resources N.T. Limited (Imperial) Norman Wells operation consists of a well field, gathering system, Central Processing Facility (CPF), and related process and ancillary infrastructure. The well field and gathering system are located on the mainland, natural islands (Bear, Frenchy's and Goose Islands) and six artificial islands in the Mackenzie River. Collectively, they are referred to as Norman Wells Operations (NWO).

The project location is shown on Figure 1. Topographic features in the area surrounding Norman Wells are shown on Figure 2.

1.2 Historical Overview

Imperial has been conducting operations at Norman Wells since the 1920s when the first well on the banks of the Mackenzie River east of 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. A producing horizon was found at a depth of 150 m. More extensive drilling in the 1920s and 1930s led to the discovery of the main reservoir at a depth of approximately 400 m.

Between 1920 and 1925, a small refinery was built and operated to process hydrocarbons from the reservoir. Around 1935, the refinery was re-opened and expanded. The refinery remained in operation until 1996 when it was decommissioned and dismantled.

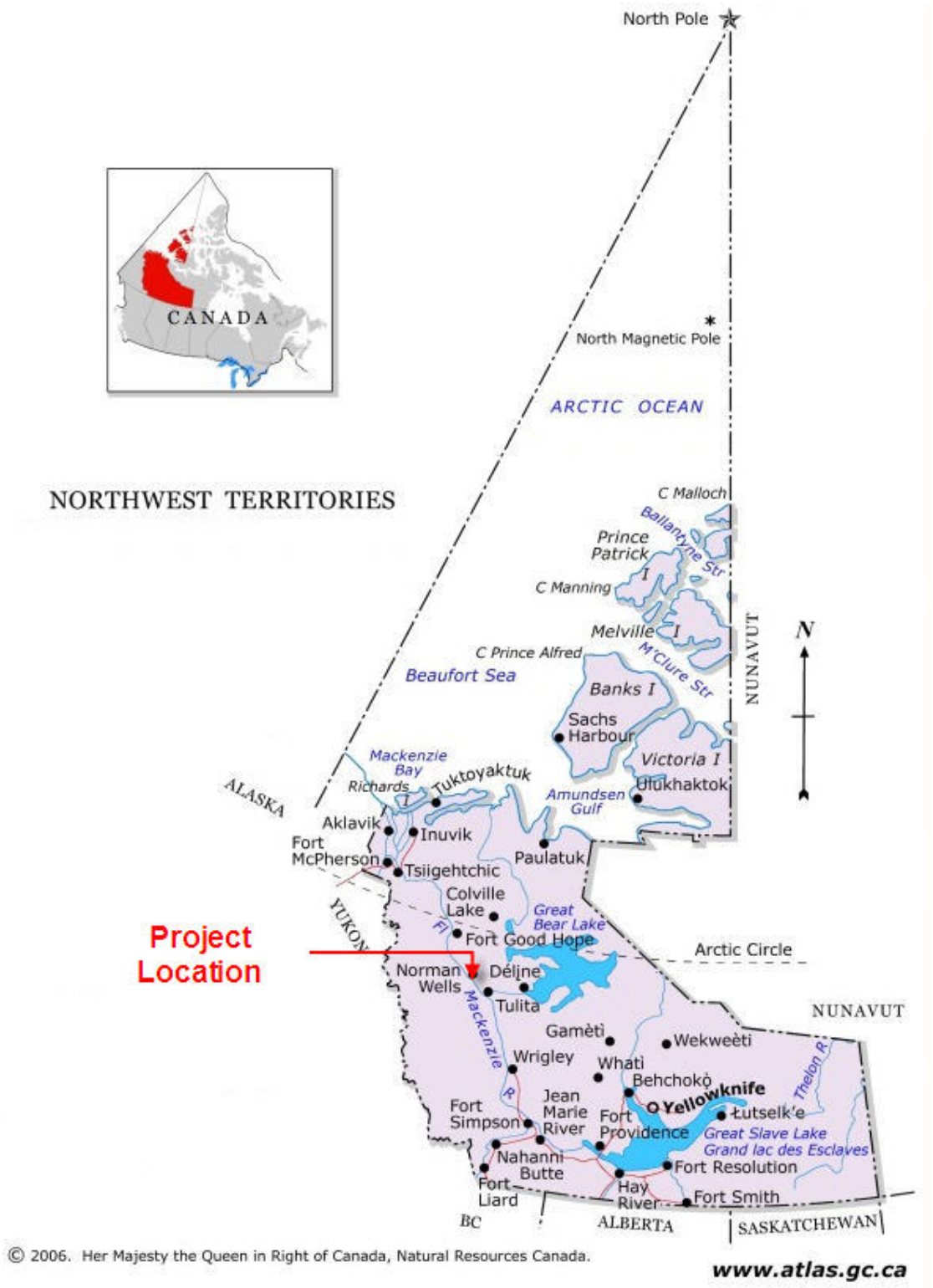
Between 1944 and 1945, the field was further developed in response to the need to supply petroleum to Alaska during and subsequent to the Second World War. Major infrastructure constructed around this time included Batteries #1 and #3 on the mainland and the Bear Island battery. Battery #1 was operational from approximately 1950 to 1983; Battery #3 was operational from the 1940s until 1990 when it was decommissioned. Bear Island Battery was operational from approximately 1950 to 1983.

In the early 1980s, Imperial's NWO underwent a major expansion, which included the construction of the CPF and six artificial islands in the Mackenzie River. A number of additional wells were drilled as part of this expansion.

1.3 Project Objectives

The objective of the work was to produce an estimate of the abandonment and restoration (A&R) costs for the NWO by undertaking the following:

- identifying and quantifying the assets associated with the Norman Wells Operation using information provided by Imperial;
- describing the methods by which Imperial proposes to undertake the abandonment and reclamation (A&R) activities (i.e., decommissioning, dismantling, remediation and reclamation) associated with the assets at time of closure; and



ABANDONMENT AND RECLAMATION COST ESTIMATE FOR NORMAN WELLS OPERATIONS

Project Location

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Figure 1

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NTS Map Sheet 96E, Norman Wells, Northwest Territories

amec		**ABANDONMENT AND RECLAMATION COST ESTIMATE FOR NORMAN WELLS OPERATIONS**		
Imperial Oil Limited		**Site Topography**		
Drawn: MP	Scale: NTS	Date: September 2014	Project No.: CE04494	**Figure: 2**

- developing current cost estimates utilizing the RECLAIM model for A&R of all subject Imperial assets.

1.4 Scope of Work

Imperial contracted AMEC to assist in the development of a liability estimate for their Norman Wells Operation. AMEC's scope of work was outlined via correspondence with Imperial on 25 June 2014 and through subsequent discussions with Imperial. The scope was met by completing the following deliverables:

- a cost estimate for the decommissioning, abandonment, remediation and reclamation of wells, facilities and flowlines;
- calculation of the cost estimate using current data provided by Imperial as follows:
  - ❑ site location and status information for wells, facilities and flowlines;
  - ❑ soil and groundwater quantity estimates; and
  - ❑ disturbed area estimates.
- incorporating unit prices provided within the RECLAIM Model, supplemented where appropriate with pricing information specific to the NWO provided by Imperial;
- a digital cost estimating system designed to:
  - ❑ present all cost estimating data;
  - ❑ incorporate all estimating assumptions; and
  - ❑ provide cost and quantity reports based on RECLAIM Model.
- preparation of a project report.

1.5 Overview of Current Operations

Imperial's NWO is located within an area known as the Proven Area (PA). "Proven Area" means the area described in Schedule "A" to the Proven Area Agreement dated 21 July 1944 between Imperial Oil Limited and His Majesty in the Right of Canada ("the Proven Area Agreement"), as amended from time to time. The Norman Wells PA, as shown on Figure 3, was interpreted using boundaries shown on the Beaufort-Mackenzie Mineral Development Area (BMMDA) web site. The PA 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 NWO includes the following infrastructure:

- 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;
- 383 operating wells and associated access roads;

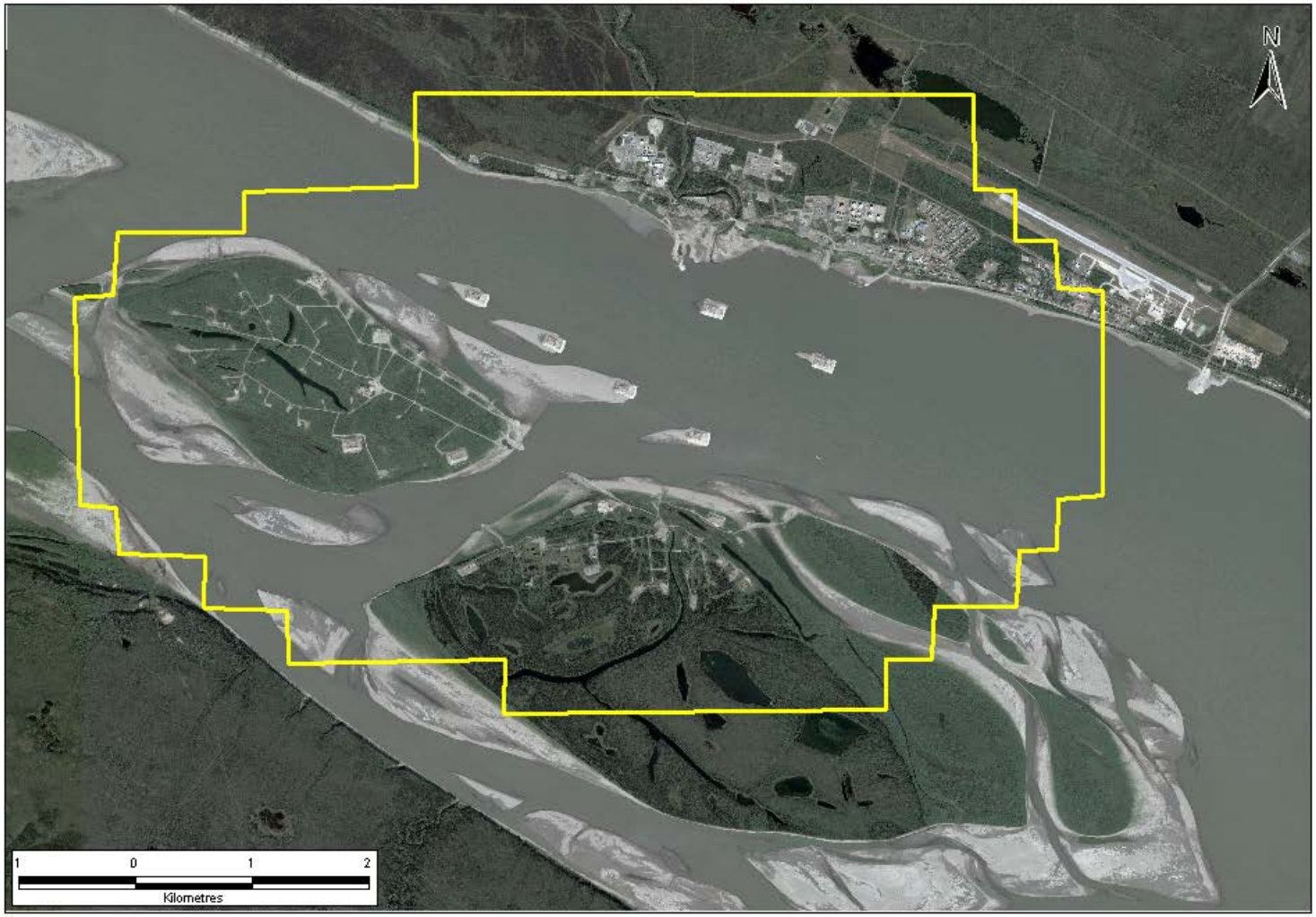


Image: Google Earth, November 2007. Proven Area boundary: interpreted from Beaufort-Mackenzie Mineral Development Area (BMMDA) web site (www.bmmda.nt.ca).

amec		**ABANDONMENT AND RECLAMATION COST ESTIMATE FOR NORMAN WELLS OPERATIONS** **VOLUME 1: BASIS OF ESTIMATE**		
Imperial Oil Limited		**Norman Wells Proven Area**		
Drawn: MP	Scale: NTS	Date: September 2014	Project No.: CE04494	**Figure: 3**

- miscellaneous infrastructure associated with gathering, testing and production;
- helicopter pads, barge and boat landings; and
- bermed areas for the storage of crude oil, hazardous waste, chemicals, methanol, diesel and gasoline.

Production from the field is collected through a gathering system and directed to the CPF. The CPF separates production into gas, oil and produced water. The gas is used to run equipment, inject into the gas lift system (a type of artificial lift used to assist in oil production), and to supply natural gas to the Town of Norman Wells.

Produced water is re-injected to maintain reservoir pressure, and oil is transported south via the Enbridge Pipeline.

1.5.1 Estimate Format

Imperial selected the RECLAIM model as the platform for the liability estimate that is the subject of this report. The RECLAIM Model, developed on the Microsoft Excel platform, was initially developed in 1994 and modified in 2013 for use in estimating security for oil and gas operations. The oil and gas version of the model is RECLAIM Model Ver. 7.0 (RECLAIM Model) developed by Brodie Consulting Ltd. of West Vancouver, BC, on behalf of AANDC.

2.0 ESTIMATE STRUCTURE

2.1 Definitions

This report applies specific terminology that has been adopted by Imperial for the Norman Wells Operation. Definitions are as follows:

- *Project Infrastructure Development* – Project infrastructure required to execute A&R work that is not related specifically to any one A&R activity.
- *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.
- *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.
- *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).
- *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.

2.2 Work Breakdown Structure

2.2.1 RECLAIM Model WBS

The estimate’s work breakdown structure (WBS) defines the various activities and tasks that are required to complete the work and describes how the work is organized. AMEC reported the estimate using the WBS in the RECLAIM Model that, at the highest level, reports costs under the following activities:

- Capital costs:
  - ❑ wells and facilities;
  - ❑ buildings and equipment;
  - ❑ chemicals and contaminated soil management;
  - ❑ construction and operation of on-site landfill;
  - ❑ surface and groundwater management; and
  - ❑ interim care and maintenance.

- Indirect Costs:
  - mobilization/demobilization;
  - post-closure monitoring and maintenance;
  - engineering;
  - project management;
  - health and safety plans/monitoring & QA/QC; and
  - contingency.

The estimate incorporates a quantity and unit price for each task that is relevant for the Norman Wells Operation. The total liability estimates are simply the sums of all task quantity and unit price extensions. Within the RECLAIM Model, costs are further reported as being associated with land or water.

The WBS modifications completed by AMEC categorize assets according to their geographic location and ownership as discussed below.

2.2.2 Geographic Areas

The estimate data contain information describing the physical location of each asset as follows:

- Mainland;
  - Mainland West;
  - Mainland Central; and
  - Mainland East.
- Bear and Frenchy's Islands;
- Goose Island;
- Artificial Islands:
  - Island 1 (Rayuka);
  - Island 2 (Rampart);
  - Island 3 (Dehcho);
  - Island 4 (Ekwe);
  - Island 5 (Tteh K'eeh); and
  - Island 6 (Little Bear).

2.2.3 Land Division

The geographic areas described above were grouped into land divisions as follows:

- Natural Islands – private;
- Artificial Islands – Canada;
- Mainland – Northwest Territories;

- Wellbores – National Energy Board (NEB); and
- Water (i.e., groundwater and surface water) – Sahtu Land and Water Board (SLWB).

Land Division was determined by the GNWT (NWT Centre for Geomatics) shown on Figure 4. Land Divisions could be subject to change in the future.

2.3 Estimate Assumptions

The Norman Wells liability estimate is based on a set of assumptions made or applied at various levels. The following sections outline assumptions that apply to the estimate as a whole, to the various major A&R activities, and to the detailed work tasks required to complete the A&R work.

2.3.1 General Estimate Assumptions

AMEC assumed that:

- spills and/or other liabilities that might be created in the future (e.g., plume migration, ongoing facility operations) are not considered in the estimate;
- the potential for physical modifications to the facilities (e.g., adding new wells) are not considered in the estimate; and
- credit for salvage value is not included in the estimate.

Imperial's asset management assumptions included:

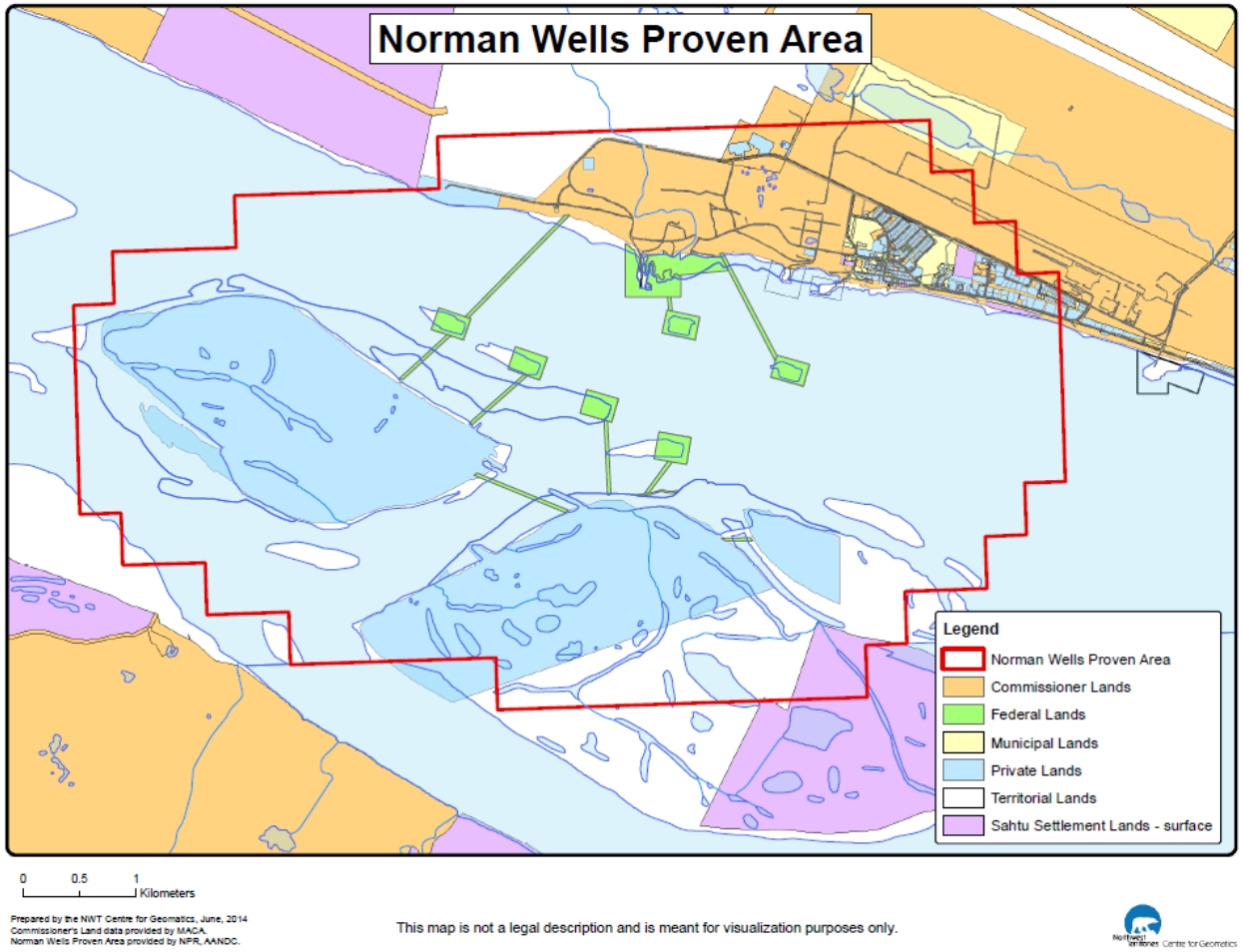
- abandoning underground flowlines in-place using cut & cap procedures;
- excluding removal of the artificial islands;
- construction of a permanent on-site Class II landfill for disposal of soil and demolition debris;
- reclaiming shale utilized in the construction of well sites, access roads and facility in-place; and
- managing and reclaiming drilling waste sumps in-place.

Regulations

- Current operating license requirements, and other regulatory structures, guidelines and philosophies are assumed to apply throughout the specified estimate timeframe.

Resources

- The estimates are based on the cost of having the work completed by a third-party contractor. Contracting, housing, utilities, infrastructure and transportation resources available for use by third parties during the A&R work were assumed to be similar to those currently available, on the premise that A&R work will be initiated roughly coincident with facility shutdown (i.e., even if Imperial did not execute the work, these resources would be available for undertaking A&R activity. It was assumed that mobilization of additional resources would be necessary to supplement locally available, third-party capabilities for some specialized components of A&R activity.



Prepared by the NWT Centre for Geomatics, June 2014.

amec		**ABANDONMENT AND RECLAMATION COST ESTIMATE FOR NORMAN WELLS OPERATIONS**		
Imperial Oil Limited		**Land Division**		
Drawn: MP	Scale: NTS	Date: September 2014	Project No.: CE04494	**Figure: 4**

2.4 Unit Prices

Where available, AMEC applied the unit prices present in the current version of the RECLAIM model. Unit prices in the RECLAIM Model are independent third-party costs (Brodie 2012). Where RECLAIM model unit prices were not available, site-specific unit prices or allowances were developed by Imperial (via data provided by WorleyParsons).

2.5 Indirect Costs

The unit costs are inclusive of equipment, labour, maintenance, fuel, consumables, field supervisor and contractor's profit (Brodie 2012). These direct costs are factored to include provisions for engineering, procurement and construction management, and contingencies.

2.5.1 Applied Factors

Factors for Engineering, Project Management and Health & Safety as a percentage of the contractor unit prices were applied to the estimate. The values shown in Table 1 were specified in the RECLAIM Model.

Table 1: Applied Factors

Activity	Factor (Percent)
Engineering	5%
Project Management	5%
Health & Safety	1%
Bonding / Insurance	1%

2.5.2 Inflation Adjustment

Unit prices in the RECLAIM Model are current to the year 2013. The estimate was adjusted to the 2nd quarter of 2014 using the current Statistics Canada machinery and equipment price indexes for support activities in the mining and oil and gas extraction sectors. The adjustment compared price indexes for the 2nd quarter of 2013 and the 2nd quarter of 2014 to arrive at the factor of 0.52% applied to the estimate (StatCan 2014).

2.5.3 Contingencies

Estimating contingency is often defined, applied and understood in various ways by different organizations. To provide some clarity, this section first defines contingency as it is applied in this estimate, and then describes the basis of the contingency percentage used.

The Association for the Advancement of Cost Engineering (AACE) defines contingency as "an amount added to an estimate to allow for items, conditions or events for which the state, occurrence and/or effect is uncertain and that experience shows will likely result, in aggregate, in additional costs (AACE 2005; as cited in Lawrence 2007)". The need for contingency results from that fact that the set of possible cost outcomes is not normally distributed on a plot of probability versus cost. Contingency is typically applied to bridge the gap between the base and median estimates

In applying this definition of contingency, it is important to acknowledge that (Lawrence, 2007):

- design allowances are not part of contingency;
- contingency is required to ensure a 50/50 likelihood of over or underrun;
- contingency is not the same as estimate accuracy;
- contingency should be expected to be consumed since 50% of the time it will be totally consumed; and
- contingency is not a fund for scope changes since it is related purely to the project scope as estimated.

Contingencies can be established:

1. on the basis of a statistical analysis of cost risks;
2. by applying a predetermined percentage prescribed by an organization's policy; or
3. on the basis of the experience and judgement of the project estimator.

For the Norman Wells A&R liability estimate, the second of these approaches was used with a single percentage applied to the total base estimate. Imperial's judgement of contingency for the various elements of the estimate WBS resulted in an overall project contingency of 10%.

2.5.4 Operating and Maintenance Costs

Prior to applying factors and contingencies, the total contractor unit price as the sum of the capital unit price plus the discounted value of any annual Operating and Maintenance (O&M) expenses was calculated. A discount rate that reflects the real cost of capital (i.e., excluding inflation), was used for the estimates. The 3.3% rate applied to the estimate was specified by Imperial (this based in turn on the outcome of meetings with AANDC held in Yellowknife on 24 July 2014). The assumed durations of annual costs were also incorporated into the estimate. The net present worth of O&M expenses was then calculated using the following formula:

$$p = a \text{ x } \left(\frac{(1+i)^n - 1}{i(1+i)^n} \right)$$

where:

p = net present worth of annual O&M expenses;
a = annual O&M expenses;
i = annual discount rate; and
n = number of years over which O&M expenses will be incurred.

3.0 ASSET QUANTITY ESTIMATE

The following Sections summarize the assets that were addressed in the financial security estimate. Additional detail for each asset class is provided with the digital estimate.

3.1 Developed Areas

The developed areas on the mainland and the islands are shown in Table 2.

Table 2: Developed Areas

Geographic Location	Developed Area (ha)
Mainland	75
Bear and Frenchy's Islands	36
Goose Island	28
Artificial Islands	14
Total	**153**

The developed lands comprise the following major assets:

- wells;
- facilities,
- flowlines;
- access roads;
- the artificial islands; and
- impacted soil and groundwater.

Descriptions of the major assets are provided in the following Sections.

3.2 Wells

The well lists were provided by Imperial and by the National Energy Board (NEB). These lists identified well name, status (e.g., operating, abandoned), drill date, location, depth and operator. Well data provided by Imperial and the NEB were compared to ensure that all wells were included in the estimate.

The wells were categorized as follows:

- geographic location (e.g., mainland, natural islands, artificial islands);
- well type (i.e., producer or injector);
- surface equipment type;
- depth below surface; and
- surface casing vent flow (SCVF).

Table 3 provides a summary of the number of wells by current status for each geographic area.

Table 3: Well Status Summary

Property	Well Status					Total
	Abandoned	Injector	Producer	Observation	Suspended	
Mainland	16	32	36	1	1	**83**
Bear and Frenchy's Islands	4	39	39	0	0	**82**
River	6	0	0	0	0	**6**
Artificial Islands	0	45	54	0	0	**99**
Goose Island	7	52	50	0	4	**113**
Total	**33**	**168**	**179**	**1**	**5**	**383**

Table 4 identifies the number of wells equipped with bunkers or pumpjacks and the estimated number of wells that may exhibit SCVF for each geographic area.

Table 4: Well Site Equipment Summary

Property	Well Site Equipment		
	Bunkered	Pumpjack	SCVF
Mainland	8	19	35
Bear and Frenchy's Islands	13	25	39
Artificial Islands	0	15	50
Goose Island	74	106	53
Total	**95**	**165**	**177**

A pumpjack is an aboveground drive for a reciprocating piston pump in an oil well. Each pumpjack and wellhead at Norman Wells contains approximately 30 tonnes of steel. Many of the wells are bunkered to protect the wellhead from winter ice. On average, each bunker contains approximately 8 tonnes of steel.

SCVF refers to the movement of gas between the production and surface casing. Imperial routinely tests wells for SCVF and reports the results to the NEB. Imperial has estimated that 50% of the wells may require SCVF repair at time of abandonment.

Well depths were determined using data provided online by the NEB (NEB 2014). The majority of the operating wells were completed at a depth of less than 1000 m. Two of the operating wells had measured depths between 1000 m and 2000 m.

3.3 Mainland Facilities

3.3.1 Central Processing Facility

The Central Processing Facility (CPF) is located on the mainland. The purpose of the CPF is to supply (Imperial 2013):

- 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 Northwest Territories Power Corporation (NTPC).

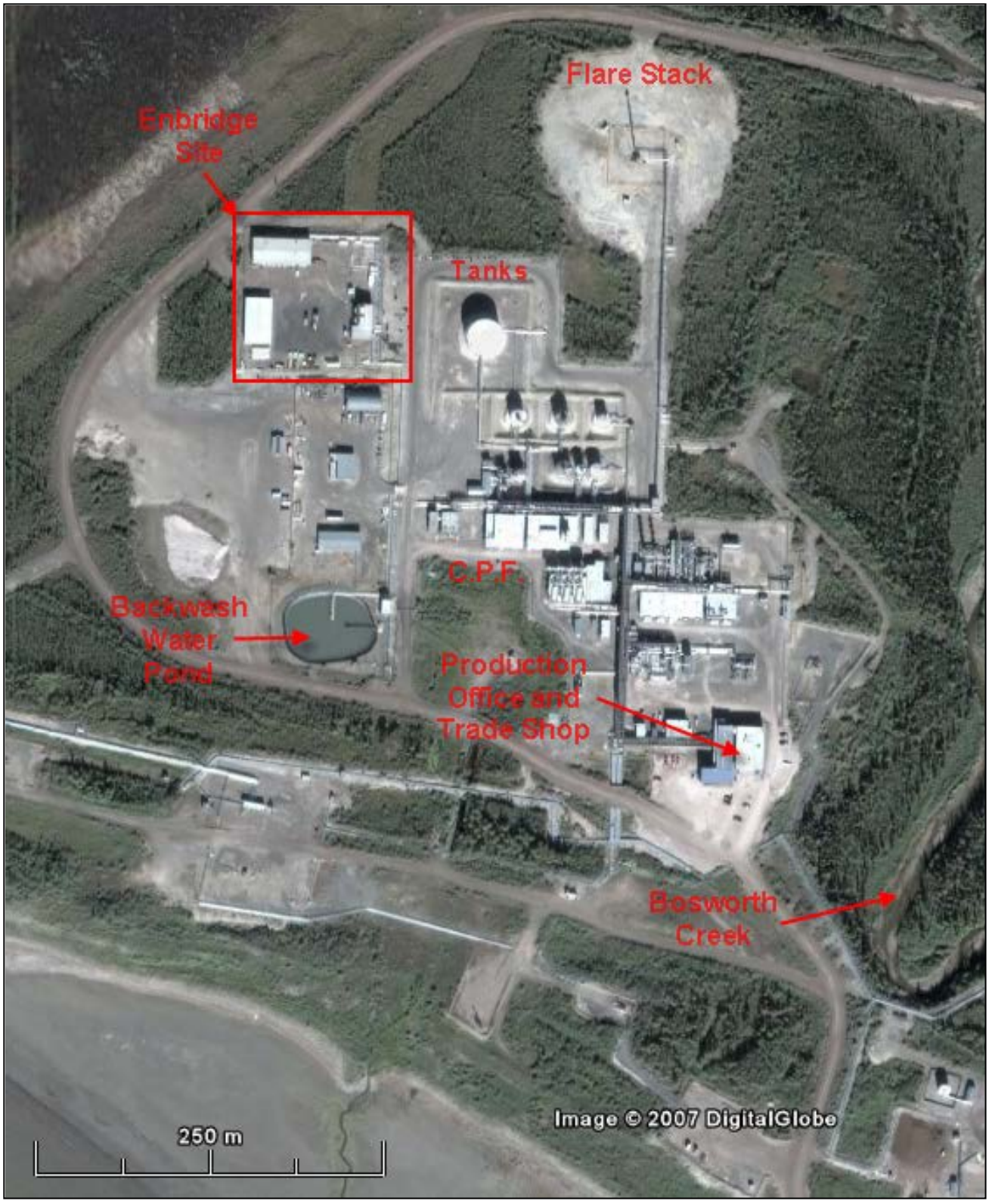
The main functional areas of the CPF include:

- 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.

The main areas within the CPF are shown on Figure 5.

Other infrastructure located on the mainland includes:

- wells (production and injection) and associated flowlines;
- four land terminals (LT) 2, 3, 7, and 11;
- on land pipeline terminal (LPT) 1;
- bermed area for storage of methanol;
- a road network, helicopter pad, and two docks;
- waste storage yard;
- F-31X treatment and Injection Facility;



ABANDONMENT AND RECLAMATION COST ESTIMATE FOR NORMAN WELLS OPERATIONS		
CPF		
amec	**Figure 5**	
	September 2014	CE04494

- well servicing yard; and
- warehouse, various other buildings for equipment storage, and laydown yards.

Historic sumps located on the mainland are not in use and have been closed. Capping and revegetation is currently in progress.

Dismantling quantities were developed by selecting particular buildings, modules and/or process units that were representative of those present across the site. Quantity calculations for these representative units were then completed from available drawings. The calculated quantities were used to develop factors that could be applied to other site facilities (e.g., tonnes of structural steel/m² of building area). These factors, or unit quantities, were used to derive quantities for all building, modules and/or process units on the site.

3.3.2 Tanks

Table 5 provides a listing of tanks. Tanks are located at the CPF and at the tank farm located 1.5 km east of the CPF. The tank farm occupies an area of approximately 8 ha.

Table 5: Tank Inventory

Tank #	Geographic Area	Capacity (m^3)
T102	Mainland CPF	870
T103	Mainland CPF	318
T114	Mainland CPF	6,430
T201	Mainland CPF	240
T202	Mainland CPF	500
T203	Mainland CPF	480
T204	Mainland CPF	870
T206	Mainland CPF	310
T104	Mainland CPF	2
T110	Mainland CPF	0.97
T113	Mainland CPF	35
T115	Mainland CPF	1.5
TK251	Mainland CPF	0.5
TK252	Mainland CPF	1
TK253	Mainland CPF	1
TK254	Mainland CPF	2.4
TANK 101	Mainland Tank Farm	3,680
TANK 102	Mainland Tank Farm	3,680
TANK 103	Mainland Tank Farm	9,222
TANK 104	Mainland Tank Farm	6,550
TANK 105	Mainland Tank Farm	1,635
TANK 106	Mainland Tank Farm	1,635
TANK 107	Mainland Tank Farm	937
TANK 109	Mainland Tank Farm	1,693
TANK 110	Mainland Tank Farm	1,693
TANK 111	Mainland Tank Farm	1,693
TANK 112	Mainland Tank Farm	1,636
TANK 113	Mainland Tank Farm	1,635
TANK 114	Mainland Tank Farm	1,552
TANK 115	Mainland Tank Farm	1,555
TANK 116	Mainland Tank Farm	761

Tank #	Geographic Area	Capacity (m^3)
TANK 117	Mainland Tank Farm	761
TANK 118	Mainland Tank Farm	759
TANK 119	Mainland Tank Farm	13,848
TANK 120	Mainland Tank Farm	7,909
TANK 121	Mainland Tank Farm	9,169
TANK 130	Mainland Tank Farm	11,286

3.4 Bear Island Facilities

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;
- a road network; and
- helicopter pads and barge loading and unloading area.

Multiphase (containing crude oil, produced water and gas) from Frenchy's Island, Bear Island, and Islands 5 and 6 flow into BIT 4, from BIT 4 it flows to GIT 4 (Goose Island) in two flowlines under the river (Imperial 2013).

Historical sumps have been closed and are currently in the process of being reclaimed.

3.5 Goose Island Facilities

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 barge loading and unloading area.

Multiphase from Goose Island, BIT 4, and Island 4 comes into GIT 4, where the produced gas is separated from 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 (Imperial 2013).

Historic sumps located on Goose Island are not in use and have been closed.

3.6 Artificial Islands

The six artificial islands were constructed in 1982 and occupy an area of approximately 14 ha as shown in Table 6.

Table 6: Artificial Island Areas

Island	Area (m^2)
Island 1 (Rayuka)	26,500
Island 2 (Rampart)	23,400
Island 3 (Dehcho)	22,900
Island 4 (Ekwe)	21,200
Island 5 (Tteh K'eeh)	21,600
Island 6 (Little Bear)	20,400
Total	**136,000**

The islands contain a total of 99 wells and associated flowlines and equipment.

3.7 Flowlines

Flowline lengths and dimensions were taken primarily from the line schedules provided by Imperial. Some line lengths were scaled from the available site layout drawings. Table 7 provides a breakdown of above and below ground flowlines and cut & cap requirements.

Table 7: Flowline Summary

Property	Flowline Description		Cut & Cap (End Plug)	
	Aboveground (m)	Underground (m)	Flowlines	River Crossings
Mainland	2,662	26,550	328	6
Bear and Frenchy's Islands	690	36,590	202	10
Artificial Islands	0	1,496	100	0
Goose Island	1,905	89,975	410	12
Total	**5,257**	**154,611**	**1040**	**28**

3.8 Access Roads

Surficial shale was used in the construction of roads, building and equipment pads and the artificial islands. Surficial shale originates from the quarry located about 10 km northeast of the CPF.

Reclamation quantities for areas containing surficial shale were developed using recent aerial photography and satellite imagery to determine disturbances that needed to be addressed in the estimate.

3.9 Soil and Groundwater

3.9.1 Soil

Characterization data for areas of the Norman Wells Operation exhibiting soil conditions exceeding criteria were provided by Imperial via data developed by WorleyParsons (WorleyParsons 2014). The methodology utilized to identify areas of potential environment concern (APECs) and estimate volumes of soil which exceed current regulatory guidelines are described below.

WorleyParsons assessed soil impacts 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.

The impacted soil volume included in the estimate for each APEC is the least volume bounded by any one of:

- applicable soil cleanup criteria;
- top of the bedrock; or
- top of the permafrost.

Soil materials within each APEC were subdivided according to the following soil management categories:

- upper 2 m of soil;
- subsurface soils (material below 2 m but above bedrock or permafrost);
- bedrock; and
- surficial shales.

Soil impact types were classified as follows:

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

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

- 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;
- presence of intermittent permafrost and ice lenses;
- several naturally occurring metals in soil which are above guidelines; and
- shallow depth to bedrock, limiting the practical excavation/remediation depths.

Table 8 summarizes soil quantity data for each geographic area.

Table 8: Soil Quantity Estimate

Geographic Area	Total (m^3)
Mainland West	49,162
Mainland Central	101928
Mainland East	239,068
Bear and Frenchy's Islands	37,575
Goose Island	10,458
Artificial Islands	7,583
Total:	**445,774**

AMEC's scope did not include a review of the Phase I and Phase II environmental site assessment documents utilized by WorleyParsons to determine soil quantities.

3.9.2 Groundwater

Groundwater management involves the operation of existing groundwater remediation programs in two areas of impact. These include:

- Mainland East (FTA and Wellhead Areas B-38X, C-40X, B-40X); and
- Mainland East (Mainland Tankfarm Area).

Groundwater remediation estimates for the above areas were provided by Imperial via data developed by WorleyParsons.

WorleyParsons also provided a groundwater remediation cost estimate for the former Battery 3 area located on the mainland. Future groundwater remediation and/or source removal may be required in this area. AMEC has assumed that groundwater remediation would be implemented in this area and has applied the WorleyParsons cost estimate accordingly.

4.0 ASSET MANAGEMENT

Asset management refers to a combination of techniques or technologies used to undertake abandonment and reclamation activity at Norman Wells. The identification of appropriate tasks is an important component of the work because it defines what cost estimates are to be developed.

The major activities associated with the A&R work at Norman Wells include:

- decommissioning;
- dismantling;
- remediation;
- reclamation; and
- post closure management.

The tasks associated with these activities are described below.

4.1 Decommissioning

Decommissioning tasks include:

- removing and transporting all product, chemical and oilfield waste inventories to approved facilities;
- disconnecting all electrical lines;
- physically isolating flowlines from operating wells or facilities;
- purging flowlines with fresh water, air or inert gas; and
- identifying dangerous materials (e.g., asbestos, naturally occurring radioactive materials) and developing management plans.

Decommissioning quantities were developed, where possible, from dimensions available from drawings and line schedules (e.g., line and vessel flushing volumes). Judgement was exercised in those circumstances where direct quantity estimates were not possible (e.g., volumes of unused chemicals/products in inventory at decommissioning).

Imperial reported that asbestos was not used to any large extent during construction of the CPF and ancillary facilities. Imperial conducted site-wide testing in the late 1990s and removed all asbestos-containing materials that were identified.

4.2 Dismantling

Dismantling involves demolition and removal of all decommissioned surface infrastructure including buildings, vessels, tanks, structures and utilities. AMEC has assumed that all demolition debris will be cut, shredded or crushed and disposed in an on-site landfill.

The dismantling of underground flowlines will involve a cutting and capping procedure for all line ends.

4.3 Wellbore Abandonment

Surface abandonment of the wellbores includes cutting and capping the casing at a depth of 1.5 m below surface. This includes cutting off the casing strings and capping the well. In addition, surface equipment, cement pads, pumpjacks and bunkers are removed.

4.4 Remediation

4.4.1 Soil Management

Impacted soils will be excavated and diverted to an on-site Class II landfill. Imperial has initiated studies to determine the optimum configuration and location for a landfill in the Norman Wells area. The landfill would be built to Class II specifications incorporating a liner system, leachate monitoring and collection systems and a cap.

4.4.2 Sump Management

As specified by Imperial, the estimate assumes that all drilling waste sumps would be managed in-situ utilizing slurry walls to reduce groundwater velocities across the areas occupied by sumps. Surfaces will be capped and reclaimed to minimize surface water seepage into the sump areas.

4.4.3 Groundwater Management

In terms of groundwater remediation strategy, areas of impact extending below 2 m are treated using a combination of three long-term techniques. For hydraulic containment to mitigate off-site migration, groundwater pumping would be the preferred treatment method. Hydrocarbon mass removal would be achieved by multiphase extraction (MPE) or dual phase extraction (DPE) systems.

4.5 Reclamation

Reclamation of disturbed lands associated with the Norman Wells Operation will be based on an approach that returns the ability of the land to support land uses that are similar, but not necessarily identical, to that which existed before the development of the site. This will include:

- recontouring and stabilizing slopes;
- addressing any soil structure, soil sterilant, hydrophobicity, and similar issues;
- restoring surface drainage patterns; and
- planting, maintaining and monitoring vegetation.

4.6 Artificial Islands

Imperial's abandonment strategy for the islands involves the following:

- decommissioning of wells, flowlines and surface infrastructure;
- abandonment of wells;
- removal of surface infrastructure;
- removal of impacted soil; and
- cutting & capping underground flowlines.

The islands would be left in-place and allowed to erode naturally.

4.7 Shale

Imperial has assumed the following management strategies for surficial shale deposits:

- use as fill material for excavations;
- use as berm and/or capping material for the on-site landfill; and
- reclamation remaining shale deposits in-place including:
  - ❑ contouring
  - ❑ capping with suitable soil materials
  - ❑ revegetation.

4.8 Post-Closure Monitoring and Maintenance

The post-closure monitoring, maintenance and reporting programs described in the estimate will be implemented to confirm that the remediation and reclamation objectives for the site have been met. AMEC has assumed that he programs would include:

- water quality;
  - ❑ surface water
  - ❑ groundwater remediation systems
- on-site landfill;
  - ❑ physical condition
  - ❑ leachate monitoring

Cost estimates for the above-noted programs have been included the A&R estimate.

5.0 DIGITAL ESTIMATE

The liability estimates for Norman Wells Operations discussed in this report were created using Microsoft Excel 2007™ in a format that:

- provides ease of access to the quantity data, calculations and significant estimating assumptions;
- facilitates consideration of changes to the assumptions, quantities and unit prices; and
- can be regularly reviewed and updated as portions of the A&R work are completed, and/or as assumptions are modified or refined.

Each line item contains a quantity with an associated unit price or estimated cost for each activity described in the RECLAIM model. The quantities and unit prices are linked to the estimate via the individual detail sheets.

To facilitate ease of use, macros have been incorporated in the digital estimates. To achieve maximum performance from the digital estimate, the user should select “enable macros” when prompted to do so upon opening the file.

To assist with ease of navigation through the digital liability estimates, a dashboard has been developed. The dashboard acts as a table of contents, describing the data available within the workbook. Clickable buttons provide immediate navigation to the associated sheet in the workbook. The user can return to the control panel at any time by clicking on the ‘home’ button found at the top of each sheet.

Several automated features have been built into the digital liability estimate:

- selection of Owner on the dashboard automatically recalculates the estimate to present only liabilities associated with the selected owner;
- changing the factors (i.e., discount rate, engineering, project management, health and safety) on the dashboard automatically recalculates the estimate;
- linkage to maps including a general overview of the Norman Wells Operation, the CPF, typical well site, artificial islands and a typical terminal are accessed by clicking on the appropriate buttons on the dashboard; and
- linkage to data summary tables applied to the estimate are available in all quantity data worksheets.

The digital estimate is fully automated and contains numerous linkages between quantity data, unit price data and the RECLAIM model reports. Modification of the data, the unit prices or any of the factors will result in changes to the estimate reported in this document.

6.0 ESTIMATE RESULTS

6.1 Cost Estimate Summary

A&R cost estimates developed on the basis of the assumptions, quantities, factors and unit prices described in this report are as shown in Tables 9 and 10. Table 9 reports total costs by the WBS specified in the RECLAIM Model. Table 10 reports total costs by Land Division.

Table 9: A&R Cost Estimate Summary

Item	Total Cost	Land Liability	Water Liability
Wells and Facilities	$42,677,251	$42,677,251	$ -
Buildings and Equipment	$41,126,888	$41,126,888	$ -
Chemicals and Contaminated Soil Management	$16,605,839	$16,605,839	$ -
Construction and Operation of On-Site Landfill	$18,650,000	$18,650,000	$ -
Surface and Groundwater Management	$12,371,181	$	$12,371,181
Interim Care and Maintenance	$5,497,039	$3,298,224	$2,198,816
Mobilization/Demobilization	$2,352,880	$2,102,519	$250,361
Post-Closure Monitoring and Maintenance	$8,210,561	$842,255	$7,368,305
Engineering	$6,846,410	$6,117,910	$728,500
Project Management	$6,846,410	$6,117,910	$728,500
Health and Safety Plans/Monitoring & QA/QC	$1,369,282	$1,223,582	$145,700
Bonding / Insurance	$1,369,282	$1,223,582	$145,700
Contingency	$13,692,820	$12,235,820	$1,457,000
Inflation Adjustment	$705,210	$630,171	$75,039
Total Costs	**$178,321,053**	**$152,851,951**	**$25,469,102**

Table 10: A&R Cost Estimate Summary by Land Division

Land Division	Cost Estimate
Commissioner GNWT	$68,396,215
Federal	$4,678,657
NEB	$45,990,866
Private	$33,786,222
SLWB	$25,469,093
Total	**$178,321,053**

7.0 CLOSURE

The work described in this report was conducted in accordance with the Contract for Environmental Consulting Services between Imperial Oil Limited and AMEC Environment & Infrastructure, and generally accepted engineering and assessment practices. The Limitation of Liability, Scope of Report and Third Party Reliance statements appearing in Appendix A form part of this document.

Respectfully submitted,

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APEGA Permit to Practice #P-04546
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Appendix A

Limitation of Liability, Scope of Report and Third Party Reliance

Limitation of Liability, Scope of Report and Third Party Reliance

This report has been prepared, and the work referred to in this report has been undertaken by, AMEC Environment & Infrastructure, a division of AMEC Americas Limited, for Imperial Oil Limited. It is intended for the sole and exclusive use of Imperial Oil Limited, its affiliated companies and partners and their respective [insurers], agents, employees and advisors (collectively, "Imperial Oil"). Any use, reliance on or decision made by any person other than Imperial Oil based on this report is the sole responsibility of such other person. Imperial Oil and AMEC Environment & Infrastructure make no representation or warranty to any other person with regard to this report and the work referred to in this report and they accept no duty of care to any other person or any liability or responsibility whatsoever for any losses, expenses, damages, fines, penalties or other harm that may be suffered or incurred by any other person as a result of the use of, reliance on, any decision made or any action taken based on this report or the work referred to in this report.

The investigation undertaken by AMEC Environment & Infrastructure with respect to this report and any conclusions or recommendations made in this report reflect AMEC Environment & Infrastructure's judgment based on the site conditions observed at the time of the site inspection on the date(s) set out in this report and on information available at the time of preparation of this report. This report has been prepared for specific application to this site and it is based, in part, upon visual observation of the site, subsurface investigation at discrete locations and depths, and specific analysis of specific chemical parameters and materials during a specific time interval, all as described in this report. Unless otherwise stated, the findings cannot be extended to previous or future site conditions, portions of the site which were unavailable for direct investigation, subsurface locations which were not investigated directly, or chemical parameters, materials or analysis which were not addressed. Substances other than those addressed by the investigation described in this report may exist within the site, substances addressed by the investigation may exist in areas of the site not investigated and concentrations of substances addressed which are different than those reported may exist in areas other than the locations from which samples were taken.

If site conditions or applicable standards change or if any additional information becomes available at a future date, modifications to the findings, conclusions and recommendations in this report may be necessary.

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