



Imperial Oil

**Renewal Application for Water Licence S03L1-001
Other Studies
(Section 11 of 20)**

Submitted to the Sahtu Land and Water Board by Imperial Oil Resources N.W.T. Limited

August 2013



Table of Contents

11.0	Other Studies	1
11.1	Introduction.....	1
11.2	IOR Commissioned Studies.....	1
11.2.1	Natural Hydrocarbon Seeps	1
11.2.2	Revegetation Trials.....	3
11.2.3	Bioremediation and Biotreatability	4
11.2.4	Bosworth Creek Weir Removal	5
11.2.5	Bosworth Creek Aquatic Resources and Surface Water Quality.....	6
11.2.6	Metals Stabilization.....	7
11.2.7	Eco-Toxicity	8
11.2.8	Geophysical Survey Applications	8
11.2.9	Studies Conducted pre-2003.....	9
11.3	Other Studies from the Norman Wells Region.....	12
11.3.1	2007-2010 Bosworth Creek Monitoring Project.....	12
11.3.2	Bosworth Creek Water Quality Data Study	13
11.3.3	Bioassessment of Streams Along Mackenzie River Valley	13
	References.....	14

Photos

Photo A:	Natural Hydrocarbon Seep Zone Along the Mackenzie River	2
Photo B:	Revegetation Trial Plots Layout	3
Photo C:	Soil Treatment in the Onsite Biocell	4
Photo D:	Bosworth Creek Weir Under Lower Bridge	5
Photo E:	Bosworth Creek Lower Bridge Following Weir Removal	6
Photo F:	Water Sampling in Bosworth Creek	6
Photo G:	Ground Penetrating Radar Survey at Norman Wells	9
Photo H:	Construction of Trenches for SVE system	10
Photo I:	Recovery Wells and Piping for MPE system	10
Photo J:	Topsoil Construction Compost Pile	10
Photo K:	Preparing Metals Impacted Soil for Offsite Shipment	11
Photo L:	Mobile Thermal Desorption Unit	11
Photo M:	Geophysical Survey Map Depicting Estimated Permafrost Thickness	12

11.0 Other Studies

11.1 Introduction

The Northwest Territories (NWT) has lent itself to numerous studies focused on a variety of geological, hydrological, ecological, and other environmental topics (NWT Discovery Portal 2013). For the purposes of the Renewal Application, the studies completed in the Norman Wells region can generally be grouped into two categories:

- studies undertaken which make specific reference to Imperial Oil Resources (IOR) Norman Wells Operations (NWO), and
- other studies which more generally describe the region.

Brief summaries of those studies undertaken or completed by IOR for the NWO in the past 10 years are presented in Section 11.2. A list of other studies that are more general to the Norman Wells region are presented in Section 11.3. Studies included in Section 11.3 were identified through previous literature reviews undertaken by IOR and by performing a search on the NWT Discovery Portal (NWT Discovery Portal 2013). A keyword search for “water” was used to look for studies with geographic coverage for the Norman Wells area.

11.2 IOR Commissioned Studies

The following studies were commissioned and/or completed in the past 10 years for IOR’s NWO:

1. Differentiation of Natural Seeps vs Spills
2. Revegetation Trial Plots
3. Bioremediation and Biotreatability
4. Bosworth Creek Weir Removal
5. Bosworth Creek Aquatic Resources and Surface Water Quality
6. Metals Stabilization Study
7. Ecotoxicity (plants and invertebrates)
8. Geophysical Survey Applications

11.2.1 Natural Hydrocarbon Seeps

In 1998, IOR commenced research to achieve the following objectives:

- confirming geographic locations and the extent of visible hydrocarbon seepage zones relative to historically documented natural seepage investigations;
- completing a detailed characterization of the seep environment, to assist in the differentiation of naturally occurring seepage relative to possible hydrocarbon releases from Norman Wells facility operations; and
- confirming the previous estimate of naturally occurring hydrocarbons entering the Mackenzie River annually.

Photo A: Natural Hydrocarbon Seep Zone Along the Mackenzie River



Results of this research, described in the 2008 Norman Wells Abandonment and Restoration Annual Report (Imperial Oil 2008), were summarized as follows:

- current natural seepage zones are similar to the zones previously identified in investigations;
- natural seepage zones have several distinguishing characteristics that differentiate them from potential anthropogenic impacts; and
- it was estimated that at least 6.7 m³/year of crude oil was entering the Mackenzie River from natural seepage. This was consistent with previous estimates.

Further information regarding natural seeps in the Sahtu Settlement Region is presented in Section 5.

11.2.2 Revegetation Trials

A lack of available site-specific revegetation data available for surface reclamation planning and implementation at the Norman Wells site led IOR to design and construct revegetation trial plots in 2000. The purpose of the trials was to gain further understanding of the viability of different plant species, planting methods, timing, and soil conditioning.

Photo B: Revegetation Trial Plots Layout



The plots were monitored annually until 2009 when the research was deemed complete. From this research, IOR has compiled a seed mix list for reclamation purposes as follows:

- 45% Adanac Slender Wheatgrass;
- 19% Boreal Creeping Red Fescue;
- 12% ARC Butte Rocky Mountain Fescue;
- 10% ARC Sentinal Spike Trisetum;
- 7% Nortran Tufted Hairgrass; and
- 7% Glaucous Bluegrass.

Further details on this research can be found in the Norman Wells Abandonment and Restoration Annual Reports (Imperial Oil, 2004 through 2009).

11.2.3 Bioremediation and Biotreatability

In 2002, IOR constructed two on-site biotreatment cells (commonly referred to as biocells) to test the effectiveness of treating petroleum hydrocarbon impacted soil during the short field season in Norman Wells. Bioremediation activities conducted between 2002 and 2013 confirm that soil biotreatment to meet the Canadian Council of Ministers of the Environment (CCME) remediation guidelines was possible over one to two field seasons if the initial petroleum hydrocarbon concentrations (particularly for heavier molecular weight hydrocarbons i.e., PHC F3) did not exceed approximately 5,000 mg/kg.

The biocell treatment system involves the placement of soil in windrows and then the addition of standard agricultural fertilizer products (monoammonium phosphate and urea) while it is being passed through a twister bucket attachment on an excavator. This process is repeated as needed until remedial objectives are met.

Photo C: Soil Treatment in the Onsite Biocell



In 2012, the two smaller biocells were decommissioned and one larger biocell was reconstructed on the same site. The new biocell has a soil treatment capacity of approximately 5,000 m³ (Imperial Oil 2013).

Further details on this study can be found in the Norman Wells Abandonment and Restoration Annual Reports (Imperial Oil, 2004 through 2013).

11.2.4 Bosworth Creek Weir Removal

The Bosworth Creek weir removal and channel restoration project took place in the summer/fall of 2005. Work in the flowing creek, and removal of bed material, was kept to a minimum. Silt fencing was installed at two locations downstream of the works.

The existing fill under the bridge was excavated down to the original creek bed. Following removal of the fill materials under the bridge, the streambed was reconstructed in accordance with recommendations made by the Department of Fisheries and Oceans (DFO). A bed slope of 3% was constructed under the bridge. Down-gradient of the bridge, a series of four steps (drop structures) and three pools were constructed. Large rock was placed onto the existing streambed both up-gradient of the bridge and under the bridge to protect against erosion. The work area closest to the riparian areas (near shores and water's edge) was seeded using a native seed species.

Photo D: Bosworth Creek Weir Under Lower Bridge



Photo E: Bosworth Creek Lower Bridge Following Weir Removal



Further details on this project can be found in the 2006 Norman Wells Abandonment and Restoration Annual Report (Imperial Oil 2006).

11.2.5 Bosworth Creek Aquatic Resources and Surface Water Quality

In 2009, IOR initiated a program to investigate aquatic resources (i.e. benthic invertebrates and fish) and to monitor surface water quality in Bosworth Creek. This was a three year monitoring program with the following components:

- surface water collection and analysis;
- benthic invertebrate collection and analysis; and
- fish habitat collection and analysis.

Photo F: Water Sampling in Bosworth Creek



Current water quality of Bosworth Creek may be characterized as slightly alkaline with low concentrations of total dissolved solids (TDS), total suspended solids (TSS), hardness, nutrients, major ions, and metals. In general, no data trends were evident between upstream reference stations and downstream test stations from 2009 to 2011.

Overall, no significant differences were observed between the benthic invertebrate stations on the lower Bosworth Creek and the upper reference stations. Benthic invertebrate index results indicated that macro invertebrate communities in the upper and lower Bosworth Creek stations were experiencing similar high quality habitat conditions. The slight differences noted among the communities of the upstream and downstream stations are likely related to natural variability and minor habitat differences.

Fish survey and fish habitat data indicate that Bosworth Creek provides suitable habitat to various fish species. Based on an assessment of representative fish species (specifically Arctic grayling, longnose sucker, and longnose dace), Bosworth Creek provides good spawning and rearing habitat. For small-bodied fish (i.e. cyprinids) and juvenile life-stages of typically found large-bodied fish, Bosworth Creek provides good summer holding/feeding, and potentially overwintering, habitat. Conversely, Bosworth Creek provides only poor to moderate summer holding/feeding and overwintering habitat for the adult life-stage of large-bodied fish. Larger, adult fish likely use the Mackenzie River for both summer and overwintering habitat.

Further details on this project can be found in the Norman Wells Abandonment and Restoration Annual Reports (Imperial Oil, 2009 through 2012).

11.2.6 Metals Stabilization

Local shale material has been imported to all portions of the Norman Wells lease, and can be found on roads, well pads, the developed portion of the CPF, storage yards, and various other areas on the lease. The shale is noted for the presence of arsenopyrite. Analytical data compiled to date indicate the shale contains naturally high concentrations (levels exceeding residential/parkland, or industrial land use guidelines under NWT or CCME guidelines) of several metals including arsenic (As), copper (Cu), molybdenum (Mo), nickel (Ni), selenium (Se), thallium (Tl) and zinc (Zn). The shale is slightly acidic (pH 6.6 to 6.7).

In 2012, a field study was conducted with the objective of assessing whether or not an effect on metal concentrations and pH can be observed in the upper soil profile underlying shale fill material. Soil and surface water samples from Bear Island and the Mainland were collected for analysis.

Further details on this research can be found in the 2012 Norman Wells Abandonment and Restoration Annual Reports (Imperial Oil 2012). Analysis is ongoing and updates will be reported in the 2013 annual Abandonment and Restoration Report.

11.2.7 Eco-Toxicity

Current contaminated site remediation guidelines are not specific to the Northwest Territories. The CCME eco-toxicity limits were not established using cold climate-specific plant and invertebrate species. Research was undertaken to develop appropriate eco-toxicity limits for plants and invertebrates indigenous to the Norman Wells area.

The overall objective of this research is to support the development of soil petroleum hydrocarbon fraction 3 (PHC F3) eco-contact guidelines that are protective of plants and invertebrates that are indigenous to the area. The developed guidelines will reflect use of the soil profile, the aged and/or weathered nature typical of hydrocarbon in soil at Norman Wells, and the effects of bioremediation. To achieve this, IOR is working in conjunction with the Saskatchewan Research Council and in consultation with Environment Canada.

Further details can be found in the Norman Wells Abandonment and Restoration Program Annual Reports (Imperial Oil 2010, 2011, 2012)

11.2.8 Geophysical Survey Applications

Two research projects in 2006 and 2007 were initiated to investigate the application of geophysical technology at the Norman Wells facility. The projects were:

- utilization of ground penetrating radar to enhance capability for detection and location of underground / buried infrastructure (i.e. ground clearance prior to intrusive activities such as drilling and excavating); and

- assessment of enhanced electrical resistivity imaging to identify the presence of, and delineate, petroleum hydrocarbons in the subsurface.

Photo G: Ground penetrating radar survey at Norman Wells



Overall, the research found that the geophysical surveys were successful in locating and/or confirming general locations of underground utilities (Imperial Oil 2008). This technology can be used to supplement traditional ground disturbance methods prior to initiating excavation work. Geophysical surveys are conducted regularly during abandonment and reclamation activities as part of site assessment activities at Norman Wells.

Results from the assessment of enhanced electrical resistivity imaging for the identification and delineation of hydrocarbons found that areas with significant subsurface hydrocarbon concentrations tend to have a resistive, rather than conductive, signature. The resistive signature can in some instances help confirm and delineate the extent of refined hydrocarbon impacts in the subsurface.

Further details can be found in the 2008 Abandonment and Restoration Program Annual Report (Imperial Oil 2008).

11.2.9 Studies Conducted pre-2003

In addition to the above, studies initiated and/or completed prior to 2003 included:

1. In-situ Remediation Technology Evaluation and Pilot-Testing (Multiphase Extraction MPE and Soil Vapour Extraction SVE)

Photo H: Construction of trenches for SVE system



Photo I: Recovery wells and piping for MPE system



2. Soil Re-engineering and Composting

Photo J: Topsoil construction compost pile



3. Heavy Metals Management

Photo K: Preparing metals-impacted soil for off site shipment



4. Thermal Desorption

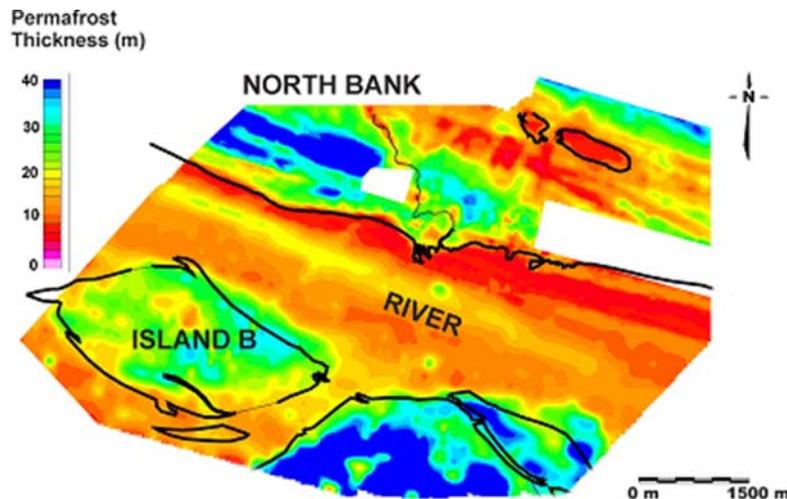
Photo L: Mobile thermal desorption unit



5. Physical Barrier Applicability for Plume Containment (Desktop Study)

6. Permafrost Mapping (Airborne Geophysical Surveys)

Photo M: Geophysical survey map depicting estimated permafrost thickness



7. Aquatic Effects Monitoring Program (Mackenzie River). (Further details regarding these studies are provided in Section 12.)

Details on these earlier studies can also be found in the Norman Wells Abandonment and Restoration Annual Reports listed in the References.

11.3 Other Studies from the Norman Wells Region

A summary of other studies identified through literature reviews completed by IOR and by using the NWT Discovery Portal (NWT Discovery Portal 2013) are presented below. The summaries presented here are taken from the abstracts in the published reports.

11.3.1 2007-2010 Bosworth Creek Monitoring Project

Between 2007 and 2010, a monitoring project of Bosworth Creek was conducted. As part of this project, local youth were engaged to monitor aquatic ecosystem health. Objectives of the project included: assessing water quality during the development and utilization of two borrow sites proposed by the Mackenzie Gas Project; monitoring possible impacts due to erosion that is occurring at a forest fire "fuel break"; monitoring fish for contaminants; creating a species inventory of the creek and riparian zones; identifying specific aquatic habitats and their components; providing a long term record of water chemistry; contributions towards creating the first NWT freshwater fish key; and tracking changes in streambed morphology over time (Snortland 2008), (Gutherie and

Snortland 2009) and (Hopkins, C. 2010). Copies of reports for the individual years are available on the Portal website (www.nwtdiscoveryportal.enr.gov.nt.ca/).

11.3.2 Bosworth Creek Water Quality Data Study

This water quality data report summarizes the existing water quality data that has been gathered on Bosworth Creek intermittently from 1953 to 2009. All water quality data were compared to established guideline values for drinking water and aquatic life. Exceedances of Guidelines for Canadian Drinking Water Quality (GCDWQ) and the Canadian Water Quality Guidelines for the Protection of Aquatic Life (GPAL) were noted for a small number of samples and parameters. Observed exceedances were generally infrequent; however, some sites were more prone to Guideline exceedances. The highest number of exceedances were for aluminum, selenium and iron. The majority of water quality parameters, including major ions, nutrients, hydrocarbons and physical parameters, were generally within acceptable water quality guidelines for both drinking water and protection of aquatic life (Collins et al 2011).

11.3.3 Bioassessment of Streams Along Mackenzie River Valley

Between 2005 and 2007, the Department of Fisheries and Oceans (DFO) conducted biological and habitat sampling at 102 streams along the Mackenzie River Valley. The purpose of the sampling program was to develop a bioassessment tool using the Reference Condition Approach (RCA) for environmental effects assessment of the Mackenzie Gas Pipeline (MGP). Data collection included habitat measurements, water quality testing, and benthic macroinvertebrates surveys. Remote sensing was used to obtain additional landscape and climatic data (Rempel and Gill 2011).

References

- Collins L., Murray C. and Stainton R., 2011. Bosworth Creek Water Quality Data Study: Final Report. Institute for Watershed Science, Report No. 02-11, 69 p. Prepared for the Environmental Studies Research Funds (ESRF), Department of Natural Resources, Government of Canada.
- Gutherie, G. and Snortland, J., 2009. Bosworth Creek Monitoring Project. Sahtu Renewable Resources Board. March 30, 2009.
- Hopkins, C., 2010. Bosworth Creek Monitoring Project 2010. March 31, 2010.
- Imperial Oil, 2004. Norman Wells Abandonment and Restoration Program Annual Report.
- Imperial Oil, 2005. Norman Wells Abandonment and Restoration Program Annual Report.
- Imperial Oil, 2006. Norman Wells Abandonment and Restoration Program Annual Report.
- Imperial Oil, 2007. Norman Wells Abandonment and Restoration Program Annual Report.
- Imperial Oil, 2008. Norman Wells Abandonment and Restoration Program Annual Report.
- Imperial Oil, 2009. Norman Wells Abandonment and Restoration Program Annual Report.
- Imperial Oil, 2010. Norman Wells Abandonment and Restoration Program Annual Report.
- Imperial Oil, 2011. Norman Wells Abandonment and Restoration Program Annual Report.
- Imperial Oil, 2012. Norman Wells Abandonment and Restoration Program Annual Report.
- NWT Discovery Portal, 2013. NWT Discovery Portal Search Page. Website Accessed July 30, 2013.
- Rempel L. and Gill G., 2011. Bioassessment of streams along the Mackenzie River Valley, Canada, using the Reference Condition Approach: biological, habitat, landscape, and climate data. Can. Data Rep. Fish. Aquat. Sci. 1236: viii + 247 p.
- Snortland J., 2008. Capacity Building & Monitoring Projects 2007-2008 Bosworth Creek Monitoring Project. Sahtu Renewable Resources Board. March 31, 2008.