



Indian and Northern  
Affairs Canada

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et du Nord Canada



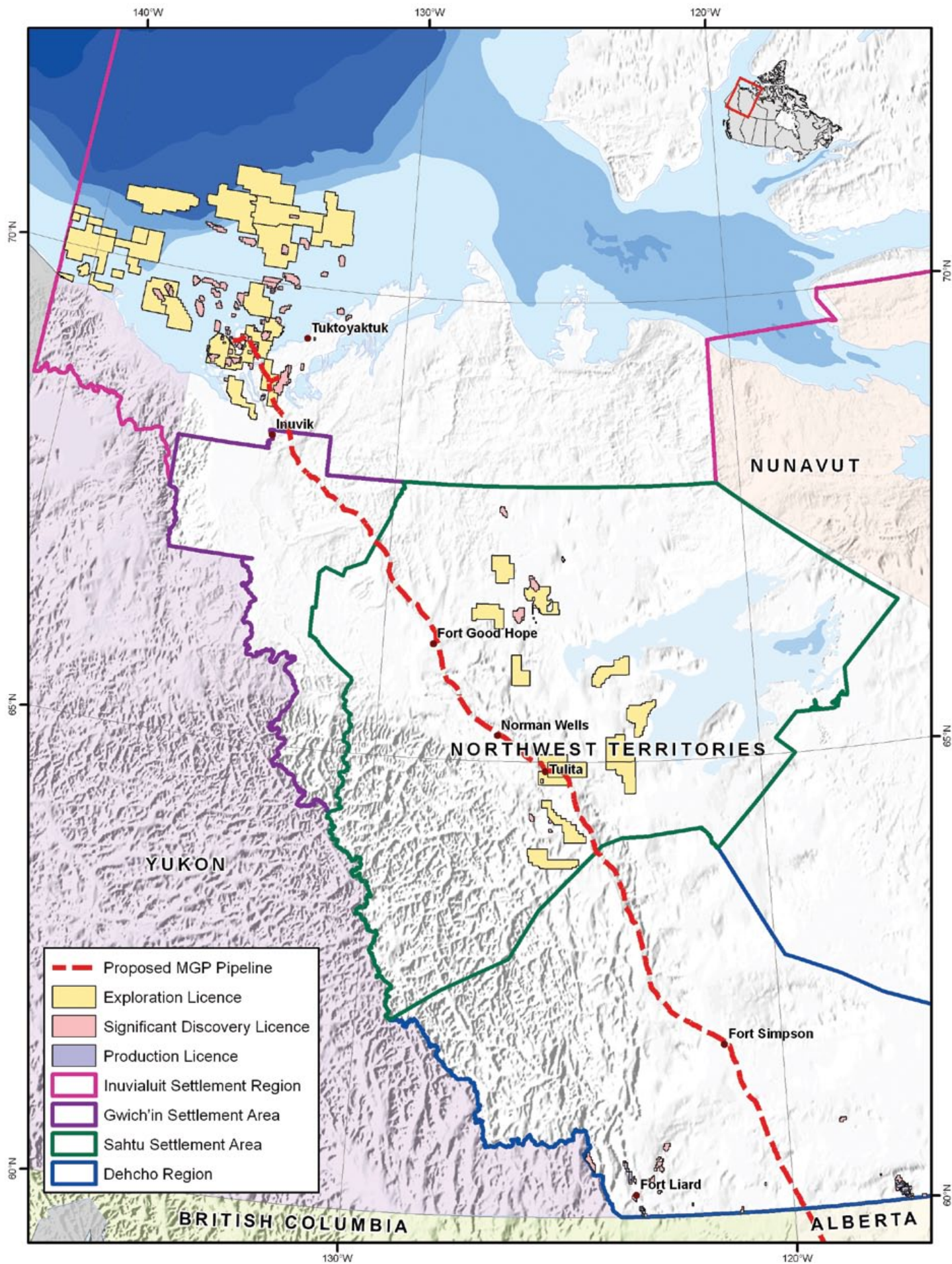
# REPORT ON FEDERAL SCIENCE CONDUCTED IN SUPPORT OF NORTHERN ENERGY DEVELOPMENT

2002–2010



Canada





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# ACRONYMS

<b>DFO</b>	<b>Fisheries and Oceans Canada</b>
<b>EC</b>	<b>Environment Canada</b>
<b>INAC</b>	<b>Indian and Northern Affairs Canada</b>
<b>GIS</b>	<b>Geographic Information System</b>
<b>GNWT</b>	<b>Government of the Northwest Territories</b>
<b>GRRB</b>	<b>Gwich'in Renewable Resources Board</b>
<b>JRP</b>	<b>Joint Review Panel</b>
<b>KIBS</b>	<b>Kendall Island Bird Sanctuary</b>
<b>MGP</b>	<b>Mackenzie Gas Project</b>
<b>NOGSRI</b>	<b>Northern Oil and Gas Science Research Initiative</b>
<b>NRCan</b>	<b>Natural Resources Canada</b>
<b>NWT</b>	<b>Northwest Territories</b>
<b>SKDB</b>	<b>Sambaa K'e Dene Band</b>
<b>SRRB</b>	<b>Sahtu Renewable Resources Board</b>

# INTRODUCTION

The proposed Mackenzie Gas Project (MGP) consists of an 1196-km pipeline system along the shores of the Mackenzie River that would deliver natural gas from northern producing wells to southern markets. The pipeline would connect to a proposed interconnection in northwest Alberta. The project would span four Aboriginal regions in the Northwest Territories (NWT): the Inuvialuit Settlement Region, the Gwich'in Settlement Area, the Sahtu Settlement Area and the Dehcho region. The MGP would also include a pipeline carrying natural gas liquid from Inuvik to the existing Norman Wells Oil Pipeline.

The natural gas exploration and drilling companies involved in the MGP have interests in three discovered natural gas fields in the Mackenzie Delta: Niglintgak, Taglu, and Parsons Lake. These fields represent the basis for the MGP and are referred to as the Anchor Fields. Together, the three fields would yield 830 million cubic feet per day of natural gas over the duration of the project. Although no other volumes of natural gas have yet been committed to the MGP, other companies exploring for natural gas in the North are also interested in having access to the pipeline. If additional natural gas fields are developed, as much as 1.2 billion cubic feet per day of natural gas could be accommodated through the 30-inch pipeline. Planning, building and operating the anticipated \$16.2 billion MGP will require cooperation among many different companies, communities, settlement regions, First Nations and Inuvialuit leadership, regulatory agencies and governments.

From 2002–2010, Indian and Northern Affairs Canada (INAC) led and coordinated the federal science research projects in support of the review of the proposed MGP and induced oil and gas activities in the Mackenzie Delta, the Beaufort Sea, and along the pipeline route. Through the Northern Oil and Gas Science Research Initiative (NOGSRI) and in collaboration with Environment Canada (EC), Fisheries and Oceans Canada (DFO), and Natural Resources Canada (NRCan), the aim was to undertake research projects in support of environmental assessment and regulatory review processes for Northern Energy Development, and the MGP in particular. Scientific information generated as a result of these research projects have and will continue to allow for expert, reliable decision-making for the MGP and induced oil and gas development.

The research conducted under the NOGSRI has been used to inform the review of the MGP through interventions made by government departments (supported by their scientific experts) during the hearings of the Joint Review Panel (JRP). Results provided federal and territorial departments, the National Energy Board, Canadian Environmental Assessment Agency and Northern Boards with science information required to respond to the report of the JRP, “Foundation for a Sustainable Northern Future”, and identify follow-up requirements, as well as support project approvals and the regulatory phases of issuing licenses, authorizations and permits towards the construction phase of the pipeline.

This research contributes to much-needed baseline information for long-term monitoring of the environment which is an important component for environmental monitoring, adaptive management and follow-up programs and essential for identification and assessment of possible impacts of development. The studies can assist identification and development of appropriate mitigation measures for the pipeline and induced activities to proceed as scheduled, while preserving the integrity of the natural environment. These studies also form an important component for regional cumulative impact monitoring programs.

Community and science workshops were held in Norman Wells and Yellowknife in 2003, early in the planning of the NOGSRI, to discuss gaps in baseline knowledge, and identify information that is needed to understand the potential impacts from northern oil and gas development. The workshops were held to improve the preparedness of government and local communities to be able to properly respond to environmental assessments associated with hydrocarbon exploration, development, and transmission in the Mackenzie Valley. A total of 90 gaps in knowledge in physical (permafrost, terrain, water) and biological (wildlife and habitat, vegetation) areas were identified in these early workshops, and these helped to shape the direction of federally-funded scientific research in support of the MGP.

Traditional knowledge was incorporated into scientific assessments throughout the research conducted under the NOGSRI. Communities and individuals who live on the land know it best. They are part of the environment and recognize its importance and subtleties. Traditional knowledge is invaluable to scientists performing research in the Mackenzie Valley and Delta, and Beaufort Sea.

The purpose of this report is to describe the research that was undertaken by the Government of Canada through the NOGSRI. This work addressed aquatic and terrestrial environmental issues related to the MGP and induced development. The report includes most of the projects that were conducted. For each project described in the report, Appendix 1 identifies the federal department responsible for the project. The Hydrocarbon Impacts database of the Arctic Science and Technology Information System lists the publications related to the research projects. Selected publications are listed in Appendix 2. It is hoped that this report is a useful resource to communities and management boards in their review of project applications in the Mackenzie Delta and along the proposed pipeline route.



# PROJECTS

## GEOLOGY / MAPPING

*To gain a better knowledge of terrain topography and geology throughout the Mackenzie Valley and Delta, as well as in the Beaufort Sea, the Northern Oil and Gas Science Research Initiative (NOGSRI) supported various topographic and geological mapping studies.*

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### Aerial Photography of the Mackenzie Valley and Delta

INAC, with partners in other government departments, collaborated to provide new aerial photography, detailed topographic maps, a Digital Elevation Model, and a colour digital photo-mosaic of the Mackenzie Delta region and the entire pipeline corridor from the Delta to the NWT-Alberta border. The project provided detailed mapping and analysis data for a large variety of scientific and regulatory purposes. It contributed to the knowledge base by providing agencies with the ability to identify surface terrain vegetation, aquatic characteristics (land, river and lake features, and riparian zones), permafrost, wildlife habitat, sources of granular material for development, terrain conditions important to site planning and engineering design, cultural resources, and existing land uses. This project supports good decision-making in regards to rights issuance such as land use, quarry permits, and oil and gas leases.

### Geospatial Database Coverage, NWT

Topographic mapping needed to be more detailed, accurate, and up-to-date to assist in the development of northern pipelines. To this end, available analog topographic maps in the NWT were converted into digital format and satellite imagery was used to improve the accuracy and resolution, and to update

the new digital maps and previously existing data sets at a scale of 1:50,000. More than 95% of NWT coverage is up-to-date. This geoscience information will be used for exploration and discovery of new energy and mineral resources, as well as environmental assessments and risk evaluation to support informed decision-making.

### Mackenzie/Beaufort Coastal Navigation Program

In the Mackenzie River and Delta and coastal Beaufort region, existing river charts were in unknown projections or dated back to the North American Datum of 1927. These river charts were ½ to 1 km or more off datum and the offshore shoreline charts were in error by up to ½ km due primarily to erosion and outdated data. In both cases, the data used to produce existing charts were 20 years and older. A Mackenzie River and Delta and Beaufort Sea coastal navigation program was conducted by DFO from 2005–2009 to correct outdated hydrographic information by using new remotely-sensed data in combination with ground-truthed data collected on board the Canadian Coast Guard Ship *Nahidik* and the two Canadian Coast Guard river boats *Dumit* and *Ekaloo*. The program yielded improved navigation and safety charts, as well as a digital product for mariners to





use as a navigation tool. With increased ship and barge traffic to local communities expected during construction phases of the MGP, this information is critical to avoiding marine and freshwater incidents that could have negative environmental impacts.

### Surficial Mapping

NRCan led a study that produced baseline geological maps for estimating environmental impact and terrain sensitivity in the poorly mapped southern half of the Mackenzie Valley. Sediment and terrain types were identified that could negatively affect the performance of a pipeline. This information is useful in gauging the potential environmental impact of the pipeline, to set guidelines for terrain use and to monitor terrain response. The study also identified potential sources of granular resources and other

materials that could be used for the pipeline, road and facilities construction, and provided new data on areas susceptible to landslides. Several maps were completed for publication.

### Geology Project to Support Oil and Gas Exploration and Development in the NWT

The objective of the Peel Petroleum Project (2005–2009), a joint project of the NWT Geoscience Office, the Geological Survey of Canada at NRCan and the Yukon Geological Survey, was to advance knowledge of hydrocarbon potential and regional geology in the Peel Plateau and Plain, a prospective area in the northwestern NWT / northeastern Yukon in the vicinity of the proposed MGP pipeline route. Although no major discoveries have been reported from the area, some encouraging shows are known

from some of the existing wells (74 wells total). Following reconnaissance in 2005, two field seasons on outcrops in the Peel area and nearby mountain ranges (northern Mackenzie Mountains, Richardson Mountains, and Franklin Mountains) were conducted to examine sedimentology, stratigraphic and structural relationships, and improve regional correlation. Depositional and tectonic histories, basin evolution, as well as petroleum geology and potential were also evaluated. The project yielded about 90 geoscientific publications over the past four years and final results were presented in a multi-author project volume

(NWT Open File 2009–02 / Yukon Geological Survey Open File 2009–25). A Geographic Information System (GIS) digital atlas (NWT Open File 2009–03) accompanies the volume and contains all of the spatial data associated with the research (a field “geo-tour”, section and core photographs, seismic profiles, core and measured section descriptions, cross-sections, geochemical analyses, and isopach and structural contours). More information and links to project publications can be found at [www.nwtgeoscience.ca/petroleum/PeelPlateau.html](http://www.nwtgeoscience.ca/petroleum/PeelPlateau.html).



# PERMAFROST, GEOHAZARDS AND TERRAIN SENSITIVITY

*The development of the MGP would be unprecedented in that it involves a buried gas pipeline at non-ambient temperature that could thaw frozen ground and freeze unfrozen ground, which can lead to ground movements related to thaw settlement and frost heave. This means the MGP can both affect and be affected by permafrost in the region.*

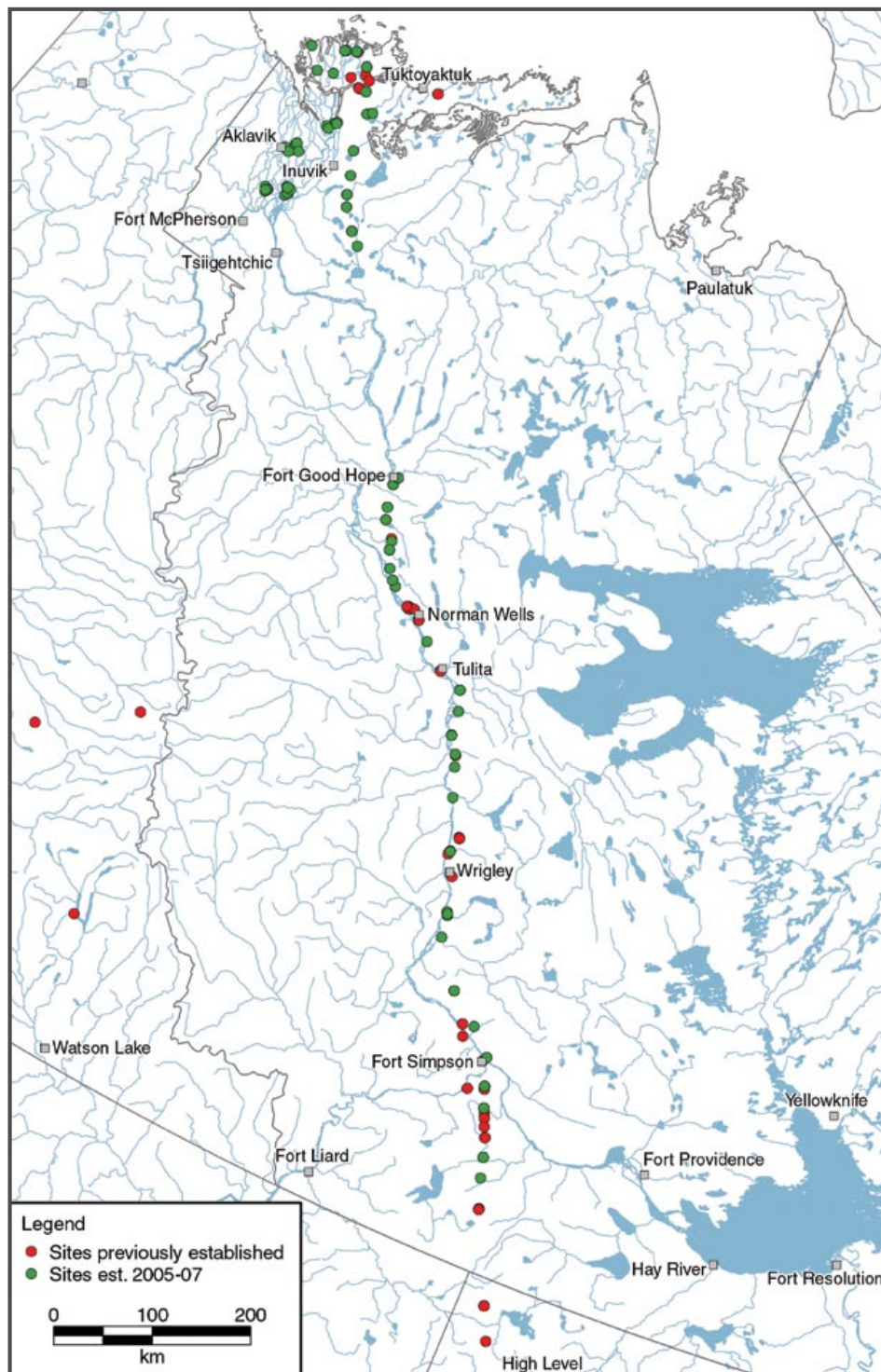
About one third of the pipeline length would be in continuous permafrost, and the remainder would be in discontinuous permafrost. Permafrost is critical to terrain stability in the region, and subsidence can be expected when the sediments are ice-rich and the ground surface is disturbed by construction activity (such as vegetation clearance on the right-of-way and trenching), as has been observed in many places along the Norman Wells Oil Pipeline. On hill slopes, thawing of this ground can lead to landslides as the thawing results in a reduction of soil strength. For these reasons, the MGP poses distinct engineering challenges to minimize adverse impacts on the environment during construction and operations.

## Permafrost Monitoring and Baseline Environmental Information

A key component of the NOGSRI was to generate baseline information on terrain (surface and sub-surface) and permafrost conditions in order to have the ability to assess the impact of any potential development to the region. In one project by the Geological Survey of Canada at NRCan, gaps in baseline environmental information and permafrost monitoring in the Mackenzie Valley and Delta were addressed, within the proposed pipeline corridor (and its gathering lines), Anchor Fields in the Delta, and potential production areas. Information was generated



*Monitoring site installed in 2007 between Norman Wells and Fort Good Hope (photo, Sept. 2008). The orange box marks the location of the borehole and the temperature cable.*



*Permafrost monitoring network in the Mackenzie corridor. New sites were established between 2005 and 2007 to fill gaps in the existing network.*



on ground thermal, permafrost and ground ice conditions and geotechnical properties of surficial materials. This information helps characterize terrain sensitivity to environmental change (including climate change, development). Project results are essential for assessing present permafrost conditions, detecting change in these conditions resulting from surface disturbance or climate change, and predicting future response to natural and human-induced processes.

Ongoing monitoring of permafrost temperatures provides a baseline against which to measure change that may be caused by hydrocarbon development and transportation and other potential development in the region. Such a monitoring network can form the basis for environmental monitoring and management programs and regional cumulative impact monitoring and assessment programs. Over 50 new boreholes were drilled throughout the corridor, and temperature cables installed to fill key regional information gaps in the Mackenzie permafrost monitoring network. Information on geologic materials and ground ice conditions was also obtained. Baseline permafrost thermal data now exists where little recent data were previously available (e.g. Norman Wells to Inuvik), for Anchor Fields and gathering systems, sensitive slopes in the pipeline corridor and southern peatlands. The ground thermal and geotechnical data are available through Geological Survey of Canada publications (e.g. Geological Survey of Canada Open File 6041; Geological Survey of Canada Current Research Papers 2010-2, 2008-20, 2007-B7) and ground temperature data are also available through the Canadian Permafrost Monitoring Network web site ([http://canpfnetwork.com/temperature/canada\\_e.html](http://canpfnetwork.com/temperature/canada_e.html)). The use of project results for engineering design and in the regulatory process contributes to safe, reliable operation of hydrocarbon production and pipeline infrastructure and minimization of environmental impacts.

## **Permafrost Investigations across Tree Line, Mackenzie Delta Region**

Permafrost and related environmental issues in the Mackenzie Delta were also examined by a team of scientists led by INAC. Similarly to the NRCan permafrost project, the INAC project aimed to collect and analyze information on terrain, permafrost and water quality conditions along the proposed pipeline corridor, but specifically focused in the Inuvialuit Settlement Region. The project also established multi-disciplinary study sites which will continue to serve as reference sites against which cumulative impacts of development can be measured. The work resulted in several complementary environmental datasets, providing a good understanding of baseline environmental conditions in the Delta region. Collection and analysis of information is required to plan and manage potential pipeline development and oil and gas exploration. Data is compiled in several publicly accessible databases including the Stream Crossings and Sumps Databases (<http://ssc-btc.inac.gc.ca/streamcrossings/> and <http://ssc-btc.inac.gc.ca/sumps/>, respectively). This information provides a basis upon which to guide environmental decision making and assess the cumulative environmental impacts of development.

## **Monitoring of Overland Winter Ice Road Impacts within the Kendall Island Bird Sanctuary**

Another project conducted in the Inuvialuit Settlement Region was led by the Canadian Wildlife Service at EC to monitor the impacts of overland winter ice road within the Kendall Island Bird Sanctuary (KIBS). The objective was to determine whether current ice road construction methods in the Mackenzie Delta result in permanent or temporary habitat alteration. Vegetation sampling was conducted at the Chevron Kumak I25 well pad and access road in 2007 and 2008. Species composition

and biomass were assessed. The study showed that the shrub component of the plant community was severely impacted by ice road construction methods.

### **Subsidence Study in the Kendall Island Bird Sanctuary**

The environmental impact of land subsidence on available bird habitat in KIBS due to gas extraction has the potential to be significant. However, there is considerable uncertainty in estimates of the potential impact, due to difficulties in measuring and monitoring subsidence and differentiating effects of natural and human-induced subsidence (as a result of gas being extracted from the reservoir) processes in the area. In partnership with other government agencies including NRCan and the Water Survey of Canada, the Canadian Wildlife Service undertook studies to improve land subsidence estimates and establish baseline information for future monitoring and permitting. High resolution IKONOS satellite imagery and water level data obtained for potential subsidence areas were used to obtain accurate seasonal water level data at Big Lake and other areas within KIBS near the proposed Taglu Anchor Field, baseline data for use in future tracking of the rate and magnitude of subsidence associated with gas extraction at Taglu, and subsidence measurements to finalize establishment of habitat conservation measures to compensate for subsidence impacts.

### **Geotechnical Evaluation of Slope Failures and Movement Mechanisms**

NRCan also led a project to investigate geotechnical behaviours of landslides in permafrost in the northern region of the Mackenzie Valley (Beaufort Sea to Fort Good Hope with focus on the northern half of the corridor) where hundreds of thaw slumps occur and remain active every summer. The project addressed knowledge gaps on landslide issues in permafrost regions. The objectives were to improve understanding of landslides in permafrost, investigate triggers that cause slope failures, study slope failure and movement mechanisms, and contribute to improved land use planning and minimization of environmental impacts. Ground thermal, pore water pressure and settlement

behaviours of thawing permafrost soils were verified through field and laboratory experimental studies. Results enhanced thaw consolidation theory for improved stability design of permafrost slopes. The project identified soil moisture characteristics near the permafrost table from hundreds of soil samples collected from numerous landslide sites in the Mackenzie Valley, thereby providing a knowledge base for understanding dynamics of near surface permafrost soils and permafrost slope behaviour. A correlation between landslide retrogression rates and the height of landslide scarp walls was developed from field monitoring of 17 active landslide sites. Along with characterization of other landslide movement behaviours, the findings improved understanding of permafrost slope failure and movement characteristics, which are useful for design and landslide hazard mitigation for pipelines, roads and other construction projects in permafrost.

### **Regional Terrain Hazards Evaluation and Landslide Mapping**

NRCan led another study that further evaluated regional terrain hazards and developed landslide mapping models that covered a corridor extending 20 km to either side of the Inuvik-Norman Wells section of the proposed pipeline route, for a length of 540 km and an area of 24,000 km<sup>2</sup> ([http://gsc.nrcan.gc.ca/landslides/activ/mackenzie/index\\_e.php](http://gsc.nrcan.gc.ca/landslides/activ/mackenzie/index_e.php)). The study area also included the Ramparts (southwest of Fort Good Hope) and the Thunder River regions, both known for widespread landslides. The project provided baseline information on the types, regional distribution, and control of landslides and created a regional terrain hazards geospatial database. The study also led to the development of a landslide susceptibility mapping methodology in permafrost terrain and a remote sensing technique, InSAR (Interferometric Synthetic Aperture Radar), for monitoring unstable permafrost slopes.



## Coastal and Nearshore Conditions

Coastal geoscience projects were conducted in the Mackenzie Delta from 2004–2010. These projects generated information about land movement, coastal stability, coastal and nearshore processes, the properties of nearshore materials, and coastal hazards (flooding and erosion) which result from a combination of storms, sea level rise, permafrost degradation and movement of the Earth's crust. Research results provide critical information in support of coastal oil

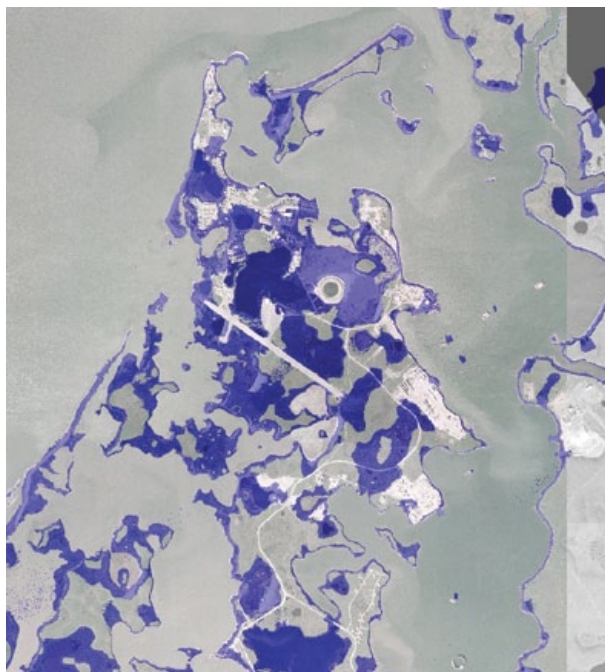
and gas development. The objectives of the study were to measure nearshore seabed erosion of more than 5 m due to drainage of spring water overflow; to develop models of waves and nearshore hydrodynamics in order to predict sediment transport; and to measure the rates of subsidence due to natural processes across the Mackenzie Delta in order to establish background rates prior to development. Results have been presented annually to the communities of Tuktoyaktuk, Sachs Harbour, Inuvik, Aklavik, Paulatuk and Holman since 2005.



*GPS measurements of subsidence on the Mackenzie Delta. Higher than expected natural rates of subsidence range from 2 to 6 mm per year.*

## Beaufort Sea Geoscience

Related work on geological stability was also conducted in the Beaufort Sea. Seabed geohazard and geoenvironmental obstacles to development were investigated and presented to regulators and industry. Key geohazards included coastal and nearshore stability, seabed ice scouring, subsea and coastal permafrost, unstable foundation conditions, shallow gas hazards and artificial island stability. Benthic ecosystem sensitivity to hydrocarbon development was a key geo-environmental challenge. Federal, territorial and Inuvialuit regulatory agencies require knowledge of the distribution and severity of coastal and seabed instability conditions for timely and informed decisions. The project involved the review of existing data and completion of surveys to generate digital maps, databases and reports required by stakeholders. The approach centered on the use of state-of-the-art digital multibeam and GIS mapping technologies.



*High resolution digital elevations models based on LiDAR (light detection and ranging) data collected over portions of the Delta and at communities allow estimation of flooding extent and depth due to spring floods or open water season storm surges. The illustration shows the extent of flooding at the Hamlet of Tuktoyaktuk during a 100 year storm surge event under present sea level.*

# WATER

*Protection of water resources and water quality in particular was identified as a key prerequisite for approval of the MGP.*

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## Water Quality Program

EC established and maintained automatic monitoring stations, measured water chemistry and monitored biological condition, assembled databases, and responded to requests for water quality information for the MGP. Achievements include acquiring water quality and biological data to determine baseline conditions at key sites along the length of the proposed pipeline, installing and maintaining automated water quality monitoring equipment at two sites allowing for real-time water quality information at proposed MGP stream crossings, and developing studies to characterize the aquatic ecology of arctic lakes and streams within the MGP area.

## Pipeline Stream Crossings Study

INAC also led a project that collected water quality and quantity information at select stream crossing locations along the proposed MGP route from 2003–2007. Data were collected from 48 locations on or near the proposed route from Jungle Ridge Creek (south of Norman Wells) northward to YaYa River on Richards Island (north of Inuvik). This information provided insights into the natural variability of environmental conditions within the study area and a basis for developing water quality monitoring programs to assess potential impacts resulting from MGP construction and operation.

## Understanding Baseline Hydrology of Streams along the Pipeline Corridor

The proposed pipeline will cut across approximately 675 stream systems along the east side of the Mackenzie Valley, where historical hydrometric (streamflow) records are limited. In 2002, the Water Survey of Canada at EC began analysis to determine potential locations of an enhanced hydrometric network resulting in ten new and four reactivated stations, including changes at four existing sites from seasonal to annual operation in the Delta region. Hydrometric data are fundamental to understanding and predicting future hydrologic changes, and are required for assessing, mitigating, designing and licensing of any induced development. Water quantity data are also used to support water quality monitoring activities of both EC and INAC to determine baseline conditions along the length of the proposed pipeline. Remotely transmitted water level data from other sites in the basin are used by the Water Survey of Canada to produce the Mackenzie River Forecast—a 4 day water level forecast for key locations on the Mackenzie River produced on contract to the Canadian Coast Guard. The Forecast will be especially useful during the construction phase of the pipeline. Preliminary flows and water levels are reported in real-time and final data published on the Water Survey of Canada web site: [http://www.wateroffice.ec.gc.ca/index\\_e.html](http://www.wateroffice.ec.gc.ca/index_e.html).



### **Mackenzie Runoff Assessment Project**

A Mackenzie basin runoff assessment project led by EC focused on further assessing streamflow characteristics in the pipeline corridor at ungauged locations. Precipitation, temperature, runoff, and evaporation in the Mackenzie basin were calculated using a variety of methods and examined on both an annual and monthly basis. A model was used to calculate streamflow using measured temperature and precipitation as input. The model was adjusted to give the best match between the simulated and measured streamflows at the Liard River at Fort Liard station. Simulated streamflows were calculated for the 59 rivers and creeks that flow into the Mackenzie River between Fort Simpson and Arctic Red River. A majority of the 59 rivers and creeks had never had any streamflow measurements made and only 4 had measured streamflow data for more than 10 years between 1961 and 1990. Models were developed to estimate flows along the major rivers of the Mackenzie Basin.

### **Assessment of Climatic Data Sets Available for the Mackenzie Valley and Delta**

Consistent and accurate climate data are also required to better understand past and current trends and variability in the hydrologic cycle and climate of the Mackenzie region. An assessment of climatic data sets available for the Mackenzie Valley and Delta was led by EC to determine the best data set for the depiction of past and current hydro-climatic trends and variability in the region, and to relate the hydro-climate to atmospheric circulation patterns at various spatial scales.

### **Hydrology of Development Areas to the East of the Mackenzie Delta**

Hydrologic conditions related to snow cover, stream flow, and water availability were further investigated by EC for the uplands within the MGP development area north of Inuvik, to better understand hydrologic requirements and impacts of winter activities, stream crossings, and water withdrawals from streams and lakes. Risks to gas infrastructure in the Delta region associated with rapid drainage of permafrost-dammed lakes were also investigated to determine critical areas, the rate of lake drainage, or the magnitude of possible drainage. Research focused on field work, including studies of the Trail Valley Creek basin, to test and validate hydrologic models, and measurements of lake level and lake evaporation. Lake and model data were analyzed to estimate changes in peak lake levels over a 30 year period. Changes in the rate of lake drainage over a large area east of the Mackenzie Delta were demonstrated, with a decrease in the number of lakes draining each year. However, a decreased rate of lake drainage in the northern portion of the study area was complemented by increased drainage in the southern portion over the last 30 years.

## **Mackenzie Delta Lake and Channel Hydrology**

Channels and lakes of the Mackenzie Delta undergo large changes in water level due to variations in the Mackenzie River discharge, ice jams, and Beaufort Sea storm surges. To better understand the relative importance of these processes and the water level regime of the Mackenzie Delta and, in particular, issues related to subsidence in KIBS, EC conducted detailed field studies in the outer Delta at sites that are typical of locations where the MGP is proposed to provide unique data on the hydrology of KIBS. Analysis of the water level regime of the main channels in the vicinity of both Taglu and Niglintak gas fields has demonstrated the flooding regime of key habitat of KIBS, and demonstrated that the factors controlling flooding of these areas are not well understood. Work in collaboration with NRCan improved the network of deep benchmarks required to obtain accurate elevations needed for comparing water levels across the Delta. The conversion of the Water Survey of Canada water level data allowed for the first time an understanding of the channel water slopes in the Delta and how these vary through flooding, storm surge, and low water periods. Work with NRCan led to the development of a system to measure water velocity in ice constrained channels in the outer Mackenzie Delta. This will provide a better understanding of the interactions between water levels in the outer Mackenzie Delta and those in the Beaufort Sea during breakup.

## **Extreme Events/Ice Jams in the Mackenzie Delta**

EC also led a study of extreme ice events and ice jams in the Mackenzie Delta that investigated the role of river ice on water levels in the main channels of the Delta. Specific focus was on extreme events, and their linkages to upstream flow and local climatic conditions. Special attention was paid to major scour holes in the Delta channels; sites that could pose major problems to operations (infrastructure and transmission). Previous work hypothesized that these holes are linked to ice-jam induced scour. This work demonstrated that extreme spring flood events, which affect the Delta, can be classified as ice-driven events, with high backwater levels in the southern and eastern/western Delta, and as discharge-driven events, with extensive high water levels in the mid/outer Delta and along Middle Channel, despite lower upstream peak water levels. The analysis of scour holes in various Mackenzie Delta channels showed that links to erosional and ice jamming processes are not part of the formative mechanism.

## FISH / MAMMALS

*The discharge of large quantities of fresh nutrient-rich water from the Mackenzie River creates a band of reduced salinity extending through the estuary and along the shore of the Beaufort Sea. This zone provides a unique habitat used by marine, freshwater and diadromous fish.*

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The Beaufort Sea and adjacent coastal areas provide a wide array of important habitats for species of international, national and regional importance, including the largest summer feeding population of bowhead whales and perhaps the world's largest summering stock of beluga whales. Marine mammals are of critical value to northern residents and other Canadians. Fish are also important components of the natural environment of the Mackenzie River. They are a valuable commercial, recreational and cultural resource and are indicators of the health of the aquatic ecosystem. Many aspects of the culture and identity of people in northern communities are vitally connected to wildlife and the habitats that support wildlife.

### **Impacts of Industrial Activities to Fish Species in Lakes of the Mackenzie Valley Region**

Accelerated exploration and development in the Mackenzie Valley has intensified the need to gather baseline information on the fish resources throughout the region. From 2004 to 2007, DFO conducted research projects in the Gwich'in and Sahtu Settlement Areas, looking at various fish species communities, their population abundances, and baseline vital statistics (growth, reproduction, mortality). DFO also examined the habitats of these species both within the lakes and the tributaries that the fish use for seasonal migrations, all with

the potential to be affected by the building of the proposed MGP. Study lakes included Sandy Lake and Travaillant Lake in the Gwich'in Settlement Area, and Loon Lake and Yeltea Lake in the Sahtu Settlement Area. A database of biological data for key harvested species as well as relative abundance data for non-harvested species was produced. Critical feeding, spawning and over-wintering habitats were identified for broad whitefish, a key harvested species in the Travaillant Lake system, by tracking fish equipped with small radio transmitters. The results are valuable to resource managers for determining both pre- and post-pipeline safe harvest levels, and for assessing if the pipeline and increased access due to industrial activities will potentially impact fish production. The results of these studies have been summarized in reports and presented to the various renewable resource boards in these settlement areas.



*Fish sampling and vital statistics being collected on sub-sample of fish*



## Reference Site Approach – Ecosystem Health

DFO led a Reference Condition Approach study to assess ecosystem health along the entire proposed pipeline corridor to evaluate potential impact and establish a baseline for long-term monitoring of freshwater streams. The project has potential application to monitoring for induced development, other land use impacts, and climate change. Field data were collected from 102 streams in the Inuvialuit Settlement Region, Sahtu Settlement Area, and Dehcho and Dene Tha' regions. Objectives were to collect physical (habitat, water chemistry) and biological (invertebrates) data to define the baseline state of streams along the pipeline corridor. The Reference Condition Approach is an internationally recognized approach to large geographic bio-monitoring, and has been supported by land claim organizations in its novel approach in the Mackenzie Valley.

## Sedimentation Effects on Habitat

Another project in the Sahtu Settlement Area examined potential sedimentation impacts on fish habitat and developed tools to assist in the regulatory process. The project focused on field data collection at Canyon Creek, Jungle Ridge Creek, and Tieda River in the Sahtu Settlement Area. First Nations were involved as local wildlife monitors. The project quantified natural arctic stream sedimentation rates, stream turbidity, and fish habitat characteristics. Results are applicable to most fish-bearing streams with gravel beds along the pipeline route. A Fisheries Risk Assessment Tool related to potential for sediment to impact on fish and fish habitat was developed to assist DFO in prioritizing proposed MGP stream crossings for regulatory review and approval.



*Sampling Campbell Creek during Reference Condition Approach*

## Sensitive Fish Habitat Study

A fish habitat research project was undertaken by DFO to improve our understanding of the distribution and habitat use of sensitive fish in the Mackenzie River Valley. This project is part of a larger, integrated project being conducted across the western Arctic to assess critical habitat for sensitive fish species (e.g., Dolly Varden) and investigate how impacts to these habitats may affect populations. The project was initiated in response to the MGP; however, the

information gathered is designed to assist regulators, industry, habitat management biologists, and First Nations communities develop mitigation measures and guidelines for environmental impacts on fisheries resources from hydrocarbon activity in this area. Field assistants, which included students from Sahtu and Dehcho communities, assisted with field work. Results describe the seasonal distribution, diet, and habitat associations of sensitive fish species such as Bull Trout and Arctic Grayling.



*To learn more about sensitive fish and their habitat, fisheries research biologist Neil Mochnacz gathers environmental and species data from waters such as the Gayna River (above), a tributary of the Mountain River in the Mackenzie River system*





*Winter road along the Mackenzie River*

### Identification and Description of Spawning and Over-wintering Habitats of Anadromous Fish Species

For the fish of the Mackenzie River and its tributaries, some migration routes and spawning grounds remain unknown. And even those documented in the past may now be different because of climate change. The Arctic, which is expected to see the greatest rise in temperature, is particularly vulnerable to ecological disruption. Research paid special attention to sensitive species and those important to local fisheries. In tracking fish migrations, DFO researchers made extensive use of Gwich'in, Shatu Dene, and Inuvialuit traditional knowledge, and combined it with modern technology. Small electronic transmitters implanted in fish generate signals to be picked up by up to six temporary towers erected along the river, and by a helicopter with receiving equipment. Researchers have so far found routes and over-wintering refuges for

Broad Whitefish, Lake Whitefish and Inconnu. The research seeks to identify areas that need to be treated with extra caution during construction activities for the MGP.

### Impacts of Winter Water Withdrawal on Fish and Fish Habitat in Small Northern Lakes

Another project investigated the impacts of winter water withdrawal on fish and fish habitat. In northern regions, water is withdrawn and used for winter road construction. Such withdrawals can lower water levels and lead to reduced oxygen concentrations that can impact fishes. Regulatory withdrawal limits are largely theoretical. Limits were tested by removing 10% and 20% of the under-ice volumes from two small lakes near Yellowknife, and comparing oxygen values, temperature, over-wintering habitat, and northern pike abundance to baseline conditions.





*River seismic testing in the Mackenzie River*



*Canadian Coast Guard Ship Nahidik,  
Beaufort Sea Shelf science platform*

### **Mackenzie River Seismic Study**

DFO led a Mackenzie River seismic study to assess the impacts of air-gun noise on fish. Extensive seismic activity in the Mackenzie River area included land, lake and river seismic. The objective of this project was to test the hearing of riverine fishes that were exposed to air-gun generated noise using the auditory brainstem response technique. The study was conducted in response to community members who raised concerns about the health of the riverine fish species, which they rely on for subsistence food sources. Results were used in the permitting and approval stages for river seismic, and mitigation measures were recommended.

### **Northern Coastal Marine Program aboard the Canadian Coast Guard Ship *Nahidik* – Marine Fish Project**

One of the major projects initiated under the NOGSRI and led by DFO from 2004 to 2009 was a multidisciplinary, coastal marine program aboard the Canadian Coast Guard Ship *Nahidik*. This program generated information on physical oceanography, water chemistry, zooplankton and benthos, as well as information on fish species' presence, distribution, and habitat use. The aim of the project was to provide baseline ecological information on Beaufort Sea oceanography and fauna to regulators and stakeholders in response to induced oil and gas exploration and

development associated with the MGP. This project was conducted in partnership with NRCan, allowing for integration of seabed, oceanography, and biological science in an ecosystem context. This information is being and will continue to be used by regulators in the assessment of oil and gas exploration and development proposals in the Beaufort Sea Shelf area. The information is currently being used by industry in their environmental assessments, planning of field studies and in the design of monitoring programs to fulfill their environmental assessment requirements in the Beaufort Sea. The information is also being used by ocean managers and other northern regional assessments and plan of actions. A variety of related research projects are utilizing this data in their studies (e.g. bowhead whale distribution in relation to seismic activity). Students from the Inuvialuit Settlement Region have been part of the *Nahidik* program to broaden awareness and mentor and foster youth interested in science in the north.

### **Assessment of the Possible Impacts on Polar Bears of Oil and Gas Activities in the Outer Mackenzie Delta and Nearshore Southern Beaufort Sea**

An assessment of the possible impacts on polar bears of oil and gas activities in the outer Mackenzie Delta and nearshore southern Beaufort Sea was led by the Canadian Wildlife Service in response to the MGP

and induced oil and gas activity in the Mackenzie Delta and nearshore Beaufort Sea. During the period from freeze-up in the fall through breakup in spring, much of the area that could be impacted is adjacent to, or overlies, habitat used seasonally by polar bears. In general, polar bears occur at low densities and have low rates of reproduction. Inuvialuit communities depend on polar bears for health and livelihood. The traditional hunt is limited to a sustainable level; however, population size could be negatively affected if the maximum sustainable harvest is exceeded as a consequence of effects on bear populations that may be attributed to oil and gas activities. Thus, a description of the location and importance of critical habitats, identification of possible impacts of development on polar bears and recommendations to minimize potential problems was deemed essential. Surveys for polar bear maternity den sites took place in March of 2006, 2007, 2008 and 2009. A GIS-based polar bear denning habitat model was completed in the spring of 2008 and was assessed for accuracy using field data collected in the summers of 2008 and 2009. The map will be used to help avoid the disturbance of denning female polar bears. Capture-recapture data was used to create a map of important feeding areas for females with cubs-of-the-year after they emerge from their den sites in the spring. These areas should be considered for protection as females with cubs are particularly susceptible to disturbance.

### Potential Effects of Hydrocarbon Exploration Activity in the Nearshore Beaufort Sea on Seals in their Land Fast Ice Habitats

A study to identify and evaluate any potential impacts of offshore industrial activities on resident seal populations was led by DFO, with a view to providing advice on any mitigating measures and monitoring studies that might be employed effectively in the future. The study area was around Devon Canada Corporation's Paktoa site in the southeast Beaufort Sea. The first three years of the study (2003, 2004, and 2005) were conducted prior to industry activity at Paktoa, whereas the fourth year (2006) was conducted during the latter part of a single exploratory drilling season when Devon Canada tested and abandoned

their exploratory well, demobilized the rig, and constructed and maintained an ice road and airstrip. DFO study methods included ice surveys using trained detection dogs, satellite tagging and tracking of 20 individuals, aerial surveys during the seals' basking period, and collection of 62 specimens to examine body condition and reproduction of individuals. Over the four years of the study, the work was greatly enhanced by the involvement of 19 Inuvialuit field technicians. The distribution of seal structures, including under-snow lairs and breathing holes, and the behaviour and distribution of tagged seals, did not differ significantly among the non-industry and industry years studied. Natural abandonment of seal structures ranged from 21 to 26 percent in 2003, 2004 and 2005, with a lower rate (10 percent) in 2006 being attributed to the significantly later date of freeze up in that year. The collected specimens showed the ringed seals in this area to be in good body condition with ample fat stores, in normal reproductive status, with zero or negligible levels of polycyclic aromatic hydrocarbons, and 74 percent with prey in their stomachs. There was a significant increase in the densities of basking seals near the floe edge compared to farther from it, but no detectable relationship between the distribution of basking seals and the Paktoa site in any year. Overall, the study provided important baseline information on the use



*A young ringed seal close to its breathing hole*

*Detection dogs near the Paktoa site*



of the nearshore Beaufort Sea by ringed seals during spring, and is a benchmark for any future studies involving multiple or longer term drilling operations. The results suggest that one season of drilling by industry at the Paktoa site had no detectable effect on ringed seals in the study area. The effects of longer exposures to industrial activity, or exposure to multiple industrial sources, remain unknown.

### **Beaufort Beluga**

The beluga whale is a culturally and ecologically important species in the Canadian Beaufort Sea. The Inuvialuit have relied on the beluga as part of their subsistence harvest for thousands of years. Concerns were raised that activities related to the MGP could affect the aggregation of Beaufort Sea beluga, so research assessed their habitat requirements in relation to oil and gas operations. With the invaluable assistance of local hunters and trappers, 42 belugas were tagged during two seasons in the Mackenzie Delta area, and the animals were tracked by satellites. Electronic tagging showed that belugas migrate further than previously thought, even as far as Russia. The results also shed light into the annual

aggregation and residence time of belugas from early July to the end of September in the Mackenzie Estuary, and on forays into other offshore areas of the Beaufort Sea. This information will help industry and regulators plan their activities so as to minimize impacts on beluga.



*DFO scientists and Inuvialuit Hunters and Trappers secure a beluga whale for tagging*



## SHOREBIRDS / WATERFOWL

*Environment Canada (EC) considers the Mackenzie Delta to be the most important migratory bird terrestrial habitat site in northern Canada. The Kendall Island Bird Sanctuary (KIBS) is an especially important area of the Delta that received protection status in 1961 under the Migratory Birds Convention Act.*

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The Niglintgak and Taglu Anchor Fields lie mostly beneath KIBS. It is critical to gain a better understanding of sensitive breeding times and places to minimize the potential impacts of oil and gas development activities on bird habitat throughout the Mackenzie Valley and Delta.

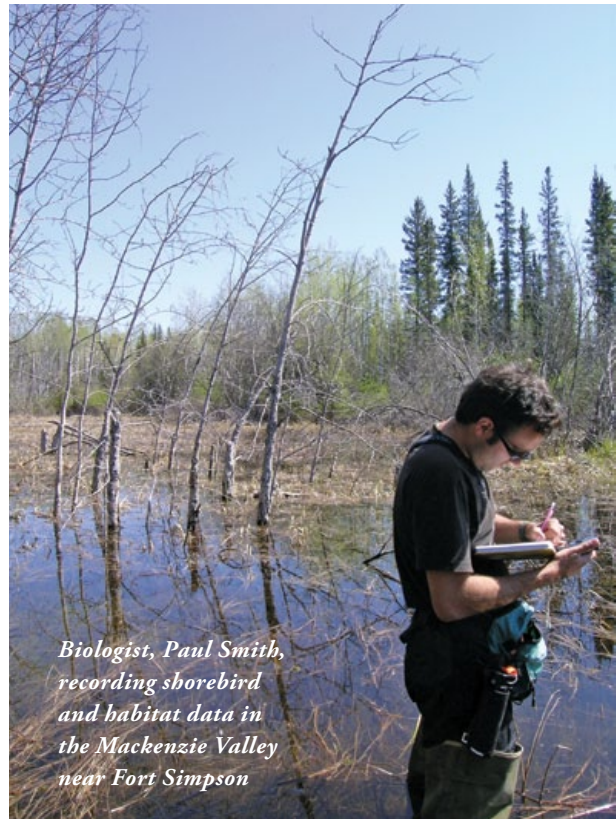
pipeline development in the Mackenzie Valley. Breeding, mating, behaviour and habitat use of target boreal shorebirds about which little is known, such as Lesser Yellowlegs, Wilson's Snipe, Solitary Sandpiper, Spotted Sandpiper, was documented.

### **Impacts of Pipeline Edges on the Predation Dynamics of Nesting Forest Songbirds**

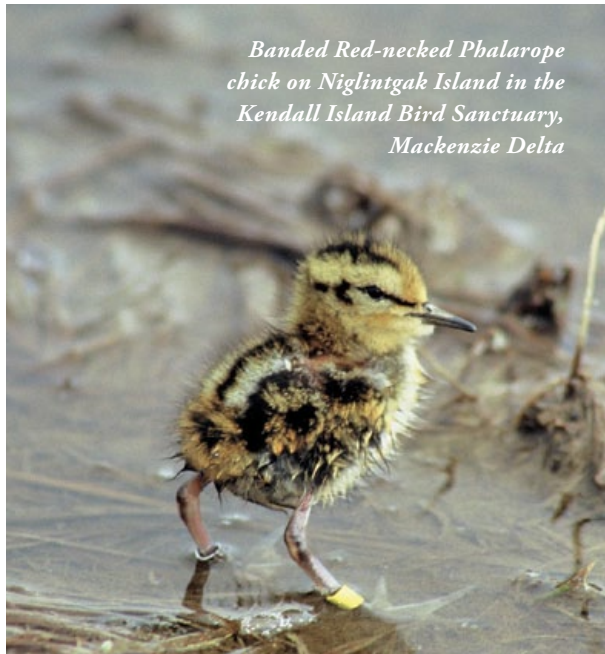
From 2004–2008, an EC-led project determined how the presence of a pipeline corridor affects bird communities by investigating how predators behave relative to the pipeline. Work was conducted in the Fort Simpson area and in northwestern Alberta. The two sites allowed for a comparison of landscape types with differing levels of development (high and low). The information can help identify remediation solutions for pipeline development that reduce the risks of altering normal predator-prey relationships in the boreal forest.

### **Shorebird Surveys along the Proposed Pipeline Route and the Mackenzie River**

From 2005–2008, the Canadian Wildlife Service led shorebird surveys along the proposed pipeline route and the Mackenzie River that focused on ground surveys for shorebirds in the boreal forest to collect much-needed breeding biology information for species that may be impacted by



*Biologist, Paul Smith,  
recording shorebird  
and habitat data in  
the Mackenzie Valley  
near Fort Simpson*



*Banded Red-necked Phalarope chick on Niglintgak Island in the Kendall Island Bird Sanctuary, Mackenzie Delta*



*The Mackenzie Delta and nearby areas comprise one of the most important breeding areas for Tundra Swans in North America. Monitoring swan numbers and productivity provides useful information on the effects of industrial development, climate change, and other stressors impacting the Mackenzie Delta ecosystem.*

## Shorebird Surveys throughout the Mackenzie Delta

Additional shorebird surveys through the Mackenzie Delta were conducted by the Canadian Wildlife Service using aerial and ground surveys, with intensive surveys in KIBS. The objectives of the surveys were: to calculate population estimates and produce distribution maps by habitat type for common and priority shorebird species in the Mackenzie Delta; to determine the number and spatial distribution of shorebird species within KIBS, particularly at the Taglu and Niglintgak production sites; to determine the number and spatial distribution of shorebird species along the gathering pipeline and at the Parsons Lake production site; and to determine alternate survey techniques for Whimbrel and survey for Short-eared Owl. The results will be used during permitting and monitoring phases of the MGP.

## Surveys of Waterfowl in the Mackenzie Delta Region

Waterfowl surveys were conducted by the Canadian Wildlife Service to monitor populations of waterfowl and other aquatic birds in the Mackenzie Delta,

Tuktoyaktuk Peninsula, and neighbouring parts of the mainland Inuvialuit Settlement Region. Many of the waterfowl are harvested by local residents for subsistence use, and the Inuvialuit are concerned that regional populations of these species are carefully managed. As well, general concerns about the status of many species exist at national and continental levels, further emphasizing the need for careful management. The proposed development of natural gas fields in the region could have an irreversible impact on waterfowl populations. Surveys were done from 2005–2008, and supplemented existing waterfowl survey data that had been annually collected in the region since the mid-1990's. Objectives were to document changes in numbers of a variety of species of waterfowl in one of the most important arctic breeding grounds, evaluate the impacts of gas and oil development on migratory bird populations in the Inuvialuit Settlement Region, and guarantee that sustainable numbers of waterfowl are maintained in the Mackenzie Delta region for the use of Inuvialuit and other Canadians. Recent survey results and historic archived data were used to determine population trends of common waterfowl and aquatic bird species of the region. Population density data were

summarized, modeled, and mapped using GIS to determine potential impacts of pipeline development on migratory bird populations in the Mackenzie Delta (including KIBS). The surveys will be continued in future years to monitor waterfowl populations if development such as the MGP goes forward.

### **Cumulative Effects of Gas and Oil Development on Waterfowl Using Tundra Swan as an Indicator Species**

Tundra swan was used as an indicator species to determine the long-term cumulative impacts of the MGP and related developments on waterfowl and other aquatic birds in the Mackenzie Delta. Detailed surveys of swan distribution, abundance, and productivity in areas impacted by oil and gas development (Niglintgak, Taglu, Parsons Lake) and suitable control sites in the greater Mackenzie Delta region (where no development is planned) were conducted. Surveys were done in 2001–2003 and 2005–2008. Surveys carried out during the pre-development period indicate similar population densities and productivity of tundra swans in both development and control sites. To date, it has been determined that existing pre-MGP developments (from developments in 1970s and subsequent exploration up to the early 2000s) have had minimal impacts on this indicator species. The surveys will be continued in future years to monitor swan populations if development such as the MGP goes forward.

### **Red-Throated Loon Study**

The Canadian Wildlife Service led a study using red-throated loons as an indicator species for early detection of the effects of offshore oil and gas on the marine environment and on migratory birds in particular. It provided data that will allow EC to participate effectively in the environmental assessment and evaluation of induced offshore oil and gas projects in the Mackenzie Delta/Beaufort Sea area. It provided an index of population status for red-throated loons, which is essential to the protection of the species as legislated by the *Migratory Birds Convention Act* and it fulfilled EC's obligations under

the Inuvialuit Final Agreement to collaborate with Aboriginal partners, as this project has been recognized as a high priority by Aboriginal co-managers. Finally, the project determined the baseline status of red-throated loons to help identify effects of current and future petroleum development within the nearshore environment of the Beaufort Sea. Aerial surveys have been completed and summary of reports distributed to Inuvialuit co-management partners.

### **Identification of Beaufort Sea Migration Corridor for Sea Ducks**

The Beaufort Sea is used by hundreds of thousands of sea ducks, primarily Long-tailed Ducks, King Eiders and Pacific Common Eiders, traveling between wintering areas west of the continent and breeding areas in northern Canada. Although there is some information on migration, little is known about the specific migration pathways and habitats used by the sea ducks. Hence, it is difficult to predict the degree of potential threat of expanded oil and gas development to these three sea duck species, all of which have experienced a population decline in recent years. Using satellite telemetry, a duck migration study is providing information about the location and timing of use of migration corridors in order to better predict and mitigate any adverse effects of offshore petroleum development on these populations. In 2006, 20 Pacific Eiders were tagged with satellite transmitters on their breeding grounds in Bathurst Inlet and their movements tracked over a 2-year period. In 2008, 30 King Eiders were tagged on their breeding grounds on Banks Island. The objectives of the study were: to identify the location of migration routes and staging areas for sea ducks in relation to areas of potential offshore oil and gas development in the Beaufort Sea; to determine the timing of migration and duration of stay in the Beaufort Sea; to determine the proportion of the Canadian population of each of the three sea duck species that stop to rest and feed in the south-eastern Beaufort Sea during spring and fall migration; and to determine temporal and spatial relationships of migrating sea ducks to shore-fast ice, bathymetry, shorelines and other physical features of the Beaufort Sea.



## ECOSYSTEM / PROTECTED AREAS

*Regional Plans of Action are intended to gather regulatory and environmental information and to plan how aspects of the NWT Environmental Stewardship Framework will be implemented in preparation for anticipated oil and gas development within specific regions. The Framework is a conceptual model that describes the linkages and relationships between various components of environmental management in the NWT.*

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### **Cumulative Effects Assessment – Regional Plans of Action and Environmental Stewardship Framework**

The NOGSRI supported the development of several regional plans of action and their contribution to assessing cumulative effects of development, including contributing to the Sahtu Target Implementation Project. The INAC-led project will assist the Sahtu Land Use Planning Board in achieving balanced development in the Sahtu Settlement Area by determining specific land use targets on a regional level that can be indicators of cumulative effects. These targets will then be used as a management tool in further developing the implementation of the Sahtu Land Use Plan. The NOGSRI also supported the development of the Water Strategy, which was aimed at gaining input from stakeholders across the NWT to develop a water management vision. The strategy would guide water management issues relevant to the MGP.

### **NWT Protected Areas Strategy – Mackenzie Valley Action Plan**

The NWT Protected Areas Strategy outlines a community-based process to establish a network of protected areas across the NWT. It recognizes the need to balance conservation and economic

development, while respecting Aboriginal rights, third party interests, and land use planning processes. The project supported the implementation of the Protected Areas Strategy in the Mackenzie Valley, which is part of the NWT Environmental Stewardship Framework. Project geologists from the NWT Geoscience Office and locally-hired field assistants collected glacial and stream bulk sediment samples, silt sediment samples, and water samples for analysis and provided technical support for the completion of non-renewable resource assessments of candidate protected areas in the Mackenzie Valley. This work provided new information on the non-renewable resource potential of candidate protected areas and is a key component of the information required to support sound decision-making on the final boundaries and management of the protected areas.

### **Advancing the Edézhíe and Ts'ude niline Tu'eyeta Candidate Protected Areas and Ecological Assessment of the Sambaa K'e Candidate Protected Area**

Two projects were undertaken to advance the Edézhíe Candidate and Ts'ude niline Tu'eyeta Protected Areas through Step 5 of the Protected Areas Strategy in preparation for the drafting of a proposal for submission to the Minister of

the Environment to establish the Edézhíé and Ts'ude nílíne Tu'yeyeta National Wildlife Areas. GIS computer modelling was used to delineate boundary options. Another project involved an ecological assessment of the floral and faunal characteristics of the Sambaa K'e candidate protected area near Trout Lake, NWT. Work included conducting forest bird point count surveys, wildlife transects, vegetation descriptions and general wildlife reconnaissance. The results of this study were digitally mapped.

### **Dall Sheep, Grizzly Bear, and Wolf Interactions in the Richardson Mountains**

INAC supported regional and community research projects which contributed to the gathering of biophysical and traditional knowledge information for the MGP and induced oil and gas development. One project led by the Gwich'in Renewable Resources Board (GRRB) studied the interactions between three wildlife species (Dall sheep, grizzly bear, wolf) in decline or at risk in the Richardson Mountains, within a landscape perspective, while attempting to identify the factors driving those interactions. The objectives were to: document home ranges, movements and habitats; quantify interactions, focusing on spatial dynamics, predation, nutritional ecology and behaviour; understand how landscape features, time of year, climate, human harvest and other disturbances affect interactions; and integrate Gwich'in traditional knowledge into the project. A database of relocation for six Dall sheep, nine wolves and fifteen grizzly bears was compiled. Two seasons of snow surveys providing information on animals' movement patterns and habitat use were completed. Community capacity was enhanced through employment opportunities for field assistants and involvement of youth and renewable resource councils in most portions of the project.

### **Woodland Caribou Field Survey**

Another project was undertaken to carry out phase 2 of Sambaa K'e Dene Band (SKDB) woodland caribou field survey in the MGP corridor from Trout River to K'eotsee in the Dehcho region. Use of the proposed MGP corridor by caribou was documented, as a



*Wildlife species at risk in the Richardson Mountains*

prerequisite to SKDB participation in the development and approval of an MGP Woodland Caribou Management Plan. Work included field surveys of caribou populations, habitat and movements. The study determined the prevalence of caribou and filled knowledge gaps on over-wintering of herds, while complementing research by the Government of the Northwest Territories (GNWT) and incorporating traditional knowledge in research methods. Information from this project was used in the MGP hearings and will be used in the ongoing process of monitoring impacts of the pipeline on the caribou herd.

### **Sahtu Barren-Ground Caribou Traditional Knowledge Study**

A Sahtu Renewable Resources Board (SRRB) project also explored Dene traditional knowledge and ways of identifying and addressing changes in the barren-ground caribou populations in the Colville Lake region of the Sahtu. Work resulted in a better understanding of ecological interactions which will provide baseline data, as well as the capacity to consider mitigations from MGP impacts. Community youth were trained, allowing for future involvement in MGP monitoring activities.

### **Bosworth Creek Monitoring Project**

The Bosworth Creek drainage basin in the Sahtu region is an important pipeline crossing in the MGP. A study gathered the baseline information necessary for environmental assessments and long term monitoring in preparation for the MGP. The project centered on generating new habitat data. Sampling and analysis of bird populations, soil and water chemistry, fisheries, fish habitat, benthic invertebrates, amphibians, and creek habitat were conducted. Community monitors and researchers were trained, and Mackenzie Mountain School students learned a wide range of scientific applications. The SRRB developed the ability to monitor impacts and account for natural and man-made changes to watersheds. This information was considered in the MGP cumulative effects hearings.

### **Ecosystem Classification: Multi-sensor Remote Sensing Data for Forest Inventory**

An NRCan study set out to enhance inventory information about forest vegetation, structure, volume and biomass, which is only available for a small portion of the vegetated areas of the NWT. Assessing the potential impacts of the proposed MGP is difficult due to lack of detailed current information about vegetation from which to assess potential impacts from development. Two assessments were undertaken. The first was a collaborative project on a detailed timber volume inventory audit of the proposed forest impacts presented by Imperial Oil. The audit and vegetation impact analysis reported to the JRP demonstrated that the timber volume estimates were highly underestimated. This led to a change and acknowledgement that the GNWT would serve as the forest manager and forest regulator on public lands. The second project was undertaken over a 616,000 ha area consisting of a 5-km swath along the entire length of the MGP footprint. Remote sensing mapping of forest structure, stand volume and above-ground biomass was conducted for an area near Fort Simpson that encompasses  $\frac{1}{6}$  of the total length of the MGP over an area 3.8 million ha in size. Maps and estimates of forest structure including stand height, crown closure, stand volume and above ground biomass across conifer, deciduous and mixed wood areas were completed, including areas where no such inventory previously existed. Conifer volume and biomass were estimated most accurately followed by deciduous and mixed wood forest types. Because MGP impacts extend beyond the footprint area, this information provides a more complete and current evaluation of the forest vegetation in the area than presently available. Inventory maps and compilations are being completed for use by the GNWT in support of inventory impact assessments.



## **Ecosystem Classification: Assessing Changes in Terrestrial Ecosystems due to Recent Climatic Changes and Human Impacts**

Another study on terrestrial ecosystems led by NRCan was designed to improve our understanding of the potential effects of recent climate change, as well as natural and human-induced disturbances, on vulnerability and sensitivity of different ecosystems in the Mackenzie Valley region. The objective of the project was to assess changes in the distribution and composition of forest and peat land ecosystems across the regional gradient due to recent climate change and permafrost thawing. Changes in ecosystem features in dominant ecozones along the planned MGP route were documented by establishing permanent plots suitable for re-measurement over time. In total, 26 sites (64 plots and 10 sub-transects) were established along the Mackenzie Valley. These sites are distributed across 12 ecoregions, within the continuous, extensive discontinuous and sporadic discontinuous permafrost zones. Site layout was designed to encompass the gradient from upland to peat land, and any associated regions of permafrost collapse. It was also determined, via modeling, which ecosystems along the pipeline corridor are most vulnerable to climatic and human disturbances. A GIS algorithm was developed to determine wet-area and flow-channel regimes for a 1.5 million ha study area within the Mackenzie Plain south of Fort Simpson. This algorithm combined a Digital Elevation Model with existing hydrographic information. A forest hydrology model was used to discern likely depth and duration of frost penetration into the soil for select

upland and wetland conditions, based on hydrothermal considerations and daily weather records, from 1963 to 2007. The data will be used at the regulatory stage for permitting and for long term monitoring.

## **Trophic Levels**

A DFO project gathered data to develop a model of the food web of the lower trophic levels of the nearshore area of the Beaufort Sea. Water, sediment and biological samples were collected for chemical analyses, biomass estimates, species identification and stable isotope measurements. This information is used to establish the components of the lower trophic levels that support the higher food web (fish and marine mammals) in the Beaufort Sea. This work complements other work that was done on higher trophic levels including fish studies and bowhead whale surveys, and is instrumental in the eventual development of monitoring programs and for an understanding of the complex interactions of fish and fish habitat as part of the environmental assessment and regulatory requirements. Additionally, the program assessed the possibilities of using fatty acid analyses of sediments to produce an environmental fingerprint or signature. There are apparently different signatures in the sediments that may be attributable to specific organisms of the lower food web. Ultimately, recommendations on key ecosystem components will allow for the development of monitoring programs to assess the success of mitigation measures in protecting aquatic resources.

# CONCLUSION

There has been renewed interest in hydrocarbon development in Canada's North, which contains abundant supplies of oil and gas. Development projects such as the MGP have the potential to generate important economic and social benefits for Northerners. However, increased development can lead to pressures on the environment and traditional ways of life. Federal science research projects in support of the MGP and induced oil and gas activities contribute to the goal of sustainable economic potential for Northerners and Aboriginal Peoples by helping safeguard the environmental health and heritage of the Mackenzie Valley and Delta, and Beaufort Sea.

The Northern Energy Development science projects described in this report have contributed to establishing baseline information for several biophysical components of terrestrial and aquatic ecosystems in the region. The research projects covered a broad range of subjects: geological and topographic maps, river and coastal charts, waves and nearshore hydrodynamics, nearshore erosion, terrain stability issues such as landslides and land subsidence, permafrost, water quality and chemistry, hydrologic cycle, ice jams, fish populations and habitat, benthic invertebrates, lake water withdrawal, seismic issues, marine mammals such as polar bears, seals and beluga whales, shorebirds and waterfowl, terrestrial wildlife such as caribou and wolves, vegetation, land use plans and protected areas. The knowledge acquired through these studies is crucial for gauging and minimizing potential adverse impacts of the MGP and induced activities. It promotes informed decision-making for rights issuance, exploration, safe and reliable hydrocarbon

production and pipeline infrastructure, assessments of environmental impacts and of cumulative effects of development, design of mitigation strategies and identification of remediation solutions, establishment of habitat conservation measures, determination of sustainable harvest levels, improvement of land-use plans and management of protected areas, and elaboration of long-term monitoring programs.

Many of these science projects involved Aboriginal community members and students. Their intimate knowledge of the environment and keen enthusiasm for learning, as well as their interest in the MGP and its implications for their livelihoods, was critical to the successful undertaking of many of the projects. Collaboration on all facets – sharing invaluable traditional knowledge with scientists, performing field work, gathering data, participating in ecosystem monitoring – led to the success of the projects and will ultimately benefit Aboriginal communities, proponents, and regulators.

The MGP represents a unique opportunity for the people of the NWT. Finding the proper balance between the social and economic benefits of oil and gas development and the conservation of largely pristine ecosystems remains a challenge. The knowledge gained through these science research projects will assist in industry and government preparedness in anticipating, preventing and mitigating potential environmental impacts of northern energy development. Our better understanding of the northern environment will help in establishing a sustainable future for Northerners and other Canadians.

# APPENDICES



# APPENDIX 1—LIST OF PROJECTS

Project	Department
<b>Geology / Mapping</b>	
Aerial Photography of the Mackenzie Valley and Delta	INAC
Geospatial Database Coverage, NWT	NRCan
Mackenzie/Beaufort Coastal Navigation Program	DFO
Surficial Mapping	NRCan
Geology Project to Support Oil and Gas Exploration and Development in the NWT	NRCan, GNWT, Gov. of Yukon
<b>Permafrost, Geohazards and Terrain Sensitivity</b>	
Permafrost Monitoring and Baseline Environmental Information	NRCan
Permafrost Investigations across Tree Line, Mackenzie Delta Region	INAC
Monitoring of Overland Winter Ice Road Impacts within the Kendall Island Bird Sanctuary	EC
Subsidence Study in the Kendall Island Bird Sanctuary	EC
Geotechnical Evaluation of Slope Failures and Movement Mechanisms	NRCan
Regional Terrain Hazards Evaluation and Landslide Mapping	NRCan
Coastal and Nearshore Conditions	NRCan
Beaufort Sea Geoscience	NRCan
<b>Water</b>	
Water Quality Program	EC
Pipeline Stream Crossings Study	INAC
Understanding Baseline Hydrology of Streams along the Pipeline Corridor	EC
Mackenzie Runoff Assessment Project	EC
Assessment of Climatic Data Sets Available for the Mackenzie Valley and Delta	EC
Hydrology of Development Areas to the East of the Mackenzie Delta	EC
Mackenzie Delta Lake and Channel Hydrology	EC
Extreme Events/Ice Jams in the Mackenzie Delta	EC
<b>Fish / Mammals</b>	
Impacts of Industrial Activities to Fish Species in Lakes of the Mackenzie Valley Region	DFO
Reference Site Approach – Ecosystem Health	DFO
Sedimentation Effects on Habitat	DFO
Sensitive Fish Habitat Study	DFO
Identification and Description of Spawning and Over-wintering Habitats of Anadromous Fish Species	DFO

Project	Department
Impacts of Winter Water Withdrawal on Fish and Fish Habitat in Small Northern Lakes	DFO
Mackenzie River Seismic Study	DFO
Northern Coastal Marine Program aboard the Canadian Coast Guard Ship <i>Nahidik</i> – Marine Fish Project	DFO
Assessment of the Possible Impacts on Polar Bears of Oil and Gas Activities in the Outer Mackenzie Delta and Nearshore Southern Beaufort Sea	EC
Potential Effects of Hydrocarbon Exploration Activity in the Nearshore Beaufort Sea on Seals in their Land Fast Ice Habitats	DFO
Beaufort Beluga	DFO
<b>Shorebirds / Waterfowl</b>	
Impacts of Pipeline Edges on the Predation Dynamics of Nesting Forest Songbirds	EC
Shorebird Surveys along the Proposed Pipeline Route and the Mackenzie River	EC
Shorebird Surveys throughout the Mackenzie Delta	EC
Surveys of Waterfowl in the Mackenzie Delta Region	EC
Cumulative Effects of Gas and Oil Development on Waterfowl Using Tundra Swan as an Indicator Species	EC
Red-Throated Loon Study	EC
Identification of Beaufort Sea Migration Corridor for Sea Ducks	EC
<b>Ecosystem / Protected Areas</b>	
Cumulative Effects Assessment – Regional Plans of Action and Environmental Stewardship Framework	INAC
NWT Protected Areas Strategy – Mackenzie Valley Action Plan	INAC
Advancing the Edézhíé Candidate Protected Area	EC
Advancing the Ts'ude niline Tu'eyeta Candidate Protected Area	EC
Ecological Assessment of the Sambaa K'e Candidate Protected Area	EC
Dall Sheep, Grizzly Bear, and Wolf Interactions in the Richardson Mountains	GRRB, INAC
Woodland Caribou Field Survey	SKDB, INAC
Sahtu Barren-Ground Caribou Traditional Knowledge Study	SRRB, INAC
Bosworth Creek Monitoring Project	SRRB, INAC
Ecosystem Classification: Multi-sensor Remote Sensing Data for Forest Inventory	NRCan
Ecosystem Classification: Assessing Changes in Terrestrial Ecosystems due to Recent Climatic Changes and Human Impacts	NRCan
Trophic Levels	DFO

## APPENDIX 2—SELECTED PUBLICATIONS BY LEAD DEPARTMENT

A complete list of publications for projects conducted under the Northern Oil and Gas Science Research Initiative can be found at the Hydrocarbon Impacts database of the Arctic Science and Technology Information System at the Arctic Institute of North America, University of Calgary: <http://www.aina.ucalgary.ca/hi/>. This list will continue to be updated as relevant publications are produced.

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### Environment Canada:

Beltaos, S. and Carter, T. 2009. Field studies of ice breakup and jamming in the Mackenzie Delta. CGU HS Committee on River Ice Processes and the Environment. Proceedings of the 15th Workshop on River Ice, St. John's, Newfoundland and Labrador, p.266–283.

Bonsal, B.R. and Kochtubajda, B. 2009. An assessment of present and future climate in the Mackenzie Delta and near-shore Beaufort Sea region of Canada. *International Journal of Climatology*, 29: 1780–1795.

Bonsal, B.R., Kochtubajda, B. and Stene, T. 2007. Climate change scenarios over the Mackenzie Delta and near-shore Beaufort Sea region. Report prepared for the Beaufort Sea Strategic Regional Plan of Action Committee.

Dornes, P.F., Tolson, B.A., Davison, B., Pietroniro, A., Pomeroy, J.W. and Marsh, P. 2008. Regionalisation of land surface hydrological model parameters in subarctic and arctic environments. *Journal of Physics and Chemistry of the Earth*, 33: 1081–1089.

Goulding, H.L., Prowse, T.D. and Bonsal, B.R. 2009. Hydroclimatic controls on the occurrence of break-up and ice-jam flooding in the Mackenzie Delta, NWT, Canada. *Journal of Hydrology*, 379: 251–267.

Marsh, P., Russell, M., Onclin, C. and Haywood, H. 2008. Modelling discharge during the rapid drainage of thaw lakes in the Western Canadian Arctic. 9<sup>th</sup> International Conference on Permafrost, Kane, D.L. and Hinkel, K.M. (editors), University of Alaska Fairbanks, p.1143–1147.

Marsh, P., Lesack, L., Hicks, F., Roberts, A., Hopkinson, C., Solomon, S., Forbes, D.L., Russell, M. and Haywood, H. 2009. Hydrology of the Mackenzie Delta: off-channel water storage and delta interaction with the Beaufort Sea. Proceedings of the 17<sup>th</sup> International Northern Research Basins Symposium and Workshop, 10p.

Marsh, P., Russell, M., Pohl, S., Haywood, H. and Onclin, C. 2009. Changes in thaw lake drainage in the Western Canadian Arctic from 1950 to 2000. *Hydrological Processes*, 23: 145–158.

Ogbebo, F. E., Evans, M.S., Waiser, M.J., Tumber, V.P. and Keating, J.J. 2009. Nutrient limitation of phytoplankton growth in Arctic lakes of the lower Mackenzie River Basin, Northern Canada. *Canadian Journal of Fisheries and Aquatic Sciences*, 66: 247–260.



Pohl, S., Marsh, P. and Bonsal, B.R. 2007. Modeling the impact of climate change on runoff and annual water balance of an Arctic headwater basin. *Arctic*, 60: 173–186.

Richardson, E.S. and Stirling, I. 2009. Polar bear maternity denning habitat in the southern Beaufort Sea: integrating science and traditional knowledge. Draft Technical Report, 50p.

Richardson, E.S. and Stirling, I. 2009. Potential impacts of induced nearshore development on polar bears (*Ursus maritimus*) in the southern Beaufort Sea. Draft Technical Report, 28p.

### Fisheries and Oceans Canada:

Asselin, N., Richard, P., Orr, J., Ferguson, S. and Loseto, L. 2008. Eastern Beaufort beluga: satellite tracking results and spring surveys. Industry Government Oil and Gas meeting, Calgary, Alberta, presentation.

Cott, P.A., Sibley, P., Gordon, A., Bodaly, R.A., Mills, K., Somers, M. and Fillatre, G. 2008. The effects of water withdrawal from ice-covered lakes on oxygen, temperature and fish. *Journal of the American Water Resource Association*, 44: 328–342.

Howland, K.L., Millar, N. and Wiley, S.F. 2008. Population analysis of harvested fish species in the Travaillant Lake system 2007. Summary report submitted to Gwich'in Renewable Resource Board and Renewable Resource Councils in Gwich'in Settlement Area, 6p.

Howland, K.L., Van-Gerwen-Toyne, M. and Tallman, R.F. 2009. Modelling the migratory patterns and habitat use of migratory coregonids in the Mackenzie River system. *American Fisheries Society Symposium*, 69: 895–897.

Majewski, A.R., Reist, J.D., Park, B.J., Sareault, J.E. and Lowdon, M.K. 2009. Fish catch data from offshore sites in the Mackenzie River estuary and Beaufort Sea during the open water season, July and August, 2005, aboard the CCGS *Nahidik*. *Canadian Data Report of Fisheries and Aquatic Sciences*, 1204: vii + 53p.

Mochnacz, N. J., Cott, P.A., Backhouse, S.M. and Reist, J.D. 2009. Biological and habitat data for fish collected during stream surveys in the Southern (Deh Cho) and Central (Sahtu) Northwest Territories, 2008. *Canadian Data Report of Fisheries and Aquatic Sciences*, 1222: vi + 34p.

Perrin, C. J., Bennett, S.A. and Rempel, L.L. 2007. Baseline conditions and model development for bioassessment of streams along the Mackenzie River valley using the reference condition approach. Report prepared by Limnotek Research and Development Inc. for Fisheries and Oceans Canada, 61p.

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Rempel, L.L. and Porter, M. 2008. A risk assessment tool for evaluating geohazards and fisheries sensitivity at pipeline water crossings. *Proceedings of the 7<sup>th</sup> International Pipeline Conference*, Calgary, Alberta, 10p.

Smith, T.G., Harwood, L.A., Melling, H., Kelly, B. and Moran, J. 2009. Assessing the potential effects of near shore hydrocarbon exploration on ringed seals in the Beaufort Sea region, 2003–2006. The 18<sup>th</sup> Biennial Conference on the biology of marine mammals, Quebec City, Quebec, poster.

Vallieres, C., Retamal, L., Ramlal, P., Osburn, C.L. and Warwick, F.V. 2008. Bacterial production and microbial food web structure in a large arctic river and the coastal Arctic Ocean. *Journal of Marine Systems*, 74: 756–773.

Walkusz, W., Paulić, J.E., Kwaśniewski, S., Williams, W.J., Wong, S. and Papst, M.H. 2010. Distribution, diversity and biomass of summer zooplankton from the coastal Canadian Beaufort Sea. *Polar Biology*, 33: 321–335.

### **Indian and Northern Affairs Canada:**

Canadian contribution to: AMAP. 2008. Arctic Oil and Gas 2007. Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway, xiii + 40p.

Canadian contribution to: AMAP. 2010. Assessment 2007: Oil and Gas Activities in the Arctic—Effects and Potential Effects. Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway. (3 volumes).

Gal, L.P. 2010. New analytical data from springs in the Carcajou River area, Mackenzie Mountains, Northwest Territories. Northwest Territories Geoscience Office, NWT Open Report 2010–009, 12 p.

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Kokelj, S.V., Lantz, T.C., Kanigan, J., Smith, S.L. and Coutts, R. 2009. Origin and polycyclic behaviour of tundra thaw slumps, Mackenzie Delta region, Northwest Territories, Canada. *Permafrost and Periglacial Processes*, 20: 173–184.

Pierce, K.L. and Jones, A.L. (compilers). 2009. ArcGIS@9.x Digital Atlas to accompany regional geoscience studies and petroleum potential, Peel Plateau and Plain, Northwest Territories and Yukon: Project Volume, Northwest Territories Geoscience Office, NWT Open File 2009–03.

### **Natural Resources Canada:**

Belanger, M., Hicks, F., Solomon, S.M. and Loewen, M. 2009. Influence of Mackenzie Delta breakup on the timing and duration of water overflow on the outer delta sea ice surface. CGU HS Committee on River Ice Processes and the Environment. 15<sup>th</sup> Workshop on River Ice, St. John's, Newfoundland and Labrador, presentation.

Bennett, R., Blasco, S., Beaudoin, J., Hughes-Clarke, J. and MacLean, B. 2007. Geohazards and navigational hazards in the Northwest Passage. ArcticNet Annual Scientific Meeting, poster.

Bergquist, C.L. and Pyle, L.J. 2009. Seventeen measured sections of Cambrian Mount Clark and Mount Cap formations, northern Mackenzie Mountains and Franklin Mountains, Northwest Territories. Geological Survey of Canada, Open File 6148, 77p.

Blais-Stevens, A., Couture, R., Page, A., Koch, J., Clague, J.J. and Lipovsky, P.S. 2010. Landslide susceptibility, hazard and risk assessments along pipeline corridors in Canada. Proceedings of the 63<sup>rd</sup> Canadian Geotechnical Conference and 6<sup>th</sup> Canadian Permafrost Conference, Calgary, Alberta, p.878–885.

Blasco, S. 2008. Seabed geo-environmental constraints to offshore hydrocarbon development in the Beaufort Sea. United States and Canada Northern Oil and Gas Research Forum, Anchorage, Alaska, presentation.

Bode, J.A., Moorman, B.J., Stevens, C.W. and Solomon, S.M. 2008. Estimation of ice wedge volume in the Big Lake area, Mackenzie Delta, NWT, Canada. Proceedings of the 9<sup>th</sup> International Conference on Permafrost, Kane, D.L. and Hinkel, K.M. (editors), University of Alaska Fairbanks, p.131-136.

Cormier, J. and Wang, B. 2009. Laboratory studies of near surface temperature and moisture conditions of permafrost soils. 62nd Canadian Geotechnical Conference, Halifax, Nova Scotia, p.1051–1059.

Duk-Rodkin, A., Huntley, D., Smith, I.R., Singhroy, V. and MacDonald, L. 2008. Surficial geologic research program in the southern Mackenzie Valley, Northwest Territories, Canada: its significance and use in planning pipeline construction and resource development. American Geophysical Union Annual Meeting, San Francisco, California, presentation.

Forbes, D. 2008. Subsidence, flooding, and erosion hazards in the Mackenzie-Beaufort region. United States and Canada Northern Oil and Gas Research Forum, Anchorage, Alaska, presentation.

Hall, R.J., Skakun, R.S., Arsenault, E.J. and Case, B.S. 2006. Modeling forest stand structure attributes using Landsat ETM+ data: application to mapping of aboveground biomass and stand volume. *Forest Ecology and Management*, 225: 378–390.

Lemieux, Y. and MacLean, B.C. 2008. Structural interpretation of seismic data in the southern Peel Plateau and Plain, Northwest Territories and Yukon: linking the northern Mackenzie and Franklin Mountains. Canadian Society of Petroleum Geologists, Annual Convention, Calgary, Alberta, poster.

Lesage, K. and Wang, B. 2008. Experimental studies of thaw consolidation of fine grained permafrost soils from the Mackenzie Valley. Proceedings of the 61<sup>st</sup> Canadian Geotechnical Conference, Edmonton, Alberta, p.911–918.

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Pyle, L.J. and Jones, A.L. (editors). 2009. Regional geoscience studies and petroleum potential, Peel Plateau and Plain, Northwest Territories and Yukon: Project Volume, Northwest Territories Geoscience Office and Yukon Geological Survey, NWT Open File 2009-02 and YGS Open File 2009-25, 549p.

Smith, S.L. and Solomon, S. M. 2007. Natural Resources Canada comprehensive written submission on the Mackenzie Gas Project environmental assessment review, submitted to Joint Review Panel (exhibit J-NRCan-00090).



Smith, S.L. and Burgess, M.M. 2010. Long-term field observations of cyclical and cumulative pipe and ground movements in permafrost terrain, Norman Wells Pipeline, Northwest Territories, Canada. Proceedings of the 63<sup>rd</sup> Canadian Geotechnical Conference and the 6<sup>th</sup> Canadian Permafrost Conference, Calgary, Alberta, p.595–602.

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Solomon, S.M., Couture, N.J., Forbes, D.L., Hoque, A., Jenner, K.A., Lintern, G., Mulligan, R.P., Perrie, W.A., Stevens, C.W., Toulany, B. and Whalen, D. 2009. Understanding nearshore processes of a large Arctic delta using combined seabed mapping, in situ observations, remote sensing and modeling. *Eos, Transactions, American Geophysical Union*, 90 (52), Fall Meeting Supplement, Abstract EP43B-0663.

Stevens, C.W., Moorman, B.J. and Solomon, S.M. 2010. Interannual changes in seasonal ground freezing and near-surface heat flow beneath bottom-fast ice in the near-shore zone, Mackenzie Delta, NWT, Canada. *Permafrost and Periglacial Processes*, 21: 256–270.

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