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Assessment of Drilling Waste Disposal Options in the Inuvialuit Settlement Region

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Assessment of Drilling Waste Disposal Options

In the Inuvialuit Settlement Region

by

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EXECUTIVE SUMMARY

In the Inuvialuit Settlement Region (ISR), the management and disposal of drilling wastes generated through the exploration and production of oil and gas resources from land-based operations remains a key issue for producers, regulators and northern communities.

AMEC Earth & Environmental (AMEC) was contracted by Environmental Studies Research Funds (ESRF) to complete an assessment of drilling waste disposal options in the ISR and to conduct a comparative analysis to select a preferred option. The disposal options considered included:

- sumps;
- down-hole injection;
- disposal at a regional treatment and/or disposal site; and
- transportation out of the NWT.

To evaluate the disposal options, AMEC contacted and solicited the opinion of interested and affected parties from three diverse groups: the ISR, petroleum and exploration companies active in the ISR and Federal Government regulators.

To clearly evaluate the potential impacts of each drilling waste disposal option and select a preferred disposal method, a comparative analysis was completed. The objective was to ensure that a wide range of issues were taken into account when comparing the options. The issues, selected by ESRF, fall into four main categories:

- environment;
- socio-cultural and economic;
- feasibility; and
- cost.

Stakeholder responses to AMEC's request for opinion were very limited. It was the opinion of the ESRF Technical Advisory Group, with which AMEC agrees, that the number of responses was insufficient to conduct further comparative analysis of the options from the viewpoint of the Inuvialuit and stakeholders.

The recommended option for drilling waste disposal in the ISR identified by the decision matrix developed and completed by AMEC was on-site waste injection. This was followed by on-site sump disposal, disposal outside of the NWT, off-site waste injection, and off-site landfill disposal. However, choosing a specific waste disposal method is complex and must involve site-specific and project-specific considerations as some sites will not be suitable for on-site waste injection or sump disposal. Further, it is expected that once resource development shifts from the exploration phase to the development phase, that off-site injection at a regional waste disposal facility would become the preferred option.

AMEC agrees with the ESRF Technical Advisory Group's concern that the adequacy of the responses from the ISR interests, industry and the regulators was considered insufficient to include in the quantitative analysis conducted in this study. As a result, it is recommended that further consultation take place, particularly with ISR representatives, to verify or supplement the results of this study.

RÉSUMÉ

Dans la région désignée des Inuvialuit (RDI), la gestion et l'élimination des déchets de forage produits au cours de l'exploration et de la production pétrolières et gazières sur terre demeurent hautement problématiques pour les producteurs, les organismes de réglementation et les collectivités du Nord.

En vertu d'un contrat financé par le Fonds pour l'étude de l'environnement (FEE), la firme AMEC Earth & Environmental (AMEC) a été chargée de réaliser une analyse comparative des diverses options d'élimination des déchets de forage dans la RDI et de choisir celle qu'elle privilégie. Les options suivantes ont été analysées :

- puisards;
- injection en fond de trou;
- élimination dans un lieu de traitement et/ou de décharge régional;
- transport au-delà des limites des T.N.-O.

AMEC a sollicité l'opinion des intéressés et parties touchées de divers groupes dans le cadre de son évaluation : la RDI, les sociétés pétrolières et d'exploration en activité dans la RDI et les organismes de réglementation fédéraux.

Une analyse comparative a été réalisée afin d'évaluer le plus justement possible les incidences potentielles de chaque option et de choisir la méthode privilégiée. Un objectif majeur était de veiller à ce qu'une grande variété d'enjeux soient pris en considération pour les besoins de l'analyse comparative. Ces enjeux, choisis par le FEE, sont répartis dans quatre grandes catégories :

- environnement;
- aspects socioculturels et économiques;
- faisabilité;
- coût.

Les opinions présentées par les parties prenantes à la demande d'AMEC ont été peu nombreuses. Le groupe consultatif technique du FEE était d'avis, à l'instar d'AMEC, que le nombre de réponses ne justifiait pas la poursuite de l'analyse comparative du point de vue des Inuvialuit et des parties prenantes.

L'option recommandée pour l'élimination de déchets de forage dans la RDI, selon la matrice de décision conçue et réalisée par AMEC, est celle de l'injection sur place. Les autres options étaient dans l'ordre l'élimination en puisard sur place, l'élimination à l'extérieur des T.N.-O., l'injection dans un site externe et l'élimination dans un lieu de décharge externe. Toutefois, choisir une méthode d'élimination particulière est une opération complexe qui doit tenir compte d'aspects propres au site et au projet, étant donné que certains sites ne conviennent pas à l'injection sur place ou à l'élimination en puisard. De plus, il est à prévoir qu'une fois que la mise en valeur passe de l'étape de l'exploitation à celle du développement, l'injection dans une installation régionale extérieure devient l'option privilégiée.

Le groupe consultatif technique du FEE était d'avis, à l'instar d'AMEC, que le nombre de réponses ne justifiait pas la poursuite de l'analyse comparative du point de vue des Inuvialuit et des parties prenantes. Par conséquent, il est recommandé que d'autres consultations aient lieu, notamment auprès des représentants de la RDI, afin de confirmer ou compléter les résultats de cette étude.

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ACRONYMS

ACIA	Arctic Climate Impact Assessment
AMEC	AMEC Earth & Environmental
CCS	CCS Landfill Services
CEAA	Canadian Environmental Assessment Act
COGOA	Canada Oil and Gas Operations Act
DEW	Distant Early Warning
DFO	Department of Fisheries and Oceans Canada
DIAND	Department of Indian and Northern Affairs
EC	Environment Canada
EIRB	Environmental Impact Review Board
EISC	Environmental Impact Screening Committee
EISRP	Environmental Impact Screening and Review Process
ENR	Environment and Natural Resources
EPS	Environmental Protection Service
ESRF	Environmental Studies Research Funds
FJMC	Fisheries Joint Management Committee
GNWT	Government of the Northwest Territories
GSC	Geological Survey of Canada
IADC	International Association of Drilling Contractors
IDC	Inuvialuit Development Corporation
IFA	Inuvialuit Final Agreement
ILA	Inuvialuit Land Administration
INAC	Indian and Northern Affairs Canada
IORL	Imperial Oil Resources Limited
IRC Corporation	Inuvialuit Regional
ISR	Inuvialuit Settlement Region
KCl	potassium chloride

MACA	Municipal and Community Affairs
NADF	non-aqueous drilling fluids
NEB	National Energy Board
NRCAN	Natural Resources Canada
NTCL	Northern Transportation Company Limited
NWT	Northwest Territories
PAS	Protected Areas Strategy
PSAC	Petroleum Services Association of Canada
TDGR	Transportation of Dangerous Goods Regulations
UNESCO	United Nations Educational, Scientific and Cultural Organization
WBF	water-based fluids
WBS	Work Breakdown Structure
WMAC (North Slope)	Wildlife Management Advisory Council (North Slope)
WMAC (NWT)	Wildlife Management Advisory Council (Northwest Territories)
YOGA	Yukon Oil and Gas Act

1.0 INTRODUCTION

The Environmental Studies Research Funds (ESRF) were established under the Canada Petroleum Resources Act "to finance environmental and social studies pertaining to the manner in which, and the terms and conditions under which, exploration, developmental and production activities on frontier lands under this Act or any other Act of parliament, should be conducted."

In the Inuvialuit Settlement Region (ISR), the management and disposal of drilling wastes generated through the exploration and production of oil and gas resources from land-based operations remains a key issue for producers, regulators and northern communities.

Concerns over the long-term integrity of historical drilling waste disposal methods in the ISR, primarily the use of sumps, has led to a re-evaluation of the disposal options available to the oil and gas industry. In addition, given the emphasis on the sustainable use of natural resources in the Northwest Territories (NWT), coupled with growing concerns over climate change and the long-term integrity of buried sumps, decisions on the selection of disposal options are now increasingly encompassing a broader consideration of economic, social and environmental factors (ESRF 2008).

AMEC Earth & Environmental (AMEC) was contracted by ESRF to conduct an assessment of drilling waste disposal options in the ISR. The waste disposal options considered in this report include the following:

1) *Sumps* – Use of current technology to dispose of drilling waste material in excavated pits and to monitor the integrity of containment over time;
2) *Down-hole Injection* – The grinding of drilling waste solids into smaller particles, mixing them with water or other fluids to make a slurry and then injecting the slurry into an underground formation, the well or a dedicated disposal well;
3) *Disposal at a Regional Treatment and/or Disposal Site* – A regional approach to the collection and consolidation of waste treatment at a dedicated site; and
4) *Transportation out of the NWT* – The collection and removal of drilling wastes from each drilling location and transportation of the material via truck and/or barge to an approved disposal location outside the NWT.

1.1 Project Objective

The objective of this study was to prepare a comprehensive report on the assessment of land-based drilling waste disposal options applicable to the oil and gas industry in the ISR. Specifically, the objectives were as follows:

- Identify the current drilling waste disposal options available to the oil and gas industry in the ISR;
- Review the regulatory status of current waste disposal options, including the permitting and monitoring requirements of each;

- Describe the current issues and environmental concerns associated with the current methods of drilling waste disposal through the use of sumps;
- Assess the positive and negative aspects of the four drilling waste disposal options while addressing economic, environmental and social considerations;
- Provide recommendations on how waste drilling options should be considered and selected in the future; and
- Describe the current industry best practices for waste disposal options in the ISR and other northern regions, including practices and procedures.

This report is intended to provide essential information required by regulators, industry and the Inuvialuit people to make informed decisions related to drilling waste disposal.

1.2 Scope of Work

The Scope of Work for this project, described in ESRF Solicitation No. ESRF-08-01, dated March 14, 2008, included the following:

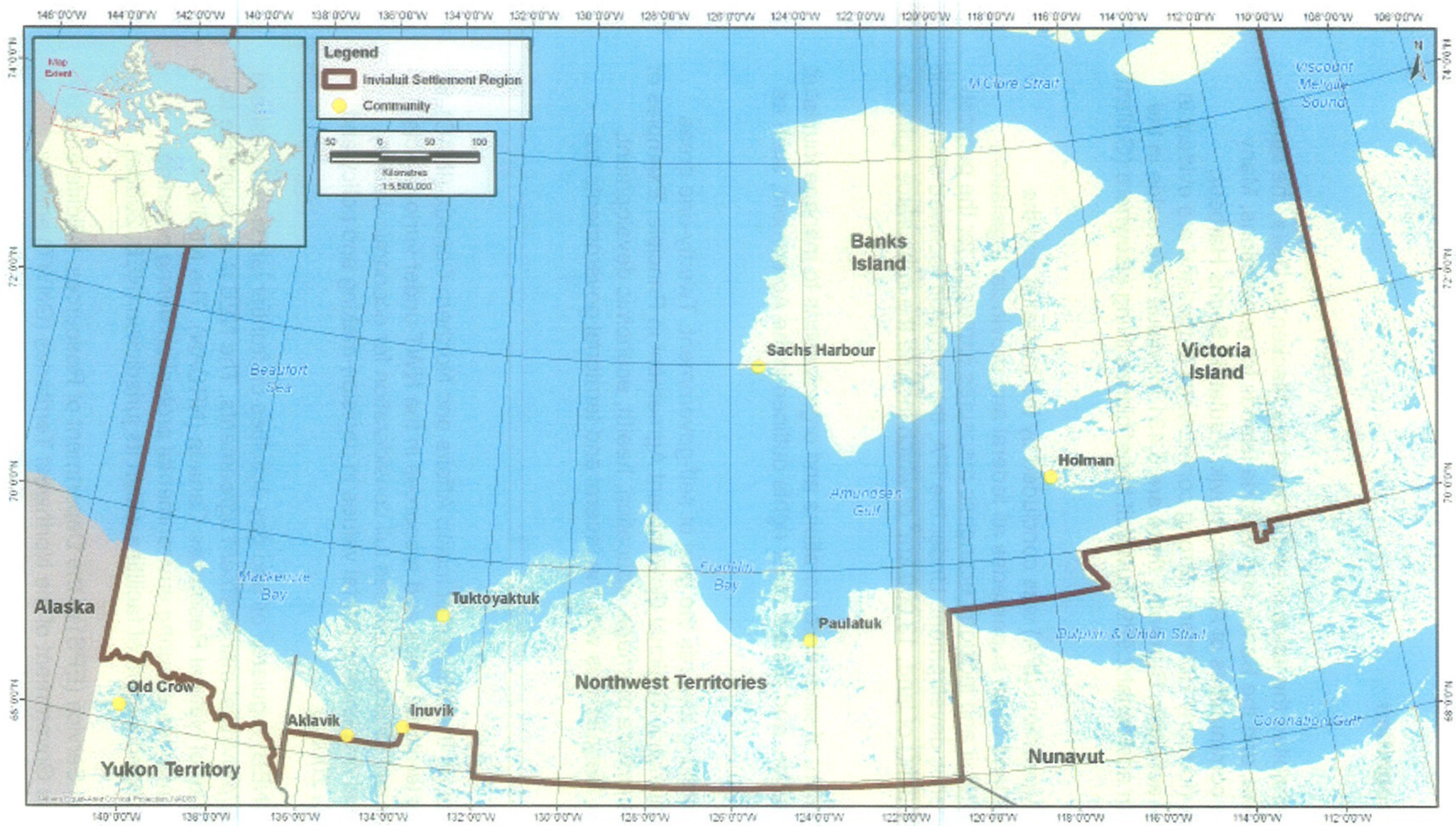
- a review of the relevant literature;
- identification of key issues associated with current waste disposal options;
- evaluation of the benefits and costs of each of the waste disposal options available to the oil and gas industry in the ISR;
- description of the current regulatory requirements and industry best practices associated with drilling waste disposal; and
- a project report.

1.3 Geographic Scope

The ISR boundary is described in "A Guide to Regulatory Approval Processes for Oil and Natural Gas Exploration and Production in The Inuvialuit Settlement Region" as follows:

> *The Inuvialuit Settlement Region (ISR) extends along the Arctic coast from the Alaska border on the west to the boundary with the new territory of Nunavut on the east. The ISR spans both land and water within its borders. It is bounded on the south by the Gwich'in and Sahtu Settlement Areas of the Mackenzie Valley and extends to the north across the Beaufort Sea to include Banks Island, parts of Victoria Island and the western Queen Elizabeth Islands.*

The geographic extent of the project encompasses the mainland areas of the ISR, as illustrated in Figure 1.



Reference: Indian and Northern Affairs Canada (INAC).

amec	**Assessment of Drilling Waste Disposal Options in the Inuvialuit Settlement Region**
Environmental Studies Research Funds	**Inuvialuit Settlement Region Boundary**

Drawn: MP	Scale: NTS	Date: July 2008	Project No.: CE03807	**Figure: 1**

1.4 Stakeholder Recognition

1.4.1 Inuvialuit

The Inuvialuit people have inhabited the lands in and around the Mackenzie Delta, the lands neighbouring the Beaufort Sea, and the Banks and Victoria islands for generations. Many Inuvialuit currently live in the communities of Aklavik, Inuvik, Paulatuk, Sachs Harbour, Tuktoyaktuk and Ulukhaktok (formerly Holman). Strong connections to the land are evident in harvesting and other cultural activities. Currently, there are 5,431 Inuvialuit who reside in the Beaufort-Delta region, and an additional 2,989 Inuvialuit beneficiaries living elsewhere (Gallant, pers. comm. 2008).

In 1984, the Inuvialuit Final Agreement (IFA) was concluded by the Inuvialuit and the Government of Canada. This land claim supersedes all federal and provincial legislation, outlines the goals of the Inuvialuit and includes economic measures expressly for the purpose of enhancing Inuvialuit economic development. Under the IFA, the Inuvialuit received ownership of 91,000 square kilometres (km^2) of land, 13,000 km^2 of which include the subsurface rights to oil, gas and minerals.

The IFA led to the establishment of several corporations and organizations to manage Inuvialuit lands and financial compensation, and protect other rights outlined in the Agreement, such as harvesting.

The Inuvialuit are currently working towards the goal of self-government. Twenty-one areas have been identified in the Inuvialuit Regional Government Agreement in Principle. Examples of self-government jurisdictions include marriage, education, health, economic development, policing, justice and taxation. Negotiations with the federal and territorial governments are ongoing.

1.4.2 Regulator

The federal government, through the Minister of Indian Affairs and Northern Canada (INAC), is responsible for administering territorial lands and resources in the NWT under various Acts. INAC's sustainable development strategy includes full consideration for economic viability, social implications and cultural and environmental values in decision-making and policy and program development (INAC, 2008a).

The National Energy Board (NEB) regulates oil and gas activities on frontier lands and offshore areas not covered by federal/provincial management agreements. The NEB is accountable to Parliament through the Minister of Natural Resources Canada (NRCAN). The NEB's environmental responsibility includes ensuring environmental protection during planning, construction, operation and abandonment of facilities within its jurisdiction (NEB, 2008a).

The Environmental Protection Service (EPS) of the Department of Resources, Wildlife and Economic Development is the Government of the Northwest Territories (GNWT) agency responsible for initiatives to control discharges of contaminants and their impact on the natural environment (GNWT, 1998). The GNWT recognizes that Aboriginal traditional knowledge is a valid and essential source of information about the natural environment and its resources, the use of natural resources, and the relationship of people to the land and to each other, and will incorporate traditional knowledge into government decisions and actions where appropriate (GNWT, 2008b).

1.4.3 Oil and Gas Industry

Oil and gas exploration began in the ISR in 1961 with the drilling of Winter Harbour No. 1 (A-09) on Melville Island by Dome Petroleum. Prior to 2005, 15 companies owned major interests in wells in the ISR. By 1986, 90% of the current wells in the ISR were completed. The majority of these wells have been plugged and abandoned (AMEC 2005). Since 2000, approximately 15 wells have been drilled in the ISR.

The oil and gas industry has developed advanced technologies to improve efficiency, productivity and environmental performance (DOE 1999). Advanced technologies developed since the 1970s height of drilling in Canada's north have significantly reduced the footprint of operations. Of particular relevance to this report, drilling waste volumes have steadily declined because of improvements in drilling efficiency and advances in drilling fluid technology.

The Mackenzie Delta/Beaufort Sea area contains discovered resources of in excess of 150 million cubic metres (m^3) of oil and 255 billion m^3 of gas in 53 significant discoveries. Over 100 billion m^3 of marketable gas have been discovered in three onshore discoveries, and offshore discoveries include over 32 million m^3 (INAC, 2008b). New discoveries will strengthen the existing resource base in anticipation of development in the next decade (INAC, 1995). Heightened interest in Arctic oil and gas exploration and development will create economic opportunities for Northern communities, help to secure Canada's energy supply, and provide a venue for Canada to clearly exercise its sovereign rights over its offshore natural resources (INAC, 2008c).

Mackenzie Gas Project proposes to develop natural gas fields in the Mackenzie Delta and deliver the natural gas to markets through a pipeline system built along the Mackenzie Valley. Four Canadian oil and gas companies and a group representing the Aboriginal people of Canada's NWT are partners in the proposed Mackenzie Gas Project (MGP 2008):

- Imperial Oil Resources Ventures Limited;
- ConocoPhillips Canada (North) Limited;
- Shell Canada Limited;
- ExxonMobil Canada Properties; and
- The Aboriginal Pipeline Group.

The four oil and gas companies hold interests in three natural gas fields located in the Mackenzie Delta:

- Taglu;
- Parsons Lake; and
- Niglintgak.

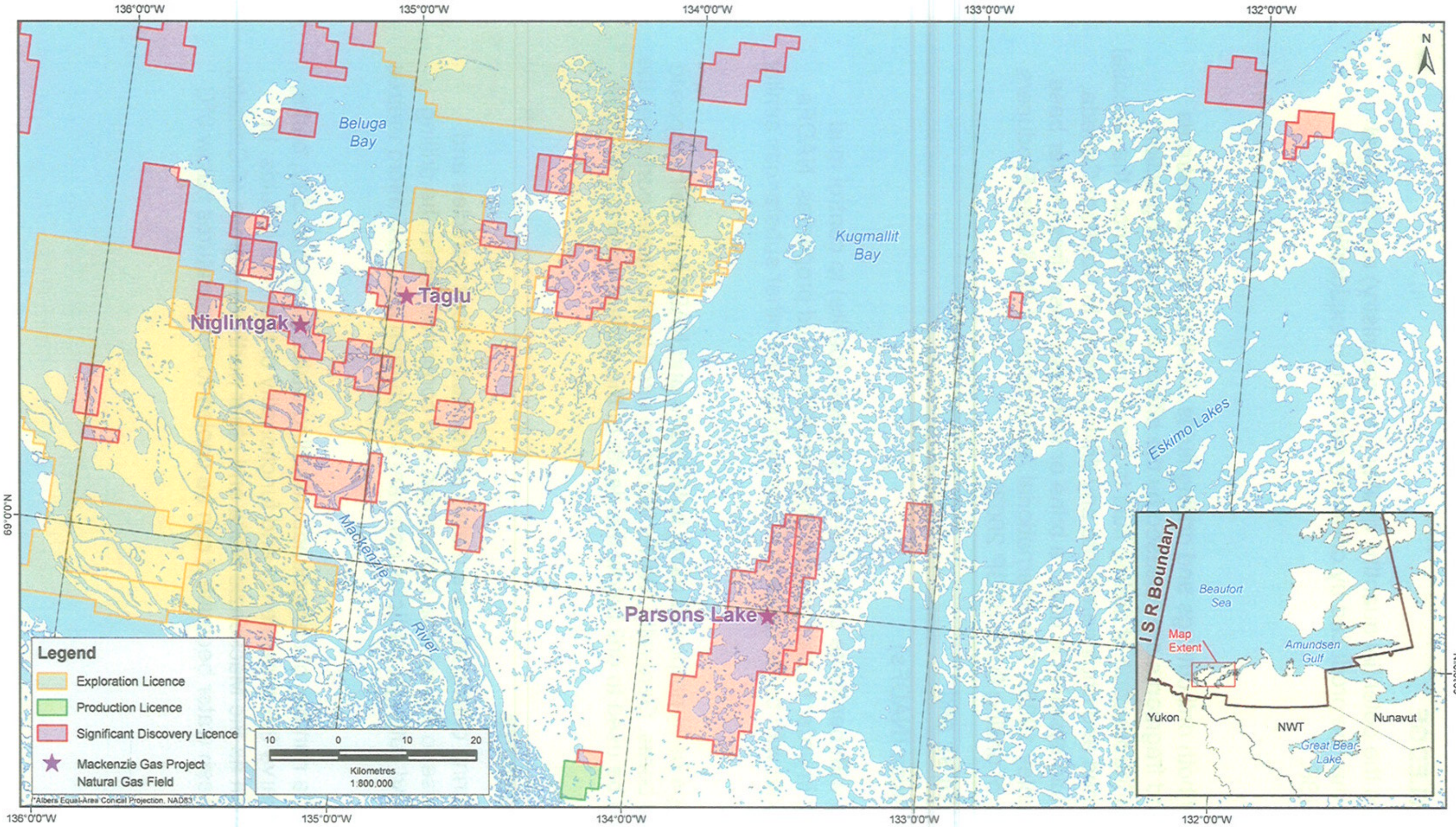
Figure 2 shows the location of these natural gas fields.

The Aboriginal Pipeline Group represents the interests of the Aboriginal peoples of the NWT in the proposed Mackenzie Valley Pipeline.

Oil and gas companies currently holding exploration licences in the ISR include:

- Talisman Energy;
- BP Canada;
- Chevron Canada;
- Petro-Canada;
- MGM Energy;
- Shell Canada;
- Imperial Oil;
- ConocoPhillips;
- Altagas;
- Nytis, and
- Devon.

Figure 2 shows current oil and gas lease boundaries in the ISR.



Source: Indian and Northern Affairs Canada, Oil and Gas Rights Digital Files (last updated June 27, 2008), http://www.ainc-inac.gc.ca/oil/act/Lan/dig/index_e.html

amec	**Assessment of Drilling Waste Disposal Options in the Inuvialuit Settlement Region**
Environmental Studies Research Funds	**Current Oil and Gas Licences in the ISR**

Drawn: MP	Scale: NTS	Date: July 2008	Project No.: CE03807	**Figure: 2**

2.0 CURRENT KNOWLEDGE

The following sections discuss the potential quantity, quality (i.e., chemistry) and disposal options for drilling waste that may be produced by on-shore petroleum exploration and development activities in the ISR.

2.1 Drilling Waste

Drilling waste is composed of both drill cuttings and drilling fluids. As the drill bit penetrates progressively deeper, rock and fragments are released by the effects of the drilling action; drilling waste is a result of the introduction of drilling fluid to these materials. Hence, the disposal of drilling waste must be planned and engineered into any drilling event. In Northern Canada, typically one of three drilling fluid systems is used: a brine or saltwater base, fresh water base, or an oil base (Hardy and Stanley 1988). The International Association of Oil & Gas Producers recognizes two primary types of drilling fluids (OGP 2003):

- water-based fluids (WBFs); and
- non-aqueous drilling fluids (NADFs).

WBFs consist of water mixed with bentonite clays, barium sulphate (barite) to control mud density and other substances in order to produce the desired drilling fluid properties. NADFs may consist of mineral oil mixed with barite to control mud density and other substances similar to those used in WBFs.

Imperial Oil and ConocoPhillips have proposed using both WBFs and NADFs in their proposed Taglu and Parsons Lake well bores. Generally, WBFs would be used in the upper portion of the well bore while NADFs would be used to drill below the depth of the surface casing (CP 2004, IORL 2004).

2.1.1 Physical Characteristics

Drill cuttings are generated during drilling and are mainly composed of rock particles and fragments. These fragments rise to the surface suspended and contained within the drilling mud. For fine clay, silt and sand cuttings, particles can vary in size from around 5 micro metres to >200 micro metres.

Drilling waste is composed of a number of compounds including water, bentonite clay, barite, cuttings and additives to preserve the consistency and functionality of the drilling fluids. In permafrost environments, such as the Mackenzie Delta and other northern regions of Canada, saltwater is used in place of fresh water because it can be cooled to temperatures below 0°C (Pembina 2004).

2.1.2 Drilling Fluid Additives

Additives are commonly used for the purpose of controlling or altering drilling fluid characteristics such as pH and viscosity or reducing fluid loss and filtrates. The following list of additive functions reflects general industry practice and terminology consistent with those accepted by the American Petroleum Institute (API) and the International Association of Drilling Contractors (IADC) (WORLDOIL 2008):

- *Alkalinity/pH control* (e.g., bicarbonate soda, caustic soda and lime) of the acidity or alkalinity of the drilling fluid;
- *Bactericides* are used in the prevention of bacterial degradation of natural organic additives;
- *Calcium reducers* are used to reduce calcium in salt water, treat cement contamination and work against calcium sulphates;
- *Corrosion inhibitors* (e.g., amine or phosphate-based products) are used in conjunction with pH control additives to control corrosion, balance out hazardous acid gases and prevent scale in drilling fluids;
- *Defoamers* reduce foaming in drilling fluids, predominantly in brackish and saturated saltwater fluids;
- *Emulsifiers* create a heterogeneous mixture of two insoluble liquids such as detergents, soaps, organic acids or water-based surfactants for water-based muds;
- *Filtrate* reducers (e.g., bentonite clays, lignite and polyacrylate) are used to reduce fluid loss into the formation during the drilling process;
- *Flocculants* (e.g., soda ash, bicarbonate of soda, brine, hydrated lime, gypsum and acrylamide-based polymers) increase viscosity, increase bentonite clay yields and/or dewater low-solids fluids;
- *Foaming agents* are used to create foam in the presence of water that assists in air or gas drilling through water-bearing formations;
- *Lost circulation materials* are used to plug zones of loss to reduce the loss of drilling fluids in subsequent operations;
- *Lubricants* (e.g., oils, graphite and glycols) are used to reduce friction occurring during drilling;
- *Pipe-freeing agents* (detergents, oils, soaps and surfactants) are designed to reduce friction and increase lubrication to release pipe that may have become stuck;
- *Shale control inhibitors* (e.g., soluble calcium or potassium inorganic salts) are used to reduce shale hydration and reduce impacts when dealing with water-sensitive shale;
- *Surface-active agents* (e.g., emulsifiers, wetting agents and flocculants or deflocculants) reduce interfacial tension between multiple contacting surfaces such as water/solid or water/air;

- *Temperature stability agents* (e.g., acrylic polymers, sulfonated polymers, copolymers, lignite and lignosulfonate) are used to stabilize fluid temperature;
- *Thinners and dispersants* (e.g., tannins, polyphosphates, lignite, and lignosulfonate) are used to alter the composition of drilling fluids in terms of viscosity and solids percentage and can also serve to reduce the gel strength of the fluid. Thinners are used to assist in deflocculation of particles in drilling fluid;
- *Viscosifiers* (e.g., bentonite, attapulgite clays and polymers) are compounds used to increase viscosity and suspension of solids; and
- *Weighting materials* (e.g., barite, leads, iron oxides and calcium carbonates) are compounds with higher specific gravity used to keep formation pressures in check and to facilitate the pulling of dry pipe.

Table 1 provides a list of WBF additives used by MGM Energy Inc. at a recently drilled well in the ISR. The major components are barite (62%) and KCl (24%). Ultrahib and Ultrafree agents are used to keep the drill bit free of solids. Calcium carbonate is also used to increase the density of the drilling fluid or as a bridging material to prevent fluid loss. Fed Pac UL additive controls fluid loss in freshwater, seawater, KCl and salt water fluids. It forms a thin, resilient, low-permeability filter cake that minimizes the potential for differential sticking and the invasion of filtrate and mud solids into permeable formations. The Ultracap additive provides cuttings encapsulation by adsorbing onto the clay surfaces and forming a protective film that prevents cuttings from sticking to each other or to the shaker screens. Fed Zan D contains Xanthan gum, which is also used as a food additive. The remaining products contribute about 1.6% of the fluid mixture.

Table 1: Drilling Fluid Additives

Product	Unit	Total	Percent Total
Barite	Kilogram (kg)	388,000	62.2
Potassium Chloride (KCl)	kg	150,125	24.1
Ultrahib	Litre (L)	27,872	4.5
Ultrafree	L	17,472	2.8
Calcium Carbonate	kg	15,000	2.4
Fed Pac (UL)	kg	6,555	1.1
Ultracap	kg	4,468	0.7
Fed Zan D	kg	4,082	0.7
Sulfamic Acid	kg	2,000	0.3
Sodium Bicarbonate	kg	1,814	0.3
Caustic Soda	kg	1,724	0.3
Fed Pac (Reg)	kg	1,474	0.2
Lime	kg	1,200	0.2
Sapp	kg	771	0.1
Chemicide	L	480	0.1
Desco Cf	kg	272	0.04
Soda Ash	kg	227	0.04
Drilling Detergent	L	189	0.03

2.1.3 Quantity

The total volume of drilling wastes has decreased since the 1970s, with historic volumes of approximately 1.0 m^3 to 1.3 m^3 to current volumes of approximately 0.25 m^3 to 0.5 m^3 per metre of well depth (ESRF, 2004). Estimates of the volume of drilling waste from wells drilled prior to 1980 are as much as 4,000 m^3 for a well 3,000 metres (m) deep (French, 1980).

The potential volume of drilling waste based on proposed future projects in the ISR is in the order of 350,000 m^3 or, on average, 1,250 m^3 per well. These potential drilling waste volumes are summarized in Table 2.

Table 2: Potential Drilling Waste Quantities

Location	Well Count	Well Depth (m)	Volume of Drilling Waste Over 25 years (m^3) Generated at 0.5 m^3/m
Taglu	15	3,000	22,500
Niglintgak	9	1,250	4,570*
Parsons Lake	15	3,000	22,500
ISR Exploration	~10/year	2,500	312,500
Ellice, Olivier and Langley Islands Areas (MGM Energy Corp.)	7 wells from 2008 to 2011 (MGM Future Program, 2008)	1,200-1,700	150 m^3 of cuttings per well (estimated) and 300–500 m^3 of waste mud for a total of 3,150 m^3 to 4,550 m^3 of waste
Total	289		362,070

* Predicted waste volume (cuttings & liquid), Shell 2005

The potential drilling waste volumes described in Table 1 include drill cuttings and drilling fluid. Total drilling waste forecast for Niglintgak development wells will amount to 4,570 m^3 comprised of 3,015 m^3 (66%) cuttings and 1,555 m^3 (34%) liquid wastes (Shell 2005). Application of this ratio to the total drilling waste volume of 362,070 m^3 shown in Table 1 results in a liquid volume of 239,000 m^3. These waste volumes are largely speculative because waste production is very dependent upon the formations encountered and the depth of the well. Any fluid loss to formations is compensated by mixing and addition of new fluid.

2.1.4 Chemistry

Typically, water-based drilling fluid used in the ISR is a potassium chloride (KCl) based fluid designed to assist in reducing the freezing point. The introduction of KCl is also used for shale inhibition at concentrations up to 8% by volume, as shown in Table 2 (Shell 2006). The components shown in Table 3 are representative of a 1,250-m well.

Table 3: Typical Drilling Fluid Components

Component	Purpose	Concentration
Fresh water	Base liquid	96% by volume
Potash (KCl)	Shale inhibition and freeze suppression	3% KCl up to 8% KCl ~ 50,000 kg
Modified Starch	Fluid loss control	5 kg/ m^3
Polyanionic Cellulose	Fluid loss control	3-4 kg/ m^3
Xanthan Gum	Viscosity	1.5-2.5 kg/ m^3
Sodium or Potassium Hydroxide	pH control	0.5 kg/ m^3
Barite	Increase mud weight	As required ~ 100,000 kg
Polymers	Encapsulation and deflocculants	As required ~ 2,000 kg
Cellulose and Sawdust	Lost circulation control	As required ~ 2,000 kg

The components listed in Table 3 are characterized as follows:

Barite

Barite, the largest component of drilling fluid, is used as a weighting agent in natural gas and oil field drilling fluids. The density of barite helps in down-hole flow and bit lubrication. Studies have indicated that the toxicity of barite is very low (AE, 2000).

Potassium Chloride

Potassium chloride (KCl) is a crystalline compound that closely resembles common salt (sodium chloride). KCl occurs pure in nature as the mineral sylvite and is found combined in many minerals and in ocean water. The Global Portal to Information on Chemical Substances of the Organization for Economic Co-operation and Development (OECD, 2008) characterizes KCl as follows:

- KCl as inorganic salt is not subjected to further degradation processes in the environment. In water, KCl is highly water soluble, and readily undergoes dissociation;
- In soil, transport/leaching of potassium and chloride is affected by the clay minerals (type and content), pH and organic matter;
- KCl is not hazardous to freshwater organisms;
- The low concern for the environment is supported by the absence of a bioaccumulation potential for the substance;
- In plants, potassium is one of the three major nutrients and chloride is an essential micronutrient;
- KCl is ubiquitous in the environment, occurring in minerals, soil and sediments, and natural waters. KCl is also present as a major and essential constituent in animals and plants. The main human exposure to KCl is the normal dietary intake (2-4 g K and 3.5-9 g Cl), and indirect exposure via the environment (drinking water); and
- More than 90 % of the total KCl consumption is used for fertilizer production.

Polyanionic Cellulose
Polyanionic cellulose is essentially non-toxic; significant additions may be made to drilling fluids with minimal impact toxicity values.

Xanthan Gum
Xanthan gum is produced by a process involving fermentation of glucose or sucrose by the Xanthomonas campestris bacterium. Xanthan gum is capable of producing a large increase in the viscosity of a liquid by adding a very small quantity of gum, on the order of 1%. While drilling, in cases where the circulation stops, the use of xanthan gum enables the cuttings to remain suspended in the drilling fluid. In foods, xanthan gum is most often found in salad dressings and sauces.

Sodium or Potassium Hydroxide
Sodium or potassium hydroxide, also known as caustic soda, is used to control pH. As a drilling mud additive, it is used sparsely. It is a strong alkali requiring workers to be protected while handling it.

Alkapam 1103A
Alkapam 1103A is a flocculent used for clear water drilling or for "stripping" solids from a mud system when a dewatering operation is in effect. In 2003, Chevron used 1,250 kg of this additive in their Langley K-30 well.

The chemical composition of drilling waste will vary, depending on the type and concentration of additives in the mix and the formations encountered while drilling. Analytical results for samples obtained from two well sites in the ISR (Olivier H-1 and Ellice I-48) are compared with CCME Parkland and Industrial criteria in Table 4. The highlighted values in Table 4 indicate that a parameter has exceeded the CCME criterion.

Table 5 compares the chemistry of drilling fluid and cuttings leachate with BC landfill criteria. The results show that drill cuttings are suitable for landfill disposal in BC. The drilling fluid from Langley E-7 was not suitable for landfill disposal because it was a free liquid.

NADFs are often used to drill highly deviated wells. In the past, NADFs contained diesel or mineral oil. Currently, NADFs use enhanced mineral oil and synthetics such as esters, olefins and paraffins. These are less toxic and more biodegradable than diesel and mineral-oil base fluids (OGP 2003). When additional wells are drilled nearby, NADFs are typically recovered and reused because of their high cost. The NADF proposed for use by Imperial Oil at their Taglu project does not freeze (IORL, 2005). The environmental impact of a base drilling fluid can only be assessed with a complete environmental data set that includes water column and sediment toxicity, aerobic and anaerobic biodegradation, and deposition of the cuttings and base fluid concentration in the sediment (Shell Chemicals, 2008).

Table 4: Drilling Waste Chemistry

Parameter	Unit	Criteria	Criteria	Olivier H-1	Ellice I-48	Ellice I-48
		CCME Parkland Fine Grained	CCME Industrial Fine Grained	April (2005)	Final Mud in Tanks (2005)	Total Sump Waste (2005)
Volume to Sump	m^3	--	--		549.5	549.5
Density	kg/ m^3	--	--		1,377	1,243
TEH (C11-C30)	mg/kg	--	--	1900		
Benzene	mg/kg	0.0068	0.0068	**0.27**		
Toluene	mg/kg	0.08	0.08	**0.75**		
Ethylbenzene	mg/kg	0.018	0.018	**0.14**		
Xylenes	mg/kg	2.4	2.4	0.89		
Total Volatiles (C5-C10)	mg/kg	--	--	3		
Boron (B), Hot Water Ext	mg/kg	--	--	2		
Cadmium (Cd)	mg/kg	10	22	<0.5	1.1	4
Chromium (Cr)	mg/kg	64	87	15.3	23.7	**109**
Copper (Cu)	mg/kg	63	91	24	50.7	**191**
Lead (Pb)	mg/kg	140	600	5	10	40.7
Nickel (Ni)	mg/kg	50	50	15	20.6	**85.9**
Vanadium (V)	mg/kg	130	130	14		
Zinc (Zn)	mg/kg	200	360	50	66.5	**441**
% Moisture	%	--	--	62		
Chlorine Free	mg/L	--	--	<0.1		
Iron	mg/kg	--	--	10,900	11,640	
Specific Gravity	kg/L	--	--			
Chloride (Cl)	mg/L	--	--	2,160	1,230	4,680
Sulphate (SO4)	mg/L	--	--	2,800		
% Saturation	%	--	--	80.8		
pH in Saturated Paste	pH	6-8	6-8	**11.5**		
Conductivity Sat Paste	dS m-1	2	4	**11.3**		
Calcium (Ca)	mg/L	--	--	365	62	511
Potassium (K)	mg/L	--	--	34	470	2,500
Magnesium (Mg)	mg/L	--	--	168		
Sodium (Na)	mg/L	--	--	1,200		1,920
SAR	SAR	5	12	**13.1**		

Bold/shaded values indicate that a parameter has exceeded the CCME criterion.

Table 5: Drilling Waste Leachate Analysis

Parameter	Units	Landfill Criteria	Aput Treated Cutting	Langley E-7 Drilling Fluid	Atik Cuttings with Gelco 100
Depth	(m)				
Date Sampled					
Landfill Suitability Analysis					
Flash Point (Solid)	°C	–	>75	>75	>75
pH @ 25°C	pH units	–	8.8	7.7	8.7
Paint Filter Test	–	–	no free liquid	**free liquid**	no free liquid
TCLP Benzene	mg/L	0.5	<0.1	<0.1	<0.1
TCLP Toluene	mg/L	2.4	<0.1	<0.1	<0.1
TCLP Ethyl Benzene	mg/L	0.24	<0.1	<0.1	<0.1
TCLP Xylenes	mg/L	30.0	<0.1	<0.1	<0.1
TCLP Antimony	mg/L	–	<0.02	<0.02	<0.02
TCLP Arsenic	mg/L	2.5	<0.02	<0.02	<0.02
TCLP Barium	mg/L	100.0	1.68	1.84	1.31
TCLP Beryllium	mg/L	–	<0.001	<0.001	<0.001
TCLP Boron	mg/L	500.0	0.109	0.196	0.080
TCLP Cadmium	mg/L	0.5	<0.003	<0.003	<0.003
TCLP Chromium	mg/L	5.0	<0.005	<0.005	<0.005
TCLP Cobalt	mg/L	–	0.018	0.016	0.024
TCLP Copper	mg/L	100.0	0.025	0.072	0.027
TCLP Iron	mg/L	–	0.067	2.34	2.13
TCLP Lead	mg/L	5.0	<0.03	<0.03	<0.03
TCLP Manganese	mg/L	–	7.06	0.296	0.758
TCLP Mercury	mg/L	0.1	<0.0004	<0.0004	<0.0004
TCLP Nickel	mg/L	–	0.070	0.046	0.064
TCLP Selenium	mg/L	1.0	<0.02	<0.02	<0.02
TCLP Silver	mg/L	5.0	<0.03	<0.03	<0.03
TCLP Thallium	mg/L	–	<0.06	<0.06	<0.06
TCLP Uranium	mg/L	10.0	<0.1	<0.1	<0.1
TCLP Vanadium	mg/L	–	<0.009	<0.009	<0.009
TCLP Zinc	mg/L	500.0	0.073	0.884	0.118
TCLP Zirconium	mg/L	–	<0.006	<0.006	<0.006

Criteria: Environmental Management Act, Hazardous Waste Regulation, BC Reg. 63/88. Deposited 1988, includes amendments up to BC Reg 261/2006, 21 September 2006. Schedule 4 (am. BC Regs 132/92, s. 36; 214/20047, s. 9; 319/2004, s.45.)
Bold/shaded values above criteria.
– no criteria

The Petroleum Services Association of Canada (PSAC) publishes a list of drilling fluid products for potential toxicity information. The information is based on data collected from various industry sources and is intended to provide useful information about a product's level of toxicity. Drilling fluid additives used in the ISR may contain some of the products identified on this list.

In 2003, a study of drilling fluid additives used in the Mackenzie Delta identified 24 additives that contained hazardous, carcinogenic or mutagenic compounds (Paget, 2003). In Alberta, toxicity assessments are required if one or more drilling fluid additives are used at a level above the threshold level identified on the PSAC drilling fluid product list. If drilling wastes cannot be treated to eliminate toxic components, they must be disposed of at an approved facility. The 2003 study reported that drilling waste samples from two waste sumps located in the Mackenzie Delta failed toxicity tests.

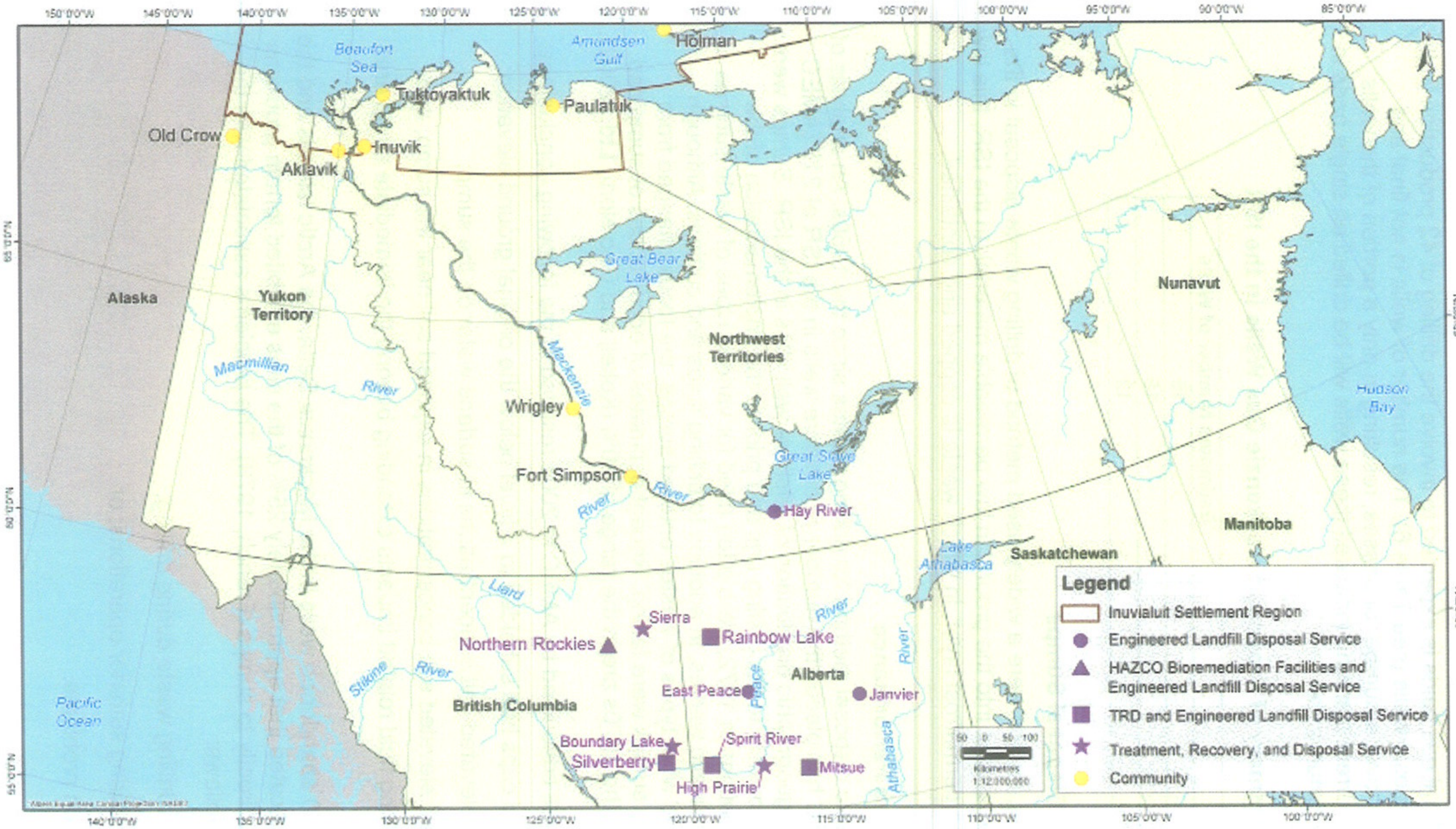
2.2 Current Waste Disposal Infrastructure

There are currently no facilities in the NWT equipped or licensed to accept drilling fluids or drilling waste for disposal. Figure 3 shows the location of several waste management facilities located in northern Alberta and BC. The four furthest north facilities are described below.

- The Silverberry landfill and waste treatment facility, operated by CCS Landfill Services (CCS), is located approximately 50 km north of Fort St. John, BC. Silverberry accepts non-hazardous waste and is also the only CCS facility that accepts hazardous waste for direct disposal (HAZCO, 2008). Liquid drilling waste is treated by removing solids before being disposed in an injection well;
- The Northern Rockies Waste Management Facility, operated by CCS, is located about 20 km south of Fort Nelson, BC. The facility accepts non-hazardous waste for landfill and has a special/hazardous waste treatment facility (HAZCO, 2008). CCS is currently upgrading this facility to accept hazardous waste for direct disposal;
- The Rainbow Lake Class II Landfill, operated by CCS, is located 40 km east of Rainbow Lake, Alberta, and accepts all oilfield waste stream material that meets landfill criteria disposal; and
- The Hay River landfill, located in the NWT, does not accept drilling fluids or drilling wastes for disposal.

2.3 Current State of Oil & Gas Development

While oil and gas leases and mineral rights exist across large areas of the north, the main area of focus at the present time is in the Mackenzie Delta. Three projects and a major pipeline system are currently in the planning stage. These projects have the capacity to produce and deliver upwards of six trillion cubic feet of natural gas over their lifetime. The northernmost field, Taglu, is wholly owned and operated by Imperial Oil Resources Ventures Limited. The Niglintgak field, operated by Shell Canada, is located southwest of Taglu. Parsons Lake is held in joint interest by ConocoPhillips Canada (North) Limited and ExxonMobil Canada Properties (MGP 2008).



Source: http://www.hazco.com/facilities/. Accessed on July 8, 2008.

amec	Assessment of Drilling Waste Disposal Options in the Inuvialuit Settlement Region		
Environmental Studies Research Funds		Landfills and Waste Treatment Facilities in Western Canada	
Drawn: MP	Scale: NTS	Date: July 2008	Project No.: CE03807	Figure: 3

Development of these natural gas fields is expected to involve the drilling of 42 production wells and possibly one or two disposal wells (see Table 6). The number of wells is not final and drilling will most likely occur over a number of phases, resulting in only a portion of the wells being drilled at one time. Current planning indicates these wells will be drilled on single pads in order to minimize surface disturbance.

Table 6: Summary of Proposed Mackenzie Gas Wells in the ISR

Project	Estimated Number of Wells
Taglu	15
Niglintgak	15
Parsons Lake	12

2.4 Drilling Waste Disposal Sumps

Over the past four decades, sumps were a widely used method of drilling waste disposal in the ISR, incorporating a pit excavated into the ground in low permeable material. In the ISR, this low permeable boundary is the permafrost layer, in which waste is capped and contained.

2.4.1 Historic Use and Performance

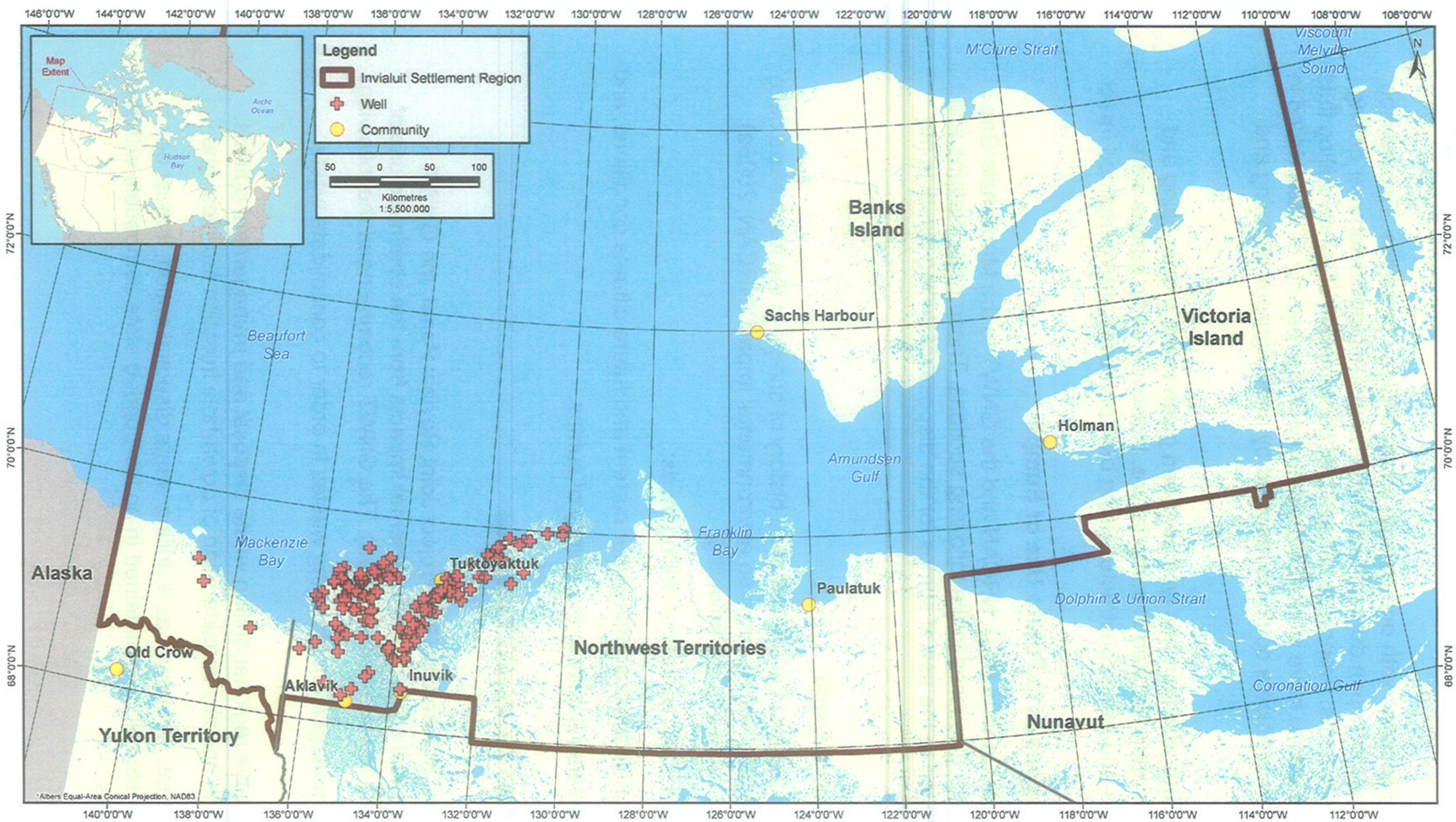
Sumps have been used as a disposal method for drilling wastes since the 1960s. An analysis of northern well lists by AMEC has placed the number of onshore wells in the ISR at 216 (AMEC 2005). Figure 4 shows the geographic distribution of onshore well sites in the ISR. Sumps were typically located in close proximity to the drilling rigs and prior to the implementation of the Territorial Land Use Regulations in 1972, were often used for various types of waste such as wood, scrap metal and domestic wastes, in addition to drilling fluids and cuttings. Although these regulations controlled what types of wastes entered sumps, the focus changed from content to design, as many sumps were failing. Recent estimates of occurrences of sump cap collapse for wells drilled in the 1970s are in the range of 50% (Kokelj and Geo North Ltd., 2002).

An assessment of 10 sumps conducted by AMEC in 2005 resulted in the following conclusions:

- Four of the 10 sump caps had subsided to a level below the original ground elevation;
- Six sites exhibited elevated salt concentrations in surface water on the sump;
- Eight sites exhibited elevated salt concentrations in exposed soil near the sump; and
- No evidence of drilling fluid related impacts extending beyond the immediate sump area was found.

In 1978, a survey of over 60 abandoned wells in the Mackenzie Delta, the Arctic Islands and the interior Yukon Territory indicated that approximately 25% of the sites exhibited terrain problems related either directly or indirectly to sumps (French, 1978). The problems associated with the sumps were classified as follows:

- non-containment of drilling waste during drilling;
- melt-out problems during summer operations; or
- sump cap restoration problems.



Well location data from NEB, August 2008

amec	Assessment of Drilling Waste Disposal Options in the Inuvialuit Settlement Region			
Environmental Studies Research Funds	**Onshore Wells in the ISR**			
Drawn: NH	Scale: NTS	Date: August 2008	Project No.: CE03807	**Figure: 4**

The fewest problems were associated with one-season winter drilling operations. Two-season winter drilling when the sump is left open during the summer and one-season summer drilling operations presented more problems. French concluded that containment of waste drilling fluids in below-ground sumps appeared to have worked satisfactorily in the majority of wells drilled in Arctic Canada and that certain problems could be resolved by more rigorous planning and careful operating techniques.

Historical data suggest that little attention has typically been given to the proper siting and construction of sumps, which often resulted in sump failure. However, when sumps were located in favourable settings and were constructed using best practices, they remained intact.

2.4.2 Stakeholder Responses to Future Use of Sumps

Presentations by Environment Canada (EC), NRCAN and the GNWT to the Mackenzie Gas Project Joint Review Panel are discussed in the following sections. These presentations and comments were, in part, related to the use of sumps for the disposal of drilling waste in the future.

2.4.2.1 Natural Resources Canada

NRCAN's representatives stated that the performance history of sumps in the Mackenzie delta suggests that sumps present potential for adverse environmental impact (NRCAN, 2006a). NRCAN expressed concerns related to the following:

- KCl concentration and liquid content of drilling muds;
- maintaining frozen conditions in sumps under current and future climate conditions; and
- impacts on soils and water quality in the vicinity of sumps.

2.4.2.2 Government of the Northwest Territories

In its written submission to the Mackenzie Gas Project Joint Review Panel, the GNWT expressed concern over potential adverse environmental impacts from the continued use of sumps in the Mackenzie Delta region (GNWT, 2006). The GNWT recommended the following:

- Co-ordination of the management of drilling wastes in order to consolidate waste disposal sites;
- Planning for co-operative regional drilling waste disposal and management options, other than sumps, with specific consideration of down-hole injection facilities; and
- That if freezing in sumps is retained as a drilling waste disposal option, it must be demonstrated that waste will be maintained in an ice-bonded state compatible with the on-site thermal regime.

2.4.2.3 *Environment Canada*

Environment Canada expressed concern about the viability of sumps to permanently contain drilling wastes. Because of the challenges posed by this waste management option and risk to the environment, EC recommended the discontinuation of the following:

- the practice of relying on permafrost integrity to contain and isolate drilling wastes containing freeze depressants (EC, 2006); and
- the use of waste disposal sumps within the dynamic environment of the Mackenzie Delta that is characterized by discontinuous permafrost, disturbance-sensitive ice-rich soils and warmer ground temperatures that are subject to active erosion, deposition and flooding (EC, 2006).

2.4.2.4 *Inuvialuit*

The Inuvialuit Environmental Impact Screening Committee (EISC) screens all development proposals of consequence to the ISR to determine whether they could have a significant negative impact on the environment or on wildlife harvesting (NRCAN, 2006b). In 2003, the Inuvialuit EISC, in a letter to ESRF, expressed discontent about the continuing use of sumps in the ISR to dispose of drilling wastes, and in the future would require industry to provide sufficient information to clearly warrant sump use, or come up with suitable alternatives.

2.4.3 Current Practice

Sumps have been used in recent years as an option for waste disposal in the Mackenzie Delta Region, to dispose of water-based drilling wastes. Given the concerns related to historic sump performance, current technology and practice focuses on ensuring that sumps retain every opportunity to succeed as a permanent disposal method. Rather than using drilling fluids with only the drilling process in mind, today fluids are selected with the environment as one of the priorities of the drilling process. This can be achieved through reduction in drilling waste volume, reuse and recycling of drilling fluids whenever possible and by choosing safer drilling additives. The success of using permafrost as a containment medium is usually a function of construction practices, site operations and abandonment practices (Kokelj and GeoNorth Ltd., 2002).

In 2004, the ISR, regulators and industry developed a set of best practices for the management and disposal of drilling wastes. With respect to the use of sumps, best practices were established for site selection, design, construction, operations, abandonment, restoration and monitoring. Operators are encouraged to use but not be limited by the best practices described in the Guide.

2.4.4 Construction Requirements

2.4.4.1 *Sump Placement*

Placement of the sump is an important consideration that needs to be addressed before the design and construction take place, with a primary focus on topography and thermal conditions. Sumps should be constructed away from any drainage areas, lowlands where flooding is common, and hillsides or slope bottoms where water can drain and/or accumulate. The placement of sumps is recommended at a minimum of 100 m from the high water mark of nearby permanent water bodies (Kokelj and GeoNorth Ltd., 2002). If sumps are to be constructed in areas of fluctuating groundwater levels, sumps should be placed so as to ensure that the water table does not induce seepage, draining or thawing of drilling wastes.

In the Mackenzie Delta, there are two major ecozones to consider when evaluating the placement location of a sump: the Southern Arctic of which most of the southern area of the on-shore ISR is contained, and the Taiga Plains to the south (EC 2008a). Locating a suitable site for sumps increases the chance of success, and with proper engineering, reduces the risk of sump failure.

2.4.4.2 *Soil*

The underlying soil requires assessment prior to construction. Ideal soils are those that are very impermeable, such as clays. In the Mackenzie Delta Region, where ice is present in soil, it is important to avoid areas containing high ice content or ice lenses that could potentially melt and increase the risk of sump failure. Since the containment of drilling waste in sumps requires the freezing of material below the active layer it becomes imperative to evaluate thermal distribution through the permafrost and active layer (Kokelj and GeoNorth Ltd., 2002).

2.4.4.3 *Sump Size*

The activities described in the previous sections help determine site conditions that will assist in designing and engineering a successful sump. Once a site or pad has been cleared and readied for drilling activities, a sump can then be constructed. The required size of the sump depends on the amount of drilling waste expected to be produced. An estimate of sump size by Hardy and Stanley suggests that there has to be between 0.78 m^3 and 1.3 m^3 of sump volume per metre of well drilled (Hardy and Stanley, 1988). One of the difficulties with estimating sump volume and expected drilling waste generation is the potential for exploratory wells to be drilled deeper than planned and as a result, the creation of more drilling waste than planned. To allow for this type of change, the NWT Water Board has implemented a standard of 1 m of freeboard below the bottom of the active layer (Kokelj and GeoNorth Ltd., 2002). This condition ensures that if the active layer fluctuates, it can do so without impacting the frozen drilling wastes contained in the sump.

If blasting is necessary to remove material to create the sump, it should be done in such a way as to reduce particle size. This will assist in reclaiming the sump and reduce the risk of collapse or subsidence. The sump walls should be as vertical as possible to minimize the footprint. A schematic diagram of a typical sump is shown in Figure 5.

2.4.4.4 Seasonal Limitations

There are several issues to consider for construction of a sump during the warmer summer months, as opposed to winter construction. Precipitation events can create runoff that can enter the sump and occupy space. In addition, rain or runoff can destabilize the temperature regime in the sump. During construction, the walls and base of the sump will be exposed to warmer temperatures; therefore it is very important to ensure that they are kept frozen (ESRF, 2004). Sump design is intended to keep wastes continuously frozen; therefore every precaution must be taken during summer construction to ensure sump stability and integrity.

Annual flooding creates a particular concern for sumps in the Mackenzie Delta because of the increased potential for contact between flood waters and sump fluids (Kokelj and GeoNorth Ltd., 2002; ESRF, 1988). Sump success is also limited in the Mackenzie Delta since the surface is characterized by poor drainage (Kokelj and GeoNorth Ltd., 2002). This results in extensive ponding, which, in turn, increases permafrost thawing because water acts as a heat sink (Kokelj and GeoNorth Ltd., 2002).

2.4.4.5 Closure and Reclamation

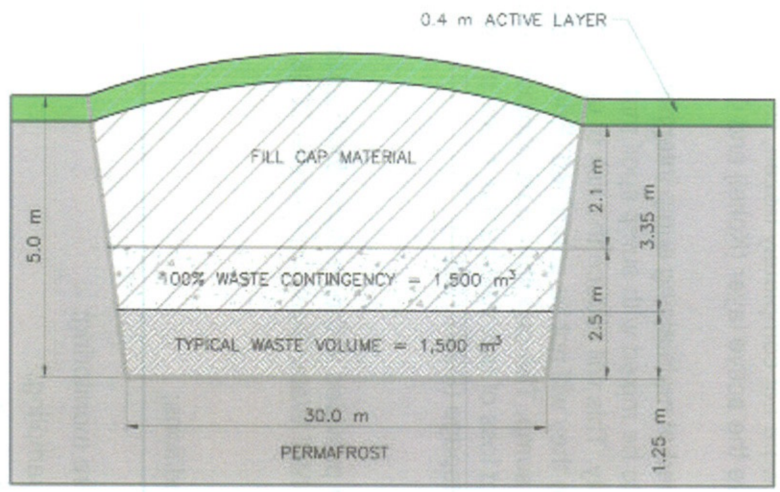
The final step in engineering and constructing a sump is reclamation and covering the sump with a soil cap. Past practices involved placing cover material directly on top of drilling wastes. Often the fill was placed onto wastes that were not completely frozen, causing them to move upwards in the sump into areas in or above the active layer (Kokelj and GeoNorth Ltd., 2002).

Current practices in sump closure are aimed at maintaining sump integrity and reducing environmental impacts. Drilling fluids are to be mixed with sump spoil materials at a 3:1 ratio (ESRF, 2004) or allowed to freeze naturally. This will reduce the risk of upward movement of unfrozen drilling wastes into a zone where they will not be contained. Prior to closure, snow should be removed from the inside of the sump. The cap should be contoured to prevent snow accumulation and should take into account loss of cap volume due to ice melting. This practice minimizes erosion and the potential for seepage (ESRF, 2004).

2.4.4.6 Monitoring

Post-closure monitoring requirements are provided in the Protocol for the Monitoring of Drilling-Waste Disposal Sumps prepared by the NWT Water Board in October 2005. This protocol includes the following tasks:

- site identification and location;
- site history and environmental conditions;
- site description after closure;
- active layer and ground temperature monitoring;
- electromagnetic surveys and soil sampling;
- interpretation of environmental data; and
- reporting and integration into an electronic database.



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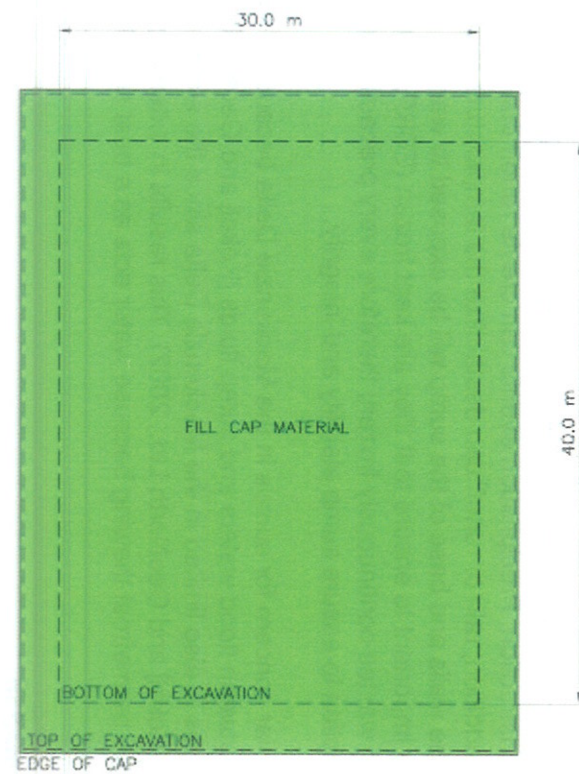


Source: Dimensions from Shell, 2005

amec	**Assessment of Drilling Waste Disposal Options in the Inuvialuit Settlement Region**
Environmental Studies Research Funds	**Sump Schematic**

Drawn: MP	Scale: NTS	Date: July 2008	Project No.: CE03807	**Figure: 5**

2.4.4.7 *Pre-Treatment*

Treating waste liquids such as drilling fluid can decrease or remove much of the water content. One method of liquid waste solidification is through the use of a technology known as PitDry™ developed by CETCO Oilfield Services Company. PitDry™ treatment results in the chemical fixation of heavy metals and the stabilization of hydrocarbons and other inorganic or organic materials in the waste (CETCO, 2008). This includes stabilizing water-soluble anions such as salts that become trapped and cannot leach unless the solid is exposed to high mechanical mixing and large quantities of water. The process permanently binds most heavy metals and hazardous organics inside the solid, eliminating any possibility of leaching and therefore reducing the risk of environmental impact. Further, the process converts liquid waste to solid, thereby rendering it appropriate for landfill disposal.

2.5 Waste Injection (On-Site and Regional Disposal Facility)

On-site waste injection involves the disposal of drilling fluids and cuttings into acceptable underground geologic formations down the annular space of an exploration well. Injecting waste down the annulus of the well eliminates several needs on the surface including waste management facilities, drilling waste pits and offsite transport equipment. Returning the waste to formations below the earth's surface minimizes the impacts of drilling operations on sensitive environments (DOE, 1999).

Regional waste injection involves the disposal of drilling fluids and cuttings into acceptable underground geologic formations down a dedicated disposal well or wells. In this application, wastes are collected and transported to a regional disposal facility for injection down an appropriate well. Development of a regional disposal facility allows for waste to be managed at a location that is favourable for down-hole injection.

2.5.1 Historical Use

Waste injection wells have not been utilized in the Mackenzie Delta Region or elsewhere in the ISR. However, the technology is used extensively in Alaska. By 1994, refined grind-and-inject technology had enabled both Prudhoe Bay operators, BP Exploration (Alaska) Inc. and ARCO, to achieve "zero discharge" of drilling wastes, eliminating the need for reserve pits. By 2000, some 917,500 m^3 of solid material, mostly cuttings, had been pumped into dedicated wells on the slope (PN, 2007).

Over the past decade, the petroleum industry in Alaska has changed their disposal method from entirely surface pits to using injection wells to dispose of the majority of drilling wastes generated. Several issues influenced this change, ranging from extremely high long-term monitoring costs, high liability for surface pits, legal issues, advancements in injection technology, drilling waste volume reductions and pressure to reduce surface impacts.

One such example is the regional disposal site known as the Prudhoe Bay Unit Grind and Inject Area. This site has three Class V and Class II injection wells that have been operational since

1998 with an application to develop three more Class I non-hazardous industrial waste injection wells late in 2006. Class I injection wells are defined by the U.S. Environmental Protection Agency in "Title 40: Protection of Environment" as follows:

- Wells used to inject hazardous waste beneath the lowermost formation containing, within one-quarter mile of the well bore, an underground source of drinking water;
- Other industrial and municipal disposal wells that inject fluids beneath the lowermost formation containing, within one-quarter mile of the well bore, an underground source of drinking water; and
- Radioactive waste disposal wells that inject fluids below the lowermost formation containing an underground source of drinking water within one quarter mile of the well bore.

A Class II injection well is defined as a well that injects fluids:

- which are brought to the surface in connection with natural gas storage operations, or conventional oil or natural gas production and may be commingled with wastewater from gas plants that are an integral part of production operations, unless those water are classified as a hazardous waste at the time of injection;
- for enhanced recovery of oil or natural gas; and
- for storage of hydrocarbons that are liquid at standard temperature and pressure.

The Class V wells at this facility are dry wells used for the injection of wastes into a subsurface formation.

The facility is used to inject liquids and solid cuttings into the Ugnu formation sands. The disposal formation is characterized by high porosity and permeability with effective cover and underlying barriers, making it an efficient and effective disposal medium.

2.5.2 Current ISR Practice

At this time there are no waste injection wells operating in the ISR. However, there is the possibility for the development of waste injection wells as part of the major gas projects currently planned in the Mackenzie Delta. It is not certain whether these wells would be capable of, or available to, handle drilling wastes from sites other than those being drilled as part of the projects themselves.

Imperial Oil Resources Limited (IORL) has proposed annular injection of drilling fluids and cuttings at their proposed Taglu project site. The injection plan for Taglu includes discrete batch injection for limited volumes and discretely scheduled drilling programs. IORL plans to inject initial drilling waste into a dedicated disposal well and as drilling progresses, into the annuli of the previously drilled well (IORL, 2005).

Annular injection is not possible in the proposed Niglintgak wells because gas is potentially present in the strata between the base of the permafrost and the top of the sand reservoir (Shell, 2005).

2.5.3 Construction Requirements

2.5.3.1 Geology

One of the most significant challenges with injection technology is the lithological composition of the formation into which the wastes are to be disposed. For successful waste injection to occur, the geologic formation must have the ideal porosity, permeability and containment barriers. It is recommended that the injection zone have a vertical thickness of greater than 10 m and extend large distances horizontally within the geologic sequence. If this ideal formation for injection is a sandstone, the porosity is suggested to be in the range of 25% with a rate of permeability larger than 1 Darcy. The injection zone will need to be overlain by a sufficiently thick impermeable barrier to confine the wastes to the injection interval. Usually this impermeable barrier is a shale. Note that the permeability/porosity criteria will be different for the various rock types. The criteria described ensure that the injection zone will exhibit the following characteristics:

- adequate storage space to accommodate the required volume of waste;
- high permeability and porosity to minimize formation pressures and stresses; and
- containment from overlying or underlying strata to prevent waste migration.

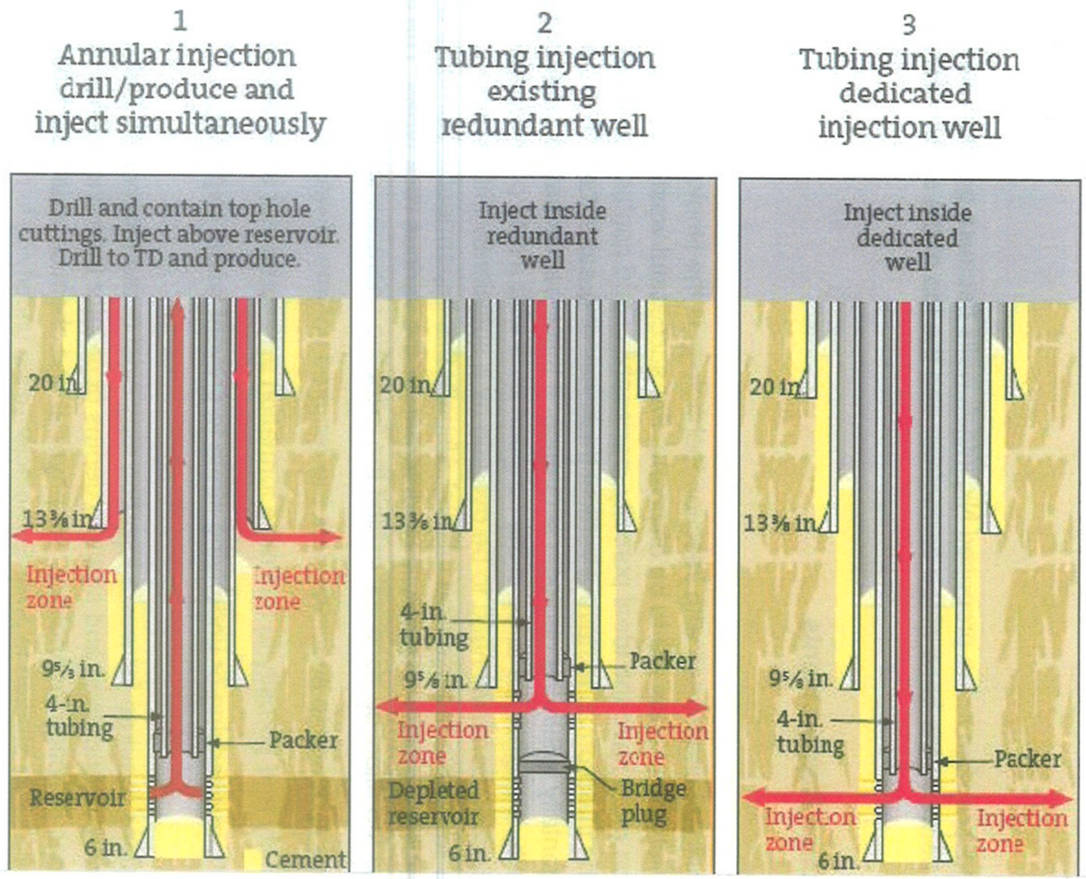
Ideal geologic formations required for waste injection may exist in the Mackenzie Delta Region. The area is dominated by sandstone and shale to depths of greater than 5 km. Prior to any development of cuttings injection technology, the physical and chemical characteristics of the target area would need to be studied in order to characterize the underlying formations.

IORL's engineering assessment and modelling of cuttings disposal by slurry injection at Taglu concluded that drilling fluids could be successfully contained within the prescribed zone without contaminating other horizons (IORL, 2005).

2.5.3.2 Technology and Equipment

Figure 6 illustrates casing configuration and injection zones for three types of waste injection:

- annular injection;
- injection into an existing redundant well; and
- injection into a dedicated well.



Source: M-I SWACO

Environmental Studies Research Funds		Assessment of Drilling Waste Disposal Options in the Inuvialuit Settlement Region		
		Waste Injection Types		
Drawn: MP	Scale: NTS	Date: July 2008	Project No.: CE03807	Figure: 6

Annular injection wells transfer waste slurries through the annulus of the well, the space between two casing strings. When the drilling waste reaches the bottom of the outermost casing, it exits the casing and enters the injection formation. The Drilling Waste Management Information System made available by the Argonne National Laboratory shows that over 88% of all drilling waste injection projects utilized annular injection methods. Annular injection of cuttings would require that the drilling rig remain over the well. The cost implications could be quite significant given that rig costs are in the hundreds of thousands of dollars per day.

Dedicated injection wells can be used to inject waste in two ways: into the formation at the end of all casing strings (i.e., at the bottom of the hole) or at a point higher up in the well bore where the casing has been perforated to allow waste to be injected in a suitable formation. Figure 7 illustrates the surface and subsurface layout of a typical waste injection system.

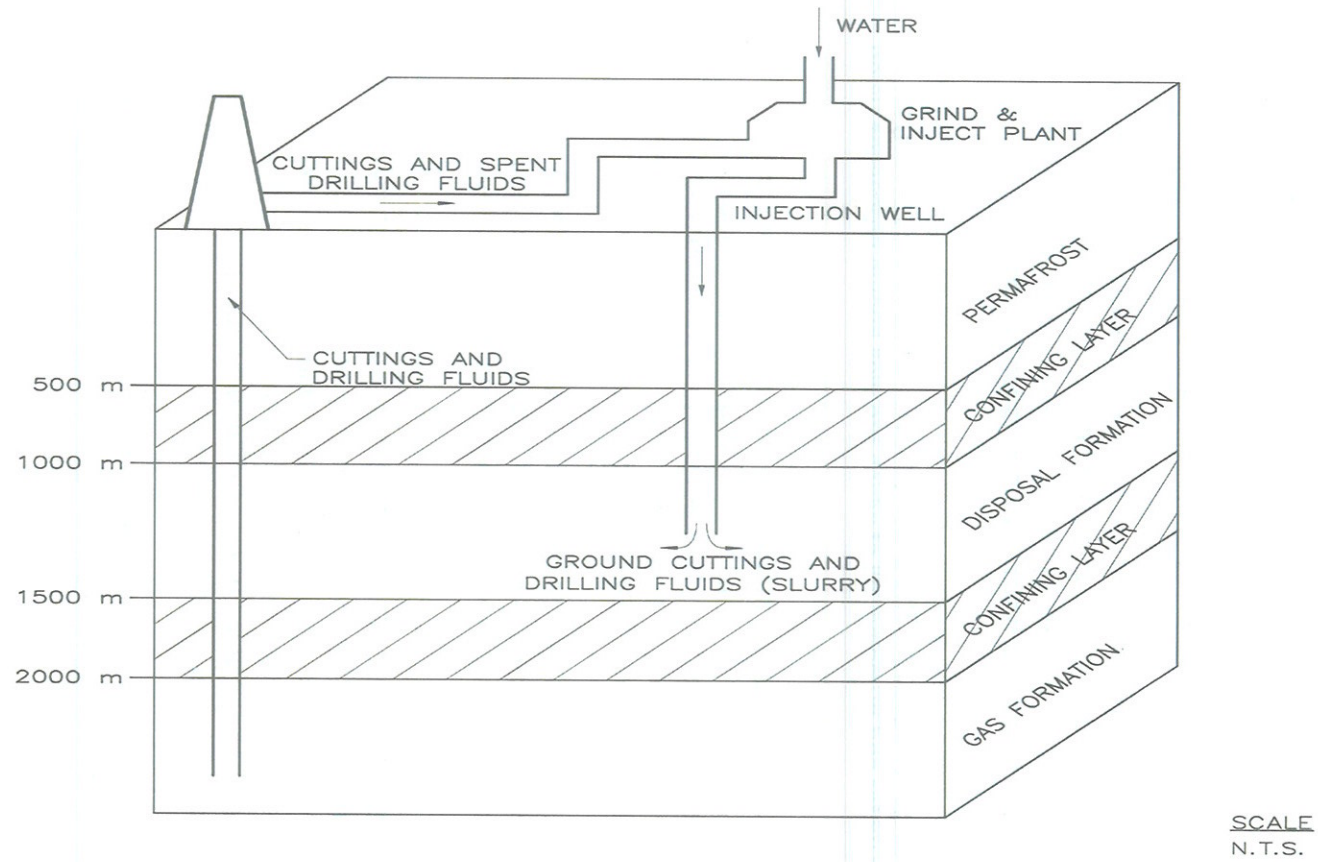
Following the choice of an injection technology, specific equipment must be brought to the site to prepare drilling fluids and cuttings for injection. The entire process involves the grinding of solids, mixing with fluids and/or water and pumping, all of which are well known processes using conventional equipment.

Drilling fluid that reaches the surface after passing through the well requires the separation of cuttings from the drilling fluid. This is typically done at the rig through the use of shakers, centrifuges and dryers. At this point, the system may take advantage of the separated drilling fluids that can be reused and sent through the well bore once more. The cuttings, which will be coated with drilling fluids, then require transport to the slurry operation for processing.

A transport system is necessary to convey cuttings to the injection system or facility. Several methods are available including gravity collection, auger or belt conveyor systems, and vacuum transport systems. Selection of a transport system will vary, depending on the site layout, elevation and water availability.

Upon reaching the grind and inject system, the drilling waste is processed into a slurry by mixing with a liquid such as water (e.g., seawater or fresh water, depending on location and availability). The solids in the newly created slurry require crushing and grinding in a mill for reduction into smaller particles that can be effectively injected. Common types of mills are ball, rolling, grinding and crushing. Screens may also be utilized to filter out larger particles that may require reintroduction into the grinding process to further reduce size.

Particle size and slurry viscosity, among other characteristics, must be controlled during the process. These factors are determined during the engineering and analysis phase of the injection formation. The final step in the grind-and-inject procedure is the injection of waste. Containment of the slurry may be necessary, requiring the use of tanks to store the slurry prior to and during the injection process.



Source:

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Injection Schematic

Drawn: MP	Scale: NTS	Date: July 2008	Project No.: CE03807	**Figure: 7**

Slurry injection requires significant amounts of water, proportional to the amount of drilling wastes processed for injection. Guo and Geehan suggest that there may be cuttings in slurry of around 20% by volume. This factor must be considered from both a regulatory perspective and from an engineering standpoint. Formations for drilling waste injection must be large enough to contain the quantity of waste processed and also the additional liquids that will be needed in the slurry process.

2.6 Regional Disposal Facility

There are two types of disposal infrastructure that could potentially be considered for regional drilling waste disposal in the Mackenzie Delta Region and the ISR: a regional waste injection well similar to the grinding and injection facilities in Alaska, and a regional landfill similar to the existing municipal and Distant Early Warning (DEW) Line contaminated soil landfills in the Arctic. The regional disposal facility could be either an injection well or landfill, or could be a combination of both types of infrastructure at one facility. A regional facility would be designed to accept waste from multiple sources, and as a result, could potentially reduce the unit costs of the facility by increasing economies of scale, depending on location and quantities of waste processed. Typically, the costs for disposal facilities are reduced when increasing volumes of waste are available.

2.6.1 Historical Use

Regional injection or landfill facilities have not been used in the Mackenzie Delta Region or other areas within the ISR for the disposal of drilling wastes. The regional use of injection wells has been discussed in the previous section. Landfills have historically been used in the ISR for the disposal of municipal solid wastes and contaminated soil.

2.6.2 Current Practice

Both historically and currently, there are no regional drilling waste disposal facilities active in the Mackenzie Delta Region or the ISR. Alaska currently operates several grind-and-inject facilities to dispose of drilling waste. One such example previously mentioned is the Prudhoe Bay Unit Grind and Inject area, currently offering three functioning disposal wells with plans for three additional wells.

Although there are very few landfills in the North, there are areas where they have been utilized. During the 1950's, the DEW Line sites were constructed across the north as part of a military early detection system. Since the 1990s, cleanup of these sites has occurred with the use of landfills to dispose of solid wastes and contaminated soils (Corrigan et al., 2005). Also, landfills are currently in use for municipal solid waste disposal in Inuvik, Norman Wells, Fort Simpson, Hay River and throughout Alaska.

Drilling waste disposal in non permafrost environments typically relies on the use of a combination of methods including mixing, burying and covering solid and liquid wastes in sumps, injecting liquids into deep wells, and land-spreading, composting, or landfilling solid wastes. Landfills in these areas are typically only permitted to accept solid wastes and are prohibited from accepting liquids. Wastes are either stabilized prior to land-filling or dewatered with the resulting liquids being bound up in the waste mass or injected at a dedicated disposal well.

2.6.3 Construction Requirements

Construction requirements for larger regional disposal facilities are similar in the equipment required, but are on a larger and more permanent scale. A regional grind-and-inject facility or landfill may require a larger area with the capacity for storage, as it would be accepting wastes from multiple sources for processing immediately or at a later time. However, this would ultimately disturb less area than having numerous disposal sites throughout the region.

Given the current and historic use of injection wells and landfills in the Arctic, it is likely that a regional disposal facility could technically be developed within the ISR, provided that it was properly sited, designed, constructed, operated and monitored. These requirements are discussed in further detail in the following sections.

2.6.4 Siting

The selection of a regional disposal facility site would need to take into account a variety of technical and non-technical issues. These would typically be documented in a site selection study that reviews available desktop information, site investigation data and public consultation results. Both areas of continuous and discontinuous permafrost could be considered; however, development and operation of a facility located on permafrost would require more strict controls. The cost of these controls could be potentially offset by the closer proximity to the waste and lower transportation costs. Site selection in permafrost should consider preservation of the active layer and the avoidance of ice-rich soil for foundations. For landfills, the availability of cover soil and the avoidance of surface water features are major considerations.

Both landfills and injection wells have similar requirements for transportation and access. The availability of all-weather access would be a benefit; so proximity to winter ice roads and barges should be considered.

The location of a regional disposal facility near Inuvik appears to be technically feasible based on the information reviewed in this study. However, a detailed siting study would be required to verify this, and to determine whether or not this would be desirable from an economic and community perspective.

2.6.5 Design

A regional disposal facility located in the north would rely on permafrost for underlying foundation support and for waste containment. The design of such a facility would need to rationalize future uncertainty from changing climatic conditions using methods such as those described by Hayley and Horne (2008).

A design basis for arctic landfills has been put forward by Hayley (2006), which includes the following:

- saturated granular fill containment berms that are keyed into the underlying permafrost;
- double containment with geomembranes;
- natural and induced permafrost for long-term containment; and
- cover design to maintain permafrost in perpetuity.

The design has two defences against contaminated pore fluid loss, the first being the geomembrane liner and the second being the underlying ice-saturated permafrost soil and is similar to the contaminated soil landfill design described by Nahir et al. (2004). A cross-section of a typical arctic landfill is presented in Figure 8.

The final soil cover is designed to retain the active layer within the cover. Geothermal analysis is used in the design process to determine the length of time for landfill freeze-back, the short- and long-term thermal regimes in the landfill (including potential effects of climate change), and the depth of the active layer in the cover material.

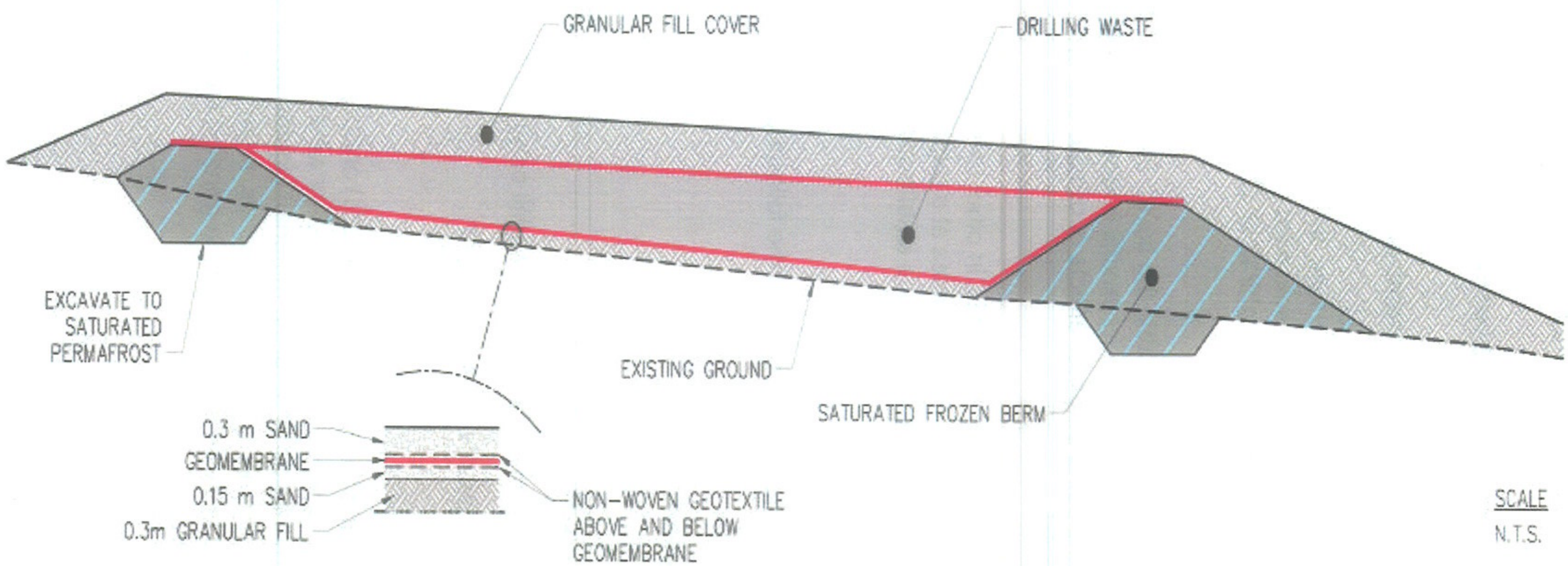
It is expected that landfills in the ISR would be similar to landfills in other jurisdictions and would not be permitted to accept liquid wastes for disposal. Liquid wastes at a regional facility would be disposed of through a dedicated injection well or would require stabilization prior to disposal.

2.6.6 Operation

A regional disposal facility would need dedicated staff to perform the following activities:

- establishing waste disposal contracts;
- characterizing wastes prior to disposal;
- accepting and screening wastes;
- processing wastes and operating on-site equipment;
- applying cover materials to maintain permafrost integrity (landfill only);
- removing snow during operation and prior to spring melt; and
- monitoring and record keeping.

Wastes could arrive at the facility either during the winter (via ice roads) or during the summer (via barge). If a landfill were selected for solid waste disposal, the facility would likely include an area for processing wastes to either remove water or stabilize material. Liquids would need to be disposed of through an injection well or bound up in the waste solids. Alternatively, if a landfill were not selected, the facility would likely be established as a grinding and injection facility similar to those currently in use in Alaska.



Source: Nahir et al. (2004)

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Environmental Studies Research Funds	**Landfill Schematic**

Drawn: MP	Scale: NTS	Date: July 2008	Project No.: CE03807	**Figure: 8**

2.6.7 Monitoring

Monitoring requirements for an operating regional waste management facility would include routine daily visual inspections for water ponding, erosion, thaw settlement, frost heaving and frost jacking. Any irregularities identified during the visual inspection should be remedied as part of routine operations. Further, monitoring of temperature, active layer thickness and surface water quality should be conducted on a semi-annual basis.

2.7 Disposal Outside the Northwest Territories

Transportation out of the NWT is an option for drilling waste disposal using facilities located in Alberta or BC. The transportation options involve repeated labour-intensive handling and repackaging of drilling wastes at the well site and at barge or truck transfer points between the ISR and Alberta or BC, a distance of about 2,200 km.

2.7.1 Current Practice

Over the past several years, drilling waste from approximately four wells has been transported out of the NWT for disposal in BC and Alberta. When the transfer of wastes out of the NWT is required, it typically involves multiple transportation modes such as the use of trucks, trains and barges. The need for various methods of transport relates to the geography, climate, and infrastructure of the NWT. Transfer of equipment and wastes to locations such as Hay River or Fort Simpson can be done by road and rail; however, more effort is required to transfer waste from points farther north (i.e., Tuktoyaktuk and Paulatuk) that do not have direct access to permanent roads. Permanent road or rail networks do not exist; therefore waterways and temporary road networks (winter roads) must be utilized for transportation.

2.7.2 Construction Requirements

The most significant construction requirement for the transfer of wastes out of the NWT is winter roads and waste containment during transportation. Other than the need for winter roads, much of the required infrastructure is already in place, whether it is established highways or existing barge services on the Mackenzie River.

Timing and snowfall are two important factors to consider when building winter roads in the north. It is preferable to begin construction as early in the season as possible to take advantage of warmer temperatures that will assist in compaction and consistency of the freezing snow. As temperatures rise, the moisture content in snow increases. This results in ease of compaction and a more solid base. It is recommended that at least 20 cm of snow accumulate before beginning the construction of a winter road. Tanker trucks apply water from nearby lakes or rivers to create a firm crust. Crushed ice is then laid down to build thickness and create a smooth surface. The crushed ice is watered and allowed to freeze. When the ice road has reached a thickness of about 30 cm, a grader scars the surface to create traction for tires. Ice roads melt in the spring and leave no significant damage to the ground surface.

2.7.2.1 *Pre-Treatment*

It may be desirable to solidify drilling wastes prior to transport and disposal out of the NWT in order to reduce the risks of potential spills during transport. PitDry™ technology, as discussed in Section 2.4.4.7, may be a viable solution should solidification of drilling waste be preferred or necessary.

2.7.3 Transportation Routes

As shown in Figure 9, there is one major land route out of the ISR: Highway 8 from Inuvik to the Yukon border, followed by the Alaskan and Dempster highway routes south. The route differs, depending on the final destination of the waste. The difference in the route only impacts travel south of Fort Simpson. Two methods can be used to transfer waste from the Mackenzie Delta region south to Fort Simpson or Hay River: barging and winter roads or the Dempster Highway route. Waste shipments sent south to BC by barge would be unloaded at Fort Simpson and then trucked to BC along the Liard Highway. This route runs southwest to Fort Liard and further south to Fort Nelson, accessing northeastern BC facilities. Waste shipped to Alberta by barge is unloaded in Hay River. At Hay River, waste can be hauled into Alberta along the Mackenzie Highway or by a rail line that runs parallel to the Mackenzie Highway. Waste shipped along this route will arrive at High Level in northern Alberta.

The use of winter roads to transport waste south from the Mackenzie Delta region is also an option; however, the waste must be shipped by barge to Fort Good Hope, where it is unloaded for further transportation on winter roads. Because of seasonal limitations (barging in summer and winter roads in winter), it may be necessary to store waste after barging for a period of time while winter roads are constructed. These winter roads are currently constructed and maintained yearly by the GNWT. Winter road use involves travel from Fort Good Hope south through Norman Wells and Tulita before arriving at Wrigley, Fort Simpson or Hay River.

2.8 Advantages and Disadvantages

Table 7 provides a list of the general advantages and disadvantages of each drilling waste disposal option. Table 7 was excerpted from Drilling Waste Management Best Recommended Practices
(ESRF 2004).

2.9 Other Disposal Options

Other drilling waste disposal options were brought to AMEC's attention during this study, including the following:

- off-shore disposal; and
- disposal at waste management centres located in Alaska.

These options were not included in the scope of work for this project and therefore were not considered. Generally, disposal of waste into sea water was brought to AMEC's attention because this form of disposal has been used in Canadian offshore operations in the past. Disposal of drilling waste in Alaska may be possible with foreign operator and regulator consent.

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Environmental Studies Research Funds	**Transportation Networks**

Drawn: MP	Scale: NTS	Date: August 2008	Project No.: CE03807	**Figure: 9**

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Table 7: Options – Advantages and Disadvantages

Option	Advantage	Disadvantage
Down-hole Injection	Preference – Environmentally preferred when rock formations allow.	Specific selection requirements for injection zone – The injection zone must be able to accept the waste.
	Less Impact – Reduces surface impacts.	Continuous operations requirement – Continuous operations may be required because of zone and rock seal characteristics.
	Can eliminate future liability.	Economics – Large volumes of drilling waste may be required to make the cost economical because of capital and ongoing infrastructure costs.
	Can be used to remove material from existing sumps.	Risk of injecting out of zone – There is the risk of other zones becoming contaminated.
		Access limitations – Wastes generated in the summer may need to be stored and transported to a central facility when weather and conditions permit (usually the following winter).
		Procedure limitation – Slurry cannot be injected into an exploration well while it is being drilled because of a lack of information on prospective injection zones.
		Blockages – Waste fluids containing solids (slurry) may plug the interconnected pores of the rock formation.
Sump	Low initial capital cost.	Controversy – Recognition of the environmentally sensitive nature of the Mackenzie Delta Region along with past practices that resulted in sump failure or collapses has led to disagreements on sump use.
	Overall operational convenience – When the sump is adjacent to the drilling rig.	Risk of sump failure – There is a risk of waste release into the environment, and possibly sump failure, if any or all of the following are not done properly: siting, design, construction and reclamation.
	These sumps are regulated through the land use permits issued by INAC or the Inuvialuit Lands Administration and Type 'B' water licences issued by the Northwest Territories Water Board.	Salt-based muds – Using salt-based drilling muds lowers the permanent freeze-back temperature and ice-bonding capability of the waste.
	The conditions of the permits and licences do not allow for the discharge of wastes from sumps.	Surface footprint – The combined use of individual sumps leaves a greater impact on the landscape than a central or regional sump design.
Regional Sump	Site selection – The best possible site for sump construction can be chosen before drilling begins.	Waste transfer – Getting the waste to a central site involves additional transportation, increases the risk of spills and pushes up operational costs.
	Monitoring – Using a single site makes monitoring and follow-up logistics (such as maintenance) easier.	Seasonal limitation – Drilling waste generated in the summer may need to be stored and transported during the following winter.

Option	Advantage	Disadvantage
Regional Sump (con't)	Minimized impacts – By reducing the number of sump sites, a smaller footprint is left and broader impacts reduced.	Risk potential – The risk at a site increases with the corresponding amount of drilling waste at that site.
		Sump site management – The use of one site by several companies would require additional management to ensure that there is no increased liability for any one company because of the others, and no cross-contamination. With more than one sump at the site, companies must not deposit their drilling waste into the wrong sump and cause cross-contamination.
		Increased paperwork – A separate land lease would be required (in addition to the drilling lease), which could result in a longer administration and review process for each company's first well.
		Practicality – Individual operator liability management issues could mean that a common remote sump for more than one operator may not be practical.
Regional Treatment and/or Disposal Sites (3rd Party Operator)	Reduced disposal costs – The disposal costs for each company may be reduced.	Liability – In the event that a 3rd party commercial operator could not handle the liability for the proper treatment and/or disposal of its drilling wastes, companies could end up sharing that liability.
	Consistent disposal methods – One operator managing a regional drilling waste site could result in consistent waste management methods for the treatment and/or disposal of each type of drilling waste.	Feasibility – To be economically feasible, sufficient and long-term waste volumes are required.
	Inspection ease – Inspectors could more easily monitor the operation of one site versus many sites.	Approval time frames – Approvals for a 3rd party commercial operator to obtain a water licence and land lease may take longer than the time required for individual companies to obtain the licences and permits for other disposal options.
	Smaller footprint – The landscape impacts of one regional drilling waste treatment and/or disposal centre would be smaller than the combined footprints of many sites throughout the Delta area.	Seasonal Access – Well sites may need to store summer wastes and transport out to a regional facility during the winter.
	Environmental impacts minimized – Depending on the type and volumes of drilling wastes, a 3rd party operator could use multiple treatment and disposal options to minimize the impacts on the environment.	NWT Water Act – The regulations under the NWT Water Act would have to be amended to allow a 3rd party operator to dispose of drilling waste other than to a sump at a regional treatment and/or disposal site with a Type B water licence.
	Simplified approvals – The water licence and land use approvals would be simplified for each operating company.	

Option	Advantage	Disadvantage
Haul out of NWT	When the drilling waste is trucked out, no drilling waste is left in the Mackenzie Delta Region.	Finding a receiving facility – The provinces may not accept NWT waste for treatment and/or disposal.
		Accident risk – There is always the risk of an accident and spill during transportation.
		TDG Regulations – Depending on the waste, transporting waste may require compliance with applicable Transportation of Dangerous Goods Regulations (e.g., labels, signage, certified drivers).
		Cumulative effects – Trucking the waste can result in a number of impacts (e.g., ground disturbance, air quality issues attributable to emissions associated with significant increase in fuel consumption).
		Winter Problems – In the winter the waste can freeze into the trucks.
		Waste Preparation – Solid wastes with high fluid content require stabilization prior to trucking

All data excerpted from ESRF, 2004.

2.9.1 Offshore Disposal

This option involves transportation of drill cuttings from the well site to an offshore area during the winter season. Drill cuttings would be deposited onto ice or below ice for dispersion in sea water. This option would apply to water-based or synthetic-based drilling wastes. The NEB Offshore Waste Treatment Guidelines (NEB, 2002) specify that synthetic base fluids also must have a total polycyclic aromatic hydrocarbon concentration of less than 10 mg/kg, be relatively non-toxic in marine environments, and have the potential to biodegrade under aerobic conditions. The disposal of oil-based mud would be approved only in exceptional circumstances where the use of water-based or synthetic-based muds is not technically feasible (NEB, 2002). The Guidelines specify that under no circumstances is whole synthetic or enhanced mineral oil-based mud to be discharged into the sea. Spent and excess water-based drilling muds may be discharged onsite from offshore facilities without treatment.

Locations for the offshore discharge of waste are subject to the approval of the NEB and will be determined on a case-by-case basis. As a rule, all points of discharge should be below the water or ice surface.

The guideline also requires operators to conduct compliance monitoring and environmental effects monitoring programs.

2.9.2 Disposal in Alaska

This option involves transportation of drilling waste from the well site to existing waste management operations located in Alaska. Transportation of drilling waste from locations in the ISR via barges to receiving points located in Alaska is the likely scenario. Regulations regarding the transboundary movement of hazardous and non-hazardous wastes are as follows:

- Agreement Between the Government of Canada and the Government of the United States of America Concerning the Transboundary Movement of Hazardous Waste; and
- Environment Canada reports that a regulatory framework is currently being developed for the export and import of non-hazardous wastes. Consistent with Canada's international obligations, the regulatory framework would control the export from and imports into Canada of these wastes.

The waste management facilities in Alaska are owned by the various operators (e.g., BP, CPAI and Pioneer). The Alaska Oil and Gas Conservation Commission (AOGCC) reported that BP has accepted 3rd party waste from other operators at their large-scale Prudhoe grind-and-inject facility. The AOGCC does not prohibit operators from accepting 3rd party waste; however, with few exceptions, most operators do not accept other waste (personal communication, Maunder, 2008).

3.0 ENVIRONMENTAL AND SOCIO-ECONOMIC SETTING

A general overview of the environmental and socio-economic characteristics and concerns in the ISR is discussed in this section.

3.1 Terrestrial Ecozones

A physiographic region is a large land area with a shared geologic structure and history. The ISR is characterized by three of these regions or ecozones: Southern Arctic region, Taiga Plains region and Taiga Cordillera region. Current oil and gas exploration activity is focused mainly in the Southern Arctic and Taiga Plains regions.

Of the three arctic ecozones in Canada, the Southern Arctic ecozone has the most extensive vegetative cover and the highest diversity of species. Most of the ISR is located within this region, including the northern part of the Mackenzie Delta, the Tuktoyaktuk Peninsula and the general north and northeastern extent of the ISR. Underlain mainly by Precambrian granitic bedrock, the terrain consists largely of broadly rolling uplands and lowlands. Much of it is mantled by discontinuous mineral deposits, except near the coasts where fine-textured marine sediments cover the surface. Throughout the region, there are exposures of bedrock. Cretaceous shale covered by thick glacial drift deposits characterizes its westernmost section from Great Bear Lake in the NWT to the Firth River on the Yukon coast. Strung out across the landscape are long, sinuous eskers reaching lengths of up to 100 km in places. The undulating landscape is studded with innumerable lakes, ponds and wetlands. Cryosols are the dominant soils, and are underlain by continuous permafrost with active (thaw) layers that are usually moist or wet throughout the summer (EC, 2008a).

The Taiga Plains ecozone is dominated by Canada's largest river, the Mackenzie, and its tributaries. The southwestern extent of the ISR is located within this region, mainly the southern part of the Mackenzie Delta. The subdued relief of broad lowlands and plateaus are incised by major rivers, the largest of which can show elevation differences of several hundred metres. Underlain by horizontal sedimentary rock—limestone, shale and sandstone—the nearly level to gently rolling plain is covered with organic deposits, with some undulating to hummocky moraine and lacustrine deposits. Alluvial deposits are common along the major river systems, including braided networks of abandoned channels. Low-lying wetlands cover 25%–50% of the zone. A large portion of the area is underlain by permafrost, and this acts to perch the surface water table and promote a regional overland seepage system. When combined with low-angle slopes, it creates a landscape that is seasonally waterlogged over large areas. The region's widespread permafrost and poor drainage create favourable conditions for cryosolic, gleysolic, and organic soils (EC, 2008).

The region of the ISR located within the Yukon Territory is within the Taiga Cordillera ecozone. The northern limit of tree growth in Canada is reached in this region. The northern unglaciated Richardson and British mountain ranges reach 1,675 m above sea level in the region's northern core. Limestone rock outcrops are significant and there are great examples of periglacial landforms, particularly cryoplanation summits and terraces, in the sedimentary rocks of the

Richardson Mountains (EC, 2008a). There are currently no oil or gas exploration programs in this region.

Figure 10 shows the location and extent of each ecozone within the ISR.

Table 8 provides a general overview of the ecozones in the ISR.

3.2 Geology

The 17 geologic provinces of Canada are characterized by rocks and structures of varying types and ages. Four of these areas are present within the ISR: Bear Province, Arctic Platform, Interior Platform and Arctic Continental Shelf (see Figure 11), with the latter two being the most prominent.

The most eastern part of the ISR is located within Bear Province, which has rock deposits of uranium, copper, chalcocite, bornite and chalcopyrite. A small part of the ISR, between Tuktoyaktuk and Paulatuk, is located within the Arctic Platform. This geological area extends beneath the islands of the Arctic archipelago and some of its strata may contain oil and gas (NRCAN, 2008b).

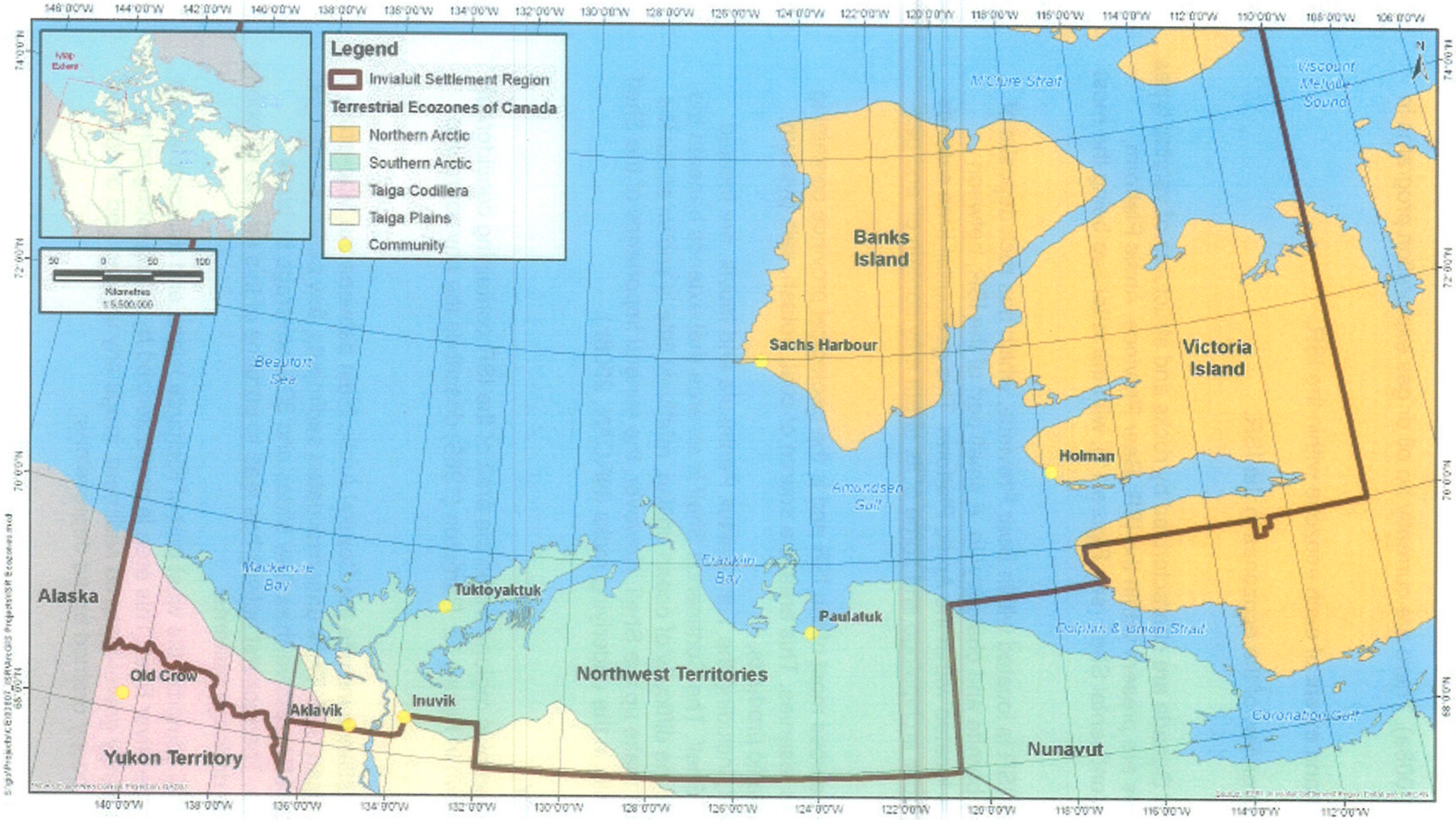
The Interior Platform ranges across most of the ISR and is the geological province containing most of Canada's oil and gas reserves. This area is a source of coal, potash, salt, gypsum, limestone and other non-metallic products.

The northern parts of the ISR, including the Tuktoyaktuk Peninsula and Inuvik, are located within the Arctic Continental Shelf. The Continental Shelf is an area that extends beneath the Arctic Ocean, but because of the difficulty of ocean drilling, relatively little is known about the composition of the rocks that make up the Shelf. However, the mineral importance of the Shelf consists of oil and gas deposits in the underlying rocks (NRCAN, 2008b).

3.3 Surficial Geology

Surficial geology and physiographic regions within the area of the ISR containing considerable oil and gas reserves are shown in Figure 12. Rampton (1988) describes the physiographic regions as follows:

- The Tuktoyaktuk Coastlands include the Coastal Arctic Plain between the Mackenzie Delta and the Amundsen Gulf. Thick unconsolidated sediments, few bedrock outcrops, pingos, massive ice, retrogressive-thaw flow slides and 30% coverage by lakes characterize this area. Thermokarst activity has lead to portions of this area to be poorly drained with irregular drainage patterns;
- The Tununuk Low Hills comprise the west part of Richards Island and adjacent land to the south of Mackenzie River East. This area is characterized by rolling topography underlain by clay to sandy gravel-textured sediment, irregularly shaped and orientated lakes and ridges and poorly drained broad depressions;



Source: Atlas of Canada

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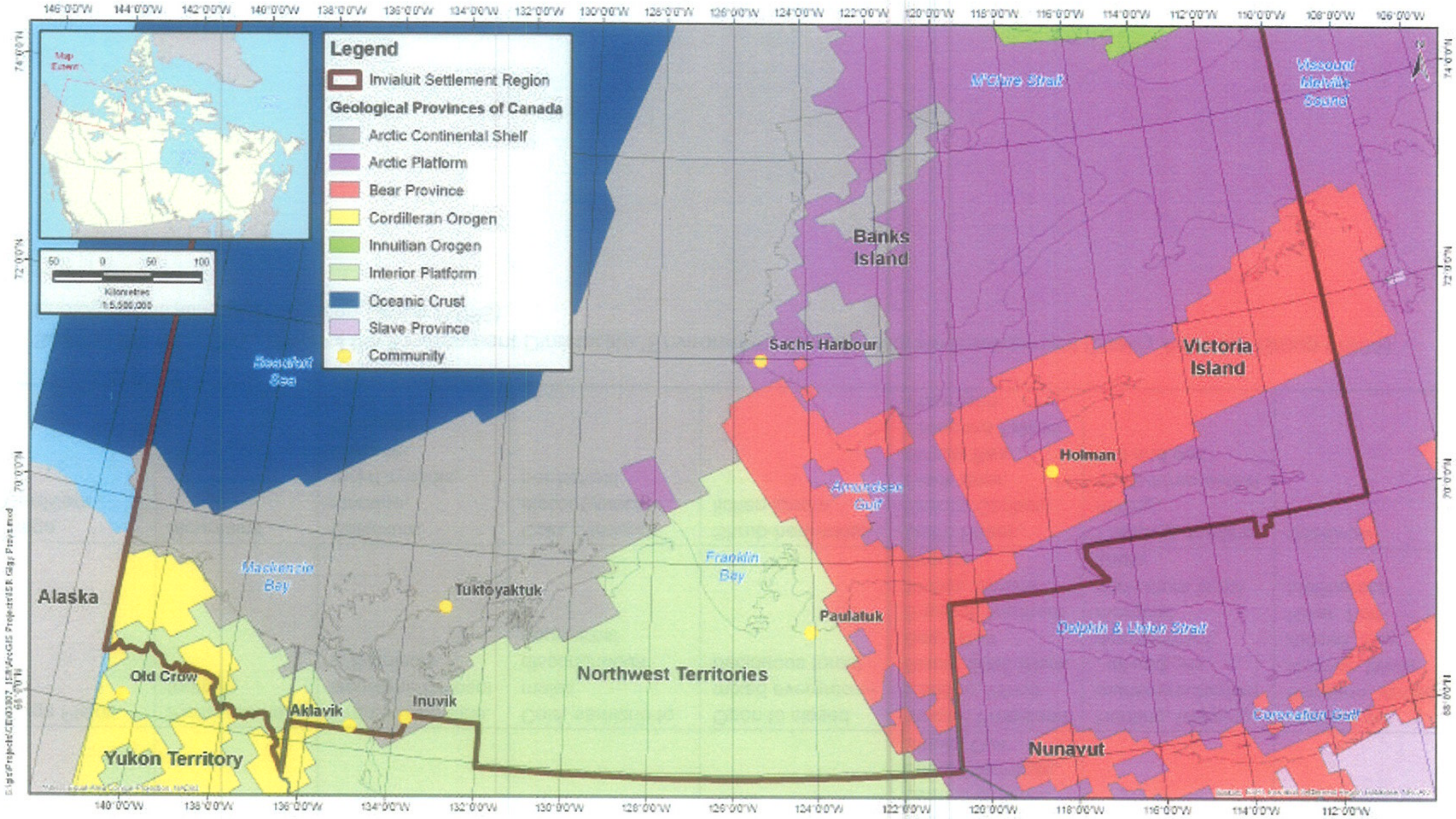
Environmental Studies Research Funds		**Ecozones**		
Drawn: MP	Scale: NTS	Date: July 2008	Project No.: CE03807	**Figure: 10**

Table 8: Biophysical Characteristics of ISR Terrestrial Ecozones

Ecozone	Landforms	Surface Materials/Soils	Climate	Vegetation	Wildlife	Human Activities	Main Communities
Southern Arctic	Plains, hills	Moraine, rock, marine/Cryosols	Cold, dry; continuous permafrost	Shrub–herb tundra	Barren-ground Caribou, Wolf, Grizzly Bear, Arctic Fox, Arctic Ground Squirrel, Lemming; Arctic Loon, Ptarmigan, Snowy Owl	Hunting, trapping, tourism/recreation, mineral development	Tuktoyaktuk, Rankin Inlet, Arviat, Paulatuk, Povungnituk, Uluhaktak and Sachs Harbour
Taiga Plains	Plains, some foothills	Organic, moraine, lacustrine/Cryosols, Brunisols	Cold, semiarid to moist; discontinuous permafrost	Open to closed mixed evergreen–deciduous forest	Moose, Woodland Caribou, Wood Bison, Wolf, Black Bear, Red Squirrel; Northern Shrike, Spruce Grouse	Hunting, trapping, tourism/recreation, oil and gas development, marginal agriculture in the south	Inuvik, Fort Simpson, Wrigley, Norman Wells, Aklavik, Hay River, Fort McPherson
Taiga Cordillera	Mountains	Colluvium, moraine, rock/Cryosols, Gleysols, Brunisols	Cold, semiarid; discontinuous permafrost	Shrub-herb-moss-lichen tundra	Dall's Sheep, Grant's Caribou, Black Bear, Grizzly Bear; Peregrine Falcon, Ptarmigan	Trapping, hunting, mining, tourism/recreation, oil and gas	Old Crow

Source: Wiken (1986); State of the Environment Directorate, Environment Canada; Marine Environment Quality Advisory Group (1994); Ecological Stratification Working Group (1996).



Source: Atlas of Canada

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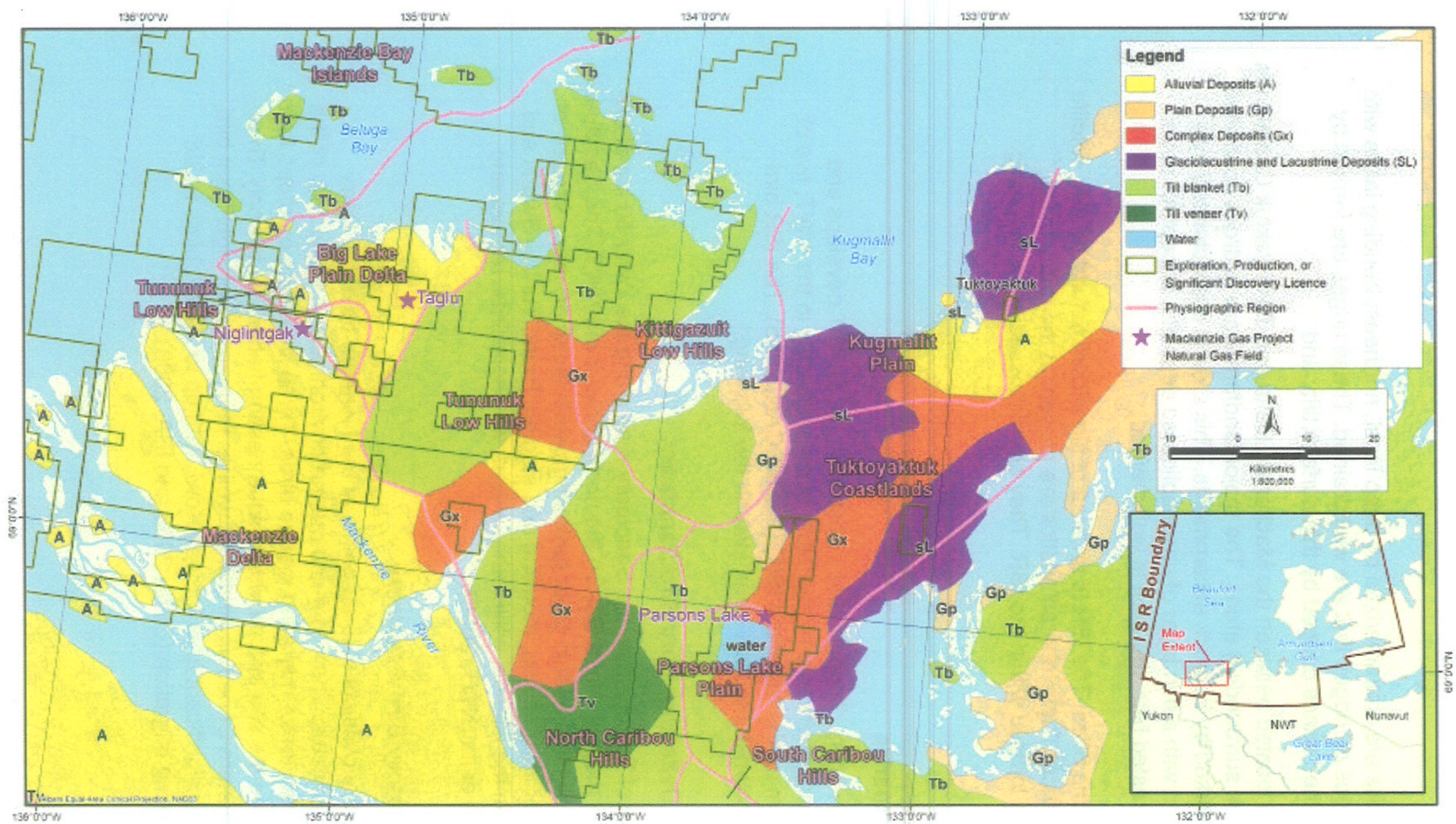
Environmental Studies Research Funds	**Geology**

Drawn: MP	Scale: NTS	Date: July 2008	Project No.: CE03807	**Figure: 11**



1995: Surficial Materials of Canada, Geological Survey of Canada, Map 1880A, scale 1:5,000,000, http://sts.gsc.nrcan.gc.ca/page1/sgm/maps.htm. Rampton (1988)

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Environmental Studies Research Funds

Surficial Geology and Physiographic Regions

Drawn: NH	Scale: NTS	Date: July 2008	Project No.: CE03807	**Figure: 12**

- The Kittigazuit Low Hills are characterized by deep inset, northeast trending lakes with moderately steep slopes on ridges that are well drained. These ridges are formed by thick, brown, fine-grained sands capped by thin surface tills; and
- The Caribou Hills are located between the Mackenzie Delta and Tuktoyaktuk Coastlands and rise steeply above surrounding areas. The major landforms are bedrock controlled with the perimeter marked by bedrock escarpments. This area is characterized by a radial drainage pattern with a thin layer of unconsolidated deposits. Except for small depressions on flat-crested hills, the area is well drained.

Parks, Sanctuaries and Historic Sites: The ISR is an area of significant natural beauty, wildlife habitat and historical importance. These characteristics are present in the many parks, sanctuaries and historic sites located within the ISR. They are discussed in the following sections and shown in
Figure 13.

3.3.1 Parks and Sanctuaries

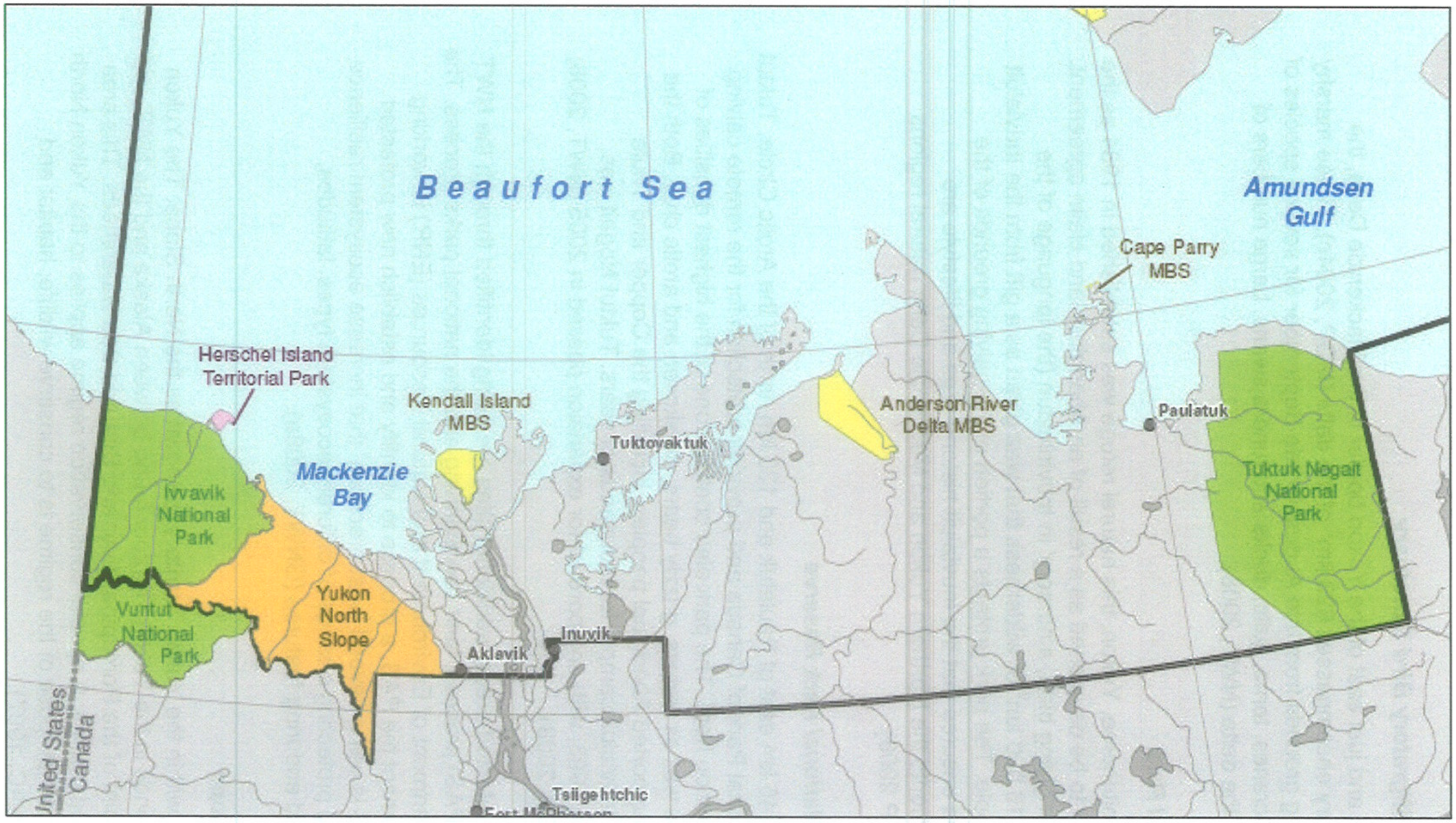
Through the Department of Industry, Tourism and Investment, the GNWT develops and operates 34 parks. Furthermore, there are 17 migratory bird sanctuaries in the NWT, five of them in the ISR (three of them on the mainland ISR) (PARKSCAN, 2008). The ISR bird sanctuaries and parks are shown in Figure 13 and include the following.

3.3.1.1 Anderson River Delta Migratory Bird Sanctuary

Located near the community of Tuktoyaktuk, the Sanctuary runs along the lower 50 km of the Anderson River and includes most of Wood Bay on the north coast of the NWT. The Sanctuary hosts North American waterfowl that nest in great gatherings each summer, many species of which use the Anderson River for breeding, moulting and staging. Brant, Tundra Swans and Lesser Snow Geese breed on the islands, while other waterfowl, shorebirds, raptors and songbirds are all found in the delta (NWT, 2008).

3.3.1.2 Cape Parry Migratory Bird Sanctuary

The Cape Parry Bird Sanctuary consists of three points at the Northern tip of the Parry Peninsula, 100 km north of Paulatuk. There is a rich marine environment in the vicinity of the sanctuary, providing critical habitat for migrating marine birds. Three limestone outcrops form coastal cliffs rising 20 m above the sea and provide unique nesting habitat for the only Thick-Billed Murre colony in the western Canadian Arctic, as well as for many other significant bird populations. This is a globally significant area for waterfowl, with up to 20,000 birds found staging in the area during spring migration (CWS, 2006 and IBA, 2008).



Gartner Lee Limited (GLL). 2007. Development of a Decision Support Tool for Resource Management in support of a Strategic Environmental Assessment for the Canadian Beaufort Sea. Prepared for Department of Indian Affairs and Northern Development. June 2007.

amec		Assessment of Drilling Waste Disposal Options in the Inuvialuit Settlement Region		
Environmental Studies Research Funds		Conservation and Protected Areas in the ISR		
Drawn: MP	Scale: NTS	Date: August 2008	Project No.: CE03807	Figure: 13

3.3.1.3 *Kendall Island Migratory Bird Sanctuary*

Located northwest of Inuvik and just east of the Yukon border in the Mackenzie Delta, the Kendall Island Bird Sanctuary encompasses 623 km^2 of the delta (MGP, 2004c). These marshy islands are important staging grounds from late August to late September for several species of shorebirds, geese, sandhill cranes, terns, gulls, ducks and tundra swans. Large numbers of shorebirds migrate through the delta (NWT, 2008).

3.3.1.4 *Ivvavik National Park*

Located 950 km north of Whitehorse, Yukon, this natural refuge was established in 1984 as the first national park in Canada to be developed as a result of an Aboriginal land claim agreement. Ivvavik, meaning 'a place for giving birth, a nursery' in Inuvialuktun (the language of the Inuvialuit), consists of over 16,000 km^2 of wilderness that was given as a gift from the Inuvialuit people to the Canadian people. The park protects a portion of the calving grounds of the Porcupine caribou herd, and ensures that the Inuvialuit historic sites and lifestyle are maintained. The park represents the Northern Yukon and Mackenzie Delta natural regions (PARKSCAN 2008 and GCP 2008).

3.3.1.5 *Tuktut Nogait National Park Reserve*

This remote park is located 45 km east of Paulatuk and 120 km north of the Arctic Circle. Tuktut Nogait is designated a National Park of Canada and provides protection for the remote calving grounds of the Bluenose caribou herd. The park also contains one of the highest densities of raptors in North America, as well as wolves, grizzly bears, muskoxen and arctic char. Both the wildlife and the land have supported Aboriginal peoples, including the Copper and Thule cultures and contemporary Inuvialuit camps, for thousands of years. Tuktut Nogait was established by Parliament in 1998, with an approval for expansion passed in 2005 (NWT, 2008; PARKSCAN, 2008; and GCP, 2008).

In addition to the existing protected areas, additional sites are being identified through the NWT Protected Areas Strategy (PAS) process, land use planning and the national parks process. The Wildlife Division of the Department of Environment and Natural Resources (ENR) is working with other partners to implement the PAS, a process to identify and establish new protected areas in the NWT. The PAS is using several 'best practices' that increase ecosystem resilience to climate change, including protecting a range of different ecosystem types, latitudes, elevations, habitat types and enduring features (GNWT, 2008a).

3.3.1.6 *Yukon North Slope*

The part of the ISR located within the Yukon Territory is known as the North Slope. The Yukon North Slope is the area of lands in the Yukon Territory found between Alaska and the NWT and lying north of the division point of the Porcupine River and Beaufort Sea watersheds. This area includes adjacent waters and islands. A special conservation regime applies to the Yukon North Slope under the IFA. The main purpose of the regime is to conserve wildlife, habitat and traditional Aboriginal use (INAC, 1997).

The Canadian people have come to appreciate the Yukon North Slope as an ecological work of art, long celebrated by the Inuvialuit, and an area to be protected and conserved. The Wildlife Management Advisory Council (North Slope) is also committed to this end (WMAC, 2008).

3.3.2 Heritage Sites

Although the ISR is not home to any United Nations Educational, Scientific and Cultural Organization (UNESCO) World Heritage Sites, there are several heritage sites within the ISR that are of historic importance to the Inuvialuit people and should be avoided in any drilling waste management or transportation scheme. These sites include the following.

3.3.2.1 Reindeer Station

Located about 50 km from Inuvik on the East Channel of the Mackenzie River, Reindeer Station was established in 1932. This heritage site was the headquarters of the Reindeer Project, which introduced reindeer farming into northern Canada as a result of the Canadian government's response to a shortage of caribou in the coastal area. At that time, 3,442 reindeer from Alaska were herded to the ISR to provide an additional food source for the Inuvialuit. Reindeer Station was abandoned in 1969, at which time the buildings were relocated and the residents moved to Tuktoyaktuk or Inuvik (IRC, 2008).

3.3.2.2 Kitigaaryuit

Located at the mouth of the East Channel of the Mackenzie River, Kitigaaryuit (or Kittigazuit) is believed to have been the largest permanent Inuvialuit settlement before contact with foreigners. Excavations indicate that people have been present in Kitigaaryuit for at least 500 years. Kitigaaryuit was an important site, both as a base camp for whale hunting and as a place to hold seasonal celebrations. Although people lived year-round in Kitigaaryuit, their numbers increased during the summer whale hunt. It has been estimated that there were 1,000 Inuvialuit living there in 1850. As a result of epidemics, by 1905 the population was reduced to 259, and by 1910 to only 130. In 1978, Kitigaaryuit was declared a National Historic Site (IRC, 2008).

3.3.2.3 Pingo Canadian Landmark

Located in the Tuktoyaktuk Peninsula area, this area protects a unique arctic landform: ice-cored hills called pingos. The Landmark features eight of the 1,350 pingos found in the region, including Ibyuk Pingo, Canada's highest pingo, standing 49 m tall. Approximately one quarter of the world's pingos are concentrated in the Tuktoyaktuk Peninsula area (PARKSCAN, 2008).

3.3.2.4 *Shingle Point*

Shingle Point (also called Tapqaq) is located on a sand spit on the Yukon coast. This area was once the site of a thriving settlement, where the first Anglican mission school for Inuvialuit children was opened in 1929. The school was built in a renovated Hudson's Bay warehouse and log houses were built nearby for student housing and a church. A series of epidemics brought by foreigners took many Inuvialuit lives, resulting in a significant decrease in the population. Survivors moved from the coast to inland communities of Aklavik and Tuktoyaktuk. In 1936, the mission school moved to Aklavik. Shingle Point continues to be used as a summer camp for traditional activities such as fishing, whaling, hunting and berry picking (IRC, 2008).

3.3.2.5 *Herschel Island*

Herschel Island (also called Qikiqtaruk) is located in the Beaufort Sea off the north coast of the Yukon Territory. It is a historically important island and its cove, Pauline Cove, served as a key whaling port between 1890 and 1910. During the height of whaling activity, approximately 2,000 people lived at Pauline Cove in the winter seasons. This cove is the only protective cove located between the Mackenzie River Delta and Point Barrow, Alaska. During the whaling years, the Inuvialuit traded food and clothing with the whalers for goods such as flour, sugar and tea (IRC, 2008).

In 1987, Herschel Island–Qikiqtaruk Territorial Park became the Yukon's first territorial park. The Park is home to a wide range of plant and animal species. There are some remaining structures on the islands, such as small whalers' cabins, warehouses and the former Anglican mission building, which has become home to the largest colony of Black Guillemots in the Western Arctic (IRC, 2008).

3.4 Climate

A continental sub-arctic climate characterizes the Mackenzie Delta with long, cold winters lasting from October to April and cool, short summers. Freezing temperatures can occur year-round. In December and January, 24 hours of darkness descend on the Delta with temperatures dropping to -45°C and colder. During the summer, sunlight hours are long with warm southern breezes, allowing the Mackenzie Valley to remain several degrees warmer than the tundra and mountains lying to the east and west. It is not unusual for Inuvik to be hotter than Edmonton or Vancouver on a July afternoon (GNWT, 2008b). Strong winds occur during the fall and winter, with stronger temperature inversions occurring than along the coast. The Delta is also characterized by complex wind patterns because of the mountainous terrain west of the Delta. Winds are of a northwest to southeast trend due to the channelling effect of the valley, while Inuvik and Tuktoyaktuk have winds predominantly from the east (AMEC, 2005).

Table 9 provides weather data from EC that describe the climate normals for the 1971–2000 period for the communities of Inuvik and Tuktoyaktuk.

Table 9: Climate Normals for ISR Communities

Location	Daily Average Temperature (°C)												Yearly Precipitation (mm)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Inuvik	-27.6	-26.9	-23.2	-12.8	0.2	11.3	14.2	11	3.7	-8.2	-21	-25.7	284.4
Tuktoyaktuk	-27	-26.6	-25.7	-16.8	-4.8	6	11	8.9	2.8	-8.3	-21	-25.4	167.8

Source: Environment Canada. Climate Normals and Averages 1971–2000 [online at http://www.climate.weatheroffice.ec.gc.ca/].

3.4.1 Climate Change

Climate models project that northern latitudes will experience more warming than anywhere else in the world. Because the Arctic plays a special role in global climate, these changes in the Arctic will also affect the rest of the world (ACIA, 2004). The Arctic Climate Impact Assessment (ACIA) is the first comprehensively researched, fully referenced and independently reviewed evaluation of the ongoing climate change in the Arctic and its impacts both for the region and for the world. It has involved an international effort by hundreds of scientists over four years, and also includes the special knowledge of indigenous people. Comprehensive studies such as the ACIA found that the average temperatures in the Arctic over the past several decades have risen at almost twice the rate of the rest of the world (ACIA, 2004; EC, 2008b). The results of these temperature changes are widespread glacial melt, reductions in the extent and thickness of sea ice, global sea level rise, thawing permafrost, coastal erosion, shifting vegetation zones, increased fire and insect outbreaks, and stress placed on populations of polar bear, seal, migratory bird, caribou and reindeer.

In October 1998, the GNWT adopted an official position on climate change. This position was reconfirmed by the Executive Council in November 2004. The GNWT maintains the belief that climate change is a serious concern that could in the future significantly disrupt the global environment, affecting the ability of northerners to lead healthy and production lives. Hence, the GNWT is prepared to develop and support global and local actions to reduce emissions of the greenhouse gases believed to enhance climate change, through co-operation with a broad range of stakeholders, including both provincial and federal governments.

3.5 Permafrost and Active Layer

3.5.1 Permafrost

Permafrost is defined on the basis of temperature, as soil or rock that remains below 0°C throughout the year, and forms when the ground cools sufficiently in winter to produce a frozen layer that persists throughout the following summer. The atmospheric climate is the main factor determining the existence of permafrost. However, the spatial distribution, thickness and temperature of permafrost are highly dependent on the temperature at the ground surface. This temperature, although strongly related to climate, is influenced by several other environmental factors such as vegetation type and density, snow cover, drainage and soil type (NRCAN, 2008a).

Almost half of Canada's landmass is underlain by permafrost, a large portion of which is at temperatures a few degrees below zero (Burgess et al., 2001). All areas of the NWT are underlain by permafrost, and within the Mackenzie Delta area, well away from river channels or lakes, the permafrost is approximately 100 m in depth. However, beneath main channels and lakes, there is no permafrost. As a result, the Mackenzie Delta resides within the discontinuous permafrost zone. Permafrost provides a strong, frozen support for infrastructure such as buildings, roads and airport runways. Throughout the NWT, much infrastructure has been constructed on permafrost, especially at more Northern latitudes where there is no alternative. Ground movement caused by melting permafrost results in significant problems to all forms of infrastructure, including dikes, bridges and culverts (GNWT, 2008a).

3.5.2 Active Layer

In areas underlain by permafrost, the active layer is defined as the top layer of ground subject to annual thawing and freezing. The thickness of the active layer is influenced by variations in many local seasonal factors and site characteristics, comprised of the environmental factors affecting ground surface temperature (Burgess et al., 2001).

The Geological Survey of Canada (GSC) maintains an active network of over 60 sites in the Mackenzie region, at which active layer conditions and ground temperatures are monitored. The GSC's Canadian Permafrost Monitoring Network provides information on the thickness of the active layer based on data gathered from these monitoring sites. Evidence from monitoring sites in the Mackenzie Delta indicates that thaw depths and ground subsidence increased during the 1990s (Smith et al., 2001). Of the 53 sites included in this program, seven are located in the mainland ISR region. These sites and their corresponding active layer thickness, as recorded from 1992 to 2002, are shown in Table 10. The maximum and minimum thickness over this time period is also indicated. An increase in active layer thickness represents an increase in temperature and a resulting decrease in the permafrost layer. At several of these sites, there was minimal variation in active layer thickness over the monitoring period, with the year 1998 representing an exception to this trend, because at this time the warming effects of El Niño resulted in an increase in the thickness of the active layer.

Climate warming would likely result in a thickening of the active layer, an increase in permafrost temperature and a decrease in permafrost thickness (SOCC, 2008).

3.6 Vegetation

The Mackenzie Delta region boasts a wide range of landscapes, ranging from high mountains to flat alluvial plains. Differing from other deltas in the world, the Mackenzie Delta is confined on two sides by high landforms: the Richardson Mountains to the west and the Caribou Hills to the east. These boundaries constrain the expansion of the Delta's width. Since most of the Delta is still within the discontinuous permafrost zone, the unfrozen nutrient-rich soil allows the tree line to reach farther north in the Western Arctic than elsewhere in the NWT.

Table 10: Active Layer Thickness at Monitoring Sites in the ISR

Site Name	Lat	Long	Active Layer Thickness (cm)													
			1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	Min	Max
90TT 2 North Point	69.70	134.40	47	46	54	53	51	50	n/a	56	54	49	47	47	46	56
90TT 12 North Point	69.70	134.40	55	56	59	57	59	53	n/a	56	51	42	n/a	43	42	59
90TT 11 North Point	69.70	134.40	61	58	63	65	64	58	n/a	70	64	55	55	53	53	70
90TT 10 Mason Bay	69.50	134.00	73	73	76	86	84	77	n/a	90	90	76	82	80	73	90
90TT 9 Mason Bay	69.50	134.00	68	67	72	70	70	64	n/a	91	68	60	61	60	60	91
90TT 8 Mason Bay	69.50	134.00	62	68	74	79	77	70	n/a	87	78	66	76	71	62	87
94TT 1 Illisarvik	69.50	134.60	n/a	n/a	n/a	n/a	63	61	n/a	66	63	54	55	53	53	66
91TT A Harry Channel	69.50	134.80	n/a	71	75	78	77	70	n/a	77	67	62	69	68	62	78
91TT F Kendel Island	69.50	135.30	n/a	117	110	117	114	95	n/a	113	98	n/a	n/a	n/a	95	117
90TT 7 Lousy Point	69.20	134.30	74	74	77	78	75	61	n/a	75	76	70	71	71	61	78
90TT 3 YaYa Lake	69.20	134.70	91	98	96	99	101	100	n/a	104	104	95	97	98	91	104
92TT 2 Involuted Hill	69.50	132.60	n/a	n/a	<44	49	50	52	53	60	66	63	61	59	<44	66
92TT 1 Involuted Hill	69.50	132.60	n/a	n/a	48	47	48	47	48	48	n/a	47	46	44	44	48
90TT 6 Lousy Point	69.20	134.30	52	52	58	61	60	46	n/a	64	<55	39	38	38	38	64
90TT 4 YaYa Lake	69.20	134.70	81	85	87	93	91	92	n/a	97	95	83	82	85	81	97
91TT 11 Trail Valley Creek	68.70	133.50	n/a	67	69	68	68	67	n/a	69	71	63	65	64	63	71
91TT 12 Reindeer Station	68.70	134.10	n/a	72	70	73	71	71	71	73	75	72	74	70	70	75
91TT 13 Reindeer Depot	68.70	134.10	n/a	127	129	132	136	134	135	140	137	134	136	123	123	140
90TT 5 Lousy Point	69.20	134.30	81	78	80	86	85	75	n/a	91	84	64	70	64	64	91
91TT C Taglu	69.40	135.00	n/a	111	<119	118	>124	112	118	n/a	>132	n/a	117	110	110	>132

Source: Canadian Permafrost Monitoring Network (CPMN, 2008).

Two types of vegetation dominate the plant communities of the Delta, tundra along the Beaufort Sea and taiga further inland. Successional changes in some plant communities are maintained by fluctuations of river level (particularly that associated with flooding and sedimentation) and by fire. In warmer climates, deltas are usually prime agricultural land; however, in the North the productivity is expressed instead in seasonal abundance of various species of wildlife (BMMDA, 2005).

The Tuktoyaktuk Coastlands are dominated by low arctic tundra vegetation, which include dwarf birch, willow, numerous heaths and sedges. The southern periphery of the Coastlands is dominated by tundra-forest vegetation with clumps of trees scattered within the dense shrub layer of scrub birch, willow and heaths. Anderson Plain is also covered by low arctic tundra vegetation (AMEC, 2005). Dry saxifrage tundra vegetation type is found on the dry, upland areas on the tundra of the Tuktoyaktuk Peninsula, particularly Parson's Lake and the North Storm Hills. The Dwarf Shrub Heath is the most common vegetation type on the Tuktoyaktuk Peninsula. It is widespread throughout flat and rolling terrain, in thin organic soils on crests to mid-slope positions where water does not accumulate (MGP, 2004a).

The southern portion of the Mackenzie Delta is dominated by dense white spruce stands and balsam poplar. Shrubs include willow and alder and are important in plant succession following alluvium deposition. Willow and alder characterize the central portion of the delta with low areas being dominated by marshy vegetation. Poplars have also extended into this region. Due to constant flooding and the cooling effects of the Beaufort Sea, outer areas of the delta are covered by sedges and willows (AMEC, 2005).

3.7 Wildlife

Wildlife is a fundamental element of northern culture and a critical subsistence resource for residents of the ISR. This section discusses wildlife that is present in the ISR, on either a permanent or migratory basis. Approximately 54 species of mammals, 137 species of birds, one amphibian and 55 fish species are known to occur in the Mackenzie Delta region (BMMDA, 2005). Although other wildlife exists in the ISR, in addition to those discussed in this section, the focus is on wildlife that play an important role in the subsistence value to the people of the ISR. To maintain the geographical scope of the work, only wildlife present on mainland areas of the ISR are discussed.

3.7.1 Ungulates

The following ungulates are present within the ISR:

- Bluenose Caribou – Considered one of the major barren-ground caribou herds in the NWT, it is an important source of food for several communities in the ISR. The Cape Bathurst Caribou herd experiences calving on the Cape Bathurst Peninsula, with rutting occurring east of Husky Lakes. The winter range stretches from the Tuktoyaktuk Peninsula to the Husky Lakes area and west to the Mackenzie River. Boreal Caribou also exist in a small part of the ISR;

- Moose – Canada's extensive boreal forest provides the largest moose range in North America. Moose exist in a large area of the ISR, where adequate forage is available;
- Dall's Sheep – Exist in a small area of the ISR, in the Richardson Mountains, approximately 50 km southwest of the community of Aklavik; and
- Muskox – Although most are found on the Arctic islands, on the mainland they are found in substantial numbers in several areas, including part of the ISR north of Great Bear Lake to the Arctic coast.

3.7.2 Furbearers

The following species of furbearing animals are present within the ISR:

- *Grizzly Bear* – There are 4,000 to 5,000 grizzly bears in the NWT, with an estimated resident population of 1,000 bears aged two years or older in the ISR. The tundra and open forest of the ISR are good quality grizzly bear habitat; the availability of good denning habitat and migrating barren-ground caribou are thought to be reasons for the large grizzly bear population in the ISR, compared with smaller populations in other areas of the NWT. Grizzly bear hunting areas were established around Paulatuk and Tuktoyaktuk in 1986 and 1989, respectively, and in Inuvik and Aklavik in 1994;
- *Polar Bear* – Highly valued for the Inuvialuit traditional harvest and for commercial sport harvest, within the ISR, polar bear harvest locations have been reported along the Beaufort Sea coastline from Herschel Island to the tip of the Tuktoyaktuk Peninsula and in the outer Mackenzie Delta near Pullen Island. Distribution varies with the seasons and is governed by the availability of food, suitable denning areas, breeding areas and ice conditions;
- *Arctic Fox* – Are widely distributed throughout the arctic tundra of the NWT. The natural southern limit is the tree line, but some foxes venture into the boreal forest, especially when their food decreases on the tundra;
- *Red Fox* – Is the most widely distributed carnivore in the world and inhabits all areas of the ISR. Higher densities are located below the tree line of the NWT;
- *Marten* – Are distributed across the NWT and occasionally range beyond the tree line to the Arctic coast, in parts of the ISR;
- *Lynx* – Inhabit Canada's boreal forest region from Newfoundland to the Yukon and are found south of the tree line in the NWT. Although lynx have never been prevalent in the Mackenzie Delta region, their range extends into this region during periods of abundance. Large populations of snowshoe hare exist in the NWT; lynx depend heavily on snowshoe hare populations to survive and as a result lynx populations fluctuate with cycles of the snowshoe hare;
- *Beaver* – North America's largest rodent, the beaver is distributed throughout the NWT, including the ISR, along small streams and lakes along the Mackenzie Delta. The NWT beaver population is unknown but is estimated to be 10,000; and

- *Wolf* – Although now extinct in many provinces of Canada, they are still found on most of their traditional range in the NWT. Although relatively abundant, their exact numbers are unknown. Densities are highest in areas of the mainland where barren-ground caribou winter.

3.7.3 Birds

The following species of birds are present within the ISR:

- *Greater-White-Fronted-Geese* – A common breeding bird on the outer Mackenzie Delta;
- *Tundra Swans* – The Mackenzie Delta is the most important breeding area in Canada for Tundra Swans, with about one third of the total population breeding there. Tundra swans arrive in the Mackenzie Delta from May to early June and depart from late September to early October;
- *Greater Scaup* – Part of the breeding range extends from the Mackenzie Delta to the Tuktoyaktuk Peninsula. Although seasonal variances are common, the Greater Scaup tends to arrive in the Mackenzie Delta area in mid to late May and leave the breeding grounds in mid-September to late October;
- *Peregrine Falcons* – Nest throughout the Mackenzie Delta region; the tundra subspecies breeds along and north of the tree line; and the continental subspecies breeds south of the tree line. Both species are migratory and are absent from the Mackenzie Delta area in the winter;
- *Whimbrel* – In the NWT, breeds from the Mackenzie Delta to the Tuktut Nogait National Park area. The North American Whimbrel population is estimated to be 57,000 birds, 2,600 of which nest on the Mackenzie Delta. It is a common breeder on the upland tundra of the Delta. Whimbrels arrive on the Mackenzie Delta in the last third of May, with most leaving the Delta by mid-August;
- *Lesser Yellowlegs* – Breed only in North America; throughout the NWT they breed in forested areas. The population in the NWT is unknown, but most arrive in late May and begin fall migration in late July and early August;
- *Arctic Terns* – Nest in most of the NWT, commonly on lake shores throughout the Mackenzie Delta. They first arrive in late May to early June and depart by August to September;
- *Boreal Chickadees* – Live only in North America and are present in the Mackenzie Delta year-round; and
- *Snow Geese* – Migrate to the NWT, mainly to the Kendall Island Bird Sanctuary in late May or early June for purposes of reproduction, and then leave in mid to late September to return south.

All information provided in this section is from MGP, 2004b and NWTWD, 2008.

3.8 Traditional Land Use

Traditional land use is that type of use that the Inuvialuit people have developed from centuries of experience of living off the land, including activities such as bird, fish and wildlife harvesting, trapping, and plant, herb and berry gathering. Other traditional land uses typically include the use of land for burial sites and sacred or ceremonial uses. Roughly 88% of residents in the Beaufort-Delta region of the NWT consume harvested meat and fish and 26% of residents obtain most or all of their meat and fish from harvesting (NWT Bureau of Statistics, 2002). The subsistence economy is strong within the ISR and represents a key element of traditional land use in the region.

Beluga whale harvesting is important to the subsistence economy in the ISR. The species is hunted primarily by whalers from Inuvik, Tuktoyaktuk, Aklavik and Paulatuk, with the products of the hunt shared among all Inuvialuit communities. In addition to the value of beluga whale as food, the annual harvest is an important Inuvialuit cultural tradition. In some years there is a small but culturally important harvest of bowhead whales by the Inuvialuit in Aklavik. Ringed seals are an important subsistence resource for the Inuvialuit and a traditional resource in the Beaufort Sea region. They continue to be harvested on a subsistence basis for food and for their pelts; young seals are preferred for food (MGP, 2004b).

The Inuvialuit Regional Corporation (IRC) describes the whaling activities of the people as follows:

> *"The long summer days provide ample opportunities for Inuvialuit to prepare for the winter. Communities appear deserted when residents move out to their whaling and fishing camps. Those from Aklavik may be found at the traditional whaling camps at Shingle Point on the Yukon coast, while those from Tuktoyaktuk and Inuvik are generally found at Kendall Island and Whitefish Station. Residents of Paulatuk usually gather at Egg Island in Argo Bay, Johnny Green Bay or Tusugiok. Sachs Harbour and Ulukhaktok (Holman) residents enjoy camps along the coast, such as Kityipvik, Angniyalik and Mangmaktukvik, to name a few." (IRC, 2008)*

Since a large part of the Inuvialuit diet comes from harvesting local fish and wildlife, the changing seasons bring a diversity of food options. Geese and muskoxen are hunted in the spring and fall, whaling and fishing take place in the summer, and caribou hunting in the fall and winter. Also hunted are arctic hare, muskrat, seal, duck, goose, and beluga and bowhead whale. Fish harvesting focuses mainly on whitefish, herring, inconnu, arctic char and trout (IRC, 2008).

Several plants are used by the Inuvialuit for food, medicine and ceremonial and material purposes. Berry picking is an important summer activity, with the blueberry and the cloudberry being important species, as well as akpiks, crowberries, currants and cranberries (MGP, 2004a; IRC, 2008). Table 11 lists areas within the ISR that are used for berry picking; many of these areas are also used for other purposes such as hunting or fishing.

Table 11: Berry Picking Sites in the ISR

Area	Plant Collecting	Other Subsistence Activities
Toker Point (Toker Point south to half way to Tuktoyaktuk)	Berry picking	Subsistence fish harvesting and hunting for geese and other waterfowl
Caribou Hills (upland area west of Parson's Lake and parallel to the east channel of the Mackenzie River)	Berry picking and unique successional plant life (transition between alluvial taiga and low tundra)	Subsistence harvesting
Reindeer Station (historic settlement in Caribou Hills)	Subsistence berry picking	None identified
Husky Lakes (south of Tuktoyaktuk – Sitidgi Lakes northeast to Liverpool Bay)	Subsistence berry picking	Year-round subsistence fishing, hunting and trapping

Source: Mackenzie Gas Project: Environmental Impact Statement for the Mackenzie Gas Project – Volume 3: Biophysical Baseline Part D, Terrestrial Resources: Soils, Landforms, Permafrost and Vegetation (MGP, 2004a).

3.9 Non-Traditional Land and Resource Use

Non-traditional land and resources users include the following:

- non-Aboriginal residents;
- non-resident hunters and anglers;
- tourists;
- Aboriginal, municipal and territorial governments; and
- resource-based industry.

The area of most significant activity is oil and gas development, with mineral rights extending across vast areas of the NWT. The Mackenzie Delta is currently the area with the most active development. Imperial Oil Resources Ventures Limited, Shell Canada Limited, ConocoPhilips Canada Limited, ExxonMobil Canada Properties and MGM Energy Corp. all hold interests within the Delta area. There is also a strong potential for future oil and gas expansion in the ISR, and many development wells and future projects are currently being planned; the Mackenzie Gas Project is one of the most significant.

Within the ISR, there are two types of land ownership: Federal Crown Lands (also called Territorial Lands), which are lands administered by INAC, and Inuvialuit Private Lands, which are administered by the Inuvialuit Land Administration (ILA).

Granular resources represent another form of non-traditional land use in the ISR. The most common type of granular material found in the ISR is sand and gravel of fair quality, generally used for fill. The Inuvialuit own granular resources found on Inuvialuit lands with subsurface rights. On all other Inuvialuit lands (i.e., surface rights only, and Crown lands), the granular resources are owned by INAC.

Because most of the ISR lies north of the tree line within the tundra region, there are no timber resources sufficient for commercial operation within the area. However, some scrub and transitional forest exists in the southern parts of the ISR, and timber is harvested in this area, specifically near Inuvik, for firewood.

There are known deposits of iron, coal, copper, lead and zinc within the Mackenzie estuary region; however, these have yet to be developed and currently there are no identified plans for developing these deposits. There has been extensive diamond exploration in the ISR.

Non-traditional resource harvesting includes hunting, fishing and trapping by non-Inuvialuit residents for domestic, sport or commercial purposes. Other commercial activities include reindeer herding, commercial transportation and agriculture. Marine operations are also significant, with the Beaufort Sea being used by a variety of vessels for several different purposes and for shipping routes.

Tourism and recreation activities in the ISR includes ecotourism, guided outfitting, river tours, cultural tours and recreational activities, such as hiking, cross-country skiing, snowmobiling and all-terrain vehicle use.
All of the information provided in this section was obtained from MGP, 2004c.

3.10 Settlements

The ISR is home to approximately 6,000 people living in six communities. These communities are the following:

- Aklavik (Aklarvik);
- Inuvik (Inuuvik);
- Paulatuk (Paulatuuq);
- Sachs Harbour (Ikaahuk);
- Tuktoyaktuk (Tuktuuyaqtuuk); and
- Holman (Ulukhaktok or Uluksaqtuuq).

The communities are comprised of predominantly Inuvialuit populations, except for Aklavik and Inuvik, which are also home to many people of Gwich'in ancestry. Inuvik is also home to a large non-Aboriginal population. The communities of Sachs Harbour and Holman are located on Banks Island and Victoria Island, respectively. The community of Paulatuk is in the easternmost area of the ISR. The communities of Paulatuk, Sachs Harbour and Holman, although located within the ISR, are not included in the geographic scope of this study owing to their distance from predominant areas of oil and gas activity. The study area communities for the purposes of this study are listed in Table 12.

Table 12: Population of Communities Located in the Study Area

Community	Population (2006)
Aklavik	594
Inuvik	3,484
Tuktoyaktuk	870
Total – Study Area Communities	4,948

Source: Statistics Canada 2006 Community Profiles at http://www12.statcan.ca/.

3.10.1 Population Characteristics

Of the total population in the ISR, roughly half (49%) identified themselves as Inuit (Inuvialuit) during the 2006 Census. Of the remaining population, 30% were non-Aboriginal, with the next largest group self-identifying as North American Indian (17%).

The largest percentage of non-Aboriginal persons in the study area resides in Inuvik. The Aboriginal population is roughly 84% in Tuktoyaktuk and 92% in Aklavik.

Educational attainment in study area communities is lower than the NWT average. The greatest differences are in the population that has achieved less than high school and those with a university certificate, diploma or degree. Nearly half of the population in the study area communities has less than a high school education. The percentages of people within the ISR study communities who have an apprenticeship or trades certificate/diploma and those with a college certificate/diploma closely reflect the NWT averages, which are about 9% and 19% respectively.

Through the Beaufort-Delta Education Council, kindergarten to grade 12 education is available in all of the study area communities (BDEC, 2008).

The profile of the experienced labour force in the four ISR communities included in this study is described in Table 13 and is occupationally similar to that of the NWT as a whole. There are some local variations in that some occupational categories are over- or under-represented in particular communities. For instance, the percentage of people working in health occupations was 0% in Tuktoyaktuk in 2006. However, sales and service occupations were over-represented in Tuktoyaktuk. The occupational groupings of natural and applied sciences and trades, transport and equipment operators are well-represented in the study area communities.

Table 13: Labour Force by Standard Occupational Category in the Study Area Communities, 2006

Occupation	NWT (%)	Study Area Total (%)	Aklavik (%)	Inuvik (%)	Tuktoyaktuk (%)
Total experienced labour force 15 years +	23,445	2,595	230	2,020	345
Management	12	12	9	13	9
Business, finance and administration	18	17	11	19	10
Natural and applied sciences and related occupations	7	6	4	5	7
Health	4	5	9	5	0
Social science, education, government service and religion	11	13	17	12	14
Art, culture, recreation and sport	3	3	0	3	3
Sales and service	23	24	24	23	29
Trades, transport and equipment operators and related occupations	18	19	24	18	25
Occupations unique to primary industry	3	1	0	1	3
Occupations unique to processing, manufacturing and utilities	1	0	0	1	0

Source: Statistics Canada, Community Profiles, 2006 Census

The labour force activity characteristics of Inuvik are similar to the overall territorial labour force characteristics. The 2006 unemployment rate in the study area varied from a low of 11% in Inuvik to a high of nearly 33% in Tuktoyaktuk.

During the 1970s and 1980s, the ISR experienced a boom-bust cycle of economic activity; however, in the recent past, it has developed local business capabilities to address the high level of oil- and gas-related activities in the region. The mandate of the Inuvialuit Development Corporation (IDC), the business arm of the IRC, is to foster business development in the region, and the IDC concentrates its investments in the energy and transportation sectors of the economy (IRC, 2008). The IRC's comprehensive business directory shows a wide range of goods and services available in the region through Inuvialuit-owned businesses (IRC, 2008). An examination of the business directory shows that the study area region is able to offer a number of services in the areas of transportation, construction and provision of related goods and services.

Although the wage economy is of particular importance, the traditional or subsistence economy is also an important element of economic vitality in the region. Traditional harvesting contributes to the economy and to the well-being of the communities through sharing and mutual assistance that occurs largely organized through kinship systems (Usher, 2003). Roughly 88%

of residents in the Beaufort-Delta region of the NWT consume harvested meat and fish and 26% of residents obtain most or all of their meat and fish from harvesting (NWT Bureau of Statistics, 2002).

3.11 Transportation Networks

The NWT has a unique transportation system composed of paved highways, gravel highways, ferries and winter/ice roads. The winter roads, ice roads and ice crossings cover a total distance of 1,400 km within the NWT (NWTDOT, 2008). Table 14 provides an overview of the transportation infrastructure serving the three ISR communities included in this study.

Table 14: Transportation Infrastructure in the ISR

	All-Season Road	Winter/Ice Road	Air	Sea/Barge
Aklavik		X	X	X
Inuvik	X	X	X	X
Tuktoyaktuk		X	X	X

Source: MGP EIS, Volume 4 (2004d)

The ISR is largely isolated from the rest of Canada, lying far from Canada's population centres. Its remoteness and geographic landscape contributes to the limited ground transportation options within the area. The Dempster Highway (Yukon Highway 5 or Northwest Territories Highway 8) connects Inuvik with Dawson City in the Yukon Territory and is the only highway that connects the area with southern Canada. Although this is the only all-weather road within the ISR, its use is seasonally restricted by the fall freeze-up and spring thaw of the Mackenzie River. During the winter months, the highway extends another 194 km to Tuktoyaktuk and 112 km to Aklavik, using frozen portions of the Mackenzie River delta as an ice road (GNWT IT, 2008).

Inuvik is the most easily accessed community within the ISR, as it has an airport with an asphalt runway, frequent scheduled flights, re-supply by barge in the summer and access to the south on the Dempster Highway.

The most important form of transportation is air transportation, which links all of the communities in the ISR, which all have a sand or gravel runway and scheduled air services. During the period from about June 15 to the first week in September, river barges on the Mackenzie River provide re-supply services to each of the ISR communities. This annual marine re-supply is provided by the Northern Transportation Company Limited (NTCL) from its staging site at Tuktoyaktuk, using three tugs and 12 barges (MGP, 2004d). NTCL is 100% owned by the Inuvialuit of the ISR and the Inuit peoples of Nunavut (NTCL, 2008).

Winter/ice roads are used by communities and mining operations not connected by all-weather roads. These roads, constructed using lake and river ice and compacted snow cover on land, connect remote regions of the NWT. Winter/ice roads are a critical factor in the movement of bulk goods and facilitate seasonal travel. The warming climate in the North has caused delayed freeze-ups in the fall and early thaws in the spring, resulting in a shorter winter/ice road season, despite improved technology and more time and effort being applied to construct and maintain roads (GNWT, 2008a). Information provided by the NWT Department of Transportation indicates that, on average, over the past ten years, most winter/ice roads in the ISR have opened in mid to late December and closed in late April or early May (NWTDOT, 2008).

There is no rail access in any of the Inuvialuit communities.

3.12 Specific Environmental and Socio-economic Considerations for Each Disposal Option

Environmental and socio-economic considerations that are of significant concern or relevance to each disposal option are shown in Table 15. Additional details on the nature of the concern are discussed in the following sections.

Table 15: Specific Environmental and Socio-economic Considerations for Each Disposal Option

	Waste Disposal Sump	On-site Waste Injection	Regional Disposal Facility	Disposal Outside the NWT
Physiographic Regions	X	X	X	
Geology	X	X	X	
Parks, Sanctuaries and Historic Sites	X	X	X	
Climate	X			X
Permafrost and Active Layer	X			
Vegetation	X	X	X	
Wildlife	X	X	X	X
Traditional Land Use	X	X	X	X
Non-Traditional Land and Resource Use	X	X	X	X
Regional Procurement	X	X	X	X
Regional Employment and Income	X	X	X	X
Regional Capacity Development	X	X	X	X
Transportation Networks and Infrastructure Demand			X	X
Public Health and Safety				X

3.12.1 Waste Disposal Sumps

Both physiographic region and geology have a significant impact on sump performance, because the topography, thermal conditions and underlying soil of an area are all important factors in the success of a sump. Locations away from a drainage area, lowland or hillside, with impermeable soil represent ideal locations for sump placement.

Climate, climate change and permafrost/active layer characteristics also have a profound effect on the performance of a waste disposal sump. Because the success of a sump depends completely on the containment of drilling waste through freezing of material below the active layer, if the thermal distribution through the permafrost and the active layer experiences significant change as a result of climate change, this will affect the sump stability. The spatial distribution, thickness and temperature of permafrost are partially related to the type and density of vegetation; hence, vegetation is an additional environmental factor to consider when reclaiming a waste disposal sump.

Because the ISR is a location of both prime wildlife habitat and significant migratory activity for many wildlife species, when building a waste disposal sump, care must be taken to ensure that wildlife pathways and natural habitats are not negatively impacted in the process. Although it is likely that a properly designed sump will not have a significant impact on wildlife populations, activities occurring during sump construction may have a negative impact. Furthermore, since parks, sanctuaries and historic sites are generally protected areas, care must be taken to ensure that a sump is not placed at a location that would jeopardize these areas.

Sump placement must also take into account the social aspects of an area, such as traditional and non-traditional land uses and the location of settlements and communities. Because of the negative reputation that sumps have acquired in the ISR following a long history of failure, public participation may be required if sump placement is to be near one of the aforementioned areas.

3.12.2 On-Site Waste Injection

The environmental factors most significant to the success of on-site waste injection are the physiographic region and the geology of the injection location. For successful waste injection to occur, the geologic formation must have specific porosity, permeability and containment barriers. Although these types of formations exist in the ISR, it is critical that the target area be studied for its suitability in relation to these characteristics before injection occurs. Furthermore, permafrost is a factor to be considered when planning equipment requirements and drilling procedures. Since the type and density of vegetation has an effect on the thickness and distribution of permafrost, vegetation is an additional point for consideration.

Planning for injection activities must take into account existing wildlife habitat and migratory paths so as to minimize disturbance of these populations.

3.12.3 Regional Disposal Facility

The regional disposal facility may be one of two types under consideration: a regional injection facility or a regional landfill. Environmental considerations for the regional injection facility are similar to those for an on-site injection facility, but with the added consideration of transportation networks.
Depending on the location of the regional facility, access requirements may be a factor. If ice roads and/or barges are necessary, climate and climate change are significant factors because they have an impact on the length of utilization time and integrity of these transportation methods, as discussed in the following section.

3.12.4 Disposal Outside the Northwest Territories

The main factor affecting the success of disposal outside the NWT is the existence and integrity of the transportation networks used to move waste to the external location. If ice roads are a component of plans to move waste, climate and climate change are potential factors. If climate change results in an increase in average seasonal temperatures, the result would be a reduced time frame during which ice roads can be safely constructed and material moved from northern locations. Furthermore, since a recommended minimum 20 cm of snow must accumulate before winter road construction proceeds, and because warmer temperatures impact snowfall, climate change may also result in a condensed timeline for construction, placing additional challenges on the process. If ferries and barges are to be used as a method of transport, careful planning must be done to properly time the movement of waste with seasonal limitations for this transportation method. Truck transportation out of the ISR is possible along Highway 8 from Inuvik to the Dempster Highway, but must take into account the brief seasonal closure in the spring and fall during breakup and freeze-up.

Wildlife habitats and pathways are an additional area of concern, since care must be taken to ensure that transportation networks do not negatively coincide with these areas, especially during migratory seasons.

3.13 Specific Socio-Economic Considerations

The specific socio-economic considerations outlined in this section are based on the view that communities experience socio-economic effects in accordance with two primary interactions: physical, social or economic interaction related to the component activities of the five waste disposal options; and community residents and their economic, social or cultural resources and pursuits; and the community supply of workers or business services for each of the five waste disposal options, generating income for firms and individuals. The spending or investment of this income could have both positive and negative effects (MGP, 2005).

3.13.1 Traditional Land Use and Culture

To understand traditional land use in an area like the ISR is to understand how the Inuvialuit used the land before contact with Canadians of European descent and how they continue to use the land at present. The relationship to the land and the culture and cultural practices are important elements in understanding the effects of activities on traditional land use (Kavik-Axys and FMA, 2008).

Traditional culture is as an integral part of life for Aboriginals in the NWT and the ISR, as well as the following:

- a source of pride, self-worth, distinctiveness and identity;
- the basis for harvesting the benefits and meeting the challenges of survival on the land they respect and love; and
- a primary defence against the prejudice and discrimination sometimes experienced from Canadians of European descent (MGP, 2004c).

Traditional harvesting, an important traditional land use, has a significant influence on wellness in Aboriginal communities (MGP, 2005). Harvesting is a means of sharing traditional knowledge, gathering food and contributing to the economy (Usher, Duhaime & Searles, 2003). It is particularly important that decisions related to the disposal of drilling waste in the ISR be made with consideration given to traditional land use and cultural values.

3.13.2 Esthetics

Esthetics in an environmental context typically refers to the visual landscape. However, there is some overlap and interaction with respect to esthetics, land use and culture. Changes in the esthetic environment have the potential to alter the look of the landscape and the perceptions of the people who use the land. Depending on the infrastructure requirements for each of the identified drilling waste disposal options, the presence of new infrastructure has the potential to alter existing esthetics.

3.13.3 Regional Procurement

Regional procurement is an important consideration in terms of the waste disposal options being envisaged. The IDC focuses on regional business development, particularly in the areas of energy and transportation. These two sectors of the local economy could potentially benefit to a greater or lesser degree, depending on the waste disposal option implemented. Local businesses likely have the capacity to handle procurement opportunities either with current capacity or through joint venture arrangements.

Capacity development in the context of regional procurement opportunities can also act as a sustainability tool, enabling communities and regions to diversify their economic bases and increase their ability to withstand economic changes. There is an expectation in the ISR that, not unlike expectations in other areas, northerners will be able to participate in economic opportunities that occur locally, thus ensuring that a portion of revenues and other benefits stay in the North.

3.13.4 Regional Employment and Income

The study region's economy is largely dependent on public administration, natural gas, transportation, tourism and furs (GNWT ITI, 2008). Given the relatively low workforce participation rates in the communities of Aklavik and Tuktoyaktuk, and high unemployment, the potential for new employment opportunities created through the various drilling waste disposal options could result in meaningful contributions to the regional population's skill levels, future employability, income and quality of life.

In remote areas such as the study area within the ISR, capacity development is often a concern as communities seek to build human resource capacity in order to more effectively respond to change and be positioned to seize economic development opportunities. Regional capacity development can be achieved through timely sharing of training and employment opportunities. Particularly when economic opportunities will be based on technology or practices that are new to the region, appropriate opportunities must be provided to help local businesses and people acquire the skills and/or resources required for meaningful involvement.

3.14 Summary of Environmental and Socio-Economic Considerations

There are four key social and economic considerations that are factors in the assessment of drilling waste disposal options in the ISR. These considerations include:

- traditional land use and culture;
- aesthetics;
- procurement; and
- employment.

Each of these four considerations is important in its own right; however, traditional land use and culture are considered of prime importance for this assessment. Traditional land use and culture serve as a basis on which potential benefits, such as employment and procurement, can be realized. Esthetics, although closely related to traditional land use and culture, are a significant consideration. However, changes in the esthetic properties of a site are often considered more palatable.

4.0 REGULATORY REVIEW

Projects and work planned in the ISR are subject to a variety of federal and territorial acts, laws, regulations and guidelines. The specific requirements for projects or work in the ISR depend on whether or not it is taking place on Inuvialuit-owned lands or Crown land. The Inuvialuit rights and degree of influence in the decision-making process regarding whether a project is approved by the regulators varies, depending on the location of the proposed project. Regardless of the location, however, the Inuvialuit have a guaranteed role in the screening and review process for proposed projects that may have a negative impact on the environment, even if it is only to voice their concerns during public consultations.

The Inuvialuit-owned and Crown lands are further divided as follows:

- Inuvialuit Private Land:
  - 7(1)(a) lands (surface and sub-surface owned by Inuvialuit); and
  - 7(1)(b) lands (surface owned by Inuvialuit, sub-surface owned by federal government).
- Crown Land:
  - onshore;
  - offshore;
  - Commissioner's Land (owned by federal government, but territorial government acts as owner of the surface in the sense they can sell, lease or transfer the land; the federal government maintains control of the sub-surface rights); and
  - Yukon (North Slope).

For lands in the ISR, the IFA establishes a formal Environmental Impact Screening and Review Process (EISRP) to examine proposed projects and developments that are subject to screening.

The EISC and the Environmental Impact Review Board (EIRB) are responsible for conducting the IFA EISRP, while other Inuvialuit government boards and committees are responsible for helping to protect wildlife, habitats and the environment on a project-specific basis. These boards and committees include:

- Wildlife Management Advisory Council (Northwest Territories) (WMAC (NWT));
- Wildlife Management Advisory Council (North Slope) (WMAC (North Slope)); and
- Fisheries Joint Management Committee (FJMC).

The six Community Corporations also have input and can comment on approved development activities on 7(1)(a) or 7(1)(b) lands near the associated community. There are also six Community Hunters and Trappers Committees that can influence the approval process by setting by-laws and quotas, and submitting comments on proposed development activities through the EISC.

The regulations and requirements for the North Slope are currently in transition and some of the legislation is only in draft form. The current regime is in the process of transferring federal responsibilities to the Yukon government. Presently the key regulatory documents include the Canada and Yukon Oil and Gas Accord, the Umbrella Final Agreement Between the Government of Canada, the Council for Yukon Indians and the Government of the Yukon between Yukon First Nations and the federal and territorial governments, and the Yukon Oil and Gas Act. Similarly to other parts of the ISR, there are provisions for consultations, access agreements, and oil and gas licensing.

Other lands in the ISR that have distinct requirements include protected areas such as national and territorial parks, migratory bird sanctuaries and archaeological sites. Site-specific requirements for certain species and associated critical habitat may also apply.

There are a number of approvals, licences, permits and agreements required for various land uses in the ISR. The intent of these authorizations is to ensure there is:

- no significant damage to the lands;
- no abuse or extension of the right;
- no mischief committed on the lands; and
- no significant interference with Inuvialuit use and enjoyment of the lands (CAPP, 2001).

Most authorizations are granted for projects or scopes of work involving oil and gas exploration, construction and/or operations. Disposal of drilling waste is most often only one aspect of these larger projects. The various authorizations required for a project in the ISR can range from one to a combination of the following:

- land participation or access agreement;
- co-operative agreement;
- concession agreement;
- land use permits;
- reconnaissance permits;
- commercial lease; and
- rights-of-way (permanent and/or temporary).

These authorizations also allow for compensation if the proponent damages the lands or interferes with the traditional use of the land. The IRC receives lands and financial compensation from proponents should this occur. The ILA, which is a division of the IRC, administers and manages the lands received.

According to the IFA with the Government of Canada, the Inuvialuit also have the right to participate in economic activity in the ISR and receive compensation for any damage to wildlife, habitat or the environment. A Participation/Action Agreement must be concluded prior to exercising a right of access for exploration, development or production activities. Additionally, water licences from the appropriate territorial water board will likely be required and, depending on the scope of the project, authorizations under the Fisheries Act and the Navigable Waters Protection Act, and other authorizations may be required. Again, such agreements typically apply to entire projects and not just to components, such as the disposal of drilling waste. Nonetheless, the method of disposal of drilling waste will be considered whether it is part of a project or on its own.

For Crown lands, the main legislation includes the Canadian Environmental Assessment Act (CEAA), the Canada Oil and Gas Operations Act (COGOA) and the Yukon Oil and Gas Act (YOGA). CEAA is applicable to all lands and is conducted by the responsible authority under CEAA. COGOA is administered by the NEB and governs all lands in the NWT part of the ISR, while YOGA is administered by the Yukon Government and applies to oil and gas projects in the Yukon. Commissioner's lands are subject to screening by Municipal and Community Affairs (MACA).

In general, the proponent should begin consultations with community groups and the ILA immediately, whether the project is occurring on Inuvialuit-owned or Crown lands. The proponent should also consult with regulatory bodies early on to ensure that they meet their expectations. Regardless of the scope of the project, land access and use permits and agreements will be required under the IFA. If the project gives rise to screening, the proponent should first notify the EISC. Applications to the NWT Water Board for water licences and to the NEB for the appropriate authorization and/or approval should be submitted, and authorizations from Fisheries and Oceans Canada (DFO) and others should be obtained as required. If the project is to take place on Crown lands, Indian and Northern Affairs will also be involved in project approval. From there, the EISC, and EIRB, if necessary, and CEAA processes will ensue.

4.1 Federal Regulations

There are countless acts, regulations, standards and guidelines with respect to oil and gas activity in the ISR. However, this section does not attempt to address all of them, only the ones that are relevant to the disposal of drilling mud and drilling fluids specifically.

Table 16 provides a list of federally mandated regulations that will need to be adhered to when disposing of drilling waste. The table identifies with an "x" which regulations govern each disposal option.

The NWT Waters Act requires that the disposal of drilling waste be licensed. Licensing is done by the NWT Water Board. The type of licence issued (either a Type A or Type B) depends on the size of the project (GNWT, 2003a).

4.2 Territorial/Regional Regulations

Table 17 identifies with an "x" a number of territorial acts and regulations that directly or indirectly apply to the disposal of drilling waste. Again, this is not a complete list, but it highlights those acts and regulations that are more relevant to drilling waste.

Table 16: Applicability of Federal Acts and Regulations to Disposal Options

Governing Body	Title of Document	Relevance	Sumps	Injection	Regional	Truck Out
Canadian Environmental Assessment Agency	Canadian Environmental Assessment Act	Sets out requirements for environmental assessment and review of projects proposed on federal lands	X	X	X	X
Indian and Northern Affairs Canada	Northwest Territories Waters Act	Provides requirements for withdrawing or depositing, out of or into, water bodies and watercourses	X	X	X	
	Northwest Territories Waters Regulations	Includes fees for permits based on quantities and reporting provisions	X	X	X	
	Territorial Lands Act	Describes how land can be sold or leased	X	X	X	
	Territorial Land Use Regulations	Describes the land use application and inspection processes	X	X	X	
Transport Canada	TDGA	Describes requirements for dangerous goods that are being handled, offered for transport, transported or imported			X	X
	TDGR	Applies to dangerous goods in transport between provinces or internationally			X	X
National Energy Board	Canada Oil and Gas Drilling Regulations	Discusses requirements for waste material including drilling fluid and drilling cuttings		X	X	
	Canadian Oil and Gas Operations Act	Provides requirements for safety, environmental protection and resource conservation		X	X	

Table 17: Applicability of Territorial Acts and Regulations to Disposal Options

Governing Body	Title of Document	Relevance	Sumps	Injection	Regional	Truck Out
Government of the Northwest Territories	Transportation of Dangerous Goods Act	Applies to the transportation of dangerous goods on highways			X	X
	Transportation of Dangerous Goods Regulations	Basically adopts the federal requirements			X	X
	Environmental Protection Act	Requirements for the preservation, protection or enhancement of the environment	X	X	X	X
	Spill Contingency Planning and Reporting Regulations	Spill preparedness, cleanup and reporting requirements	X	X	X	X
	Waste Reduction and Recovery Act	Requirements related to waste	X	X	X	X
	Water Resources Agreements Act	Controls and regulates the use of water	X	X	X	
	Explosives Regulations	Provides for the care and use of explosives	X			
	General Safety Regulations	Safety requirements for different tasks	X	X	X	X
	Large Vehicle Control Regulations	Truck requirements including dimensions, weight, signage, etc			X	X
	General Sanitation Regulations	Requirements to ensure the safety of public health	X	X	X	X
Government of Yukon	Water Regulation	Requirements for industrial undertakings needing water	X	X	X	
Government of Yukon	Oil & Gas Act	Section 164 refers to handling of oilfield waste, including drilling waste	X	X	X	X

In addition to regulations, the territorial government also provides some guidelines for waste management. The following guidelines should be reviewed, as applicable, for all proposed projects in the ISR:

- Environmental Impact Screening Committee Operating Guidelines and Procedures – Environmental Impact Screening Committee;
- Guideline for Industrial Waste Discharges in the NWT – Department of Environment and Natural Resources of the Government of Northwest Territories;
- Guideline for the Planning, Design, Operations and Maintenance of Modified Solid Waste Sites in the NWT – Municipal and Community Affairs of the Government of Northwest Territories;
- Oil and Gas Approvals in the Northwest Territories: Inuvialuit Settlement Region – Canadian Association of Petroleum Producers; and
- Water Licensing in the Inuvialuit Settlement Region Northwest Territories: Summary of Procedures and Information Requirement – Northwest Territories Water Board.

4.3 Regulatory Requirements for Each Disposal Option

This subsection briefly describes the permitting, monitoring and any other regulatory requirements for the selected disposal option.

4.3.1 Sumps

Sumps have been used for drilling waste for almost 50 years and have a long history of failure in the ISR. Because of their negative reputation, the use of sumps is generally looked upon as a last resort. Additionally, regulations and best practices have been developed in an attempt to address the causes of failure and reduce the risk associated with sump use.

The key piece of federal legislation that governs the use of sumps is INAC's Territorial Lands Act and Territorial Land Use Regulations. Almost all of the territorial regulations in Table 16 apply, except for those dealing with transportation. However, even transportation regulations such as the Transportation of Dangerous Goods Regulations (TDGR) will apply if the drilling waste is transported to the sump by vehicle.

4.3.2 Down-hole Injection

Down-hole injection of drilling waste and hazardous waste as a means of disposal is taking place in areas such as Alberta, British Columbia and Alaska, but has not yet been used in the ISR. However, regulations, as listed in Tables 16 and 17, do govern the use of down-hole injection for disposal of drilling waste in the ISR.

Federally, both INAC and NEB have regulations that apply to down-hole injection. The Northwest Territories Water Board (NWTWB) and the National Energy Board (NEB) each have jurisdiction over drilling waste management in the ISR. In 2008, the NWTWB and the NEB signed a memorandum of understanding that minimizes duplication of effort in applications seeking authority to dispose of waste by means of down-hole injection. The purpose of the Memorandum of Understanding is to ensure that water licence applications to the NWTWB for issuance of water licences that include a request for disposal of waste by down-hole injection are reviewed by both parties with a minimum of duplication (NEB, NWTWB, 2008c).

4.3.3 Regional Treatment/Disposal

The regional site may be a central down-hole disposal facility, but could also be a central landfill. Both options would be considered new to the ISR and would have to meet federal and territorial requirements. Whether a central down-hole disposal facility or a central landfill is chosen, the regulatory and permitting requirements will be relatively similar.

For either regional option, siting is important. Suitable site characteristics are required for both landfills and injection wells. Also, as previously mentioned and as a best practice, MACA's guidelines for modified solid waste sites should be used.

4.3.4 Trucking out of Northwest Territories to an Approved Site

Trucking the waste out of the NWT to an approved site would require the approval of the receiving facility. On-site treatment of the drilling waste to remove water would also have to be considered for this option. Off-site treatment and/or disposal would require transportation and any associated regulations for the destination. The drilling waste would need to be sampled and classified and treated according to the receiving facility's regulations.

Typically, drilling waste is classified as non-hazardous. However, should the waste be tested and meet the definition of hazardous waste, additional regulations such as the Export and Import of Hazardous Waste and Hazardous Recyclable Material Regulations and the Interprovincial Movement of Hazardous Waste Regulations will apply for transportation within Canada. If the drilling waste is transported to Alaska, the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal would govern.

4.4 Summary of Regulatory Requirements

For most of the drilling waste disposal options, the regulatory requirements and most of the licensing, permitting and approvals will apply to the main project (i.e., well drilling) as opposed to being specific to the drilling waste disposal method. The one exception to this is the regional treatment/disposal facility since it is more than simply a component of a project and can be considered a project in and of itself. This does not necessarily mean that the regional facility will need to comply with stricter environmental and operating requirements; just that there will be more permitting and approval requirements. However, there are limitations on each disposal option discussed.

Given increased public scrutiny and climate change concerns, it may be difficult to obtain regulatory buy-in for sumps. Geological investigations and appropriate disposal settings are necessary for deep-well injection and landfill disposal. If trucking of the waste outside the NWT is considered, it will be necessary to obtain approval from the receiving destinations and comply with local handling, storage and transportation regulations.

The key legislation, regardless of the disposal option, is the IFA, NWT Water Act, CEAA and COGOA. Co-ordination between the various government bodies has helped to reduce redundancy and streamline the regulatory approval process. For every disposal option, it is best to be timely and forthright with all of the project and engineering details, including the method of drilling waste disposal.

Lastly, the key piece of regulatory advice, as with all aspects of an oil and gas project, is that it is vital to make the intended disposal option(s) known to the Community Corporation(s) and the Hunters and Trappers Committee(s) (either Inuvik, Aklavik or Tuktoyaktuk), and to residents most likely to be affected so that their concerns can be addressed in the planning phase. This will expedite the approval process. Because many government and Inuvialuit organizations must be consulted during the authorization process, it is vitally important to start early and not rush the regulatory and associated consultation processes.

5.0 DISPOSAL OPTION CONCEPTUAL COST ESTIMATES

The methods and assumptions used to develop conceptual cost estimates for the five disposal options are described in the following sections. These estimates are classified as Class V estimates, having a low level of project definition (AACE, 1997). They are defined as being feasibility or screening level estimates designed to show a realistic relationship between the disposal options and having a low (i.e., order of magnitude) level of accuracy (+/- 100%).

5.1 Work Breakdown Structure

The cost estimates use a Work Breakdown Structure (WBS) to describe how the work is organized and to define the activities and tasks required to complete the work. The WBS is built up through a number of line items that serve as the basis for the estimate. Each line item combines an estimate of quantity for the activity and task with an appropriate unit price to produce the line item cost estimate. The WBS includes a breakdown of the disposal option, activity and associated tasks.

5.1.1 Activity and Task

The WBS incorporated the activities applied to each disposal option along with the associated tasks for each option. The activities for each disposal option were identified as follows:

- engineering/permitting;
- equipment;
- construction;
- lifetime operation; and
- closure.

5.2 Quantity Estimates

The quantity estimate was developed from available characterization data, from data obtained from public sources in the literature review and from the application of generic quantity factors based on the availability of data. The data sources and the methods used to develop potential drilling waste quantities are described in the following sections.

5.2.1 Drilling Waste Volumes

The volume of potential drilling waste generated over a period of 25 years was determined by assuming completion of proposed projects as well as additional volume based on a hypothetical number of future wells. Proposed projects include the Mackenzie Gas Project (i.e., Taglu, Niglintgak and Parsons Lake) and a 2008-to-2011 exploration program planned by MGM Energy Corp.

For the purpose of determining generic drilling waste volumes, the depth of wells was estimated to be 2,500 m per well, based on the range of well depths for previous wells. The Drilling Waste Management Recommended Best Practices suggests volumes of 0.25 m^3 to 0.5 m^3 of drilling waste per metre of well depth. The quantity assumption for the cost estimate assumes the higher end value of 0.5 m^3.

The estimated volume per metre was multiplied by the estimated potential well depth and again by a number of wells to achieve the total potential volume of drilling waste. Using generic well depths as an example, the calculation was completed as follows:

$$\text{Total Potential Drilling Waste } (m^3) = 2{,}500 \text{ m (depth)} * 0.5 \text{ } m^3 \text{ (potential volume)} * 250 \text{ wells} = 312{,}500 \text{ } m^3$$

5.2.2 Composition and Density

Both the solid and liquid components of drilling waste were considered in the cost estimates. This was necessary because of the differing costs and disposal methods required for solids and liquids in at least one of the disposal options. While the ratio between solids and liquids is highly variable, drilling waste was broken down into a representative value of 66% solids and 34% liquids (Shell, 2005).

Because some unit prices are represented on a tonnage basis, it was necessary to determine a soil density conversion value to use for drilling waste. The density of drilling fluid is highly variable and dependent on the original composition as well as additives used to alter the fluid to suit conditions. Based on a number of data sources and on analytical results, an estimated value of 1.5t/ m^3 was used to convert the waste volumes to tonnes.

5.3 Disposal Outside the Northwest Territories

This option takes into consideration the disposal of both solid and liquid drilling wastes outside the NWT. Solids would be transported to the CCS Northern Rockies landfill in BC. Liquid wastes are not eligible for disposal at this location and therefore must be transported farther south to Silverberry for injection. Unit prices are provided in Table 18 and are used as a basis for the cost estimate.

5.4 Waste Disposal Sump

Unit prices for a waste disposal sump are shown in Table 19. This option takes into consideration the engineering, construction and monitoring required to construct and operate a sump.

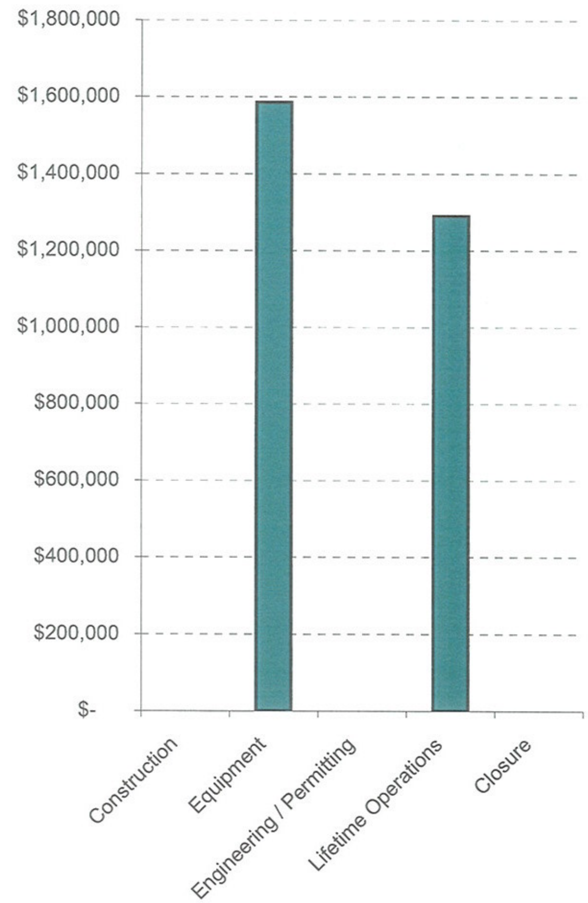
5.5 On-Site Waste Injection

This option takes into consideration the injecting of solid and liquid drilling wastes into an on-site well. Several variations of the waste injection option are possible; however, only annular injection and injection into a dedicated well have been included as part of this estimate. The conversion from an exploratory well to a disposal well would require engineering and conversion costs, but overall the costs would be significantly reduced because a dedicated disposal well is not required.

Table 18: Estimated Construction and Operating Costs for Disposal Outside of the Northwest Territories

Drilling Waste Quantity

Item	Quantity	Solids (66%)	Liquids (34%)	Unit
Total drilling waste quantity	562,500	371,250	191,250	t
	375,000	247,500	127,500	m3
Treatment period	25			Years
Single source drilling waste quantity	1,875	1,238	638	t
	1,250	825	425	m3



Cost Summary

Summary of Estimated Construction and Operating Costs		Cost for 1 Well	Cost for 25 Years or 250 Wells
Activity			
Cost to Construct	Construction	$ -	$ -
Cost to Construct	Equipment	$ 1,586,250	$ 474,609,375
Cost to Construct	Engineering / Permitting	$ -	$ -
Lifetime Operations	Lifetime Operations	$ 1,290,625	$ 387,187,500
Cost to Construct	Closure	$ -	$ -
	TOTAL	$ 2,876,875	$ 861,796,875
	Total Cost/tonne	**$ 1,534**	**$ 1,532**

Cost Considerations

Activity	Task	Quantity	Unit	Unit Price	Cost	Comment
Equipment	HAZCO Specialty Roll Off Bin - Delivery	94	Each	$ 16,875	$ 1,586,250	15 Yard (20 tonne) sealed bin. Delivery cost from Edmonton to Inuvik per trip.
Lifetime Operations	Winter Haul - Inuvik to Northern Rockies (Solids)	1,238	tonnes	$ 575	$ 711,563	HAZCO estimated cost/tonne & disposal at CCS Northern Rockies - includes all fees.
Lifetime Operations	Winter Haul - Inuvik to Silverberry (Liquids)	638	tonnes	$ 675	$ 430,313	Estimated cost/tonne & disposal at CCS Silverberry - tranported frozen. Based on solids rate above.
Lifetime Operations	Liquids Disposal Fee	425	m3	$ 350	$ 148,750	HAZCO - Liquids injection disposal fee at CCS Silverberry.

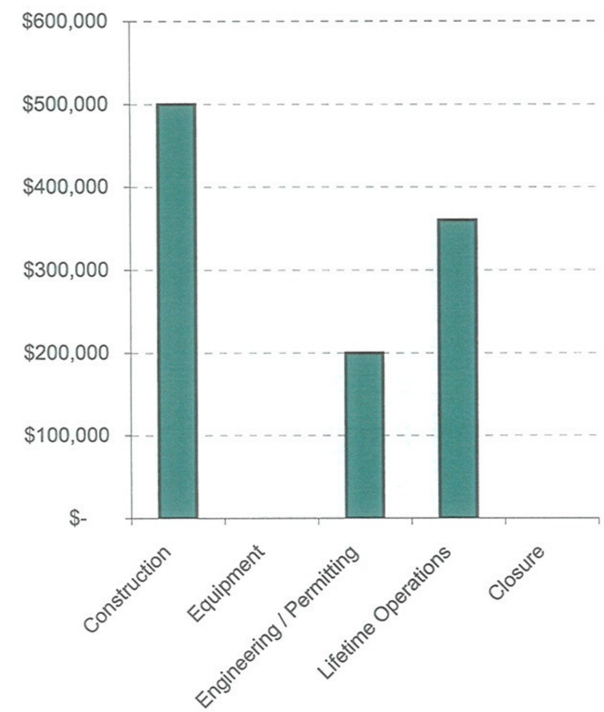
Table 19: Estimated Construction and Operating Costs for a Waste Disposal Sump

Drilling Waste Quantity

Item	Quantity	Solids (66%)	Liquids (34%)	Unit
Total drilling waste quantity	562,500	371,250	191,250	t
	375,000	247,500	127,500	m3
Treatment period	1			Years
Single source drilling waste quantity	1,875	1,238	638	t
	1,250	825	425	m3

Cost Summary

Summary of Estimated Construction and Operating Costs		Cost for 1 Well	Cost for 25 Years or 250 Wells
Activity			
Cost to Construct	Construction	$ 500,000	$ 150,000,000
Cost to Construct	Equipment	$ -	$ -
Cost to Construct	Engineering / Permitting	$ 200,000	$ 60,000,000
Lifetime Operations	Lifetime Operations	$ 360,000	$ 108,000,000
Cost to Construct	Closure	$ -	$ -
	TOTAL	$ 1,060,000	$ 318,000,000
	Total Cost/tonne	$ 565	$ 565



Cost Considerations

Activity	Task	Quantity	Unit	Unit Price	Cost	Comment
Engineering / Permitting	Design and Engineering	1	Each	$ 200,000	$ 200,000	Allowance
Construction	Sump Construction	1	Each	$ 500,000	$ 500,000	Min $60,000 at Norman Wells to $800,000 in Arctic Islands for a single well sump (ESRF, 1988).
Lifetime Operations	Permitting / Monitoring / Reporting	9	Years	$ 40,000	$ 360,000	Once per year for the first 5 years (Northwest Territories Water Board, 2005). Once per five years thereafter.

Annular injection may be used for the disposal of drilling waste in a production well; however, this option may be geologically limited in this region. Shell has stated that annular injection is not an option at Niglintgak because the formations between the base of the permafrost and the top of the gas production reservoir are not suitable for injection. However, there may be areas in the ISR suitable for annular injection. Either of these latter options is site and project specific. Unit prices are provided in Table 20 and are used as a basis for the cost estimate.

5.6 Regional Waste Disposal

5.6.1 Injection Well

The option of using a regional injection well to dispose of drilling waste requires the construction and operation of a centralized facility to handle drilling wastes from multiple sources and transportation networks to transfer waste to the facility. Using current technologies, both solid and liquid waste would be disposed of at this facility. The volume of waste that a formation can accept varies and it has been assumed that a single disposal well can be used for the disposal of up to 125,000 m^3 of drilling waste. Given this assumption there may be a total of three wells required at such a facility to accommodate the estimated potential volume of 325,000 m^3. Unit prices are provided in Table 21 and are used as a basis for the cost estimate.

5.6.2 Landfill

Similar to the regional injection facility, this option is a centralized landfill designed to contain drilling wastes from multiple sources and would require construction and maintenance of a transportation network to transfer waste to the facility. As was the case when disposing wastes at a landfill outside the NWT, this option requires differentiation between solids and liquids. Solids will be disposed of at this facility while liquids are assumed to be transported outside of the ISR and taken to Silverberry for disposal. Unit prices are provided in Table 22 and are used as a basis for the cost estimate.

5.7 Waste Disposal Option – Summary of Cost Estimates

A summary of the five disposal options is provided in Tables 23 and 24. The cost-effectiveness of the options varies depending on the volume of drilling waste. Table 23 shows the total cost for each disposal option for a number of different well count scenarios. The table indicates that a regional injection facility becomes the most cost-effective option if the drilling waste from over 24 wells is injected. A waste disposal sump is the least costly option for less than 24 wells or 45,000 tonnes of drilling waste.

Table 24 compares the cost of each drilling waste disposal option on a per tonne basis for a number of well count scenarios. If a regional injection facility is used, the cost of drilling waste disposal reaches $194/tonne if the waste from 300 wells is injected.

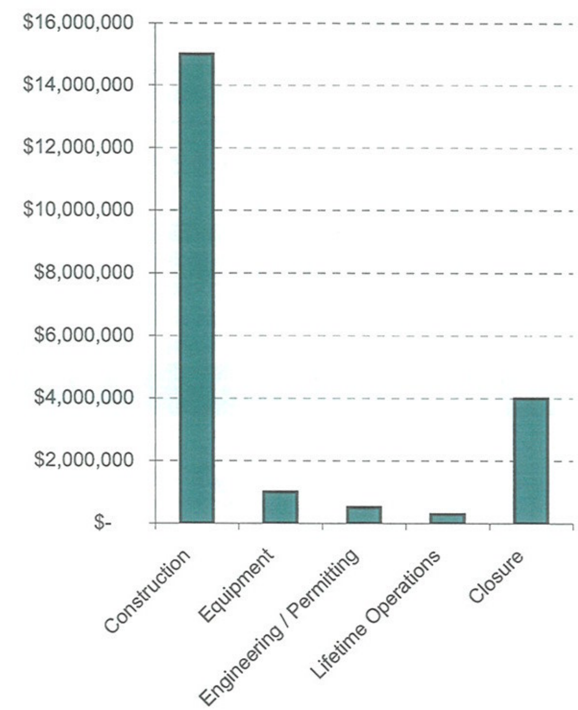
Table 20: Estimated Construction and Operating Costs for On-Site Waste Injection

Drilling Waste Quantity

Item	Quantity	Solids (66%)	Liquids (34%)	Unit
Total drilling waste quantity	562,500	371,250	191,250	t
	375,000	247,500	127,500	m3
Treatment period	1			Years
Single source drilling waste quantity	1,875	1,238	638	t
	1,250	825	425	m3

Cost Summary

Summary of Estimated Construction and Operating Costs		Cost for 1 Well	Cost for 25 Years or 250 Wells
Activity			
Cost to Construct	Construction	$ 15,000,000	$ 4,500,000,000
Cost to Construct	Equipment	$ 1,000,000	$ 300,000,000
Cost to Construct	Engineering / Permitting	$ 500,000	$ 150,000,000
Lifetime Operations	Lifetime Operations	$ 300,000	$ 90,000,000
Cost to Construct	Closure	$ 4,000,000	$ 1,200,000,000
	TOTAL	$ 20,800,000	$ 6,240,000,000
	Total Cost/tonne	**$ 11,093**	**$ 11,093**
	Cost/tonne (less well)	**$ 960**	**(Potential annual injection cost)**



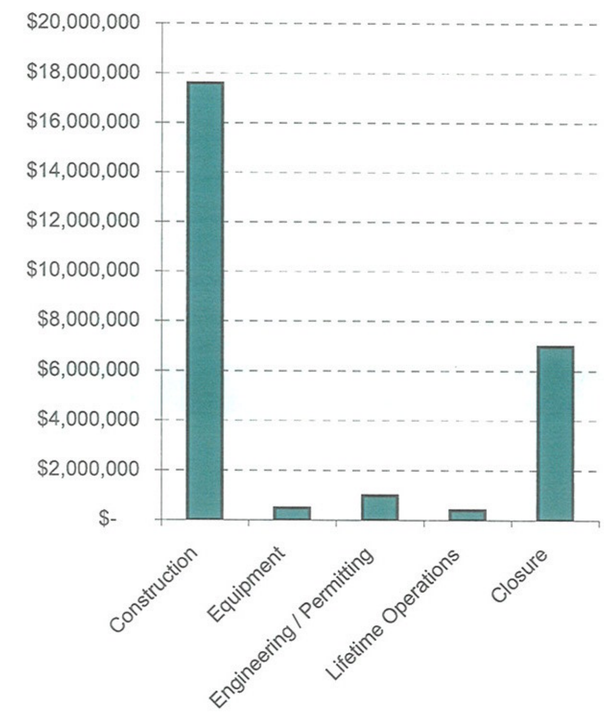
Cost Considerations

Activity	Task	Quantity	Unit	Unit Price	Cost	Comment
Construction	Dedicated Disposal Well	1	Each	$ 15,000,000	$ 15,000,000	MGM Energy Corp. Based on update of 2008/09 Winter Program. Estimated cost to drill a dedicated disposal well.
Engineering / Permitting	Design and Engineering	1	Each	$ 500,000	$ 500,000	Allowance. Variable - highly project and site specific.
Equipment	Grind & Inject Technology	2	Month	$ 500,000	$ 1,000,000	Allowance assuming $500,000 monthly rental costs for injection technology and equipment. Includes Mob/Demob.
Lifetime Operations	Injection Operations	2	Month	$ 150,000	$ 300,000	Estimated operating costs - includes 6 operators and one supervisor.
Closure	Wellbore Abandonment	1	Each	$ 4,000,000	$ 4,000,000	Allowance. Variable - highly project and site specific.

Table 21: Estimated Construction and Operating Costs for a Regional Waste Disposal Facility

Drilling Waste Quantity

Item	Quantity	Solids (66%)	Liquids (34%)	Unit
Total drilling waste quantity	562,500	371,250	191,250	t
	375,000	247,500	127,500	m3
Treatment period	1			Years
Single source drilling waste quantity	1,875	1,238	638	t
	1,250	825	425	m3



Cost Summary

Summary of Estimated Construction and Operating Costs		Cost for 1 Well	Cost for 25 Years or 250 Wells
	Activity		
Cost to Construct	Construction	$ 17,600,000	$ 47,600,000
Cost to Construct	Equipment	$ 500,000	$ 12,500,000
Cost to Construct	Engineering / Permitting	$ 1,000,000	$ 3,000,000
Lifetime Operations	Lifetime Operations	$ 405,000	$ 30,750,000
Cost to Construct	Closure	$ 7,000,000	$ 15,000,000
	TOTAL	$ 26,505,000	$ 108,850,000
	Total Cost/tonne	**$ 14,136**	**$ 194**

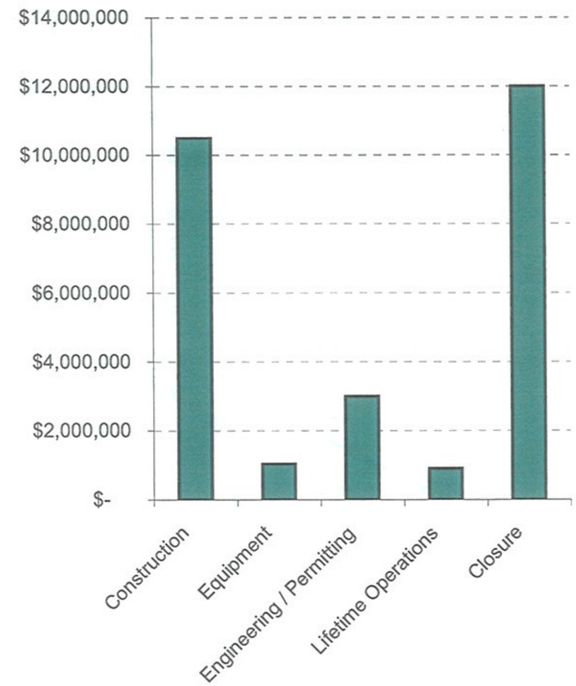
Cost Considerations

Activity	Task	Quantity	Unit	Unit Price	Cost	Comment
Construction	Dedicated Disposal Well	1	Each	$ 15,000,000	$ 15,000,000	MGM Energy Corp. Based on update of 2008/09 Winter Program. Estimated cost to drill a dedicated disposal well.
Construction	Gravel Base Pad	40,000	m3	$ 65	$ 2,600,000	Northwind Industries - Cost per m^3 of crushed rock (gravel).
Equipment	Grind and Inject System	25	Years	$ 500,000	$ 12,500,000	Allowance assuming $500,000 yearly rental costs for injection technology and equipment.
Engineering / Permitting	Design and Engineering	1	Each	$ 1,000,000	$ 1,000,000	Allowance
Lifetime Operations	Winter Haul - Well to Regional Injection Facility	1,875	tonnes	$ 40	$ 75,000	Estimated cost/tonne for transport & unloading at the regional injection facility.
Lifetime Operations	Grind and Inject Operations	25	Years	$ 300,000	$ 7,500,000	Estimated operating costs - includes 6 operators and one supervisor.
Lifetime Operations	Monitoring / Reporting	25	Years	$ 30,000	$ 750,000	Yearly monitoring.
Closure	Site Reclamation	40,000	m2	$ 75	$ 3,000,000	Allowance for site reclamation including $75/$m^3$ for removal and disposal of gravel base pad.
Closure	Wellbore Abandonment	1	Each	$ 4,000,000	$ 4,000,000	Taglu Abandonment & Restoration Cost Estimate (AMEC, 2004).

Table 22: Estimated Construction and Operating Costs for a Regional Waste Disposal Facility - Landfill

Drilling Waste Quantity

Item	Quantity	Solids (66%)	Liquids (34%)	Unit
Total drilling waste quantity	562,500	371,250	191,250	t
	375,000	247,500	127,500	m3
Treatment period	1			Years
Single source drilling waste quantity	1,875	1,238	638	t
	1,250	825	425	m3



Cost Summary

Summary of Estimated Construction and Operating Costs		Cost for 1 Well	Cost for 25 Years or 250 Wells
Activity			
Cost to Construct	Construction	$ 10,500,000	$ 10,500,000
Cost to Construct	Equipment	$ 1,040,000	$ 162,875,625
Cost to Construct	Engineering / Permitting	$ 3,000,000	$ 3,000,000
Lifetime Operations	Lifetime Operations	$ 908,563	$ 195,568,750
Cost to Construct	Closure	$ 12,000,000	$ 12,000,000
	TOTAL	$ 27,448,563	$ 383,944,375
	Total Cost/tonne	**$ 14,639**	**$ 683**

Cost Considerations

Activity	Task	Quantity	Unit	Unit Price	Cost	Comment
Construction	Infrastructure	1	Each	$ 2,000,000	$ 2,000,000	AMEC internal northern landfill cost estimate.
Construction	Mobilization/Demobilization	1	Each	$ 3,000,000	$ 3,000,000	AMEC internal northern landfill cost estimate.
Construction	Excavating and Berming	1	Each	$ 2,000,000	$ 2,000,000	AMEC internal northern landfill cost estimate.
Construction	Liner System	1	Each	$ 3,500,000	$ 3,500,000	AMEC internal northern landfill cost estimate.
Equipment	Equipment	3	Each	$ 500,000	$ 1,500,000	AMEC internal northern landfill cost estimate - Cat purshase every 8 years (3 total over 25 years).
Equipment	HAZCO Specialty Roll Off Bin - Delivery	32	Each	$ 16,875	$ 540,000	15 Yard (20 tonne) sealed bin. Delivery cost from Edmonton to Inuvik per trip.
Engineering / Permitting	Construction Supervision and Design	1	Each	$ 3,000,000	$ 3,000,000	AMEC internal northern landfill cost estimate.
Lifetime Operations	Landfill Operations	25	Years	$ 250,000	$ 6,250,000	AMEC internal northern landfill cost estimate - operators, manager, fuel, maintenance.
Lifetime Operations	Monitoring / Reporting	25	Years	$ 30,000	$ 750,000	AMEC internal northern landfill cost estimate.
Lifetime Operations	Winter Haul - Well to Regional Landfill	1,238	tonnes	$ 40	$ 49,500	Estimated cost/tonne for transport & unloading at the regional landfill.
Lifetime Operations	Winter Haul - Inuvik to Silverberry (Liquids)	638	tonnes	$ 675	$ 430,313	Estimated cost/tonne & disposal at CCS Silverberry - tranported frozen. Based on solids rate (HAZCO).
Lifetime Operations	Liquids Disposal Fee	425	m3	$ 350	$ 148,750	HAZCO - Liquids injection disposal fee at CCS Silverberry.
Closure	Cap System	1	Each	$ 12,000,000	$ 12,000,000	AMEC internal northern landfill cost estimate.

Table 23: Disposal Options - Cost Estimate Summary

Well Count	Waste Quantity (m3)	Waste Quantity (t)	Drilling Waste Disposal Option: Disposal Outside of the NWT — Cost (2008 CDN$)	Waste Disposal Sump	On-site Waste Injection	Regional Waste Disposal Facility - Injection	Regional Waste Disposal Facility - Landfill
1	1,250	1,875	$ 2,876,875	$ 1,060,000	$ 20,800,000	$ 26,505,000	$ 27,448,563
12	15,000	22,500	$ 34,471,875	$ 12,720,000	$ 249,600,000	$ 27,330,000	$ 40,285,875
24	30,000	45,000	$ 68,943,750	$ 25,440,000	$ 499,200,000	$ 29,060,000	$ 54,554,875
36	45,000	67,500	$ 103,415,625	$ 38,160,000	$ 748,800,000	$ 30,790,000	$ 68,840,750
48	60,000	90,000	$ 137,887,500	$ 50,880,000	$ 998,400,000	$ 32,520,000	$ 83,109,750
60	75,000	112,500	$ 172,359,375	$ 63,600,000	$ 1,248,000,000	$ 34,250,000	$ 97,395,625
72	90,000	135,000	$ 206,831,250	$ 76,320,000	$ 1,497,600,000	$ 35,980,000	$ 111,664,625
84	105,000	157,500	$ 241,303,125	$ 89,040,000	$ 1,747,200,000	$ 37,710,000	$ 125,950,500
96	120,000	180,000	$ 275,775,000	$ 101,760,000	$ 1,996,800,000	$ 39,440,000	$ 140,219,500
108	135,000	202,500	$ 310,246,875	$ 114,480,000	$ 2,246,400,000	$ 61,170,000	$ 155,005,375
120	150,000	225,000	$ 344,718,750	$ 127,200,000	$ 2,496,000,000	$ 62,900,000	$ 169,274,375
132	165,000	247,500	$ 379,190,625	$ 139,920,000	$ 2,745,600,000	$ 64,630,000	$ 183,560,250
144	180,000	270,000	$ 413,662,500	$ 152,640,000	$ 2,995,200,000	$ 66,360,000	$ 197,829,250
156	195,000	292,500	$ 448,134,375	$ 165,360,000	$ 3,244,800,000	$ 68,090,000	$ 212,115,125
168	210,000	315,000	$ 482,606,250	$ 178,080,000	$ 3,494,400,000	$ 69,820,000	$ 226,384,125
180	225,000	337,500	$ 517,078,125	$ 190,800,000	$ 3,744,000,000	$ 71,550,000	$ 240,670,000
192	240,000	360,000	$ 551,550,000	$ 203,520,000	$ 3,993,600,000	$ 73,280,000	$ 254,939,000
204	255,000	382,500	$ 586,021,875	$ 216,240,000	$ 4,243,200,000	$ 95,010,000	$ 269,724,875
216	270,000	405,000	$ 620,493,750	$ 228,960,000	$ 4,492,800,000	$ 96,740,000	$ 283,993,875
228	285,000	427,500	$ 654,965,625	$ 241,680,000	$ 4,742,400,000	$ 98,470,000	$ 298,279,750
240	300,000	450,000	$ 689,437,500	$ 254,400,000	$ 4,992,000,000	$ 100,200,000	$ 312,548,750
252	315,000	472,500	$ 723,909,375	$ 267,120,000	$ 5,241,600,000	$ 101,930,000	$ 326,834,625
264	330,000	495,000	$ 758,381,250	$ 279,840,000	$ 5,491,200,000	$ 103,660,000	$ 341,103,625
276	345,000	517,500	$ 792,853,125	$ 292,560,000	$ 5,740,800,000	$ 105,390,000	$ 355,389,500
288	360,000	540,000	$ 827,325,000	$ 305,280,000	$ 5,990,400,000	$ 107,120,000	$ 369,658,500
300	375,000	562,500	$ 861,796,875	$ 318,000,000	$ 6,240,000,000	$ 108,850,000	$ 383,944,375

*Note: Shading indicates the least expensive option

*Note: Quantities are based on potential drilling waste volumes over a 25 year period as presented in Table 1 in the report.

Estimated Total Costs for 1 to 300 Wells

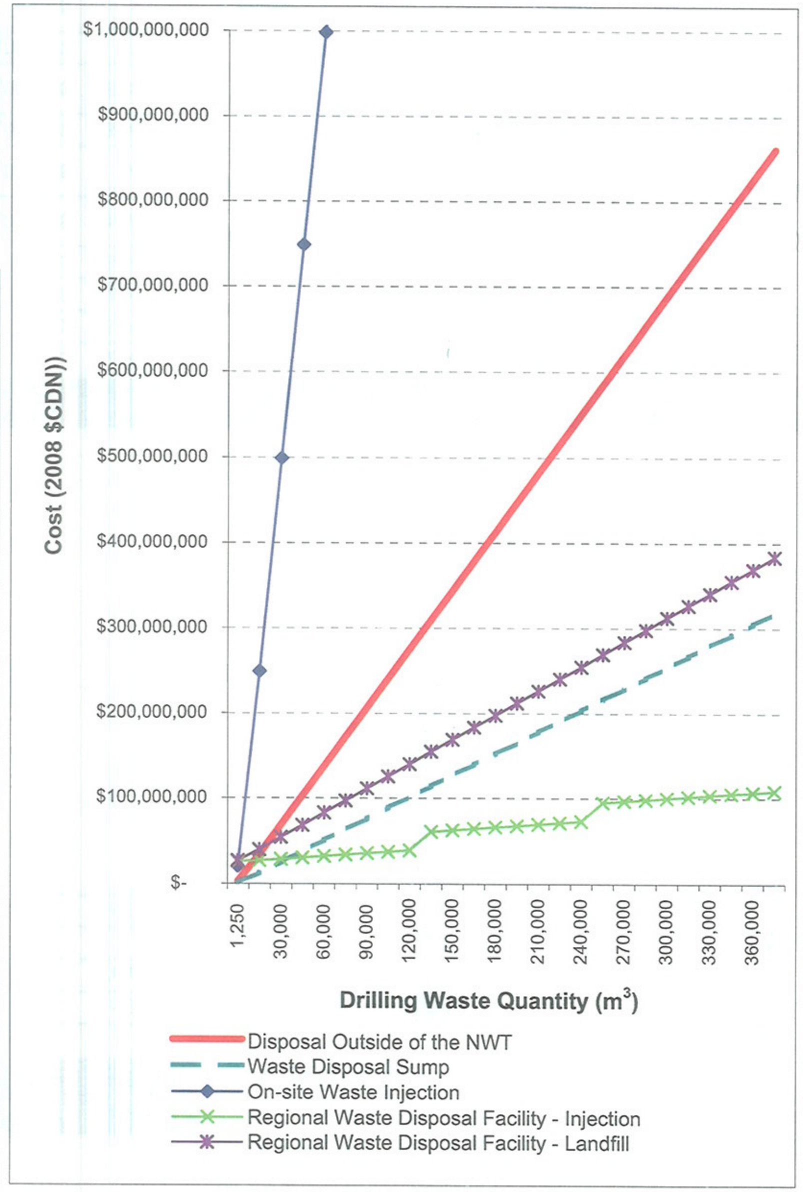


Table 24: Disposal Options - Cost/tonne Estimate Summary

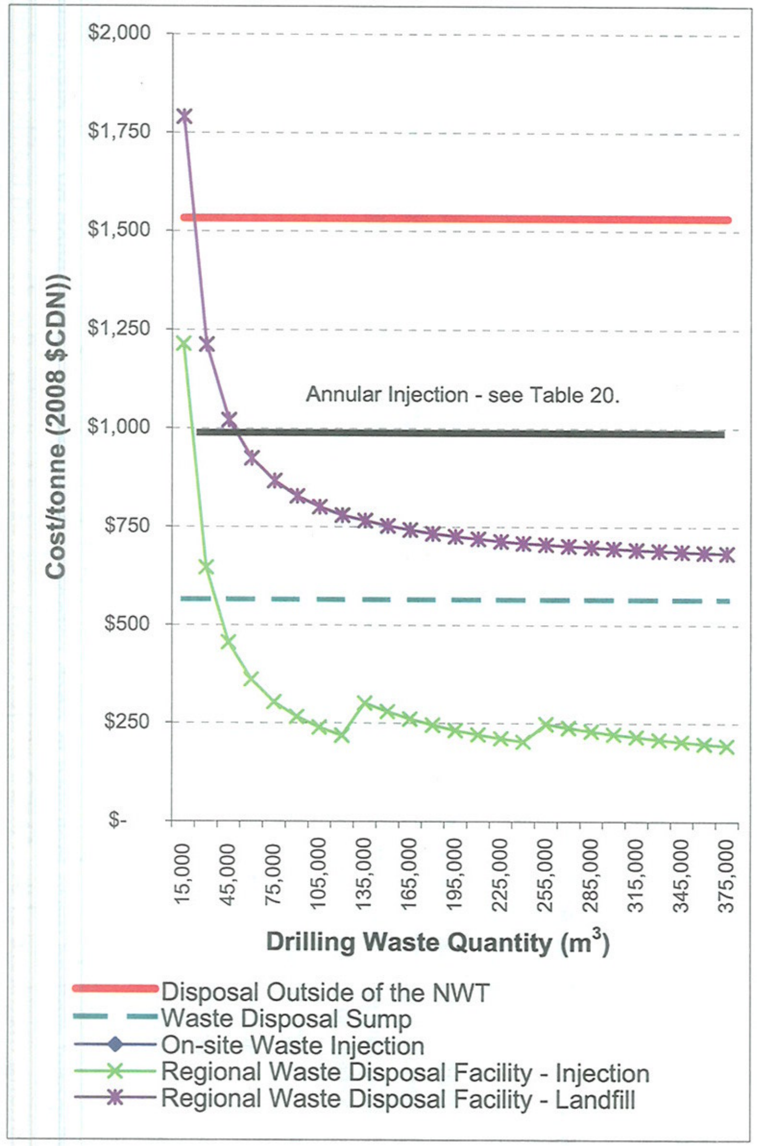
Well Count	Waste Quantity (m3)	Waste Quantity (t)	Disposal Outside of the NWT	Waste Disposal Sump	On-site Waste Injection	Regional Waste Disposal Facility - Injection	Regional Waste Disposal Facility - Landfill
			Cost/tonne (2008 CDN$)				
1	1,250	1,875	$ 1,534	$ 565	$ 11,093	$ 14,136	$ 14,639
12	15,000	22,500	$ 1,532	$ 565	$ 11,093	$ 1,215	$ 1,790
24	30,000	45,000	$ 1,532	$ 565	$ 11,093	$ 646	$ 1,212
36	45,000	67,500	$ 1,532	$ 565	$ 11,093	$ 456	$ 1,020
48	60,000	90,000	$ 1,532	$ 565	$ 11,093	$ 361	$ 923
60	75,000	112,500	$ 1,532	$ 565	$ 11,093	$ 304	$ 866
72	90,000	135,000	$ 1,532	$ 565	$ 11,093	$ 267	$ 827
84	105,000	157,500	$ 1,532	$ 565	$ 11,093	$ 239	$ 800
96	120,000	180,000	$ 1,532	$ 565	$ 11,093	$ 219	$ 779
108	135,000	202,500	$ 1,532	$ 565	$ 11,093	$ 302	$ 765
120	150,000	225,000	$ 1,532	$ 565	$ 11,093	$ 280	$ 752
132	165,000	247,500	$ 1,532	$ 565	$ 11,093	$ 261	$ 742
144	180,000	270,000	$ 1,532	$ 565	$ 11,093	$ 246	$ 733
156	195,000	292,500	$ 1,532	$ 565	$ 11,093	$ 233	$ 725
168	210,000	315,000	$ 1,532	$ 565	$ 11,093	$ 222	$ 719
180	225,000	337,500	$ 1,532	$ 565	$ 11,093	$ 212	$ 713
192	240,000	360,000	$ 1,532	$ 565	$ 11,093	$ 204	$ 708
204	255,000	382,500	$ 1,532	$ 565	$ 11,093	$ 248	$ 705
216	270,000	405,000	$ 1,532	$ 565	$ 11,093	$ 239	$ 701
228	285,000	427,500	$ 1,532	$ 565	$ 11,093	$ 230	$ 698
240	300,000	450,000	$ 1,532	$ 565	$ 11,093	$ 223	$ 695
252	315,000	472,500	$ 1,532	$ 565	$ 11,093	$ 216	$ 692
264	330,000	495,000	$ 1,532	$ 565	$ 11,093	$ 209	$ 689
276	345,000	517,500	$ 1,532	$ 565	$ 11,093	$ 204	$ 687
288	360,000	540,000	$ 1,532	$ 565	$ 11,093	$ 198	$ 685
300	375,000	562,500	$ 1,532	$ 565	$ 11,093	$ 194	$ 683

Drilling Waste Disposal Option

*Note: Shading indicates the least expensive option

*Note: Quantities are based on potential drilling waste volumes over a 25 year period as presented in Table 1.

Estimated Cost/Tonne for 1 to 300 Wells



*Note: On-site waste injection ($11,093 / tonne (dedicated well)) not visible on chart.

6.0 COMPARATIVE ANALYSIS

6.1 Approach

To clearly evaluate the potential impacts of each drilling waste disposal option and select a preferred disposal method, a comparative analysis was done. The objective was to ensure that a wide range of issues were taken into account when comparing the options. The issues, selected by ESRF, are represented in four main categories:

- environment;
- socio-cultural and economic;
- feasibility; and
- cost.

Factors that represent potential benefits and/or impacts that may result from the use of each disposal method were included in each category. A process of participation by and discussion among members of the AMEC project team was used to design the decision matrix in order to identify appropriate categories and factors that would address key aspects of the drilling waste disposal options. These categories and associated factors are listed in Table 25.

Table 25: Decision Matrix Categories and Factors

Category	Factor	Comment
Environment	Surface Water Exposure	Potential for disposal option to result in an exposure
	Groundwater Exposure	
	Direct Contact Exposure	
	Food Chain Exposure	
	Airborne Exposures	Potential for air emissions due to equipment activity required to implement the disposal option
	Impact of Climate Change	Potential impact of climate change on the integrity of the drilling waste disposal option. (The impact of the disposal option on climate change was not considered).
Socio-Cultural and Economic	Traditional Land Use and Culture	Impact of the disposal option on traditional land use and cultural values
	Esthetics	
	Business Opportunities	Impact of the disposal option on commercial and employment opportunities.
	Jobs	
Feasibility	Technical	Extent of technical resources required to implement the disposal option
	Regulatory	Extent of regulatory approval required to implement the disposal option.
	Safety	Extent of safety risks encountered in implementing the disposal option
Capital and Operating Costs	Cost to Construct	Relative costs required to implement each disposal option
	Cost to Operate and Maintain	

6.1.1 Standardization of the Matrix

To properly illustrate the results of the decision matrix, the data were standardized. Because of the different number of factors within each category, it was necessary to standardize in order to represent each factor equally and accurately compare the results of each category. All of the results presented in the following sections have been standardized.

6.1.2 Numerical Weighting

After the categories and associated factors were identified, each factor was assigned two numerical weighted values: one value based on its importance, as perceived by AMEC, and the other value based on the likelihood of occurrence and/or impact. For both importance and likelihood, a scale of 1 to 5 was used, with five representing the most desirable choice or outcome, and one representing the least desirable choice or outcome (e.g., for the factor of "Cost to Construct", 5 represents a low cost while 1 represents a high cost).

The resulting score for each factor was the product of the numerical value for importance, the numerical value for likelihood and the weighting for each category. A total score for each disposal option was calculated by adding up the individual scores for each factor. The preferred disposal option was the one with the highest score. This calculation is as follows:

Score = Importance x Likelihood x Weight
Overall Score for each Disposal Option = (Environment Factors Total Score) + (Socio-Cultural and Economic Factors Total Score) + (Feasibility Factors Total Score) + (Capital and Operating Cost Factors Total Score)

It is important to recognize that the scores are significant because of their relative values only, not because of their absolute values (i.e., the disposal option with the highest score is perceived to be the most desirable option; the score does not yield any additional information other than this preference relative to the other options). Furthermore, the scores are relevant within the same categories and factors only; individual scores cannot be compared against different factors and/or categories to obtain a meaningful result.

A value for likelihood was assigned to each disposal option based on the assumption that each would be constructed and/or implemented using current technology and best management practices. Historical challenges with each disposal option that may have been attributed to outdated technology or methods were not considered when assigning likelihood values.

Prior to completing the comparative analysis, AMEC conducted research on and a technical review of each disposal option. This exercise was used to develop the categories and factors presented in the decision matrix, and allowed AMEC to determine the likelihood of the disposal options having an impact on each of the factors. The likelihood of impact is objective, because it is based entirely on the technical characteristics of the disposal option and not on personal opinions or interpretations. Therefore, AMEC evaluated likelihood for each factor, whereas the stakeholders were asked to evaluate importance. Importance is subjective because it is based on an individual's values, priorities and perceptions. Stakeholder validation of factor importance is discussed further in Section 6.1.3.

When evaluating the likelihood for each factor, AMEC considered uncontrollable versus controllable risks for each option. For example, when building a sump, most aspects of the design and construction are controllable and not impacted by external factors. However, when trucking material outside the NWT, there are many uncontrollable factors (e.g., poor weather, collisions with wildlife and/or other vehicles, poor road conditions). Furthermore, AMEC considered the consequence of each option impacting the factors. For example, a low consequence result was rated higher (i.e., more desirable) than an impact with a high consequence result.

The factors and categories were presented in a structured matrix to facilitate side-by-side comparisons of each disposal option. All inputs were based on a drilling waste volume scenario of 375,000 m^3.

6.1.3 Stakeholder Validation

To evaluate the five disposal options, AMEC contacted interested and affected parties from three diverse groups: the ISR, petroleum and exploration companies active in the ISR, and federal government regulators.

The Inuvialuit stakeholders represent the various organizations representing the people of the ISR. The regulators represent organizations that are active governing bodies associated with drilling activities in the ISR. The three industry representatives were chosen because of their past, current and/or future drilling activities in the ISR.

All stakeholders were sent the same letter in which they were given basic background information on drilling waste, the disposal options, the project and the comparative analysis. They were asked to indicate the importance to them of each factor and their preferred disposal option, and to include any associated comments. A copy of this letter is included in Appendix A1. Within ten days after mailing the letter, each stakeholder was contacted by telephone by an AMEC representative to discuss any questions or comments they might have. The stakeholder categories, stakeholder groups and organizations and position of each contacted stakeholder group or organization are shown in Table 26.

Table 26: Stakeholder Representatives Contacted by AMEC

Stakeholder Group	Company/Organization	Individual Contacted
Inuvialuit	Joint Secretariat	Chairperson
	Inuvialuit Game Council	Chairperson
	Inuvialuit Land Administration	Chief Land Administrator
	Aklavik Community Corporation	Chairperson, Office Manager
	Inuvik Community Corporation	Chairperson, Corporation Manager
	Tuktoyaktuk Community Corporation	Chairperson
	Aklavik Hunters and Trappers Committee	President, Office Manager
	Inuvik Hunters and Trappers Committee	President, Office Manager
	Tuktoyaktuk Hunters and Trappers Committee	President, Office Manager
Stakeholder Group	**Company/Organization**	**Individual Contacted**
Regulators	Environment Canada, Environmental Impact Assessment Section	Mackenzie Gas Project Review Team Member
	Indian and Northern Affairs Canada	District Manager
	NWT Water Board	Executive Director
	Government of the NWT	Industrial Specialist – Oil and Gas
Industry	Chevron Canada Resources	Environmental & Remediation Specialist
	MGM Energy Corp.	HSE Advisor
	Shell Canada Energy	Reclamation and Drilling Waste Manager

6.1.4 Inuvialuit and Stakeholder Response

Inuvialuit and stakeholder responses to AMEC's request for opinion were limited to the following:

- one response from industry;
- two responses from the Inuvialuit; and
- two responses from the regulators.

Generally, the reasons provided for not participating in the study included:

- lack of time;
- disagreement with the waste disposal options presented;
- disagreement with the format and engagement method used; and
- a perceived lack of qualification.

Appendices A3 through A5 include the response, as completed by each group that responded to AMEC's request for feedback. It was the opinion of the ESRF Technical Advisory Group (TAG), with which AMEC agrees, that the number of responses was insufficient to conduct further comparative analyses of the options from the viewpoint of the Inuvialuit and stakeholders.

AMEC's discussion regarding the Inuvialuit and stakeholder responses is included in Appendix A2.

6.2 Comparative Analysis Results

AMEC completed the decision matrix with values for importance and likelihood for each factor; importance based on AMEC's values and priorities, and likelihood based on the technical characteristics of each option. The completed version of the decision matrix is shown in Table 27.

AMEC ranked the environmental and socio-cultural and economic factors with a higher importance than the cost and feasibility factors. In AMEC's opinion, these factors are critical because they have the potential to affect human health, traditional values and the environment. Although cost and feasibility are important to project budget and scheduling, they do not affect health or life; so they were ranked with a lower value for importance. An explanation of the methodology used to assign likelihood values within each category is included in the following sections.

6.2.1 Environment

Within the category of environment, the on-site disposal options had the highest scores indicating that they are the preferred disposal choice from this perspective. Both on-site sumps and on-site waste injection involve minimal waste handling (because the waste is contained on site), requires minimal additional equipment and would not be significantly impacted by climate change. Furthermore, current technology and best practices provide assurance that waste can be permanently contained, thus reducing the risk of exposure to surface water, groundwater, air or the food chain.

Disposal outside the NWT had the lowest score in this category, and was significantly lower than any other option, indicating that it the least preferred disposal option within the environment category. Because this option involves repeated handling of the waste and a significant haul distance requiring many truckloads, there is a heightened risk to human health, surface water, food chain and air quality. Furthermore, climate change may impact the ability of trucks to use winter roads over extended periods of time.

6.2.2 Socio-Cultural and Economic

Within the socio-cultural and economic category, an off-site landfill and disposal outside the NWT were the preferred disposal methods. Disposal outside the NWT results in waste being permanently contained outside the ISR, thus resulting in minimal impact on esthetics and the potential for local business opportunities and employment in the transportation sector. This option does have some impact on traditional land use and culture because the extensive trucking activity may result in collisions with wildlife; however, the positive impacts of the other factors balance out this impact. Although an off-site landfill would be located on ISR land, resulting in impacts to traditional land use and culture and esthetics, this option represents an excellent opportunity for business development and employment, because the construction and operation of a landfill requires considerable labour and resources. Off-site waste injection represents a minimal impact on both traditional land use and culture and esthetics; however, because it does not yield as significant an opportunity for local businesses and employment, there was less of a preference for this option than for the other two off-site disposal options.

Table 27: AMEC Defined Decision Matrix

Legend	
Importance	1 = Low Importance to 5 = High Importance
Score	Importance x Normalized Weighting x Likelihood = Score

Legend: green / yellow / orange, with the arrow pointing up to "Most Preferred".

Waste Scenario: 375,000 m^3

					On-Site Drilling Waste Disposal Options						Off-Site Drilling Waste Disposal Options								
					On-site Sump			On-Site Waste Injection			Off-Site Waste Injection			Off-Site Landfill			Disposal Outside of the NWT		
Category	Factor	Importance	Likelihood Scheme	Normalized Weighting	Likelihood	Score	AMEC Comment	Likelihood	Score	AMEC Comment	Likelihood	Score	AMEC Comment	Likelihood	Score	AMEC Comment	Likelihood	Score	AMEC Comment
Environment	Surface Water Exposure	5	1 = high risk of contact 5 = low risk of contact	4.167	2	42	Heightened risk using current protocols	5	104	Low risk - no waste handling beyond site boundary.	3	63	Involves transporting waste over and on water bodies.	3	63	Involves transporting waste over and on water bodies.	2	42	Involves transporting waste over and on numerous water bodies.
	Groundwater Exposure	5	1 = high risk of contact 5 = low risk of contact	4.167	3	63	Low risk using current protocols	4	83	Low risk if injected below confining layers.	4	83	Low risk if injected below confining layers.	3	63	Risk mitigated if constructed according to current protocols.	3	63	Assumes disposal in secure landfill.
	Direct Contact Exposure	5	1 = high risk of contact 5 = low risk of contact	4.167	5	104	Waste handling kept to a minimum.	5	104	Waste is contained on site.	4	83	Involves repeated handling of wastes.	3	63	Involves repeated handling of wastes.	1	21	Involves repeated handling of wastes.
	Food Chain Exposure	5	1 = high risk of contact 5 = low risk of contact	4.167	5	104	Low risk using current protocols	5	104	Little risk to food chain.	5	104	Low risk to the food chain.	4	83	Little risk to the food chain.	3	63	Involves repeated handling of wastes over long distances.
	Airborne Exposures	2	1 = high risk of contact 5 = low risk of contact	4.167	5	42	No additional equipment required.	4	33	Involves equipment operation.	4	33	Involves equipment operation.	3	25	Involves equipment operation.	2	17	Involves long haul and numerous trucks.
	Impact of Climate Change	3	1 = high risk of impact 5 = low risk of impact	4.167	3	38	Extreme climate change could increase risk of surface water contact.	5	63	Climate change would have no impact.	4	50	Marginal impact on transportation routes.	2	25	Climate change could impact landfill operations.	4	50	Marginal impact on transportation routes.
				Environment Score:		392			492			417			321			254	
Socio-Cultural & Economic	Traditional Land Use and Culture	5	1= highest risk of negative effect 5= lowest risk of negative effects	6.250	1	31	Cumulative land disturbance results in greatest percieved adverse effect.	5	156	Use of existing wells will result in negligible land disturbance = minimal effect on traditional land use	4	125	Minimal land disturbance because only 1 - 3 wells required = minimal effect on traditional land use.	2	63	Impact to landfill site and adjacent area due to noticeable disturbance from landfill and assocated infrastruture.	3	94	Some effect due to extensive trucking activity and potential truck/wildlife collisions
	Aesthetics	3	1= highest risk of negative effect 5= lowest risk of negative effects	6.250	1	19	Largest cumulative alteration to the landscape as a result of disturbance; greater than all other disposal methods.	5	94	Not likely to change the aesthetics in a noticeable way.	4	75	Minimal impact on land and aesthetics.	2	38	Visual impact on the landscape.	5	94	No waste in the NWT = no aesthetic impact
	Business Opportunities	4	1 = lowest benefit 5 = highest benefit	6.250	3	75	Construction and environmental monitoring requirements could provide local business opportunities.	2	50	Opportunity for joint venture.	3	75	Provides some business opportunities to truck waste from original well site to a regional site and some road construction may be required.	5	125	High probability of local businesses participating in construction and management and the movement of waste from drilling sites to the landfill.	4	100	May create substantial local business opportunities associated with the potential storage and transportation of waste.
	Jobs	4	1 = lowest benefit 5 = highest benefit	6.250	3	75	Construction and environmental monitoring requirements could provide local employment opportunities	2	50	Opportunity for joint venture.	2	50	Provides some business opportunities to truck waste from original well site to a regional site and some road construction may be required.	5	125	Will create local employment opportunities related to local landfill construction, moving waste from well sites to the landfill and monitoring/operations of the landfill.	4	100	Could create substantial local employment opportunities in the transportation sector.
				Socio-Cultural & Economic Score:		200			350			325			350			388	
Feasibility	Technical	3	1 = high degree of complexity 5 = minimal degree of complexity	8.333	4	100	Construction methods are understood.	3	75	Design and planning intensive.	2	50	Design and planning intensive.	2	50	Construction design understood.	5	125	Not very complex - haul routes established.
	Regulatory	3	1 = significant regulatory approval 5 = minimal regulatory approval	8.333	2	50	Regulators are unsupportive of sump option.	3	75	NEB and INAC working towards streamlining the regulatory framework.	2	50	Uncertain regulatory framework.	1	25	Assumes regulatory hurdles need to be overcome.	5	125	Few approvals required.
	Safety	5	1 = significant safety risks 5 = minimal safety risks	8.333	5	208	Minimal safety risk - very little handling	4	167	Requires additional drilling and material handling operations.	3	125	Requires additional drilling and material handling operations	3	125	Safety risks increase with handling.	1	42	Extensive and repeated handling
				Feasibility Score:		358			317			225			200			292	
Capital and Operating Costs	Cost to Construct	3	1 = high cost 5 = low cost	12.500	5	188	Sumps are economical however perpetual liability needs to be considered.	4	150	Assumes annular injection is viable.	2	75	Regional injection facility becomes more economic with an increasing number of wells.	1	38	Off-site landfill is not capable of handling liquid wastes. A dedicated diposal well would also be required.	5	188	Low capital cost but high operating cost.
	Cost to Operate and Maintain	2	1 = high cost 5 = low cost	12.500	3	75		4	100		4	100		3	75		1	25	
				Capital and Operating Cost Score:		263			250			175			113			213	
				Total Score:		1213			1408			1142			983			1146	

The on-site disposal options were least preferred within the socio-cultural and economic category. Although the construction and ongoing environmental monitoring of an on-site sump provides local business and job opportunities, the cumulative effect of a sump at each well site with the waste remaining on ISR land represents a significant impact on both traditional land use and esthetic values. Alternatively, on-site waste injection has a minimal potential impact on land use and esthetics. However, because it provides minimal opportunities for Inuvialuit involvement in business and employment, it is not a preferred option within this category.

6.2.3 Feasibility

Within the category of feasibility, the on-site sump was the most preferred disposal option, compared to all of the other options. Because the regulatory framework for a sump is well-established, the current design and construction methods are well-understood and there are minimal safety risks during the construction and maintenance of a sump, the on-site sump was most preferred.

The other four options had a lower feasibility score. Both on-site and off-site waste injection require relatively intensive design and planning of the technical requirements and are subject to an uncertain regulatory framework. However, as described in Section 4.3.2, the NEB and INAC have signed a Memorandum of Understanding intended to streamline the regulatory process associated with waste injection. Although an off-site landfill has relatively few safety concerns and a well-understood construction design, the regulatory framework for this option is still in the early development stages, making it a more difficult option to implement. Disposal outside the NWT has minimal technical requirements, because haul routes and trucking methods are well-understood and few approvals are required. However, the extensive handling of waste and significant haul distances present many uncontrollable risks (e.g., weather, wildlife, other drivers, road conditions) that may pose heightened safety risks.

6.2.4 Cost

Within the cost category, off-site waste injection was most preferred because the cost of a regional injection facility becomes increasingly more economical with an increasing number of wells. Disposal outside the NWT was the least preferred option within the cost category, because the significant haul distances result in this option not being economical. Because an off-site landfill cannot accept liquid waste, a dedicated disposal well is likely required, resulting in significant costs for this option. On-site waste injection may not be economical unless annular injection is feasible.

7.0 RECOMMENDATIONS

7.1 Drilling Waste Disposal Option

The recommended option for drilling waste disposal in the ISR, identified through use of the decision matrix and developed and completed by AMEC, was on-site waste injection. This was followed by on-site sump disposal, disposal outside the NWT, off-site waste injection, and off-site landfill disposal. However, choosing a specific waste disposal method is complex and must involve site-specific and project-specific considerations since some sites will not be suitable for on-site waste injection or sump disposal. Further, it is expected, once resource development shifts from the exploration phase to the development phase, that off-site injection at a regional waste disposal facility would become the preferred option.

Table 28 can be used as guide in choosing a drilling waste disposal option when more detailed information is available. This table recognizes two potential types of drilling waste (i.e., water-based and non-aqueous), the suitability of the environment in which the activity occurs, the project scale (i.e., an exploration program with less than 10 wells versus a multi-well development program), and whether or not there is a regional waste management facility in the activity area. The table suggests a 1st, 2nd and 3rd choice of drilling waste disposal option.

In Table 28, environmental suitability is intended to address favourable areas for the construction and use of drilling waste disposal sumps. Generally, these favourable areas would include upland areas located outside the Mackenzie Delta and would include the physiographic regions identified in Figure 11. Favourable areas would also include those that are not located in protected areas, are not utilized by the Inuvialuit for traditional land uses and are not located in sensitive areas utilized by wildlife. It is important to note that the use of a sump as a disposal method is recommended only under the following conditions:

- when no regional waste disposal facility is available;
- when on-site waste injection is not feasible;
- when the drilling waste is water based and will freeze under site conditions;
- where the environment is favourable for construction and long-term containment; and
- where wastes are generated during an exploration program.

7.2 Preparation of Drilling Waste Disposal Guidance Material

AMEC, in agreement with ESRF's Technical Advisory Group, suggests that discussions involving the regulators, industry and appropriate ISR representatives would be useful for the development of guidance material that specifically address the management of drilling waste in the ISR. This guidance material would have to recognize and address current regulations, the environmental diversity of the ISR and the type and quantity of drilling waste expected to be generated by oil and gas development and exploration in the foreseeable future.

Table 28: ISR Drilling Waste Disposal Option Selection by Scenario

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Scenario				Waste Management Option			
Waste Type	Environmental Suitability	Project Type	Regional or NO Regional Waste Management Centre	On-site Sump	On-Site Waste Injection	Regional Waste Management Centre	Disposal Outside of the NWT
Water Based and Freezable	Favourable Sump Environment	Exploration	Regional Waste Management Centre			1	
			NO Regional Facility	2	1		3
		Development	Regional Waste Management Centre			1	
			NO Regional Facility	2	1		3
	Unfavourable Sump Environment	Exploration	Regional Waste Management Centre			1	
			NO Regional Facility		1		2
		Development	Regional Waste Management Centre			1	
			NO Regional Facility		1		2
Non-Ageous or Non-Freezable		Exploration	Regional Waste Management Centre			1	
			NO Regional Facility		1		2
		Development	Regional Waste Management Centre			1	
			NO Regional Facility		1		2

Legend:

Legend	1	1st Choice
	2	2nd Choice
	3	3rd Choice
		Not Recommended

7.3 Review of Inuvialuit and Stakeholder Feedback

AMEC agrees with the ESRF Technical Advisory Group's concern that the adequacy of the responses from the ISR interests, industry and the regulators was considered insufficient to include in the quantitative analysis conducted in this study. As a result, it is recommended that further consultations take place, particularly with ISR representatives, to verify or supplement the findings of this study.

8.0 PROJECT CD

8.1 Contents

A CD containing the project report is included in Appendix B. The CD contains the following files:

- ISR Drilling Waste Disposal Options Decision Matrix.xls;
- ISR Drilling Waste Disposal Options Cost Estimates.xls; and
- a PDF version of this report.

9.0 CLOSURE

The work described in this report was conducted in accordance with the Scope of Work outlined in the proposal and with generally accepted engineering and assessment practices. The Limitation of Liability, Scope of Report and Third Party Reliance statements in Appendix C form part of this document.

Respectfully submitted,

AMEC Earth & Environmental

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Signature Dec 21, 2009
Defined Scope of Practice: Within the discipline of environmental Engineering: Design, report and manage environmental liability assessments and Phase I and Phase II environmental site assessments.
THE ASSOCIATION OF PROFESSIONAL ENGINEERS, GEOLOGISTS AND GEOPHYSICISTS OF ALBERTA

ECW/cf

APEGGA Permit to Practice #P-04546
AMEC Earth & Environmental
A Division of AMEC Americas Limited

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Appendix A

Inuvialuit and Stakeholder Input

Appendix A1

Letter from AMEC to Inuvialuit and Stakeholders

_October 2008

Dear _:

Re: Evaluation of Drilling Waste Disposal Options in the Inuvialuit Settlement Region

AMEC Earth & Environmental (AMEC) is a consulting business that offers environmental, geotechnical and water resources services to clients across Canada and throughout North America. Environmental Studies Research Funds (ESRF) is a joint federal and petroleum industry funded research program that sponsors environmental and social studies related to oil and gas exploration and development in Canada's frontier lands.

ESRF has contracted AMEC to evaluate five options for the disposal of petroleum drilling waste from onshore wells in the Inuvialuit Settlement Region (ISR). This study considers current disposal technologies that have been successful in northern locations like the ISR. Historically, some methods of drilling waste disposal have not worked well. However, improvements to design and construction procedures and the use of industry best practices for drilling waste management has resulted in current waste disposal technologies that are successful in northern environments. The information you provide, along with AMEC's research and technical considerations, will be used to create a decision–making tool to guide the choice of a preferred drilling waste disposal method.

To evaluate the five disposal options, AMEC is contacting interested and affected parties including: representatives from Inuvialuit Hunters and Trappers Committees, the Land Administration and three mainland ISR communities; federal government regulators; and petroleum exploration and development companies that are active in the ISR.

The purpose of this letter is to ask for your feedback on the five options for disposal of drilling waste and the factors that will be used to evaluate and compare each of the options. Your opinion will be taken into consideration in the final evaluation and recommendations of the drilling waste disposal options.

This letter also includes:

- a description of the amount and type of drilling wastes produced by exploration activities in the ISR;
- a description of the five options for disposal of the drilling waste;
- a list of factors to compare and evaluate each of the different disposal options; and
- two tables for you to complete.

1.0 Drilling Waste

Drilling waste is a mix of both drill cuttings (rock fragments) and drilling mud or fluid (used to assist drilling activities). The drilling mud typically used for oil and gas operations in the ISR is a

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salty fluid designed to help reduce the freezing point of the mud. Potassium chloride salt (KCl) is the mineral used, with the amount of KCl in the drilling mud ranging from 3% to 8%. This amount of KCl in drilling mud is comparable to sea water, which has a 3.5% salt concentration. The drilling waste created as a result of drilling activities is water-based and non-hazardous.

2.0 Amount of Drilling Waste

Each well drilled in the ISR will produce drilling waste. The following wells may be drilled in the future:

- Mackenzie Gas Project – about 42 wells over the next five years; and
- about 10 wells per year may be drilled by other petroleum exploration companies that are active in the ISR.

The total amount of drilling waste that these wells might produce over five years is about 100,000 cubic metres, covering an area of 10 hectares (25 acres) if spread evenly to a depth of one metre. The amount of drilling waste produced by a single well depends largely on the depth of the well. AMEC has assumed that the average well would be about 2,500 metre deep and would produce drilling waste at a rate of about 0.5 cubic metres per metre of depth.

Drilling waste volumes have decreased significantly since the 1980s. With less waste, less land is required for disposal and fewer resources are needed.

3.0 Disposal Options

This study is focussing on five drilling waste disposal options, including both on-site and off-site disposal methods. These options are:

- **On-Site Waste Disposal Options:**
  - ❑ *Disposal Sump* - a disposal sump is a widely used method of waste disposal, involving a pit dug into the ground into the permafrost layer to contain the waste, at or near the well site. Historically, sumps have had limited success within the ISR due to poor design and construction methods. However, modern technology and construction methods are designed to ensure permanent containment of the drilling waste (pre-construction site assessments, smaller sumps, deeper containment, engineered design, detailed monitoring programs, and increased regulatory participation). This option requires no additional infrastructure beyond what is already present for on-site drilling activities. The average surface area of a sump built for a well in the ISR is comparable to the size of a basketball court.
  - ❑ *On-Site Waste Injection* – waste injection is pumping the drilling fluids and cuttings back underground, directly at the well site. The drilling waste is injected back into the well and is permanently contained in a geological formation several hundred metres below ground surface. This option requires additional temporary infrastructure other than what is already on-site for drilling activities (tanks, grinding equipment etc.). Although this technology has not been used previously in the ISR, it is used extensively and successfully in Alaska.

- **Off-Site Waste Disposal Options:**
  All off-site waste disposal options involve waste handling, containment, pre-treatment and transportation to the designated disposal area, using a network of winter/ice roads, barges, all-season roads and/or trains.
  - *Off-Site Waste Injection* – this option uses the same technology as on-site waste injection, however it would occur at a designated location in the region away from the original well sites. A regional injection site would be built, with the capability to contain drilling waste from numerous wells located throughout the ISR.
  - *Landfill* – a secure landfill is a carefully engineered containment area for drilling waste and/or other oilfield wastes. A synthetic liner inside the landfill and a granular cover on top of the landfill is used to avoid mixing of the waste with the surrounding environment. A regional landfill would be built to permanently store drilling waste from numerous wells located throughout the ISR. Landfills are a frequently used waste disposal option in the NWT. Numerous Distant Early Warning (DEW) sites in the NWT have been cleaned up by building single-use landfills.
  - *Haul out of the NWT* – transportation networks like winter/ice roads, barges, all-season roads and trains would be used to haul waste from the well site to a suitable landfill in Alberta or British Columbia. This option is based on current regulations that allow waste to be transported and disposed of across provincial boundaries. It requires multiple handling of the drilling waste, is seasonal-dependent and energy intensive, involving many truckloads to transport all of the waste to and from the barge loading/unloading sites or directly out of the NWT.

4.0 Factors

AMEC intends to evaluate the five drilling waste disposal options using the factors shown under the four categories listed below. We would like your feedback on the four categories and factors associated with them. Specifically, we would like to know:

- Are the four categories complete? Or, do you think that there are there other categories that should be considered in the evaluation?
- How important to you are each of the factors listed under the categories in evaluating the different waste disposal options?

The current list of factors includes:

- *Environment:*
  - Surface Water Exposure
  - Groundwater Exposure
  - Direct Contact Exposure
  - Food Chain Exposure
  - Airborne Exposures
  - Impact of Climate Change
- *Socio-Cultural and Economic:*
  - Traditional Land Use and Culture
  - Aesthetics

- Business Opportunities
- Jobs

- *Feasibility:*
  - Technical
  - Regulatory
  - Safety
- *Capital and Operating Costs:*
  - Cost to Construct
  - Cost to Operate and Maintain

We would also like to know which disposal option(s) you prefer among the five options being evaluated. On Page B of this letter, please indicate your preference for each of the five disposal options using a scale of 1 to 5, with 1 being your least preferred option and 5 being your most preferred option.

AMEC has conducted extensive research and a technical review of each of the disposal options. This exercise was used to develop the categories and factors presented here and will be used to evaluate the waste disposal options. This research will allow users of the AMEC study to estimate the likelihood of potential effects of each waste option on the categories and factors listed here, based on technical considerations. The information you provide, along with AMEC's research and technical considerations, will be used to create a decision–making tool for land managers, regulators and people from industry to guide the choice of a preferred drilling waste disposal method.

In summary, **AMEC is requesting your opinion on the following:**

1. The importance of each factor to you – Assign each factor a number between 1 and 5 (1 = not important at all, 5 = extremely important). Please provide this information in the table on Page A, at the end of this letter.
2. The disposal options – which option(s) do you prefer? Assign each option a number between 1 and 5 (1 = least preferred option, 5 = most preferred option). Please provide this information in the table on Page B, at the end of this letter.

A representative from AMEC's Human Environment division (Krista Maydew or Bruce Ramsay) will contact you within the next 10 days to discuss this letter, to answer any questions you may have, to discuss your views regarding the factors used to evaluate each disposal option and your preferences regarding the different disposal options.

Thank you kindly for your time and your opinion.

Yours truly,

AMEC Earth & Environmental

C. Wenzel

Chris Wenzel, R.P.T. (Eng)
Project Manager

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Appendix A2

AMEC Review of Inuvialuit and Stakeholder Responses

APPENDIX A2: AMEC REVIEW OF INUVIALUIT AND STAKEHOLDER RESPONSES

A2-1.0 ISR RESPONSE

AMEC received two responses from the ISR stakeholders; the Tuktoyaktuk Hunters and Trappers Committee and the ILA.

The ISR representatives indicated that the environmental and socio-economic factors were more important to them than the feasibility and cost factors. The original completed decision matrices, including comments to explain the way the ISR representatives rated the factors, are included in Appendix A3.

When asked to designate their most preferred disposal option, both ISR representatives indicated that disposal outside of the NWT was most preferred. One representative indicated that all other options would be least preferred, without differentiating between them, while the other indicated that on- and off-site injection would be viable options, but an off-site landfill or on-site sump would not. The preferred disposal options, as indicated by the ISR stakeholders, are shown in Table A2-1.

Table A2-1: ISR Preferred Disposal Options

Stakeholder	Stakeholder Preference (1=least preferred, 5=most preferred)				
	On-Site Sump	On-Site Waste Injection	Off-Site Waste Injection	Off-Site Landfill	Disposal Outside of the NWT
Tuktoyaktuk Hunters and Trappers Committee	1	1	1	1	5
Inuvialuit Land Administration	1	3	4	2	5

A2-2.0 REGULATOR RESPONSE

AMEC received two responses from the regulatory stakeholders; the Government of the NWT and the NWT Land and Water Board. The original completed decision matrices, including comments to explain the way the regulator representatives rated the factors, are included in Appendix A4.

The representative from the GNWT provided ratings for the factors within the environment category, indicating that exposures via surface water, groundwater and airborne were most important. Direct contact exposure, food chain exposure and impact of climate change were rated as less important, not because they were seen to be less significant than the other factors, but because it was felt that if the former three factors were eliminated than the latter three would not be an issue. Ratings were not provided for factors within the feasibility, socio-cultural and economic and cost categories.

The representative from the NWT Land and Water Board provided ratings for the factors within the environment and feasibility categories. Surface water exposure, groundwater exposure and direct contact exposure were rated as most important, while impact of climate change was rated as least important. Both the technical and regulatory factors were rated as very important. Ratings were not provided for the remaining factors, as it was indicated that they were not directly related to the NWT Water Board mandate relating to the deposit of wastes, as defined in the NWT *Water Act*.

When asked to designate their most preferred disposal option, the GNWT representative indicated that off-site waste injection and disposal outside of the NWT were the only appropriate disposal methods. The NWT Land and Water Board Representative indicated that both on- and off-site waste injection were most preferred, and an on-site sump was least preferred. The preferred disposal options, as indicated by the regulatory stakeholders, are shown in Table A2-2.

Table A2-2: Regulator Preferred Disposal Options

Stakeholder	Stakeholder Preference (1=least preferred, 5=most preferred)				
	On-Site Sump	On-Site Waste Injection	Off-Site Waste Injection	Off-Site Landfill	Disposal Outside of the NWT
GNWT	0	0	5	0	0
NWT Land and Water Board	1	5	4	2	3

A2-3.0 INDUSTRY RESPONSE

AMEC received one response from the industry stakeholders, from Chevron Canada Resources. The original completed decision matrices, including comments to explain the way the industry representative rated the factors, are included in Appendix A5.

The industry representative indicated that within the category of environment, surface water exposure was the most important factor, while traditional land use and culture was the most important factor within the socio-cultural and economic category. All feasibility and cost factors were rated with equal importance, feasibility rated as slightly more important than cost.

When asked to designate their most preferred disposal option, the Industry representative indicated that on-site sump, and both on-and off-site waste injection were all equally preferred, with off-site disposal and disposal outside of the NWT least preferred. These preferred disposal options, as indicated by the Industry stakeholder, are shown in Table A2-3.

Table A2-3: Industry Preferred Disposal Options

Stakeholder	Stakeholder Preference (1=least preferred, 5=most preferred)				
	On-Site Sump	On-Site Waste Injection	Off-Site Waste Injection	Off-Site Landfill	Disposal Outside of the NWT
Chevron Canada Resources	4	4	4	2	2

Appendix A3

Responses from the ISR

Factors to Evaluate Drilling Waste Disposal Options:

Category	Factor	Importance to You 1= not important at all 5 = extremely important	Comments
Environment	Surface Water Exposure	5	
	Groundwater Exposure	5	
	Direct Contact Exposure	5	
	Food Chain Exposure	5	
	Airborne Exposure	5	
	Impact of Climate Change	5	
Socio-Cultural & Economic	Traditional Land Use and Culture	5	
	Aesthetics	5	
	Business Opportunities	5	
	Jobs	5	

Category	Factor	Importance to You 1= not important at all 5 = extremely important	Comments
Feasibility	Technical	5	
	Regulatory	5	
	Safety	5	
Capital & Operating Costs	Cost to Construct	5	
	Cost to Operate and Maintain	5	

Evaluation of Drilling Waste Disposal Options:

Drilling Waste Disposal Option	Your Preference 1 = least preferred option 5 = most preferred option	Comments
On-Site Drilling Waste Disposal Options		
On-Site Sump	1	
On-Site Waste Injection	1	
Off-Site Drilling Waste Disposal Options1		
Off-Site Waste Injection	1	
Off-Site Landfill	1	
Disposal Outside of the NWT	5	

Additional Comments:

No mention of off-shore waste. The Tuktoyaktuk Hunters and Trappers Committee would like the disposal outside of the NWT.

Your Contact Information:

Name: James Pokiak, Chair Person, Tuktoyaktuk Hunters and Trappers Committee

Phone Number: 867-977-2457

Email Address: tuk.htc@gmail.com

Mailing Address: PO Box 286, Tuktoyaktuk, NT X0E 1C0

Inuvialuit Land Administration

PO Box 290, Tuktoyaktuk, NT X0E 1C0
Tel: 867 977 7100 Fax: 867 977 7101

FACSIMILE

Date: Oct 28/08 Cover +

To: Chris Wenzel Fax: (403) 248-2188

C.C.

From:

- ☑ Todd Romaine, Chief Land Administrator
- ☐ Marilyn Cockney, Land Use Applications Manager
- ☐ Barry Jacobson, GIS Tech. / Land Management Officer
- ☐ Emily Borsy, Land Use Policy Coordinator
- ☐ Reagen Stoddart, Environmental Specialist
- ☐ Christina Carter, Land Use Research Advisor
- ☐ Tina Steen, Office Manager
- ☐ Kendyce Cockney, Secretary / Receptionist
- ☐ Janet Elias, Environmental Monitor Coordinator

Originals: ☐ To Be Mailed ☐ Not To Be Mailed

RE:

COMMENTS:

Please see attached

– TR

Factors to Evaluate Drilling Waste Disposal Options:

Category	Factor	Importance to You 1= not important at all 5 = extremely important	Comments
Environment	Surface Water Exposure	4	Still important issues - but ILA'S main concerns would be for the land and the mitigation of associated impacts
	Groundwater Exposure	4	to surrounding area, wildlife, people ⇒ traditional land use.
	Direct Contact Exposure	5	Our main priority - to preserve the land and mitigate potential impacts to the environment. Direct contact to the environment would have to be shown as having no negative impact
	Food Chain Exposure	5	Disposal method would have to ensure that drill waste was contained so as not to expose wildlife to potential contaminants
	Airborne Exposure	5	This pathway for effect is anticipated to be minimal but the disposal method and mitigation strategies would still have to address
	Impact of Climate Change	5	An important community issue has always been the impact of global warming to existing previous disposal areas & the effect that
Socio-Cultural & Economic	Traditional Land Use and Culture	5	climate change has on the integrity of disposal areas.
	Aesthetics	5	Important to the Inuvialuit, is the action taken to restore the land use area to its original condition (or as close to it as possible)
	Business Opportunities	4	Our first concern is the land and its protection, but employment opportunities for the Inuvialuit is a high priority for our corporate organization
	Jobs	4	

Category	Factor	Importance to You 1= not important at all 5 = extremely important	Comments
Feasibility	Technical	3	This aspect is controlled by the proponent.
	Regulatory	5	Ensuring that the disposal option meets all the necessary regulatory requirements is of extreme importance to the ILA.
	Safety	4	While of importance to the proponent, ILA does employ environmental monitors on-site and their safety during operations is a conce
Capital & Operating Costs	Cost to Construct	2	Since the cost to construct would be the responsibility of the proponent this is not that important of an issue to ILA
	Cost to Operate and Maintain	2	Has some importance in that, the cost of operating / maintaining the disposal methods would (may) affect the proponents decision to develop in the ISR.

Evaluation of Drilling Waste Disposal Options:

Drilling Waste Disposal Option	Your Preference 1 = least preferred option 5 = most preferred option	Comments
On-Site Drilling Waste Disposal Options		
On-Site Sump	1	This method has been reviewed extensively by the ILA and with community input is a method that is discouraged as an option for disposal.
On-Site Waste Injection	3	This method is proposed by many developers presently, but not a lot is known about
Off-Site Drilling Waste Disposal Options		the potential impact of the saline drill
Off-Site Waste Injection	4	waste on the integrity of the permafrost "down-hole". Would like more information about the technique and post-action results.
Off-Site Landfill	2	Landfills - and there permanent liabilities to the Inuvialuit are also discouraged as a disposal method.
Disposal Outside of the NWT	5	If feasible, this method would be most preferred, as it poses no impact to Inuvialuit land

Additional Comments:

Would like additional info/research on injection techniques - if all waste can be disposed this way - or if this method only contains a portion of the generated drill cuttings/fluids?

Your Contact Information:

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Phone Number: 867. 977. 7104

Email Address: rstoddart@ irc.inuvialuit.com

Mailing Address: P.O. Box 290, Tuk NT X0E1C0

Appendix A4

Responses from the Regulators

Factors to Evaluate Drilling Waste Disposal Options:

Category	Factor	Importance to You 1= not important at all 5 = extremely important	Comments
Environment	Surface Water Exposure	5	See comments
	Groundwater Exposure	5	See comments
	Direct Contact Exposure	0	It's not that these are not important, but that if surface water exposure, groundwater exposure, and air exposure are eliminated, then the others are not of issue.
	Food Chain Exposure	0	It's not that these are not important, but that if surface water exposure, groundwater exposure, and air exposure are eliminated, then the others are not of issue.
	Airborne Exposure	5	See comments
	Impact of Climate Change	0	It's not that these are not important, but that if surface water exposure, groundwater exposure, and air exposure are eliminated, then the others are not of issue.
Socio-Cultural & Economic	Traditional Land Use and Culture		
	Aesthetics		
	Business Opportunities		
	Jobs		

Category	Factor	Importance to You 1= not important at all 5 = extremely important	Comments
Feasibility	Technical		
	Regulatory		
	Safety		
Capital & Operating Costs	Cost to Construct		
	Cost to Operate and Maintain		

Evaluation of Drilling Waste Disposal Options:

Drilling Waste Disposal Option	Your Preference 1 = least preferred option 5 = most preferred option	Comments
On-Site Drilling Waste Disposal Options		
On-Site Sump	0	
On-Site Waste Injection	0	
Off-Site Drilling Waste Disposal Options		
Off-Site Waste Injection	5	
Off-Site Landfill	0	
Disposal Outside of the NWT	5	

Additional Comments:
With respect to the Chart "Factors to Evaluate Drilling Waste Disposal Options", it is not possible for me to rate 1 through 5 least to most preferred. The mandate of the Environmental Protection Section is to prevent the release of contaminants to the environment. Therefore, zero discharge is the preferred choice. Zero discharge is not identified within the options found. It is desired to eliminate the vectors for contaminant transport – in this case, any or all options that avoid exposure to air, land, or water, will eliminate exposure. Hence I cannot comment on the other considerations.

Also, it is noted that remote sumps are not included as options. Is this considered off-site landfill?

Your Contact Information:

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Factors to Evaluate Drilling Waste Disposal Options:

Category	Factor	Importance to You 1= not important at all 5 = extremely important	Comments
Environment	Surface Water Exposure	5	Directly related to NWTWB mandate as relates to deposit of wastes as defined in the NWT Waters Act.
	Groundwater Exposure	5	Directly related to NWTWB mandate as relates to deposit of wastes as defined in the NWT Waters Act.
	Direct Contact Exposure	5	Directly related to NWTWB mandate as relates to deposit of wastes as defined in the NWT Waters Act.
	Food Chain Exposure	4	Directly related to NWTWB mandate as relates to deposit of wastes as defined in the NWT Waters Act. ENR and local HTC mandates relate more directly to regulation of wildlife.
	Airborne Exposure	4	Directly related to NWTWB mandate as relates to deposit of wastes as defined in the NWT Waters Act. This issue needs clarification in an NWT context as to jurisdiction and standards.
	Impact of Climate Change	3	Directly related to NWTWB mandate as relates to deposit of wastes as defined in the NWT Waters Act. This is a very hard issue to conceptualize for any regulator, although it should not be discarded.
Socio-Cultural & Economic	Traditional Land Use and Culture	NA	Not directly related to NWTWB mandate as relates to deposit of wastes as defined in the NWT Waters Act.
	Aesthetics	NA	Not directly related to NWTWB mandate as relates to deposit of wastes as defined in the NWT Waters Act.
	Business Opportunities	NA	Not directly related to NWTWB mandate as relates to deposit of wastes as defined in the NWT Waters Act.
	Jobs	NA	Not directly related to NWTWB mandate as relates to deposit of wastes as defined in the NWT Waters Act.

Category	Factor	Importance to You 1= not important at all 5 = extremely important	Comments
Feasibility	Technical	5*	Directly related to NWTWB mandate as relates to deposit of wastes as defined in the NWT Waters Act. *The NWTWB will consider the proposed technical design of waste disposal facilities from the point of view of ensuring wastes do not migrate into water.
	Regulatory	5	Directly related to NWTWB mandate as relates to deposit of wastes as defined in the NWT Waters Act.
	Safety	NA*	*Design and safety requirements are taken into account by the NWTWB when considering water licence applications but other organisations (i.e. NEB, WCB) have direct involvement in regulating these requirements.
Capital & Operating Costs	Cost to Construct	NA	Not directly related to NWTWB mandate as relates to deposit of wastes as defined in the NWT Waters Act.
	Cost to Operate and Maintain	NA	Not directly related to NWTWB mandate as relates to deposit of wastes as defined in the NWT Waters Act.

Evaluation of Drilling Waste Disposal Options:

Drilling Waste Disposal Option	**Your Preference** 1 = least preferred option 5 = most preferred option	**Comments**
On-Site Drilling Waste Disposal Options		
On-Site Sump	1	Sumps are not a 100% proven technology and there are strong regional concerns surrounding this technique.
On-Site Waste Injection	5	If approved by the NEB for technical consideration, this method is highly considered for drilling waste disposal. It can ensure wastes are treated appropriately while reducing the amount of emissions from vehicles for waste transportation.
Off-Site Drilling Waste Disposal Options		
Off-Site Waste Injection	4	Same as above, however, may involve creation of vehicle emissions due to transportation requirements. It is assumed the injection location would not be too far from the well site.
Off-Site Landfill	2	This method may not provide the same comfort as downhole injection concerning waste containment. Vehicle emissions another potential issue
Disposal Outside of the NWT	3	This method eliminates wastes from the region, which is great, but may create other wastes in the process.

Additional Comments:

The Board itself has not had a chance to review this letter.

Your Contact Information:

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Appendix A5

Responses from Industry

Factors to Evaluate Drilling Waste Disposal Options:

Category	Factor	Importance to You 1= not important at all 5 = extremely important	Comments
Environment	Surface Water Exposure	4	This is likely the most significant pathway/receptor for onsite disposal
	Groundwater Exposure	2	Not considered to be overly significant given lack of groundwater potential in permafrost conditions
	Direct Contact Exposure	2	Likelihood of exposure is low in all scenarios. Handling risks can be readily mitigated
	Food Chain Exposure	3	Important but not necessarily high-risk
	Airborne Exposure	2	No significant pathway
	Impact of Climate Change	2	Important, but not considered a significant risk given limited emissions and intermittent sources
Socio-Cultural & Economic	Traditional Land Use and Culture	4	
	Aesthetics	1	Preferred and approved option must be technically and scientifically valid/sound. Using aesthetic criteria to evaluate waste disposal options is not recommended
	Business Opportunities	2	Suggest putting jobs and business opportunities under same category
	Jobs	2	Suggest putting jobs and business opportunities under same category

Category	Factor	Importance to You 1= not important at all 5 = extremely important	Comments
Feasibility	Technical	5	Must have confidence upfront that the method can be implemented within reasonable costs and must prevent a long term liability
	Regulatory	5	Must be an acceptable approach to disposal that regulators are willing to support/endorse
	Safety	5	Must take the position that the Option selected can be done incident and injury free, both from a public safety and worker safety perspective
Capital & Operating Costs	Cost to Construct	4	Costs for a given option must be competitive with other options reviewed
	Cost to Operate and Maintain	4	Costs for a given option must be competitive with other options reviewed

Evaluation of Drilling Waste Disposal Options:

Drilling Waste Disposal Option	Your Preference 1 = least preferred option 5 = most preferred option	Comments
On-Site Drilling Waste Disposal Options		
On-Site Sump	4	
On-Site Waste Injection	4	
Off-Site Drilling Waste Disposal Options		
Off-Site Waste Injection	4	
Off-Site Landfill	2	
Disposal Outside of the NWT	2	

Additional Comments:

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Appendix B

Report CD

Appendix C

Limitations

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Limitations

1. The work performed in the preparation of this report and the conclusions presented are subject to the following:
   (a) The Standard Terms and Conditions which form a part of our Professional Services Contract;
   (b) The Scope of Services;
   (c) Time and Budgetary limitations as described in our Contract; and
   (d) The Limitations stated herein.
2. No other warranties or representations, either expressed or implied, are made as to the professional services provided under the terms of our Contract, or the conclusions presented.
3. The conclusions presented in this report were based, in part, on visual observations of the Site and attendant structures. Our conclusions cannot and are not extended to include those portions of the Site or structures, which are not reasonably available, in AMEC's opinion, for direct observation.
4. The environmental conditions at the Site were assessed, within the limitations set out above, having due regard for applicable environmental regulations as of the date of the inspection. A review of compliance by past owners or occupants of the Site with any applicable local, provincial or federal by-laws, orders-in-council, legislative enactments and regulations was not performed.
5. The Site history research included obtaining information from third parties and employees or agents of the owner. No attempt has been made to verify the accuracy of any information provided, unless specifically noted in our report.
6. Where testing was performed, it was carried out in accordance with the terms of our contract providing for testing. Other substances, or different quantities of substances testing for, may be present on Site and may be revealed by different or other testing not provided for in our contract.
7. Because of the limitations referred to above, different environmental conditions from those stated in our report may exist. Should such different conditions be encountered, AMEC must be notified in order that it may determine if modifications to the conclusions in the report are necessary.
8. The utilization of AMEC's services during the implementation of any remedial measures will allow AMEC to observe compliance with the conclusions and recommendations contained in the report. AMEC's involvement will also allow for changes to be made as necessary to suit field conditions as they are encountered.
9. This report is for the sole use of the party to whom it is addressed unless expressly stated otherwise in the report or contract. Any use which any third party makes of the report, in whole or the part, or any reliance thereon or decisions made based on any information or conclusions in the report is the sole responsibility of such third party. AMEC accepts no responsibility whatsoever for damages or loss of any nature or kind suffered by any such third party as a result of actions taken or not taken or decisions made in reliance on the report or anything set out therein.
10. This report is not to be given over to any third party for any purpose whatsoever without the written permission of AMEC.
11. Provided that the report is still reliable, and less than 12 months old, AMEC will issue a third-party reliance letter to parties that the client identifies in writing, upon payment of the then current fee for such letters. All third parties relying on AMEC's report, by such reliance agree to be bound by our proposal and AMEC's standard reliance letter. AMEC's standard reliance letter indicates that in no event shall AMEC be liable for any damages, howsoever arising, relating to third-party reliance on AMEC's report. No reliance by any party is permitted without such agreement.