Background Report for Updating the
Guidelines for the Planning, Design, Operations and Maintenance of Modified Solid Waste Sites
in the Northwest Territories

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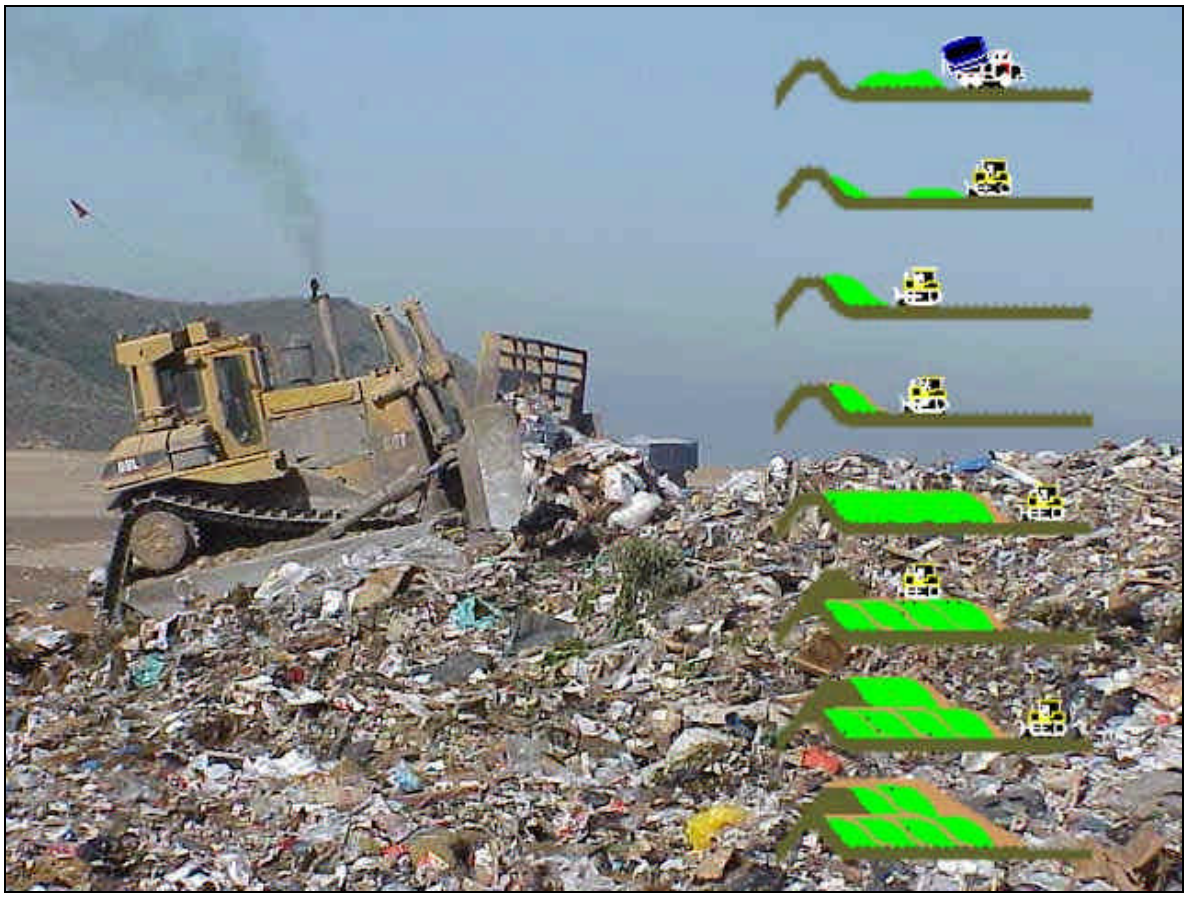

Northwest Territories
Municipal and Community Affairs

Background Report

Updating the Guidelines for the Planning, Design, Operations and Maintenance of Modified Solid Waste Sites in the NWT

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FSC Project No: 2001-1330

April 10, 2003

Acknowledgements

The writers of this report wish to acknowledge the technical contributions of the following individuals:

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- Don Helfrick, Resources, Wildlife & Economic Development, Environmental Protection Service, Hazardous Waste Specialist, Government of the Northwest Territories
- Rick Semeniuk, Canadian Waste
- Heather Stockard, Program Manager, Alaska Department of Environmental Conservation
- Glenn Miller, Environmental Engineer, Alaska Department of Environmental Conservation
- Shannon Jensen, Environmental Protection Analyst, Department of Renewable Resources, Yukon Government
- Terry Bidniak, Program Engineer, Community & Transport Services, Yukon Government
- Dave Parker, Senior Municipal Planning Engineer, CG&T
- Stéphan Ferrero, Project Engineer, Nord-du-Québec region, Government of Québec
- Thomas Rihm, Technical Officer (Landfill), The Swedish Association of Waste Management (RVF), Sweden
- Anette Engraff, Acting Manager, Ministry of Nature and the Environment, Greenland
- Hugh Lloyd, Executive and Inter-government Affairs, Government of Nunavut

Forward

This project serves to update the Guidelines for Solid Waste Management in the Northwest Territories for the Government of the Northwest Territories Department of Municipal and Community Affairs. The deliverables are in two separate reports: this analysis report entitled *Updating the Guidelines for the Planning, Design, Operations and Maintenance of Modified Solid Waste Sites in the NWT* and the subsequent updated guidelines itself.

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1. AN EVALUATION OF EXISTING SOLID WASTE TECHNIQUES AND IMPROVED OPERATIONS AND MAINTENANCE PRACTICES

The solid waste techniques practised at a municipal landfill facility have an associated level of regulatory compliance, protection of public health and environmental quality. Economics of landfill operations reflect the efficiency and scale of such techniques. Current guidelines Heinke and Wong, Community Works Management System (CWMS) and Maintenance Management Operation System (MMOS) and the operational standard set out by the Solid Waste Association of North America (SWANA), have been examined for the purpose of determining the best landfill management practices for communities in the Northwest Territories. The review of these four documents follows.

1.1 CURRENT HEINKE GUIDELINES FOR THE PLANNING, DESIGN, OPERATION, AND MAINTENANCE OF SOLID WASTE MODIFIED LANDFILL SITES

Guidelines for the Planning, Design, Operation, and Maintenance of Solid Waste Modified Landfill Sites in the Northwest Territories (the Guidelines) by Gary Heinke and Jeffrey Wong remains a well-regarded and useful document. However, many changes have come about in the Northwest Territories since the development of the Guidelines in 1990. These changes include the inception of Nunavut in 1999, the creation of various co-management land and water boards, the enacting of *Mackenzie Valley Resource Management Act* in 1998, and the development of various new territorial guidelines (see Section 4.2 for details). Further, the territorial government seeks to instate the best current practices that may have not been available or feasible in 1990. Areas to be given particular consideration are operator training/certification, recycling and hazardous waste management, collection and siting practices, oil and gas industry impacts, and environmental monitoring procedures.

The following is a section-by-section review of the Guidelines.

1.1.1 Objectives of the Guidelines

The purpose of the Guidelines was to show that a modified landfill is the most effective waste disposal method for the NWT and to establish the guidelines for its planning, design, operation and maintenance. These objectives still hold true; no advancement in solid waste management has replaced the modified landfill as a versatile yet basic waste disposal option.

The comment that the open dump is simple and well suited to small northern communities is valid. However, as land claim settlement issues prevail and co-managed land and water boards begin regulation, there is a new interest in taking environmental responsibility, increasing public

health and safety and improving aesthetics in the communities. Stating that the open dump/landfill can be a practical and safe alternative if properly managed, would best be removed from the updated guideline. It is understood the intent of this statement is practical in nature, but as a government guideline, a higher standard ought to be presented.

1.1.2 Existing Solid Waste Disposal System

The Heinke and Wong Guidelines offer that the solid waste collection system is considered "adequate" for the climatic conditions, community size and equipment limitations. In the eleven years since the Guidelines were developed, increased community populations, estimated increased waste generation and ageing equipment might mean this system today requires additional review and analysis.

To update the collection frequency of waste, the point may be made that collection occurs daily in some communities—a practice used to maintain steady employment of staff.

The Guidelines note that honey bags are scheduled to be phased out by 2000 but should still be included in the event that this does not transpire. This point proves to be insightful since in 2002 there remains honey bag collection, though its extent is unknown since our most current data is from 1994/95. As stated in the Guidelines, accommodation of honey bags should remain in the updated Guidelines.

One of the stated concerns of the existing solid waste disposal system is the proximity to airports. This section has a typographical error which makes it unclear how many facilities in the NWT conform to the Transport Canada recommendation that siting should not be within an 8 km radius of airports. Although only in draft form when the Guidelines were developed, reference was made to the report by Soberman, *et. al*. (1990) regarding siting solid waste facilities in the vicinity of airports. The interim guideline states that the Department of Municipal and Community Affairs has elected to use a minimum setback of 3.0 kilometres. Details are given in Soberman regarding the submission of an information package to the regional office of Transport Canada for approval of the siting of a sanitary landfill.

In a discussion of planning and design considerations, mention is made that per capita generation rates and waste composition data is lacking. The National Packaging Protocol, a 1992 CCME initiative responding to municipalities concerning consumer packaging, reports a decrease in per capita packaging consumption. The north likely has not seen the same waste generation decrease due to little recycling available in the communities. It has been estimated that waste generation, in fact, has increased 1% since 1990 due to population increases (FSC, 2000). The rate presented in 1990, of 0.014 m^3/capita/day, should be updated to 0.015 m^3/capita/day. The latest data available for waste composition is a study by Quay and Heinke (1992) for Inuvik, Tsiigehtchic and Fort McPherson. A table of this data should replace the Nunavut waste composition table.

Since the publication of the Guidelines, the Department of Renewable Resources and Economic Development (RWED) has developed draft Regulations for waste oil and fuel which should be law by 2002. For industrial waste oil and fuel, shipment to a recycling facility is the preferred option, and alternately use as a fuel in CSA or ULC approved waste oil furnaces (Helfrick, 2001).

In developing the Guidelines, Heinke and Wong surveyed solid waste collection and disposal in NWT communities. The survey questionnaire was never completed for 8 out of the 61 communities and no attempts were made to complete the survey or to update the data since 1990. Many communities included in the survey are located in what is now Nunavut and are therefore not relevant to the updated Guidelines. It is best to not include this information, or possibly mention only the few pertinent facts from this section.

1.1.3 Objectives of Solid Waste Management

Much of Section 3 of the Guidelines is a repeat of the concerns raised in Section 2.4 "Concerns of Existing System" but in greater detail. Under Basic Objectives, existing NWT practices are presented such as honey bags, waste combustion, proximity to airports, etc. Focus should be given to remedy, monitor or otherwise clearly dissuade certain practices.

Public health and safety of solid waste facilities in particular is repetitive and lacking in a response to the concerns. Mention of the consequences of the Public Health Act, and roles and responsibilities of communities, government departments, and other agencies would strengthen this section.

The Environmental Protection section presents data still valid (65 % of waste is non-hazardous paper and food) but this is followed by the vague, unsubstantiated claim that either burning waste or surface and groundwater contamination is the biggest concern in NWT communities. Without mention of which communities have which concerns, it would be best to leave out the subjective comment altogether. Mention is made of the Quay and Heinke (1992) report *Co-disposal of Hazardous and Solid Wastes in the Northwest Territories*. Lacking is a brief general discussion of residential, industrial and commercial hazardous waste issues. Further, no mention is made of environmental monitoring as well as the responsibilities of communities, various agencies and government departments; reporting of monitoring results; and lines of communication.

To Update the Water Pollution objective a discussion of the permafrost and groundwater situation unique to the arctic and sub-arctic regions is required. Mention may be made of the current initiative of Environment Canada and the GNWT to Study Water and Sediment Quality Valued Ecosystem Components (VECs) in the Mackenzie Valley Cumulative Impacts Monitoring Program. Groundwater remains poorly understood, and not qualified nor quantified in the north. This program seeks, among other objectives, to gain a greater understanding of groundwater issues. In addition, information is

available on groundwater monitoring that was conducted at several landfill facilities in the NWT suggesting that groundwater contamination from landfills is not an issue.

1.1.4 Disposal Methods

The Modified Landfill discussion is still valid. To update the Guidelines mention may be made that there are no new advances applicable to small northern communities in recent years. Sophisticated gas control or leachate management systems are not necessary, unless monitoring proves otherwise. A discussion of reactive barriers as a means of disposing waste iron as well as reducing leachate contamination may be included.

There is a typographical error in the Sanitary Landfill section. Sanitary Landfills serve populations "greater than 5000 to 10 000 people" should read "between 5000 and 10 000 people." Figure 4.1 provides disposal options for populations under 5000 (most NWT communities) and between 5000 and 10 000 (no NWT communities) but leaves out the city of Yellowknife (population 18 000). Breakpoints for various solid waste techniques based on community size and location is lacking. Presenting such information in the form of a decision tree would serve community planners and facility designers.

A discussion of regionally based recycling and composting would update the Disposal Options section. The Guidelines state in the Other Alternatives section that recycling in northern communities needs further consideration. Again, breakpoints that are provided in a decision tree would be a useful addition.

Incineration is another alternative not developed in the guidelines. A six year old study into incineration in the NWT (Bryant/EBA, 1996) would provide some information into the viability of incineration as a means of waste reduction and for waste-to-energy systems.

1.1.5 Guidelines for the Planning of the Disposal Site

To update community population, April 2000 data from NWT Bureau of Statistics should be used.

Descriptions of various types of solid waste would be more complete with the addition of hazardous wastes, and biomedical wastes. It should be made clear, however, that these wastes are covered under separate Resources, Wildlife and Economic Development guidelines, namely the *Guideline for the General Management of Hazardous Waste,* and the *Guideline for Institutional Commercial and Industrial Waste Management* and *Biomedical Waste Management.* The latter two documents are in draft form and will be considered for public review in the spring of 2002 (Helfrick, 2001). However, honey bag waste is certainly pertinent to the north and should have been included.

The Waste Composition table (Table 5.1) includes only Nunavut communities and would obviously be omitted in the updated Guidelines. Quay and Heinke (1992) have more recent data for the NWT communities of Inuvik, Tsiigehtchic, and Fort McPherson (see comparison of data in Table 1).

Although based on data from the Baffin region, the 1990 solid waste volume figure of 0.014 m^3/capita/day is the most conservative estimate and is therefore accepted. To update this figure for 2002, a 1% increase has been estimated, as discussed previously. It is assumed the community refuse volume model is still valid, which due to conservative volume rate, most likely would tend to overestimate refuse volume during the planning horizon and therefore would result in a longer than expected facility life. Also worth mentioning is the fact that any recycling efforts would reduce waste volumes resulting in longer than planned facility life. It is obviously better to err on the side of safety when estimating waste volumes.

Siting Criteria mentions again the proximity to airports issue in the Northwest Territories. To update the Guidelines, the minimum separation distance of 3.0 km as set out in the Soberman, *et al*. report should be used rather than the 2.0 km as reported in the Guidelines. The 3.0 km setback should, however, be negotiated with Transport Canada in the design stage of landfill development.

Table 1 Solid Waste Composition, Quay and Heinke, 1992

Component (%)	Inuvik	Fort McPherson	Tsiigehtchic	Average Percentage
Food	18.7	21.4	20.9	20.3
Cardboard	8.7	12.1	8.6	9.8
Newsprint	6	0.6	0.5	2.4
Other Paper	15.8	10.2	18.3	14.8
Cans	3.9	6.7	2.5	4.4
Other Metal	6.6	4.6	7.4	6.2
Plastics, Rubber	14.3	13.7	14.1	14.0
Textiles	4.4	6.1	6.5	5.7
Glass, Ceramics	4.1	4.4	2.8	3.8
Wood	9.1	10	10.6	9.9
Dirt	4.5	4.5	2.5	3.8
Diapers	3.8	5.7	5.3	4.9
	99.90	100	100	100

1.1.6 Guidelines for the Design of the Disposal Site

The descriptions of the three methods of modified landfilling are generally good. For clarity, a definition of a "cell" and an explanation of dimensions of each cell would be helpful. Worth noting is how waste density varies and, subsequently, site operations will need to be adjusted accordingly.

1.1.7 Regulatory Review

A discussion of internal reporting and monitoring would be useful in this section. A system may be implemented to promote the interrelation between staff and management to ensure environmental compliance. Regulatory requirements associated with each job/task or the organisation as a whole should be identified and then clear roles, responsibilities and authorities can be defined for each job in order to comply with any and/or all regulations.

There should be a brief discussion of due diligence as defined as (i) establishing a proper system to prevent contravention of environmental standards and (ii) taking reasonable steps to ensure effective operation of a system. This should include:

- Administration and organisation of environmental matters
- Environmental standards to be met
- Emergency response
- Employees' environmental awareness and training
- Potential or actual charges, cleanup orders or civil actions

The advent of the Mackenzie Valley Resource Management Act and the various aboriginal/government co-management boards has vastly changed the regulatory environment in the NWT. Since the Heinke and Wong Guidelines were developed, the following boards were created:

- Mackenzie Valley Land and Water Board
- Gwich'in Land and Water Board
- Gwich'in Land Use Planning Board
- Gwich'in Renewable Resources Board
- Sahtu Land and Water Board
- Sahtu Land Use Planning Board

Although now established, these boards have not yet processed many developments and thus the regulatory environment is not well understood. The Mackenzie Valley Land and Water Board, for instance, has announced for this report that more strict regulations are forthcoming.

New landfill developments as well as significant changes to existing sites would trigger review by the appropriate Board. The *Mackenzie Valley Resource Management Act* replaces the *Canadian Environmental Assessment Act* in the Mackenzie Valley. As of March 9, 2000 the Government of

Canada and the Environmental Impact Review Board (EIRB) for the Inuvialuit Settlement Region have outlined how the environmental assessment process of the EIRB under the Inuvialuit Final Agreement may be substituted for a panel review under the *Canadian Environmental Assessment Act*.

Another significant regulatory change in the NWT is the adoption of the Canada-Wide Standard for Dioxins and Furans (CCME. 2001), which prohibits open burning. Open burning has always been tolerated in the North as a means of solid waste volume reduction. Adoption of this new Standard clearly announces to communities that improving air quality is now a priority.

1.2 COMMUNITY WORKS MANAGEMENT SYSTEM / MAINTENANCE MANAGEMENT OPERATING SYSTEM

The CWMS is a task based maintenance management system developed in 1990 by MACA. The system is made of several parts, each contributing to the overall running of the system. The parts include:

- An inventory of assets to be maintained
- Quality standards to which assets are to be maintained
- Maintenance procedures and production levels
- A work order system to authorise work
- A maintenance schedule
- Stock control
- A method to collect data and report results
- A method to develop annual budgets and work programs

The CWMS is a paper-based system. The MMOS is a computer-based system developed using the identical algorithm as the CWMS.

1.3 SOLID WASTE ASSOCIATION OF NORTH AMERICA (SWANA)

The Solid Waste Association of North America's mission is "advancing the practice of environmentally and economically sound management of municipal solid waste in North America." Best known for their training and certification of landfill managers and operators, SWANA is a resource network for solid waste professionals in North America. SWANA has the following organisation:

- Training and Certification Programs

- Manager of Landfill Operations (MOLO) Training Course and Certification Examination

- WASTECON
  - Organises a yearly technical conference for solid waste professionals

- Technical Divisions (8 divisions providing factual information);
  - Collection & Transfer
  - Communication, Education & Marketing
  - Landfill Gas Management
  - Landfill Management
  - Planning & Management
  - Special Waste Management
  - Waste Reduction, Recycling & Composting
  - Waste-to-Energy

- Advocacy Programs
  - Advocates environmentally and economically sound solid waste legislation and regulations

- Specialities/Symposia Training
  - Provides training courses and hosts conferences on such topics as "Landfill Gas Basics Course" and the "10th Annual Waste-to-Energy Conference."

The Manager of Landfill Operations (MOLO) course material and general material available through SWANA's web pages have been reviewed for this report. The material serves landfill operations throughout North America, but to be useful to most jurisdictions, it focuses on large-scale municipal landfill operations in moderate climate zones.

1.3.1 SWANA Objectives

SWANA members universally hold the principle that "local governments are responsible for solid waste management within their jurisdictions, but not necessarily the ownership or operation of solid waste management systems." While local governments may contract out some or all of their solid waste operations, they must remain accountable to the public. SWANA maintains that solid waste management is strongly grounded in the need to protect public health, safeguard the environment and conserve and recover material and energy resources. Solid waste management decisions must reflect community values and are therefore an essential prerogative of local government. This is not contrary to

private sector provision of services, but instead establishes the foundation for responsible partnerships between local governments and private service providers.

1.3.2 The Role of Sanitary Landfills

This section has some very useful definitions of solid waste presented in a glossary format.
Generation of municipal solid waste data is derived from US Environmental Protection Agency (EPA) data. Although generally useful, data includes yard trimmings yet does not include diapers. A section of no relevance is State/Provincial and US Federal Rules.

SWANA provides data in this section that may be of interest:

- Proximate analysis (total waste stream)
- Ultimate analysis (individual waste components)
- Heating value of waste
- Leachate characteristics
- Landfill gas composition

1.3.3 Site Selection Basics

A detailed overview is presented of site selection. Mention is made of the difficulty of choosing a site that is unobjectionable. The selection criteria provided by communities are outlined in a general format (e.g. Sites must be "x" many feet from a body of water…")

US regulations are mentioned throughout this section and a map of US seismic impact zones is presented.

1.3.4 Complying with Design Requirements

This section is very practical in nature with explanations of reading and understanding landfill plans, basic mathematics for landfill managers and field measurement techniques. Since landfill operators are not expected to design a landfill, the information in this section is geared toward the landfill operator's compliance of the site design.

1.3.5 Waste Acceptance and Screening

Waste prohibited by US federal law is listed and discussed. Very practical information is provided on refrigerant-containing appliances, blood-borne pathogen waste and other commonly prohibited wastes. A general discussion is provided on record-keeping and notification requirements.

1.3.6 Leachate, Landfill Gas and Settlement

This section is a somewhat academic description of landfill phenomena that occur over time, namely leachate production, gas generation, waste decomposition and settlement.

1.3.7 Control Processes for Landfill Gas and Leachate

This section consists of a very long and detailed lesson in the control, treatment and management of landfill gas and leachate.

1.3.8 Operation and Maintenance

This very practical section contains information on practices that contribute to or reduce the generation of leachate and gas, the pros and cons of various types of cover, factors that contribute to operational health and nuisance problems and unsafe practices. It also contains useful information on equipment types and operation (e.g. maximum compaction efficiency is obtained in three to five passes over waste in a landfill).

1.3.9 Closure and Post Closure

Closure plans; post-closure monitoring and maintenance, and final cover design are provided.

1.3.10 Landfill Economics

This section includes the components of landfill cost as well as the fundamentals of a sensitivity analysis for key cost factors. A model site was considered whereby an economic analysis was varied to evaluate eight factors that affect the total disposal cost in different ways. For just this example, the disposal costs (in 1990 US$) could vary from $10 to $50 per ton.

1.3.11 State/Provincial Legislation

This section is a short checklist for operators to use to find out information pertinent to their facilities.

1.3.12 Site Safety and Security

Site safety and security is reviewed in a practical format. Details of confined space maintenance are provided in detail.

1.3.13 Personnel Training

This is a short overview to establish minimum training goals at landfill facilities.

1.4 HEINKE AND WONG/SWANA COMPARISON

1.4.1 Comparison of Solid Waste Data

Component (%)	SWANA (2000)▪	Heinke and Wong (1991)•	Fort Good Hope O & M Manual (FSC (2000))
All paper products	32.8	32.7	27.0
Glass▫	5.7	2.4	5.7
Total metal	6.9	10.1	10.6
Plastic, rubber, leather	18.2	10.3	14.0
Textiles	3.9	3.6	3.8
Wood	9.3	12.6	9.9
Food wastes	8.5	18.8	20.3
Yard wastes	11.0	N/a	N/a
Diapers	N/a	8.4	3.8
Dirt	N/a	3.7	4.9
Other▫	3.7	N/a	N/a
	100	100	100

▫ Includes ceramics for Heinke and Wong (1991) and Fort Good Hope O & M Manual (2000).
▪ Discards after recovery for recycling and composting of yard trimmings.
• Communities averaged: Iqaluit, Pangnirtung, and Broughton Island (all in Nunavut).

Generation Rate Comparison:

	SWANA (2000) ▫	Heinke and Wong (1991)•	Fort Good Hope O & M Manual (FSC (2000))
Residential Generation Rate (tonnes/capita/day)	0.0012	0.0014	0.0015

▫ Prior to recycling and composting

Resident Solid Waste Density Comparison:

	SWANA (1991)			NWT Standard
		Average	Range	
Municipal Solid Waste Density (tonnes/m^3)	Uncompacted at curb	0.148	0.089 - 0.178	0.099
	Compacted in truck	0.445	0.297 - 0.593	N/a
	Landfill	0.593	0.445 - 0.741	

1.5 SECTION SUMMARY

The current guidelines Heinke and Wong, Community Works Management System (CWMS) and Maintenance Management Operation System (MMOS) and the operational standard set out by the Solid Waste Association of North America (SWANA), each provide details of landfill management practices. The Heinke and Wong guidelines could be improved by updating the information to reflect changes since 1990. These changes include the inception of Nunavut in 1999, the creation of various co-management land and water boards, the enacting of *Mackenzie Valley Resource Management Act* in 1998, and the development of various new territorial guidelines. Further, the Guidelines could be improved with SWANA information such as:

- More detailed SWANA site selection information;
- SWANA recommends a 30 year design life rather than "at least 20 year" design life recommended in Heinke and Wong;
- SWANA's screening of hazardous waste section would be useful in the Guidelines particularly the record-keeping and notification requirements;
- Leachate and landfill gas information would be only pertinent to the North if environmental monitoring of a particular site proved these issues are a concern; the SWANA information is a useful basic overview;
- Information on settlement, as outlined in SWANA but with the addition of permafrost effects, would be useful in the Guidelines;
- Closure and post-closure is not considered in the scope of Heinke and Wong and should be;
- The principles given in the Economics section of SWANA are useful but the dated and US dollar figures need to be recognized;

- The checklist provided in SWANA's State/Provincial Regulations section would be an effective tool in the Guidelines; and
- Details provided in SWANA are superfluous for the NWT application (e.g. confined space details provided in the safety section of SWANA is of little relevance to the North and SWANA's control processes for landfill gas and leachate section is far too detailed to be of much use in the NWT guidelines).

2. EXAMINATION OF OPERATOR TRAINING / CERTIFICATION

Currently, water treatment plant and sanitation environmental operators do not need to be certified to operate a facility in the Northwest Territories. Each facility in the Northwest Territories is able to distribute water pursuant to a federal water licence. These facilities have been voluntarily classified by the NTWWA. The Solid Waste Association of North America trains and certifies landfill operators in their MOLO (Manager of Landfill Operations) program. Alberta has developed a certification program that is based on MOLO. Health and Safety legislation also provides general rights and responsibilities that are applicable to landfill operations.

2.1 NORTHERN TERRITORIES WATER AND WASTE ASSOCIATION (NTWWA)

At this time, the NTWWA administers a voluntary training and certification program in the Northwest Territories. Among its objectives, the NTWWA:

1. Promotes the advancement of knowledge in the design, construction, operation, and management of water works, wastewater treatment and disposal works, and solid waste site works;

2. Encourages amongst its members a friendly exchange of information and experience in an effort to continuously improve the provision of water and sanitation services provided to the public; and,

3. Fosters the improvement of the professional status of all personnel engaged in all aspects of water and sanitation services to the public.

Voluntary certification of operators first begins with a voluntary classification of the facility where the operator is employed. The classification will clearly identify the category of the facility; both those eligible under the reciprocity agreement, as well as those facilities that are unique to the Northwest Territories. This classification is also done to determine the class of certification the operator should possess to operate such a facility. Once certified at the appropriate class, the operator may continue to train for higher classes.

The classification of facilities and the certification of operators are strictly voluntary. Operators need not be certified or, once certified, are not required to continue in the program.

The operator in charge of the facility can hold a certificate equal to or greater than the facility classification.

Certification of operators is based on a combination of formal education, experience, training, and examination. Certification will be designated based on the type and complexity of the facility.

NTWWA provides training to support the following operator Classifications:

- Small Water Systems
- Small Wastewater Systems - Lagoons
- Class 1 Water Treatment Plant Operations;
- Class 2 Water Treatment Plant Operations;
- Class 1 Water Distribution; and
- Class 1 Wastewater Treatment Plant Operations.

The NTWWA provides a full reciprocity program. If an operator achieves a certification in a member province, that certification will be recognized by the NTWWA. The NTWWA adopts the basic principles of the Association of Boards of Certification (ABC) guidelines.

2.2 ASSOCIATION OF BOARDS OF CERTIFICATION (ABC)

The Association of Boards of Certification (ABC) is an organization that has been recognized by several jurisdictions for its standards and guidelines for the classification of potable water and for the certification of operators. The ABC has been assisting states and provinces with environmental certification programs since 1972. Their membership consists of over 80 certifying authorities representing over 40 states and 10 Canadian provinces who certify over 150,000 water and wastewater treatment operators, laboratory analysts, and backflow prevention assembly testers.

2.3 SOLID WASTE ASSOCIATION OF NORTH AMERICA (SWANA)

The Solid Waste Association of North America (SWANA) serves to train and certify managers of solid waste management facilities and systems. Training courses are held periodically in major centres across North America. SWANA points out in their training manual that more stringent environmental regulations have brought about increasingly complex systems and facilities to assure compliance and environmental integrity. It follows from this a need for assuring proper qualifications of solid waste facility managers charged with this responsibility.

The program for certification in the Manager of Landfill Operations (MOLO) discipline has three categories: Manager, Technical Associate and Inspector, where the first two categories differ in years of experience. The training course is three days in duration and includes both in-class course work and field exercises. The certification examination follows. There is a three-year term for certification that

requires 30 hours of continuing education during this period. SWANA certified individuals are expected to follow and uphold a code of ethics.

The MOLO course is intended for operator of solid waste facilities not for those designing or regulating the facilities. There is information on site selection, for example, but understandably, the focus is on complying with design requirements.

The course material is thorough and comprehensive, comprised of 224 pages of text and diagrams. The following is the course outline.

Lesson I: Introduction & Pre-Test
Lesson II: The Role of Sanitary Landfills in Integrated Municipal Solid Waste Management
Lesson III: Basics of Site Selection
Lesson IV: Complying With Design Requirements
Lesson V: Waste Acceptance and Screening
Lesson VI: Leachate, Landfill Gas and Settlement
Lesson VII: Control Processes for LFG and Leachate
Lesson VIII: Homework
Lesson IX: Operational Techniques
Lesson X: Compliance and Inspection
Lesson XI: Field Exercise
Lesson XII: Closure and Post-Closure
Lesson XIII: Landfill Economics
Lesson XIV: State/Provincial Regulations
Lesson XV: Site Safety and Security
Lesson XVI: Training On-Site Personnel

The 2001 Course provides an additional section on Communications and minor changes were made to other sections (a complete 2001 manual was not available for review at this time).

Although very informative, much of the material presented is applicable to large, southern solid waste facilities. Often the level of sophistication presented is not warranted for cities with populations under a million. In addition, no population breakpoints for landfilling techniques are given. An argument may be made that although such information may not be directly applicable in the North, it is important for site operators to be made aware of more sophisticated techniques and have a general understanding of solid waste management systems.

2.4 HEALTH AND SAFETY LEGISLATION REQUIREMENTS

The Northwest Territories Safety Act sets out general rights and responsibilities, basic requirements and fundamental principals of occupational health and safety law in the NWT.

Every employer shall:

1. Maintain his establishment in such a manner that the safety and health of persons in the establishment are not likely to be endangered;
2. Take all reasonable precautions and adopt and carry out all reasonable techniques and procedures to ensure the safety and health of every person in the establishment;
3. Provide first aid service requirements set out in legislation pertaining to his class of establishment;
4. Maintain for reference by all his workers and copy of the Safety Act and Ordinance; and
5. Provide personal protective equipment as required.

Workers are required to:

1. Know their rights;
2. Work safely;
3. Wear personal protective equipment as appropriate;
4. Report all hazards; and
5. Report all accidents.

2.5 ALBERTA LANDFILL OPERATOR CERTIFICATION

The Alberta Municipal Waste Management Operator Certification Program was developed following the passing of the Waste Control Regulation under the Alberta *Environmental Protection and Enhancement Act* in September 1996, which stated that certain classes of landfills and compost facilities shall be supervised by certified operator(s) during their hours of operation. The following objectives were established by Alberta Environment for the Program:

- To enhance environmental quality;
- To protect public safety;
- To assure regulatory compliance;
- To minimise operation and maintenance costs;
- To achieve optimum use of landfill and composting facilities; and

- To ensure waste reduction objectives are met.

Varying levels of certification are required, depending on the size and complexity of the facility being operated. The Program is designed for operators of facilities that serve municipalities, and does not apply to operators of non-municipal facilities or of facilities that are approved to receive hazardous waste. Full Municipal certificates are issued to operators who meet the complete education, experience and examination requirements of the Program, while temporary conditional certificates may be issued on a restricted 'grandfather' basis to experienced operators who work (and continue to work) at a particular facility prior to the requirement for certification.

Operators who meet the education and experience requirements of the Program are eligible to write the Certification Exam. This exam comprises 100 multiple choice questions selected from an exam bank developed by Alberta Environment, Northern Alberta Institute of Technology, Olds College and other key stakeholders within Alberta. The questions cover the following range of operational issues:

- **Landfill facilities critical tasks** – including site management, environmental monitoring, waste handling and screening, general site maintenance and operations, scale operations, equipment operation, site administration, safety, public relations and transfer stations; and
- **Compost facilities critical tasks** – including feedstock management, health and safety, site management, regulatory compliance, compost chemistry and ecology, process control, equipment operation, quality control, information management, communications, public relations and marketing.

A passing grade for the examination is 70%. Unsuccessful candidates may undertake re-writes within not less than 6 months and not more than 1 year of the date of the original examination. Candidates who fail three successive examinations must provide evidence of relevant additional training prior to being eligible for re-writes.

The program allows operators to upgrade their certificates by one facility category each year, conditional on evidence of appropriate experience. Certificates must be renewed every three years, and operators must demonstrate ongoing operational duties during at least 70% of the preceding three years for renewal applications to be considered. The certificates of those operators who cannot meet this requirement are considered 'inactive'. Certificates may be re-activated by application to Alberta Environment, and potentially by successful re-examination (depending on circumstances).

The program is governed by a Certification Advisory Committee that comprises a maximum of 12 people appointed from the following areas of expertise by the Minister of Environment:

- One representative from the Alberta Environment Municipal Program Development Branch;
- At least one representative from management ranks of municipal government;
- One representative from the Solid Waste Association of North America (SWANA);

- At least one faculty member of a post-secondary institution, who conducts training related to municipal solid waste facility operations;
- Four active operating personnel from landfill and composting categories;
- One representative from Regional Approvals division of Alberta Environment; and
- One other person appointed by the Minister.

Each member serves a three-year term on the Committee.

The Alberta Program generally follows the guidelines established by SWANA for waste management certification, with modifications where appropriate to accommodate Albertan waste management conditions and legislation.

2.6 CERTIFICATION SUMMARY

The GNWT has spent millions and millions of capital and O&M dollars on the disposal of municipal solid waste, and the design construction and restoration of MSW sites. But virtually no investment has been made to train the operators of these sites to protect the GNWT's investment.

The NTWWA provides some four hours of training for operations, however, does not provide certification. Currently, the GNWT is entertaining the idea of mandatory certification of water treatment plant operators. Such certification is preceded by specialized training, examination and operations experience.

The Solid Waste Association of North America (SWANA) trains and certifies landfill operators in their MOLO (Manager of Landfill Operations) program. Alberta has developed a certification program that is based on MOLO. Alaska MOLO certifies its operators of large facilities and provides a more basic, northern applicable program for its small, rural facilities.

The GNWT should also consider developing a specialized MSW training program that could, in future, lead to some form of certification. This is the same model used by Alberta and others. First, certification of water and wastewater treatment operators, followed by certification of solid waste operators.

3. LANDFILL MANAGEMENT IN VARIOUS NORTHERN JURISDICTIONS

Current landfill management practices and recent advances to the regulations or guidelines in other northern jurisdictions have been compiled and analysed. Interviews were conducted with officials from Alaska, Yukon, Nunavut, Nord-du-Québec, Sweden and Greenland. This review serves to determine if the Northwest Territories is current in its guidelines, and if not, which practices are successful in other jurisdictions that may be included to improve the guidelines. The Cold Regions Utilities Monograph, since it was developed by experts in cold climate engineering, is also included in the review.

3.1 ALASKA

The state of Alaska is comparable to the Northwest Territories insofar as it is northern and has small remote communities. Its population, however, is over 600,000 and there are several large cities.

The Program Manager for the Alaska Department of Environment and Conservation, Heather Stockard and the Engineer responsible for drafting the solid waste regulations, Glenn Miller were interviewed via conference call for the information that follows.

3.1.1 Background

Solid waste landfills in Alaska, including municipal, military and industrial facilities, are categorized in three classes as follows.

Class I	▪ more than 20 tons of waste per day
Class II	▪ less than 20 tons of waste per day; ▪ located on a site where there is no evidence of groundwater pollution caused or contributed to by the landfill; ▪ is not connected by road to a Class I facility or, if connected by road, is located more than 50 miles from a Class I facility; and ▪ serves a community with interrupted transportation to a Class I facility for greater than 3 months a year
Class III	▪ less than 5 tons of waste per day; ▪ is not connected by road to a Class I facility or, if connected by road, is located more than 50 miles from a Class I facility

There are 330 communities (cities, villages, and other population centres with greater than 25 people) in Alaska and about 216 communities have a solid waste facility. Only 10 of these may be considered modified landfills. About 114 communities transport their waste to a regional landfill.

Given that many communities are linked by a highway system, there is a regional approach to solid waste management whereby smaller communities transport their waste to a large facility. The Anchorage Regional Landfill, for example, serves a population of 240,000 accepting municipal waste from the City of Anchorage proper, nine surrounding communities and three military bases. About 52 percent of the waste generated in the state is deposited in the Anchorage Regional Landfill.

3.1.2 Qualification

The guideline for the state of Alaska is entitled *Title 18, Environmental Conservation Chapter 60 Solid Waste Management* (18 ACC 60). These are legislative regulations, rather than guidelines, and apply to municipal solid waste as well as that of military bases, mining and recreational camps and industry.

The regulations also serve as instructions for the permitting of solid waste facilities. Recommendations may not always be presented; in some instances, the permit application will require landfill facilities to present for approval details of the design and operation and maintenance procedures. For example, no guideline is given for compaction of waste but descriptions of such operational procedures are required in the permitting process of landfill facilities.

The solid waste regulations are very thorough and specify sophisticated and advanced solid waste technologies and management systems. The regulations apply to new and existing landfills as well as landfill expansions.

For simplicity, Alaska does have guidelines available for Class III solid waste facilities, those small, rural and remote facilities that accept less than 5 tons of municipal solid waste a day and are usually in communities with populations less than 800 people. This 14-page guidance document presents sections from the 18 ACC 60 regulations pertinent to Class III landfills only and gives the steps required to establish, permit, operate and close the facility.

3.1.3 Siting Criteria

The Alaska regulation specifies a minimum setback of 50 feet between the waste management area and the property line of the facility. In addition, dust, odour, noise, traffic, and other effects from the operation of the facility must not become a nuisance or a hazard to the public health, safety, or welfare.

New solid waste facilities must exceed a 5 mile radius of an airport and for any new or existing site; it must be proven that the location is not a bird hazard.

Solid waste facilities may not be located on a surface that is within 10 feet of the highest measured level of an aquifer of resource value unless the landfill is constructed two feet or more above the natural

ground surface. No specific limitations are required of siting facilities near surface waters (although run-on control measures, leachate control measures and stormwater run-off systems are all specified).

The siting criterion for permafrost zones is currently being rewritten. There will be an exemption for gas and groundwater monitoring for sites located in permafrost areas. Thermal monitoring will be required of sites to confirm its permafrost status.

Specifications of seismic impact zones, fault areas, unstable areas and wetlands are also given in the regulations.

3.1.4 Design Criteria

The regulations for landfill design approach follow the U.S. Federal guidelines: for Class I facilities, 2 feet of clay or geomembrane is required and for Class II or III facilities a lining is not necessary unless required in its permit.

The owner or operator of a Class I or Class II facility is to cover solid waste with six inches of earthen material at the end of each operating day, or at more frequent intervals if necessary to control disease vectors, fire, odour, blowing litter, animals, or scavenging.

If a facility is being filled with municipal waste combustion ash, no cover is necessary unless blowing dust causes or contributes to a nuisance or a violation of the air quality standards, or unless animals are feeding on unburned scraps in the waste. The department will approve an alternative material of an alternative thickness, other than that specified if the owner or operator demonstrates that the alternative will control disease vectors, wildlife attraction, fire, odour, blowing litter, and scavenging, without posing a threat to public health or the environment. Further, the department will waive the cover requirements if it can be demonstrated that there are extreme seasonal climatic conditions that make meeting the requirements impractical and that public health and the environment will not be adversely affected.

3.1.5 Collection Procedures

Collection of municipal solid waste is left to the discretion of municipalities and is not included in the solid waste regulations.

3.1.6 Operational Criteria

The Alaska regulations refer to the U.S. federal definition of hazardous wastes for wastes prohibited in landfills. If such wastes are generated by households, they are collected and stored separately at the facility and transported south when convenient. Industrial hazardous wastes are not permitted at municipal landfill facilities. Except for a Class III facility, the owner or operator of a landfill shall

implement a program at the facility to detect and prevent the disposal of regulated hazardous waste and PCB waste. The program must include the following items at a minimum:

1. Random inspections of incoming loads or other methods to minimise the risk that incoming loads will contain a regulated hazardous waste or PCB waste;
2. Maintenance of records of any inspections; and
3. Training of appropriate facility personnel to recognise regulated hazardous waste and PCB waste (training may include that described in the EPA's technical manual entitled Solid Waste Disposal Facility Criteria, Subpart C Operating Criteria, EPA 530-R-93-017, November 1993, as amended through April 13, 1998).

The regulations do not specify how solid waste facilities should segregate their wastes. Municipalities, however, use their discretion for waste segregation. The organisation of waste segregation varies from community to community, but usually appliances, motors and wood products are located in separate area at the facility. Scavenging is not addressed in the regulations, but it is accepted as a means of reducing waste volume through reuse. Some more organized landfills have restricted the public to certain times for scavenging, and safety measures (reflective vests, etc.) are implemented.

Certification of landfill operators is dependent upon the size of the facility. For large landfills (Class I), SWANA/MOLO certification is required. For smaller landfills, Alaska has developed their own training program that is conducted periodically at hub communities. The Rural Alaska Landfill Operator (RALO) certification program has the following curriculum:

- Solid Waste Planning/Regional Sharing
- General operations & types of landfill equipment
- Operations Planning, Management and Public Access Control
- Safety and Infection Control
- State Regulations and Permits
- Waste Collection
- Open Burning & Incineration Methods
- Waste Separation & Screening
- Wildlife Control
- Waste Transfer Sites
- Household Hazardous Waste
- Solid Waste Management Plan

- Regional Solid Waste Management

The Alaska regulations make no mention of municipal waste volume estimations. The landfill permits do require a survey near the end of the permit expiration. Waste compaction recommendations are not given in the regulations. Alaska government officials note that SWANA recommendations for waste compaction are not applicable to the North due to differences in equipment and climatic conditions.

One contingency specified for extreme weather conditions is that Class I and II sites are not required to uphold their cover requirements. The requirement of 6 inches of daily cover can be waived if the owner or operator demonstrates that there are extreme seasonal climatic conditions that make meeting the requirements impractical and that public health and the environment will not be adversely affected.

The regulations require that efforts be made to reduce disease vectors, wildlife and domestic animals from entering solid waste facilities, but it is up to the discretion of each community as to what measures are taken. All Class I solid waste facilities have an electric fence for the prevention of wildlife entering the site.

Open burning is prohibited for Class I and II facilities but is allowed with a permit for Class III facilities.

3.1.7 Monitoring

The owner or operator of solid waste facilities must visually inspect the site at least once a month for signs of damage or potential damage to any component of the facility from settlement, ponding, leakage, thermal instability, frost action, erosion, thawing of the waste, or operations at the facility. Further, any violations of permit conditions or regulation requirements should be monitored. A five-year record of visual monitoring must be kept.

Surface and ground water monitoring procedures are very detailed in the regulations. Surface water must be sampled at points of compliance selected by the permittee and approved by the department. For surface water monitoring, the points of compliance must be chosen so that highest concentrations of hazardous constituents migrating off the facility will be detected and so that interference from sources of pollution unrelated to the facility's solid waste management operations will be minimized. The point of compliance will normally be located no more than 50 feet outside a waste management area boundary and on land owned by the owner of the facility. Details are provided on groundwater monitoring well design, installation, and decommissioning. Sampling procedures must be submitted for approval; the regulations outlines all the criteria required in the sampling protocol including the line of communications required of all sampling results.

Further, the Alaska regulations outline in considerable detail corrective action for problems discovered during visual, surface/ground water monitoring or during an inspection.

3.1.8 Regulatory Requirements

In 1996, Alaska became an "approved state" and was then required to incorporate the federal rules for solid waste management. At this time, the solid waste regulations were completely rewritten and its requirements became more thorough and detailed. Additional powers were given to the government authority for solid waste management, the Department of Environmental Conservation, Division of Environmental Health. Sections of the regulations are continuously updated as need be, such as the current update of the permafrost regulation. There are no anticipated changes to any applicable acts, guidelines or regulations.

The Department of Environmental Conservation may manage some community landfill operations while others are privately operated. This department also administers the permitting of landfills. One of their goals is to permit all landfills that may be considered a Class III type, that is, small, rural and remote. Landfill operations are required to keep records for 5 years, and submit monitoring results and operational reports to the Department of Environmental Conservation. Inspections are routinely conducted by this department. For Class III landfills, it is often only through public complaint or visual inspection that air quality, ground or surface water monitoring will be required.

3.1.9 Closure and Post-Closure

Closure standards and post-closure care is detailed in the regulations. Municipal solid waste facilities require an 18" minimum infiltration layer with a permeability no greater than 1×10^{-5} cm/s and a minimum of 6" cover of earthen material capable of sustaining native plant growth. Details are provided for post-closure monitoring programs.

Financial assurance requirements are required of the solid waste facility.

3.2 YUKON

Yukon has a population density twice that of the Northwest Territories. Although there are several small, remote communities, about 70% of the population live in the capital city, Whitehorse.
Dave Bidniak of the Community and Transport Services (C&TS) Department of the Yukon Government was interviewed for this section. Additional information was collected via email from Shannon Jansen of the Renewable Resources Department.

3.2.1 Background

There are 27 waste disposal facilities in the Yukon. Eight of these facilities are operated by municipalities (Whitehorse, Haines Junction, Watson Lake, Dawson City, Mayo, Faro, Carmacks, and Teslin) and the remaining 19 are in unincorporated communities and are operated by Community & Transport Services of the Yukon government. There are also three highway maintenance camps that operate small disposal facilities at the campsites.

3.2.2 Qualification

For solid waste management in the Yukon, there is the *Solid Waste Regulation* of the *Environment Act*. Like Alaska, these are legislative regulations, rather than guidelines. As a result, recommendations are often not presented, but rather there is a requirement for facilities to produce a Management Plan and details of what goes into such a plan are itemized under Section 96 of the Act. It is up to the community developing a solid waste facility to present this plan for regulatory approval.

Like the Northwest Territories, Yukon has more than one government branch involved in landfill issues. The Department of Renewable Resources is the Yukon Government authority for solid waste legislation. C&TS is responsible for landfills at all Unincorporated Communities, and is involved in capital projects and operation and maintenance at landfill facilities.

The Renewable Resources department has developed *Guidelines for the Preparation of Solid Waste Management Plans* to be used by consulting engineers in their preparation of the Regulations' requirement of a Solid Waste Management Plan. This 2-page document details mandatory content, factors to consider (environmental, social and legal) and other suggestions to facilitate the approval process. It is up to the Plan developer to design how best to comply with the guideline.

3.2.3 Future Guidelines – Haines Junction Example

Community and Transportation Services official, Terry Bidniak, relayed that Guidelines similar to that of the Northwest Territories may be developed in the near future. C&TS commissioned a plan to be prepared for the Village of Haines Junction, not only to fulfil the Solid Waste Management Plan requirement for that municipality, but also to be used as a template for all other municipalities' plans, whether incorporated or not (Jansen. Personal Correspondence. 2001). However, the specific methods that will be used by Haines Junction may or may not be applicable to other waste disposal sites throughout the Territory. Each municipality and C&TS will have to examine the Haines Junction plan and determine which sections/methods/etc. are applicable to their particular site, when preparing their own plans. It should be stressed that although the Haines Junction plan is intended to be used as a

template, it is not a guideline per se (i.e. it is not an indication of policy put out by Renewable Resources).

The Haines Junction Solid Waste Management Plan is very thorough and details methods for managing solid waste for the next decade and beyond. This plan is useful as a template to demonstrate the kind of information that is required, and the procedures used to obtain that information. Such particulars as general waste generation calculations and how to extend the life of trench landfills are provided. With additional generalisation of this document, a guideline will be developed for the design, operation and maintenance of landfill facilities in the Yukon.

3.2.4 Siting Criteria

The Regulations do not have a specific section for siting criteria of landfill facilities. It is required of the permit applicant, however, to provide a description of the location and the rationale behind selecting the location. Further, a description of the physical and natural environment must be provided.

Schedule 1, Section 6 of the Regulations (entitled "Operating Standards for Dumps") requires that the active working area be located a minimum of 100 metres from the high water mark of any waterway and at least 1.5 metres from the groundwater table. The active working area must also be located a minimum of 50 metres from any highway and a screen of vegetation of at least 10 metres must be maintained so that the landfill is not visible from the highway.

3.2.5 Design Criteria

Landfills are required to cover every half metre of solid waste deposited in the active working area by approximately 10 centimetres of soil or comparable material. Other design parameters must be provided in the Solid Waste Management Plan submitted by the permittee of the landfill. For purposes of preparing such a plan, the planning period shall be ten years from the date of permit application.

3.2.6 Collection Procedures

Collection of municipal solid waste is left to the discretion of municipalities and is not included in the solid waste regulations.

3.2.7 Operational Criteria

The *Solid Waste Regulations* refers to the *Special Waste Regulations* for the handling of hazardous waste. No waste is specifically prohibited, although segregation of hazardous waste at the landfill is required.

Specifics of landfill operations are required in the Solid Waste Management Plan. The Regulations do state that waste shall be deposited such that the environment is protected, littering is minimized, attraction of wildlife is minimized, etc. Incineration or open burning of waste must be done in accordance with the *Air Emissions Regulations*, the *Forest Protection Act*, and the *Yukon Forest Protection Regulations*.

One contingency for extreme weather is given: the cover requirement waived between November 15 and April 15 if cover material cannot be reasonably obtained.

3.2.8 Monitoring

The owner or operator of solid waste facilities must monitor surface and groundwater only if required in the landfill permit. No details are provided in the regulations.

3.2.9 Regulatory Requirements

As previously mentioned, landfills must be permitted by the Department of Renewable Resources. This process involves the submission of a 10-year Solid Waste Management Plan describing in detail the design, construction, operation, upgrading, closure and post-closure plans. Municipalities and the Department of Community & Transportation Services must submit these Plans before July, 2002 (extended from the published date of January, 2002).

Details are provided in the Regulations regarding the records that must be kept on landfill management. A public register must be established for this information. An Environmental Protection Officer may inspect landfill facilities from time to time. Government Officials stress that a heavy-handed approach is not taken with respect to enforcing the *Environment Act*. Rather, government departments will go into the communities and provide advice on how to best manage their solid waste.

The Regulations provides details for landfill site emergencies and spills.

3.2.10 Closure and Post-Closure

Landfill facilities require waste compaction, one metre of cover and revegetation upon site closure.

3.3 KATIVIK

Nord-du-Québec is comprised of two regions: Kativik (north of the 55 parallel) and Baie-James (south of the 55 parallel). Kativik supports a mere 9 341 people in 15 communities. Being a northern, remote

region of a mainly southern province sets this area apart from the more autonomous regions addressed in this report.

Stéphan Ferrero, Project Engineer, Nord-du-Québec division of the Québec government was interviewed for the following information.

3.3.1 Background

There are 14 landfills in Kativik (1 in each community) and one site considered a garbage dump near Kuujjuarapik that serves at any one time roughly 1200 Inuit during camp periods.

3.3.2 Qualification

Kativik is administered by the government responsible for Nord-du-Québec and so all information gathered for this region applies to both the north and south regions of Nord-du- Québec. Further, solid waste management legislation for this area was developed for all of Québec. Rather than include the entire Québec legislation in this review, only the applicable criteria garnered from the interview with Stéphan Ferrero, an engineer with the Nord-du-Québec government, are considered. It must be understood that when no information is given, it is because the provincial legislation applies.

A brief section pertaining to Nord-du-Québec has recently been developed to include in the provincial solid waste regulations. These two pages of draft regulations are so far only available in French. These regulations are three years in the making and will be adopted in the near future.

A government document translated as the *Québecois Solid Waste Management Action Plan 1998-2008* includes a substantial section on Solid Waste Management in Nord-du-Québec. This plan provides some insight into Kativik landfill operations, and is therefore included in this review.

3.3.3 Siting Criteria

The draft regulations stipulate a siting restriction of 150 metres from any waterway with the exception of a 500 metre siting restriction for a community drinking water source.

Although the official interviewed noted that the federal restriction for siting landfill facilities in the vicinity of airports is unrealistic in the north, and complied with in one community, the new regulations omit this criterion altogether. Possibly, this oversight may be addressed when the regulations are finalized.

3.3.4 Design Criteria

No specific design criteria are given in the new Nord-du-Québec regulations. The government official interviewed stated that landfills in Kativik are quite basic in design. The design for facilities is provided during the permitting process.

3.3.5 Collection Procedures

Collection of municipal solid waste is left to the discretion of municipalities and is not included in the solid waste regulations.

3.3.6 Operational Criteria

The draft regulations stipulate one operational criterion: permits will be required for open burning at landfill facilities.

3.3.7 Advances

The Nord-du-Québec government is currently looking into inviting Inuit communities to participate in a trial project for small-scale incineration. This is in response to haphazard solid waste management practices found in the most northern communities. Incineration is being considered at this time likely because of the fact that Greenland has recently installed two new incinerators. The proximity to Greenland has resulted in a sharing of solid waste information between the jurisdictions. The official interviewed for this report visited Greenland one year ago to gather such information.

The Nord-du-Québec government is looking into ways of reducing waste and generating revenue through incentives for contractors not to take advantage of dumping at municipal landfills.

Recycling efforts found in the rest of Québec are not found in the north. Only in the James Bay region is there any significant recycling with the assistance of Hydro-Québec. However, in January 2002, the major recycling organisation of Québec, Recyc-Québec plans a visit to Kativik to consider recycling in the region.

3.3.8 Regulatory Requirements

Kativik landfills fall under the jurisdiction of the government of Québec that has separate administration for the Nord-du-Québec region.

New facilities follow an approval process where the community makes a request for a certificate of authorisation that requires the approval of the Minister of Environment, the Landholding Corporation and other stakeholders. These locally managed landfill facilities are granted permits and must undergo subsequent government inspection once a year. Monitoring is conducted on a site-by-site basis and only if a problem is suspected. No annual reporting is conducted.

3.3.9 Closure and Post-Closure

Landfill facilities require a final cover of 30 cm upon site closure.

3.4 NUNAVUT

Nunavut is the least populated and most remote region considered in this review. Since its establishment in 1999, Nunavut has not developed its own guidelines but rather has adopted the Heinke and Wong guideline of the Northwest Territories.

There is one landfill per community in Nunavut.

Dave Parker, Senior Municipal Planning Engineer, Department of Community Government and Transportation (CG&T) was interviewed for this section.

3.4.1 Regulatory Requirements

For new facilities, or expansions of existing facilities, a similar process to the Northwest Territories is used. A proposal for a development is submitted to the Nunavut Water Board and the Nunavut Impact Review Board, which, in turn, circulate for comment to typical stakeholders (e.g. Department of Fisheries and Oceans, Coast Guard, Hunters and Trappers Associations, etc.). This year Nunavut plans to develop an Environmental Assessment Act similar to the Mackenzie Valley Resource Management Act in the NWT.

Monitoring is done on a site by site basis. An impacted site will have a monitoring plan that is administered by a Department of Public Works Project Officer.

3.4.2 Advances

The Nunavut Government official interviewed expects a solid waste guideline to be developed at some point in the future. The Heinke and Wong guideline is still applicable to Nunavut since this region was part of the Northwest Territories when the guideline was developed.

Recycling efforts are sporadic in Nunavut. Iqaluit is working on a recycling program to collect metal cans, glass and possibly plastic. In 27 other communities, there is no formal recycling, although sporadically cans and glass are carried out of communities if there is room in out-going flights. Recyclables are then shipped to a recycler in Ottawa.

Incineration for Iqaluit and Repulse Bay is being considered. The high capital and operating costs are seen as a detriment, but certain unnamed regulators and public groups want to see incineration considered for Nunavut. Hugh Lloyd of Executive and Inter-governmental Affairs, Government of Nunavut, is currently reviewing information from Greenland on small incinerators. He relayed that he is gathering information and will provide a synopsis for the CG&T to assess for applicability to Nunavut.

3.5 SWEDEN

Sweden has a population of 8.8 million occupying a landmass about half the size of the Northwest Territories. The population density of Sweden is approximately 20 people/km^2 compared with a range of 0.01 to 0.4 people/km^2 for the other jurisdictions considered here. Although its climate, geography and socio-economic situation more closely resemble southern Canada, their progressive approach to solid waste management makes Sweden an interesting inclusion in this review.

3.5.1 Background

Sweden has 250 landfill facilities ranging from a few hundred tonnes per year to 250 000 tonnes per year. There is one landfill per community

3.5.2 Qualification

Sweden has one set of regulations for management of solid waste for the entire country, rather than regional regulations as is found in all other jurisdictions reviewed. These directives are based on the European Union (EU) directive, which makes them universally acceptable for all countries in the EU. The Swedish landfill expert interviewed for this section, Thomas Rihm of the RVF(The Swedish Association of Waste Management) stressed that many siting and design criteria are left up to the discretion of the landfill management and they trust that good engineering practices will prevail. Regardless, the details provided are extensive.

The regulations are not yet available in English, but are expected to be in the near future. They will be made available on a web site once translated.

3.5.3 Siting Criteria

The Regulations are applicable to new as well as existing facilities and their lateral expansions. Due to the more densely populated land, Sweden's landfills currently have an average age of 30 years and will tend to undergo expansion rather than the facility close and a new site is developed.

Siting restrictions such as distances from airports, waterways, property boundaries, etc. are not specified in the Regulations. Permafrost is not found in the areas of any Swedish landfills.

3.5.4 Design Criteria

The only design criterion specified in the Regulations pertains to the geological base of landfills. The EU directive specifies a 1.0 metre barrier with a permeability of less than 10^{-9} m/s. Since Sweden varies geologically from much of the rest of Europe, Sweden has developed a criterion that leachate from normal waste must not penetrate the landfill barrier within 50 years and for hazardous waste, a limit of 200 years has been set. Engineered calculations are available for this.

3.5.5 Collection Procedures

Collection procedures specified in the Regulations relate to recyclable materials. Sweden requires that the "producer" take responsibility for the waste generated from its products. Manufacturers of paper, beverage containers, vehicles and their parts, to name a few, are required to arrange for the collection of their waste products. For paper products and packaging materials, for example, producers must realise 80% recovery. Arrangements for such collection are usually contracted to local organisations.

3.5.6 Operational Criteria

Various wastes such as explosives, hazardous and infectious wastes, are listed in the EU directive and prohibited from Swedish landfills. By 2003, Sweden intends to prohibit all combustible waste from entering landfills. Incineration of all combustibles will then be required. Currently, 1/3 of all municipal waste is incinerated, 1/3 is recycled and 1/3 is landfilled. By 2005, no organic waste of any variety will be accepted at landfill facilities.

As there is so much recycling of materials and prohibited hazardous wastes, there is no segregation at landfill facilities. Fencing and gating of sites is required, but scavenging at smaller facilities is still a problem from a public safety point of view.

Seventy-five facilities have gas collection used for energy recovery and 10 or 11 sites produce electricity.

3.5.7 Monitoring

Details for monitoring at landfill facilities are presented in the EU directive or are otherwise site specific. Monitoring programs are provided in each landfill facility permit and are based upon facility size, hydrogeological conditions, etc.

3.5.8 Regulatory Requirements

Landfills receiving less than 100 000 tonnes per year are required to hold a regional permit for its operation, while those over this size have a federal permit and undergo a more rigorous approvals process.

The records kept for monitoring results are maintained internally and no reporting of such results is required. Only if results indicate there is a problem is the landfill operator obligated to report the results to the Department of Environment and establish a remediation plan. This same philosophy of no government intervention unless a problem arises is found with government inspections. Again, no inspections are routinely conducted at landfill operations unless as an investigation into a problem or to review remediation measures. The landfill expert interviewed stressed that there is an element of trust involved in the management of solid waste. However, if public health or the environment is threatened, thorough and stringent government controls are then exercised.

3.5.9 Closure and Post-Closure

One metre of cover is required upon closure of a landfill. Financial assurance is not required of municipal solid waste facilities, only that of industry.

3.6 GREENLAND

Greenland has a population of 56 000 and a landmass of over 2 million square kilometres. Although part of the Kingdom of Denmark, as a transition to self-government Greenland is under Home Rule. Greenland has taken over from Denmark all the special administrative areas mentioned in the Home Rule Act, but receives annual block grants from the Danish government. Greenland withdrew from the European Union in 1985, thereafter basing its relations with the EU on a special agreement.

Greenland and Nunavut have forged a co-operation agreement because they are geographic neighbours with many common and similar natural features and characteristics. The government official from Kativik interviewed for this report also mentioned a relationship with Greenland.

3.6.1 Background

There is one landfill per community in Greenland.

3.6.2 Qualification

There is no guideline, *per se*, for the design and operation of solid waste facilities in Greenland. The applicable regulations, which are only available in Danish, are therefore followed. Annett Graff, Acting Manager for the Ministry of Nature and the Environment was contacted but not available at this time to discuss landfill policy. Also contacted was Hugh Lloyd, Executive and Inter-government Affairs, Government of Nunavut. Mr. Lloyd is currently reviewing documents on incineration in Greenland that he will provide to CG&T for their review of incineration feasibility in Nunavut.

3.6.3 Incineration in Greenland

There is a large capacity incinerator in the capital Nuuk (population 10 000), a medium capacity incinerator in Sisimiut (population 4 700) and 41 small capacity units in the other communities. Officials from both Kativik and Nunavut have toured incinerators in Greenland.

3.7 COLD REGIONS UTILITIES MONOGRAPH REVIEW

The Cold Regions Utilities Monograph Review was developed in 1996 by ASCE and CSCE as a means of compiling and reviewing engineering information pertinent to the unique conditions of northern regions. Experts from industry, government and engineering consultant firms contributed sections. The layout of this document is followed by Heinke and Wong, with sections including existing systems; concerns and objectives of current systems; objectives of solid waste management; solid waste disposal methods; site planning and design; regulatory review; hazardous wastes; and management plans.

3.7.1 Existing Systems

Objectives of solid waste management in regions north or south are to maintain a positive attitude towards, and awareness of, proper waste reduction, handling, and disposal throughout the solid waste management process.

Solid waste disposal has traditionally been a neglected area of municipal services in northern communities. Many communities are reassessing their current systems and finding that old landfills that often do not meet the needs of the community are often replaced by new better-planned landfills.

3.7.2 Concerns with Existing Systems

Concerns with the current methods of solid waste management in the North are site location (including airport separation), area available for a 20-year plan, available cover material, fencing and the general operation and maintenance of landfill facilities.

Acceptable methods of operation and maintenance are not followed in the majority of solid waste sites in cold regions due to low priority, inadequate funding, a lack of equipment, lack of trained personnel, and severe climatic conditions. No clear guidelines or requirements exist for the disposal of domestic waste oil.

3.7.2.1 Assessment of Current Systems

The NWT government performed a questionnaire survey in 1990 where 53 of the 61 communities participated. Survey results were also compiled in the Heinke and Wong guidelines. The following facts were identified.

- Communities are improving solid waste collection and disposal practices.
- Two third of the communities have less than 5 years before expansion or relocation of their solid waste facilities.
- The design life for a disposal facility should be 20 years. Often sites constructed before 1985 are will need to be expanded soon.
- The modified landfill method is the minimum standard for NWT communities (15 of the communities met this standard with the reason for not meeting this standard often being lack of covering material).
- All communities meet the requirement of collection once per week.
- 75% of communities still use the honey bag system (only three communities do not meet this standard).

The survey indicated a reduction in public health deficiencies and environmental deficiencies of solid waste facilities from 58% to 18% and 32% to 11% respectively between 1982 and 1990.

3.7.3 Objectives of Solid Waste Management

Basic objectives of solid waste management are itemized in the Cold Regions Monograph Review including public health and safety, environmental protection and aesthetics. Disposal objectives are also detailed in the review such as minimising air pollution and water pollution, improving aesthetics, discouraging unsupervised scavenging and reducing wildlife access to the facilities.

3.7.4 Solid Waste Disposal Methods

A description and assessment of various disposal methods are provided in the Review:

- Open dump/landfill
- Modified landfill
- Burning and landfilling
- Sanitary landfill
- Incineration
- Shredding/baling for waste reduction
- Recycling

Descriptions are also provided for burning methods commonly used in the North:

- Open burning
- Trench burning
- Burning in Oil Drums
- Controlled Trench Burning

3.7.5 Site Planning and Design

Guidelines are provided for planning a disposal site that include taking into account the community conditions (population, solid waste characteristics and volumes, collection vehicles and crew sizes, and design life) and siting criteria (proximity to airport, geology, terrain, availability of cover material and geotechnical factors, climate, land use patterns).

Also provided are guidelines for designing various landfill options. Descriptions of each option and its applicability to certain conditions are given:

- Modified Landfill Disposal Option
- Area Method
- Trench Method
- Depression Method

The section of design of site facilities considers areas on site for refuse disposal, bulky waste, honey bag waste, waste oil and battery storage. Further, consideration is included for the design of access roads, site drainage, and fencing.

3.7.6 Regulatory Review

A brief, general section in the Review states that the planning and design of solid waste landfill sites must comply with applicable federal, state, and territorial guidelines.

3.7.7 Overview of Hazardous Wastes in Northern Regions

The review provides a working definition of hazardous waste, categorized by the Transportation of Dangerous Goods Act (TDGA), as:

1. Flammable
2. Corrosive
3. Reactive
4. Poisonous
5. Infectious
6. Environmental

An industry, business, and community survey of the hazardous waste generated within the NWT was conducted and its data provided in the review.

Technologies for hazardous waste treatment and disposal such as waste minimisation, co-disposal, solidification, and incineration are provided in the Review.

3.7.8 Management Plans

The Review states that important parts of a Community Management Plan include:

1. Codes and Ordinances: local codes address the:
   - Statement of objectives of solid waste management
   - Responsibility of the local government
   - Methods of handling complaints and enforcement of rules
   - Methods of disposal of hazardous wastes
   - Community aesthetics
2. Consolidation of Waste

3. Control of the Site

4. Waste Minimisation

5. Community Commitment

6. Visual Monitoring

7. Closure Planning

3.8 ANALYSIS OF SOLID WASTE MANAGEMENT IN NORTHERN JURISDICTIONS

Only the Northwest Territories have a comprehensive guideline for the design and O&M of modified landfill facilities. All other jurisdictions reviewed mainly use legislation regulations for solid waste management. Alaska does have a guidance document for their very small facilities for the main purpose of encouraging the permitting of such facilities through a simplified regulatory process. Yukon plans to develop guidelines similar to the NWT guideline in the near future based on the Haines Junction model. For the most part, other northern jurisdictions leave the details of solid waste management to the discretion of communities with the fail-safe being a permitting process that allows all aspects to be fully considered before permit approval. Refer to Table B-1 in Appendix B for a comparison of the various jurisdictions considered for this report.

The applicability of information from other jurisdictions must be carefully examined since population densities, climate, geography and government administration differences are vast. Sweden's solid waste management is most different and, hence, least applicable, while Yukon and Nunavut are generally more applicable, to the NWT.

The following is a compilation of the main points from this section:

- Alaska takes a regional approach to landfilling which is only viable for such a highway-linked region with 52% of waste generated in the Anchorage area. Yukon has a limited regional approach. All other regions have one landfill per community. The NWT would not benefit from a regional approach to solid waste management due to the remote locations of many communities.
- Kativik, Alaska and the Yukon all have specific setback restrictions from surface waters, the water supply and/or the groundwater table. The NWT guideline suggests that a facility should be in a watershed separate from the community's drinking water supply. Further, analysis of leachate quality has proven that contamination from solid waste facilities is better than the average of North American landfill facilities (see section 8.1, Assessment of NWT Leachate Quality). This approach

taken by the NWT is simple yet effective and, therefore adopting another jurisdiction's setback restriction is unwarranted.

- Alaska requires that landfills in permafrost zones prove their permafrost status through thermocouple monitoring. All other regions do not require this. For NWT communities undoubtedly within continuous permafrost, thermocouple monitoring is redundant. Also redundant is thermocouple monitoring in communities known to not be in permafrost. However, those communities in discontinuous permafrost zones or in regions where permafrost determination has not been universally recognized, thermocouple monitoring would be an asset (see Monitoring in section 10.4).
- Sweden and Alaska both require liners in there, mostly larger, landfills. Only Alaska's Class I sites (which receive solid waste in excess of 20 tons/day) must have liners. The quality of leachate found at NWT landfill facilities does not warrant the use of liners (see Assessment of NWT Leachate Quality in Section 8.1).
- Only Sweden's regulations have recommendations for lateral expansions due to Sweden's tendency toward expanding existing sites well beyond 30 years. A design life of 30 years, rather than the previous guideline of 20 years, is recommended for the NWT.
- Alaska, Yukon and Sweden each refer to other Acts and Regulations for lists of prohibited hazardous waste at landfills. Alaska trains its landfill operators in recognising prohibited wastes. For the NWT, reference to Resources Wildlife and Economic Development (RWED) hazardous waste guidelines will be included in the updated Guidelines.
- Only NWT and Nunavut provide descriptions of various landfilling methods. This is still useful and should remain in the updated Guidelines.
- Yukon, NWT and Nunavut provide guidelines for segregation of wastes at landfills. All other jurisdictions leave segregation up to the discretion of communities. This is still useful and should remain in the updated Guidelines.
- In Alaska, SWANA/MOLO certification is required for Class I facilities; for other facilities local training is given for operators. In the Yukon, operators must be familiar with regulations and trained (no specifics given). The emphasis on large, southern solid waste facilities makes the SWANA/MOLO certification inapplicable to the NWT, and is therefore not recommended.
- All jurisdictions admit scavenging is a problem. Alaska exercises safety measures for large facilities. Sweden has fencing at all sites and restricted hours of access. Yukon, Kativik, NWT and Nunavut have no guidelines for scavenging. Some guidelines aimed to reduce safety and nuisance issues with scavenging will be included in the new Guidelines.
- Open burning is frowned upon in all northern jurisdictions but accepted in certain cases. Alaska allows open burning at their small, Class III facilities, Yukon allows burning in accordance with air quality and forest fire regulations and Kativik's new regulations permits open burning once a week. Sweden and Greenland have extensive incineration of solid waste. The NWT has adopted the

Canada-Wide Standard for Dioxins and Furans (CCME. 2001), which requires a prohibition on all open burning.

- Alaska has upgraded its regulations since becoming an "approved state" in 1996 and follows federal regulations for solid waste management. Yukon developed new solid waste regulations in 2000 and requires each facility to have a Solid Waste Management Plan. Nunavut has adopted NWT's guidelines and will develop its own at a future date. Kativik is following the draft Nord-du-Québec Regulations soon to be published. Sweden follows the EU directorate for solid waste management and will legislate the prohibition of combustible waste in landfills in 2002 and all organic wastes will be composted by 2005.
- All the northern Canadian jurisdictions and the state of Alaska provide details for reporting. Kativik is fairly lax in that they have no yearly reporting unless a problem is detected. Sweden, similarly, has no regular inspections or reporting but is required to monitor, keep records and only report to the government any problems that may arise. The new guidelines for the NWT will outline systematic record-keeping procedures, which may be filed then provided during inspections.
- Only Alaska provides comprehensive monitoring requirements in their regulations. Other jurisdictions have requirements on a site-by-site basis provided in the facility permit. See Section 10 for landfill facility monitoring in the NWT.

4. RECYCLING AND HAZARDOUS WASTE MANAGEMENT OPTIONS

In 1989, the Canadian Council of Ministers of the Environment (CCME) set a goal of reducing the amount of solid waste by 50% per capita within Canada before the year 2000. Between 1988 and 1994 there has been a national 23% solid waste reduction obtained through legislation, educational programs, and the development of organisational infrastructure to promote the 3R's (recycling, reuse, and reduction) within different sectors of the Canadian economy.

Recycling is difficult in northern regions primarily due to the high transport cost of recyclable products to markets in southern Canada. The small volume of recoverable material, lack of local markets, and lengthy shipping distances are some of the problems facing the development recycling programs within small northern communities. Within smaller communities, salvage areas remain the primary method of recycling. Small-scale recycling programs have recently been implemented within larger northern urban centres including Whitehorse, Iqaluit, and Yellowknife. For comparison, an account of recycling and hazardous waste handling is provided for British Columbia, Alaska and Sweden.

4.1 YUKON

The Yukon government has developed various initiatives with regard to recycling and hazardous waste management.

4.1.1 Yukon Recycling Initiatives

The *Beverage Container Regulation* establishes a deposit-refund system for beverage bottles. The deposit is larger than the refund to provide funding for this recycling program. For example, for a 10-cent deposit on a small beverage container, there is 5-cent refund. This difference helps fund the recycling system and it allows for the transport of the recycled cans to markets in southern Canada. The recycling program is organized through Raven Recycling in Whitehorse. There is currently some discussion on including plastic milk containers.

4.1.2 Whitehorse Recycling Programs

In an effort to double the life of the Whitehorse landfill (expected to reach capacity by 2033), the city of Whitehorse set a target to reduce the amount of solid waste entering the landfill by 50% per capita by the year 2000. The municipal council drafted the 1995 *Solid Waste Action Plan* (SWAP) for Whitehorse. Through the SWAP, the percentage of material recycled and removed from landfill waste has risen from 15% in 1995 to 20% in 1997. Though this percentage increase shows that the SWAP

has been moderately effective, more waste reduction initiatives need to be implemented for the city of Whitehorse to meet the CCME targets.

In the 1998 *Solid Waste Action Plan Update*, it was acknowledged that the primary barrier to the implementation of waste reduction initiatives is a lack of a solid waste reduction implementation plan. Such an implementation plan must make waste reduction cost effective commercially. The slow rise in the percentage of recycled material was thought to be a result of commercial waste generators for which the disposal at the landfill continues to be the most cost-effective method.

There have been initiatives by the city of Whitehorse to establish a "Full Cost Accounting" at the landfill. Thus, users of the landfill would help pay for the cost of processing and treating generated waste by using a weigh scale system. Material that is recycled would be removed from a dumping truck system before entering this weigh scale system similar to systems in place in southern communities.

At the landfill, there are segregation areas for composting, metals, tires, animal carcasses, and other recyclable material. The primary use of this landfill continues to be for residential purposes. The city of Whitehorse uses a series of unstaffed depots that are used to collect beverage containers. The city of Whitehorse subcontracts the removal of tires and the scrap metal from the landfill. Initially, this removal of scrap metal from the landfill was subcontracted to a contractor within British Columbia. However, when the contractor removed the metals but did not remove tires, the contract was changed to a Whitehorse-based contractor, McInroy Disposals. The operation of the landfill is subcontracted by the municipality to General Waste Management.

Waste reduction measures are contracted from General Waste Management to a non-profit organisation promoting waste reduction, the Raven Recycling Society. The Raven Recycling Society is a waste reduction and recycling advocacy organisation. Through the promotion of waste reduction and recycling issues within schools in Whitehorse, the society helps organise a Recycling Club for students. The society has both employees, and volunteer workers whom operate one of the largest depots in Whitehorse. Raven Recycling also employs about 20 people within its processing centre.

Raven Recycling accepts newspaper, magazines, textiles, aluminium cans, and plastic for recycling. The vast majority of these recyclables from the Whitehorse landfill are sold to markets in southern Canada, primarily within Vancouver. The cost of the transport of these recyclables is more than the value at which the products are sold. This recycling operation is made financially viable through extending the costly infrastructure improvements associated with new landfill development.

Raven Recycling operates a paper-recycling program, the Paper Save program. This program separates different quality paper that is then sold to different paper mills in the region. White office paper is sold for a profit to generate income to pay for the recycling costs of other paper types (3). The Paper Save program operates on a fee for service basis.

The city of Whitehorse established a landfill diversion credit formula by which the city would refund the value of landfill cost savings to organisations providing landfill diversion activity. The Recycle Organics Together Society (ROTS) and the Raven Recycling Society have received funding through this diversion credit.

Composting is a large component of the Whitehorse solid waste management system. One program to promote composting activity and to divert organic compounds from the Whitehorse landfill is Waste Watch. Whitehorse citizens who receive garbage collection services from the city can purchase a compost collection container from the city for $15. Participants in this program receive starter kits from the Raven Recycling society including seed to start the decomposition process.

4.1.3 Hazardous Waste Management

The handling of hazardous wastes in the Yukon Territory changed dramatically in 1995 with regulations imposed by the Yukon Government. Prior to this time, there was a debate over the responsibility for the disposal of waste oil. In 1995, Environment Canada investigated the source of hazardous waste within the Yukon. The amount of hazardous waste in the Yukon increased by 1000 tonnes while household hazardous waste (HHW) decreased from 56 tonnes to 32 tonnes. Hazardous waste became the responsibility of the generator of the hazardous waste within the Yukon. The Yukon Government organises an annual waste collection of solid waste for commercial waste generators. The cost of shipping this waste is shared between the generator and the government. Some commercial hazardous waste providers are allowed to use the government HHW collection but at higher costs because the full disposal cost is paid by the waste generator.

Yukon has considered two options for handling waste oil: acid-clay processing and vacuum distillation. The availability of refineries and the lack of available markets for recycled oil limit recycling oil products. With the acid-clay process, used oil is screened and directed through a separator to remove water contamination. The oil is then heated at 150 degrees Celsius. The oil is then mixed with sulphuric acid resulting in coagulation. The acid sludge containing the contaminants is removed. The oil is then treated with clay to remove light fuel, mercaptons, and colour from the oil. The oil is then treated with a filter press and stored. With vacuum distillation, the oil is initially pre-treated to dehydrate the oil by heating to 150 degrees C and then distilled at 370 degrees C at a low pressure to boil the oil to remove contaminants. Finishing involves transferring the middle portion of this liquid through a caustic clay treatment stage. Such refineries continue to be uneconomical because re-refined oil has costs associated with the collection that makes this product cost-comparable to crude oil. Thus, this product has not made in-roads into significant larger markets. The demand for used oil is dependent on the price of crude oil.

4.2 NORTHWEST TERRITORIES

4.2.1 NWT Recycling Initiatives

There are various different recycling initiatives in the Northwest Territories such as those developed by the Northwest Territories Liquor Commission, and non-profit organisations such as the Girl Guides in Norman Wells and the Inuvik Recycling Society. In addition, there are municipal recycling programs within both Inuvik and Yellowknife.

The first recycling or waste reduction initiative is the deposit/refund system that is operated through the Northwest Territories Liquor Commission. Consumers currently pay a 10-cent deposit on refillable alcoholic bottles. Consumers receive a portion of this deposit when they return the bottles. Businesses in Yellowknife, Fort Simpson, Hay River, Fort Smith, and Inuvik have a contract to collect the bottles. However, there is no commitment to recycle by the contractors that return the bottles, and most of the bottles are landfilled. This deposit return system prevents the littering of alcohol bottles within Northwest Territories communities.

There are recycling operations within the Northwest Territories organized through non-profit groups in the communities of Norman Wells and Inuvik. In Norman Wells, the local Girl Guide organisation generates revenue for their organisation through collecting and storing cans and bottles. The Girl Guides shred and bag the plastic, cans and bottles. These bags are transferred by barge to Hay River and then shipped by truck to an Edmonton recycling depot.

The Inuvik Recycling Society was formed to promote the 3 R's (reuse, recycling, and reduction) within Inuvik. The Inuvik Recycling Society provides a recycling service for those materials that have the most effect on the local environment including hazardous wastes. The recycled materials are shipped from Inuvik through the action of this non-profit organisation to the Raven Recycling processing centre in the municipality of Whitehorse.

The government of the Northwest Territories, responding to public interest in the recycling of beverage containers, is currently considering implementing a beverage deposit and refund system within the territory. Containers may be collected within a deposit and refund system at the local retail outlets and at a recycling depot. Recycling depots need to be secured locations to prevent people from obtaining multiple refunds. In addition, the depot will sort and bale the containers. After beverages are returned to the depots, they are sent to a central processing centre where the containers are then transported to locations where they can be sold at market value. The proposed Northwest Territories beverage refund system involved setting up processing centres in Yellowknife and in Hay River. Beverage containers can be transported from depots within different communities in the Northwest Territories to these processing centres.

The major problem associated with implementing this type of system in the Northwest Territories as opposed to southern locations is the large transportation cost between the different communities to southern markets. The planning document to implement this program stated that recyclable products should be transported consistently with the goal of minimising the weight, the volume, and the cost of transport. Transportation trucks should only transport full truckloads, as it would be a waste of transportation funding for this program. It was estimated that this cost could be reduced as trucks or barges entering communities with supplies generally return to the supplying location without a load. Thus, recyclable bottles could be transported to southern markets on the return trip of these trucks. Another factor is that in some communities, the only access is by air. An example of this type of community would be Wekweti. The availability of transport is a major factor within the development of a cost-effective recycling system in the Northwest Territories. The proposed recycling system of the government of the Northwest Territories had a larger deposit than the refund to fund the high transportation expenses.

This project was estimated to be financially viable within the report. However, the start-up costs were not included within the cost estimating process. These start-up costs could increase this overall expense of such a program. The calculations within this report estimated a 75% return rate, which may be high for communities in the Northwest Territories. This return rate is similar to rates in the South that vary between a 75% return rate to 85 to 90% return.

4.2.2 Yellowknife Recycling Programs

The city of Yellowknife operates a recycling program within the operation of the municipal landfill. Currently, 2% of all solid waste entering this landfill is recycled. There are three drop-off-recycling depots in the city and one located at the landfill. The three recycling depots are located at the Yellowknife Arena Parking Lot, the Yellowknife Direct Charge Co-operative, and Franklin Avenue.

There have been several different site locations for the Yellowknife landfill. The first site location was at the current location of the William MacDonald School. The second location was located near Fritz Trail Park. The current solid waste management facility (SWMF) is located in a facility outside Yellowknife at the beginning of the Ingraham Trail highway. The recycling depots collect aluminium, tin cans, corrugated cardboard, newsprint, and other types of paper to be recycled at the city's Solid Waste Management Facility (SWMF).

At the solid waste management facility, residents separate waste into four different categories including recyclable material, reusable material, garbage, and hazardous waste. Household hazardous waste is collected at the landfill. Hazardous waste includes oils, batteries, and paints. The used oil collected is shipped south to Edmonton for processing. There is a salvage area within the Yellowknife landfill where residents can place reusable products that can be salvaged by other people. The items that are left in

this area for a long period will be landfilled. Material is placed within the baling facility where it is loaded into a hopper and compressed into a 2000-pound cube. This process reduces the volume of the waste by 2/3 for volume and cost efficient disposal.

One problem associated with operating sanitary landfill facilities within northern regions is obtaining the soil required to cover the landfill. This covering process can be expensive as the soil required for this covering process is often imported from southern regions. Most landfill facilities in northern communities, to operate cost effectively, attempt to minimise the amount of covering soil that is utilized. However, there are problems associated with covering this waste less frequently including the attraction of animals, groundwater leaching of contaminants, and other associated problems. The attraction of animals has been minimized with electric fences. The city of Yellowknife is attempting to obtain a balance between the use of covering soil and the development of recycling within its landfill operations. This covering process minimises the amount of land required by a landfill, prevents leaching, and the attraction of animals to the facility.

The city of Yellowknife is developing more recycling initiatives at their solid waste facility. Recently, after a debate within the city council between the options of greater sanitary burial of solid waste versus the increased funding of recycling programs, the city of Yellowknife voted to pass the Community Waste Management Strategic Plan. The solid waste management planning committee (SWMPC) adopted this waste management strategy to attempt to reduce the percentage per capita of the waste stream by approximately 40% and to increase the recovery of recyclable materials. Cost estimates indicate that this plan would initially be more expensive due to the funding of the transport of recyclable materials to southern locations and the processing of recyclables. However, it is believed that this cost would be recovered through savings in the operation and construction of the current and future landfills. The operational costs of increased recycling would be lower in the future because it would minimise the costs associated with this sanitary burial process. This sanitary burial process is expensive for northern communities. The community of Yellowknife is attempting to meet this goal of the 40% recycling of solid waste through a community waste reduction program and environmental education within schools.

4.2.3 Hazardous Waste Management in the NWT

Resources, Wildlife and Economic Development (RWED) have various publications pertaining to hazardous materials handling in the NWT. These publications are listed as follows.

- *Guideline on Waste Lead and Paint* (GNWT. 1999)
- *Guideline for Agricultural Waste* (GNWT. 1999)
- *Guideline on Waste Batteries* (GNWT. 1998)
- *Guideline on Waste Paint* (GNWT. 1998)
- *Guideline on Waste Asbestos* (GNWT. 1998)

- *Guideline on Waste Antifreeze* (GNWT. 1998)
- *Guideline on Waste Solvents* (GNWT. 1998)
- *Guideline for the General Management of Hazardous Waste in the NWT* (GNWT. 1998)
- *Guideline for Institutional Commercial and Industrial Waste Management* and *Biomedical Waste Management* (GNWT (draft). 2001)

The Northwest Territories has a similar method of hazardous waste treatment to the government of the Yukon. The City of Yellowknife will accept household hazardous waste for eventual transport to a hazardous waste facility. Commercial waste generators are responsible for management of the waste that they generate.

Resources, Wildlife, and Economic Development (RWED) permits the use of CSA or UCC approved waste oil furnaces for heat recovery. Contaminants may be removed from used lubricating oil and it can be mixed with different additives to be used as transmission oil, hydraulic oil, or chainsaw oil. The government of the Northwest Territories has been interested in developing a waste management strategy for used oil that may include re-refining the oil for reuse or as waste oil for heating fuel.

4.3 NUNAVUT

4.3.1 Recycling Initiatives

There are currently few recycling programs within Nunavut primarily because of high transportation costs. The problem of waste accumulation and solid waste hydrological contamination continues to be a problem within Nunavut communities. This problem is demonstrated through the example of the recent establishment of a recycling and garbage separation program within the city landfill within the town of Iqaluit. Traditionally, Nunavut communities have relied on waste reduction through burning to prevent garbage accumulation at landfills.

4.3.2 Iqaluit Recycling Programs

The city of Iqaluit has recently moved towards a recycling and garbage separation program. Prior to June 1, 2001, Iqaluit relied heavily on a burning program to minimize plastics, woods, and food waste from entering its landfill. There remains a major problem with waste accumulation and Iqaluit's solid waste facility is expected to reach full capacity this October.

The Nunavut Water Board (NWB) challenged the waste burning policy when granting a water licence for the solid waste facility. The NWB maintained that the burning of plastic waste was a source of air pollution. In addition, the NWB cited evidence that material entering the landfill is not subject to a

proper sorting protocol or a recycling program. Also, a group of Iqaluit residents challenged the open-burning policy in court to force the city to establish other mechanisms of managing solid waste. The group wanted to establish a moratorium on the burning of unsorted solid waste at the city landfill citing air and water contamination. Iqaluit representatives argued that the landfill is near capacity and that solid waste stockpiling created by a ban on burning would attract birds that could interfere with the nearby airport. The new conditions of the water license, subsequently, includes the prohibition on open burning and the requirement that waste reduction initiatives, such as recycling segregation programs, be established.

The city of Iqaluit, in response to the Nunavut Water Board decision, has drafted a new waste management strategy for the city of Iqaluit. A component of this strategy is the construction of a new incinerator and the development of another solid waste facility. The community is investigating using the heat generated from the incineration to provide heat for buildings. Plastic waste is to be separated from other waste materials, however, there is no plastic recycling facility transport of collected material to a recycler is costly. The city is thus investigating another potential site location to landfill plastic materials.

A recent initiative of the city of Iqaluit, because of this waste management strategy, is a paper-recycling program located at the city's solid waste facility. The city is distributing 300 recycling boxes for use throughout the community. The paper will then be transported by First Air Airlines to a recycling plant near Ottawa for processing.

This official recycling program in Iqaluit follows various volunteer recycling programs. A non-profit organisation, the Rotary Club, was one of the original organisations to start a recycling program for club members in Iqaluit. The Rotary Club purchased blue boxes to collect paper for recycling. Members of the Iqaluit youth correctional centre would transfer the collected paper to a government warehouse where the papers were collected and transported south by Canadian North. There was a commercial recycling depot in operation to recycle used cans. The town of Iqaluit operated the Iqaluit Recycling Centre until 1993 when the operation was transferred to private enterprise. The centre processed approximately 35,000 to 50,000 aluminium cans per year, shipping the crushed cans by barge to markets in Montreal. The Iqaluit Recycling Centre, however, was not economically viable and it eventually closed.

One of the main factors of excessive waste accumulation at the landfill was the construction of the Peterson and Auger plastic bottling plant for Coca-Cola products within the city. City councillors believe that the bottling plant is creating excessive garbage accumulation and problems regarding the burning of plastics. The Iqaluit city council's Development, Works, and Public Safety (DWPS) Commission has written a letter to the company asking it to switch to a glass product which can be more easily recycled.

4.4 BRITISH COLUMBIA

4.4.1 Recycling Initiatives

Following the CCME report on the solid waste reduction in 1995, British Columbia attempted to reduce the amount of solid waste being landfilled by 50% per capita. By 1998, there was a 36% reduction in the solid waste generated within the province of British Columbia. Between the years of 1990 to 1997, there was a 107% percent increase in recycled material. However, it did not seem likely that the 50% solid waste reduction goal would be met.

There is a deposit/refund system operating for beverage containers within British Columbia. The main emphasis of this system is product stewardship. Beverage container producers are responsible for the collection and recycling of beverage containers. British Columbia has a deposit system with a complete refund. There are 160 depots and retail deposits within British Columbia. The majority of the containers are processed through the Encorp Pacific processing centre that represents 180 different brand owners in British Columbia.

4.4.2 Greater Vancouver Regional District Recycling Program

The Greater Vancouver Regional District (GVRD) is a partnership between 21 municipalities within the Greater Vancouver region and the Fraser Valley. The municipalities within the GVRD generate approximately 2.7 million tonnes of solid waste per year. The solid waste and recycling programs within the GVRD manage to recycle approximately 48% of the waste. A further 9% of this waste is incinerated and the rest of the waste is landfilled. There are nine solid waste facilities in the Greater Vancouver Region including six transferring stations.

In addition, the GVRD operates the Cache Creek landfill, the Burnaby incinerator, and the Vancouver landfill. The Burnaby incinerator converts garbage to steam that is sold to a nearby paper recycling facility. The incinerator burns approximately 240,000 tonnes of garbage producing 700,000 tonnes of steam annually.

The Cache Creek Landfill is located in the dry climate of Cache Creek near the city of Kamloops. This dry climate reduces operations costs and reducing the environmental impact associated with leachate from the landfill entering the local groundwater. The transportation costs associated with operating a landfill in a location approximately 3 hours drive from Vancouver are made viable because of the construction of a wood chip plant near the facility. The wood chips are transported from the landfill to markets in the GVRD, Bellingham, and Washington State. Thus, there is no wasted transportation associated with trucks returning from Cache Creek to Vancouver with an empty load. The garbage is

covered daily with soil to prevent odours as well as to control litter to surrounding regions. The landfill contains a number of areas, called stages, each of which is lined with synthetic or soil liners to prevent groundwater contamination. An underground piping system collects methane gas. Once a portion of the landfill is filled, the landfill is covered with a layer of soil to promote the growth of vegetation.

In addition, the GVRD contains a series of transfer stations each of which contains a recycling depot to collect recyclables. These depots are typically sponsored through non-profit groups or through municipally funded organisations in the municipality within which the depot is located.

The GVRD promotes job site and workplace recycling education programs. The job site-recycling program promotes reuse and recycling within the construction industry. The construction industry generates a large amount of wood, drywall, and glass waste. This program, thus, is attempting to promote recycling within this industry as a financially viable option. The workplace-recycling program helps promote recycling within the work place. Approximately 75% of businesses within the GVRD have a recycling program. However, approximately ½ of recyclable paper is being recycled. Thus, this program includes different methods including education and providing boxes and facilities to develop effective workplace recycling programs.

4.4.3 Hazardous Waste Management

Household hazardous waste within British Columbia is managed through regulated industry stewardship systems. In 1993, the cost of treating hazardous waste was moved from the taxpayer to the industries that produce and sell the wastes. Industries are responsible for collection, treatment, and management systems of household hazardous wastes. This system is known as the Extended Producer Responsibility (EPR) where producers take responsibility over the life cycle of their products. This concept attempts to relieve taxpayers from the funding of waste management programs.

It is required by legislation, for hazardous waste generators as well as transporters of hazardous waste, to register with the BC Ministry of Water, Land, and Air Protection. The treatment of the hazardous waste is the responsibility of the waste generator. In addition, in BC, there is motor oil recycling.

4.5 ALASKA

Although there are no requirements for recycling in Alaska's solid waste legislation, recycling programs have been developed in many communities.

There is a program for the collection of metal cans, glass, and plastics in the larger centres. No community is too small for a recycling program; it is merely dependent upon the will of each community whether a program is initiated (Glenn Miller. 2001). The Alaskan Air Carriers Association has arranged the "Flying Cans Program" whereby regularly scheduled flights from communities will transport, at no

cost, metal cans to a major community in Alaska then to a recycler in the southern U.S. Small communities just have to collect recyclables in a cardboard box, for example, which incurs no real cost just effort. There is no threshold population where recycling is feasible since there is no cost of air transport from the smaller communities to a major city. The only cost factor in a statewide recycling program is that arranged with a southern recycler. Problems do exist with the program such as inconsistent can collection in the communities, or an air carrier refusing to take a soiled container of cans on board.

Waste oil, wood and paper products are burned for energy recovery in most communities. Municipal equipment buildings are heated and there are currently discussions on initiating energy recovery for "washeterias," the buildings for public collection of water for household use in small rural communities.

4.6 SWEDEN

4.6.1 Recycling Initiatives

The expectation placed on Swedish industry to recover its waste is a means of reducing waste volumes at landfills at no cost to municipalities. It must be noted that this approach only makes sense if applied to an entire country, or as in Sweden, to the entire European Union. Arguably, Northern regions of Canada need to provide incentives, not restrictions, for industries to do business in such a low populated, costly marketplace. A requirement that producers recover their products for reuse may just force producers to do business in more hospitable regions. Producer responsibility ordinances may be effective only if they are made applicable to all of Canada or all of North America.

Waste minimisation achieved through lighter packages, refill packs, and the phasing out of unnecessary packaging to reduce waste volumes used in Sweden is an alternate approach. Since the waste producers also hold this responsibility, the same argument may be applied to waste recovery in northern regions.

4.6.2 Hazardous Wastes

Predictably, Sweden requires its hazardous waste producers to ensure the collection of its used hazardous wastes in many instances.

The Swedish Association of Waste Management (known in Swedish as "RVF"), together with authorities and other organisations, has targeted households, via the municipalities, about hazardous waste handling. Collection systems are usually at waste disposal sites and manned recycling centres, but they can also be located at filling stations, country shops, shopping malls, battery boxes, red boxes, and "environmental lorries."

Sweden's treatment of hazardous waste is as follows.

- Chemical substances and metals are recycled, destroyed, or enclosed through long-term storage. Batteries are melted down and the contained lead, cadmium, and other substances are recovered.
- Substances that are toxic and difficult to decompose, such as pesticides and other hazardous chemical waste, are incinerated in special furnaces at high temperatures.
- Polluted soil undergoes biodegradation.

4.7 SUMMARY

4.7.1 Recycling

Recycling efforts in the NWT appear to be "behind" the efforts of other northern jurisdictions. However, the circumstances that drive those other jurisdictions to such aggressive diversion programs are not clearly stated and are assumed to be directly related to the cost and availability of land. Many European and Asian countries, for example, have such a scarcity of land and high population densities, that there is often no other choice than to prohibit recyclables or combustibles from landfills. Such drivers do not exist in the NWT.

Alaska and the Yukon are two northern jurisdictions similar to the NWT with comprehensive recycling programs, due on a large part, to volunteerism and community activism. Officials contacted in these regions believe there is no population threshold whereby recycling programs become viable; it is rather the will of each community that makes its recycling program successful. The transportation industry's Flying Cans program in Alaska, and the re-use store in the Yukon, both run by volunteers, are two examples of such efforts. Regardless, the GNWT should continue to monitor recycling initiatives in the NWT and other jurisdictions, and support those local initiatives that are viable.

4.7.2 Hazardous Wastes

The GNWT has guidelines on hazardous wastes prohibited at municipal landfills, listed in Section 4.2.3, Hazardous Waste Management in the NWT. In our experience, few communities are even aware that these guidelines exist.

Further, communities do not have an inventory of hazardous wastes stored at their site, nor do they generally know if hazardous substances are being disposed. Clearly, training is required of landfill operators in recognising prohibited substances, as is done in Alaska.

The practice of storing selected hazardous wastes in an enclosed storage container at the solid waste site continues to have merit, however, it also provides the opportunity for the storage of incompatible reactive wastes. The results could be explosive and life threatening. On-going training is required to ensure the safety of operators.

5. WASTE COLLECTION PRACTICES

Waste collection in small remote communities is challenging due to the small waste volumes, the large distances between communities, and the need to manage both residential and local commercial wastes in a cost effective and environmentally sound manner. Each community and/or series of communities has different waste characteristics and requires customized collection techniques to meet local needs. Research into collection systems in more populated areas has resulted in the development of relatively sophisticated models for designing and optimising waste collection. However, most of this research is based on large population bases, the incorporation of multi-stream collection (including a range of recyclables), and other collection aspects that are of little applicability in remote areas.

Collection systems in northern areas are highly sensitive to local conditions, including terrain, seasonal variations in accessibility and community preferences. The interplay of these variables can result in different collection systems being developed in response to ostensibly similar conditions, and in this context it is not possible to produce a meaningful 'recipe' by which these systems can be designed. Despite this variability however, the following collection principles can be identified as having broad applicability throughout the Northwest Territories:

- The design of an effective waste collection system must include consideration of the size of community, proximity to neighbouring communities, and proximity to landfill;
- The collection system may involve direct haul of waste from residences to landfill, or may include a transfer station where a central landfill is appropriate; and
- Physical waste collection techniques will range from the use of small manual-load vehicles, to semi-automated or automated vehicles capable of handling both residential and commercial wastes.

Each waste collection system must meet technical and financial requirements as well as public preferences and priorities. Convenience to users, and level-of-service issues typically play a large part in the selection of the preferred system, and these aspects of waste collection cannot be meaningfully generalized. Technical requirements are susceptible to local geographic conditions (e.g. presence of year-round access), however the following general principles may be used for guidance:

- Waste collection equipment should be selected according to the length of waste haul, frequency of collection, and the types and quantities of waste to be collected. Collection frequency is an issue of local preference, with collection every week or every two weeks generally being considered to be a reasonable standard;
- In communities where each residence operates an individual garbage can, collection service will usually be most efficiently delivered by 1 tonne compactor-type vehicles;
- In communities where it is feasible for individual bins to service several residences, collection service may be delivered by 3 tonne side loader type vehicles. In this case, 1½yd^3 bins would typically be

shared between 2, 3 or 4 houses. Operating efficiencies can be achieved in this system, since in addition to being used in the residential sector, the 1½yd^3 bins are large enough to be used by many commercial outlets (stores, offices etc), and consequently a single vehicle can be used to collect waste from both residential and commercial collection points;

- In remote communities (i.e. communities more than approximately 200 miles apart, or more than 200 miles from a landfill), a transfer station may provide the opportunity for cost savings. In this scenario, waste would be hauled from the residential or commercial source to a central transfer location, then bulked at the station prior to hauling for final disposal; and
- Small remote communities (e.g. less than 1,000 residences) will typically be most efficiently serviced by simple bin-style transfer stations, in which the bins are coated to prevent freezing of waste onto the container under winter conditions. Larger communities may benefit from more sophisticated compactor-style transfer stations, in which mechanical compaction is used to reduce the volume of waste prior to hauling for final disposal.

In general, cost efficiencies will be maximized where the following collection fundamentals can be combined:

- Reasonable collection frequency;
- Combined residential and commercial collection;
- Optimised use of transfer facilities (if appropriate); and
- Optimum catchment areas for 'regional' landfills.

Design and cost estimating for collection systems requires a determination of these fundamentals for each individual community, or series of communities (if shared transfer stations or landfills is possible). Operating costs expressed on a dollar per tonne basis may vary widely between communities because of local level-of-service preferences, economies of scale, and distance from landfill.

6. SITING PRACTICES FOR SOLID WASTE DISPOSAL FACILITIES

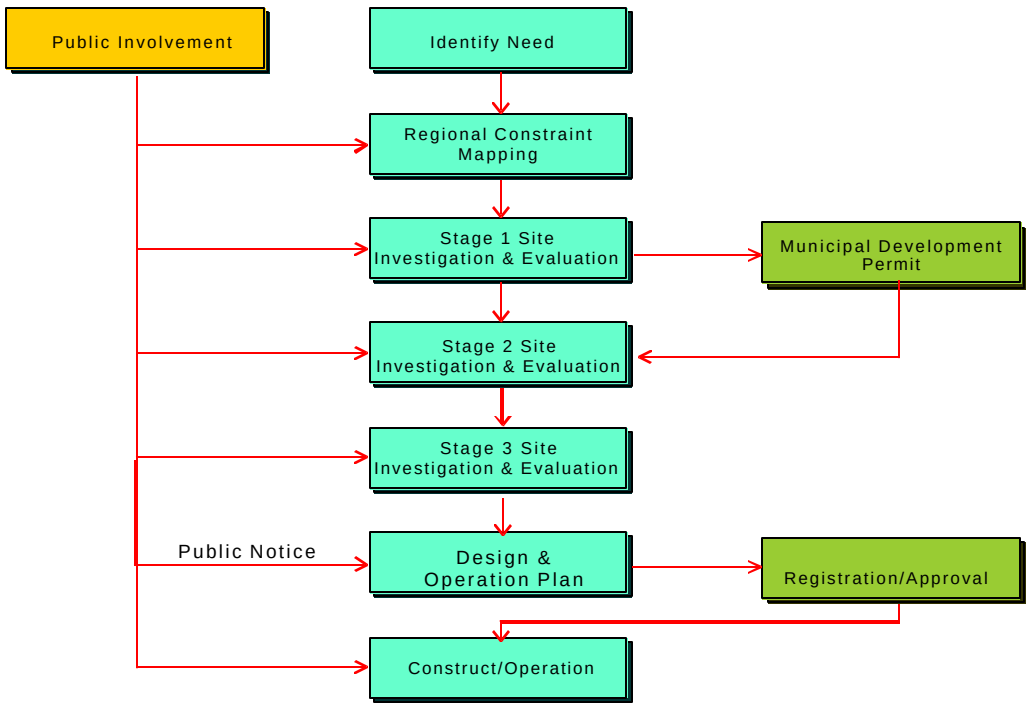
Current guidelines states that modified landfill facilities not be visible from the community, be setback from the airport (8 km federal regulation and 3 km interim regulation), and be in a watershed that drains away from the community's drinking water source. The most current applicable siting information is from Alberta.

6.1 LANDFILL SITING IN ALBERTA

The new Standards and Guidelines currently in draft in Alberta provide extensive guidance on the siting process for new landfills. The process may be summarized as follows:

- **Identification of need** – this step requires the proponent to identify the waste types and quantities expected at the facility, the alternative waste management techniques available (including waste reduction), and the rationale for the new facility in light of these alternatives;
- **Regulatory disclosure plan** – this step requires proponents to file a 'road map' of the proposed landfill siting process with the provincial regulators so that deficiencies can be identified early in the siting process;
- **Public participation** – this step requires the ongoing involvement of directly affected parties in the selection of a new site;
- **Constraint mapping** – this step involves the mapping of the area of interest to identify significant constraints against landfill development. This portion of the process is intended to ensure that all potential sites are identified within a given radius of interest;
- **Site investigation and evaluation** – this step is conducted in a series of stages, and involves obtaining technical (e.g. geologic, environmental risk) and non-technical (e.g. socio-economic) data for the potential site or sites;
- **Site selection** – this step requires the analysis of all available data to identify the preferred site for development. Appropriate choice decision techniques should be used in this step where appropriate to ensure comprehensive and equable treatment of objectives; and
- **Development of design and operations plan** – this step should include consideration of the principal technical and non-technical constraints and sensitivities identified in previous steps.

The siting process is illustrated graphically in the following figure.



Alberta ENVIRONMENTAL PROTECTION

Conceptual Landfill Siting Process & Staging of the Landfill Investigaion

Figure 6.1

The detailed technical investigation recommended in the draft Alberta guidelines comprises the following stages:

Stage 1 – this stage includes a review of regional topography, regional hydrogeology and regional geology. In addition, potentially affected surface water and groundwater resources are identified, along with the identification of any other potential fatal flaws to site development.

Stage 2 – this stage includes the preliminary investigation of hydrogeologic and geologic conditions at the potential site(s), including the identification of groundwater flow direction and velocity, groundwater quality and groundwater depth. Surface water drainage patterns in and immediately around the site are identified at this stage, as are the site design concepts that the siting team considers would be most appropriate for the conditions identified.

Stage 3 – this stage is usually executed at a single preferred site only, and includes the detailed investigation of sub-surface conditions relating to environmental performance and site construction. This stage of investigation is generally focussed on any sub-surface anomalies identified in previous stages of investigation, and on any critical features identified in the design concepts developed in Stage 2. This stage of investigation also generally includes the collection of material engineering data related to site construction (e.g. grain size distribution data and the general availability of materials needed for the construction, operation and closure of the landfill)

6.2 NWT APPLICABILITY

The current siting criteria for the NWT is simple and has proven to protect surface water contamination given the recent results of Surveillance Network Program (SNP) data analysis for municipal landfills. Analysis of SNP data for this report has revealed a leachate quality better than that of North American landfill facilities; so environmental contamination within the landfill's watershed is minimized in the NWT (see Section 8.1). Stating in the Guidelines that all solid waste facilities be situated in a water table separate from the community drinking water source ensures the protection of drinking water.

The fact that the cost of constructing an access road is exorbitant in the NWT and not a factor in Alberta must be taken into account. Siting a landfill at a greater distance from the community is desirable to residents, not only because of aesthetic and nuisance reasons, but because roads are useful for recreational purposes as well.

Such a systematic approach to landfill siting taken by Alberta may be simplified and adopted by the NWT.

7. EVALUATION OF ENVIRONMENTAL IMPACTS OF THE OIL AND GAS INDUSTRY ON MUNICIPAL SOLID WASTE SITES

AMEC is currently working with various components of the oil & gas sector, including the Beaufort Delta. AMEC and FSC will contact areas that have already had extensive oil and gas development, such as Fort Liard, and use any available resources to determine all possible impacts on a municipal solid waste site. We will also look into tipping fee options for industrial waste.

The disposal of industrial wastes at 'municipal' landfills has been a problem at many landfills throughout the oil and gas-producing regions of western Canada. 'Municipal' style landfills in small communities are typically characterized by small size facilities, with relatively unsophisticated design, operational and monitoring frameworks, and limited equipment. The principal difficulties that can arise from the acceptance of upstream oil and gas wastes at these landfills are described in the following paragraphs.

Most municipal solid waste landfills in the study area were developed to receive small quantities of household waste from one or more local communities. The advent of oil and gas exploration and exploitation can introduce a variety of wastes into these communities that may be incompatible with the local municipal landfill in the following ways:

- **Quantity.** Waste from the oil and gas sector can frequently be generated at many times the rate that would typically be expected from local residential sources. The acceptance of large quantities of waste into small landfills can lead to rapid depletion (or in extreme cases, exhaustion) of air space, and leave communities with little or no life-span for the on-going disposal of residential wastes from the community;
- **Type of waste for disposal.** Many of the wastes generated by upstream oil and gas activities may be unsuitable for disposal in municipal waste landfills. Unsuitable wastes would include liquids, acidic or caustic solids and sludges, and other materials which would not normally be found in a municipal waste stream. Of particular note in this regard is NORM (Naturally Occurring Radioactive Material), which can contaminate other wastes and be sent for landfill disposal if not specifically excluded;
- **Type of waste for recycling.** Upstream oil and gas activities may generate significant quantities of waste metal in the form of piping, tubing, tanks, vessels and other ferrous and non-ferrous metals. While these materials may be suitable for recycling, there are frequently significant costs in handling (e.g. shearing, shredding or cutting), as well as in transporting these materials to re-processors. In many cases these costs exceed the value of the material.

8. TYPICAL DESIGN PARAMETERS AND DRAWINGS FOR SOLID WASTE SITE CONSTRUCTION

Design parameters for the construction of solid waste facilities and the subsequent drawings is an essential tool in the updated design and O & M guidelines. Before such details can be finalized, however, the information provided thus far needs to be considered.

Although not in the original scope of this report, an assessment of the likely leachate quality from NWT landfill sites has been undertaken.

8.1 ASSESSMENT OF NWT LEACHATE QUALITY

The "driver" to decisions regarding landfill design is often leachate quality. That is, only if leachate from landfill facilities can be proven contaminated, do barriers, liners, and leachate collection, treatment and monitoring need to be considered. Otherwise, a well-sited, basic modified landfill is sufficient.

For purposes of this report, therefore, it was necessary to determine the quality of leachate from NWT landfill facilities. The DIAND permitting process requires that landfill operators conduct surface water monitoring at site-specific Surveillance Network Program (SNP) sampling points. These data have been collected by DIAND, but not reviewed as a whole. DIAND SNP data from 1993 to 2001 was obtained for Yellowknife, Hay River, Rae Edzo, Fort Smith, Lutsel K'e, Wha Ti and Dettah and compiled. This compilation was compared with typical leachate characteristics as reported by the Solid Waste Association of North America (SWANA). This comparison is provided in Tables C-1 through C-7 (see Appendix C).

Through the comparison of the typical leachate characteristics and the data collected from NWT community landfill SNP stations, it has been determined that the leachate from NWT landfills is well below the typical characteristics of landfill leachates. Average contaminant levels are generally in the range of 0.5 to 6% of typical levels. The only reading that exceeds the SWANA typical leachate characteristics is the sulphate level in Rae Edzo, but this is only by 7%. The value for pH is generally closer to neutral than typical, with the exception of Yellowknife, which has an average pH of 4.46. Overall, the leachate of NWT landfills is very good with low contaminant levels. Although the sensitivity of NWT's northern ecosystem is undisputed the associated low populations generate less hazardous wastes.

8.2 DESIGN PARAMETERS FOR THE UPDATED GUIDELINES

Now that leachate quality appears not be a concern at landfill facilities in the NWT, modified landfill design in the update guidelines will not vary drastically from the Heinke and Wong model.

FSC will develop a sketch of design parameters for solid waste construction and corresponding typical costs for construction. Costs for operations and maintenance will be based on MACA's MMOS task based analysis program.

9. A REVIEW OF VARIOUS SOLID WASTE MANAGEMENT METHODS

A synopsis of conceptual systems and review appropriate alternative methods for MSW management is provided. Although it has been stated that the basic modified landfill is sufficient for the NWT, new advances in solid waste management ought to be followed and considered in turn.

9.1 MODIFIED LANDFILLS

No significant new advances in modified landfills have been developed since the Heinke and Wong guidelines of 1990. Landfill liners, leachate collection and gas collection and management may have seen some technological advances, but these landfill practices are not currently in use in the Northwest Territories. Some landfill advances are reviewed and their applicability to northern landfills assessed.

9.1.1 Overview of Modified Landfill Advances

The International Solid Waste Association (ISWA) has targeted four areas of landfill management being currently studied by technical working groups as follows.

- Pre-treatment of land wastes
- Landfill laws and guidelines
- Landfill gas
- Graded standards for landfills in developing countries

Of these four areas, landfill gas management is not currently addressed in the Northwest Territories. Note that pre-treatment refers to various types of incineration processes.

The United States Environmental Protection Agency (USEPA) states certain new technologies for landfill management such as barriers both proven (e.g. Waterloo Barrier™, slurry walls) and experimental (frozen barriers, and composite walls); phytoremediation of landfill sites (the use of plants for site remediation or deep-rooted vegetative uptake near barriers in existing sites); and gas collection and recovery for energy generation.

9.1.1.1 Liners

The purpose of a liner is to prevent leachate from migrating from the landfill site and entering an aquifer. A liner is a hydraulic barrier that prevents or greatly restricts leachate migration, thus allowing it to be removed by a leachate collection system. Liners function by two mechanisms: (1) they impede the flow

of liquid to the subsurface and aquifers and (2) they absorb or attenuate pollutants, reducing the concentration of contaminants in the leachate. This absorption and attenuation capacity is dependent largely upon the chemical composition of the liner material and its mass. Liners are either synthetic (flexible membrane) or natural (soil or clay). A combination of both types is known as a composite liner.

Geosynthetic clay liners (GCLs) are a relatively new technology (developed in 1986) currently gaining acceptance as a barrier system in municipal solid waste landfill applications. GCL technology offers some unique advantages over conventional bottom liners and covers. GCLs are fast and easy to install, have low permeability, and have the ability to self-repair any rips or holes caused by the swelling properties of the bentonite from which they are made. GCLs are cost-effective in regions where clay is not readily available. A GCL liner system is not as thick as a liner system involving the use of compacted clay, enabling engineers to construct landfills that maximise capacity while protecting area ground water.

9.1.1.2 Barriers

The use of underground containment barriers is an important means of reducing or eliminating the movement of contaminants through the subsurface. Barriers are currently used mainly for the containment of contaminated waste until a remediation method is designed and undertaken. There are many commercially available barriers and others in the development stage.

Slurry walls are the most common type of barrier. In use since 1970, the technology is accepted and regarded as an effective method of isolating hazardous waste and preventing the migration of pollutants. There are different materials, and combinations of materials, that can be used to construct slurry cut-off walls including soil-bentonite, cement-bentonite, and plastic concrete. The backfill and composite typically contain a mixture of materials such as cement, bentonite, fly ash, ground-blasted furnace slag, and clay.

Sheet pile cut-off walls are constructed by driving vertical strips of steel, precast concrete, aluminum, or wood into the soil forming a subsurface barrier wall. The sheets are assembled before installation and driven or vibrated into the ground, a few feet at a time, to the desired depth. A continuous wall can be constructed by joining the sheets together. The joints between the sheet piles are vulnerable to leakage, and a number of patented techniques have evolved to seal them. In addition to different types of joints, a variety of sealants including grout, fly ash, and cement have been used to seal joints.

The Waterloo Barrier™ is an adaptation of the sheet pile wall that addresses the problem of leaky joints. The Waterloo Barrier™ is specially designed to interlock sealable joints. Installation involves driving sheet piles into the ground, flushing the interlocking joint cavity to remove soil and debris, and injecting sealant into the joints. Depending on site conditions, the cavity may be sealed with a variety of materials including clay-based, cement polymers, or mechanical sealants. Video inspection of the joint cavity prior to sealing ensures that the joint can be sealed. The barrier can easily be installed to depths of 75 ft and possibly deeper if piles are spliced together.

Frozen barrier walls, also called cryogenic barriers, are constructed by artificially freezing the soil-pore water. As the moisture freezes, the permeability decreases thereby forming an impermeable barrier. Once the wall is frozen, it remains impermeable and can prevent the migration of contaminants. When the barrier is no longer needed, the refrigeration system can be turned off, allowing the barrier to melt. In the past, this technology has been used for groundwater control and to strengthen walls at excavation sites.

The construction of a frozen barrier wall involves installing pipes called thermoprobes into the ground and circulating refrigerant through them. As the refrigerant moves through the system, it removes heat from the soil and freezes the pore water. In arid regions, water can be injected into the soil to provide the moisture necessary to form the barrier or to repair the frozen wall.

The choice of refrigerant, typically chloride brine and carbon dioxide, is site and contaminant specific. This barrier system is lower cost than other barriers and is flexible (thermoprobes may be installed in various configurations).

9.1.1.3 Gas Management

Uncontrolled landfill gas migration can be a major problem at a municipal solid waste landfill. The gas must be controlled to avoid explosions and vegetation damage in the vicinity of the landfill. In addition to being a hydrocarbon source and greenhouse gas, landfill gas entering the atmosphere will carry with it trace quantities of a large number of volatile organic compounds, some of which have known detrimental health effects. Landfill gas travelling underground may enter structures, where explosive concentrations may build up, or it may displace oxygen, causing a danger of asphyxiation. Landfill gas in the soil profile may damage the vegetation on the surface of the landfill or on the land surrounding the landfill.

The composition of municipal landfill gas is controlled primarily by microbial processes and reactions in the refuse. Methane is usually the gas of concern. It is produced in about a 50:50 ratio with carbon dioxide. The total amount of gas generated in a full-sized landfill is difficult to determine because of the inherent uncertainty using isolated samples to predict total generation rates over long periods. The gas that is generated will either vent to the atmosphere or migrate underground. In either case, monitoring and control equipment must be used to detect and control air pollution or damage to structures or vegetation.

Gas probes are used to detect the location and movement of methane gas in and around a landfill. The probe is installed by boring a hole into the landfill or the ground around it.
Active or passive systems are used for gas management. Passive systems rely on natural pressure and convection mechanisms to vent the landfill gas to the atmosphere. Active gas collection systems remove the landfill gas with a vacuum pump from the landfill or the surrounding soils. These systems may

provide migration control or recover methane for use as energy. In both cases, gas recovery wells or trenches and vacuum pumps are employed. A pipe network is built to interconnect wells and blower equipment. When the primary purpose is migration control, recovery wells are constructed near the perimeter of the landfill.

9.1.2 Northern Applicability

Modified landfilling practices have steadily increased in sophistication over the years in the Northwest Territories. Waste segregation, regular waste compaction and recycling efforts have slowed the increase of solid waste volumes entering landfills hence increasing landfill life and reduced environmental impacts within northern communities. Analysis has found that the NWT, however, may be ignoring improvements to landfill management seen in other northern jurisdictions. Not all advances, however, are suitable to northern, remote, low population communities.

Landfill design improvements, such as the installation of liners and barriers is only justified for landfills expected to produce contaminated leachate. The United States and members of the European Union require all new landfills and lateral expansions of landfills to have liners. It may be argued that in regions with the potential for groundwater contamination, new landfills should have liners and groundwater monitoring. Most importantly, liners should only be used if they are to be monitored for effectiveness. Using liners means leachate needs to be collected and monitored. Unless prepared to design and implement leachate recovery and treatment systems, liners are not necessary. This is case for the Northwest Territories.

Barriers are also rather sophisticated for use in the north if slurry walls and Waterloo Barriers™ are considered. Waterloo Barriers™ in particular cannot be used in areas with dense or rocky soils and are unable to key into rock.

However, barrier technology in general is quite well suited to northern landfills because the collection and treatment of leachate is not performed. The design of more robust versions of such barrier technologies may be easily undertaken. Disposing of shredded scrap iron from vehicles and demolition in a trench down gradient from a landfill is a means of both landfilling scrap metal and "engineering" a reactive barrier for landfill percolate. If a particular NWT community is considering a new landfill and also has a considerable amount of scrap metal to landfill, including a reactive barrier of scrap metal should be considered in the landfill design process.

The volumes of gas produced at landfills in the Northwest Territories has not been studied and the requirement to management it is, therefore, unsupported. Alaska requires air quality controls if a landfill facility is over 2.5 million cubic metres. Communities or municipal buildings in the NWT are located at distances sufficient to make explosions not a concern.

9.2 INCINERATION

Burning municipal solid waste can reduce the amount of waste by up to 90 percent in volume and 75 percent in weight. Pollution control technologies such as scrubbers and filters reduce the toxic materials emitted in combustion smoke. Burning waste at extremely high temperatures also destroys harmful chemical compounds and disease-causing bacteria. Regular testing ensures that residual ash is non-hazardous before being landfilled.

9.2.1 Incineration Overview

Although incineration is a contentious issue in North America, European countries have been using this technology for waste reduction and for energy generation for decades. Sweden and Denmark have embraced this technology fully. Sweden currently incinerates about one-third of its solid waste and intends to eliminate all combustible waste entering landfills by 2003. Now Sweden wants to reduce the amount of waste being incinerated by focusing on more stringent recycling requirements and reducing waste generation through packaging reduction, etc. In Denmark in 1997 just 5% of household waste was landfilled, 80% incinerated and 15% recycled. That same year, Denmark introduced a ban on landfilling any waste suitable for incineration. This ban was so successful that Denmark's new goal is to improve the incineration process by prohibiting certain products (impregnated wood, electronic parts and PVC). Denmark has vowed to recycle 70% of products from incineration (slag and cleaning residues) by 2004. About 550 000 tonnes of residues are generated each year in Denmark—enough to be a waste disposal problem in itself. Both Sweden and Denmark are now focusing more on post-incineration options to solid waste management.

The U.S., Canada and the United Kingdom favour landfilling to incineration, due to air quality concerns and plentiful availability of land compared with Europe. In the Great Lakes Water Quality Agreement, International Joint Commission requested its International Air Quality Advisory Board (IAQAB) to assess available information on emissions from municipal waste incinerators and their contribution to the loadings of persistent toxic substances to the Great Lakes basin. IAQAB recognises that municipal solid waste incinerators are sources of persistent toxic substances that can be transported long distances. Any incinerator application should be viewed in the larger context of an integrated solid waste management approach, which includes life-cycle analysis, with a priority on reduction and recycling initiatives. The IAQAB notes that there is an inherent conflict between the maximisation of waste recycling, particularly of combustible fibre such as newsprint and cardboard, and sustainable, stable operation of an incinerator, as removal of such materials from the refuse significantly reduces its properties as a fuel.

In Kativik, Inuit communities will be experimenting with the use of small-scale incinerators. The Quebec government would like to determine if incineration is a feasible alternative to the haphazard landfilling

that is conducted in these small remote communities. Kativik may be considering incineration now because of its tendency to look toward Greenland for technological inspiration due to their geographic and demographic similarities. Nunavut, as well, has an interest in Greenland's use of incineration. Government officials from both Kativik and Nunavut have visited incinerators in Greenland for the purposes of gathering information and assessing its applicability to their respective regions.

Greenland has a large capacity incinerator in the capital Nuuk (population 10 000), a medium capacity incinerator in Sisimiut (population 4 700) and 41 small capacity units in the other communities. Greenland is influenced by Denmark, one of world's leading proponents of incineration, so it is not surprising the extent to which this form of solid waste handling is embraced. Further, the block funding from Denmark for such services would offset the economic obstacle of incinerating in remote regions.

Alaska incinerates municipal waste in several communities and even has regulations in place specifying the amounts of incinerated ash to landfill. Although incineration is not popular in the southern U.S. states, its prevalence in Alaska may be due to the strong military presence in that state.

Currently Nunavut is considering incineration for Iqaluit and Repulse Bay. In discussions with Dave Parker, CG&T, certain regulators and public interest groups have been urging the government to incinerate Iqaluit's solid waste as a means of reducing the dependency on landfills. Repulse Bay has a unique situation in that it is not economically feasible for a new landfill to meet the setback requirement of 450 m from the community while in a different watershed from the drinking water source. The cost of incineration for Resolute Bay is estimated at 2 million dollars for capital cost and an estimated operating cost of approximately 2%. Incineration for both these Nunavut communities is still in the analysis stage.

A report (Bryant/EBA. 1996) commissioned by the Department of Indian Affairs and Northern Development (DIAND) on incineration in the NWT stated the high cost of incineration as the biggest obstacle to its feasibility. Four Nunavut communities were included in this analysis. A full cost analysis comparing modified landfill operation with incineration (an average cost from two batch feed incinerators considered) in Iqaluit and Resolute Bay determined the following:

- Iqaluit: $9/tonne MSW for modified landfilling and $25/tonne MSW for incineration
- Resolute Bay: $86/tonne MSW for modified landfilling and $479/tonne MSW for incineration

In should be noted that a landfill would still be required for incineration ash and non-combustible wastes. The manufacturers of the two batch feed incinerators studied, claimed they met CCME emission standards for small communities (such as Resolute Bay) but would not meet these standards for Iqaluit. A larger incinerator with an additional filter and scrubber would therefore be required. The Bryant/EBA report concluded that the most cost-effective method available for disposal of MSW is the modified landfill. The disadvantages to incineration stated are:

- The equipment is difficult and costly to maintain;
- Experienced and highly trained operators are required;
- Chemicals such as hydrated lime and actuated carbon are required; and
- The 20 year operating life of the incinerator is questionable.

Only in situations, as determined on a site-by-site basis, where no alternative exists, should incineration be considered In Resolute Bay, for example, incineration is currently being considered because there is likely no site that meets the current guideline's setback conditions.

9.2.2 Northwest Territories Applicability

The applicability of incineration in the Northwest Territories now hinges on the adoption of the CCME Canada Wide Standards for dioxins and furans. The generation of these contaminants during incineration and the resultant requirement of scrubbing the stack emissions may render incineration unaffordable.

9.3 BALING

Baling is a mechanical compaction process that is applied to municipal solid wastes (MSW) before it is placed in a landfill, or in this case, balefill. The waste is compressed into bales that are easily handled and stacked like building blocks three or more high at the balefill. Compaction of the waste at the fill site is no longer required and the quantity of cover material needed is reduced by at least a factor of three. The density of the bales virtually eliminates any fire hazard and discourages rodents and scavengers. Figure 1 shows the schematic of a typical baling process.

There are three basic types of balers:

- High-density balers, achieve waste densities of up to 2,000 lbs./cu.yd. and are usually designed for high volume, large-scale operations. (typical capacities are 400 to 650 tonnes per day)
- Medium density balers with wire tying attachments are available for a variety of applications including low to medium quantities of MSW and recycling. Typical densities achieved by these balers are approximately 1,000 lbs./cu.yd. and capacities range from 100 to 400 tonnes per day.
- Low-density balers with wire tying attachments are not normally considered suitable for MSW. (These are suitable for recycling of products such as paper only).

The type of baler most suited for the waste quantities generated in Yellowknife is a medium density baler with an automatic wire tie arrangement. High-density balers have very high capacities suited for large-scale operations and are several times more costly than medium density units.

9.3.1 Advantages of Baling Waste

The following table provides a summary of the benefits to a typical landfilling operation that a low, medium or high density baling system can provide.

Table 9.1 Summary of Baling System Benefits

Problem	Waste Management Solution	Comments
Lack of cover material	Create cover material by crushing rock	Baling of waste reduces cover material required
	Cover waste with synthetic foam	
Large number of birds scavenging at site	Cover landfill site with nets to keep birds away	Baling of waste discourages scavenging by birds
	Ensure waste is covered daily with granular material	
	Ensure waste is covered daily with synthetic foam material	
Uncontrolled burning of waste	Ensure waste is covered daily with granular material	Baled waste will not burn as easily as open waste
	Ensure waste is covered daily with synthetic foam material	
	Ensure waste is covered daily with granular material	Baled waste will not burn as easily as open waste
	Ensure waste is covered daily with synthetic foam material	
	Control access to the site	

Table 9.1 (cont'd)

Problem	Waste Management Solution	Comments
Frozen waste and cover material make normal sanitary landfill operations impossible	Foam can be placed in winter	Baling of waste provides a simpler and cleaner operation of landfill (cont'd)
Scavenging at site is a health and liability concern to the landfill Owner	Controlled access to the site	Baling of waste greatly reduces scavenging
	Foam cover will reduce ability to scavenge waste	
Wind blown debris littering the site	Cover on a regular basis	Baling reduces the amount of debris that can be scattered by the wind
	Hire staff to collect debris from area surrounding landfill	
Compaction of waste not sufficient	Purchase, rent or lease the appropriate equipment	Waste is compacted into bales at the plant and no compaction equipment is required at the landfill
Leachate generation	Ensure that cover material is placed over the waste to prevent infiltration	Waste in bales is tightly compacted and precipitation will tend to go around rather than through the waste and thus reducing concentrations of contaminants in leachate
No facilities for recycling	Construct new facilities	The baling plant can be used to sort and bale recyclable material

9.3.2 Disadvantages of Baling

- Purchase and operation of the baler and associated equipment are more expensive than conventional landfilling.
- A building is required to house the baler and the materials handling equipment.
- Not all materials can be baled. Large objects will still require conventional landfill disposal.
- Baling is not expected to completely eliminate the birds at the balefill. Bird control measures will be required if the site is near the airport.

9.3.3 Bale Plant Description

A bale station could function as a centrally located transfer station reducing the transport distance for pick up vehicles. Bales would be formed at the station and taken to the balefill on conventional flat bed trailers. All city and surrounding area waste would be taken to the bale station for processing. Separate storage areas could be provided for recyclable material and for reclaimable materials (i.e. furniture, dimensional lumber, etc.).

At this location, a small landfill cell can be designed to handle wastes in an emergency should mechanical difficulties arise with the baling equipment. A separate storage area for salvageable materials could be established next to the baler structure.

The balefill itself would not be accessible to the general public.

A baling facility is ideally suited to act as a transfer station for several reasons:

- Wastes are compacted and the number of required trips to take bales to the balefill would be substantially less than the number of trips required to deposit unprocessed MSW at a landfill site.
- Bales are compact, clean and easy to transport on conventional flatbed trailers.
- If and when desired, the baler facility can be also used to bale recyclable materials extracted from the waste stream.

Balers should be installed inside a heated building because of the need to protect the hydraulic systems from extreme cold. The building would provide access for refuse collection vehicles, private firms and individuals, and access for flatbed trailers for the removal of bales. An outside storage area for loaded bales should also be provided.

A bale facility would also be excellent to set up charges for disposal if desired. In a typical arrangement, wastes would be dumped onto a large tipping floor, sorted for recyclable and non-baleable goods, and then pushed into a small pit by a front-end loader. A heavy-duty conveyor would lift wastes from the pit into the receiving hopper of the baler. When the hopper is filled, the waste contained therein would be compacted into approximately 1.6 cu. m. (2 cu. yd) bales with an average weight of about 900 kg. (2,000 lbs.). These would be wire-tied and ejected at the rear of the baler. The bales can then be moved by conveyor or fork lifted for loading on a flat bed trailer.

Baling would allow a tight scheduling of operations at the balefill site. Bales could be accumulated on flatbed trailers until quantities warrant transportation to the balefill, where they are then stacked. At the balefill, a front-end loader or forklift could be used for positioning bales. While a cover to waste ratio of 1:9 is generally recommended for balefills, most of this is required for final capping, thus reducing the cover requirement during the winter months without creating health problems.

9.3.4 Costs

The following are estimated costs of baling operations.

Item	**Estimated Cost**
Building	$ 750,000
Baler	$ 450,000
Bobcat	$ 30,000
Fork Lift Loader	$ 60,000
Flat Bed Trailers (2)	$ 80,000
Miscellaneous	$ 100,000
Subtotal	**$1,470,00**
Contingencies 15%	$ 221,000
Engineering 15%	$ 221,000
TOTAL	**$1,912,000**

Annual costs when recovered over 15 years at 6% (CRF=0.10296) $197,000 p.a.

Annual Operating Costs:

Item	Estimated Cost (p.a.)
Baler Facility Operator and Equipment Operators (2 1/2 @ $55,000)	$137,500
Maintenance	$ 25,000
Utilities (fuel/power/water)	$ 50,000
Equipment (2 machines x 2 hrs/day x $25/hr x 250 days)	$ 25,000
Miscellaneous	$ 20,000
SUB TOTAL	$257,500
Contingencies 15%	$ 38,600
TOTAL	**$296,100**

9.3.5 Cost Summary

Item	Capital Cost	Operating Cost	Total Annual Cost
Baler and Building	$197,000	$296,100	$493,100

10. REVIEW ENVIRONMENTAL MONITORING PROCEDURES

The current monitoring procedures used the Nunavut Water Board, Alberta and Alaska are reviewed and assessed for applicability to the Northwest Territories.

10.1 NUNAVUT WATER BOARD

10.1.1 Purpose

The Nunavut Water Board requires that discharges from solid waste sites be sampled to ensure that license requirements are being met. The NWB will specify the parameters to be sampled and the frequency of sampling in the Surveillance Network Program for each water licence, if necessary. The Licensee is responsible for sampling, analysis and reporting results to the NWB, and any other authority, within the time period defined in the licence. All sampling results should be submitted to the NWB upon completion. An annual report is also required in which the data is not only provided but results are analysed and used to discuss compliance issues and future plans for the project.

The following is from the NWB's draft *Guidelines for the Discharge of Wastewater Associated with Sewage & Solid Waste Facilities in Nunavut* (2001).

10.1.2 Sampling Frequency

10.1.2.1 General

The NWB will define a Surveillance Network Program for each Water Licence. This program will list the required parameters, sampling locations, and a reporting schedule.

For municipalities, compliance sampling frequency is based on population considering that, as the population of a community increases, so does the potential for hazardous materials to be discharged to the municipal collection system.

10.1.2.2 Sampling Frequency for Discharges from Solid Waste Sites

Table 10.1 outlines the general requirements for sampling intermittent and/or seasonal discharges and apply generally to solid waste sites. Results are to be submitted as shown in Table 10.1.

Table 10.1 Sampling Frequency for Discharges from Solid Waste Sites, Landfarms & All Other Intermittent and/or Seasonal Discharges

Discharge Category	Frequency for Submission of Data to NWB	Flow	BOD_5, TSS	NH_3-N, PO_4-P Discharge to fresh water	NH_3-N Discharge Overland to Marine Water	Faecal Coliform	Heavy Metals and Other Parameters of Interest
All Fresh Water	Monthly	Weekly	Monthly	Monthly	n/a	Monthly	Monthly
All Special Permit	Weekly	Daily	Weekly	Weekly	n/a	Weekly	Weekly
All Marine	Monthly	Weekly	Monthly	n/a	Monthly	Monthly	Monthly

10.1.3 Receiving Water Sampling

Receiving water needs to be sampled to ensure that objectives outlined in Section 3 are being met. Normally, the NWB will arrange for sampling of the receiving environment by the DIAND Water Inspector or a consultant to the Board. In specific cases, the NWB may require Licensees to undertake a receiving environment sampling program, or components of a program.

Groundwater sampling by the Licensee may be required where contamination is present or suspected. The NWB will specify sampling frequency and parameters.

10.2 ALBERTA

The new Standards and Guidelines currently in draft in Alberta provide extensive guidance on landfill monitoring. The recommended approach includes the monitoring of groundwater, surface water and landfill gas as appropriate to the natural setting and environmental sensitivity of the landfill, plus the monitoring of engineered systems during the operation and post-closure periods of the landfill life. The general approach to these aspects of the recommended monitoring programs is summarized in the following sections of the report.

10.2.1 Groundwater

The key components of the recommended groundwater monitoring programs include the following:

- initial sub-surface assessment to identify the hydrogeologic setting of the landfill;
- design and implementation of a baseline monitoring network of groundwater monitoring wells to identify the groundwater conditions prior to landfill development and operation;
- design and implementation of a groundwater sampling and testing program that can identify groundwater quality parameters relative to natural conditions and expected future landfill leachate chemistry. Interpretation of the baseline groundwater quality data should include the establishment of ongoing groundwater performance requirements relative to concentrations of these parameters identified in the baseline program;
- quality assurance and quality control programs to ensure the reliability and reproducibility of the groundwater quality data obtained;
- data interpretation techniques to identify any landfill-derived effects on groundwater;
- development and implementation of response monitoring plans to establish the extent and frequency of groundwater monitoring during routine operation of the landfill;
- groundwater response plans to identify the responses which are appropriate under a range of groundwater monitoring scenarios (e.g. routine re-sampling and re-testing in response to minor anomalies, immediate re-sampling and re-testing in response to potential major environmental anomalies, emergency intervention in response to major health-related anomalies); and
- reporting to establish a database of groundwater data with the appropriate regulatory agencies.

The Alberta guidelines acknowledge that the setting of each landfill is unique, and that the groundwater monitoring approach at different sites may need to respond to different conditions. These differences will generally be based on environmental sensitivity, and would include recognition of nearby groundwater use, proximity of potentially affected aquatic or other ecological habitats, or other conditions that would be considered of particular sensitivity to leachate-affected groundwater.

10.3 ALASKA

The state of Alaska has detailed monitoring regulations for landfills. The following is a generalized summary:

- Visual and Air Monitoring
  - damage or potential damage to any component of the facility from settlement, ponding, leakage, thermal instability, frost action, erosion, thawing of the waste, or operations at the facility;

- Surface Water Monitoring: if surface water monitoring is required,
  - the points of compliance must be chosen so that highest concentrations of hazardous constituents migrating off the facility will be detected and so that interference from sources of pollution unrelated to the facility's solid waste management operations will be minimized
  - The point of compliance will normally be located no more than 50 feet outside a waste management area boundary
  - Sample during high flow and low flow conditions each year
  - A list of parameters is provided and may vary depending on site
  - A monitoring program will be designed to include proper sampling procedures and techniques (e.g. analytical procedures, quality assurance/quality control)

- Corrective Action for Problems Detected during Visual and Surface Water Monitoring
  - If a problem is detected, the operation shall take action to correct the change, damage, or violation, to prevent the escape of waste or leachate, and to clean up waste that was disposed of in an unauthorized manner
  - If a statistically significant change in water quality is detected, the operator shall determine the extent and migration of the contamination
  - A report on the violation must be submitted within 30 days or immediately if a drinking water source may be threatened

- Groundwater Monitoring and Corrective Action
  - Details are provided for sites and conditions that do not require groundwater monitoring
  - Groundwater sampling and analysis requires procedures and techniques as required for surface water analysis

- Other details specific to groundwater monitoring (groundwater elevation measurements, avoiding temporal variation in groundwater flow, etc.) are provided
- Details are provided on the statistical methods of analysis that are required
- A Detection Monitoring Program for Groundwater Quality is required of all facilities with groundwater wells
- Assessment Monitoring and Corrective Action as set out in federal regulation are required if problems are detected during groundwater monitoring

10.4 MONITORING RECOMMENDATIONS

In the current Heinke and Wong guidelines, there are no recommendations for ground and surface water monitoring. The DIAND permitting process requires monitoring at municipal landfill SNP stations, but as determined in this evaluation, such data are not routinely compiled and reviewed.

As is done is Alaska, the guidelines will recommend a routine visual monitoring program for landfill facilities, and leave water monitoring on a site-by-site basis as required of permit holders. The updated Guidelines, therefore, have included visual monitoring checklist as well as make references to water monitoring as required by a community's water licence.

Thermocouple monitoring is recommended for those communities where the permafrost conditions are not well understood to determine if a site is within permafrost. Sites in permafrost regions should be exempt from groundwater monitoring. Those sites not within continuous permafrost should be monitored for groundwater on a site-by-site basis.

11. GUIDELINES SUMMARY

The following is a summary of guidelines presented sequentially as they appear in *Guidelines for the Planning, Design, Operations and Maintenance of Modified Solid Waste Sites in the NWT.* Likewise, this summary presents guidelines based on the sequences taken when developing a new, or expanding an existing modified landfill facility.

11.1 PLANNING SOLID WASTE FACILITIES

Citation in Guidelines	Guideline	Reference / Justification
2.2.1	*Model: Total Community Solid Waste Volume (m^3) in Any Year;* Model: Total Community Solid Waste Volume (m^3) in a Planning Horizon.	MACA (1986) models are is still valid for use in the N.W.T. – professional judgement.
2.2.1	Average residential solid waste volume = 0.015 m^3/person/day .	This figure is a 1% increase over the 1990 figure of 0.014 m^3/person/day due to population increases (despite CCME1992 reported decrease in per capita packaging consumption). FSC (2000).
2.2.2	Uncompacted waste density of 0.099 tonnes/m^3.	Waste densities vary widely. This standard is conservative and has been applied in NWT solid waste planning – professional judgement.
2.2.3	Table 2.1 NWT Typical Modified Landfill Waste Compositions (% by weight).	Best available data for the NWT based on a solid waste study of Inuvik, Tsiigehtchic and Fort McPherson. Quay and Heinke (1992).
2.2.6	Compaction rate for a modified landfill is 3:1.	Heinke and Wong, 1990.
2.5	Recommended collection frequency of MSW once every two weeks in the winter, once per week in the summer.	Collection frequency is an issue of local preference (involving employment practices, equipment availability, etc.) This guideline is a reasonable standard based on professional judgement.

2.5	Recommended collection frequency of honey bags is five days per week with no more than two days between collections.	As above. More frequent service than MSW due to health and aesthetic reasons.
2.6	In communities where each residence operates an individual garbage can, collection service by 1 tonne compactor-type vehicles is recommended.	Professional judgement including personal correspondence with Rick Semeniuk, Canadian Waste.
2.6	In communities where 1½ yd^3 bins would typically be shared between 2, 3 or 4 houses, collection service May be delivered by 3 tonne side loader type vehicles.	As above.
2.6	Where communities are less than 300 kilometres apart by all-weather road (or more than 300 kilometres from a landfill), a transfer station may provide the opportunity for cost savings if regional landfills are considered.	Such an approach is taken in other remote regions such as Alaska, northern Alberta
2.6	Small communities (<1,000 residences) may be best serviced by simple bin-style transfer stations; larger communities serviced by compactor-style transfer stations for volume reduction.	Professional judgement including personal correspondence with Rick Semeniuk, Canadian Waste.
2.7	Modified landfill facilities should not be visible from the community, should be set back from the airport (8 km federal regulation and 3 km interim regulation), and should be in a watershed that drains away from the community's drinking water source.	Heinke and Wong (1990); Soberman, *et al* (1990); FSC (2002).
2.7	Table 2.3: Modified Landfill Siting Checklist	See Guidelines for stipulations and references. Those references citing "these guidelines" are based on professional judgement.
2.8	Monitoring need issues:	Level of risk and associated is based on professional judgement.

11.2 DESIGNING SOLID WASTE FACILITIES

Citation in Guidelines	Guideline	Reference / Justification
3.2	All landfills should be designed for a minimum 30-year design life.	A 30-year design life is the acceptable North American standard (SWANA (1991)); review of other jurisdictions has not found a *longer* than 30 year design life requirement. Further, this standard is reasonable – professional judgement.

11.3 OPERATION AND MAINTENANCE

Citation in Guidelines	Guideline	Reference / Justification
4.1	Compaction rates of 3:1 or better are achieved by working a bulldozer or other appropriate heavy equipment over the waste 3 to 5 times.	Professional experience/judgement.
4.1	Compaction of wastes is undertaken once per week or in combination with collection frequency.	Professional experience/judgement.
4.1	Cover material should be 100mm between cells, 300mm on the surface of cells, and 600mm as part of close out.	Professional experience/judgement.
4.2.1	The area method of modified landfilling should have a berm 2 m high.	Professional experience/judgement.
4.2.1	In the spring or fall, or when the compacted garbage is 3 metres thick, the compacted wastes are covered with a minimum 100 mm of material.	Professional experience/judgement.

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13. APPENDICES

Appendix A Questionnaire for Landfill Management in Various Northern Jurisdictions

Appendix B Summary of Landfill Management in Various Northern Jurisdictions

Appendix C Constituent Comparison for SNP Surface Water Stations versus SWANA (1991) Typical Leachate Characteristics

Appendix A

Questionnaire for Solid Waste Management in Various Northern Jurisdictions

1. Qualification

Does the guideline address existing landfills, new landfills and lateral expansions?

2. Monitoring

Does the guideline present a program for

a) Ground and surface water quality monitoring?
b) Landfill gas management and odour nuisance monitoring?
c) Public health, safety and nuisance monitoring?

3. Siting Criteria

Does the guideline specifically mention the following issues and present a minimum distance radius (if applicable) or other recommendations?

a) Property boundary
b) Airports
c) Surface water
d) Floodplain
e) Permafrost
f) Excluded areas

4. Design Criteria

Does the guideline

a) Mention a landfill design approach eg. natural control landfills/engineered landfills?
b) Recommend a cover depth and material?
c) Specify design requirements of the facility's access road?
d) Mention fencing, signage and access requirements?
e) Require that the facility be designed by a qualified persons?
f) Make any provisions for future expansion?

5. Collection Procedures

Does the guideline specify

a) Truck size, type, and number based on community sizes?
b) Time and motion routing?
c) Collection frequency?
d) Collection of recyclable materials?
e) Household hazardous wastes?
f) Large recyclable items (appliances, small motors, snowmobiles?)

g) Recycling programs/transportation procedures?

6. Operational Criteria

Does the guideline specify the following?

a) Prohibited wastes
b) Landfilling method
c) Designated areas (segregation of wastes such as appliances, wood products)
d) Facility signage
e) Supervision/operator training and certification
f) Waste measurement
g) Scavenging
h) Dust control
i) Waste compaction and covering
j) Contingency for extreme weather conditions
k) Litter control
l) Vectors
m) Wildlife
n) Open burning
o) Recycling and hazardous waste handling (i) is there a regional approach to recyclables and/or hazardous materials (ii) are there recycling programs with a community population threshold (eg. communities over 750 people will have a recycling program)?

7. Advances

a) What advances in solid waste techniques/management have been integrated into the guidelines (eg. incineration, compaction equipment?)
b) Do the guidelines specify if advances are feasible only at certain community population thresholds?

8. Regulatory Requirements

a) Are there any anticipated changes to acts, regulations and guidelines?
b) Does the guidelines explain the roles and responsibilities of communities, various agencies and government departments?
c) What kind of reporting of monitoring results and lines of communication are specified in the guidelines?

9. Closure and Post-Closure

a) Are closure plans required of all solid waste facilities?
b) Is financial security required of all solid waste facilities?

Appendix B

Table B.1 Summary of Landfill Management in Various Northern Jurisdictions

Criterion	Does the guideline…	NWT	Alaska	Yukon	Nunavut	Kativik	Sweden
1. Qualification	Address existing landfills, new landfills and lateral expansions?	Yes, all three	Yes, all three	For existing and new facilities	Yes, all three	No	Yes, all three

Criterion	Does the guideline…	NWT	Alaska	Yukon	Nunavut	Kativik	Sweden
2. Siting	Mention or provide a minimum distance for the following? (a) property boundary	Not be visible from community	a minimum setback of 50' between the facility and the property line	No	Not be visible from community	No	No
	(b) airports	8 km from airport (federal regulation); 2 km distance from airport	10 000' for turbo jet and 5 000' for prop aircraft unless waived by FAA	No	8 km from airport (federal regulation); 2 km distance from airport	No	No
	(c) surface water/groundwater (cont'd)	Siting in watershed that drains away from the community water supply	>10' from the highest aquifer level unless constructed 2' or more above the natural ground surface; 200' from drinking water source and 100' from other surface waterr	The active area must be located at least 100 m from the high water mark of any waterway and at least 1.5 m from the groundwater table	Siting in watershed that drains away from the community water supply	150 metres from waterway and 500 metres from source of drinking water	No

Criterion	Does the guideline…	NWT	Alaska	Yukon	Nunavut	Kativik	Sweden
2. Siting (cont'd)	(d) floodplain	No	Sites within 100- year floodplain must not restrict flow of 100-year flood	No	No	No	No
	(e) permafrost	No	Must prove with thermal monitoring (section currently being rewritten)	No	No	No	N/a
	(f) other	Sufficient capacity for at least a 20 year life	Seismic impact zones and unstable areas	At least 50 m from any highway and a minimum 10 m depth vegetation screen	Sufficient capacity for at least a 20 year life	Diversion ditch must surround facility	No

Criterion	Does the guideline…	NWT	Alaska	Yukon	Nunavut	Kativik	Sweden
3. Design Criteria	(a) Mention a landfill design approach? (cont'd)	Area, Trench and Depression designs described in detail	Follows Federal guidelines: for Class I – 2' of clay or geomembrane; for Class II or III lining not necessary unless required in permit	No	Area, Trench and Depression designs described in detail	No	Landfill barrier designed such that non hazardous leachate does not penetrate liner in 50 years; that of hazardous leachate in 200 years

Criterion	Does the guideline…	NWT	Alaska	Yukon	Nunavut	Kativik	Sweden
3. Design Criteria (cont'd)	(b) Recommend a cover depth or cover material?	0.15 m to 0.2 m on slope and minimum of 0.5 m on top layer	For Class 1 and II sites, 6" cover of earthen material each operating day, or more frequently if necessary; for Class III, 6" cover of earthen material as needed	Approximately 10 cm of soil or other comparable cover for every 0.5 m of solid waste (not required between November 15 and April 15)	0.15 m to 0.2 m on slope and minimum of 0.5 m on top layer	Daily covering requirement waived	No
	(c) Specify design requirements of the access road?	Access road cross section recommended	No (department of Transport responsibility)	No	Access road cross section recommended	No	No
	(d) Mention fencing, signage, and access requirements?	Site drainage, fencing and segregation given	Fencing, signage, required	No	Site drainage, fencing and segregation given	No	No
	(e) Require the facility be design by qualified persons?	No	If >75 tons/day – plans by registered professional engineer	No	No	No	Yes
	(f) Make provisions for future expansion?	No	No, in permit application only	No	No	No	Yes

Criterion	Does the guideline…	NWT	Alaska	Yukon	Nunavut	Kativik	Sweden
4. Operational Criteria	Specify each of the following? (a) prohibited wastes	No	Federal definition of hazardous waste is used; household hazardous waste is accepted	Special Waste Regulations detail prohibited wastes; Asbestos handled in accordance with Occupational Health Regulations	No	No	Yes, in EU directorate
	(b) landfilling methods	Yes, details provided	No, required in permit	No	Yes, details provided	No	No
	(c) designated areas	Site facility design detailed: bulky wastes, refuse, honey bag waste, waste oil	Some segregation (left to the discretion of communities)	Wood for burning must be segregated; substances that may cause fire, explosion, gaseous emissions must be stored separately	Site facility design detailed: bulky wastes, refuse, honey bag waste, waste oil	No	No
	(d) supervision/ operator training	No	SWANA/MOLO certification required for Class I facilities; for other facilities local training is given for operators	Operators must be familiar with regulations and trained (no specifics given)	No	No	No
	(e) waste measurement (cont'd)	No	No scales at site; near the end of permit, a survey is required	No	No	No	No

4. Operational Criteria (cont'd)	(f) scavenging	Method of recycling, fencing, site supervision required	Accepted as a method of recycling; permits may be issued; large facilities have safety measures	No	Method of recycling, fencing, site supervision required	No	No
	(g) waste compaction and covering	Details given in disposal operations section	No, addressed in permitting	(see Design)	Details given in disposal operations section	no	No
	(h) contingency for extreme weather	No	Recommended that cover material be set aside for winter	Covering not required in winter	No	Cover not required in winter	No
	(i) litter control	Yes, under Aesthetics	Cover and fencing	yes	Yes, under Aesthetics	No	No
	(j) vectors	No specifics	No specifics (must be minimized)	No	No specifics	No	No specifics
	(k) wildlife (cont'd)	Fencing	Electric fences for Class I	No	Fencing	no	No (not a problem)

Criterion	Does the guideline…	NWT	Alaska	Yukon	Nunavut	Kativik	Sweden
4. Operational Criteria (cont'd)	(l) open burning	Prohibited in accordance with the CCME Canada-wide Standard for Dioxins and Furans	Allowed at Class III facilities only	Conducted in accordance with various Acts and Regulations; a Permit is required	Not recommended but reluctantly accepted	New regulations allows open burning once a week	Not permitted, incineration well established
	(m) recycling programs	No	Cardboard & used oil burned for energy recovery; some composting; cans collected and sent to southern U.S. for recycling	Recycling cans and bottles (cans sent south for recycling; glass used in road construction); recycling club provides point system and rewards for collection	No	A Québec recycler will tour region in 2002 to develop a recycling program	Extensive details given; producer of waste, rather than municipality, is responsible for its recycling

Criterion	Does the guideline…	NWT	Alaska	Yukon	Nunavut	Kativik	Sweden
5. Advances	Mention techniques/ Management advances (eg. Incineration)?	Incineration being considered for Iqaluit	Incineration, gas management, liners, groundwater monitoring	Recycling, reuse programs extensive	Incineration being considered for Iqaluit	Small scale incineration will be tried for small Inuit communities; disincentives (user fees) for commercial dumping at landfills	In 2002 combustible waste will no longer be accepted at landfills; in 2005 all organic waste to be composted

Criterion	Does the guideline…	NWT	Alaska	Yukon	Nunavut	Kativik	Sweden
6. Regulatory Requirements	(a) anticipate changes to acts, regulations, and guidelines?	MVLWB requirements currently under review; Inuvialuit requirements will follow Mackenzie Valley approach	Alaska became an "approved state" in 1996 (incorporated into the Federal system); legislation rewritten; sections currently being updated	Solid Waste Regulations new in January 2000; Permits issued under Solid Waste Regulations; Government of Yukon conducting pilot project for no-burn operations	New environmental assessment act will be drafted in 2002	draft 2 page Nord-du-Québec regulations will go into effect	See section 5
	(b) explain roles and responsibilities of communities, various agencies, and government dept.?	No	More regulatory requirements since becoming federally approved; Alaska can now regulate how municipalities manage solid waste	Solid Waste Management Plan required of facilities by January 2002 detailing design, construction, operation, upgrading, closure and post closure plans	Guideline for Nunavut not yet drafted	Details process for new developments; locally operated and managed; yearly government inspections	Small facilities (<100,000 tonnes/year) are locally permitted, large facilities need federal approval; Waste generators responsible for recycling; gov't intervention only when needed
	(c) outline reporting and lines of communications?	No	Reporting done to Department of Environmental Conservation	Details given on record maintenance (operations; waste volume, etc.); Minister shall establish a public register	Guideline for Nunavut not yet drafted	no yearly reporting, landfill operator submits monitoring results if problem detected	Reporting done only if problem detected; monitoring results, remediation plans and measures taken submitted to gov't

Criterion	Does the guideline…	NWT	Alaska	Yukon	Nunavut	Kativik	Sweden
7. Monitoring	(a) outline ground and surface water quality monitoring?	Required in permit but not specified in regulations	Numerous details provided; waived for facilities located in permafrost areas	Required in permit but not specified in regulations	Required in permit but not specified in regulations	Required in permit on site by site basis	Required in permit on site by site basis
	(b) outline landfill gas management and odour nuisance monitoring?	No	Methane monitoring for Class I, sometimes for Class II facilities	No	No	No	Required in permit on site by site basis
	(c) outline public health, safety and nuisance monitoring?	No	Visual monitoring, microbiological monitoring if public complain issued	No	No	No	No

Criterion	Does the guideline…	NWT	Alaska	Yukon	Nunavut	Kativik	Sweden
8. Closure and Post-Closure	(a) provide closure recommendations?	No	18" minimum infiltration layer with a permeability $<1 \times 10^{-5}$ cm/s; minimum 6" cover capable of sustaining native plant growth	Waste compacted and covered with a least 1.0 m of compacted soil; site returned to re-vegetated state	No	30 cm cover required upon closing	1.0 m of cover required upon closing
	(b) require closure plans?	No, required for permit	Details given for required closure plans	Closure plans required	No, required for permit	No, required for permit	No, required for permit
	(c) financial security?	No	No, required for permit	No	No	no	No

Appendix C

Constituent Comparison for SNP Surface Water Stations versus SWANA (1991) Typical Leachate Characteristics