Northwest Territories Environment and Natural Resources

July 6, 2011

Kathleen Graham
Regulatory Officer
Mackenzie Valley Land and Water Board
7th Floor – 4910 50th Avenue
P.O. Box 2130
Yellowknife, NT
X1A 2P6

Dear Ms. Graham:

Re: Request for Comments - Town of Fort Smith, Type A Water Licence Renewal Application #MV2011L3-0001

The Department of Environment and Natural Resources (ENR) has reviewed the above noted application based on its mandated responsibilities under the *Environmental Protection Act*, the *Forest Management Act*, the *Forest Protection Act* and the *Wildlife Act*.

Please find attached ENR's written intervention, and supporting documents with regards to the scheduled Public Hearings concerning this application.

Should you have any questions or concerns please do not hesitate to contact Patrick Clancy, Environmental Regulatory Analyst, at (867) 920-6591 or email at patrick_clancy@gov.nt.ca.

Sincerely,

Terri Bugg
Environmental Assessment Analyst

Attachments

Environmental Assessment and Monitoring
Environment and Natural Resource, Government of the Northwest Territories
PO BOX 1320
Yellowknife NT X1A 2L9
Telephone (867) 920-6591
Fax (867) 873-4021

Table of Contents

Introduction

The Department of Environment and Natural Resources (ENR) understands that the current application is a renewal for the activities included in Water Licence MV2003L3-0006. Hence ENR specifically addresses the scope of activities included in the application and the related Terms and Conditions in the current WL. However, through the A Water Licence application process and its related deliberations (i.e. discussion at the Technical Session[1]) the issue of offsite disposal of sewage sludge solids and landfarming of contaminated materials has been discussed ENR has also provided background and recommendations, to aid the Mackenzie Valley Land and Water Board (MVLWB) and the Town of Ft. Smith in the effort to aid in moving forward on these subjects.

ENR recognizes that additional materials and information in support of the application is arriving late or yet to be received, and is beyond the deadlines in the workplan and timelines set forward by the MVLWB. ENR understands that the MVLWB is allowing comments/questions on this information at the hearing. ENR hence reserves the right to alter its comments and/or recommendations to accommodate evidence not reviewed to date.

Groundwater and Surface Water Quality at the Solid Waste Facility

ENR has reviewed the application and supporting documentation and provides the following summarized discussion for use by the MVLWB and the Town of Fort Smith, and in support of ENR recommendations in respect to the issue of leachate and groundwater monitoring for the Fort Smith Landfill.

"Leachate may be defined as liquid that has percolated through solid waste and has extracted dissolved or suspended materials. In most landfills leachate is composed of the liquid that has entered the landfill from external sources, such as surface drainage, rainfall, groundwater, and water from underground springs and the liquid produced from the decomposition of wastes, if any"[2].

Due to the location of the landfill in a ravine, and proximity of the landfill to the Slave River, leachate monitoring and management is a priority to prevent contamination of the surrounding environment.

Information regarding the location of the landfill and its proximity to water bodies is described by the *Town of Fort Smith Renewal Background Report Volume 1,* AECOM, January 2011:

> *"The site is located in a ravine area so that much of the runoff flows to a natural stream discharging at the north end of the landfill, which in turn flows to a wetland before entering the Slave River. The landfill site is underlain by sand, so some of the runoff infiltrates through the sand layer"[3].*

---

[1] Transcript, Mackenzie Valley Land And Water Board, Technical Session For Town Of Fort Smith, Type A Water Licence Renewal, MV2011L3-001, HELD AT: Yellowknife, NT, June 15th, 2011

[2] Tchobanoglous/Theisen/Vigil. *Integrated Solid Waste Management – Engineering Principles and Management Issue, 1993*. Chapter 11. Disposal of Solid Wastes and residual Matter, 11-5 Composition, Formation, Movement, and Control of Leachate in Landfills, page 417.

[3] Section 3.3 Solid Waste Disposal Facility, *Town of Fort Smith Renewal Background Report Volume 1*, AECOM, January 2011

Since the issuance of the current water licence in 2003, two reports were commissioned by the Town to evaluate and assess the surface and groundwater quality leaving the landfill and the ability of the downstream wetland to treat any potential leachate. The objective of the *Fort Smith Landfill Wetlands Characterization*[4] completed in 2004 was to determine the capacity of the wetland to treat landfill effluent. The report studied the wetland located northwest of the site; however the Indian and Northern Affairs Canada (INAC) inspection report in 2005 indicated that the water flows in a northeasterly direction. The IEG study also concludes that "*there is insufficient information from the IEG's current study to conclude that the groundwater may be recharging the wetland.*"

The 2006 Earth Tech study was conducted to evaluate trends in groundwater quality at the site to reduce the number of parameters being analyzed and frequency of sampling. The report includes various recommendations[5], including but not limited to replacing the current general chemistry parameters for sampling with the parameters listed in the *Alberta Code of Practice*, continue to measure groundwater elevations, and to discontinue monitoring for petroleum indicators given the fact that the land-farming at the site is complete.

The AECOM Report, May 2010, drawing upon information from previous reports (in particular the 2006 Earth Tech Report), provides an overarching recommendation in stating that the existing groundwater and surface water monitoring program should be continued without change to the list of parameters analyzed, only to the number of wells sampled[6].

Discussion

Leachate Generation and Monitoring, Groundwater Wells and Sampling Methodology

Various consultants have collected groundwater data from the landfarm and landfill area. It has been demonstrated that the groundwater monitoring data supports the conclusion that the solid waste facility is generating leachate and is impacting the groundwater at the site[7]. It's also evident that based on elevated concentrations of nickel, chromium, copper, and phosphorus, combined with the increased concentrations of sulphate, chloride, and sodium in the 2009 and 2010 downgradient samples, that leachate is impacting stream water[8].

The 2006 Earth Tech Report was conducted to evaluate trends in groundwater quality at the solid waste disposal site, and to reduce the number of parameters analyzed and frequency of sampling (as discussed in number 5 above). However, Sections 3.0, Methodology, and 3.1 Groundwater Monitoring, do not provide rationale for the locations of the groundwater wells.

---

[4] Section 4.0 Conclusions, 4.2 Soil and Water Analysis, *Fort Smith Wetlands Characterization*, IEG Environmental. November 2004.

[5] Section 5.2, Recommendations, *Groundwater Monitoring Program Evaluation – Fort Smith Municipal Landfill, Fort Smith, Northwest Territories*, Earth Tech Canada, Inc., May 2006.

[6] Page 7, Section 5. Conclusions and Recommendations, *Groundwater Monitoring Program Review, Fort Smith Municipal Landfill*, AECOM, May, 2010.

[7] Page 6, Section 4. Field Investigation Results and Discussion, 4.1 Groundwater Monitoring, 4.1.2 Laboratory Analysis, and Page 7, Section 5. Conclusions, *Groundwater Monitoring Program Review, Fort Smith Municipal Landfill*, AECOM, May, 2010.

[8] Page 7, Section 5. Conclusions and Recommendations, *Groundwater Monitoring Program Review, Fort Smith Municipal Landfill*, AECOM, May, 2010.

The recommendations provided in the AECOM Report, May 2010, (presented in 7 above), may or may not have merit. However, the sampling design has not been justified or determined adequate. It is not demonstrated how reported parameters are relevant to this site, and rationale is not provided for the location of the groundwater well installations. This is critical information to validate any related monitoring program and risk assessment to establish meaningful mitigation strategies.

Seasonal variations in the water table have not been presented. Seasonal variations in the water table and groundwater flow will impact water infiltration rates and leachate generation and its subsequent impact on the environment.

In summary, without a clear understanding of the hydrogeological conditions, it does not appear possible that a current examination of the data from monitoring wells, the extent of leachate migration from the site, comparison of contaminants in leachate to established background levels, and an examination of the associated risk can be adequately performed.

Wetlands Characterization and Capacity to Treat Landfill Effluent

The *Fort Smith Landfill Wetlands Characterization,* 2004*,* also does not demonstrate that hydrogeology of the site is fully defined or understood, and there is no evidence that demonstrates the wetland has the capacity or ability to treat landfill effluent, or if it is even the receiving environment for the landfill leachate.

Applicability of the Alberta Code of Practice

The rationale for the reference, adoption, and use of aspects of the *AB Code of Practice* and its Class II Landfills performance standards is not demonstrated as relevant, and thus its current value is questionable.

AB landfill leachate parameter thresholds are devised for use with AB landfill design criteria, which include site location requirements, liners, and leachate collection systems. Hence, the application of these performance standards to the Ft Smith Landfill, that is not designed to the AB criteria, must be demonstrated as relevant to be of use. For example:

- Class II landfills that follow the *AB Code of Practice* are designed with a liner (synthetic or natural) and leachate collection system; to ENR's knowledge, the Fort Smith landfill was not constructed with a liner system or a leachate collection system.
- Chloride and sulphate concentrations in monitoring wells BH09 and BH10 at the Fort Smith Landfill are reported as above the *Alberta Code of Practice* performance standards. According to the *AB Code of Practice*, if at any time during the life, closure or post closure of the landfill these performance standards are not met, the owner is required to submit a groundwater remediation plan and implement the approved plan.
- Furthermore, AB Class II Landfills located in a ravine (as is the case with the Ft. Smith Landfill) are subject to additional approvals, given the increased risk to the environment that such a location introduces. The *Environmental Code of*

Practice for Landfills, Alberta Environmental Protection, Introduction", 2(2) states:

> *"Landfills that accept more than 10,000 tonnes of waste per year, that accept hazardous waste, or that are located in a ravine* (underline added), *gully or coulee or over a buried valley will require an approval under the Environmental Protection and Enhancement Act* ." (Alberta)

Clarification of Section 2(2) of the *Alberta Code of Practice* was obtained via discussion between ENR Staff and Alberta Environment staff. (References to applicable materials are provided here[9] for use by the town and the MVLWB). This clarified that in the case a landfill is located in a ravine, where there is an increased risk of adverse environmental impacts from water flow in such areas, (as referenced earlier, the Fort Smith site *is located in a ravine)* it is subject to review for additional scrutiny and approvals, including specific design, monitoring, and mitigation requirements, to mitigate additional risk[10].

Further, evidence of elevated metals concentrations as per the above mentioned reports, and gaps in surface and groundwater monitoring data to date, would indicate a need to consider augmenting existing monitoring to determine contaminant sources, assess risk, and subsequently determine appropriate management and mitigative measures.

Uranium Burial Site

ENR understands that there is a uranium burial site located at the landfill that was established in 1998 by Atomic Energy of Canada Ltd. (AECL). This was confirmed by the Town of Fort Smith at the Technical Session held in support of the current application process[11]. Furthermore, ENR understands that AECL manages the site but is unaware of any formal relationship or agreement established between AECL and the Town of Fort Smith, and there is no evidence provided that demonstrates the presence of related contaminants are included in any groundwater monitoring occurring at the site.

This uranium burial site has created a permanent risk of contaminant contribution to leachate and subsequent groundwater contamination from the landfill.

Landfill Gas

Landfill gas can pose significant health and safety issues - specifically, issues related to possible explosion and asphyxiation hazards, odours, and low-level chemical emissions. There are also health and safety issues associated with landfill fires (which may or may not be the direct result of landfill gas). However, ENR has not seen information that demonstrates landfill gas is considered within the documentation provided.

---

[9] Code of Practice for Landfills: http://www.qp.alberta.ca/570.cfm?frm_isbn=0773269533&search_by=link;
Waste Control Regulation (provides the definition for class I, II and III landfills):
http://www.qp.alberta.ca/574.cfm?page=1996_192.cfm&leg_type=Regs&isbncln=9780779739332&display=html ;
Standards for Landfills in Alberta: http://www.environment.gov.ab.ca/info/library/7316.pdf

[10] Personal communication, June 5, 2011, between Todd M. Paget, P. Eng, ENR, and David Curran, P. Eng., Municipal Approvals Group, Northern Region, Alberta Environment, Government of Alberta.

[11] Transcript, Mackenzie Valley Land And Water Board, Technical Session For Town Of Fort Smith, Type A Water Licence Renewal, MV2011L3-001, HELD AT: Yellowknife, NT, June 15th, 2011.

Landfill gas is composed of a mixture of hundreds of different gases. By volume, landfill gas typically contains 45% to 60% methane and 40% to 60% carbon dioxide. Landfill gas also includes small amounts of nitrogen, oxygen, ammonia, sulfides, hydrogen, carbon monoxide, and nonmethane organic compounds (NMOCs) such as trichloroethylene, benzene, and vinyl chloride[12].

The following equation is provided for reference[13]:

$$\underset{\text{(solid waste)}}{\text{Organic matter}} + H_2O \xrightarrow{\text{bacteria}} \text{biodegraded organic matter} + CH_4 + CO_2 + \text{other gases}$$

Hence the most proactive manner in which to mitigate landfill gas generation is to reduce the volume of water and biodegradable organic material entering the facility.

Landfarming

Land farming contaminated soils is not included or applied for as a new activity in the current application, nor is it currently included in the Terms and Condition of the current WL[14]. ENR understands that the assessment and approval of such operations are outside the scope of this current process. However, Figure 7[15] titled Plan Showing Solid Waste Facility, contained in the Background Report Volume , depicts a landfarm. Based on previous reports, it is known that contaminated soils from within the community of Ft. Smith have been placed in a lined contaminated soils treatment cell, (sump) constructed by the Department of Public Works and Services (GNWT).

The *Town of Fort Smith Renewal Background Report Volume 1[16],* states:
"Landfarm for Hydrocarbon-Impacted Soils: During the spring and summer of 2001, a portion of the area prepared in 1999 for future expansion, was developed by the GNWT Department of Public Works and Services (DPW) into a landfarm for the remediation of hydro-carbon-impacted soils from the clean-up of the Aurora College site. A lined area (45 x 85 m) adjacent to the landfarm was also constructed for the treatment of soils saturated with hydrocarbons.

The landfarm had been managed by DPW since it was established. However, it is currently being transferred from DPW to the Town. A separate "Type B" Water Licence application was submitted by the Town in August of 2009 to address the control and operation of the landfarm. As contaminated soil is reclaimed it will be used as cover for the landfill.

For background and clarification, ENR offers the following:

---

[12] Tchobanoglous/Theisen/Vigil. *Integrated Solid Waste Management – Engineering Principles and Management Issue, 1993*. Chapter 11. Disposal of Solid Wastes and residual Matter, Composition and Characteristics of Landfill Gas, page 382,

[13] Tchobanoglous/Theisen/Vigil. *Integrated Solid Waste Management – Engineering Principles and Management Issue, 1993*. Chapter 11. Disposal of Solid Wastes and residual Matter, 11-4, Composition and Characteristics, Generation, Movement and Control of of Landfill Gases, page 387.

[14] **Note:** In the current application, **Section 5 – Solid Waste Disposal, Question 5.3. Are there any sources of commercial or industrial solid waste being deposited in the municipal system which may affect the quality of the effluent or leachate produced?** Answer is no.

[15] Section 3.3 Solid Waste Disposal Facility, Town of Fort Smith Renewal Background Report Volume 1, AECOM, January 2011.

[16] ***3.3.1 Designated Disposal Areas****, Section 3.3 Solid Waste Disposal Facility, Town of Fort Smith Renewal Background Report Volume 1,* AECOM, January 2011.

In 2001, a lined treatment cell (sump) was constructed by the Department of Public Works and Services (GNWT) adjacent to the successful remediation of 17,500m^3 of hydrocarbon–impacted soil from the Thebacha Campus Trades Building spill[17]. It was built for the purpose of accepting heavily contaminated soil from the Thebacha spill[18].

ENR understands that in November 2006, EBA Engineering Consultants Ltd. (EBA) wrote a letter of recommendations to PWS[19] for the purpose of facilitating the future use of the treatment cell by the Town of Ft. Smith. This letter indicates that:

- The sump was only used for one load of soil during the excavation and the Town of Fort Smith would like to continue to use the area for landfarming after the sump (and the landfarm) is handed over by Public Works.
- Additional dumping of contaminated material in the sump has occurred without the consent of Public Works, and this material is currently piled in the lined wet soil sump.[20]

In September 2009, the Town of Ft. Smith submitted a Type B Water license application[21] to the MVLWB. This application (which includes the above mentioned EBA letter) states that the lined treatment cell had been constructed for the original purpose to remediate a single load of soil from the Thebacha Campus spill from the Fort Smith College, and was not designed for other purposes.

The Type B water license application was deemed incomplete by the MVLWB until further information could be provided[22]. To date, ENR has not seen information requested by the MVLWB in Sept 2009, or other information that demonstrates additional contaminated soils dumped at the site and in the treatment cell have been remediated. In addition ENR has not seen a letter of transfer or acceptance between DPW and the Town of Fort Smith that is implied in its attached consultants reports.

Summary

With respect to groundwater sampling and monitoring, it is imperative that the adopted components of a guideline or standard are proven to be relevant to its application. The composition, formation, movement, and control of leachate is a complex matter, and not addressed or solved in short order. Without a clear understanding of the hydrogeological conditions, it does not appear possible that a current examination of the data from monitoring wells, the extent of leachate migration from the site, comparison of contaminants in leachate to established background levels, and an examination of the associated risk can be performed.

[17] Written Correspondence between ENR and PWS July 9, 2007.

[18] LANDFARM OPERATING MANUAL THEBACHA CAMPUS LANDFARM FORTH SMITH LANDFARM FACILITY FORT SMITH, NT. EBA report submitted to PWS. December 2003.

[19] Letter of Recommendations from EBA to PWS (GNWT), November 30, 2006. Also available online at: http://www.mvlwb.ca/mv/Registry/2009/MV2009L8-0024/MV2009L8-0024%20-%20Application%20for%20Water%20Licence%20-%20Sept%202-09.pdf

[20] Memorandum from AECOM to MVLWB, July 31, 2009. Also available online at: http://www.mvlwb.ca/mv/Registry/2009/MV2009L8-0024/MV2009L8-0024%20-%20Application%20for%20Water%20Licence%20-%20Sept%202-09.pdf

[21] Town of Ft. Smith Type B Water License application, Sept 02, 2009. Also available online at: http://www.mvlwb.ca/mv/Registry/2009/MV2009L8-0024/MV2009L8-0024%20-%20Application%20for%20Water%20Licence%20-%20Sept%202-09.pdf

[22] MVLWB letter to Town of Ft. Smith, September 17, 2009. Also available online at: http://www.mvlwb.ca/mv/Registry/2009/MV2009L8-0024/MV2009L8-0024%20-%20Application%20Deemed%20Incomplete%20-%20Sept17-09.pdf

The most proactive way to reduce both the generation of leachate and landfill gas, is to mitigate the amount of water entering the facility, and work toward reducing or eliminating organic material from entering the solid waste disposal cells. This will have an immediate and long-term benefit of the reduction of leachate and landfill gas generation. However, again, efforts to mitigate the amount of water entering the facility cannot be determined without a clear understanding of the hydrogeological conditions.

Recommendations

Landfarming

Land farming contaminated soils is not included or applied for as a new activity in the current application, nor is it currently included in the Terms and Conditions of the current WL. ENR understands that the assessment and approval of such operations are outside the scope of this current process. However, information is provided that demonstrates additional contaminated soils have been and/or continue to be dumped at the former landfarm site. Hence, ENR recommends that the monitoring for petroleum indicators continue as a component of the sampling program.

ENR recommends that for the continued treatment of hydrocarbon contaminated soils at the Town of Fort Smith Landfill, the site be subject to additional screening, assessment, and authorization that may or may not be a future component/amendment of the current WL, or an activity applied for separately. ENR would provide its expertise to facilitate that process at that time.

Leachate/Groundwater Monitoring

ENR recommends and the Town commits that a *Water and Leachate Modelling and Monitoring Plan* (the Plan) be developed for the landfill. The Plan should initially prioritize a study to delineate hydrogeological information at the site, including seasonal variations in the water table and groundwater inflow and outflow. Then, a revision of groundwater and surface water monitoring stations can be conducted, based on this information.

The suite of parameters for leachate monitoring should also be developed and validated. This suite could be developed either using a conceptual leachate generation model, from a sampling of the leachate within the SWF for an exhausting suite of analytes, or by parallelling a monitoring program from a modern landfill.

The uranium burial site at this landfill has created a permanent risk of contaminant contribution to leachate and subsequent groundwater contamination from the landfill. Monitoring parameters should include those that can detect whether this material is present in leachate and groundwater.

The *Water and Leachate Modelling and Monitoring Plan* should also evaluate mitigative measures to divert water entering the solid waste site, and how these can be integrated into development and application of the recommended *Interim Abandonment and Reclamation Plan,* and its updated *Operations and Maintenance Plan*.

ENR recommends and the Town commits that the Plan be submitted to the MVLWB and technical experts for review and approval prior to implementation. ENR also recommends that a Technical Working Group (TWG) is established specifically for the purpose of providing aid to both the Town and to the MVLWB. At TWG would facilitate a coordinated approach to technical review and provision of expert advice on the development of this Plan, or other issues, on an ongoing basis for the duration of the Water Licence.

The following references may prove useful:

- *Guidance Document On Federal Interim Groundwater Quality Guidelines For Federal Contaminated Sites*, May 2010.
- Parameters that monitor and detect the effect of uranium tailings.
- While dated, the following reports are also recommended as useful reference:
  - *Chemical Characterization of leachate from Northwest Territories Municipal Dumps, Coppermine Municipal Dump, M. M. Dillon Limited Consulting Engineers and Planners, Prepared for Indian and Northern Affairs Canada, Water Resources Division, Regulatory Approvals Section, March 1991, N 3360-00.*
  - *Chemical Characterization of leachate from Northwest Territories Municipal Dumps, Hay River Municipal Dump, M. M. Dillon Limited Consulting Engineers and Planners, Prepared for India and Northern Affairs Canada, Water Resources Division, Regulatory Approvals Section, March 1991, N 3360-00.*

Operations and Maintenance Plan

The purpose of an Operations and Maintenance (O&M) Plan is to assist community staff in the proper operation and maintenance of their waste facilities. The current O&M Plan for the solid waste disposal facility (SWDF) was completed in 2004 as part of the previous water licence renewal, and to ENR's knowledge, has not been revised since.

The *Guideline for the Planning, Design, Operations and Maintenance of Modified Solid Waste Sites in the Northwest Territories*[23], is endorsed by the Departments of Municipal and Community Affairs (MACA) and ENR, Government of the Northwest Territories. It provides specific advice in this regard, has been developed specifically for use in the NWT, and provides definitions, uses terminology, and instructs on common procedures that will provide all stakeholders certainty and clarity when discussing, planning for, and operating waste facilities. Also, for specific guidance on the development of an O&M Plan, consult the *Guidelines for the Preparation of an Operation and Maintenance Manual for Sewage and Solid Waste Disposal Facilities in the Northwest Territories*[24].

Recommendations

a) ENR recommends that the Operations and Maintenance Plan is updated and submitted to the Board for approval. It should be noted that the water licence also requires an O&M Plan for the sewage waste disposal facility.

b) The Town should also consult the *Guideline for the Planning, Design, Operations and Maintenance of Modified Solid Waste Sites in the Northwest Territories* and the

[23] Municipal and Community Affairs. 2003. *Guideline for the Planning, Design, Operations and Maintenance of Modified Solid Waste Sites in the Northwest Territories*.

[24] Municipal and Community Affairs. 1996. *Guideline for the Preparation of an Operation and Maintenance Manual for Sewage and Solid Waste Disposal Facilities in the Northwest Territories*.

Guidelines for the Preparation of an Operation and Maintenance Manual for Sewage and Solid Waste Disposal Facilities in the Northwest Territories in developing this plan.

c) The O&M Plan should consider integrating the following additional precautionary procedures:
   - Waste Reduction and Recovery methods, including measures to reduce the bio-degradable organics entering the landfill.
   - Integrate progressive reclamation strategies on an ongoing basis.

d) And, once this plan is developed, ENR recommends that it is made available to any staff, operators, and/or contractors performing any functions related to the management of the SWF, and that the Plan is followed.

Interim Abandonment and Reclamation

It is projected in the application supporting information that, based on the historical expansion rate at the landfill, it is expected the site will have sufficient capacity for the next 20 years and possibly beyond, and that preparation for landfill remediation following the closure of the active area will commence once the expansion has started[25].

However information has not been provided that demonstrates how capacity has been determined.

ENR understands that a Closure and Reclamation Plan (C&R Plan) for the current SWDF is not in place.The early stages in the development of a C&R Plan are critical steps in ensuring the community is thinking, preparing and planning for the facility's ultimate closure. This is very relevant in this case, as it has not been demonstrated that the lifespan and capacity of the landfill has been determined.

There are three distinct steps, performed in the proper order, through the development of a Final C&R Plan:

1. Preliminary Closure and Reclamation Plan
2. Interim Closure and Reclamation Plan
3. Final Closure and Reclamation Plan

Step 1, a Preliminary C&R Plan, is appropriately prepared in conjunction with the planning and permitting stage of the SWDF. The general purpose is to propose closure objectives, alternatives analysis, and proposed closure criteria to understand the Proponent's intent. Determining appropriate closure options should also be integrated with a level of community engagement to build consensus upfront.

Step 2, the Interim C&R Plan, is to identify uncertainties surrounding certain closure options that guide corresponding areas for reclamation research during operations prior to closure. There are typically several versions that are prepared during the life of the facility to address changes in development alternatives, and to refine as the facility

---

[25] Section 4. System Improvements, 4.3 Solid Waste Facility, 4.3.2 Future Expansion, *Town of Fort Smith Renewal Background Report Volume 1*, AECOM, January 2011.

progresses towards closure. Thus, subsequent versions of Closure and Reclamation Plans are produced. Interim plans are prepared on a regular basis to coincide with operational changes, advances in technology, key milestones, information collected during reclamation research, and results of community engagement.

Step 3, the Final C&R Plan, should be more detailed because more information and studies are available to determine duration, frequency, and magnitude of the effects. The final version of the C&R Plan is to contain detailed reclamation activities, and should be prepared and approved prior to a scheduled permanent closure or immediately after an unplanned closure.

Recommendations

Although the current SWDF is expected to have a lifespan of at least another 20 years, ENR recommends that the Proponent prepare and submit an Interim Closure and Reclamation Plan for the current SWDF. This should be a working document that integrates progressive reclamation strategies, which in turn can be used in conjunction with the facilities Operation and Maintenance Plan.

The development of interim abandonment and reclamation planning process will:

- Enable the Town to begin discussion of options for the end use of the site (i.e. post abandonment and closure);
- Help ensure that the development of progressive reclamation techniques (for example the ongoing construction and closure of solid waste cells) are consistent with or directed toward interim abandonment and reclamation planning;
- Integrate leachate characterization and impact mitigation measures, and measures to reduce water infiltration to the landfill, into longer term reclamation and management decisions, operations, and costs.

Adaptive Management

Recommendation

ENR recommends and the Town commits to and submits in an annual report a comparison of annual quantities of solid waste accepted and generated, and compares this annual data to the projected lifespan of the SWF, and modify/update future projections and operations and maintenance requirements accordingly.

Hazardous Waste Management

Hazardous waste is generated by both the Industrial, Commercial, and Institutional (ICI) sectors as well as by residents. The plan does not clearly state the types of hazardous wastes that are accepted from the ICI sector and which are not. For example, hydrocarbon-contaminated soils, or asbestos may be accepted from the ICI sector where solvent, pesticides, corrosive liquids, etc. would not be accepted from the ICI sector and only from residents.

Recommendations

The Town of Fort Smith develop a comprehensive Hazardous Waste Management Plan that clearly states which materials will or will not be accepted at the solid waste facility, and from which sector, and includes details about the type of household hazardous waste collection. ENR's draft document titled *Developing a Community Based Hazardous Waste Management Plan* can be referenced for this purpose.

Offsite Disposal of Dredged Lagoon Sewage Sludge

The offsite disposal of sewage sludge originating from the primary treatment cells of the lagoon system, is not included as a Term and/or Condition in the existing WL, and is not applied for as a new activity in the current application. It is ENR's understanding that the disposal of this material offsite requires additional assessment and approval, and is currently outside the scope of this current process.

However, this issue has come to ENR's attention through review of consultant reports provided with the application, and through discussion that has occurred at the Technical Session supporting the current review[26,27]. ENR understands from these sources that the decanting and offsite disposal of sewage sludge originating from primary lagoon treatment cells is presently occurring or may occur in the future.

Sewage sludge, particularly untreated and stabilized sludge, is a highly variable mixture of domestic sanitary waste that may also include other discharges from industrial, hospital, laboratory, road runoff, etc. It may contain toxic metals, antibiotic resistant bacteria, pesticides, priority pollutants, etc.

ENR does not have any guidelines or standards for the use of and/or disposal of sewage sludge. Furthermore, this is an issue that is currently being reviewed at a national level by the Canadian Council of Ministers of the Environment (CCME) Biosolids Task Group, that has proposed the release of a national guideline for Fall 2011.

Recommendation

ENR understands the final use and/or disposal of dredged sewage sludge and its location, are currently not included in the Terms and Conditions of the current Water Licence, and it has not been applied for in the current Water Licence application. Hence, this issue is outside the scope of the current process and Water Licence. If the offsite disposal of dredged sewage sludge from the primary cells is proposed in the future, ENR recommends that this deposit and/or discharge of sewage waste is subject to additional screening, assessment, and authorization that may or may not be a future component/amendment of the current WL, or an activity applied for separately. ENR would provide its expertise to facilitate that process at that time.

Technical Working Group (TWG)

Recommendation

Given the complexity, related technical expertise, and costs required of evaluating the various components of the requirements of the Water Licence, ENR recommends that a Technical Working Group (TWG) is established. The purpose of the TWG is specifically

---

[26] *Mackenzie Valley Land And Water Board Technical Session For Town Of Fort Smith Type A Water Licence Renewal*, MV2011L3-001, Held At: Yellowknife, NT, June 15th, 2011, page 23 and 24 "The material is then collected and donated to the local golf course".

[27] Section 4 of the supplied *Background Report Volume 1*, states: "*Maintenance of the sewage lagoon involves removal of sludge from the cells and removing cattails every four to five years. This work was last completed in the summer and fall of 2010*".

for facilitating and providing a coordinated approach to technical review and provision of advice on an ongoing basis for the duration of the Water Licence. The TWG would benefit the Town of Fort Smith, the MVLWB, and the technical reviewers in the regulatory review phase of the Land and Water Board processes.

Government of Alberta ■

ENVIRONMENTAL CODE OF PRACTICE FOR LANDFILLS

© Published by Alberta Queen's Printer

Queen's Printer Bookstore
5th Floor, Park Plaza
10611 - 98 Avenue
Edmonton, AB T5K 2P7
(780) 427-4952
Fax (780) 452-0668

E-mail: qp@gov.ab.ca
Shop on-line at http://www.gov.ab.ca/qp

ENVIRONMENTAL CODE OF PRACTICE FOR LANDFILLS

TABLE OF CONTENTS

ENVIRONMENTAL CODE OF PRACTICE FOR LANDFILLS

ALBERTA ENVIRONMENTAL PROTECTION

Preface

1(1) The Code of Practice for Landfills is incorporated by the *Waste Control Regulation* (A.R. 192/96), under the authority of section 36 of the *Environmental Protection and Enhancement Act*. Persons responsible for landfills accepting 10,000 tonnes or less of non-hazardous waste per year must meet all its requirements to ensure that their activities are in compliance with Alberta's environmental laws. Persons responsible must comply with all requirements of the *Environmental Protection and Enhancement Act*, its associated regulations, and all other applicable laws.

(2) Persons responsible for landfills affected by this Code must register with Alberta Environmental Protection prior to commencing construction and operation of a landfill. Section 4 of this Code deals with registration in greater detail.

Introduction

2(1) This Code of Practice outlines minimum requirements for the construction, operation and reclamation of landfills that accept 10,000 tonnes or less per year of non-hazardous and inert waste, and promotes environmentally sound management practices at those landfills.

(2) Landfills that accept more than 10,000 tonnes of waste per year, that accept hazardous waste, or that are located in a ravine, gully or coulee or over a buried valley will require an approval under the *Environmental Protection and Enhancement Act*. Persons responsible for these landfills should consult the *Activities Designation Regulation* (A.R. 211/96) to determine whether their activities will require an approval.

(3) Questions or concerns regarding the application or contents of this Code of Practice can be made to:

Alberta Environmental Protection
Northeast Boreal & Parkland Regions
Regional Director
5th Floor, 9820 - 106 Street
Edmonton, AB T5K 2J6
Phone: (403) 427-9562
Fax: (403) 422-5120

or:

Alberta Environmental Protection
Northwest Boreal & Northern East Slopes Regions
Regional Director
Provincial Building
203, 111 - 54 Street
Edson, AB T7E 1T2
Phone: (403) 723-8395
Fax: (403) 723-8542

or:

Alberta Environmental Protection
Southern East Slopes & Prairie Regions
Regional Director
201 Deerfoot Square
2938 - 11 Street N.E.
Calgary, AB T2E 7L7
Phone: (403) 297-7605
Fax: (403) 297-5944

Definitions

3(1) In this Code of Practice,

(a) "active life" means the period of operation of a landfill, beginning with the initial receipt of waste and ending at completion of closure activities;

(b) "active portion" means that part of a landfill that has received or is receiving wastes and has not been closed;

(c) "cell" means compacted solid wastes that are enclosed by natural soil or cover material in a landfill;

(d) "closure" means the construction of a final cover for a landfill including replacement of topsoil and subsoil as required for the intended future use of the landfill site;

(e) "condensate" means the liquid generated as a result of a gas recovery process or processes at a landfill;

(f) "cover material" means soil or other material that is used to cover compacted solid wastes in a landfill;

(g) "disease vectors" means animals capable of transmitting disease to humans;

(h) "landfill" means a Class II or Class III landfill that accepts 10,000 tonnes or less of waste per year;

(i) "lateral expansion" means an expansion of the waste boundaries of a landfill beyond the property area approved for landfilling;

(j) "leachate" means liquid that has percolated through and drained from solid waste and has extracted dissolved or suspended materials from the waste;

(k) "liner" means a continuous layer constructed of natural or man-made materials, beneath or on the sides of a landfill or a cell, which restricts the downward or lateral migration of the waste constituents;

(l) "monitoring system" means all equipment used for sampling or recording data including, but not limited to, equipment used for continuous monitoring;

(m) "points of compliance" means the location or locations where measurements of groundwater quality are taken to assess landfill performance;

(n) "post-closure period" means the period of 25 years from final closure of a landfill, or so long as leachate that does not meet the performance criteria set out in Table 1 is generated at a landfill;

(o) "run-off" means any rainwater or meltwater that drains as surface flow from developed or active landfill areas;

(p) "run-on" means any rainwater or meltwater that drains as surface flow onto developed or active landfill areas;

(q) "structural components" means liners, leachate collection systems, final covers, run-on and run-off systems, and any other landfill components necessary for protection of human health and the environment;

(r) "subsoil" means a layer of lighter colour soil containing the root zone which is situated beneath the topsoil layer;

(s) "topsoil" means the uppermost layer of soil material, containing organic matter and ordinarily moved in tillage, or its equivalent in uncultivated soils;

(t) "unstable area" means land which may be subject to differential settling due to soil conditions, geologic or geomorphologic features, or man-made features;

(u) "uppermost formation" means a continuous water-saturated geological stratum or strata, including but not limited to sand lenses and aquifers, that is projected to be the most probable pathway or pathways for lateral transport of leachate.

(2) Terms defined in section 1 of the *Environmental Protection and Enhancement Act* and in the *Waste Control Regulation* (A.R. 192/96) are incorporated into and become part of this Code of Practice, unless otherwise defined or modified within this Code of Practice.

Registration

4 In addition to any information required by the Director under the *Approvals and Registration Procedure Regulation* (A.R. 113/93), the person responsible shall complete the registration form attached to this Code and submit the completed form with the required information to the Director, prior to commencing construction of a landfill.

Person Responsible's Duty

5 The person responsible shall comply with all requirements of this Code of Practice.

Siting and Design Requirements

6(1) Prior to construction or lateral expansion of a landfill, an investigation shall be designed and conducted by a professional geologist or engineer registered with the Association of Professional Engineers, Geologists and Geophysicists of Alberta to assess the geological and hydrogeological conditions specific to the landfill and its surrounding area.

(2) After an investigation is designed and conducted in accordance with section 6(1), a landfill design shall be prepared by a professional geologist or engineer registered with the Association of Professional Engineers, Geologists and Geophysicists of Alberta, and the person responsible shall construct the landfill according to the design.

(3) Prior to construction or lateral expansion of a landfill, the person responsible shall determine the depth and volume of topsoil and subsoil available at the landfill site.

(4) Prior to construction or lateral expansion of a landfill, the person responsible shall determine storage locations for salvaged topsoil, and measures to be taken to prevent the use or loss of salvaged topsoil during storage.

(5) The landfill design for construction or lateral expansion of a Class II landfill shall include the following engineered features:

- (a) a liner and leachate collection system that provides for containment of the waste constituents and allows gathering and collection of leachate;
- (b) a groundwater monitoring system, which shall consist of at least
    - (i) 2 groundwater monitoring well locations downgradient from the landfill, and
    - (ii) 1 groundwater monitoring well location upgradient from the landfill;

(c) a run-on control system to prevent flow onto the active portion of the landfill for events up to at least the peak discharge from the larger of a 1 in 25-year storm or snowmelt event;

(d) a run-off control system for the active portion of the landfill to collect and control at least the runoff water volume resulting from the larger of a 1 in 25-year storm or snowmelt event; and

(e) where the landfill will be located in an unstable area, measures to ensure that the integrity of the landfill's structural components will not be disturbed.

(6) A person responsible constructing or expanding a Class II landfill may develop a landfill design with an alternate feature to that required in section 6(5)(a) if

(a) the following hydrogeological conditions are met:

(i) there is a 5 metre thick layer of a clayey deposit having a permeability less than 1 x 10^{-8} metres/second immediately beneath all waste disposed at or below the original grade, and

(ii) the permeability of the natural geologic materials beneath the clayey deposit

(A) is less than 1 x 10^{-8} metres/second to a depth of at least 5 metres beneath the clayey deposit; or

(B) provides equivalent protection to the requirements in subclause (A) above; or

(b) the person responsible provides evidence in writing to the Director that groundwater quality will not exceed the performance standards set out in Table 1 at the points of compliance.

(7) A person responsible constructing or laterally expanding a Class II landfill shall ensure that each groundwater monitoring well location includes 1 groundwater monitoring well designed to allow collection of groundwater samples from the uppermost formation.

(8) A person responsible constructing or laterally expanding a Class II landfill shall construct each groundwater monitoring well location

(a) at least 20 metres inside the property boundary, and

(b) at least 10 metres but not more than 60 metres from the designed boundary of the landfill.

(9) The Director may, by notice in writing, require the person responsible for a Class II landfill to construct and maintain additional groundwater monitoring wells at each groundwater monitoring well location if there is more than one significant uppermost formation underlying the landfill site. The person responsible shall comply with the notice in accordance with its terms.

(10) The Director may, by notice in writing, require the person responsible for a Class II landfill to construct and maintain additional groundwater monitoring wells where the Director is of the opinion that it is necessary due to

(a) the size, area or hydrogeology of the landfill, or

(b) the nature of waste proposed to be accepted at the landfill.

The person responsible shall comply with the notice in accordance with its terms.

(11) Throughout the active life and post-closure period of a Class II landfill, the groundwater quality shall meet the performance standards listed in Table 1 in the uppermost formation or formations at the points of compliance. The person responsible may apply in writing to the Director where the person responsible seeks to use alternate performance standards, providing justification for the use of the proposed alternate performance standards.

Table 1 - Performance Standards for Landfills

Chemical	Concentration (mg/L)
Chloride (Cl)	250
Sodium (Na)	200
Sulphate (SO_4)	500
pH	6.5 to 8.5 units

(12) The person responsible constructing or expanding a Class II landfill shall ensure that no waste is deposited between the property line and the designed boundary of the landfill.

(13) The design of a Class III landfill shall

(a) provide for containment of the waste disposed, and

(b) include the features required in sections 6(5)(c) and (d).

(14) The Director may, by notice in writing, require the person responsible for a Class III landfill to meet the groundwater monitoring requirements of this section, where the Director is of the opinion that it is necessary. The person responsible shall comply with the notice in accordance with its terms.

Operating Requirements

7(1) During construction and operation of a landfill, the person responsible shall selectively salvage and stockpile all topsoil as follows.

(a) All topsoil stockpiles shall be located on undisturbed topsoil in a location that is not affected by the landfill operations.

(b) Topsoil shall not be used to meet daily cover requirements.

(c) All topsoil stockpiles shall be contoured, stabilized and seeded to prevent soil loss by wind and water erosion.

(2) The person responsible shall develop, maintain and implement an operations plan that ensures landfill operations are consistent with the landfill design and includes as a minimum:

(a) operational procedures such as waste control, soil cover operations, surface water management and nuisance controls;

(b) waste acceptance procedures and policies;

(c) an emergency response program, covering fires, releases and medical concerns;

(d) for Class II landfills, a remediation program to be implemented if groundwater quality fails to meet performance standards set out in section 6(11); and

(e) a plan for the management of gas, which may include detection, interception, venting, or recovery.

(3) The operations plan for a Class II landfill shall include a program for detecting and preventing the disposal of hazardous wastes at the landfill.

(4) The operations plan for a Class III landfill shall include a program for detecting and preventing the disposal of hazardous and non-inert wastes at the landfill.

(5) Where a landfill accepts any of the following wastes, the person responsible shall include in the operations plan procedures for their special handling, as follows.

(a) Biomedical waste shall be managed in compliance with the latest edition of *Guidelines for the Management of Biomedical Wastes in Canada*, published by the Canadian Council of Ministers of the Environment.

(b) Asbestos waste shall be managed in compliance with the latest edition of *Guidelines for the Disposal of Asbestos Waste*, published by Alberta Environmental Protection.

(c) Hydrocarbon contaminated soils shall be managed in compliance with the *Code of Practice for the Land Treatment and Disposal of Soil Containing Hydrocarbon*, published by Alberta Environmental Protection.

(d) Contaminated sulphur and sulphur containing wastes shall be managed in compliance with the latest edition of *Guidelines for the Disposal of Sulphur Containing Solid Wastes*, published by Alberta Environmental Protection.

(e) Dead animals or animal parts shall be immediately covered with soil.

(6) Where a Class II landfill accepts any of the following wastes, the person responsible shall provide specific areas for the sorting, recovery, conditioning or storage of these wastes:

(a) empty pesticide containers;

(b) petroleum hydrocarbon contaminated soils;

(c) automobile hulks;

(d) scrap metal;

(e) sump waste from vehicle wash bays;

(f) used tires;

(g) sorted household hazardous wastes.

(7) A person responsible shall not place bulk liquid waste or liquid waste in a container in a Class II landfill, unless

(a) the liquid waste is domestic wastewater sewage from a community that is not served by a wastewater treatment plant;

(b) the liquid waste is the liquid phase separated from sump waste of car wash bays or similar operations, and is used within the landfill area for irrigation or dust suppression;

(c) the liquid waste is leachate, condensate from a landfill gas recovery system or contaminated run-off water from the landfill where

(i) no wastewater treatment plant is reasonably available to receive that liquid waste, or

(ii) the landfill is equipped with a leachate collection system;

(d) the liquid waste is in a container that is less than 5 litres in size; or

(e) the liquid waste is in a container used for a purpose other than liquid storage.

(8) The person responsible for a Class II landfill shall cover wastes with 15 centimetres of soil or an alternative cover material approved by the Director to control litter, prevent spread of fires, minimize propagation of disease vectors, reduce odours, and minimize infiltration of moisture. Wastes shall be covered within

(a) 30 days from the last cover operation at landfills that receive less than 1,000 tonnes of waste per year or serve a population of less than 1,000;

(b) 15 days from the last cover operation at landfills that receive between 1,000 and 3,000 tonnes of waste per year or serve a population between 1,000 and 3,000;

(c) 7 days from the last cover operation at landfills that receive between 3,000 and 5,000 tonnes of waste per year or serve a population between 3,000 and 5,000;

(d) 48 hours from the last cover operation at landfills that receive between 5,000 and 10,000 tonnes of waste per year or serve a population between 5,000 and 10,000.

(9) If soil is used to meet the requirements of section 7(8), the person responsible is not required to apply the required soil cover during the period between November 15 and April 15 if the necessary soil cover material cannot reasonably be obtained.

(10) The Director may, by written notice to the person responsible, increase the frequency of cover required by section 7(8) where the Director is of the opinion that it is necessary. The person responsible shall comply with all terms of such notice.

(11) The person responsible for a Class III landfill shall cover wastes as necessary to control nuisances such as litter, fires, disease vectors, odours and dust.

(12) The person responsible shall remove water that accumulates in a landfill trench to avoid contact with the waste.

(13) The person responsible shall treat any leachate or contaminated surface or groundwater prior to discharging it to the surrounding environment to meet the least stringent of the following parameters:

(a) surface water background quality,

(b) the latest edition of *Alberta Ambient Surface Water Quality Interim Guidelines*, published by Alberta Environmental Protection, or

(c) the latest edition of *Canadian Water Quality Guidelines*, published by the Canadian Council of Resource and Environment Ministers.

(14) The person responsible shall post signs at the landfill entrance providing the following information:

(a) the name of the person responsible,

(b) the landfill class,

(c) any waste restrictions, and

(d) telephone numbers for

(i) the person responsible,

(ii) the local fire department,

(iii) Alberta Environmental Protection, Pollution Emergency Response Team (1-800-222-6514), and

(iv) the local police department.

(15) The person responsible shall use artificial or natural barriers to control public access to the landfill and prevent unauthorized vehicular traffic and illegal dumping of wastes.

(16) The person responsible shall ensure that fires, other than those permitted by the *Waste Control Regulation* (A.R. 192/96), are extinguished immediately upon detection.

(17) The person responsible shall establish and maintain litter controls to minimize the escape of waste from the landfill and shall retrieve waste that is washed or blown onto adjacent properties or accumulates on the landfill site.

Monitoring, Analysis, and Corrective Action

8(1) The person responsible shall obtain and analyse representative samples from the groundwater monitoring system on an annual basis throughout the active life and post-closure period of the landfill. The person responsible shall analyse the samples for the parameters set out in section 6(11).

(2) The Director may, by written notice to the person responsible,

(a) require that groundwater samples be analyzed for parameters other than those set out in section 6(11),

(b) change the frequency of groundwater monitoring and analysis required under section 8(1), or

(c) require the person responsible to install additional groundwater monitoring wells,

where the Director is of the opinion that it is necessary due to

(d) the character of waste received at the landfill,

(e) changes in groundwater quality at the landfill, or

(f) other evidence that suggests an impact on groundwater quality.

The person responsible shall comply with the notice in accordance with its terms.

(3) Where groundwater at the landfill fails to meet the performance standards set out in section 6(11), the person responsible shall notify the Director and shall implement the groundwater remediation plan developed under section 7(2)(d).

(4) Where groundwater monitoring is required,

(a) all groundwater monitoring wells shall be protected from damage and shall be locked except when being sampled, and

(b) the person responsible shall clean, repair or replace groundwater monitoring wells which have been damaged or are no longer able to produce representative groundwater samples prior to the next scheduled sampling date.

(5) The person responsible shall conduct analyses of samples collected to meet this Code in the following manner:

(a) for water and leachate samples, in accordance with

(i) the latest edition of *Standard Methods for the Examination of Water and Wastewater*, published by the American Public Health Association, American Water Works Association, and the Water Environment Federation,

(ii) the *Methods Manual for Chemical Analysis of Water and Wastes* (1987), published by Alberta Environmental Protection, as amended from time to time, or

(iii) any other equivalent method accepted by the Director in writing;

(b) for solid wastes samples, in accordance with

(i) the latest edition of *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*, SW-846, published by the United States Environmental Protection Agency,

(ii) the latest edition of *Manual on Soil Sampling and Methods of Analyses*, published by the Canadian Society of Soil Science,

(iii) the *Interim Compilation of Test Methods under the Transportation of Dangerous Goods Regulations*, prepared by Environment Canada, or

(iv) any other equivalent method accepted by the Director in writing.

Reclamation, Closure, and Post-Closure Care

9(1) At the time of closure of the landfill or any trench, the person responsible shall install a final cover system designed to minimize infiltration and erosion. The final cover system shall meet the following requirements, and the layers shall be constructed in the following order.

(a) The final cover system shall include a barrier layer of

(i) 0.60 metres of earthen material with a maximum permeability of

1×10^{-7} metres/second, or

(ii) alternate material that will achieve equivalent protection to subclause (i).

(b) Subsoil shall be placed as the second layer of the final cover system and salvaged topsoil as the third layer of the final cover system as follows.

(i) Required subsoil shall be spread evenly over the barrier layer.

(ii) All salvaged topsoil shall be spread evenly over the replaced subsoil.

(c) The depths of the replaced topsoil and subsoil shall be equal to the depths determined at the landfill site prior to its construction, or shall meet the following minimum requirements:

(i) for pasture or recreational uses, 0.20 metres of topsoil and 0.35 metres of subsoil, and

(ii) for cultivated land use or forestry, 0.20 metres of topsoil and 0.80 metres of subsoil.

(d) After the subsoil and topsoil are replaced,

(i) water permeability and rooting in topsoil or subsoil shall not be restricted, and

(ii) vegetation shall be established with a suitable seed mixture compatible with the intended land use.

(e) The final cover system shall have a final topography that ensures that water does not pool over the landfill area, with a minimum final grade of 5 percent and a maximum final grade of 30 percent.

(2) The person responsible shall begin closure no later than 180 days after the landfill or trench reaches its final design elevation.

(3) The person responsible shall complete closure no later than 180 days after the beginning of closure as specified in section 9(2). The person responsible may apply for an extension of the closure period by providing written information to the Director indicating the reasons why closure will take longer than 180 days, and indicating steps that the person responsible will take to prevent adverse effects from the unclosed landfill or trench.

(4) Prior to final closure of the landfill, the person responsible shall notify the Director in writing of the intent to close the landfill.

(5) Following final closure of the landfill, the person responsible shall notify the Director in writing, verifying that

(a) closure and reclamation have been completed in accordance with this Code of Practice, and

(b) a closure and reclamation report containing the following information has been completed and placed in the operating record:

(i) a description of the final cover system, and the installation methods and procedures used;

(ii) an estimate of the maximum quantity of wastes on site over the active life of the landfill;

(iii) a description of how the following elements have been or will be dealt with:

(A) the final use of the reclaimed areas,

(B) drainage restoration,

(C) soil replacement,

(D) final cover slopes,

(E) erosion control,

(F) revegetation and conditioning of the site, and

(G) subsidence remediation.

(6) After final closure of the landfill and during the post-closure period, the person responsible shall

(a) maintain the integrity of the final cover system and diversion and drainage structures, and make repairs to the cover system as necessary to correct the effects of settling, subsidence, erosion, or other events;

(b) maintain, operate, and monitor the groundwater monitoring, leak detection, leachate collection, and gas venting systems, where such systems or structures are installed; and

(c) protect and maintain surveyed benchmarks.

Record Keeping

10(1) The person responsible shall establish and maintain an operating record for the landfill, and shall provide the operating record and its contents to Alberta Environmental Protection upon request. The operating record shall contain the following information:

(a) a copy of the registration number for the landfill;

(b) survey records and as-built records for the landfill showing the location and development of excavations, fill areas, final grades and structural components;

(c) the current version of the design and operations plan for the landfill;

(d) records of the handling of any wastes accepted at the landfill under section 7(5), including the amounts accepted and disposal locations within the landfill;

(e) all annual reports for the landfill, as required by section 10(2).

(2) During the active life of the landfill, the person responsible shall prepare an annual report for the landfill covering the calendar year from January 1 to December 31, and shall place the report in the operating record by March 31 of the following year. The annual report shall contain the following information:

(a) the types and volume of wastes disposed of at the landfill in the preceding year, and the locations of disposal of wastes requiring special handling;

(b) the following environmental monitoring records and their interpretation:

(i) groundwater monitoring, as specified in section 8(1) or (2),

(ii) gas monitoring as specified in section 7(2)(e), and

(iii) records on the quality of surface water released to the environment, as specified in section 7(13);

(c) any remedial action taken in relation to clause (b).

(3) Following final closure of the landfill, the person responsible shall prepare the closure and reclamation report required in section 9(5)(b) and place it in the operating record.

(4) During the post-closure period, the person responsible shall compile the following information and place it in the operating record:

(a) an annual compilation of the monitoring data listed in section 10(2)(b) and its interpretation;

(b) an annual compilation of records of maintenance and repairs carried out under section 9(6)(a);

(c) any remedial action taken.

The person responsible may apply to the Director to vary the requirement for annual compilation set out in clause (b), providing written justification for the proposed variation.

(5) The person responsible shall maintain the operating record until the end of the post-closure period.

Reporting

11 The person responsible shall immediately report any contravention of this Code of Practice by telephone to the Director of Pollution Control Division at (403) 422-4505. The Director of Pollution Control Division may require the person responsible to provide a written report of any contravention.

Code Amendment

12 This Code of Practice will be reviewed at least every 5 years beginning in 2001. Alberta Environmental Protection will accept and compile written comments on the contents of this Code at any time, and will review all comments received at the next review. The Director may institute review and amendment of this Code of Practice at any time. All proposed amendments to this Code of Practice will be reviewed by government, industry, and the interested public. The Director shall have the final decision on amendments made to this Code of Practice. Amendments to this Code of Practice shall become effective when published by Alberta Environmental Protection.

For office use only:

Date Received: ____________________

Registered by:

____________________ ____________________ ______________

Director's Signature Title Date

Registration Number: ______________________________

STANDARDS FOR LANDFILLS IN ALBERTA

February 2010

Government of Alberta

TABLE OF CONTENTS

FOREWORD

Alberta Environment is updating its waste management regulatory requirements. It is anticipated that the new regulatory requirements will be in place for all landfills by 2011. The *Standards for Landfills in Alberta* (*Standards*) is one initiative in upgrading waste management regulatory requirements. The *Standards* were developed by a group of people with extensive knowledge of landfill technology from Alberta Environment and the industry. Alberta Environment acknowledges, with gratitude, the guidance and direction provided by the participants in developing this document. The members willingly participated in the process by volunteering their expertise, attend meetings and review documents.

STEERING COMMITTEE

Bob Chandler, Ph.D., P.Eng.	Alberta Environment, Environmental Assurance
Donna Chaw, Ph.D	Alberta Environment, Environmental Assurance
Rhonda Lee Curran, P. Eng, QEP	Alberta Environment, Environmental Management
John Deagle, CET	Foothills Waste Management Facility
Susan Halla, CET	Energy Resources Conservation Board
Jasna Hundal, M.Sc., P.Eng.	City of Calgary
Steve Johnson, M.Eng., P.Eng.	Waste Management of Canada Corp.
Jim Lapp, CET	City of Edmonton/SWANA-NLC
Pete Marshall, B.Sc.	Adelantar Consulting
Norm Richards, P.Eng.	NLR Consulting Ltd.
Kerry D. Robertson, B.Sc.	Energy Resources Conservation Board
Paul Ruffell, P.Eng.	EBA Engineering Consultants
Pat Sliworsky, Manager	Mackenzie Regional Waste Mgmt Commission
Mary Stewart, P. Eng	Alberta Environment, Environmental Management
Alison Walker, M.Sc.	Hazco Environmental Services

ISBN No.: 978-0-7785-8825-2 (Printed Version)

978-0-7785-8826-9 (online Version)

APPLICATION OF THE STANDARDS FOR LANDFILLS

The Alberta Standards for Landfills (*Standards*) outline the minimum requirements for development, operation, monitoring, closure and post-closure of Class I, Class II, and Class III landfills. The *Standards* are intended to provide public assurance regarding the protection of groundwater and surface water, and the appropriate management of nuisances associated with landfill development.

The *Standards* apply to disposal activities at new landfills, new cells at existing landfills, and lateral expansions at existing landfills. The *Standards* will also apply to existing registered landfills that are required to apply for an Approval due to an increase in annual waste disposal tonnage. A transition plan will be developed in consultation with landfill approval and registration holders for existing landfills operating under an Approval or Registration.

The *Standards* are intended to be a continuous improvement document. A review of the *Standards* will be conducted a minimum of every 5 years by a multi-stakeholder technical committee comprised of representatives from industry and government. The next scheduled review will be in 2015. Written requests for improvements to the *Standards* may be directed to:

Donna Chaw, Waste Policy Advisor,
Air, Land and Strategic Policy Branch
Alberta Environment
10th Floor Oxbridge Place
9820-106 Street
Edmonton, Alberta T5K 2J6

or

donna.chaw@gov.ab.ca

DEFINITIONS

All definitions as stated in the *Environmental Protection and Enhancement Act* and associated regulations shall apply to these *Standards***.**

In these *Standards*,

(a) "Act" means the *Environmental Protection and Enhancement Act, R.S.A 2000, c E-12*, as amended;

(b) "action leakage rate" means the amount of leakage that would occur through the primary liner, based on two holes per hectare, each with a diameter of 2 mm;

(c) "active landfill area" means the portion of the landfill that has received or is receiving waste for disposal, where final cover has not been placed, and includes areas that are being used for interim management of waste prior to disposition;

(d) "active landfill life" means the period of operation during which waste is received for disposal at the landfill, beginning with the initial receipt of waste and ending with the start of final landfill closure activities;

(e) "adjacent" means lands that are contiguous to the landfill or would be contiguous if not for a river, stream, railway, road, or utility right of way;

(f) "APEGGA" means the Association of Professional Engineers, Geologists and Geophysicists of Alberta;

(g) "aquifer" means an aquifer as defined in the *Water Act*;

(h) "background" means the natural concentration of a substance in a particular groundwater zone in the absence of any input from anthropogenic activities or sources;

(i) "background level monitoring" means a sampling and analysis program that establishes water quality representative of pre-development conditions;

(j) "bulk liquid" means a liquid transported in a vehicle tank or body that is not contained in barrels or other such containers;

(k) "certified operator" means a person who holds a valid Certificate recognized by the Director;

(l) "clay liner" means a liner meeting the specifications in section 3.5(c);

(m) "clayey deposit" means an unconsolidated geological unit that is capable of achieving a hydraulic conductivity of 1×10^{-8} metres per second;

(n) "compliance boundary" means locations where measurements of groundwater quality for regulatory purposes are taken to assess a landfill's performance;

(o) "composite liner" means a liner meeting the specifications in section 3.5(d);

(p) "construction quality assurance" means an integrated system of management activities involving planning, implementation, documentation, assessment, reporting and quality improvement to identify the level to which the construction is in compliance with the specifications;

(q) "construction quality control" means the overall system of technical activities that measures the attributes and performance of construction to verify that the construction meets the specifications;

(r) "coulee" means a dry or intermittent stream valley or wash, especially a long steep-walled gorge representing a Pleistocene overflow channel that carried melt water from an ice sheet;

(s) "day" means any period of 24 consecutive hours unless otherwise specified;

(t) "detection level monitoring" means a monitoring program that is undertaken during the active landfill life, final landfill closure and post-closure for the purpose of detecting the migration of a contaminant constituent to the surrounding environment;

(u) "equivalent hydraulic conductivity" means and is obtained from the following calculation:

$K = d/\Sigma(d_i/K_i)$, where:

K = equivalent hydraulic conductivity
d = thickness of natural geologic material between the bottom of a landfill and the top of an exceptional underlying aquifer
d_i = thickness of each distinctly different geologic layer within the thickness of d
K_i = the hydraulic conductivity of geologic layer d_i
Σ = means the summation of all d_i/K_i values for the distinctly different geologic layers

(v) "exceptional underlying aquifer" means a hydrostratigraphic unit with a transmissivity of greater than 2.5×10^{-3} m^2/sec yielding water with a total dissolved solids (TDS) concentration not exceeding 4000 mg/L;

(w) "final cover" means a designed system, natural or man made, that is placed on the surface of a landfill or landfill cell that has reached its maximum designed waste elevation to control transmission of moisture and gas, and conforms to the end use plan;

(x) "final landfill closure" means the period of time when waste is no longer placed in the defined portion of a landfill and activities are undertaken to complete the final cover system and decommission components and facilities that are no longer required, and includes the construction of any additional components or monitoring systems that are necessary for post-closure;

(y) "fractured non-porous bedrock" means fractured bedrock with a primary porosity of less than 5 percent as measured by a helium porosimeter;

(z) "geologic materials" for the purpose of these *Standards* means one or more geologic formations;

(aa) "geomembrane" means a sheet of manufactured synthetic material designed to control migration of liquid and gas;

(bb) "geosynthetic clay liner (GCL)" means a liner that is made of a thin layer of bentonite either bonded to a geomembrane or fixed between two sheets of geotextile;

(cc) "grab sample" means an individual sample collected in less than 30 minutes and which is representative of the substance sampled;

(dd) "groundwater" means groundwater as defined in the Water Act;

(ee) "groundwater quality control limit" means a concentration of a key indicator parameter above which there is a risk that groundwater quality is impacted by landfill activity;

(ff) "gully" means a small channel with steep sides caused by erosion and cut by concentrated but intermittent flow of water usually during and immediately following heavy rains or after ice or snow melt;

(gg) "hydraulic conductivity" means the ease with which water can be transported through a material;

(hh) "hydrogeologist" means a person who is registered with APEGGA with a specialization in hydrogeology;

(ii) "hydrogeology" means the study of the relationship between water and geology with particular emphasis on the movement and chemistry of water;

(jj) "hydrostratigraphic unit" means the geological formation, or part of a geological formation, or a group of geological formations, in which the hydraulic properties are similar and allow for grouping into aquifers or aquitards;

(kk) "inert waste" means a solid waste that, when disposed of in a landfill or re-used, is not reasonably expected to undergo physical, chemical or biological changes to such an extent as to produce substances that may cause an adverse effect and includes without limitation, demolition debris, concrete, asphalt, glass, ceramic materials, scrap metal and dry timber or wood that has not been chemically treated;

(ll) "industrial solid waste" means solid waste resulting from or incidental to any process of industry;

(mm) "ISO 17025" means the international standard, developed and published by International Organization for Standardization (ISO), specifying management and technical requirements for laboratories;

(nn) “key operating personnel” mean all staff that are in responsible charge of daily operations of a landfill;

(oo) “landfill cell” means a designed or designated area of a landfill comprised of an excavation or earthen structure in which waste is enclosed;

(pp) “landfill gas” means a mixture of gases generated by the microbial decomposition of and chemical reactions between wastes in a landfill;

(qq) “laterally expanding landfill” means a landfill that is being expanded beyond the previously approved waste footprint;

(rr) “leachate” means a liquid that has been in contact with waste in the landfill cell and has undergone chemical or physical changes;

(ss) “leachate collection system” means a system that gathers leachate so that it may be removed from a landfill;

(tt) “leachate pond” means a pond that is designed for temporary storage of leachate;

(uu) “liner” means a continuous layer placed beneath and at the sides of a landfill cell that is compatible with the waste and restricts the migration of leachate, or landfill gas or both;

(vv) “lower explosive limit (LEL)” means the lowest percentage, by volume, of an explosive vapour or gas that must be present in air to ignite;

(ww) “maximum acceptable leachate head” means the maximum depth of leachate above the primary liner, not including the sumps or leachate pipe trenches;

(xx) “monitoring system” means all equipment used for sampling, analyzing or recording data in respect of any parameter;

(yy) “monitoring well” means a well drilled at a site to measure groundwater levels and collect groundwater samples for the purpose of physical, chemical, or biological analysis to determine the concentration of groundwater constituents;

(zz) “municipal solid waste” means solid waste resulting from or incidental to municipal, community, commercial, institutional and recreational activities, and includes garbage, rubbish, ashes, street cleanings, abandoned automobiles, and all other solid wastes except hazardous waste, industrial solid waste, oilfield waste and biomedical wastes;

(aaa) “post-closure” means the period of time after completion of the final landfill closure;

(bbb) “primary liner” means the uppermost liner;

(ccc) "primary porosity" means the pore space in the rock matrix excluding pore space created by processes such as dissolution or fracturing;

(ddd) "prohibited waste" means a waste that may not be accepted for disposal at a landfill because of the classification of the landfill as defined in the *Waste Control Regulation,* as amended, or that is otherwise prohibited by the Province of Alberta;

(eee) "ravine" means a small stream channel, narrow, steep-sided, and commonly V-shaped in cross-section, and larger than a gully;

(fff) "recycle" means to do anything that results in providing a use for a thing that otherwise would be disposed of or dealt with as waste, including collecting, transporting, handling, storing, sorting, separating and processing the thing, but does not include the application of waste to land or the use of a thermal destruction process;

(ggg) "response level monitoring" means a monitoring program that is undertaken following detection of contaminant constituents above specified limits or performance standards and is continued until corrective measures have mitigated the contaminant constituents to below the specified limits or meets performance standards;

(hhh) "run-off" means any rainwater or melt water that drains as surface flow from the active landfill area, excluding leachate;

(iii) "run-on" means any rainwater or melt water that may drain as surface flow onto the active landfill area;

(jjj) "secondary leachate collection system" means a system that gathers liquids between a primary liner and a secondary liner system;

(kkk) "secondary liner" means the lowermost liner of a double liner system;

(lll) "site specific conditions" means all conditions related to the landfill site that may influence its design or operation including climate and quantity and nature of the waste received or proposed to be received at the landfill;

(mmm) "siting" means the process of identifying, investigating, evaluating and selecting locations for solid waste management and disposal facilities;

(nnn) "soil" means mineral or organic earthen materials that can, have, or are being altered by weathering, biological processes or human activity;

(ooo) "structural components" means liners, leachate collection systems, final cover systems, run-on and run-off systems and any other landfill components that are necessary for the protection of human health and the environment;

(ppp) "subsoil" means the layer of soil directly below the topsoil, to a maximum depth of 1.2 metres below the topsoil surface, that consists of the B and C horizons as defined in *The System of Soil Classification for Canada, Agriculture and Agri-Food Canada, 1998, Publication 1643, 3rd Edition*, as amended or replaced from time to time;

(qqq) "topsoil" means the uppermost layers of soil that consist of the L, F, H, O, and A horizons as defined in *The System of Soil Classification for Canada, Agriculture and Agri-Food Canada, 1998, Publication 1643, 3rd Edition*, as amended or replaced from time to time;

(rrr) "unstable area" means land which may be subject to differential settling due to soil conditions, geologic and geomorphic features or man-made features;

(sss) "uppermost formation" means a continuous water-saturated geological stratum or strata, including but not limited to sand lenses and aquifers, that is projected to be the most probable pathway or pathways for lateral transport of leachate;

(ttt) "waste footprint" means the areas within a landfill where waste has been disposed of and is proposed to be disposed of, but does not include those areas used for purposes other than disposal such as surface water storage, recycling facilities, buffer zones and buildings; and

(uuu) "year" means calendar year, unless otherwise specified.

SECTION 1: REGULATORY DISCLOSURE PROCESS FOR A NEW OR LATERALLY EXPANDING LANDFILL

1.1 Disclosure Plan

(a) Prior to submitting an application for a landfill approval or registration, the person responsible for a proposed new or laterally expanding landfill shall submit a written Disclosure Plan to the Director.

(b) The Disclosure Plan shall include, at a minimum, all of the following:
- (i) the proposed process for public consultation;
- (ii) a proposed process for responding to concerns identified during the public consultation process; and
- (iii) the proposed process for technical investigation of the site.

(c) The person responsible for a proposed new or laterally expanding landfill shall implement the Disclosure Plan as authorized in writing by the Director.

1.2 Application Submission

(a) In addition to any information required by the Director under the *Approvals and Registration Procedure Regulation* (AR 113/93), an application for approval or registration of a new or laterally expanding landfill shall be submitted to the Director prior to commencing construction of the landfill.

(b) The application for a new or laterally expanding landfill shall contain at a minimum, all the following documents:
- (i) documentation that demonstrates conformance with the Disclosure Plan;
- (ii) detailed Technical Investigation Program Report as per section 2.4;
- (iii) financial security or environmental reserve fund documentation for closure and post-closure activities;
- (iv) Landfill Design Plan and Specifications as per section 3.1;
- (v) Operations Plan as per section 4.3; and
- (vi) Landfill Monitoring Plan as per section 5.1.

SECTION 2: LANDFILL DEVELOPMENT AND SITING

2.1 Natural Environment Separation

(a) The person responsible for a new landfill shall comply with setbacks as provided in Table 2.1.

Table 2.1
Standards for Environmental Separation

Setting	Distance from waste footprint
Land subject to slope failure	*100 meters*
A natural area that permanently contains water such as a lake, river or creek.	*300 meters, unless otherwise authorized in writing by the Director*
A man-made surface feature that permanently contains water such as an irrigation canal, drainage ditch, but not a road-side ditch, or dugout.	*300 meters, unless otherwise authorized in writing by the Director*

(b) The person responsible for a laterally expanding landfill shall comply with setbacks as provided in Table 2.1 unless:
(i) the landfill existed prior to September 1st,1996; or
(ii) the Director accepts evidence in writing from the person responsible that surface water and groundwater will not be impacted.

(c) A new landfill or the new waste footprint of a laterally expanding landfill shall not be situated at a location where there exists one or more of the following conditions:
(i) the area is situated within a ravine, coulee or gully;
(ii) there is less than 30 metres of geologic materials with an equivalent hydraulic conductivity greater than 1 x 10^{-8} metres/second between the bottom of the liner, or where no liner is required, immediately beneath where waste will be deposited, excluding sumps or leachate pipe trenches, and an exceptional underlying aquifer; or
(iii) the geologic materials within 10 metres below the bottom of the liner, excluding sumps or leachate pipe trenches, include fractured non-porous bedrock or karst features.

(d) A new landfill, or the new waste footprint of a laterally expanding landfill, shall only be situated at a location where:
   (i) there is a 5 metre thick layer of a clayey deposit having an equivalent hydraulic conductivity less than 1 x 10^{-8} metres per second immediately beneath the lowest part of the liner, or where no liner is required, immediately beneath where waste will be deposited, excluding sumps or leachate pipe trenches; and
   (ii) the geologic materials immediately beneath the clayey deposit required in 2.1(d)(i) or 2.1(d)(ii) consist of at least 3 metres of material providing equivalent or better protection to the requirements in 2.1(d)(i).

(e) The clayey deposit in 2.1(d) may include one or more layers of a material with a hydraulic conductivity greater than 1 x 10^{-6} metres per second provided that:
   (i) the accumulated thickness of the layers are less than 0.5 metres; and
   (ii) any such layers do not extend beyond the compliance boundary.

(f) The thickness of the clayey deposit required in 2.1(d) may be attained by reconstruction of compacted earthen materials to an equivalent hydraulic conductivity less than 1 x 10^{-8} metres per second.

(g) Sections 2.1(c) to 2.1(d) do not apply to the new waste footprint of a laterally expanding landfill if the Director accepts written evidence from the person responsible that the groundwater quality will not exceed groundwater performance standards as per section 5.3 at the compliance boundary.

(h) Section 2.1(g) only applies to landfills which were in existence prior to January 1, 2010.

2.2 Requirements for a Technical Investigation Program

(a) Prior to the design of a new or laterally expanding landfill, the person responsible shall complete a Technical Investigation Program specific to the landfill site and its surrounding area.

(b) The person responsible shall ensure that the components of the Technical Investigation Program are prepared by APEGGA registered professionals with expertise in the subject area.

(c) The Technical Investigation Program shall include characterization of the geologic, hydrologic, hydrogeologic and geotechnical settings expressed on regional and local scales.

(d) The Technical Investigation Program shall identify the geologic, hydrologic, hydrogeologic and geotechnical characteristics of the site including, at a minimum, all of the following:
   (i) the groundwater and surface water regimes associated with the new or laterally expanding landfill;
   (ii) the potential contaminant flow paths from the landfill into the receiving environment;

(iii) for a laterally expanding landfill, the potential impacts on groundwater and surface water regimes relative to the existing landfill;
(iv) characterization of the variability, depth, and engineering properties of onsite soils; and
(v) a site stability assessment.

(e) The boreholes completed for the Technical Investigation Program shall be distributed at:
(i) an evenly distributed spacing of not more than 200 metres; or
(ii) a minimum of five evenly distributed locations for landfills with a waste footprint smaller than 5 hectares.

(f) The minimum depth of the hydrogeologic characterization component of the Technical Investigation Program shall be deeper than 30 metres below the proposed base of the new or laterally expanding landfill.

(g) The Director may require additional boreholes for hydrogeologic characterization required in 2.2(e) and 2.2(f) to adequately delineate geologic formations.

(h) A topographic survey shall be conducted for the area of the new or laterally expanding landfill as part of the Technical Investigation Program.

2.3 Groundwater Monitoring Wells

(a) The drilling, construction, maintenance and reclamation of boreholes and monitoring wells for the purposes of conducting the Technical Investigation Program shall be done in accordance with all applicable requirements described in Part 7 of the *Water (Ministerial) Regulation (AR 205/98)*, as amended.

2.4 Detailed Technical Investigation Program Report

(a) The person responsible for a new or laterally expanding landfill shall ensure that APEGGA registered professionals with expertise in the subject area prepares components of the Detailed Technical Investigation Program Report.

(b) The Detailed Technical Investigation Program Report shall include, at a minimum, all of the following information:
(i) a description of the topography, surface drainage patterns, geology, hydrogeology, existing and surrounding land use within 800 metres of the proposed site;
(ii) a drawing showing the proposed site in relation to:
a. adjacent development and infrastructure;
b. natural and constructed physical features such as streams, rivers, water bodies, canals and drainage controls;
c. domestic, municipal and other licensed water well locations within 5 km of the proposed site; and
d. municipal wellhead protection zones;
(iii) a detailed site plan showing:
a. surface topography; and
b. locations and surface elevations of all boreholes and monitoring wells;

(iv) the profile and depths of the topsoil and subsoil;
(v) detailed borehole records showing the geologic and hydrogeologic conditions encountered and the depth of all major stratigraphic features;
(vi) site stability;
(vii) cross-sections showing:
  a. an interpretation of the geologic stratigraphy to the depth of the hydrogeologic characterization component;
  b. directions of groundwater flow; and
  c. hydraulic conductivities of the geologic strata that influence or control groundwater movement;
(viii) a detailed written interpretation of the hydrologic, hydrogeologic and geotechnical conditions on a regional and local scale;
(ix) a statement that the site is suitable for landfill development in accordance with applicable regulatory requirements in Alberta; and
(x) recommendations for:
  a. the area suitable for landfilling;
  b. the landfill design based on the hydrologic and hydrogeologic conditions; and
  c. dealing with the implications of the conditions in section 2.4(b)(viii) on possible landfill development.

SECTION 3: DESIGN AND CONSTRUCTION

3.1 Landfill Design Plan and Specifications

(a) The person responsible shall ensure that APEGGA registered professionals with expertise in the subject area prepares the Landfill Design Plan and Specifications for a new or laterally expanding landfill.

(b) The Landfill Design Plan and Specifications for a new or laterally expanding landfill shall include, at a minimum, all of the following information:

- (i) an engineering design report that provides:
  - a. a description of the type and quantity of waste that is anticipated to be accepted at the landfill;
  - b. a description of the design intent and a summary of the components included in the design to achieve the design intent;
  - c. an evaluation of the potential for leachate generation and leachate composition based on site specific conditions;
  - d. an evaluation of the potential for landfill gas generation and gas composition based on the type of waste accepted, climate, the landfill design, or other site specific conditions;
  - e. a description of monitoring systems;
  - f. a preliminary landfill closure plan that includes at a minimum:
    - i a staging plan for closure of the landfill or portions of the landfill;
    - ii a plan to manage surface water infiltration or moisture additions according to the design intent of the landfill cells;
    - iii a proposed design for the final landfill cover system;
    - iv general information of the final elevation and slopes;
    - v a re-vegetation plan of completed areas of the landfill; and
    - vi a description of the potential end-use of the landfill after final landfill closure; and
- (ii) engineering design maps and plans that provide:
  - a. topographic maps showing the overall proposed site development and setbacks;
  - b. a site plan that shows the proposed landfill footprint and the location of the compliance boundary;
  - c. a minimum 30 metre separation between the waste footprint and the landfill property line;
  - d. cross-sections showing the proposed surface elevations, base elevations and grades for the landfill development;
  - e. drawings for structural components of the landfill including, but not limited to, liner systems and leachate collection and removal systems;
  - f. a run-on control system to prevent flow onto the active landfill area for events up to at least the peak discharge from a 1 in 25 year – 24 hour duration rainfall event;
  - g. a run-off control system for the active landfill area to collect and control at least the run-off water volume resulting from a 1 in 25 year – 24 hour duration rainfall event; and
  - h. a groundwater monitoring system as per the minimum requirements in section 5.6.

(c) If a new or laterally expanding landfill accepts segregated material for the purpose of waste minimization, sorting, recovery, processing, or storage then the Landfill Design Plan and Specifications shall include specific areas to be used for these activities.

(d) Any deviations to the Landfill Design Plan and Specifications must be authorized in writing by the Director prior to implementation.

3.2 Design of a Class II Landfill

(a) In addition to the requirements in section 3.1, the Landfill Design Plan and Specifications for the construction of a new or laterally expanding Class II Landfill shall include, at a minimum, all of the following:
  (i) a liner; and
  (ii) a leachate collection system capable of maintaining the maximum acceptable leachate head.

3.3 Design of a Class III Landfill

(a) In addition to the requirements as described in section 3.1, the Landfill Design Plan and Specifications for construction of a new or laterally expanding Class III landfill shall provide for the containment of inert wastes.

3.4 Design of a Leachate Pond

(a) The Design Plan and Specifications for the construction of a leachate pond shall include, at a minimum, all of the following:
  (i) a primary geomembrane liner;
  (ii) a secondary geomembrane liner; and
  (iii) a secondary leachate collection system.

(b) The liner system in 3.4(a) shall be constructed over a prepared clay sub-grade suitable to protect the integrity of the liner system.

3.5 Construction

(a) The person responsible shall construct a new or laterally expanding landfill or landfill cell in accordance with the Landfill Design Plan and Specifications authorized in an Approval or Registration.

(b) Detailed Construction Plans and Specifications, prepared in accordance with the Landfill Design Plan and Specifications, shall be submitted to the Director prior to each major stage of construction, including but not restricted to cell construction and closure.

(c) If the new landfill, laterally expanding landfill or landfill cell is to be constructed with a clay liner, the clay liner shall be constructed by compacting earthen material:
  - (i) that has a hydraulic conductivity of less than 1 x 10^{-9} metres/second to a thickness of not less than 1 metre, measured perpendicular to the slope, or
  - (ii) that has a hydraulic conductivity greater than 1 x 10^{-9} metres/second to a thickness greater than 1 metre that will achieve an equivalent advective performance to 3.5(c)(i).

(d) If the new landfill, laterally expanding landfill or landfill cell is to be constructed with a composite liner, the composite liner shall be constructed with a geomembrane placed directly on the surface of:
  - (i) a liner that is comprised of earthen material with a hydraulic conductivity of less than 1 x 10^{-9} metres/second compacted to a thickness of not less than 0.6 metres, measured perpendicular to the slope, or
  - (ii) a liner that is comprised of earthen materials with a hydraulic conductivity greater than 1 x 10^{-9} metres/second compacted to a thickness greater than 0.6 metres that will achieve an equivalent advective performance to 3.5(d)(i), or
  - (iii) a liner that is comprised of a geosynthetic clay liner and earthen material compacted to a thickness of not less than 0.6 metres, measured perpendicular to the slope, that will achieve a combined equivalent advective performance to 3.5(d)(i).

3.6 Construction Quality Assurance and Control

(a) Prior to the construction of a new landfill, laterally expanding landfill or landfill cell, the person responsible shall submit to the Director a Construction Quality Assurance Plan and a Construction Quality Control Plan.

(b) The person responsible shall construct a new landfill, new landfill cell, laterally expanding landfill or landfill cell according to the Construction Quality Assurance Plan and the Construction Quality Control Plan as authorized in writing by the Director.

(c) Any deviations to the Construction Quality Assurance or Construction Quality Control Plan or the Detailed Construction Plans and Specifications, must be authorized in writing by the Director prior to implementation.

(d) Section 3.6 (c) does not apply to deviations where:
  - (i) the deviation results in a minor adjustment to the Detailed Construction Plan and Specifications to suit field conditions encountered; and
  - (ii) the deviation will not result in a change in the design performance of the landfill or landfill cell.

(e) Prior to commencing operation of a new or laterally expanding landfill or landfill cell, the person responsible shall submit a report detailing the Construction Quality Assurance Results to the Director confirming that the landfill has been constructed according to the Construction Quality Assurance Plan, Construction Quality Control Plan, and the Landfill Design Plan and Specifications.

(f) If the construction of the new or laterally expanding landfill or landfill cell has not been carried out according to some or all of the Construction Quality Assurance Plan, the Construction Quality Control Plan or the Landfill Design Plans and Specifications, the person responsible shall provide a report to the Director that explains the deviation(s) and includes a description of any potential impacts that may result from the deviation(s).

SECTION 4: LANDFILL OPERATION

4.1 Operator Certification

(a) The person responsible for a landfill shall ensure that during active landfill life and until final landfill closure all key operating personnel hold a valid basic landfill operator certificate after 18 months of employment at the facility.

(b) To qualify for basic certification, the operator must:
- (i) be at least 18 years of age; and
- (ii) have one year of full time operational experience at a landfill which is current to within the last 3 years from the date of application.

(c) The following landfill operator certificates are recognized by the Director:
- (i) Alberta Environment Certificate of Qualification issued under the Municipal Waste Facility Operator Certification Guideline; and
- (ii) Alberta Basic Landfill Operator Certificate issued by the Solid Waste Association of North America-Northern Lights Chapter.

(d) The person responsible for the facility shall ensure that the facility has operators with the required certification endorsements as per the *Alberta Landfill and Composting Facility Operator Certification Guidelines*, published by Alberta Environment.

(e) The person responsible for the landfill shall notify the Director in writing of the names of all the key operating personnel, the required facility endorsements, and any change in any of the key operating personnel or facility endorsements within 30 days of the change.

4.2 Topsoil and Subsoil Salvaging and Storage

(a) During the construction and operation of a landfill, the person responsible shall separately recover and stockpile all topsoil and subsoil such that all topsoil and subsoil stockpiles:
- (i) shall be constructed in a manner that allows for maximum recovery of the topsoil and subsoil;
- (ii) shall be contoured, stabilized and seeded to protect against soil loss by erosion; and
- (iii) shall only be used for reclamation at the landfill site.

4.3 Operations Plan

(a) The person responsible for a landfill shall
- (i) develop;
- (ii) maintain; and
- (iii) implement

an Operations Plan that is consistent with the Landfill Design Plan and Specifications and these *Standards*.

(b) The Operations Plan shall include, at a minimum, all of the following information:
- (i) waste acceptance policies and procedures as per section 4.4;
- (ii) polices and procedures for wastes requiring special handing, if accepted;
- (iii) operating procedures for nuisance management as per section 4.5;
- (iv) a Wildlife Management Plan as per section 4.6;
- (v) procedures for covering the waste including a description of proposed materials and the frequency of cover applications;
- (vi) a plan for the protection of liners;
- (vii) an emergency response plan;
- (viii) a site safety plan;
- (ix) a plan for the detection and management of subsurface landfill gas, if applicable;
- (x) a plan for the management of leachate including its collection, removal, treatment and disposal;
- (xi) a plan for leachate pond management, if applicable;
- (xii) a plan for the management of surface water run-off and run-on control systems;
- (xiii) the Landfill Monitoring Plan in accordance with section 5.1; and
- (xiv) a plan for other operations where they are included at the landfill site such as the storage, processing, recycling or composting of segregated waste or feedstocks.

4.4 Waste Acceptance Policies and Procedures

(a) The waste acceptance policies and procedures in the Operations Plan shall be consistent with the requirements as described in the *Waste Control Regulation* (AR 192/96), as amended, or as specified in writing by the Director.

(b) The waste acceptance policies and procedures shall include a program to detect a prohibited waste so that it is prevented from being disposed of in a landfill cell.

4.5 Nuisance Management

(a) The person responsible for a landfill shall take all necessary measures to control nuisances such as litter, fires, disease vectors, odours and dust, including but not limited to:
- (i) erecting artificial barriers, utilizing natural barriers, or other effective measures to control access to the site;
- (ii) covering solid waste that is disposed in the landfill with soil or other cover material at a frequency specified in the Operations Plan;
- (iii) maintaining areas for storage, processing or recycling of segregated waste in a clean and orderly manner;
- (iv) establishing and maintaining litter controls to minimize the escape of waste from the landfill site;
- (v) retrieval of litter that accumulates on the landfill site; and
- (vi) retrieval of litter that is washed, blown, or transported onto adjacent properties, provided the consent of the owner of the adjacent property is first obtained.

4.6 Wildlife Management

(a) The person responsible for a landfill shall restrict wildlife from the landfill in accordance with both of the following:
- (i) *Waste Management Facilities and Wildlife*, Alberta Sustainable Resource Development, as amended; and
- (ii) *The Landfill Guidelines,* Alberta Environment, as amended.

(b) Where wildlife problems are not resolved, the person responsible must develop a wildlife management plan acceptable to local Fish and Wildlife officials.

4.7 Controlled Burning

(a) No person shall conduct opening burning or permit open burning at a landfill unless:
- (i) the open burning is conducted in accordance with the *Substance Release Regulation (AR 124/93*); and
- (ii) the open burning is done in an area that is:
  - a. constructed with a fire break consisting of barren mineral soil;
  - b. located so that is separated from disposal operations, storage compounds and buildings; and
  - c. supervised at the time of burning.

(b) At least 7 days prior to the date of the burning, the person responsible for the landfill shall notify all of the following:
- (i) the local authorities;
- (ii) all adjacent property owners; and
- (iii) the local fire department.

informing them of the proposed burning and the date on which the proposed burning is to take place.

4.8 Liquid Waste Restriction

(a) No liquid waste shall be disposed in a Class III landfill cell.

(b) No oilfield waste that is liquid shall be disposed in any landfill cell.

(c) No hazardous waste that is liquid shall be disposed in any landfill cell.

(d) A containerized liquid, that is waste, greater than 5 litres shall not be disposed in any landfill cell.

(e) A bulk liquid, that is waste, greater than 5 litres shall not be disposed in a Class II landfill unless the landfill cell is designed with a liner and leachate collection system and acceptable liquid addition limits are as described in the Landfill Design and Specifications Plan authorized in writing by the Director.

(f) Section 4.8(e) includes wastewater sewage from a community that is not served by a wastewater treatment plant.

4.9 Signage

(a) The person responsible shall erect and maintain signs at the landfill entrance providing, at a minimum, all of the following information:
- (i) the name of the approval or registration holder;
- (ii) the landfill class;
- (iii) any waste restrictions; and
- (iv) the telephone numbers for:
  - a. the person responsible;
  - b. the local fire department; and
  - c. Alberta Environment (1-800-222-6514).

4.10 Leachate Management

(a) Section 4.10 applies to all landfills with leachate collection systems.

(b) During active landfill life, final landfill closure and post-closure the maximum acceptable leachate head in landfill cells constructed after July 1, 2009 shall not exceed 300 mm.

(c) During active landfill life, final landfill closure and post-closure the maximum acceptable leachate head for landfill cells constructed prior to July 1, 2009 shall not exceed the maximum acceptable leachate head as authorized in writing by the Director.

(d) The person responsible for a landfill shall remove leachate from the cell at a frequency that maintains the level of leachate at or below the maximum acceptable leachate head.

(e) Notwithstanding the requirements in 4.10(b), 4.10(c) and 4.10(d), upon detection of any exceedances of the maximum acceptable leachate head, the person responsible shall reduce the leachate head level to below the maximum acceptable leachate head level within a maximum of 14 calendar days subsequent to the detection.

(f) Landfills or landfill cells that have been approved by the Director to include an alternative design for liner and leachate collection systems shall manage leachate as authorized in writing by the Director.

SECTION 5: MONITORING, ANALYSIS AND CORRECTIVE ACTION

5.1 Landfill Monitoring Plan

(a) The person responsible for a landfill shall
- (i) develop;
- (ii) maintain; and
- (iii) implement

a Landfill Monitoring Plan.

(b) The Landfill Monitoring Plan shall include, at a minimum, all of the following:
- (i) a Groundwater Monitoring Program; and
- (ii) a Surface Water Monitoring Program.

(c) In addition to the requirements in section 5.1(b) the person responsible for a landfill that is designed and constructed with a leachate collection system shall develop a Leachate Monitoring Program as part of the Landfill Monitoring Plan.

(d) In addition to the requirements in section 5.1(b), the person responsible for a landfill that accepts organic waste that is reasonably expected to undergo microbial decomposition shall develop a Subsurface Landfill Gas Monitoring Program as part of the Landfill Monitoring Plan.

(e) The person responsible shall ensure that APEGGA registered professionals with expertise in the subject area prepares the Landfill Monitoring Plan.

(f) If the Director finds the Landfill Monitoring Plan to be deficient, the person responsible shall correct all deficiencies as outlined by the Director in writing.

(g) The person responsible shall implement the Landfill Monitoring Plan as authorized in writing by the Director.

(h) The person responsible shall implement the Landfill Monitoring Plan from the beginning of the active landfill life until the end of post-closure, unless otherwise authorized in writing by the Director.

5.2 Groundwater Monitoring Program

(a) The person responsible for a landfill shall develop the Groundwater Monitoring Program to include, at a minimum, all of the following:
- (i) background groundwater quality for each monitoring well;
  - a. existing landfills or landfill cells may establish background levels after the start of landfill operations by:
    - i using historical data; or
    - ii obtaining groundwater samples from monitoring wells established in nearby areas not affected by landfill activity;
- (ii) establish groundwater quality control limits for each naturally occurring parameter;

(iii) a detailed program for groundwater sample collection frequency and analysis, that includes, at a minimum, all of the following:

a. retrieval of representative samples from the groundwater monitoring system at a frequency set out in Table 5.1, or as otherwise authorized in writing by the Director; and

b. laboratory analysis of the samples for parameters as described in Table 5.2; and

(iv) a Groundwater Contingency Plan

(b) The Groundwater Monitoring Program for a Class II landfill that receives wastes other than municipal solid wastes shall include additional parameters than those specified in Table 5.2 as specified in writing by the Director and based on site-specific conditions.

(c) Response level monitoring parameters and frequency shall be as authorized in writing by the Director.

(d) The groundwater monitoring data shall be presented using control charts and interpreted by a professional registered with APEGGA, or other professional authorized in writing by the Director, to determine any groundwater quality impacts as a result of the landfill operations.

Table 5.1
Frequency for Groundwater Sampling and Analysis

Landfill	Background Monitoring	Detection Level
Class II and III Landfills with liner and leachate collection systems	• Twice[1] per year for the first four (4) years of operations. • Once per year every 3rd year after background levels have been established.	Twice per year[2]
Class II and III Landfills without liner and leachate collection systems	• Twice per year for the first four (4) years of operations. • Once per year after background levels have been established.	Once per year

[1] The two sampling events should be considerate of seasonal variations.
[2] The frequency is reduced to 1 time per year during the year when the background parameters are done.

Table 5.2
Groundwater Parameters for Background Level and Detection Level Monitoring Parameters

Parameter	Background	Detection level
General and Inorganic Parameters		
pH, Total Dissolved Solids, Alkalinity, Ammonia, Total Kjeldahl Nitrogen, Electrical Conductivity, Hardness (CaCO3)	√	√
Major Ions		
Chloride, Calcium, Magnesium, Sodium, Potassium, Sulphate, Nitrate-N, Nitrite - N	√	√
Dissolved Metals		
Arsenic, Barium, Beryllium, Boron, Cadmium, Chromium, Copper, Iron, Lead, Lithium, Manganese, Molybdenum, Mercury, Nickel, Phosphorus, Silicon, Silver, Strontium, Thallium, Tin, Vanadium, Uranium, and Zinc	√	
Iron and Manganese	√	√
Other Organics		
Dissolved Organic Carbon (DOC)	√	√
Volatile Organic Compounds[3]		
Benzene, Toluene, Ethylbenzene, Xylene, F1, F2, Phenols	√	
Methylene Chloride, Vinyl Chloride, Trichloroethylene (TCE), Tetrachlorethylene (PCE).	√	

5.3 Groundwater Performance Standards

(a) Throughout the active landfill life, final landfill closure, and post-closure of the landfill, the groundwater quality within the compliance boundary shall meet the all of the following groundwater performance standards:
   (i) groundwater quality of one or more parameters shall not display an increasing trend;
   (ii) groundwater parameters shall not exceed the corresponding groundwater quality control limit; and
   (iii) any parameters not naturally present in groundwater is not detected in three consecutive sampling events.

5.4 Implementation of Groundwater Contingency Plan

(a) The person responsible shall immediately notify the Director and shall implement the Groundwater Contingency Plan developed in accordance with section 5.2(a)(iv), if at any time until the end of post-closure the groundwater fails to meet the groundwater performance standards within the compliance boundary.

[3] Parameters not naturally present in groundwater

5.5 Compliance Boundary

(a) The person responsible shall establish the compliance boundary at locations that are:
- (i) at least 20 metres inside the property boundary of the landfill; and
- (ii) at least 10 metres, but not more than 60 metres from the waste footprint.

5.6 Groundwater Monitoring Wells

(a) The person responsible for a new or laterally expanding landfill shall construct groundwater monitoring wells that are:
- (i) no more than 200 metres from the nearest groundwater monitoring well as measured along the compliance boundary;
- (ii) at locations that provide an accurate representation of upgradient and downgradient groundwater quality.

(b) The person responsible shall ensure that each groundwater monitoring location along the compliance boundary includes at least one well designed to allow for the collection of groundwater samples from the uppermost formation.

(c) All groundwater monitoring wells shall be protected from damage and shall be locked, except when being sampled, unless otherwise authorized in writing by the Director.

(d) If a groundwater sample cannot be collected because the monitoring well is damaged or is no longer capable of producing a representative sample:
- (i) the groundwater monitoring well shall be cleaned, repaired or replaced; and
- (ii) a representative groundwater sample shall be collected prior to the next scheduled sampling date unless otherwise authorized in writing by the Director.

5.7 Surface Water Monitoring Program

(a) The Surface Water Monitoring Program shall include, at a minimum, all of the following:
- (i) a detailed program for surface water sample collection and analysis, that includes, at a minimum, all of the following:
  - a. retrieval of representative samples from the run-off control system at a frequency as described in Table 5.3, or as otherwise authorized in writing by the Director;
  - b. laboratory analysis of the samples for parameters as described in Table 5.3;
  - c. surface water quality of the receiving water body; and
  - d. upstream and downstream surface water quality of any run-off water receiving stream, if applicable.
- (ii) identification of potential sources of contamination, spills and leaks at the landfill;
- (iii) release procedures for run-off that meets release limits in Table 5.3;
- (iv) management of run-off that exceeds the release limits in Table 5.3; and

(v) a Surface Water Contingency Plan for response and assessment in the event that:
   a. the run-off containment is contaminated from spills or leaks;
   b. there is an accidental release to the surrounding watershed; or
   c. there is an unauthorized release to the surrounding watershed.

(b) Releases from the run-off control system shall comply with the limits for the parameters specified in Table 5.3.

(c) Notwithstanding 5.7(b), the person responsible may use alternate run-off control system release limits, if the Director accepts written justification for the use of the proposed run-off control system release limits.

(d) The Surface Water Monitoring Program for a Class II landfill that receives wastes other than municipal solid wastes shall include additional parameters additional to those specified in Table 5.3, as specified in writing by the Director and based on site-specific conditions.

(e) The person responsible shall not release any substances from the run-off control system to the surrounding watershed, except in accordance with the Surface Water Monitoring Program, as approved in writing by the Director.

(f) The surface water monitoring data shall be interpreted by a professional registered with APEGGA, or other professional authorized in writing by the Director, to determine any surface water quality impacts as a result of the landfill operation.

Table 5.3
Surface Water Monitoring and Release Limits

Parameter	Frequency	Sample Type	Sample Location	Release Limit Maximum Concentration or Range (in mg/L unless otherwise specified)
pH	a) prior to each release; and b) during any unanticipated release from the runoff control system	Representative grab sample	Each runoff Control System Pond from which a release: (a) is to occur, or (b) is occurring	6.0 – 9.5 pH units
Total Dissolved Solids				2500
Total Suspended Solids				25
Ammonia (Total)				5.0
Chloride				250
Sodium				200
Sulphate				500
Chemical Oxygen Demand				50
Oil and Grease				No visible sheen
Volume	When released	When released	Discharge Point	When released

5.8 Implementation of the Surface Water Contingency Plan

(a) If at any time until the end of post-closure, there are accidental or unauthorized releases from the run-off control system to the receiving watershed, the person responsible shall immediately notify the Director and shall implement the Surface Water Contingency Plan developed in accordance with section 5.7(a)(v).

5.9 Leachate Monitoring Program

(a) The Leachate Monitoring Program shall include, at a minimum, all of the following:
  (i) a detailed program for leachate collection system sample collection and analysis, that includes, at a minimum, all of the following:
    a. a program to measure the depth of leachate head in the cells;
    b. retrieval of representative samples at a frequency as described in Table 5.4, or as otherwise authorized in writing by the Director; and
    c. laboratory analysis of the leachate samples for parameters as described in Table 5.4;
  (ii) if applicable, a detailed program for leachate pond sample collection and analysis, that includes, at a minimum, all of the following:
    a. retrieval of representative samples at a frequency as described in Table 5.4, or as otherwise authorized in writing by the Director; and
    b. laboratory analysis of the leachate pond content for parameters as described in Table 5.4;
  (iii) an Action Leakage Rate shall be developed for the sump(s) associated with the leachate pond leak detection system, as applicable, as per the *Action Leakage Rate Guideline* published by Alberta Environment.
  (iv) a Leak Detection Response Action Plan shall be developed, in accordance with section 6.2 of the *Action Leakage Rate Guideline*, for response and action if the Action Leakage Rate is exceeded.

(b) The Leachate Monitoring Program shall be implemented during the active landfill life, final landfill closure and post-closure for the landfill.

Table 5.4
Landfill Leachate Sampling and Analysis

Monitoring Activity	Monitoring		
	Minimum Frequency	Method	Sampling Location
Leachate level monitoring in cells	April to October - weekly November to March - Monthly	Measurement	At each leachate manhole and sump
Volume of leachate removed from cells	As removed	Measurement	At each leachate manhole and sump
Volume of leak detection liquid removed from the secondary leachate collection system	Monthly or as removed	Measurement or calculated	At secondary leachate collection system sump(s)
Leachate parameters:			
pH, Total Dissolved Solids, Total Suspended Solids Ammonia (total), Total Kjeldahl Nitrogen, Chloride, Sodium, Sulphate, COD. Metals BTEX, F1, F2, Phenols	Annually	(a) grab sample (b) representative grab	(a) at each leachate manhole and sump; and (b) at the leachate pond, if applicable

5.10 Implementation of the Leak Detection Response Action Plan

(a) Throughout the active landfill life, closure, and post-closure of the landfill, the total flow per month at the leachate pond leak detection system shall not be greater than the Action Leakage Rate, or as otherwise authorized in writing by the Director.

(b) If at any time until the end of post-closure, the total flow per month at the leachate pond leak detection system is greater than the Action Leakage Rate, then the person responsible shall immediately notify the Director and shall implement the Leak Detection Response Action Plan developed in accordance with section 5.9(a)(iv).

5.11 Subsurface Landfill Gas Monitoring Program

(a) The Subsurface Landfill Gas Monitoring Program shall include, at a minimum, the all of the following:
- (i) a description of the subsurface landfill gas monitoring sites and their locations;
- (ii) the methods to be used for measurement and detection of the lateral migration of subsurface landfill gas;
- (iii) the frequency for measurement of subsurface landfill gas; and
- (iv) a Subsurface Landfill Gas Contingency Plan for the mitigation of subsurface landfill gas migration.

(b) The subsurface landfill gas monitoring data shall be interpreted by a professional registered with APEGGA, or other professional authorized in writing by the Director, to determine the potential impacts from the subsurface migration of landfill gas.

5.12 Implementation of the Subsurface Landfill Gas Contingency Plan

(a) Throughout the active landfill life, final landfill closure, and post-closure the subsurface landfill gas shall not exceed the landfill gas explosive limits as described in Table 5.5.

(b) If at any time until the end of the post-closure, the explosive gas limits as described in Table 5.5 are exceeded, the person responsible shall immediately notify the Director and shall implement the Subsurface Landfill Gas Contingency Plan developed in accordance with section 5.11(a)(iv).

Table 5.5
Subsurface Landfill Gas Explosive Limits

Sampling Location	Explosive Gas Limits
In the subsurface at the property boundary	50% LEL
In an on-site building or enclosed structure or in the area immediately outside the foundation of the building or structure	20% LEL
In an off-site building or enclosed structure or in the area immediately outside the foundation of the building or structure	1% LEL

5.13 Methods for Water, Leachate and Solid Waste Analysis

(a) With respect to any sample required to be taken, the person responsible shall ensure that:
- (i) collection;
- (ii) preservation;
- (iii) storage;
- (iv) handling; and
- (v) analysis;

shall be conducted in accordance with the following, or as otherwise specified in writing by the Director:

- (vi) For air monitoring:
  - a. The *Methods Manual for Chemical Analysis of Atmospheric Pollutants*, Alberta Environment, as amended; and
  - b. The *Air Monitoring Directive*, Alberta Environment, as amended;

- (vii) For surface water, leachate and groundwater monitoring:
  - a. the Standard Methods for the Examination of Water and Wastewater, American Public Health Association, American Water Works Association and the Water Environmental Federation, as amended; and
  - b. the Methods Manual for Chemical Analysis of Water and Wastes, Alberta Environment Centre, Vegreville, Alberta, October 1987,AEC V96-M1, as amended.

- (viii) For whole effluent toxicity tests:
  - a. the *Biological Test Method: Reference Method for Determining Acute Lethality of Effluents to Rainbow Trout*, Environment Canada, Environmental Protection Series I/RM/13, July 1990, as amended;
  - b. the *Biological Test Method: Reference Method for Determining Acute Lethality of Effluents to Daphnia Magna*, Environment Canada, Environmental Protection Series, I/RM/14, July 1990, as amended;
  - c. the *Biological Test Method: Growth Inhibition Test Using the Freshwater Alga Selenastrum capricornutum*, Environment Canada, Environmental Protection Series, November 1992, as amended;
  - d. the *Biological Test Method: Test of Reproduction and Survival Using the Cladoceran Ceriodaphnia dubia*, Environment Canada, Environmental Protection Series 1/RM/21, February 1992, as amended;
  - e. the *Biological Test Method: Test of Larval Growth and Survival Using Fathead Minnows*, Environment Canada, Environmental Protection Series 1/RM/22, February 1992, as amended; and
  - f. the *Biological Test Method: Toxicity Test Using Luminescent Bacteria (Photobacterium phosphoreum),* Environment Canada, Environmental Protection Series,1/RM/24, November 1992, as amended.

(ix) For soil samples:

a. *Manual on Soil Sampling and Methods Analysis*, Lewis Publishers, 1993, as amended;

b. The *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*, USEPA, SW-846; September 1986, as amended;

c. The *Soil Quality Criteria Relative to Disturbance and Reclamation*,Alberta Agriculture, March 1987, as amended;

d. the Guidance Manual on Sampling, Analysis and Data Management for Contaminated Sites – Volume I: Main Report, CCME EPC-NCS62E, 1993, as amended; and

e. the Guidance Manual on Sampling, Analysis and Data Management for Contaminated Sites – Volume II: Analytical Method Summaries, CCME EPC-NCS66E, 1993, as amended.

(x) For waste analysis

a. the*Test Methods for Evaluation of Solid Waste, Physical/Chemical Methods, USEPA, SW-846*, September 1986, as amended;

b. the *Methods Manual for Chemical Analysis of Water and Wastes, Alberta Environmental Centre*, Vegreville, Alberta, 1996, AECV96-M1 as amended;

c. the *Standard Methods for the Examination of Water and Wastewater*, American Public Health Association, American Water Works Association, and the Water Environment Federation, as amended;

d. the *Interim Compilation of Test Methods and Methods of Dangerous Goods Regulations*, Environment Canada, as amended; or

e. the *Toxicity Characteristic Leaching Procedure (TCLP), USEPA Regulation 40 CFR261, Appendix II,* Method No. 1311, as amended.

.

(b) The person responsible shall analyze all samples that are required to be obtained by this approval in a laboratory accredited pursuant to ISO 17025, as amended, for the specific parameter(s) to be analyzed, unless otherwise authorized in writing by the Director.

SECTION 6: FINAL LANDFILL CLOSURE AND POST-CLOSURE

6.1 Detailed Final Landfill Closure Plan

(a) The person responsible for a landfill shall submit a Detailed Final Landfill Closure Plan and notify the Director in writing of the intent to close the landfill at least 180 calendar days prior to implementing final landfill closure.

(b) The Detailed Final Landfill Closure Plan shall include, at a minimum, all of the following:
- (i) a schedule for completion of the final landfill closure;
- (ii) a plan for design and completion of final cover;
- (iii) a design plan for erosion control;
- (iv) a design plan for restoration of surface water drainage;
- (v) design plans for changes to the groundwater and landfill gas monitoring systems, including, but not limited to the addition or reclamation of monitoring wells;
- (vi) design plans for changes to the leachate collection and landfill gas control systems, including but not limited to the addition or deletion of components of those systems;
- (vii) a schedule for decommissioning and removal of buildings, storage areas, processing areas or any other operations or facilities that are on the landfill property that will no longer be required; and
- (viii) a Post-Closure Plan.

(c) The design plan of the final cover shall include as a minimum, all of the following:
- (i) a drawing that shows the proposed geometry of the final cover, which shall have a slope at a minimum of 5 percent and a maximum of 30 percent;
- (ii) a final cover system consisting of three layers constructed in the following order from bottom to top:
  - a. 0.60 metres barrier layer with a maximum hydraulic conductivity of 1×10^{-7} metres per second;
  - b. subsoil; and
  - c. 0.20 metres of topsoil.
- (iii) subsoil depth in 6.1(c)(ii)b. shall be:
  - a. 0.35 metres for pasture or recreational uses; or
  - b. 0.80 metres for cultivated land use or forestry;
- (iv) vegetation establishment as per the intended land use;
- (v) alternative final cover systems may be authorized by the Director.

(d) The person responsible shall ensure that APEGGA registered professionals with expertise in the subject area prepares components of the Detailed Final Landfill Closure Plan.

(e) If the Director finds the Detailed Final Landfill Closure Plan to be deficient, the person responsible shall correct the deficiencies as outlined by the Director in writing prior to completion of the final landfill closure.

(f) The person responsible shall complete the final landfill closure in accordance with the Detailed Final Landfill Closure Plan as authorized in writing by the Director.

6.2 Post-Closure Plan

(a) The Post-Closure Plan shall include, at a minimum, all of the following:
- (i) a plan for maintaining the integrity of the final cover;
- (ii) a plan for remediation of areas affected by subsidence and differential settlement;
- (iii) a plan for maintaining surface water drainage systems; and
- (iv) a plan for maintaining and operating the following components where they are part of the landfill design:
  - a. groundwater monitoring systems;
  - b. leachate collection and removal systems; and
  - c. landfill gas control systems.

(b) If the Director finds the Post-Closure Plan to be deficient, the person responsible shall correct the deficiencies as specified in writing by the Director within 120 calendar days of the date of the deficiency letter.

6.3 Post-Closure

(a) Post-Closure shall be a minimum period of 25 years following the final landfill closure.

(b) Post-Closure will begin 30 days following submission of the Final Landfill Closure Report, unless otherwise authorized in writing by the Director.

(c) In addition to 6.3(a), Post-Closure shall continue until the following circumstances occur:
- (i) groundwater quality performance standards for each parameter are met within the compliance boundary;
- (ii) subsurface landfill gas concentrations are below explosive limits as described in Table 5.5 at subsurface gas monitoring locations;
- (iii) the leachate constituents are:
  - a. below the upper groundwater quality control limits established for each parameter; and
  - b. parameters not naturally present in groundwater is not detected in three consecutive sampling events; and
- (iv) the accumulated volume of leachate is equal to or less than the previous years accumulated volume of leachate for five consecutive years.

(d) During Post-Closure, the person responsible, at a minimum, shall:
- (i) protect and maintain the integrity of the final cover and surface water drainage systems;
- (ii) make repairs to the cover system as necessary to correct the effects of settling, subsidence, erosion, leachate break-out or other such events within one year of discovery of any problem; and
- (iii) protect, maintain, operate and monitor the following components where they are part of the landfill design:

a. groundwater monitoring system;
b. leachate collection system; and
c. landfill gas control system.

(e) During Post-Closure, the person responsible shall inspect the final cover a minimum of two times per year.

SECTION 7: RECORD KEEPING AND REPORTING

7.1 Reporting of Contraventions

(a) In addition to any other reporting required pursuant to the Act or the regulations, any person carrying out a landfill operation shall immediately report any contravention of these *Standards* to:
- (i) the person responsible; and
- (ii) the Director:
  - a. by telephone at (780) 422-4505; or
  - b. by any other method authorized in writing by the Director.

(b) In addition to any other reporting required pursuant to the Act or the regulations, where a contravention is reported under section 7.1(a), the person responsible shall provide a report to the Director:
- (i) in writing; or
- (ii) by any other method authorized in writing by the Director

within 7 calendar days of the reporting of the contravention, or within any other time period specified in writing by the Director.

(c) The report required in section 7.1(b) shall contain, at a minimum, all of the following:
- (i) a description of the contravention;
- (ii) the date of the contravention;
- (iii) an explanation as to why the contravention occurred;
- (iv) the legal land description of the location of the contravention;
- (v) the name of the registered owner or owners of the parcel of land on which the contravention occurred;
- (vi) a summary of all preventative measures and actions that were taken prior to the contravention;
- (vii) a summary of all measures and actions that were taken to mitigate any effects of the contravention;
- (viii) the measures that will be taken to address any remaining potential effects related to the contravention;
- (ix) the Approval number or Registration number provided by the Director for the landfill site, and the name of the person who held the Approval or Registration number at the time when the contravention occurred;
- (x) the names, addresses, telephone numbers and responsibilities of all persons operating the site at the time that the contravention occurred;
- (xi) the names, addresses and telephone numbers of all persons who had charge, management or control of the site at the time that the contravention occurred;
- (xii) a summary of proposed measures that will prevent future contraventions including a schedule of implementation for those measures;
- (xiii) any information that was maintained or recorded under these *Standards*, as a result of the contravention; and
- (xiv) any other information required by the Director in writing.

7.2 Report Requested by the Director or Representative of the Director

(a) The person responsible shall provide within 7 calendar days, or any other time period specified in writing by the Director, any records, reports, documents, or data required to be created by these *Standards* to the Director, or a representative of the Director, upon request.

7.3 Operating Record

(a) The person responsible for a landfill shall establish and maintain an Operating Record for a landfill until the end of Post-Closure.

(b) The person responsible shall provide the Operating Record to the Director upon a request in writing.

(c) The Operating Record shall contain, at a minimum, all of the following information:
- (i) the Approval or Registration number;
- (ii) as-built records for the landfill showing the location and development of excavations, fill areas, final grades and structural components;
- (iii) annual topographic survey records and plans showing the areas where waste has been disposed in the previous year of operation;
- (iv) the most recent version of the design and operating plan for the landfill;
- (v) records of handing of any wastes accepted at the landfill including the amounts accepted and the disposal locations within the landfill;
- (vi) all Annual Reports for the landfill as described in section 7.5;
- (vii) nuisance records;
- (viii) the Final Landfill Closure Report as described in section 7.6; and
- (ix) all Post-Closure Annual Reports for the landfill as described in section 7.7.

7.4 Tonnage Records

(a) The person responsible shall submit annual tonnage records though Alberta Environment's online Waste Measurement System for wastes accepted by March 31 of the year following the year in which the waste was accepted.

7.5 Annual Report

(a) For each year of the active landfill life, the person responsible shall prepare an Annual Report for the landfill covering the calendar year reported on.

(b) The person responsible shall submit the Annual Report to the Director by March 31 of the year following the year on which the report is based.

(c) The Annual Report shall contain, at a minimum, all of the following information:
- (i) a report from Alberta Environment's online Waste Measurement System including the types and quantities of wastes disposed at the landfill;
- (ii) the deposition location of wastes requiring special handling;

(iii) all of the following environmental monitoring records and their interpretations:
a. groundwater monitoring;
b. leachate monitoring, if applicable;
c. landfill gas monitoring, if applicable;
d. records on the quality and quantity of leachate removed from each landfill cell for treatment or disposal;
e. records on the quality and quantity of leachate removed from each leachate pond for treatment or disposal, if applicable; and
f. records on the quality and quantity of impounded surface water released to the environment;

(iv) a statement of compliance

(v) a site development plan showing the status of landfill operations at the end of the operating year, including but not limited to:
a. contour mapping;
b. the location of active and inactive disposal areas;
c. areas where a final cover has been placed; and
d. the location of cells constructed;

(vi) any remedial action taken;

(vii) any complaints received and the action or actions taken as a result of a complaint; and

(viii) adjustments to financial security or the environmental reserve fund necessary for final landfill closure and post-closure activities.

7.6 Final Landfill Closure Report

(a) The person responsible shall ensure that APEGGA registered professionals with expertise in the subject area prepares components of the Final Landfill Closure Report.

(b) The person responsible shall submit a copy of the Final Landfill Closure Report to the Director within 60 calendar days of completion of the final landfill closure.

(c) The person responsible shall file a copy of the Final Landfill Closure Report in the operating record for the landfill within 60 calendar days of completion of the Final Landfill Closure Report.

(d) The Final Landfill Closure Report shall include, at a minimum, all of the following:

(i) the date of completion of the final landfill closure;

(ii) a statement including supporting evidence that the Final Landfill Closure has been completed in accordance with the Final Landfill Closure Plan;

(iii) a description of any deviations to the Final Landfill Closure Plan and the reasons for the deviations;

(iv) a description of the final cover system and the installation methods and procedures used;

(v) an estimate of the total quantity of waste placed on the site over the active landfill life; and

(vi) a description of how all of the following elements have been, or will be dealt with:
a. the final use of the closed areas;
b. drainage restoration;

c. soil replacement;
d. final cover slopes;
e. erosion control;
f. re-vegetation and conditioning of the site; and
g. subsidence and differential settlement remediation.

7.7 Post-Closure Annual Report

(a) During each year of post-closure, the person responsible shall prepare a Post-Closure Annual Report for the landfill covering the calendar year reported on.

(b) The person responsible shall place the Post-Closure Annual Report in the Operating Record by March 31 of the year following the year on which the report is based.

(c) During the Post-Closure the person responsible shall compile all of the following information, unless otherwise authorized in writing by the Director:
(i) the annual groundwater monitoring report;
(ii) the annual surface water monitoring report;
(iii) a report on the operation of the leachate collection and removal systems, if required in section 5.1(c);
(iv) the leachate monitoring report if required in section 5.1(c);
(v) the annual landfill gas monitoring report if required in section 5.1(d);
(vi) a report on the operation of the landfill gas control systems, if required in section 5.1(d);
(vii) a record of any maintenance and repairs carried out; and
(viii) a report of any remedial or corrective action taken.

7.8 End of Post-Closure Report

(a) The person responsible for the landfill shall notify the Director of the end of the Post-Closure by submitting an End of Post-Closure Report within 60 days following the end of post-closure.

(b) The End of Post-Closure Report shall include, at a minimum, all of the following:
(i) a summary of Post-Closure activities;
(ii) a summary of Post-Closure monitoring data; and
(iii) supporting evidence that the requirements as described in 6.3(c) have been achieved.

APPENDIX A:

Document Submission Checklist

Disclosure Process

Document	Timing of Submission	Reference
Written Disclosure Plan	Prior to application submission.	1.1(a)

Landfill Application (prior to construction)

Document	Timing of Submission	Reference
Landfill Application Form	Upon submission of application and completion of Disclosure Plan	*Approvals and Registrations Procedure Regulation*
Report that the Disclosure Process was carried out as planned.	Upon submission of application and completion of Disclosure Plan	1.2(b)
Detailed Technical Investigation Program Report	Upon submission of application and completion of Technical Investigation Program	1.2(b)
Landfill Design Plan and Specifications	Upon submission of application	1.2(b)
Operations Plan	Upon submission of application	1.2(b)
Financial Security or environmental reserve fund	Upon submission of application	1.2(b)
Landfill Monitoring Plan	Upon submission of application	1.2(b)

Construction Documents

Document	Timing of Submission	Reference
Detailed construction plans and specifications	Prior to each major stage of construction (e.g. new cells and final landfill closure)	3.5(b)
Construction QA Plan and Construction QC Plan	Prior to construction of a new or laterally expanding landfill	3.6(a)
Deviations in Construction QA Plan and Construction QC Plan	These must be authorized prior to implementation.	3.6(c)
Construction Quality Assurance Results	Prior to operations and each major stage after construction	3.6(e)
Report that details any environmental impacts that may result from deviations to the construction QA Plan, construction QC plan, and Landfill Design and Specifications Plan.	Prior to operations and each major stage after construction	3.6(f)

Operations

Document	Timing of Submission	Reference
Certified Operators	Within 30 days of any change	4.1(e)
Contraventions	7 calendar days after the reporting of the contravention to the Director	7.1(b)
Online Tonnage Reports	On or before March 31	7.4 (a)
Annual Reports	On or before March 31	7.5 (b)

Closure and Post-Closure

Document	Timing of Submission	Reference
Detailed Final Landfill Closure Plan	180 days prior to implementation	6.1(a)
Post-Closure Plan	To be submitted as part of the Detailed Final Landfill Closure Plan	6.1(b)
Final Landfill Closure Report	Within 60 days upon completion of Final Landfill Closure Plan	7.6(b)
End of Post-Closure Report	Within 60 days of End of Post-Closure date.	7.8(a)

Province of Alberta

ENVIRONMENTAL PROTECTION AND
ENHANCEMENT ACT

WASTE CONTROL REGULATION

Alberta Regulation 192/1996

With amendments up to and including Alberta Regulation 68/2008

Office Consolidation

Queen's Printer Bookstore
Main Floor, Park Plaza
10611 - 98 Avenue
Edmonton, AB T5K 2P7
Phone: 780-427-4952
Fax: 780-452-0668

E-mail: qp@gov.ab.ca
Shop on-line at www.qp.alberta.ca

Note

All persons making use of this consolidation are reminded that it has no legislative sanction, that amendments have been embodied for convenience of reference only, and that the original Regulations should be consulted for all purposes of interpreting and applying the law.

(Consolidated up to 68/2008)

ALBERTA REGULATION 192/96

Environmental Protection and Enhancement Act

WASTE CONTROL REGULATION

Table of Contents

Definitions

1 In this Regulation,

(a) "Act" means the *Environmental Protection and Enhancement Act*;

(b) "agricultural waste" means waste generated by a farmer;

(c) "biomedical waste" means waste that is generated by

(i) human health care facilities,

(ii) medical research and teaching establishments,

(iii) clinical testing or research laboratories, and

(iv) facilities involved in the production or testing of vaccines,

and contains or may contain pathogenic agents that may cause disease in humans exposed to the waste;

(d) "certified operator" means a person who holds a valid certificate of qualification issued in accordance with the Act and this Regulation;

(e) "Class I compost facility" means a waste management facility where waste, not including hazardous waste, is decomposed through a controlled bio-oxidation process, including a thermophilic phase, that results in a stable humus-like material, but does not include

(i) a residential composter,

(ii) a compost facility that receives only sludge as defined in the *Wastewater and Storm Drainage Regulation* (AR 119/93),

(iii) a Class II compost facility, or

(iv) a manure storage facility as defined in the *Agricultural Operation Practices Act*;

(f) "Class II compost facility" means a waste management facility where only vegetative matter or manure is decomposed through a controlled bio-oxidation process, including a thermophilic phase, that results in a stable humus-like material, but does not include

(i) a residential composter, or

(ii) a manure storage facility as defined in the *Agricultural Operation Practices Act*;

(g) "Class I landfill" means a landfill for the disposal of waste that has

(i) 2 liners of which at least one is a synthetic liner,

(ii) a leachate collection and removal system,

(iii) a leak detection system between the 2 liners, and

(iv) a groundwater monitoring system;

(h), (i) repealed AR 162/2005 s2;

(j) "Class II landfill" means a landfill for the disposal of waste, not including hazardous waste;

(k) "Class III landfill" means a landfill for the disposal of inert waste;

(l) repealed AR 162/2005 s2;

(m) "container" means any portable device which is or was used to store or hold hazardous waste or dangerous goods;

(m.1) "dangerous goods" means a product, substance or organism that is by its nature or by the regulations under the *Transportation of Dangerous Goods Act*, *1992* (Canada) included in any of the classes listed in the Schedule to that Act;

(n) "Director" means the person designated as Director for the purposes of this Regulation;

(o) "dispersible form" means any of the following or a mixture of them:

(i) a liquid;

(ii) a solid that can pass through a 9.5 mm mesh opening;

(iii) a friable solid that can be reduced by grinding in a mortar and pestle to a particle size that can pass through a 9.5 mm mesh opening;

(p) "dispose", when used with respect to waste at a landfill or by deepwell injection, means the intentional placement of waste on or in land as its final resting place;

(q) "empty container" means a container that contains less than 2.5 centimetres of the original contents or less than 3% of the original contents, whichever is the lesser amount;

(r) “farmer” means a person engaged in an agricultural operation as defined in the *Agricultural Operation Practices Act*;

(s) “Federal Regulations” means the *Transportation of Dangerous Goods Regulations* (SOR/2001-286) made under the *Transportation of Dangerous Goods Act, 1992* (Canada);

(t) “hazardous recyclable” means a recyclable that has one or more of the properties described in Schedule 1;

(u) “hazardous recyclable facility” means a facility for storing or processing hazardous recyclables;

(v) “hazardous waste” means waste that has one or more of the properties described in Schedule 1, but does not include those wastes listed in Schedule 2;

(w) “hazardous waste management facility” means a facility for the collection, storage, treatment or disposal of hazardous waste, but does not include an on-site facility;

(w.1) “inert waste” means solid waste that, when disposed of in a landfill or re-used, is not reasonably expected to undergo physical, chemical or biological changes to such an extent as to produce substances that may cause an adverse effect, and includes, but is not limited to, demolition debris, concrete, asphalt, glass, ceramic materials, scrap metal and dry timber or wood that has not been chemically treated;

(x) “internal volume” means the nominal capacity of a container;

(y) “land treatment” means

(i) the controlled application of a substance on the land surface and the incorporation of the substance into the upper soil zone,

(ii) the controlled application of soil containing hydrocarbons on the land surface, with or without incorporation of the soil containing hydrocarbons into the upper soil zone, or

(iii) the controlled application of soil containing hydrocarbons onto a man-made surface or containment system, in such a manner that physical, chemical or biological removal or degradation of the substance or hydrocarbons takes place, but does not include

(iv) the controlled application to land of sludge as defined in the *Wastewater and Storm Drainage Regulation* (AR 119/93), or

(v) the controlled application of a substance to land where that activity constitutes an agricultural operation as defined in the *Agricultural Operation Practices Act*;

(z) "landfill" means a waste management facility at which waste is disposed of by placing it on or in land, but does not include a land treatment facility, a surface impoundment, a salt cavern or a disposal well;

(aa) "liquid", when used with respect to waste, means a waste that has free liquids;

(bb) "oil production site" means the field production facilities for recovering oil or oil sands by drilling or other in-situ recovery methods, including any injection or pumping facilities, and any associated infrastructure, where the site is located within the area illustrated in the guideline entitled *Guide for Oil Production Sites* published by the Department;

(cc) "oilfield waste" means an unwanted substance or mixture of substances that results from the construction, operation, abandonment or reclamation of a facility, well site or pipeline within the meaning of the *Oil and Gas Conservation Act* and the regulations under that Act but does not include an unwanted substance or mixture of substances from such a source that is received for storage, treatment, disposal or recycling at a facility authorized for that activity pursuant to the *Environmental Protection and Enhancement Act*;

(dd) "oilfield waste management facility" means a facility that is approved under the *Oil and Gas Conservation Act* and the regulations under that Act to process, treat, dispose of, store or recycle oilfield waste;

(ee) "on-site facility" means a facility that is used solely to deal with wastes or recyclables generated on property that is owned, rented or leased by the person responsible for the facility;

(ff) “person responsible” for a facility of any kind under this Regulation means

(i) the owner or previous owner of the facility,

(ii) every person who has or has had charge, management or control of the facility or any portion of the facility,

(iii) any successor, assignee, executor, administrator, receiver, receiver-manager or trustee of a person referred to in subclause (i) or (ii), and

(iv) a person who acts as a principal or agent of a person referred to in subclauses (i), (ii) or (iii);

(gg) “recyclable” means a substance or mixture of substances that is intended to be recycled;

(hh) “residential composter” means a composter that

(i) is located at a residence,

(ii) is used to decompose manure, food scraps or vegetative matter resulting from gardening, horticulture, landscaping or land clearing, and

(iii) uses a controlled bio-oxidation process that results in a stable humus-like material;

(hh.1) “soil containing hydrocarbons” means soil that is contaminated with only gasoline, kerosene, jet fuel or diesel fuel, or any combination of them;

(ii) “storage site” means a waste management facility, where waste, other than hazardous waste, is

(i) stored,

(ii) sorted, compacted, shredded, ground or processed, or

(iii) collected and held for removal to another waste management facility;

(jj) “surface impoundment” means a facility that consists of an excavation or diked areas that is formed primarily of earthen material and is used for the storage of waste;

(jj.1) “TEQ” means dioxin toxic equivalent with respect to the following toxicity equivalency factors:

Congener	Toxicity equivalency factor
2,3,7,8-tetrachloro-dibenzo-p-dioxin	1.000
1,2,3,7,8-pentachloro-dibenzo-p-dioxin	0.500
1,2,3,4,7,8-hexachloro-dibenzo-p-dioxin	0.100
1,2,3,6,7,8-hexachloro-dibenzo-p-dioxin	0.100
1,2,3,7,8,9-hexachloro-dibenzo-p-dioxin	0.100
2,3,7,8-tetrachloro-dibenzofuran	0.100
1,2,3,7,8-pentachloro-dibenzofuran	0.050
2,3,4,7,8-pentachloro-dibenzofuran	0.500
1,2,3,4,7,8-hexachloro-dibenzofuran	0.100
1,2,3,6,7,8-hexachloro-dibenzofuran	0.100
1,2,3,7,8,9-hexachloro-dibenzofuran	0.100
2,3,4,6,7,8-hexachloro-dibenzofuran	0.100

(kk) “unrinsed empty container” means an empty container that previously held a hazardous waste

(i) that has not been rinsed 3 times, using for each rinse a clean solvent that is in an amount equal to 10% of the container volume and that is capable of removing the previously contained hazardous waste, or

(ii) that, in the opinion of the Director, has been rinsed or cleaned by a method that does not produce results equal to or better than those produced by the method set out in subclause (i);

(ll) “waste” means any solid or liquid material or product or combination of them that is intended to be treated or disposed of or that is intended to be stored and then treated or disposed of, but does not include recyclables;

(mm) “waste management facility” means a facility for the collection, storage, treatment or disposal of waste.

AR 192/96 s1;272/2003;162/2005

Part 1
Hazardous Waste

Definitions

2 In this Part,

(a) “carrier” means a person who accepts hazardous waste for transport or who transports hazardous waste;

(b) “consignor” means a person who consigns hazardous waste for storage, transport, treatment or disposal;

(c) “receiver” means a person who receives hazardous waste for storage, treatment or disposal.

Personal identification numbers

3 An application for a personal identification number under section 188(2) of the Act must be submitted to the Director in a form and manner acceptable to the Director.

AR 192/96 s3;251/2001

Generator’s duties

3.1 A person who generates hazardous waste or hazardous recyclables shall

(a) characterize, and

(b) classify

the hazardous waste or hazardous recyclables prior to consignment for transportation.

AR 162/2005 s3

Exemption

4 Sections 188 and 191 of the Act do not apply to the consignor or carrier of hazardous waste when the hazardous waste is transported to on-site facilities if the operation is carried out in compliance with the Federal Regulations.

AR 192/96 s4;251/2001;162/2005

Form of manifest

5 The manifest referred to in section 191 of the Act must be in the form for the manifest set out in the Federal Regulations.

AR 192/96 s5;251/2001

Manifest completion

6 The consignor, carrier and receiver of hazardous waste shall complete the applicable parts and copies of the manifest to the satisfaction of the Director.

Generator’s and consignor’s manifest duties

7(1) A consignor, on consigning a hazardous waste, shall

(a) sign all copies of the manifest, and ensure that the carrier certifies receipt of the hazardous waste,

(b) mail the first copy of the manifest to the Director within 2 days, excluding Saturdays and holidays, after consigning the hazardous waste,

(c) retain the 2nd copy for at least 2 years following the consignment, and

(d) deliver the 3rd, 4th, 5th and 6th copies to the carrier.

(2) The consignor of hazardous waste that is shipped out of Alberta shall ensure that a copy of the manifest completed by the out-of-province receiver is given to the Director, the carrier, the consignor and, if the waste is shipped out of Canada, to the Department of Environment (Canada).

Carrier's manifest duties

8 A carrier, on accepting hazardous waste for transportation, shall

(a) sign all copies of the manifest,

(b) return the first and 2nd copies of the manifest to the consignor,

(c) ensure that the 3rd, 4th, 5th and 6th copies accompany the hazardous waste during transportation, and

(d) deliver the 3rd, 4th, 5th and 6th copies to the receiver.

Receiver's manifest duties

9(1) A receiver, on accepting hazardous waste for storage, treatment or disposal, shall

(a) sign the 3rd, 4th, 5th and 6th copies of the manifest and return the 4th copy to the carrier,

(b) mail the 3rd copy to the Director within 2 days, excluding Saturdays and holidays, after receiving the hazardous waste,

(c) retain the 5th copy for at least 2 years after receiving the hazardous waste, and

(d) mail the 6th copy to the consignor within 2 days, excluding Saturdays and holidays, after accepting the hazardous waste.

(2) The receiver of hazardous waste generated outside of Alberta shall ensure that the Director and, if the waste was generated outside of Canada, the Department of Environment (Canada), receive a copy of the manifest.

(3) The consignor shall retain the 6th copy of the manifest referred to in subsection (1)(d) for at least 2 years following its receipt from the receiver.

Multiple carriers' manifests

10(1) If multiple carriers are used for a consignment of hazardous waste,

(a) the consignor shall complete a separate manifest and comply with section 7 with respect to each carrier;

(b) each carrier, on accepting hazardous waste for transportation, shall

(i) sign one manifest form and return the first and 2nd copies of that form to the consignor, and

(ii) deliver the remaining copies and remaining manifest forms to the receiver or next carrier;

(c) the receiver shall, on accepting the hazardous waste for storage, treatment or disposal,

(i) sign the 3rd, 4th, 5th and 6th copies of all manifest forms,

(ii) cross-reference all of the manifests,

(iii) mail the 3rd copy of each manifest form to the Director within 2 days, excluding Saturdays and holidays, after accepting the hazardous waste,

(iv) mail the 4th copy of the appropriate manifest to each carrier,

(v) retain the 5th copy of each manifest for at least 2 years after receiving the hazardous waste, and

(vi) mail the 6th copy to the consignor within 2 days, excluding Saturdays and holidays, after accepting the hazardous waste.

(2) The consignor shall retain the 6th copy of the manifest referred to in subsection (1)(c)(vi) for at least 2 years following its receipt from the receiver.

Storing hazardous waste

11(1) A person who stores hazardous waste shall store it in an amount and in a manner so that

(a) it will not cause an adverse effect,

(b) any leakage is contained and prevented from entering into the remainder of the hazardous waste management facility and places beyond, including sewers and the ground underneath the site,

(c) at least secondary containment is provided for liquid hazardous waste, and there are no openings in the secondary containment system that provide a direct connection to the area surrounding the system,

(d) the hazardous waste is adequately labelled, stating the identity of the hazardous waste that is being stored,

(e) incompatible hazardous wastes are stored in such a manner that there will be no contact between them, even in the event of a release, and

(f) routine inspections of the site can be performed.

(2) A person who stores hazardous waste shall ensure that the hazardous waste is stored in a place that

(a) is secure from entry by unauthorized persons,

(b) is prominently identified as a hazardous waste management facility where hazardous waste is being stored,

(c) is equipped with suitable equipment to handle emergency situations,

(d) is provided with operators trained to respond to emergency situations specific to the hazardous waste stored, and

(e) is designed and maintained so that surface run-off water cannot enter the secondary containment system.

(3) Subsection (2)(b) applies only to a hazardous waste management facility whose only function is the storage of hazardous waste, and does not apply to a hazardous waste management facility that is located in or is part of a manufacturing, processing or other operation.

Storage of PCBs

12(1) In this section,

(a) “PCB” means any chlorobiphenyl that has a molecular formula of $C_{12}H_{10-n}Cl_n$, in which “n” is greater than 2;

(b) “PCB equipment” means any equipment, machinery or similar manufactured item, including but not limited to a capacitor or an electrical transformer, that contains a PCB liquid, PCB solid or PCB substance;

(c) “PCB liquid” means a liquid that contains more than 50 mg of PCB per kilogram of the liquid;

(d) “PCB solid” means a solid that contains more than 50 mg of PCB per kilogram of the solid;

(e) “PCB substance” means a substance, other than a PCB liquid or a PCB solid, that contains more than 50 mg of PCB per kilogram of the substance;

(f) “PCB waste” means any PCB liquid, PCB solid, PCB substance or PCB equipment that is stored as hazardous waste.

(2) In determining the quantity, volume or weight of PCB waste for the purposes of subsection (3), the total amounts stored in or around one site that is under the responsibility of the same person shall be added together.

(3) Subject to the terms and conditions of an approval, a person who stores PCB waste in the following amounts shall advise the Director in writing in accordance with subsection (4) and keep and provide records in accordance with subsections (5) and (6):

(a) PCB liquids in an amount of 100 L or more;

(b) PCB solids or PCB substances in an amount of 100 kg or more;

(c) PCB liquids, PCB solids or PCB substances or a combination of them, in an amount less than that referred to in clause (a) or (b), that contain 1 kg or more of PCB;

(d) PCB equipment that contains an amount of PCB, PCB liquids, PCB solids or PCB substances referred to in clauses (a) to (c).

(4) The person who stores PCB wastes

(a) must advise the Director in writing no less than 30 days after that person first stores PCB waste in amounts referred to in subsection (3), and

(b) must disclose the name of the person, the location of where the PCB waste is being stored and a description and inventory of the PCB waste that is stored at the site.

(5) The records referred to in subsection (3) must contain the following information:

(a) with respect to each item of PCB waste received at the site,

(i) the date of receipt of the PCB waste,

(ii) the quantity of PCB waste received,

(iii) a description of the PCB waste, including, where applicable, the nameplate description, the serial number and the PCB registration number,

(iv) the condition of the PCB waste,

(v) the source of the PCB waste,

(vi) the name of the carrier of the PCB waste, and

(vii) the name of the individual who received the PCB waste;

(b) with respect to each item of PCB waste removed from the site,

(i) the date of removal of the PCB waste,

(ii) a description of the PCB waste, including, where applicable, the nameplate description,

(iii) the condition of the PCB waste,

(iv) the name of the carrier of the PCB waste,

(v) the destination of the PCB waste, and

(vi) the name of the individual authorizing the removal of the PCB waste;

(c) the results of any inspections conducted and any action taken as a result of those inspections.

(6) A person who is required to keep the records referred to in subsection (3) shall provide a copy of the records to the Director on January 1 and July 1 of each year containing the required information for the preceding 6-month period.

Landfills

13(1) No person shall dispose of hazardous waste into a landfill.

(2) Despite subsection (1), the following solid hazardous waste may be disposed of in a Class I landfill:

(a) solid hazardous waste containing one or more halogenated organic compounds in a combined concentration less than 1000 milligrams per kilogram, of which no more than 50 milligrams per kilogram is polychlorinated biphenyl;

(b) solid hazardous waste containing one or more of the following compounds in a combined concentration less than 1000 milligrams per kilogram:

(i) acetone;

(ii) benzene;

(iii) n-butyl alcohol;

(iv) carbon disulphide;

(v) cresol and cresylic acid;

(vi) cyclohexanone;

(vii) ethyl acetate;

(viii) ethyl benzene;

(ix) ethyl ether;

(x) isobutanol;

(xi) methanol;

(xii) methyl ethyl ketone;

(xiii) nitrobenzene;

(xiv) 2-nitropropane;

(xv) pyridine;

(xvi) toluene;

(xvii) xylene;

(c) solid hazardous waste that ignites, reacts or corrodes according to a test method set out in the Alberta User Guide for Waste Managers, 1996, published by the Department, as amended from time to time, that describes ignitable, reactive or corrosive hazardous waste, provided that those substances or mixtures of substances are not liable to ignite, propagate combustion, react or corrode under the conditions of disposal;

(d) solid hazardous waste producing a waste extract in which the concentration of each of the following substances, if present, is less than the following value:

(i)	arsenic:	500 mg/L;
(ii)	beryllium:	100 mg/L;
(iii)	cadmium:	100 mg/L;
(iv)	chromium (VI):	500 mg/L;
(v)	lead:	500 mg/L;
(vi)	mercury:	20 mg/L;
(vii)	nickel:	500 mg/L;
(viii)	selenium:	200 mg/L;
(ix)	silver:	100 mg/L;
(x)	thallium:	200 mg/L;

(e) solid hazardous waste with a pH greater than 12.5.

(3), **(4)** Repealed AR 162/2005 s5.

AR 192/96 s13;162/2005

Codes of practice

14(1) The Codes of Practice listed in Column B of Schedule 4 to this Regulation are adopted pursuant to section 38 of the Act and form part of this Regulation.

(2) A person who, pursuant to a registration, carries on any activity referred to in Column A of Schedule 4 to this Regulation shall comply with the corresponding Code of Practice referred to in Column B of that Schedule in the carrying on of that activity.

(3) Notwithstanding subsection (2), where the Director issues an approval in respect of the activity pursuant to section 6(3) of the *Activities Designation Regulation* (AR 276/2003), the approval holder

(a) is not required to comply with the Codes of Practice in Schedule 4, and

(b) shall comply with the terms and conditions of the approval.

AR 192/96 s14;162/2005

Importation

15(1) No person shall knowingly import any hazardous waste into Alberta for the purpose of storage for a period exceeding 30 days without first obtaining written authorization from the Minister.

(2) No person shall knowingly import hazardous waste into Alberta for the purpose of disposal.

(3) Subsection (2) does not apply to the disposal of residues resulting from the treatment of imported hazardous waste.

Dilution or division

16(1) No person shall mix hazardous waste with any solid or liquid for the primary purpose of dilution or of avoiding the requirements of this Regulation.

(2) No person shall divide a hazardous waste for the purpose of avoiding the requirements of this Regulation.

Part 1.1
Hazardous Substances

Hazardous substances

16.1 Any chemical or combination of chemicals that was used in or arose from the production of methamphetamine is designated as a hazardous substance.

AR 87/2007 s2

Part 2
Hazardous Recyclables

Application

17(1) Section 169 of the Act does not apply to a person consigning for shipment less than 205 litres, or less than 205 kilograms, of hazardous recyclables.

(2) Section 169(b) of the Act does not apply to a hazardous recyclable that is being consigned for shipment to an oilfield waste management facility.

AR 192/96 s17;251/2001;272/2003

Storage

18(1) A person who stores a hazardous recyclable shall store it in an amount and in a manner so that

(a) it will not cause an adverse effect,

(b) any leakage is contained and prevented from entering into the remainder of the hazardous recyclable facility and places beyond, including sewers and the ground underneath the site,

(c) at least secondary containment is provided for liquid hazardous recyclables, and there are no openings in the secondary containment system that provide a direct connection to the area surrounding the system,

(d) the hazardous recyclable facility is adequately labelled, stating the identity of the hazardous recyclable that is being stored,

(e) incompatible hazardous recyclables are stored in such a manner that there will be no contact between them, even in the event of a release, and

(f) routine inspections of the hazardous recyclable facility can be performed.

(2) A person who stores hazardous recyclables shall ensure that the hazardous recyclables are stored in a place that

(a) is secure from entry by unauthorized persons,

(b) is prominently identified as a hazardous recyclable facility where hazardous recyclables are stored,

(c) is equipped with suitable equipment to handle emergency situations,

(d) is provided with operators trained to respond to emergency situations specific to the hazardous recyclables stored, and

(e) is designed and maintained so that surface run-off water cannot enter the secondary containment system.

(3) Subsection (2)(b) applies only to a hazardous recyclable facility whose only function is the storage of hazardous recyclables, and does not apply to a site that is located in or is part of a manufacturing, processing or other operation.

Recycle docket

19 The recycle docket referred to in section 169 of the Act must

(a) meet the requirements for the shipping document for dangerous goods specified in the Federal Regulations, and

(b) have an attachment showing

(i) the name of the consignor of the hazardous recyclable in the shipment,

(ii) the location from which the hazardous recyclable in the shipment originated,

(iii) the amount of hazardous recyclable in the shipment, and

(iv) the signature of an authorized representative for the consignor of the hazardous recyclable in the shipment.

AR 192/96 s19;251/2001;162/2005

Information

20 The person responsible for a hazardous recyclable facility shall

(a) keep the following information for at least 2 years from the last day of the year in which the information was produced:

(i) copies of all recycle dockets for hazardous recyclables received at the facility;

(ii) a record of releases of substances at the facility;

(iii) calibration and maintenance records of monitoring equipment;

(iv) the results of all physical inventories of hazardous recyclables at the facility;

(v) any other information prescribed in a notice in writing by the Director;

(b) make the information available to the Director on the Director's request in writing.

Importation

21 No person shall import hazardous recyclables into Alberta without first obtaining written authorization from the Minister.

Part 3
Non-hazardous Waste

Application

22 This Part applies to the management of waste, other than hazardous waste.

Prohibition

23(1) No person shall deposit waste for disposal in any place other than a waste management facility authorized in accordance with the Act and this Regulation.

(2) Subsection (1) does not apply to

(a) the disposal of agricultural waste by a farmer on his own land where the waste is produced on his farm,

(b) the depositing of earth, or

(c) inert waste used for reclamation.

AR 192/96 s23;162/2005

General

24(1) The person responsible for a Class II or Class III landfill shall ensure that the landfill is sited, designed, constructed, operated and reclaimed so as to meet as a minimum

(a) the requirements specified in this Regulation, and

(b) the standards and requirements set out in the *Code of Practice for Landfills.*

(2) The person responsible for a Class I or Class II compost facility shall ensure that the compost facility is sited, designed, constructed, operated and reclaimed so as to meet as a minimum

(a) the requirements specified in this Regulation, and

(b) the standards and requirements set out in the Code of Practice for Compost Facilities.

(3) Subsection (1) does not apply to a waste management facility that is operating at the time of publication of the Code of Practice for Landfills until such time as the Director provides written notice to the person responsible for the waste management facility that the Code of Practice or part of the Code of Practice is to apply.

(4) Subsection (2) does not apply to a waste management facility that is operating at the time of publication of the Code of Practice for Compost Facilities until such time as the Director provides written notice to the person responsible for the waste management facility that the Code of Practice or part of the Code of Practice is to apply.

(5) Where the waste management facility is not required to comply with subsection (1) or (2) because of subsections (3) and (4), the person responsible for the waste management facility must comply with the conditions specified in the approval and permit issued under the *Waste Management Regulation* (Alta. Reg. 250/85) before its repeal or the permit issued by the Provincial Board of Health which is deemed a permit under section 14 of that Regulation.

(6) A person responsible who receives a notice in writing from the Director under subsection (3) or (4) shall comply with the notice in accordance with the terms specified in the notice.

(7) The notice referred to in subsections (3) and (4) must specify that all or part of the Code of Practice is to apply and if only part, which part, and specify the date on which all or part of the Code of Practice is to apply.

Certified operators

25(1) The person responsible for a Class II or Class III landfill or Class I or Class II compost facility shall ensure that the facility is supervised by a certified operator during its hours of operation.

(2) A certified operator may have one or more assistants who may supervise the facility in his temporary absence.

(3) The person responsible for a Class II or Class III landfill or Class I or Class II compost facility shall notify the Director in writing of the names of all certified operators and their assistants and any change in any of the certified operators or their assistants within 30 days of the change.

(4) Subsections (1), (2) and (3) do not apply until September 1, 2001.

Burning

26 No person shall burn or permit burning at a waste management facility unless

(a) the burning is conducted in accordance with the *Substance Release Regulation* (AR 124/93),

(b) the burning is done in an area that is

(i) constructed with a fire break consisting of barren mineral soil,

(ii) located so that is separated from disposal operations, storage compounds and buildings, and

(iii) supervised at the time of burning,

and

(c) the person responsible for the waste management facility has notified

(i) the local authorities,

(ii) all adjoining property owners,

(iii) the Director, and

(iv) the local fire department

at least 7 days prior to the date of the burning, informing them of the proposed burning and the date on which the proposed burning is to take place.

AR 192/96 s26;162/2005

Part 4
Security

Security required

27(1) Where an approval or a registration is required in respect of

(a) a waste management facility, excluding an on-site facility, or

(b) a hazardous recyclable facility,

the Director shall require the applicant for the approval or registration to provide security before operation or reclamation of the facility commences.

(2) Subsection (1) does not apply where the applicant for the approval or registration is the Crown or a local authority.

Amount of security

28(1) Security shall be in an amount determined by the Director to be sufficient to ensure completion of conservation and reclamation as required by the Act and the Regulations under the Act based on

(a) the estimated costs of conservation and reclamation submitted by the applicant, approval holder or registration holder,

(b) the nature, complexity and extent of the facility's operations,

(c) the probable difficulty of conservation and reclamation, giving consideration to such factors as topography, soils, geology, hydrology and revegetation, and

(d) any other factors the Director considers to be relevant.

(2) Within 30 days of any changes to the most recent conservation and reclamation plan submitted under the *Approvals Procedure Regulation* (Alta. Reg. 113/93), the approval holder or registration holder shall recalculate the applicable cost estimates and submit adjusted cost estimates to the Director.

Adjustment of security

29(1) The Director may increase or decrease the amount of security that is to be provided where

(a) the cost of future conservation and reclamation changes,

(b) the extent of the operation of the facility is increased or reduced,

(c) the land or any portion of it is conserved and reclaimed,

(d) the conservation and reclamation plan in the approval or registration is changed,

(e) the approval holder or registration holder is conducting on the site of the facility more than one activity for which security is required, or

(f) any other circumstances exist that may increase or decrease the estimated cost of conservation and reclamation.

(2) The Director may specify times or set a schedule for re-evaluating and adjusting the security provided.

(3) The Director shall notify an approval holder or registration holder of any proposed adjustment to the amount of the security.

Form of security

30 Security must be in one or more of the following forms as required by the Director:

(a) cash;

(b) cheques and other similar negotiable instruments payable to the Minister of Finance and Enterprise;

(c) Government guaranteed bonds, debentures, term deposits, certificates of deposit, trust certificates or investment certificates assigned to the Minister of Finance and Enterprise;

(d) irrevocable letters of credit, irrevocable letters of guarantee, performance bonds or surety bonds in a form acceptable to the Director;

(e) any other form that is acceptable to the Director.

AR 192/96 s30;27/2002;68/2008

Return of security

31(1) Where a reclamation or remediation certificate is issued in respect of all or part of a facility, the Minister may return or direct the return of all or part of the security provided, as the case may be.

(2) Notwithstanding subsection (1), if conservation and reclamation has been partially completed as required under the Act and the Regulations, the Minister may, on application by the approval holder or registration holder, return or direct the return of a part of the security, as determined by the Minister.

(3) Where the Director decreases the amount of security under section 29 the Minister shall return or direct the return of part of the security provided.

(4) The Minister shall return or direct the return of all security provided where an application for an approval or registration is submitted but no approval or registration is issued.

Retention of security

32 In a case to which section 15 of the *Conservation and Reclamation Regulation* (Alta. Reg. 115/93) applies, the Minister may, notwithstanding that a reclamation certificate has been issued, retain all or part of the security until the expiration of the applicable period referred to in that section.

Forfeiture of security

33(1) The Minister may order that all or part of the security provided by the approval holder or registration holder be forfeited if

(a) the approval holder or registration holder fails to commence and complete conservation and reclamation in a timely fashion,

(b) the approval holder fails to meet conservation and reclamation standards specified in an approval,

(c) the registration holder fails to meet conservation and reclamation standards specified in the applicable Code of Practice,

(d) the approval holder or registration holder fails to renew existing security before its expiry date,

(e) the approval holder or registration holder fails to adjust the amount of security for inflation or to account for changes in the conservation and reclamation plan,

(f) the approval holder or registration holder has not complied with an environmental protection order or enforcement order issued by the Director, or

(g) a receiver, receiver-manager or trustee has been appointed in respect of the operations of the approval holder or registration holder,

and as a result, conservation and reclamation of the facility as required by the Act and the Regulations would, in the Minister's opinion, be prevented or interfered with.

(2) Where the Minister orders security to be forfeited under subsection (1), the Minister shall

(a) give written notice of the decision to the approval holder and registration holder, and

(b) direct the Minister of Finance and Enterprise to transfer the security from the Environmental Protection Security Fund to the Environmental Protection and Enhancement Fund.

(3) On the request of the Minister the Minister of Finance and Enterprise shall pay to the Minister from the Environmental Protection and Enhancement Fund as much of the security transferred under subsection (2) as the Minister considers is necessary to carry out the conservation and reclamation in accordance with the Act, the Regulations and the approval, and the Minister shall use the security for that purpose.

(4) Subsection (3) applies despite the fact that the approval holder or registration holder may not have actually received the notice referred to in subsection (2)(a).

(5) Where the amount of the forfeited security exceeds the amount required for conservation and reclamation, the Minister of Finance and Enterprise shall on the direction of the Minister pay the excess amount to the approval holder or registration holder.

(6) Where the amount of the forfeited security is insufficient to pay for the cost of conservation and reclamation, the approval holder or registration holder remains liable for the balance.

AR 192/96 s33;27/2002;68/2008

Part 5
Miscellaneous

Expanded definition of waste

34 A motor vehicle that is not registered and is inoperative is waste for the purposes of the sections referred to in section 168(k) of the Act.

AR 192/96 s34;251/2001

Form of order

35(1) An enforcement order issued under section 211 of the Act must be in Form 1 in Schedule 3.

(2) An environmental protection order issued under section 183 of the Act must be in Form 2 in Schedule 3.

AR 192/96 s35;251/2001

Review of EPO

36(1) A committee appointed under section 186(3) of the Act must consist of at least 3 members.

(2) Where a request for review under section 186(1) of the Act is made to a local authority, the following applies:

(a) the committee shall give written notice to the inspector, investigator or Director who issued the environmental protection order that a request for review has been made;

(b) the committee may request from the inspector, investigator or Director any information that it considers necessary;

(c) no action may be taken under the Act with respect to the enforcement of the order during the time that the decision of the committee on the review is pending;

(d) the committee may conduct any investigation that it considers necessary to properly review the order and shall complete its review within 30 days after receipt of the request for the review or within any further extended period under subsection (3);

(e) the committee shall issue a written decision on the review and shall give a copy of the decision to the inspector, investigator or Director who issued the order and to the person to whom the order was directed, all within 45 days after receipt of the request for the review or within any extended period under subsection (3).

(3) Where the committee considers that extenuating circumstances exist that make it impractical for the committee to complete its duties within the period of time imposed under subsection (2)(d) or (e) it may extend that period of time.

(4) Where the decision of the committee confirms or varies the environmental protection order, the decision shall prescribe the time within which the order must be complied with, which shall not be more than 60 days after the date the person to whom the order was directed receives a copy of the decision.

AR 192/96 s36;251/2001

Part 6
General

37 Repealed AR 230/2005 s2.

Standards for compost facilities

38 All compost facilities shall be constructed and operated so that

(a) the generation of odours is minimized,

(b) run-on and run-off water is controlled so that surface water and groundwater are not contaminated, and

(c) animals and vectors of disease are controlled.

AR 192/96 s38;162/2005

Records

39(1) The Director may, by notice in writing to the person responsible for a waste management facility, including but not limited to a hazardous waste management facility or a hazardous recycling facility, require that person to keep records in the form and manner and containing the information specified by the Director in the notice.

(2) The person shall keep information in a record referred to in subsection (1) for at least 5 years after the information was entered in the record.

(3) The person shall provide the records referred to in subsection (1) to the Director on demand.

Plans and reports

40 The Director may, by notice in writing directed to the person responsible for a waste management facility, including but not limited to a hazardous waste management facility or a hazardous recycling facility, require that person to submit plans and reports respecting the construction, operation or reclamation of the facility.

Waste collection containers

41(1) The Minister may by notice in writing given to a person require that person to provide waste collection containers in the numbers, at the locations and within the time specified in the notice.

(2) A person who receives a notice under subsection (1) shall comply with it in accordance with its terms.

Offenses

42 A person who contravenes sections 3.1, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 18, 19, 20, 21, 23, 24, 26, 37, 39, 40 or 41 is guilty of an offence and is liable

(a) in the case of an individual, to a fine of not more than $50 000, or

(b) in the case of a corporation, to a fine of not more than $500 000.

AR 192/96 s42;162/2005

Due diligence

43 No person shall be convicted of an offence referred to in section 42 if that person establishes on a balance of probabilities that he took all reasonable steps to prevent its commission.

AR 192/96 s43;87/2007

Transition

44 A person who on August 31, 1996 was registered under section 13.1 of the *Waste Control Regulation* (Alta. Reg. 129/93) is deemed to have complied with section 12 of this Regulation with respect to PCBs stored before September 1, 1996.

Repeal

45 The following Regulations are repealed:

(a) the *Waste Control Regulation* (Alta. Reg. 129/93);

(b) the *Waste Management Regulation* (Alta. Reg. 250/85).

Coming into force

46 This Regulation comes into force on September 1, 1996.

Schedule 1

Properties of hazardous waste

1 Waste is hazardous and a recyclable is a hazardous recyclable waste if, when tested according to a test method set out in the Alberta User Guide for Waste Managers, 1996, published by the Department, as amended from time to time, or a test method authorized in writing by the Director,

(a) it has a flash point of less than or equal to 60.5ºC,

(b) it ignites and propagates combustion in a test sample,

(c) it contributes oxygen for combustion at a rate that is equal to or greater than that provided by ammonium persulphate, potassium perchlorate or potassium bromate,

(d) it is toxic because it

(i) has a rat oral toxicity LD_{50} not greater than 200 mg/kg, if a solid, or 500 mg/kg, if a liquid,

(ii) has a dermal toxicity LD_{50} not greater than 1000 mg/kg, or

(iii) has an inhalation toxicity LC_{50} not greater than 10,000 mg/m^3 at normal atmospheric pressure,

(e) it has a pH value less than 2.0 or greater than 12.5,

(f) it contains polychlorinated biphenyls at a concentration equal to or greater than 50 mg/kg, or

(g) it is a toxic leachate because it is in a dispersible form and

(i) it contains at a concentration of 100 mg/L or higher of any substance listed in Table 1 of the Schedule to the Alberta User Guide for Waste Managers, published by the Department, as amended from time to time,

(ii) its leachate contains any substance listed in Table 2 of the Schedule to the Alberta User Guide for Waste Managers, published by the Department, as amended from time to time in excess of the concentrations listed in that Table, or

(iii) it contains any of the following substances in a concentration greater than 0.001 mg/L:

hexachloro-dibenzo-p-dioxins
pentachloro-dibenzo-p-dioxins
tetrachloro-dibenzo-p-dioxins
hexachloro-dibenzofurans
pentachloro-dibenzofurans
tetrachloro-dibenzofurans.

Hazardous waste

2 The following waste is hazardous waste:

(a) waste types listed in Table 3 of the Schedule to the Alberta User Guide for Waste Managers, published by the Department, as amended from time to time;

(b) commercial products or off-specification products listed in Part A of Table 4 of the Schedule to the Alberta User Guide for Waste Managers, published by the Department, as amended from time to time;

(c) a container, other than an empty container, that has an internal volume greater than 5 litres and contains a substance listed in Part A of Table 4 of the Schedule to the Alberta User Guide for Waste Managers, published by the Department, as amended from time to time;

(d) a number of containers, other than empty containers, that have an aggregate internal volume greater than 5 litres and contain a substance listed in Part A of Table 4 of the Schedule to the Alberta User Guide for Waste Managers, published by the Department, as amended from time to time;

(e) commercial products or off-specification products listed in Part B of Table 4 of the Schedule to the Alberta User Guide for Waste Managers, published by the Department, as amended from time to time;

(f) an unrinsed empty container that has an internal volume greater than 5 litres and contained a substance listed in Part B of Table 4 of the Schedule to the Alberta User Guide for Waste Managers, published by the Department, as amended from time to time; or

(g) a number of unrinsed empty containers that have an aggregate internal volume greater than 5 litres and contained a substance listed in Part B of Table 4 of the Schedule to the Alberta User Guide for Waste Managers, published by the Department, as amended from time to time.

Hazardous recyclables

3 Substances or mixtures of substances specified in section 2 of this Schedule as being hazardous waste are, if they are intended to be recycled, hazardous recyclables.

AR 192/96 Sched.1;162/2005

Schedule 2

Not hazardous waste

1 The following are not hazardous waste for the purposes of the Act and this Regulation:

(a) household waste in the possession of the householder or while unsegregated in a municipal waste management system;

(b) agricultural waste;

(c) domestic sewage;

(d) waste regulated under the *Nuclear Safety and Control Act* (Canada);

(e) wastes resulting from emergency spill clean-ups, if the Director or an investigator has authorized the handling of the clean-up debris;

(f) biomedical waste;

(g) waste described in Schedule 1, other than those substances listed in Table 4, Part B of the Schedule to the Alberta Users Guide for Waste Managers published by the Department, as amended from time to time, that is produced in an amount less than 5 kilograms per month if a solid or 5 litres per month if a liquid and the total quantity accumulated does not exceed 5 kilograms or 5 litres at any one time;

(h) waste resulting from the treatment of hazardous waste where the treatment employs a method, technique or process that represents acceptable industry practice.

Not hazardous recyclables

2 The wastes specified in section 1 of this Schedule as not being hazardous waste are also not hazardous recyclables.

AR 192/96 Sched.2;162/2005

Schedule 3

Form 1

Enforcement Order

(Environmental Protection and Enhancement Act, section 211)

To____________________(name)__________________________
of_____________________(address)_________________________

Take notice that:

I have reason to believe that you have contravened section (indicate appropriate section number 178, 179, 180 or 182) of the *Environmental Protection and Enhancement Act*.

Pursuant to section 211 of the *Environmental Protection and Enhancement Act*, you are hereby ordered

(a) to pick up and remove all waste unlawfully disposed of within ____ days, and in particular to take the following action:

____________________(list particulars if necessary)___________

(b) to refrain from any further or continuing unlawful disposal of waste.

Contravention of this order may result in one or more of the following actions being taken against you:

- you might be prosecuted under the Act in respect of the contravention;
- an application might be made to the Court of Queen's Bench for an order that you comply with the enforcement order;
- the enforcement order might be carried out by the Director and the costs are recoverable from you.

Dated this _______________ day of ________________, 20___.

____
Director/Investigator

Form 2

Environmental Protection Order

(Environmental Protection and Enhancement Act, Section 183)

To_____________________(name)_________________________
of_____________________(address)_______________________

Take notice that:

The property located at ____(address or legal description)____ is considered to be unsightly by reason of the existence of waste on it.

You are hereby ordered, pursuant to section 183 of the *Environmental Protection and Enhancement Act*, to clean up the unsightly property by doing the following: ____________________ on or before ____

Contravention of this order may result in one or more of the following actions being taken against you:

- you might be prosecuted under the Act in respect of the contravention;
- an application might be made to the Court of Queen's Bench for an order that you comply with the environmental protection order;

- the environmental protection order might be carried out by the local authority or the Director and the costs are recoverable from you.

This environmental protection order may be reviewed by a committee appointed by the (name of local authority or Minister of Municipal Affairs) if a written request for review is made within 21 days of the date of receipt of this order to (name and address of local authority or Minister of Municipal Affairs) .

Dated this ________ day of ________, 20__.

____
Director/Investigator

AR 192/96 Sched. 3;251/2001;35/2007;68/2008

Schedule 4

COLUMN A	COLUMN B
The construction, operation or reclamation of a small incinerator as set out in clause (b) of Schedule 2, Division 1 of the *Activities Designation Regulation* (AR 276/2003).	Code of Practice for Small Incinerators, 2005, published by the Department.
The construction, operation or reclamation of a fixed facility for the land treatment of soil containing hydrocarbons as set out in clause (f) of Schedule 2, Division 1 of the *Activities Designation Regulation* (AR 276/2003).	Code of Practice for Land Treatment of Soil Containing Hydrocarbons, 2005, published by the Department.
The construction, operation or reclamation of a facility for energy recovery by the production of alternate fuel or the burning of waste as fuel, as set out in clause (d) of Schedule 2, Division 1 of the *Activities Designation Regulation* (AR 276/2003).	Code of Practice for Energy Recovery, 2005, published by the Department.

AR 192/96 Sched.4;162/2005

CHEMICAL CHARACTERIZATION OF
LEACHATE FROM NORTHWEST
TERRITORIES MUNICIPAL DUMPS

<u>COPPERMINE MUNICIPAL DUMP</u>

M. M. DILLON LIMITED
CONSULTING ENGINEERS
AND PLANNERS

MARCH 1991
N 3360-00

DILLON
Consulting Engineers • Planners
Environmental Scientists

OUR FILE N 3360-00
YOUR FILE

21 March 1991

Indian, Northern Affairs Canada
Water Resources Division
Regulatory Approvals Section
P.O. Box 1500
YELLOWKNIFE, N.W.T.
X1A 2C9

Attention: Mr. Greg Cook

Chemical Characterization of Leachate from the Coppermine, Northwest Territories Municipal Dump

Dear Sirs:

We are pleased to submit the final report for the Chemical Characterization of the Coppermine, Northwest Territories Municipal Dump. This report provides the basis for leachate characterization and leachate impact on the surrounding environment.

We appreciate the opportunity to serve as your consultants.

Yours truly,

Chris Robinson, P. Eng.
Project Manager

DMH:kc

Encl.

M.M. DILLON LIMITED — 2ND FLOOR, URBANIA BUILDING, 5102 - 51 ST. STREET,
YELLOWKNIFE, N.W.T., CANADA X1A 1S7 MAIL: BOX 55, YELLOWKNIFE, N.W.T. X1A 2N1
TELEPHONE (403) 920-4555
FAX (403) 873-3328

EXECUTIVE SUMMARY

Indian and Northern Affairs Canada, Water Resources Division and the Government of the Northwest Territories, Department of Renewable Resources have requested Dillon to study the Coppermine Landfill to determine the extent of leachate generation and the effect on the surrounding environment.

Coppermine is a small northern community, with approximately 600 t/year of waste largely comprised of paper products and food wastes. As well, approximately 50 m^3/day of liquid sewage was deposited at the landfill site. The landfill is located approximately 1 km southwest of Coppermine. It consists of a mound of fill and waste deposited on the slope of a hill. The landfill was shut down at the end of August, 1990 and a new waste disposal site was developed approximately 2 km west of the site under investigation.

A landfill investigation took place between 21 August and 23 August 1990. The investigation consisted of three phases: an initial reconnaissance of the site, the installation of five monitoring wells, and the monitoring of these wells and the collection and analyses of the ground water samples.

Investigations of the ground water in the vicinity of the landfill site indicated a degradation of the ground water quality downgradient of the landfill site by both leachate originating in the landfill site and by the dumped liquid sewage. The local ground water regime appears to be highly variable and dependent upon the seasonal variations in the active zone above the permafrost. An area downhill from the landfill appears to act as an impoundment area where ground water and surface runoff are temporarily impounded prior to a natural release into the Coronation Gulf.

The ground water downgradient of the landfill contains large concentrations of salts and micro-organisms. This is due to both the leachate produced by the landfill site and by the presence of the liquid sewage. There is an apparent attenuation of the chemical and biological characteristics of the ground water as it moves toward Coronation Gulf. It is estimated that approximately 900 cubic metres of leachate per year is generated by the landfill. The liquid contribution is from seasonal ground water infiltration and surface water infiltration. Liquid from sewage dumping operations contributed to the majority of contaminated liquid leaving the site.

Leachate production from the landfill can be expected to continue for a number of years into the future, but probably at declining quantities, since liquid waste disposal has been discontinued, with landfill closure. Leachate generation will be limited to ground water migration and some surface water infiltration into the fill mass.

The potential environmental effects of the migration of the contaminated ground water into the Coronation Gulf are considered minor due to large capacity of the ocean to dilute the contaminated water.

Further work may be desirable to monitor the downgradient ground water conditions at this closed landfill and to further outline the potential environmental effects of the contaminated ground water draining into the Coronation Gulf. With closure of the site, it is speculated that with a metre of soil cover, the waste mound will freeze and become part of the permafrost zone. Ground water samples should be recovered once a year from the piezometers installed during this study. This monitoring could determine if the waste is entombed and no longer impacting on the surrounding environment.

TABLE OF CONTENTS

Page No.

LIST OF TABLES

LIST OF FIGURES

COPPERMINE MUNICIPAL LANDFILL

1.0 INTRODUCTION

Indian and Northern Affairs Canada, Water Resources Division and the Government of the Northwest Territories, Department of Renewable Resources have begun to introduce regulatory requirements regarding the operation of solid waste landfill sites in the water licenses being issued to applicants. In the past, minimal control was exercised over the deposition of wastes at the landfill sites. Wastes ranging from typical household garbage to raw sewage were often dumped in close proximity to the community which produced the waste material. Although the new regulatory requirements will improve the landfill operations, it is important to study these existing landfill sites to determine the effects on both the community and the surrounding environment. This will not only aid in the successful management of new landfill sites and improve the operations of existing sites, but could assist in producing regulations which are more specific to N.W.T. conditions.

One method of quantifying the impacts of these landfill sites is to analyze the leachates in the surrounding water. Toxic chemicals present in the landfill will leach out into the local ground water and surface water and can be collected and analyzed in laboratories. It is also possible to estimate the type and volume of waste which is being dumped.

As a result of a request from the Department of Indian and Northern Affairs, M. M. Dillon has carried out an investigation of the Municipal Landfill at Coppermine, N.W.T. The priorized objectives for this investigation were as follows:

a) to determine the quality and characterization of leachate emanating from the landfill site;

b) to provide information concerning the quantity and extent of surface and ground water movement at the site;

c) to provide a correlation between the waste deposition and the quality, characterization and quantity of leachate at the landfill site;

d) to give some indication of the environmental impacts of the landfill site.

This study was done concurrently with a similar study of the Municipal Landfill at Hay River, N.W.T., by the same study team.

Figure 1.1 shows a map of part of the Northwest Territories, highlighting the location of Coppermine.

The terms "dump" and "landfill" are often used inter-changeably. For this report, the term "dump" is used in the title as in the Terms of Reference. For the remainder of this report, the term "landfill" is used. Landfill, in the context of this report implies a designated site area for the disposal of municipal wastes.

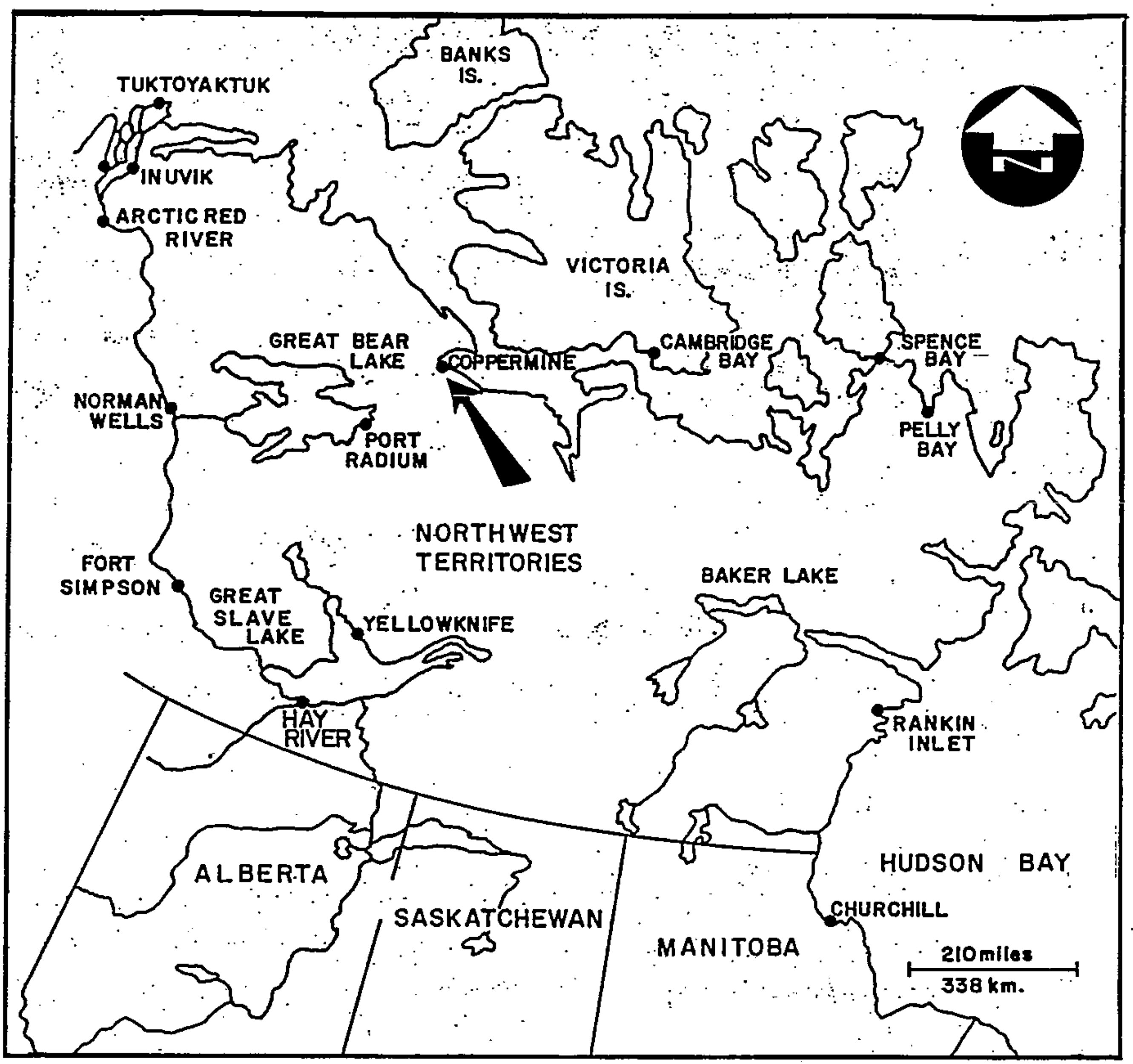


FIGURE 1.1 : MAP OF NORTHWEST TERRITORIES SHOWING STUDY AREA

2.0 BACKGROUND INFORMATION

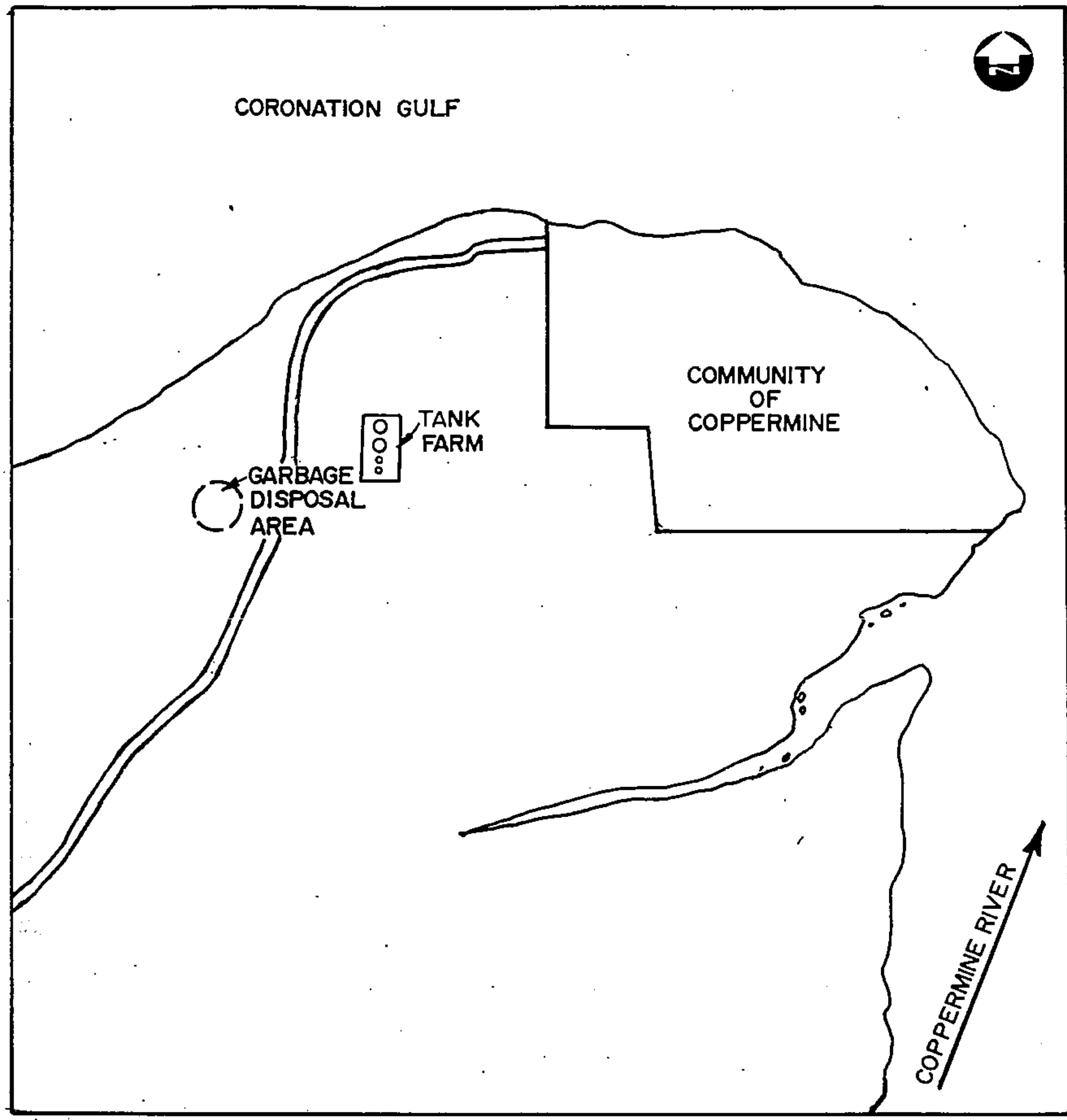
2.1 Community Information and Waste Generation

Coppermine is situated approximately 670 km north of Yellowknife in the Northwest Territories. The present population of Coppermine is approximately 956 people (1988). Archaeological evidence indicates that the region has been occupied by people of various cultures for the last 3,000 years (N.W.T., 1988). The town site developed slowly in the 20th Century with the establishment of a trading post in 1927, an Anglican mission in 1928, an R.C.M.P. post in 1932, a nursing station in 1948 and a school in 1959. The hamlet grew throughout the 20th Century as Inuit families began to rely more on the marine resources of the area and less upon the hunting of caribou in the interior. Consequently, there was a gradual relocation of families in the Coppermine area. Coppermine was incorporated as a Hamlet in 1981.

The local economy is based upon the natural environment for subsistence hunting and fishing, which is supplemented by a small commercial fishery, guiding sport fishermen and hunters, the production of arts and crafts, and government assistance. Given the dependence of the community on its natural environment, there is the potential for environmental contaminants to directly affect the health of the community's inhabitants and their ability to earn a living.

The waste that has been sent to the Coppermine Landfill consists of two main components. The first is domestic waste collected from households and businesses in the town. The second is liquid sewage which is collected from sewage holding tanks in the hamlet and disposed at the landfill. Domestic wastes have been buried with clean fill and the liquid wastes have been dumped to the side of the landfill heap. Figure 2.1 shows the location of the municipal landfill.

In order to estimate the waste generation and characteristics at Coppermine, the study team has combined its own observations with available literature on the subject. The "standard" reference work on Canadian waste stream characteristics is the report by Bird and Hale, (1979). Unfortunately, this report is of limited use for N.W.T. communities since its subject matter is large communities in southern Canada.



SCALE 1:25,000

DILLON Consulting Engineers • Planners Environmental Scientists	TITLE LOCATION PLAN	PROJECT NO. 3360 - 00
DATE MARCH 1991	PROJECT CHARACTERIZATION OF LEACHATE COPPERMINE MUNICIPAL LANDFILL	FIGURE NO. 2.1

MMD 501 72 (REV.)

Since patterns of consumption and standard of living are different in communities such as Coppermine, different patterns of waste generation are expected. Recent sources of information on waste generation in Arctic communities were reviewed and tabulated against field observations for this study. A summary of the general waste stream characteristics from the above study is shown on Table 2.1.

Recent studies reviewed, shown on Table 2.2, were also used to assist in obtaining estimates of the gross quantity of waste generated at Coppermine. A review of the literature indicated that waste generation in northern communities varies between 500 and 700 kg/capita/year. Observations made by the study team indicated that waste generation at Coppermine fell within this range. Table 2.2 shows a comparison of waste generation at a number of Canadian Arctic communities.

2.2 Coppermine Landfill Facility

Prior to 1970, most domestic waste from the town was dumped onto the ice in Coronation Gulf during the winter and was carried away by ocean currents during the spring thaw. In 1970 the landfill being investigated by this study was established.

The Coppermine Municipal Landfill is located approximately 1 km southwest of Coppermine, along the airport road (Figure 2.1). It consists of a mound of fill and waste deposited on the slope of a hill, and extends from the road to approximately 250 m west of the road. At the time of the investigation, the top of the mound was approximately 12.5 m above sea level, almost level with the road at that point, and formed a small plateau. The western edge of the waste heap rises approximately 9 to 10 m above the pre-existing slope.

As mentioned above, the landfill has been in continuous use from 1970 to 1990. Based upon the estimated per capita yearly waste generation of 500 to 700 kg, and adding 250 to 500 kg of fill as cover material for every 1000 kg (1 t) of waste, it is estimated that between 15 000 and 20 000 t of waste and fill have been deposited at the Coppermine Municipal Landfill over the last 20 years.

Shortly after the field portion of this study was completed, the landfill was shut down, and a new waste disposal site was developed, approximately 2 km west of the old landfill site.

TABLE 2.1 : COMPARISON OF ESTIMATED
WASTE STREAM CHARACTERISTICS

Waste Stream Items	National Estimates (a)	Alaskan Communities Estimates (b)	Eastern Arctic Estimates (c)	Coppermine Estimates
Food Wastes (Putrescibles)	20.6%	15.2%	15.9 - 21.4 %	15 - 20 %
Yard Waste	5.3%	0 - 6.5%	-	
Paper Products	42.3%	43 -46 %		30 - 40 %
Cardboard			9.3 - 14.4 %	
Newsprint			0.3 - 5.0 %	
Other Paper			14.0 - 18.5 %	
Metals	7.0%	10 - 13 %		10 - 12 %
Cans			5.0 - 5.5 %	
Other Metal			4.0 - 6.5 %	
Plastic, Rubber Leather	10.1% (including textiles)	5 - 5.5 %	8.8 - 13.3 %	5 - 10 %
Textiles		2 - 3 %	3.3 - 4.1 %	3 - 4 %
Glass, Ceramics	8.6%	15 - 17 %	1.7 - 3.1 %	2 - 3 %
Wood	4.1%	0.6 - 1.2 %	4.5 - 20 %	5 - 10 %
Dirt, Ash	1.4%	0.4 - 1.7 %	3.1 - 4.8 %	4 - 5 %
Diapers			3.5 - 11.6 %	3 - 5 %

References: a. Bird & Hale, 1979; b. Environment Canada, 1979; c. Heinke & Wong, 1989

TABLE 2.2
COMPARISON OF PER CAPITA WASTE GENERATION

LOCATION	Estimated daily per capita waste generation, cubic metres	Estimated annual per capita waste generation, kilograms (average 127 kg/cubic metre times 365 days)
Eastern Arctic Communities (c.)	0.013 - 0.015	600 - 700
Tuktoyaktuk (b.)	0.014	650
Alaskan Communities (b.)	0.015	700
Coppermine	0.013 - 0.015	600 - 700

References: a. Bird & Hale, 1979; b. Environment Canada, 1979; c. Heinke & Wong, 1989

During its operation, liquid sewage was routinely deposited at the Municipal Landfill. This waste material was collected from holding tanks in the town and was composed primarily of human sewage and domestic wash-water. Small communities the size of Coppermine typically produce 50 to 80 L/capita/day (10 to 15 Igal/capita/day based on G.N.W.T. design guidelines) of sewage. Observed transport of sewage to the landfill site was approximately 50 000 L/day (= 50 L/capita/day).

2.3 Regional Geology and Hydrogeology

The topography of Coppermine is typical of the western Arctic coastal areas and consists of rolling hills, interspersed with wide valleys and tundra flats. The bedrock geology of the Coppermine region is primarily Precambrian plutonic and volcanic rocks which occur as extensive outcrops at the surface.

The most important factor in describing the hydrogeology of the Coppermine region is the presence of permafrost. Permafrost is defined as that portion of the subsurface that is permanently frozen. The depths to permafrost in the Coppermine region vary from 10 to 200 cm. Most ground water flow is either in the depths below the permafrost or in the seasonally active zone, the extent of which varies both spatially and temporally. In the Coppermine region, the permafrost zone acts as an impermeable barrier to vertical ground water movement. This means that almost all of the ground water flow originating near the surface travels laterally through the active zone. The active zone varies in depth throughout the year, reaching its greatest depth in late summer.

In the Coppermine area, the regional ground water flow follows the topography; the ground water in the active zone flows from the high ridge of land in the centre of the peninsula upon which Coppermine is located towards the low-lying land adjacent to Coronation Gulf and the Coppermine River. Rates of ground water migration vary with the local geology; however, talus, beach sands and alluvial sands, which are the predominant surface materials, typically have hydraulic conductivities in the order of 1×10^{-3} cm/sec (Freeze & Cherry, 1979). This means that ground water in the active zone is effectively flushed out to the ocean after 10 summers (or thaw cycles).

2.4 Surface Drainage Patterns

Surface drainage patterns in the Coppermine area follow the natural topography. The general pattern is from the high regions in the centre of the peninsula towards Coronation Gulf or the Coppermine River. Surface drainage takes place only during the summer months since most surface water is frozen during the winter. The largest body of fresh water in the Coppermine area is the Coppermine River, with Coppermine being located on its outlet into Coronation Gulf. The Coppermine River forms a zone of fresh to brackish water in Coronation Gulf. The pattern of near-shore currents that result from the interaction of the river and local offshore currents, is from the mouth of the river and outward. In the case of the area immediately offshore of the municipal landfill, the near-shore current was observed to be in an westerly direction with an estimated speed of 1 knot (1.85 km/hr). Areas in the ocean where fresh and salt water mix are often rich in aquatic life.

2.5 Natural Environment of the Coppermine Region

Coppermine lies in the Arctic climatic zone and mean daily temperatures range from - 35.0°C in February to +13.0°C in July. The average total yearly precipitation is 202.3 mm, and prevailing winds are from the Northwest and average 20 to 25 km/hr.

The natural ground cover varies within the area. On the higher and drier ground lichens predominate, while on the lower and wetter ground, grasses, arctic willow, alder, and wildflowers predominate and sphagnum moss is common in the marshy areas. The tallest trees are the alders and Arctic willows, which grow over 1 m in height in sheltered areas, but are typically no more than 30 cm in height.

The most common land mammals in the area surrounding Coppermine are Arctic ground squirrels and lemmings. Larger mammals, such as caribou and polar bears, are occasionally found in the Coppermine area. Arctic fox are occasionally seen in the Coppermine region, but wolverines and barren lands grizzly bears are rarely found. Waterfowl and shore birds are also known to be present. Ravens are found year-round in the area, and gulls, terns, sparrows, and snow buntings are found in abundance in the summer months.

Ringed and Arctic grey seals are known to occur in the Gulf, and fish species include Arctic char, Arctic cod, capelin, and two species of flatfish. Capelin are often caught immediately offshore in a location approximately 0.5 to 1.0 km west of the landfill when they move onto this area to spawn. The fish found in the Coppermine River include Arctic char, Arctic grayling, suckers, cisco, whitefish, northern pike, lake trout, and burbot.

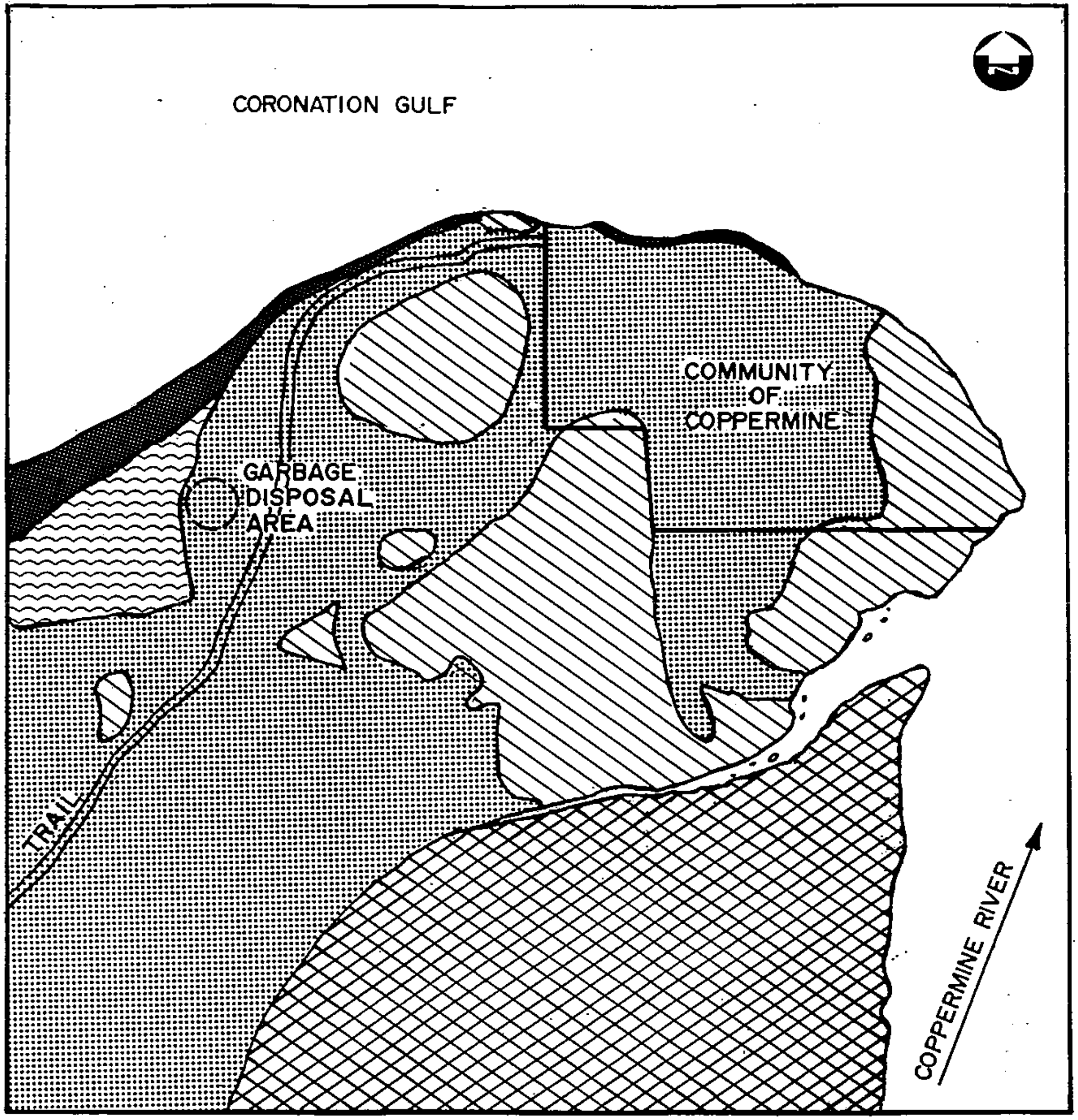
3.0 FIELD INVESTIGATION

Prior to implementation of the investigation program, a meeting was held in Yellowknife with officials from the Indian and Northern Affairs and Government of the Northwest Territories regarding the field investigation. The investigation consisted of three phases. Phase One was an initial reconnaissance of the site, Phase Two was the installation of monitoring wells (piezometers) and Phase Three was the collection of ground water samples.

Upon arrival in Coppermine, the study team carried out a reconnaissance of the area. Figure 3.1 shows the surface geology of Coppermine based upon this reconnaissance. Using the guidance provided during the meeting with G.N.W.T. officials, final locations of the piezometers were decided. The suggested locations were: one piezometer upgradient of the landfill to get background water quality (TH1); two piezometers immediately adjacent to the landfill to obtain an indication of the raw leachate quality (TH2, TH3); and two piezometers further downgradient to obtain ground water samples (TH4, TH5), which would show if there was an attenuation of the contaminant concentrations in this direction. These locations are shown in Figure 3.2.

Phase Two of the field program involved the piezometer installation. The piezometers were installed on 22 August 1990. The method of installation consisted of drilling a 10 cm diameter hole using a hand auger. The maximum depths were determined by refusal at assumed permafrost. PVC pipe and screens were installed with locally available beach sand, obtained 500 m east of the landfill on Coronation Gulf. The sand was packed around the screens. The top of the installation was sealed with commercial-grade hydraulic cement. The data logs of the test holes and the details of the piezometer installations may be found in Appendix "A", Test Hole Logs.

Phase Three of the field program involved the ground water sampling. Ground water samples were collected from the piezometers on 23 August 1990 using a tube bailer. The bailer consisted of an open-ended tube with a ball-valve at the closed end. The bailer was attached to a length of cord, lowered into the piezometer and allowed to fill with water. The piezometer well were first bailed "empty," and allowed to refill, prior to filling sample bottles. The bailer was then pulled up and the water transferred to a sample bottle. This process was continued until the sample bottles for each sample piezometer were filled. A duplicate sample was taken at each piezometer. Between

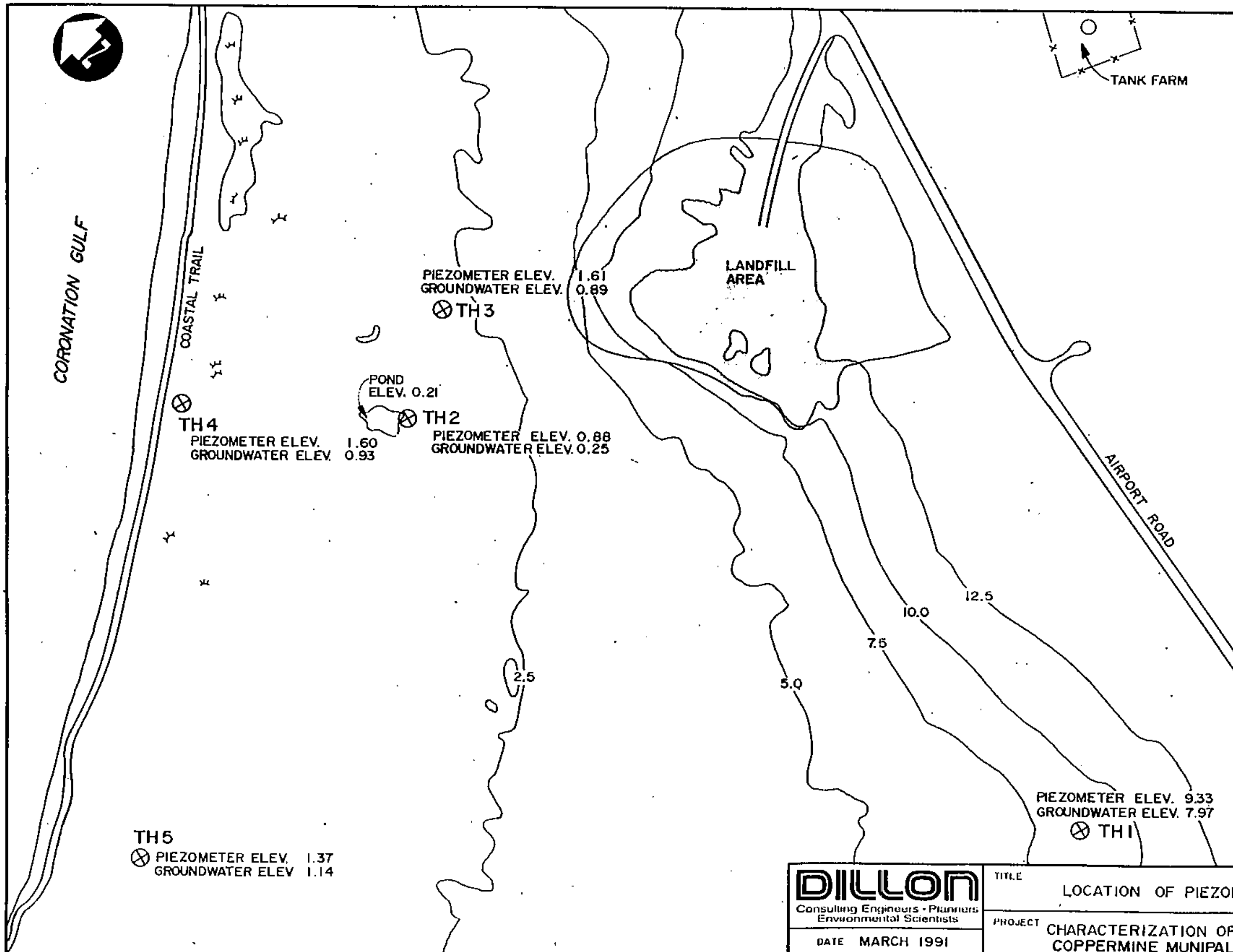


SCALE 1 : 25,000

LEGEND

- ALLUVIAL DEPOSITS
- BEACH SAND
- OUTCROP
- CLAY
- TALUS - GRAVEL & SAND

DILLON Consulting Engineers • Planners Environmental Scientists	TITLE SURFACE GEOLOGY	PROJECT NO 3360 - 00
DATE MARCH 1991	PROJECT CHARACTERIZATION OF LEACHATE COPPERMINE MUNICIPAL LANDFILL	FIGURE NO. 3.1



LEGEND

- ⊗ PIEZOMETER LOCATION ELEVATION MEASURED AT TOP OF PIPE
- SWAMPY GROUND
- ALL ELEVATIONS IN METERS ABOVE SEA LEVEL
- —12.5— CONTOUR
- CONTOUR INTERVAL 2.5 m
- 100 m
- SCALE 1 : 2000

DILLON
Consulting Engineers · Planners
Environmental Scientists

DATE MARCH 1991

TITLE LOCATION OF PIEZOMETERS

PROJECT CHARACTERIZATION OF LEACHATE COPPERMINE MUNIPAL LANDFILL

PROJECT NO. 3360-00

DETAIL NO. FIGURE 3.2

sampling locations, the bailer was rinsed thoroughly with clean water. After sampling, the sample bottles were stored in coolers at approximately 4°C for shipment to the laboratory. The results of the laboratory testing and the test parameters are discussed in Section 4.2.

Measurements of ground water elevation were made before and after sampling. The time required for the ground water level to return to the initial level prior to sampling enabled the calculation of estimates of the hydraulic conductivity of the soil.

During the on-site visit, subjective observations were made regarding the potential environmental impacts of the landfill site. These included notes on plant and animal species observed in the area. This information was obtained through direct observation or through conversations with local Renewable Resources staff. This information was supplemented through background research to determine typical species present in the Coppermine area.

4.0 RESULTS OF INVESTIGATION

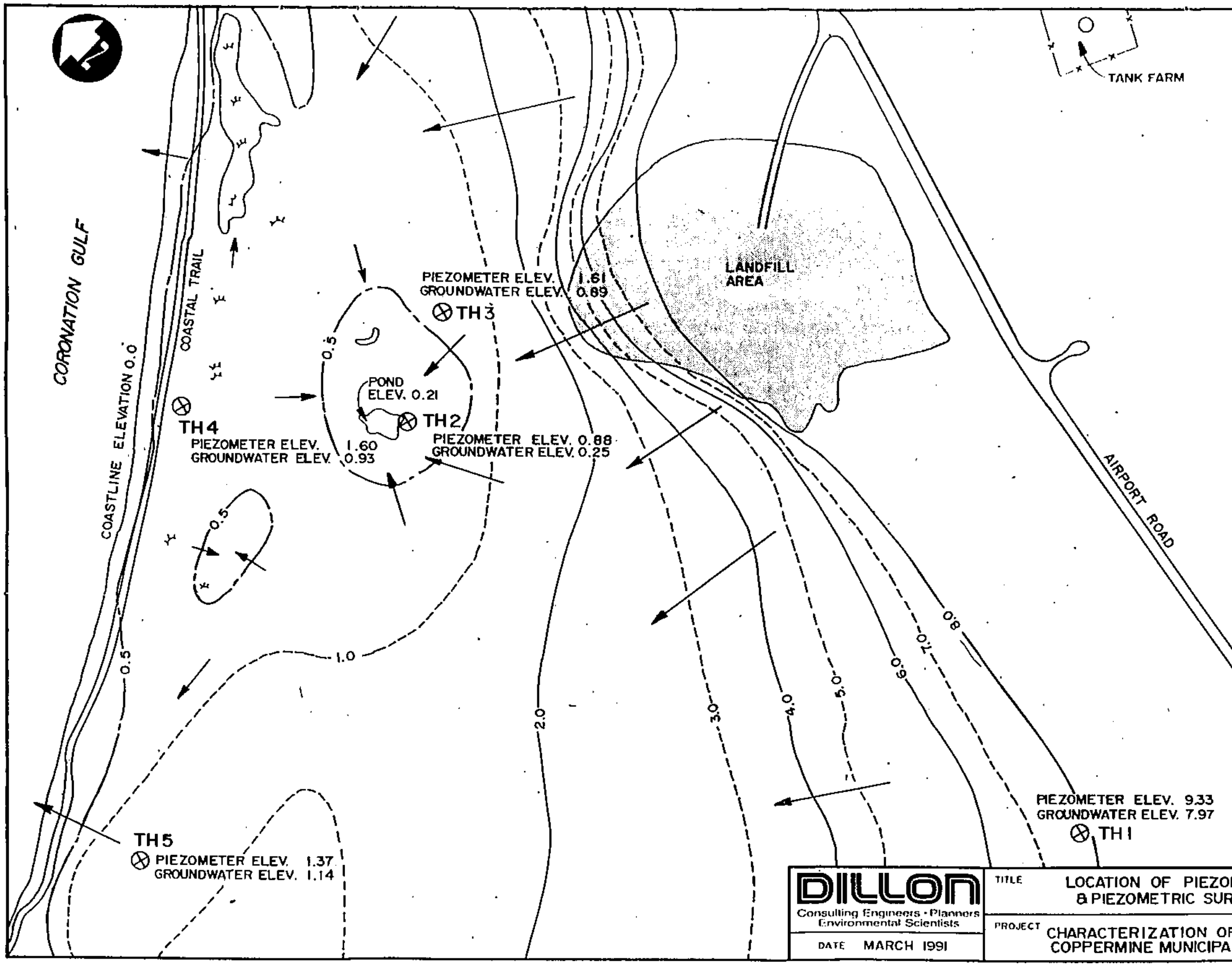
4.1 Hydrogeology of the Landfill Area

The piezometer locations and the piezometric surface of the ground water in the area of the landfill are outlined in Figure 4.1. Arrows on the map indicate the direction of ground water flow. In general, ground water in the area flows towards the ocean. However, in the area immediately to the north-west of the landfill site there is a ground water impoundment. This is due to the higher ground water elevations found in the beach deposits adjacent to Coronation Gulf. The effect of this impoundment is to create an area where ground water temporarily collects and stagnates. The area within in the impoundment is marshy, as the ground water is generally at or above the surface. Leachate and surface runoff carrying the sewage deposited at the landfill tends to collect in the impounded area for a period of time. When a sufficient amount of ground water builds up in this area, the hydraulic gradient should be enough to cause the ground water to move towards the northwest and eventually into Coronation Gulf. Complicating the ground water regime, is the fact that since the active zone is generally shallow, it is strongly affected by surface runoff events. In fact, the flow of surface runoff and ground water in this area is really a single system during the summer months.

During the spring, when the ground is frozen to within 10 cm of the surface, the runoff will tend to carry away any contaminants in the ground water at the surface. Despite the apparent impoundment of ground water, there are a number of ways that it can drain into Coronation Gulf, and thus into the wider environment.

As mentioned in Section 2.2, the hydrogeology of lands affected by permafrost is time-dependent; therefore, the hydrogeology map represents a snap-shot of the study period for the day in which observations were made. Although general trends can be observed from the hydrogeology data, temporal extrapolations should be made with caution.

In order to calculate the rates of movement of ground water through the soil it is necessary to know the hydraulic conductivity of the soil, the hydraulic gradient and the effective porosity of the soil. The hydraulic conductivity (K) of the soils between the landfill and the ocean, as determined by field observations, is calculated to be 4.45×10^{-3} cm/sec. The effective porosity (n) of soils such as those observed in the



LEGEND

- FLOW LINES OF GROUNDWATER FLOW
- PIEZOMETRIC SURFACE
- PIEZOMETER LOCATION ELEVATION MEASURED AT TOP OF PIPE
- SWAMPY GROUND

ALL ELEVATIONS IN METERS ABOVE SEALEVEL

100 m

SCALE 1 : 2000

DILLON Consulting Engineers · Planners Environmental Scientists	TITLE LOCATION OF PIEZOMETERS & PIEZOMETRIC SURFACES	PROJECT NO. 3360-00
DATE MARCH 1991	PROJECT CHARACTERIZATION OF LEACHATE COPPERMINE MUNICIPAL LANDFILL	DETAIL NO. FIGURE 4.1

area are typically 30 percent. The horizontal hydraulic gradient (i) from the landfill site to the impounded ground water area is 0.07. The rate of ground water movement (V_s) is found by the formula: $V_s = Ki/n$ (Freeze and Cherry, 1979). In the case of the soils adjacent to the landfill this equals a movement rate of 1.04×10^{-3} cm/sec, which translates into lateral ground water movements of approximately 0.9 m per day.

The amount of ground water flowing beneath the landfill was estimated using a "flow net" (Freeze and Cherry, 1979). The result of the calculations is that approximately 15 m^3 of ground water-diluted leachate per day flows out of the area of the landfill. This translates into a 900 m^3/year flow, with total flow occurring over a period of 60 days, the period in which the active zone is unfrozen.

The production of leachate at Coppermine Landfill is strongly influenced by the presence of frozen ground. Much of the material deposited over the years at the landfill is now part of the permanently frozen zone and is unlikely to contribute to leachate production. This could change if the landfill heap is eroded away in the future. At present, all leachate production at the landfill takes place during the summer in the unfrozen part of the landfill within 1 m of the surface. Much of the leachate produced by the landfill comes from the sewage discharged, the thawing of the frozen ground and the release of water. The cold climate restricts the production of leachate but also ensures that leachate will continue to be produced by the landfill for a number of years. This is because the yearly freezing of the site tends to "lock up" the ground water, which can only flow during the summer months. The frozen conditions at the landfill site also tend to slow down chemical reactions, thus ensuring a slow release of the leachate into the ground water and a longer period of time to stabilize when compared to landfills in southern Canada.

4.2 Leachate Characteristics

As discussed in Section 2.1, estimated annual production of solid waste at Coppermine is approximately 500 - 700 tonnes, with a waste characterization similar to estimates shown in Table 2.1.

Liquid sewage was also disposed at the Coppermine landfill. Observations indicated that approximately 50 000 L/day (50 cubic metres/day) of liquid sewage was disposed at the landfill.

The chemical characteristics of leachate generated by a landfill are dependent upon the types of garbage deposited in the landfill. Unfortunately, there are too many unknown variables to accurately predict or estimate the concentrations of a specific contaminant in the leachate, for any given material in the landfill. However, it is possible to outline which chemicals can be expected and the potential for environmental impacts, given an approximate composition of the garbage present in the landfill. A list of contaminants typically generated by materials in a municipal landfill is presented in Table 4.1.

Since many items at the Coppermine landfill were burned before being buried, ash is a common component of the landfill waste. Ashes are sometimes considered "inert" in landfills. However, when wet, they can release a number of chemicals into the landfills leachate, depending on the source of the ashes. Ashes from paper and wood can generate sodium and potassium hydroxides (lye) when wet. The incomplete burning of plastics can produce a wide variety of chemicals such as PAHs, MAHs, phenols, dioxins and furans. Other chemicals released by ashes can include: aluminum, magnesium, calcium and heavy metals associated with the coatings of paper and wood products. The chemicals released by ashes into ground water probably form a large part of the leachate characteristics. Ash leachate tends to have higher concentrations of pollutants than leachate generated from the unburned parent materials.

The liquid sewage deposited at the Coppermine Municipal Landfill tends to drain off the sides of the landfill heap and, based on observed surface drainage patterns, does not appear to percolate through the landfill material. Liquid sewage typically contains a wide variety of chemicals and micro-organisms. The micro-organisms in sewage include fecal coliform and fecal streptococci, enteric parasites and enteroviruses. Chemicals found in sewage include: ammonia, nitrates, nitrites, phosphates, sodium, potassium, lead, copper, phenols, PAHs, MAHs, and ketones. Soaps and detergents contribute phosphates, nitrates, potassium, sodium, benzene, chlorides and phenols to the sewage mix. The dumping of sewage at the Coppermine landfill can be expected to greatly alter the quality of the ground water downgradient of the landfill.

TABLE 4.1 : WASTE STREAM ITEMS AND POSSIBLE SOURCES OF POLLUTANTS IN LEACHATE

WASTE STREAM ITEM	POLLUTANTS GENERATED IN LEACHATE
Paper Products	Organic Carbon, Phosphates, Sulfides, Ammonia Nitrate, Nitrite, Sodium, Mercury, Aluminum, Magnesium, Calcium, Chromium, Polyaromatic Hydrocarbons (PAH's), Polychlorinated Biphenyls (PCB)
Glass and Ceramics	Arsenic, Cadmium, Lead, Chloride, Fluoride,Phosporous, Potassium
Metals	Iron, Aluminium, Lead, Zinc, Tin Mercury, Cadmium, Chromium, PCB's
Electronics/batteries/fluorescent lights	Copper, Zinc, Iron, Lead, Mercury, Silver Cadmium, Aluminum, Phenols, PCB's
Plastics	PAH's, Monocyclic Aromatic Hydrocarbons (MAH's) PCB's, Phenols, Cadmium, Iron, Lead, Chloride, Organic Carbon
Tires	PAH's, MAH's, Chlorides, PCB's
Putrescibles (Food Wastes/Carcasses)	Organic Carbon, Ammonia,Nitrates & Nitrites, Phosphates, Coliform & Streptococci bacteria, Ketones, Phenols, Calcium, Magnesium, PAH's, MAH's
Leather/Fabric waste	Organic Carbon, Ammonia, Nitrates, Nitrites, Phosphates, Calcium, Magnesium, Phenols, PAH's, MAH's
Contruction/Demolition Waste	Copper,Iron,Lead,Calcium,Magnesium,Sulfates,Cobalt
Ashes	Sodium & Potassium Hydroxides, Aluminum, Magnesium, Calcium, Mercury
Hazardous Wastes	
Fuel, Oil, & Lubricants	Oil and grease, Cyanide, Lead, Calcium, Phosphorous, Benzene, Nitrobenzene, Toluene, PAH, MAH, Phenols
Paints & Pigments	Iron, Lead, Copper, Mercury, Chromium, Sodium, Aluminum, Cadmium, Benzene, Phenols, Toluene, PCB's
Solvents	Benzene, Ethylbenzene, Toluene, PAH's, MAH's, 1,1,1 Trichlorethane
Pesticides	Arsenic, Mercury, Cyanide, Phosporous,Potassium, Chromium, Fluoride, Chloride, Benzene, Phenols, Pesticides residues
Liquid Sewage	Coliform & Streptococci Bacteria, Enteroviruses Ammonia, Nitrates & Nitrites, Phosphates, Lead, Copper, Ketones, Phenols, PAH's, MAH's
Soaps and Detergents	Phosphorus, Potassium, Sodium, Benzene, Chlorides, Phenols

(Source: Compiled from information in CCREM, 1989)

4.3 Laboratory Results

4.3.1 Analytical Results

The results of the laboratory analysis on the ground water samples taken at the Coppermine Municipal Landfill are shown on Table 4.2. These samples were taken from the monitoring wells described in Section 3.0.

Test Hole 1 (TH1) is the control well sited to give the background water quality of the area upgradient of the landfill (Figure 4.1). The results indicated that the ground water in the Coppermine area was naturally slightly alkaline and the conductivity (730 umho/cm) indicated moderate dissolved salts content in the ground water (Table 4.2). This was confirmed by the results for hardness, alkalinity, sodium, potassium, chlorides and sulphates. The results from the biological activity indicators (total coliform, fecal coliform and fecal streptococci and BOD_5, indicated a considerable amount of natural microbial activity in the ground water. This was to be expected given the shallowness of the active zone above the permafrost (<1 m). Levels of the other parameters appeared to indicate that the natural ground water for the area was relatively clean, although the levels of phenol and iron were relatively high.

Test Hole 2 (TH2) is located at the base of the landfill (Figure 4.1). The ground water from this well showed a marked difference in quality compared to the background sample from TH1. The pH was lower and the conductivity was higher, as were the levels of alkalinity, sodium, potassium, chloride and sulphate concentrations, levels of biological indicators were also high: total coliforms were 1.25×10^4 mg/L, fecal coliforms were 2800 mg/L, fecal strep were 750 mg/L and BOD_5 was 14 mg/L. Several other parameters also had high levels in comparison to the control sample. These included phosphorus, phenols, oil and grease, arsenic, iron, and copper.

Test Hole 3 (TH3) is also located near the base of the landfill heap (Figure 4.1), however it is situated such that the liquid sewage does not influence the ground water at its location, being slightly above and away from the path that the sewage effluent usually follows when it is dumped at the landfill. The levels of pH and conductivity of the ground water were lower in TH3, as compared with TH2 (Table 4.2). Levels of sodium, potassium, and chloride levels were somewhat higher in TH3 than the background levels found in the sample from TH1, but were not as great as the sample from TH2 (Table 4.2). The sulphate levels in TH3 were greater than in TH2 and TH1

TABLE 4.2 : LABORATORY ANALYSIS OF LEACHATE SAMPLES, COPPERMINE MUNICIPAL LANDFILL

ANALYSES BY DIAND WATER LAB, YELLOWKNIFE

PARAMETER	units	Minimum Detection Limit	MONITORING WELLS (SAMPLE NUMBERS) TH1 (0001)	TH2 (0003)	TH3 (0005)	TH4 (0007)	TH5 (0009)
pH			8.1	7.5	6.9	7.1	6.7
Conductivity	umhos/cm		730	1870	1510	2000	1930
S.S.	mg/L		18.4	44	536	2000	4760
Hardness(CaCO3)	mg/L		288	237	465	358	363
Alkalinity	mg/L		186	590	106	636	199
Sodium	mg/L		32	154	101	226	208
Potassium	mg/L		2.8	46.8	13.3	62	13.2
Chlorides	mg/L		12.8	172	100	289	475
Sulphate	mg/L		7	75	123	95	39
Tot.Coliform	*		1200	12500	8800	1700	1200
Fecal Coli.	*		<1	2800	6	<10	2
Fecal Strep.	*		10	750	280	300	2
B.O.D.-5	mg/L		3	14	8	86	11
C.O.D.	mg/L		45	242	88	1745	1695
NO3+NO2	mg/L		<0.04	<0.04	86	<0.04	<0.04
Phosphorus	mg/L		0.035	19	0.65	50	4.3
Cyanide	mg/L		0.005	0.004	0.012	0.004	0.079
Sulphide	mg/L		<0.003	<0.003	<0.003	0.044	<0.003
Oil & Grease	mg/L		<0.5	5.18	<0.05	4.97	<0.5
Phenols	mg/L		5	18	10	72	12
Fluoride	mg/L		0.1	0.09	<0.05	0.11	0.1
Arsenic	mg/L		<1.0	5	3	7	120
Cadmium	mg/L		<10	<10	<10	<10	<10
Copper	mg/L		<20	23	41	<20	<20
Iron	mg/L		327	992	1080	5700	4700
Lead	mg/L		<25	<25	<25	25	35
Nickel	mg/L		<25	25	<25	25	29
Zinc	mg/L		<20	<20	20	46	<20
Chromium	mg/L		<20	<20	<20	<20	<20

** Bacteria readings in counts per 100 mL*

ANALYSES BY DILLON ENVIRONMENTAL LABORATORY

PARAMETER	units	Minimum Detection Limit	TH2 (0004)
Mercury	ug/L	0.1	0.1
Monocyclic Aromatic Hydrocarbons			
Benzene	ug/L	1.0	ND
Bromoform	ug/L	1.0	ND
Bromomethane	ug/L	1.0	ND
Bromodichlormethane	ug/L	1.0	ND
sec-Butylbenzene	ug/L	1.0	ND
tert-Butylbenzene	ug/L	1.0	ND
Carbon Tetrachloride	ug/L	1.0	ND
Chlorobenzene	ug/L	1.0	ND
Chloroform	ug/L	1.0	ND
Chloromethane	ug/L	1.0	ND
Chloroethane	ug/L	1.0	ND
2,4 Chlorotoluene	ug/L	1.0	ND
Dibromochloromethane	ug/L	1.0	ND
1,2 Dichlorbenzene	ug/L	1.0	ND
1,3 Dichlorobenzene	ug/L	1.0	ND
1,4 Dichlorobenzene	ug/L	1.0	ND
1,2 Dichloroethane	ug/L	1.0	ND
1,1 Dichloroethylene	ug/L	1.0	ND
1,2 Dichloropropane	ug/L	1.0	ND
1,3 Dichloropropylene(E)	ug/L	1.0	ND
1,3 Dichloropropylene(Z)	ug/L	1.0	ND
Ethylbenzene	ug/L	1.0	ND
Methlylene Chloride	ug/L	1.0	Trace
Tetrachlorethylene	ug/L	1.0	ND
Toluene	ug/L	1.0	2.0
iso-Propylbenezene	ug/L	1.0	ND
n-Propylbenzene	ug/L	1.0	ND
1,1,1 Trichlorethane	ug/L	1.0	ND
1,1,2 Trichlorethane	ug/L	1.0	ND
Trichloroethylene	ug/L	1.0	ND
Trichlorofluoromethane	ug/L	1.0	ND
Vinyl Chloride	ug/L	1.0	ND
m & p Xylene	ug/L	1.0	ND
o Xylene	ug/L	1.0	ND

ND : not detected

(Table 4.2). The total coliform count in the sample from TH3 was also lower than the count from TH2 and considerably higher than the background levels established by the sample from TH1 (Table 4.2). These trends were also observed when the sample from TH3 was compared with the sample from TH2 (Table 4.2), as the sample from TH3 also had lower levels of fecal strepocci and BOD_5. The other test parameters indicated similar trends.

Test Holes 4 and 5 (TH4 and TH5) are located further down gradient and showed an attenuation of the effects of the leachate and liquid sewage upon the ground water quality (Figure 4.1). Also, there were higher salt levels and higher conductivity, sodium, potassium and chloride levels in these wells, when compared to the wells upgradient (Table 4.2). The sulphate levels were high in TH4, but attenuated downgradient in TH5 (Table 4.2). The total coliform, fecal strep, and BOD-5 counts also remained high in TH4 and attenuated downgradient in TH5 (Table 4.2). The chemical oxygen demand (COD) was also very high in both TH4 and TH5. Levels of phosphorus, sulphide, oil and grease, phenols and fluoride all remained high in TH4 and attenuated further downgradient in TH5. The levels of both nitrates, nitrites and copper appeared to attenuate in both TH4 and TH5. There appeared to be an accumulation of arsenic, lead, and nickel in the area of TH5, and the iron levels in both wells were high.

4.3.2 Second Phase of Laboratory Testing

A number of parameters were analyzed to more fully characterize the leachate. These additional tests were confined to the sample from the most contaminated monitoring well; TH2. Additional testing was conducted to determine the concentrations of mercury, and monocyclic aromatic hydrocarbons (MAHs).

Laboratory analyses indicated no evidence of leachate characteristics which would be considered significant. The mercury level is much lower than the allowable 0.6 mg/L discharge guidelines (N.W.T. Water Board 1981). Mercury is a common inorganic pollutant that is known to bioaccumulate at higher concentrations. The presence of mercury in leachate is attributable to a number of sources including paper products, paints, pesticides, batteries, and electronic equipment. MAHs are common organic chemicals associated with a wide variety of products, including solvents, fuels, lubricants, and sewage. The levels of these parameters in the leachate were too low to be detected. The trace levels present are considered insignificant.

4.4 Inventory of Typical Biota in the Area

During the on-site visit, two species of waterfowl and several wading birds were observed in or around the natural lagoon area downslope of the landfill. Ravens, gulls and sparrows were observed on the landfill. Groups of gulls were also observed feeding immediately offshore in the area. Birds of prey, such as rough-legged hawks, peregrine falcons, and gyrfalcons have also been observed in the past. Several arctic ground squirrels and lemmings were observed in the vicinity of the landfill and the area downslope of the landfill contained many burrows. Several residents mentioned that they had caught Arctic char and Arctic grayling in the Coppermine River, which is also known to contain suckers, cisco, lake whitefish, northern pike, lake trout and burbot. Cod and flounder species are known to be present in the Gulf, and capelin spawned in the autumn, downshore from the landfill site in the shallow waters of the beaches. In the past, these capelin have been harvested by local residents, although in some years no capelin have come to the area to spawn.

There are a variety of biota that could potentially become exposed to the leachate and the toxins associated with the landfill. This exposure could be either direct, or indirect, through absorption into tissues or through ingestion of vegetation or other food items. It should be noted that the landfill is small and is now closed. The contact is casual and transitory and further reduces the level of exposure. The following is a list of typical plant, invertebrate and fish, mammal and bird species whose ranges extend into the study area and that could therefore become exposed to the leachate. It must be noted that this is not a complete species inventory but is merely an example of the types of species affected. These are shown on Table 4.3.

It is also known that there are several species that have been classified as being particulary vulnerable to extinction. These include the beluga whale and the Eskimo curlew (endangered), the Peary caribou and peregrine falcon (threatened), the wolverine, ivory gull, and Ross' Gull (rare), and the Bering wolffish, blackline prickle-back, and fourhorned sculpin (vulnerable). There is the potential that some of these species could be exposed to the municipal landfills in the Northwest Territories, including Coppermine.

TABLE 4.3
SENSITIVITY OF TYPICAL BIOTA
TO LEACHATE, COPPERMINE, NWT.

BIOTA	DEGREE OF SENSITIVITY (see below)
VEGETATION	
spagnum moss	1b
lichens	1b
grasses	1a
arctic willow	1a
wildflowers	1a
INVERTEBRATES	
scallops	1a,2a
shrimps	1a,2a
crabs	1a,2a
marine plankton (approx. 100 species)	1a,2a
FISH	
arctic charr	1a,2a
capelin	1a,2a
arctic cod	1a,2a
flounder (two species)	1a,2a
four horned sculpin	1a
MAMMALS: prey species	
arctic hare	1a
arctic groundsquirrel	1a,2a
voles (several species)	1a,2a
lemmings (two species)	1a,2a
MAMMALS: predators	
grizzly bear	1b,2b
wolverine	1b,2b
wolf	1b,2b
arctic fox	1b,2b
MAMMALS: ungulates	
caribou	1b,2b
muskox	1b,2b
MAMMALS: marine	
bearded seal	1a,2a
ringed seal	1a,2a
beluga whale	1a,2a
narwhal	1a,2a
bowhead whale	1a,2a

BIOTA	DEGREE OF SENSITIVITY (see below)
BIRDS: waterfowl	
canvasback	1b,2b
jaeger	1b,2b
king eider	1b,2b
whistling swan	1b,2b
snow goose	1b,2b
canada goose	1b,2b
mallard	1b,2b
widgeon	1b,2b
common pintail	1b,2b
BIRDS: seabirds	
arctic tern	1a,2a
thayers/herring gull	1a,2a
ross' gull	1a,2a
ivory gull	1a,2a
glaucous gull	1a,2a
BIRDS: raptors	
rough-legged hawk	2a
peregrin falcon	2a
gyrfalcon	2a
snowy owl	2a
BIRDS: others	
northern raven	1a,2a
plover (several species)	1a
sandpiper (several species)	1a
phalarope (two species)	1a
ptarmigan (two species)	1a
eskimo curlew	1a
sparrow (several species)	1a,2a

DEGREE OF SENSITIVITY
(1a=primary contact-high potential)
(1b=primary contact-low potential)
(2a=secondary contact-high potential)
(2b=secondary contact-low potential)

5.0 DISCUSSION

5.1 Significance of Results

A preliminary examination of the leachate emanating from the now abandoned Coppermine municipal landfill has indicated that there is considerable contamination of the ground water in the immediate vicinity. However, the potential environmental consequences are greatly reduced due to several factors. One factor in that the topography has created a natural lagoon which appears to be containing the pollutants. Another factor is that the leachate will be greatly diluted as it enters Coronation Gulf. However, there is still some potential for environmental impacts, although these will be confined to the area immediately surrounding the landfill.

Due to the hard rocky substrate and the presence of permafrost, it was difficult to install most wells, particularly those located in the higher areas. Although the characterization of the leachate from the wells was, in general, consistent with the items found at the landfill (which were typical of small northern communities), there were some inconsistencies in the results. These included levels of biological activity, phenols and iron, which were higher than expected in the control sample well. Levels of phenol and iron could be due to the proximity of the well to the road since this appeared to be the best location at which a well could be dug. It is possible that these chemicals leached from the road, particularly if there were residues of oil and solvents present. This could have occurred since the road has been sprayed with oil in the summer, for dust control. The higher biological activity at this control well could be due to the active zone above the permafrost. However, in general, the analysis results were as expected.

Ground water samples taken downgradient of the landfill provided evidence of ground water contamination. Chemical and biological analyses indicate that the leachate has affected the local ground water quality as follows:

- increased chloride levels, a persistent indicator ion of leachates

- increased conductivity, indicating a large amount of dissolved salts

- high total coliform and fecal coliform counts, indicating severe biological contamination of the ground water and the presence of abundant organic nutrients resulting from sewage wastes

- high chemical oxygen demand, typical of domestic leachates

- high levels of phosphorous, an organic nutrient and indicator of sewage wastes

- high levels of phenols, an indicator of waste oils, plastics and detergents, typically

The presence of the sewage landfill site on the northern slope of the landfill had interesting consequences on the well samples. Although TH2 and TH3 were located at similar distances from the landfill site, the levels of pollutants were often quite different. Levels of biological parameters in TH2 were higher, due to the accumulation of sewage at this site. However, the sewage appeared to dilute the inorganic parameters, since their levels in TH2 were less than in TH3. As expected, the levels of most parameters in TH4 and TH5 were lower, due to both dilution with ground water and attenuation. However, some of the salts had higher levels at these locations, due to the proximity to the ocean, and the COD was higher, perhaps due to the marshy conditions.

Significant dilution of the leachate and polluted ground water is considered to take place when the ground water discharges into Coronation Gulf. An indication of the rationale for this statement includes the following:

- Approximately 900 m^3 of leachate is estimated to be generated at the landfill each year from ground water migration and surface water infiltration

- Approximately 18,250 m^3/year of sewage is drained off at landfill (50 000 L/day x 365 = 18,250 cubic metres per year)

- Annual runoff from the landfill area is estimated to be 70 000 m^3/year, diluting the leachate and sewage by a factor of 4.

- The quantity of flow in the littoral zone of the Coronation Gulf is estimated to be 185,000 m^3/h (based on 100 m offshore littoral zone of influence, a current observed at one knot, 1.85 km/h and a one metre water depth). Assuming that flow of ground water into the Gulf takes place only during the approximately 60 days per year when the active zone in the soil is unfrozen, the total quantity of ocean flow that will dilute the ground water and runoff is 2.7×10^8 m^3 of water. Assuming all combined runoff, sewage, and leachate is flushed into the Gulf at this time will lead to a further dilution by a factor of approximately 14,000. This is a conservative estimate since much more water in Coronation Gulf may flow past the area immediately offshore of the landfill site. As well, not all the leachate and sewage may flow into the Gulf during the year, due to the impounding of ground water in the area immediately below the landfill.

5.2 Potential Environmental Impacts

The on-site visit suggested that the ravens, gulls, sparrows, waterfowl, wading birds, ground squirrels and lemmings would have the potential for direct contact with landfill debris and sewage effluent. Fish, any aquatic vegetation and planktonic and benthic organisms, would be exposed to a diluted effluent in the nearshore down-current areas of the Gulf. This concentration would be greatly influenced by the natural lagoon located downslope of the landfill. In this location, the leachate would pool. While this could reduce or eliminate the constant draining to the ocean, the lagoon could act to concentrate toxic chemicals, which could be flushed into the gulf during the spring thaw. Indirect exposure would occur through consumption of vegetation that had absorbed the leachate, or through consumption of organisms that had been exposed to the leachate.

Ground squirrels, lemmings and waterfowl would consume vegetation. Gulls, ravens and perhaps ground squirrels would feed on carcasses, and predator fish species in the gulf, such as Arctic charr, could feed on prey items that have been exposed to contaminants. Gulls would also feed on these items. Birds of prey would feed on rodents and perhaps other birds. This predation on contaminated food items raises the possibility of bioaccumulation. Capelin are known to spawn in the area in the autumn and the sensitive early life stages of this species could become exposed to toxic chemicals. Coppermine is known to be within the range of many land predators, but the chance of these species being present to feed is minimal due to their fear of man and their transient nature.

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

The waste stream generated at Coppermine is typical of small northern communities, being largely paper products and food wastes. Approximately 600 t/year of garbage is generated at Coppermine. As well, approximately 50 m^3 of liquid sewage per day was deposited at the landfill site.

The landfill site investigated in this study was closed at the end of August, 1990. Investigation of the ground water in the vicinity of the landfill site indicated a degradation of the ground water quality downgradient of the landfill site by both leachate originating in the landfill site and by the dumped liquid sewage. The local ground water regime appears to be highly variable and dependent upon the season variations in the active zone above the permafrost. An area downhill from the landfill appears to act as an impoundment area where ground water and surface runoff are temporarily impounded prior to a natural release into the Coronation Gulf.

The ground water downgradient of the landfill contains large concentrations of salts and micro-organisms. This is due to both the leachate produced by the landfill site and by the presence of the liquid sewage. There is apparent attenuation of the chemical and biological characteristics of the ground water as it moves toward Coronation Gulf. It is estimated that approximately 900 cubic metres of leachate per year is generated by the landfill. The liquid contribution is from seasonal ground water infiltration and surface water infiltration. Liquid from sewage dumping operations contributed to the majority of contaminated liquid leaving the site.

Leachate production from the landfill can be expected to continue for a number of years into the future, but probably at declining quantities, since liquid waste disposal is now discontinued, with landfill closure. Leachate generation will be limited to ground water migration and some surface water infiltration into the fill mass. The potential environmental effects of the migration of the contaminated ground water into the Coronation Gulf are considered minor due to large capacity of the ocean to dilute any contaminated water.

6.2 Recommendations

Further work may be desirable to monitor the downgradient ground water conditions at this closed landfill and to further outline the potential environmental effects of the contaminated ground water draining into the Coronation Gulf.

With closure of the site, it is speculated that with a metre of cover, the waste mound will freeze and become part of the permafrost zone. Ground water samples should be recovered once a year from the piezometers installed during this study. The samples should be analyzed for the following indicator parameters:

- pH
- conductivity
- major ions (Na, K, Ca, Mg, C1, SO_4, NO_2 and NO_5)
- biological oxygen demand
- total phenols
- oil and grease

With this monitoring, it could be determined if the waste is entombed and no longer impacting on the surrounding environment.

The relatively small volume of leachate generated is considered to be of minor concern due to the high dilution effect of the receiving body of water, Coronation Gulf. Water analyses of the Coronation Gulf waters could be taken to test this speculation on leachate dilution and dispersion. Biological analyses of the local biota could be undertaken to determine whether an accumulation of persistent chemicals may be occurring in the local food chain.

Consideration should be given to installing piezometers at the new landfill site to monitor ground water conditions at that location.

REFERENCES (in order of appearance in text)

N.W.T., 1990, "Northwest Territories Data Book," Government of the Northwest Territories, Yellowknife.

Bird and Hale Ltd., 1979, "Municipal Refuse Statistics for Canadian Communities over 100,000," Environmental Protection Service, Environment Canada, Ottawa.

Environment Canada, 1979, "Cold Climate Utilities Delivery Design Manual," Environment Canada, Ottawa.

Heinke, G. W. and J. Wong, 1989, "Solid Waste Composition Study for Iqualuit, Pangnirtung, and Broughton Island of the Northwest Territories." Department of Municipal and Community Affairs, Government of the Northwest Territories, Yellowknife.

Institute for Environmental Studies, 1990, unpublished data on hazardous waste generation and composition, at selected sites in the Northwest Territories, Institute for Environmental Studies, Toronto.

Freeze, R. A. and J. A. Cherry, 1979, "Ground Water," Prentice Hall Inc., Toronto.

N.W.T. Water Board, 1981, "Guidelines for Municipal Wastewater Discharges in the Northwest Territories," N.W.T. Water Board, Yellowknife.

APPENDIX

TEST HOLE LOGS

DILLON	PROJECT No. 3360	BOREHOLE No.	1
	DATUM	Sheet	1 of 1
PROJECT	Characterization of Leachate: Coppermine Municpal Dump	DATE	22 August 1990
LOCATION	Coppermine, N.W.T.	INSPECTOR:	R. Reichelt

DEPTH cm.	Elev. Depth m.a.s.l.	Lith.	Description	LABORATORY ANALYSIS Sample No.	Tested for:	Monitor Installation Details
			Elevation of top of piezometer: 9.33 m.a.s.l.			Stickup 74 cm
00.0	8.59					
		-----	0 - 111 cm, CLAY: brown, firm, damp, plastic, slow dilatancy, 80% clay, 10% silt, 10% pebbles	0001	pH, alkalinity, hardness, anions, conductivity, metals, TOC, total phenols, bacterial analysis, BOD, Oil & Grease, total cyanide	^^^^^^^^
05.0		-----				^^^^^^^^
10.0		-----				25.5 cm PVC Pipe Sched.40
15.0		-----		0002	Duplicate sample, not tested	::::::::::
20.0		-----				::::::::::
25.0		-----				::::::::::
30.0		-----				::::::::::
35.0		-----				::::::::::
40.0		-----				90.5 cm #10 Slotted PVC Pipe Sched.40
45.0		-----				::::::::::
50.0		-----				::::::::::
55.0		-----				::::::::::
60.0		-----				::::::::::
65.0		-----				::::::::::
70.0		-----				::::::::::
75.0		-----				::::::::::
80.0		-----				::::::::::
85.0		-----				::::::::::
90.0		-----				::::::::::
95.0		-----				::::::::::
100.0		-----				::::::::::
105.0		-----				::::::::::
110.0	7.48	-----				::::::::::
		***	111 cm, PERMAFROST, no further drilling possible			Sand packed around piezometer, top sealed with cement
115.0						

----- CLAY

::::: SAND

*** PERMAFROST

^^^^ CEMENT

DILLON	PROJECT No. 3360 DATUM	BOREHOLE No. Sheet	2 1 of 1
PROJECT LOCATION	Characterization of Leachate: Coppermine Municpal Dump Coppermine, N.W.T.	DATE INSPECTOR:	22 August 1990 R. Reichelt

DEPTH cm.	Elev. Depth m.a.s.l.	Lith.	Description	LABORATORY ANALYSIS Sample No.	Tested for:	Monitor Installation Details
			Elevation of top of piezometer: 9.33 m.a.s.l.			Stickup 61 cm
00.0	0.27					
05.0		----	0 - 31 cm, CLAY: grey, sandy, firm, plastic, swampy odour, slow dilatancy, 80% clay, 20% silt	0003	pH, alkalinity, hardness, anions, conductivity, metals, TOC, total phenols, bacterial analysis, BOD, Oil & Grease, total cyanide	91.5 cm #10 Slotted PVC Pipe Sched.40 top 70 cm taped
10.0		----				
15.0		----				
20.0		----		0004	Sample tested for Mercury and Volatile Organic Compounds	
25.0	0.00	----				
30.0	-0.04	----				
35.0		***	31 cm, PERMAFROST, unable to drill any more			
40.0						Sand packed around piezometer, top sealed with cement
45.0						
50.0						
55.0						
60.0						
65.0						
70.0						
75.0						
80.0						
85.0						
90.0						
95.0						
100.0						
105.0						
110.0						
115.0						

---- CLAY   *** PERMAFROST

:::::: SAND   ^^^^ CEMENT

DILLON	PROJECT No. 3360 DATUM	BOREHOLE No. Sheet	3 1 of 1
PROJECT LOCATION	Characterization of Leachate: Coppermine Municepal Dump Coppermine, N.W.T.	DATE INSPECTOR:	22 August 1990 R. Reichelt

DEPTH cm.	Elev. Depth m.a.s.l.	Lith.	Description	LABORATORY ANALYSIS Sample No.	Tested for	Monitor Installation Details
			Elevation of top of piezometer: 1.61 m.a.s.l.			Stickup 47 cm
00.0	1.14					
05.0		::::::	0 - 45 cm, SAND: dark grey brown, firm to dense, wet, coarse grained, angular grains, swampy odour, rapid dilatancy, arkose, 50% quartz, 40% feldspar, 10% mafic minerals	0005	pH, alkalinity, hardness, anions, conductivity, metals, TOC, total phenols, bacterial analysis, BOD, Oil & Grease, total cyanide	
10.0		::::::				92 cm #10 Slotted PVC Pipe Sched.40 top 50 cm taped
15.0		::::::				
20.0		::::::		0006	Duplicate sample, not tested	
25.0		::::::				
30.0		::::::				
35.0		::::::				
40.0		::::::				
45.0	0.65	::::::				
		***	45 cm, PERMAFROST, unable to drill any more			
50.0		***				Packed sand around piezometer, top sealed with cement
55.0						
60.0						
65.0						
70.0						
75.0						
80.0						
85.0						
90.0						
95.0						
100.0						
105.0						
110.0						
115.0						

----- CLAY	*** PERMAFROST
:::::: SAND	^^^^ CEMENT

DILLON	PROJECT No. 3360	BOREHOLE No.	4
	DATUM	Sheet	1 of 1
PROJECT	Characterization of Leachate: Coppermine Municpal Dump	DATE	22 August 1990
LOCATION	Coppermine, N.W.T.	INSPECTOR:	R. Reichelt

DEPTH cm.	Elev. Depth m.a.s.l.	Lith.	Description	LABORATORY ANALYSIS Sample No.	Tested for:	Monitor Installation Details
			Elevation of top of piezometer: 1.60 m.a.s.l.			Stickup 48 cm
00.0	1.12					
05.0		::::::	0 - 44 cm, SAND: brown-grey, firm, wet, sub-angular, coarse grained, swampy odour, rapid dilatancy, arkose, 50% quartz, 40% feldspar, 10% mafics, occaisional pebbles	0007	pH, alkalinity, hardness, anions, conductivity, metals, TOC, total phenols, bacterial analysis, BOD, Oil & Grease, total cyanide	92 cm #10 Slotted PVC Pipe top 50 cm taped
10.0		::::::				
15.0		::::::				
20.0		::::::		0008	Duplicate sample, not tested	
25.0		::::::				
30.0		::::::				
35.0		::::::				
40.0		::::::				
45.0	0.68	***	44 cm, PERMAFROST: unable to drill any more			Packed sand around piezometer, top sealed with cement
50.0						
55.0						
60.0						
65.0						
70.0						
75.0						
80.0						
85.0						
90.0						
95.0						
100.0						
105.0						
110.0						
115.0						

----- CLAY

:::::: SAND

*** PERMAFROST

^^^^ CEMENT

DILLON	PROJECT No. 3360 DATUM	BOREHOLE No. Sheet	5 1 of 1
PROJECT LOCATION	Characterization of Leachate: Coppermine Municpal Dump Coppermine, N.W.T.	DATE INSPECTOR:	22 August 1990 R. Reichelt

DEPTH cm.	Elev. Depth m.a.s.l.	Lith.	Description	LABORATORY ANAYSIS Sample No.	Tested for:	Monitor Installation Details
			Elevation of top of piezometer: 1.37 m.a.s.l.			Stickup 0.22 cm
00.0	1.15	:::::	0 - 33 cm, SAND: brown-grey, firm, wet, sub-angular, coarse grained, swampy odour, rapid dilatancy, arkose, 50% quartz, 40% feldspar, 10% mafics, occaisional pebbles	0009	pH, alkalinity, hardness, anions, conductivity, metals, TOC, total phenols, bacterial analysis, BOD, Oil & Grease, total cyanide	
05.0		:::::				
10.0		:::::				
15.0		:::::				92 cm #10 Slotted PVC Pipe Sched. 40 Top 30 cm taped
20.0		:::::		0010	Duplicate sample, not tested	
25.0		:::::				
30.0	0.82	:::::				
35.0		-----	33 - 70 cm, CLAY: blue-grey, firm, wet, plastic, slow dilatancy, 90% clay, 10% silt, occaisional pebbles			
40.0		-----				
45.0		-----				
50.0		-----				
55.0		-----				
60.0		-----				
65.0		-----				
70.0	0.35	***	70 cm, PERMAFROST, unable to drill any more			
75.0						Packed sand around piezometer, top sealed with cement
80.0						
85.0						
90.0						
95.0						
100.0						
105.0						
110.0						
115.0						

----- CLAY

::::: SAND

*** PERMAFROST

**** CEMENT

CHEMICAL CHARACTERIZATION OF LEACHATE FROM THE NORTHWEST TERRITORIES MUNICIPAL DUMPS

HAY RIVER MUNICIPAL DUMP

M. M. DILLON LIMITED
CONSULTING ENGINEERS
AND PLANNERS

MARCH 1991
N 3360-00

DILLON
Consulting Engineers • Planners
Environmental Scientists

OUR FILE N 3360-00
YOUR FILE

21 March 1991

Indian, Northern Affairs Canada
Water Resources Division
Regulatory Approvals Section
P.O. Box 1500
YELLOWKNIFE, N.W.T.
X1A 2C9

Attention: Mr. Greg Cook

Chemical Characterization of Leachate from the Hay River, Northwest Territories Municipal Dump

Dear Sirs:

We are pleased to submit the final report for the Chemical Characterization of the Hay River, Northwest Territories Municipal Dump. This report provides the basis for leachate characterization and leachate impact on the surrounding environment.

We appreciate the opportunity to serve as your consultants.

Yours truly,

Chris Robinson, P. Eng.
Project Manager

DMH:kc

Encl.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

Indian and Northern Affairs Canada, Water Resources Division and the Government of the Northwest Territories, Department of Renewable Resources have requested Dillon to study the Hay River Landfill site to determine the extent of leachate generation and effect on the surrounding environment.

Hay River is a typical moderately sized community in the discontinuous permafrost zone. The major components of the waste stream include paper, packaging, food wastes, construction wastes, and discarded appliances and vehicles.

The Hay River Municipal Landfill consists of an active dumping area, a scrap metal pit, a liquid waste pit, and a number of abandoned pits. Ground water flow in the area is towards the Hay River, northeast of the landfill. The water table is 4 to 7 m below the soil surface. Most of the waste or buried in the landfill is deposited above the water table.

A landfill investigation took place between 6 September and 14 October 1990. The investigation consisted of three phases: an initial reconnaissance of the site, the installation of five monitoring wells, and the monitoring of these wells and the collection and analyses of ground water samples.

Study results of the investigation and analyses include the following:

- Leachate emanating from the landfill site was found to be higher in metals, salts, and suspended solids than the background ground water.
- The outflow of ground water from the landfill site(s) area into the Hay River is estimated to be typically 1,800 m^3/year.
- The dilution of seepage from the banks of the Hay River, in the vicinity of the landfill, by the flow of the Hay River is in order of 2,000,000 to 1.
- The potential environmental effects of the landfill are limited. The flow of ground water contaminated by the landfill site into the river can affect the organisms in the water and those dependent on them for food.
- The potential for environmental effects from the landfill can be minimized by prudent operational practises and control of surface drainage at the landfill.

It may be desirable to continue monitoring the ground water quality by taking samples from the monitoring wells installed for this study on a periodic (eg. yearly) basis. This would provide an indication of any changes in the ground water quality. It may also be desirable to install another monitoring well between the active disposal area and the Hay River, which was inaccessible to the drilling equipment used in this study.

The net environmental impacts of the Hay River Landfill are low, however, due to its proximity to the river, it may be desirable to seek an alternate, more isolated landfill site.

HAY RIVER MUNICIPAL LANDFILL SITE

1.0 INTRODUCTION

Indian and Northern Affairs Canada, Water Resources Division and the Government of the Northwest Territories, Department of Renewable Resources have begun to introduce regulatory requirements regarding the operation of solid waste landfill sites in the water licenses being issued to applicants. In the past, minimal control was exercised over the deposition of wastes at the landfill sites. Wastes ranging from typical household garbage to raw sewage were often dumped in close proximity to the community which produced the waste material. Although the new regulatory requirements will improve the landfill operations, it is important to study these existing landfill sites to determine the effects on both the community and the surrounding environment. This will not only aid in the successful management of new landfill sites and improve the operations of existing sites, but could assist in producing regulations which are more specific to N.W.T. conditions.

One method of quantifying the impacts of these landfill sites is to analyze the leachates in the surrounding water. Toxic chemicals present in the landfill leach out into the local ground water and surface water and this leachate can be collected and analyzed in laboratories. It is also possible to estimate the type and quantity of waste which is being dumped.

As a result of a request from the Department of Indian and Northern Affairs, M. M. Dillon has carried out an investigation of the Municipal Landfill at Hay River, N.W.T. The priorized objectives for this investigation were as follows:

a) to determine the quality and characterization of leachate emanating from the landfill site;

b) to provide information concerning the quantity and extent of surface and ground water movement at the site;

c) to provide a correlation between the waste deposition and the quality, characterization and quantity of leachate at the landfill site;

d) to give some indication of the environmental impacts of the landfill site.

This study was done concurrently with a similar study of the Municipal Landfill at Coppermine, N.W.T. by the same study team.

Figure 1.1 shows the location of Hay River in the Northwest Territories.

The terms "dump" and "landfill" are often used inter-changeably. For this report, "dump" is used in the title as in the Terms of Reference. For the rest of the report, the term "landfill" is used. Landfill in the context of this report implies a designated site area for the disposal of municipal wastes.

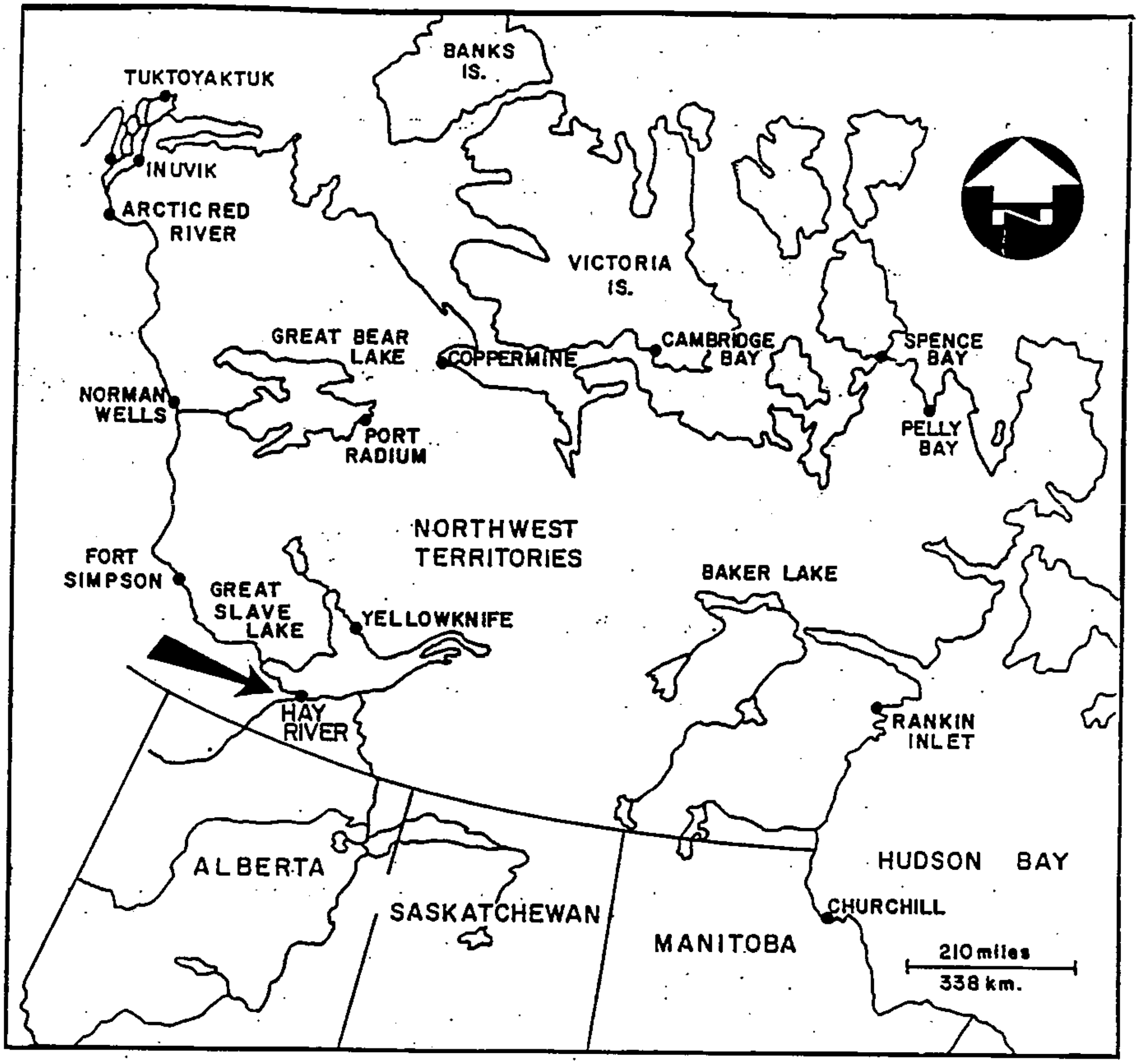


FIGURE 1.1 : MAP OF NORTHWEST TERRITORIES SHOWING STUDY AREA

2.0 BACKGROUND INFORMATION

2.1 Hay River Community Information and Waste Generation

The Town of Hay River with a population of over 2,900, is located 848 air km north of Edmonton and 201 air km south of Yellowknife in the Northwest Territories. The town is situated on the delta of the Hay River which flows into the southern end of Great Slave Lake. Two main channels of this river flow around the east and west sides of Vale Island, which was the original town site. The town was resituated in 1963 after a major flood, and is now located on the west bank of the river, just upstream from the delta; however, the old town site is still the location of the airport and several residential and industrial properties. The town is actually composed five or six communities spread out along Hay River. These include the West Channel Village, on the shore of Great Slave Lake, and the old and new Dene villages on the Hay River Dene Reserve, on the east bank of Hay River.

The nomadic aboriginal Dene have been in the area for hundreds of years, but it was not until 1806 that a permanent trading post was built in the area. A trading post and a missionary church were established on the town site in 1868. In the 1930s, the 150 residents were serviced by aircraft and steamboats. Mineral development prompted the construction of a railway into the area at the end of that decade and in the 1960s the Great Slave Railway reached Hay River.

Hay River is located as a communications "hub" for the north. It has been called the most road accessible town in the N.W.T. and has good road, rail and air transportation to Edmonton in the south and to many points by road and air in the north. The access to Canada's largest river, the Mackenzie, which flows into the Arctic, allows barges from the offshore Arctic oil projects access to shipways and repair yards which have been constructed on the Vale Island waterfront at Hay River.

Due to its location, the economy of Hay River is based on transportation, and as a supply centre for industrial parts and service. Although commercial fishing was once the leading industry, the economy is now largely dependent on these other activities. Agriculture is becoming somewhat more important, with the development of cattle and hog producers.

Since Hay River is a larger and more industrialized community, the composition of the waste material is quite different from that generated by smaller communities in the Northwest Territories, such as Coppermine. There is likely to be a larger percentage of hazardous wastes generated in Hay River than in smaller communities, due to the fact that it is a supply and service centre with large scale construction, repair and transportation and storage activities.

The quantity of waste generated in Hay River can be estimated by analyzing the results of studies of generation of waste in similar communities. In general, two basic types of waste are generated by a community. The first type is general municipal solid waste and includes all discarded solid material from households, commercial, and institutional establishments. The second type of waste is classified as industrial waste and this includes waste from industrial processes, construction/demolition waste, and special wastes, such as discarded automobiles, machinery and hazardous wastes.

No specific study has been made of general municipal waste generation at Hay River. However, it is possible to estimate the amounts of general municipal waste which are generated by using studies of similar communities. In a recent study on solid waste for the City of Yellowknife, a total of 10,550 t/year was estimated. This total included all residential/commercial/industrial waste (including some car bodies), but excluded construction and demolition wastes (Stanley, 1990). This corresponds to a per capita waste generation rate of 0.78 t/year. Recent studies of cities in southern parts of Canada show average waste generation rates to be approximately 1 tonne/capita/year (Dillon, 1990).

Based on activities of industry and commerce in Hay River, a conservative estimation of total waste generation is 1 tonne/capita/year. This corresponds to approximately 3,000 t/year of solid waste generated.

The composition of waste deposited at the Hay River Municipal Landfill can be estimated from field observations made by the study team, from previous studies made of the Hay River Landfill and from studies made on landfills in similar communities. Observations made by the study team indicated that about one-third of the waste deposited at the Hay River Landfill was from paper products. Another third of all the material at the landfill consisted of construction/demolition wastes, used cars and appliances. The remaining third included food wastes, plastics, metals, and hazardous wastes, such as used motor oil. A pit measuring approximately 35 m by 10 m (depth unknown) was observed to be full of used engine oil and possibly other liquid wastes.

Yaworsky (1985) observed a high percentage of combustible paper, food, and wood products and considerable amounts of construction wastes, metals, tires, appliances, furniture, propane cylinders, drums, and several discarded cars. Yaworsky (1985) also noted the presence of wastes, currently classified as hazardous, at the landfill site. These observations were consistent with those subsequently made by the study team.

An estimate of the composition of the general municipal waste at Hay River can be made by observing the results from studies of municipal waste composition in Canada. Table 2.1 summarizes these results and also indicates the estimated composition of total municipal waste stream for the Town of Hay River.

It is more difficult to estimate the composition of waste in the industrial/special category. Rough estimates from observations at the Hay River Landfill indicated that waste in this category was approximately 30 percent cardboard and wood (eg: packaging materials from industrial facilities), 30 percent construction/demolition rubble, 30 percent discarded vehicles and machinery, and 10 percent hazardous waste, mostly used engine oil. Temporal extrapolations of these levels should be made with caution as they are based only upon observations made at one point in time, and would not be recognized as a waste stream audit.

The composition of hazardous waste is of particular interest, since the leachate from these materials is most toxic to the environment. An inventory of hazardous waste at selected communities in the N.W.T. is currently being undertaken on behalf of the G.N.W.T. by the Institute for Environmental Studies, University of Toronto. The study is not complete, but preliminary results indicate that the largest components of hazardous waste generated at Hay River are waste oil, contaminated fuels, fuel tank sludge, and sewage sludge. The inventory also noted the presence of animal carcasses, discarded lead/acid batteries, and drums at the Hay River Landfill Site.

2.2 Hay River Municipal Landfill Facility

The present landfill site has been in use since 1973 and is located approximately 7.5 km south of the town, on the north side of N.W.T. Highway #5 to Pine Point (Figure 2.1). Before the establishment of this site, there were a number of other landfill sites, some of which were located closer to the town. These included an old railway borrow pit opposite the caboose on Highway #2 and an oil disposal lagoon located on the west

TABLE 2.1 MUNICIPAL WASTE COMPOSITION (PERCENTAGE OF TOTAL)

Waste Stream Item	Canadian Annual Averages (Bird & Hale, 1979)	Alaskan Communities (Environment Canada, 1979)	Yellowknife:Residential/ Industrial/Commercial	Iqaluit (Heinke & Wong, 1989)	Hay River Estimates
Food Waste	20.7%	15.2%	25%	21.4%	22%
Paper Products	42.3%	43.7% - 45.8%	33%	37.9%	40%
Plastics	5.5%	4.0% - 45.8%	10%	} 13.3%	10%
Rubber & Leather	} 4.6%	0.9% - 1.3%	(a)		2%
Textiles		2.1% - 3.0%	(a)	3.5%	3%
Wood	4.0%	0.6% - 1.2%	4%	4.5%	4%
Metals	7.0%	10.0% - 12.5%	8%	9.4%	10%
Glass & Ceramics	7.6%	14.5% - 17.1%	4%	3.1%	4%
Yard Wastes	5.3%	0% - 6.5%	(b)	(c)	2%
Inerts & Others	3%	0.4% - 1.7%	16%	6.5% (d)	3%

Notes: (a) Rubber, leather and textiles included in "Others".
(b) Yard waste and food waste listed as "organics" in original report.
(c) Yard waste not mentioned in report.
(d) 3.5% of "Others" made up of diapers.

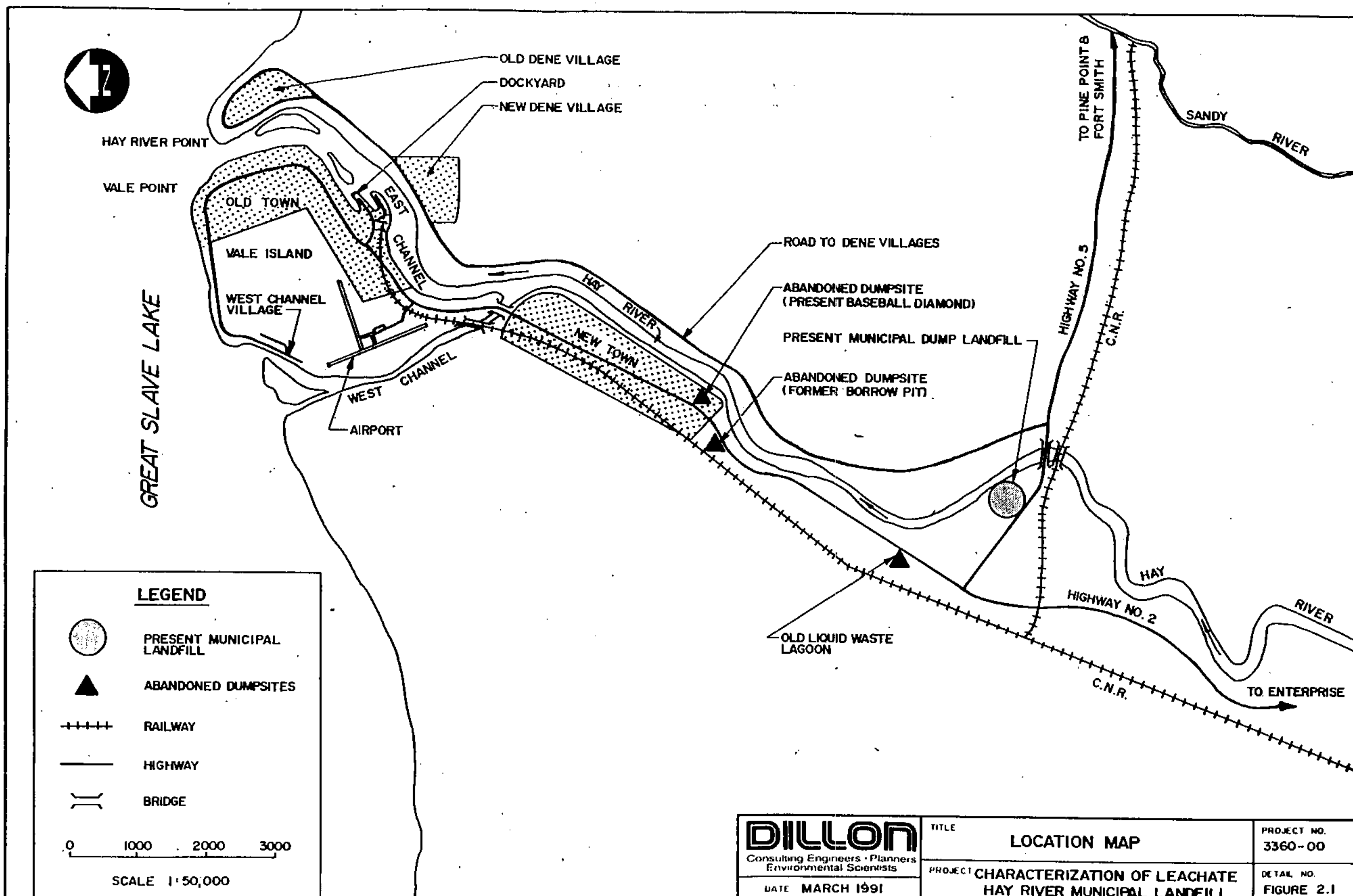
side of the highway to Enterprise, 5.5 km south of the town (Figure 2.1). Most of the previous sites were used for a period of less than two years (Yaworsky, 1985).

The present landfill site consists of an active pit west of the access road, two abandoned pits east of the access road, (one being opposite the current active area), a scrap metal pit directly north of the abandoned pit and two more abandoned pits north of the scrap metal pit, with a waste oil pit in between (Figure 2.2). Associated with the landfill, but reached by a separate access road, is a site where fish waste is disposed (Figure 2.2). The abandoned sites appear well covered and contoured to the approximate original grade of the land.

Wastes appeared to be dumped wherever it was convenient for the truck operators and were later pushed into the active pit by a caterpillar tractor. Scavenging of wastes at the landfill by residents of Hay River appeared to be a common activity. There were no signs at the landfill which indicated where dumping was permitted, or what type of wastes, if any, were prohibited at the landfill site. The area to the northwest, where fish wastes were dumped, also showed evidence of the dumping of general household waste. This household waste was not buried, but left on the ground. Windborne litter was found throughout the perimeter of the landfill site and up to 100 m away, in the bush surrounding the site. Uncontrolled burning of waste in the active pit has also been observed. Numerous gulls and ravens were also observed scavenging at the landfill site.

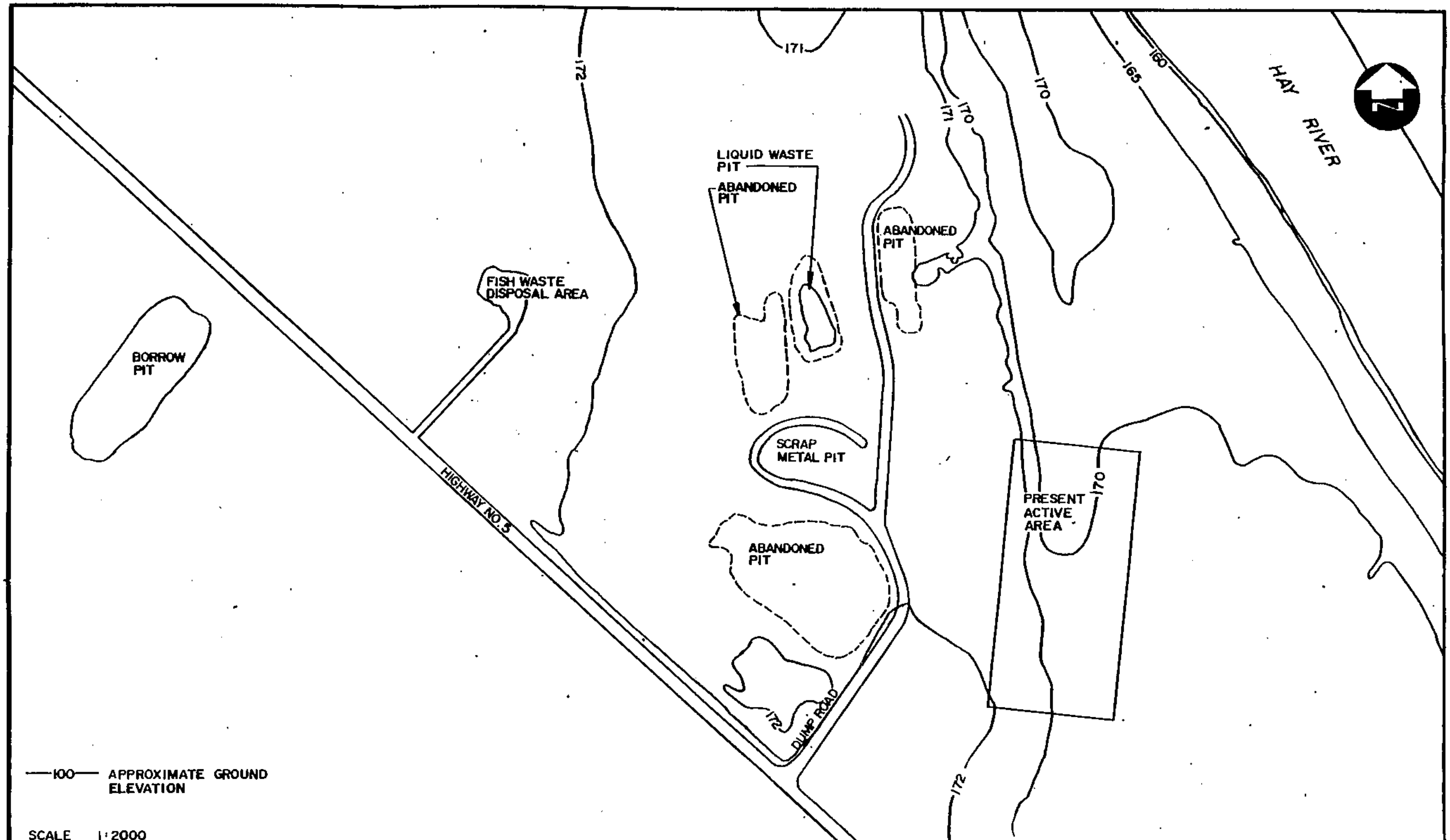
2.3 Regional Geology and Hydrogeology

The surface geology of the Hay River area consists of deltaic deposits overlying glacial tills. The deltaic deposits vary in thickness from 3 to 10 m. The glacial deposits vary in thickness from 10 to 20 m. The overall thickness of overburden varies from 20 to 30 m. The deltaic deposits near the surface are predominantly silts and clays with discontinuous sand stringers. The underlying glacial deposits are silty-sandy tills overlying clay tills. Discontinuous sand lenses are common in both the silty-sandy tills and the clay tills. The bedrock consists of calcareous shale of the Hay River Formation (Geological Survey of Canada, 1974).



DILLON
Consulting Engineers · Planners
Environmental Scientists

DATE MARCH 1991	TITLE LOCATION MAP	PROJECT NO. 3360-00
	PROJECT CHARACTERIZATION OF LEACHATE HAY RIVER MUNICIPAL LANDFILL	DETAIL NO. FIGURE 2.1



DILLON Consulting Engineers · Planners Environmental Scientists	TITLE PIEZOMETER LOCATION HAY RIVER MUNICIPAL LANDFILL	PROJECT NO. 3360 - 00
DATE MARCH 1991	PROJECT CHARACTERIZATION OF LEACHATE HAY RIVER MUNICIPAL LANDFILL	DETAIL NO. FIGURE 2.2

Hay River lies within the region of discontinuous permafrost (Brown, 1970). Land near major bodies of water is often not favourable to the presence of permafrost.

Ground water flow in the Hay River region generally follows the topography in the unconsolidated overburden. Thus, ground water flow is from the topographic highs towards the topographic lows. In the area of the Hay River Municipal Landfill, ground water flow in the surficial aquifer is in an easterly direction toward the Hay River. Depths to the water table vary from near the surface in areas south of Highway No. 5, to 4 to 5 m below surface in the area of the landfill.

Ground water flows through both the surficial deltaic deposits and the glacial tills. The flow through the deltaic deposits is limited in areal extent by the discontinuous nature of the sand lenses in the clays and silts which predominate. The glacial tills, which normally have a low hydraulic conductivity, are fractured in the Hay River area and allow much higher flow rates than areas of unfractured tills. In the immediate area of the Hay River Landfill, the deltaic deposits are generally above the water table and most lateral ground water flow is in the fractured tills. Fracturing in the tills can be expected to decrease with depth.

The fractured shale of the Hay River Formation is the major aquifer in this region. It is probably in direct hydraulic contact with the Hay River (Yaworsky, 1985). There may be some hydraulic communication through the overlying tills but, as the fracturing in these tills decreases with depth, hydraulic communication is expected to be small. Studies of this aquifer (Harlan, 1972; Environment Canada, 1981) suggest low hydraulic transmissivities for this aquifer (4.3×10^{-5} to 5.2×10^{-5} m^2/S). The Hay River is probably a major source for recharge of this aquifer. The aquifer dips towards the southwest and regional ground water movement is in that direction.

Ground water seeps into the Hay River have been noted by a previous study (Yaworsky, 1985) and it is considered likely that leachate from the Hay River Municipal Landfill migrates to the Hay River predominantly via this pathway.

2.4 Surface Drainage Patterns

Regional surface drainage trends in the Hay River area are towards the north. The major water course in the area, the Hay River, flows into Great Slave Lake. Local drainage patterns tend to follow local topography and usually lead to either the Hay River or Great Slave Lake.

Historic water flow records for the Hay River were obtained from the Inland Waters Directorate (1977) and indicate a mean annual flow of 98.5 m^3/S. Mean flows are greatest in May (mean monthly flow 441 m^3/S) and are lowest in March (mean monthly flow 3.1 m^3/S).

3.0 FIELD INVESTIGATION

3.1 Landfill Site Investigation

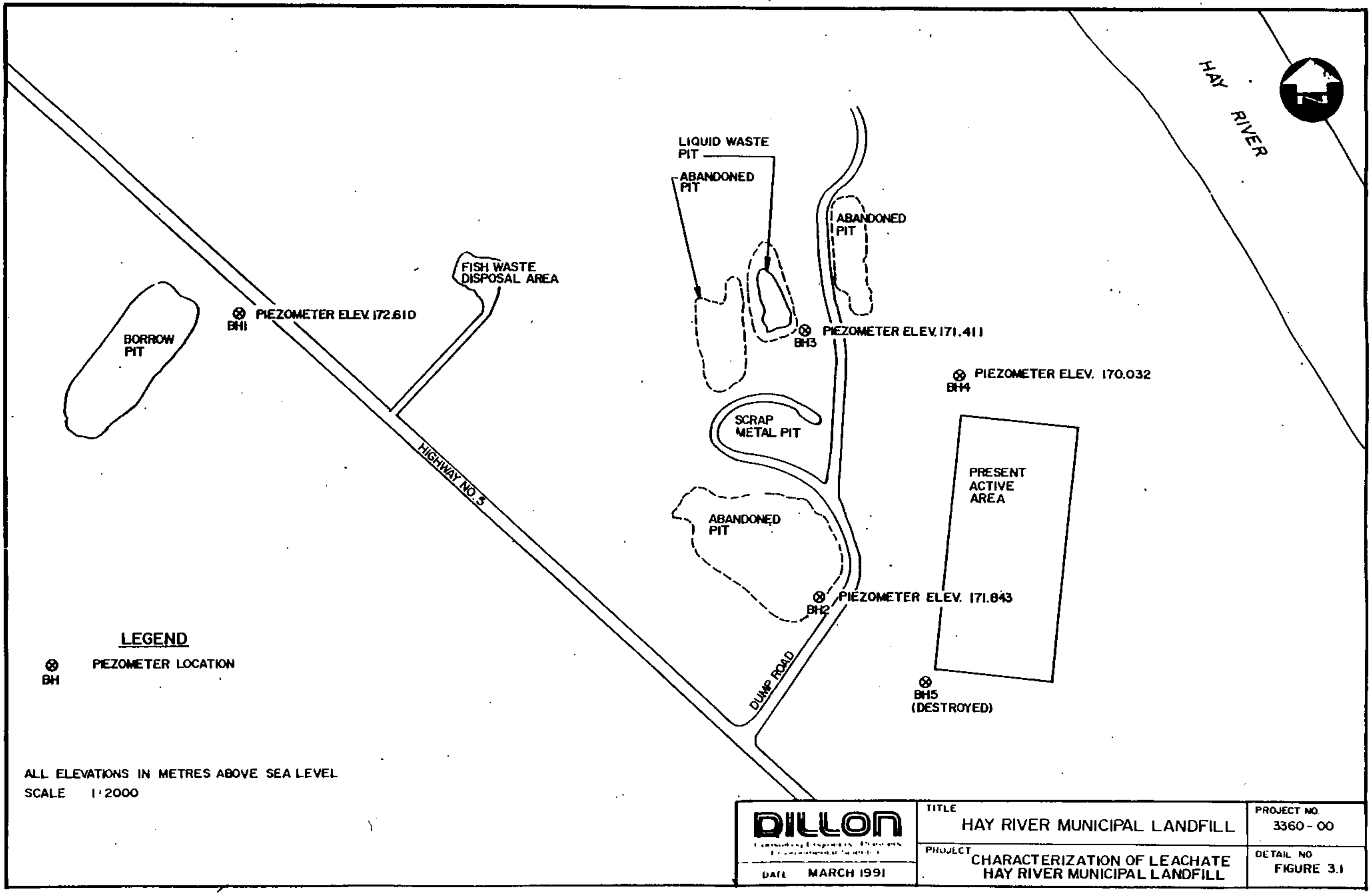
The landfill site investigation took place between 6 September 1990 and 14 October 1990. The investigation consisted of three phases. Phase One was an initial reconnaissance of the site, Phase Two involved the installation of monitoring wells (piezometers) and Phase Three was the regular monitoring of the piezometers and the collection of ground water samples.

The field reconnaissance was undertaken on the afternoon of September 6, 1990. A general reconnaissance was made of the site and the local conditions were noted. Observations of the composition and deposition of the waste were made, as previously discussed in Section 2.1 and 2.2. The sites for monitoring wells were selected on the basis of the need to obtain representative ground water samples and the accessibility for the drilling rig. As the area around the landfill is heavily forested, drilling for this investigation could only be done in areas which were accessible to the drilling rig.

Five piezometers were originally installed in the investigation. Locations of the piezometers are shown in Figure 3.1. Borehole 1 (BH1) was installed northwest of the landfill site across Highway No. 5 in a location upgradient of the landfill site, in order to provide background water quality samples. Borehole 2 (BH2) was installed on the edge of an abandoned pit across the access road from the present active area, in order to monitor leachate generation at that location. Borehole 3 (BH3) was installed adjacent to the waste oil pit, in order to monitor ground water conditions at that location. Borehole (BH4) was installed in the most accessible location downgradient of the present active pit, to the northwest of the active pit, to monitor ground water installation, Borehole (BH5), was installed on the southern edge of the active pit, in order to obtain ground water samples at that location.

The drilling program and installation of the piezometers was undertaken on September 7, 1990. The drilling rig used was a truck mounted rotary type drilling rig (Brat 22) provided and crewed by Canadian Geological Drilling Ltd. of Edmonton. Locations of the piezometers are shown on Figure 3.1.

All boreholes were drilled with 152 mm (6") solid stem augers. The auger flights were lifted out of the hole every metre and the lithology noted. Holes were drilled to between 9 and 11 m depth in order to intercept the water table. After drilling each hole, the auger flights were cleaned off with clear water.


HAY RIVER
LIQUID WASTE PIT
ABANDONED PIT
ABANDONED PIT
FISH WASTE DISPOSAL AREA
BORROW PIT
PIEZOMETER ELEV. 172.610
BH1
PIEZOMETER ELEV. 171.411
BH3
PIEZOMETER ELEV. 170.032
BH4
SCRAP METAL PIT
PRESENT ACTIVE AREA
ABANDONED PIT
PIEZOMETER ELEV. 171.843
BH2
BH5 (DESTROYED)
HIGHWAY NO. 5
DUMP ROAD
LEGEND
BH PIEZOMETER LOCATION
ALL ELEVATIONS IN METRES ABOVE SEA LEVEL
SCALE 1:2000
DILLON
DATE MARCH 1991
TITLE HAY RIVER MUNICIPAL LANDFILL
PROJECT CHARACTERIZATION OF LEACHATE HAY RIVER MUNICIPAL LANDFILL
PROJECT NO. 3360-00
DETAIL NO. FIGURE 3.1

In each hole, 50 mm (2") Schedule 40 PVC pipe was installed with the bottom three metres being #10 slotted PVC pipe. The slotted pipe was installed so as to intercept ground water flow through the sandy and fractured clay tills below the water table. To complete the installation, sand was packed around the slotted pipe and the remainder of the hole was backfilled with bentonite pellets to seal off the installation. Borehole logs are found in Appendix "A."

The final phase of the field investigation involved the monitoring of the wells. First, the elevation and location of each well was surveyed and then, the water levels in the piezometers were monitored over time. Table 3.1 shows the water levels in the piezometers. Borehole (BH5) well was particularly interesting as permafrost was encountered at a depth of 8.0 metres. Unfortunately, BH5 was later accidentally destroyed by a vehicle during operations at the landfill site and could not be sampled.

The sampling of each piezometer involved a series of steps, when the water level in the piezometer appeared to have stabilized and water sampling could be undertaken. Prior to sampling, the initial water level in each well was recorded. The wells were then bailed to remove the water in the boreholes, so that samples would be representative of the ground water. After allowing the wells to recover for 12 hours, water samples were removed from the wells using a tube bailer. The tube bailer consisted of a PVC tube, 60 cm long, with a diameter of 25 mm, and a ball valve at the lower end. The bailer was lowered into the well on a nylon cord and allowed to fill with water. The bailer was then removed from the well and the sample immediately transferred to sample bottles. This process continued until all the sample bottles for the location were filled. The bailer was then cleaned with distilled water and the procedures repeated at the next well. The samples recovered are further discussed in Section 3.2.

TABLE 3.1
WATER ELEVATIONS IN PIEZOMETERS
9 Sept. 1990 to 14 Oct. 1990

Borehole Number	Piezometer Elevation (metres above sea level)	Water level elevation on the following dates: 09/09/90	23/09/90	30/09/90	11/10/90	14/10/90
BH1	172.610	172.065	172.018	171.884	171.728	171.862
BH2	171.843	-	166.856	166.837	166.671	166.755
BH3	171.411	-	165.502	165.574	165.533	165.535
BH4	170.032	-	164.276	164.538	164.151	162.397

After the samples were obtained, the water levels in each piezometer were monitored in order to record the recovery rate of the wells. This enabled an estimate of the hydraulic conductivity of the soil to be calculated, using a formula developed for this purpose (Hvorslev, 1951). Hydraulic conductivities in the fractured clay till and sandy till were found to vary from 2×10^{-8} to 4×10^{-7} m/s. Average hydraulic conductivity was found to be 9×10^{-7} m/s.

3.2 Laboratory Analysis

Two sets of samples were taken at each monitoring well. After collection, all samples were stored in coolers at a temperature of approximately 4°C. The first set was sent to the Department of Indian and Northern Affairs Water Laboratory in Yellowknife, for analysis. The duplicate set was retained for the second stage of analysis.

The water was sampled for general chemistry (pH, conductivity, alkalinity, hardness, anions), heavy metals, Total Organic Carbon (TOC), total phenols, bacterial analysis, Biological Oxygen Demand (BOD), oil and grease, and total cyanide. Bacterial and BOD samples were not taken for the duplicate set since they would not give reliable results after storage periods greater than 24 hours.

4.0 RESULTS OF FIELD INVESTIGATION

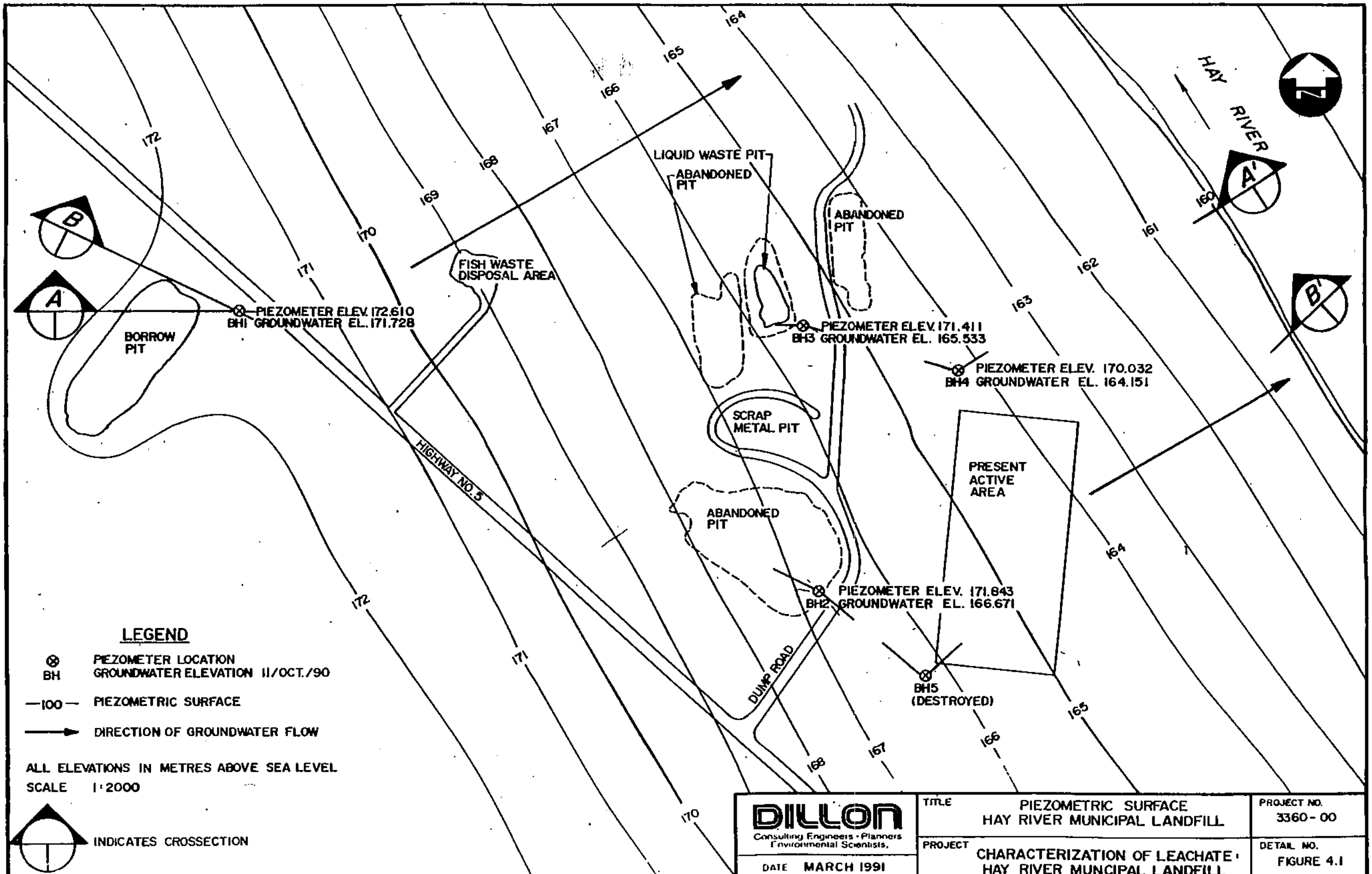
4.1 Hydrogeology of Landfill Site

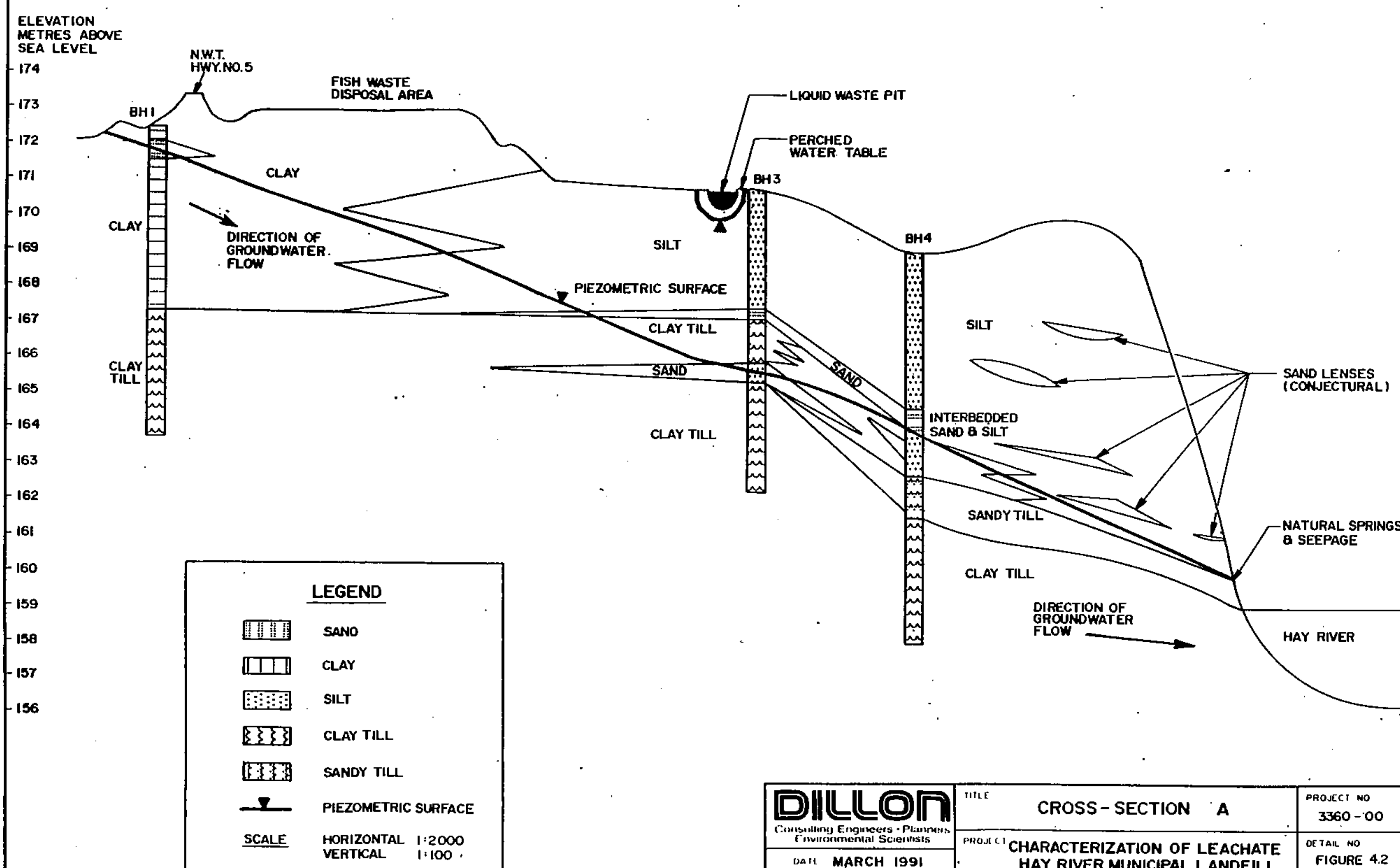
The results from estimates of the piezometric surface of the ground water in the area of the landfill site (Figure 4.1) indicate that ground water flow is predominantly towards the northeast. The west bank of the Hay River appears to be a discharge area for ground water migrating beneath the landfill area.

Most lateral ground water flow is in the formations below the water table (piezometric surface). These formations, as shown on the borehole logs in Appendix A, are predominantly sandy tills and fractured clay tills with lenses of sand. The overlying formations are predominantly deltaic silts and clays. Ground water movement is predominantly vertical and consists of water percolating downward through the unsaturated zone.

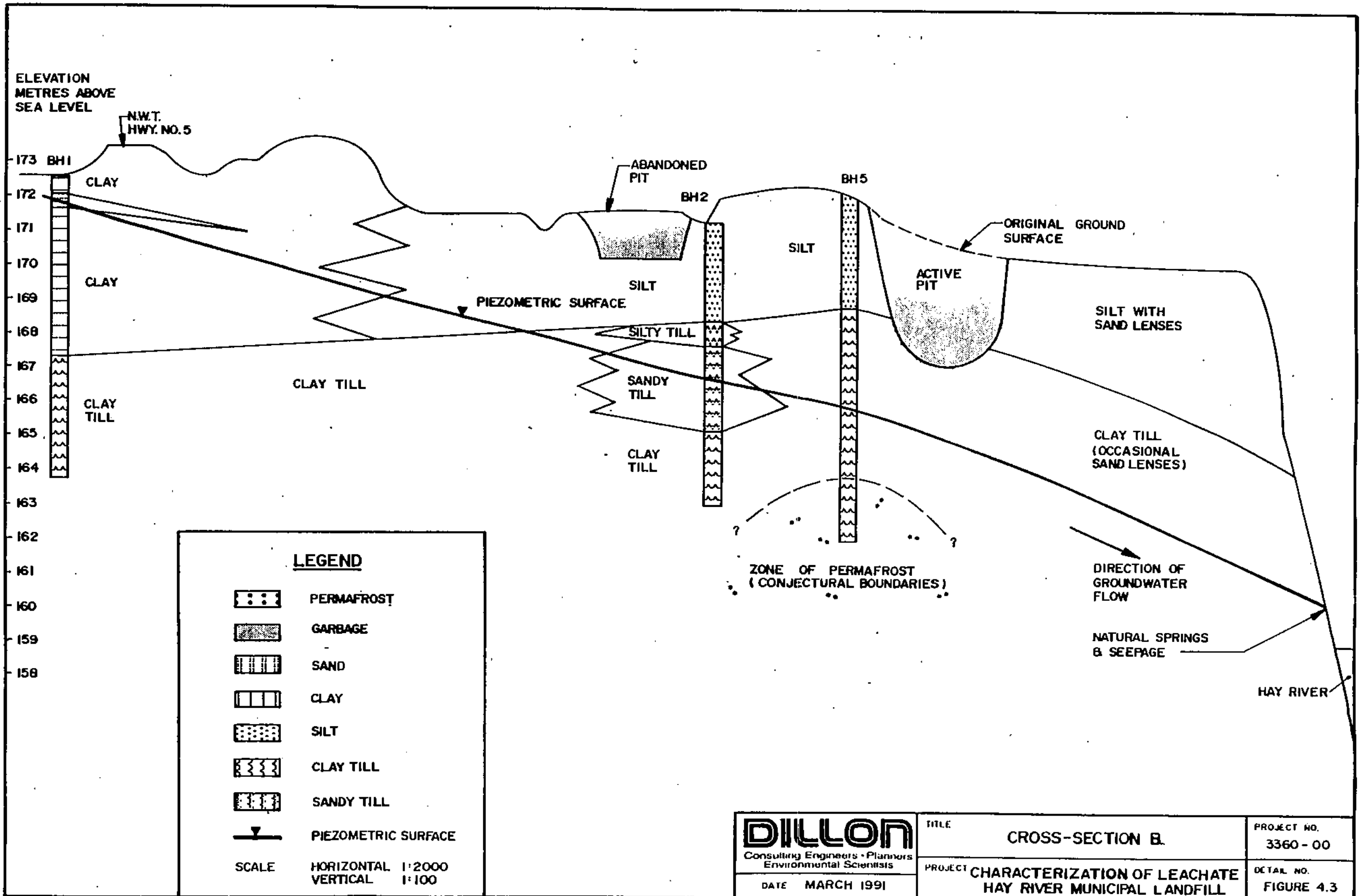
Figures 4.2 and 4.3 show cross-sections through the study area. Cross-section A to A^1 (Figure 4.2), is from BH1 to BH3 to BH4 and through the Hay River. Cross section B to B^1 (Figure 4.3), is from BH1 to BH2 to BH5 and also passes through the Hay River.

Field measurements of the hydraulic conductivity of the glacial tills beneath the landfill site (discussed in Section 3.1) showed a range of between 2×10^{-6} to 4×10^{-9} m/s with an average hydraulic conductivity of 9×10^{-7} m/s. The hydraulic gradient from BH2 to the Hay River was approximately 0.02, based upon field measurements. The rate of ground water movement was estimated using the formula "$V_s = Ki/n$". (Freeze and Cherry, 1979) where "V_s" is the rate of ground water movement (seepage velocity), "K" is the average hydraulic conductivity, "i" is the hydraulic gradient and "n" is the porosity of the porous medium. Fractured tills typically exhibit porosities in the order of 1×10^{-4} (Grisak, Cherry, Vonhof, and Blumele). Using this formula for seepage velocity on the range of hydraulic conductivities established during field measurements, gives an average seepage velocity of 5700 m/year.


HAY RIVER
A
A'
B
B'
N
160
161
162
163
164
165
166
167
168
169
170
171
172
LIQUID WASTE PIT
ABANDONED PIT
ABANDONED PIT
ABANDONED PIT
SCRAP METAL PIT
PRESENT ACTIVE AREA
FISH WASTE DISPOSAL AREA
BORROW PIT
HIGHWAY NO. 5
DUMP ROAD
PIEZOMETER ELEV. 172.610
BH1 GROUNDWATER EL. 171.728
PIEZOMETER ELEV. 171.411
BH3 GROUNDWATER EL. 165.533
PIEZOMETER ELEV. 170.032
BH4 GROUNDWATER EL. 164.151
PIEZOMETER ELEV. 171.843
BH2 GROUNDWATER EL. 166.671
BH5 (DESTROYED)
LEGEND
BH PIEZOMETER LOCATION GROUNDWATER ELEVATION 11/OCT./90
—100— PIEZOMETRIC SURFACE
DIRECTION OF GROUNDWATER FLOW
ALL ELEVATIONS IN METRES ABOVE SEA LEVEL
SCALE 1:2000
INDICATES CROSSECTION
DILLON
Consulting Engineers • Planners Environmental Scientists,
DATE MARCH 1991
TITLE PIEZOMETRIC SURFACE HAY RIVER MUNICIPAL LANDFILL
PROJECT CHARACTERIZATION OF LEACHATE · HAY RIVER MUNCIPAL LANDFILL
PROJECT NO. 3360-00
DETAIL NO. FIGURE 4.1



DILLON Consulting Engineers · Planners Environmental Scientists	TITLE CROSS - SECTION A		PROJECT NO 3360 - 00
DATE MARCH 1991	PROJECT CHARACTERIZATION OF LEACHATE HAY RIVER MUNICIPAL LANDFILL		DETAIL NO FIGURE 4.2


ELEVATION
METRES ABOVE
SEA LEVEL
173
172
171
170
169
168
167
166
165
164
163
162
161
160
159
158
BH1
N.W.T.
HWY. NO. 5
CLAY
CLAY
CLAY TILL
CLAY TILL
ABANDONED
PIT
BH2
BH5
SILT
SILT
PIEZOMETRIC SURFACE
SILTY TILL
SANDY TILL
CLAY TILL
ORIGINAL GROUND SURFACE
ACTIVE PIT
SILT WITH SAND LENSES
CLAY TILL (OCCASIONAL SAND LENSES)
ZONE OF PERMAFROST (CONJECTURAL BOUNDARIES)
DIRECTION OF GROUNDWATER FLOW
NATURAL SPRINGS & SEEPAGE
HAY RIVER
LEGEND
PERMAFROST
GARBAGE
SAND
CLAY
SILT
CLAY TILL
SANDY TILL
PIEZOMETRIC SURFACE
SCALE
HORIZONTAL 1:2000
VERTICAL 1:100
DILLON
Consulting Engineers • Planners
Environmental Scientists
DATE MARCH 1991
TITLE CROSS-SECTION B.
PROJECT CHARACTERIZATION OF LEACHATE
HAY RIVER MUNICIPAL LANDFILL
PROJECT NO. 3360 - 00
DETAIL NO. FIGURE 4.3

The quantity of ground water flow out of the area of the landfill site into the Hay River was estimated using the Dupuit-Forscheimer equation (Dupuit, 1863, Forscheimer, 1930). The quantity of flow, "Q", can be estimated using the formula: $Q = K(h_1^2 - h_2^2)/2L$ per unit length of seepage face where "K" is the hydraulic conductivity, an average of 1.15×10^{-6} m/s; "h_1" and "h_2" are the different elevation of the piezometric surface across the study area. This means an outflow of ground water from the area of the landfill into the Hay River is estimated to be typically 1,800 m^3/year.

Estimates of seepage dilution from the landfill to Hay River can be made using the known discharge of the Hay River. The ratio of estimated potentially contaminated ground water to Hay River discharge is 1 to 2,000,000.

4.2 Typical Waste and Typical Characteristics of Leachate Generated

The chemical characteristics of leachate generated by a landfill depend upon the types of garbage deposited in the landfill. Accurate predictions of specific contaminants in the leachate require records of the types of waste deposits, operating procedures, and comprehensive knowledge of the site specific fill environment. Typical leachate characteristics and their origins can be anticipated based on the general types of waste which are landfilled. A list of contaminants typically generated by materials in a municipal landfill is presented in Table 4.1 (CCREM, 1989).

Results from the on-site visit indicated that paper products formed a considerable portion of the garbage at the Hay River landfill. Paper products deposited in a landfill contribute two main types of chemicals to the leachate generated by the landfill. The first type is associated with the chemical and biological decomposition of the paper fibres. This group of chemicals includes: organic carbon, ammonia, nitrates, nitrites, phosphates, sulfides, calcium, sodium, and magnesium. The second type of chemicals that leach out of decomposing paper in a landfill originate in the inks and finishes used on paper products. The inks in these products have changed over the years. Prior to the late 1970's, polychlorinated biphenyls (PCB's) had been associated with the inks. The levels of PCB are insignificant since these inks are no longer used and the quantity of old newsprint is less than commonly found in southern Canada. This group includes a wide variety of chemicals such as mercury, aluminum, chromium, polycyclic aromatic hydrocarbons (PAHs), and PCBs. Although paper decomposes slowly in a landfill, the large amounts of paper products in a landfill and the fact that many of the decomposition products are readily soluble in water mean that paper products will contribute considerably to the overall chemical characteristics of the landfill's leachate.

TABLE 4.1 : WASTE STREAM ITEMS AND POSSIBLE SOURCES OF POLLUTANTS IN LEACHATE

WASTE STREAM ITEM	POLLUTANTS GENERATED IN LEACHATE
Paper Products	Organic Carbon, Phosphates, Sulfides, Ammonia Nitrate, Nitrite, Sodium, Mercury, Aluminum, Magnesium, Calcium, Chromium, Polyaromatic Hydrocarbons (PAH's), Polychlorinated Biphenyls (PCB)
Glass and Ceramics	Arsenic, Cadmium, Lead, Chloride, Fluoride,Phosporous, Potassium
Metals	Iron, Aluminium, Lead, Zinc, Tin Mercury, Cadmium, Chromium, PCB's
Electronics/batteries/fluorescent lights	Copper, Zinc, Iron, Lead, Mercury, Silver Cadmium, Aluminum, Phenols, PCB's
Plastics	PAH's, Monocyclic Aromatic Hydrocarbons (MAH's) PCB's, Phenols, Cadmium, Iron, Lead, Chloride, Organic Carbon
Tires	PAH's, MAH's, Chlorides, PCB's
Putrescibles (Food Wastes/Carcasses)	Organic Carbon, Ammonia,Nitrates & Nitrites, Phosphates, Coliform & Streptococci bacteria, Ketones, Phenols, Calcium, Magnesium, PAH's, MAH's
Leather/Fabric waste	Organic Carbon, Ammonia, Nitrates, Nitrites, Phosphates, Calcium, Magnesium, Phenols, PAH's, MAH's
Contruction/Demolition Waste	Copper,Iron,Lead,Calcium,Magnesium,Sulfates,Cobalt
Ashes	Sodium & Potassium Hydroxides, Aluminum, Magnesium, Calcium, Mercury
Hazardous Wastes	
Fuel, Oil, & Lubricants	Oil and grease, Cyanide, Lead, Calcium, Phosphorous, Benzene, Nitrobenzene, Toluene, PAH, MAH, Phenols
Paints & Pigments	Iron, Lead, Copper, Mercury, Chromium, Sodium, Aluminum, Cadmium, Benzene, Phenols, Toluene, PCB's
Solvents	Benzene, Ethylbenzene, Toluene, PAH's, MAH's, 1,1,1 Trichlorethane
Pesticides	Arsenic, Mercury, Cyanide, Phosporous,Potassium, Chromium, Fluoride, Chloride, Benzene, Phenols, Pesticides residues
Liquid Sewage	Coliform & Streptococci Bacteria, Enteroviruses Ammonia, Nitrates & Nitrites, Phosphates, Lead, Copper, Ketones, Phenols, PAH's, MAH's
Soaps and Detergents	Phosphorus, Potassium, Sodium, Benzene, Chlorides, Phenols

(Source: Compiled from information in CCREM, 1989)

Other waste stream items occurring in large quantities included food wastes/organics, metals and plastics. Product leachate from these and other typical waste items are itemized in Table 4.1.

Uncontrolled burning often takes place at the Hay River landfill. Thus, ashes are a common component of the landfilled material. Ashes are sometimes considered "inert" in landfills. However, when wet, they can release a number of chemicals into the landfills leachate, depending on the source of the ashes. Ashes from paper and wood can generate sodium and potassium hydroxides (lye) when wet. The incomplete burning of plastics can produce a wide variety of chemicals such as PAHs, MAHs, phenols, dioxins and furans. Other chemicals released by ashes can include: aluminum, magnesium, calcium, and heavy metals associated with the coatings of paper and wood products. The chemicals released by ashes into ground water can contribute to the leachate characteristics.

4.3 Laboratory Results

4.3.1 Lab Results

Table 4.2 summarizes the results of analyses performed upon the ground water samples from the area of the Hay River Municipal Landfill. These analyses were undertaken by the DIAND Water Laboratory in Yellowknife.

Sample 0101 from Borehole 1 (BH1) shows the background water quality upgradient of the landfill site. The ground water was slightly alkaline and the high conductivity indicated a moderately high concentration of dissolved salts. The water was very hard and showed a relatively high concentration of magnesium and calcium, ions of which are major contributors to hardness (Freeze and Cherry, 1979). The level of total dissolved solids concurred with the conductivity results in indicating moderately high concentrations of dissolved salts. This was further confirmed by the sodium, potassium, chloride, and sulfate concentrations, these being the major ions in ground water (Freeze & Cherry, 1979).

TABLE 4.2 : LABORATORY ANALYSIS OF LEACHATE SAMPLES
HAY RIVER MUNICIPAL LANDFILL

ANALYSES BY DIAND WATER LAB, YELLOWKNIFE — MONITORING WELLS (SAMPLE NUMBERS)

PARAMETER	units	Minimum Detection Limit	BH1 (0101)	BH2 (0103)	BH3 (0105)	BH4 (0107)
pH			7.62	7.35	7.11	7.56
Conductivity	umhos/cm		2200	1350	2000	1710
S.S.	mg/L		56	18600	1040	159
T.D.S.	mg/L		1520	840	1330	1150
Calcium	mg/L		210	130	210	196
Magnesium	mg/L		130	58	97	81
Hardness(CaCO3)	mg/L		1060	563	949	833
Alkalinity	mg/L		672	500	715	477
Sodium	mg/L		78	71	78	69
Potassium	mg/L		3.5	7.9	23	9.9
Chlorides	mg/L		275	111	99.1	130
Sulphate	mg/L		194	98	370	368
Tot.Coliform	*		100	<100	26	<100
Fecal Coli.	*		1	<2	1	<1
Fecal Strep	test not conducted					
B.O.D.-5	mg/L		<2	4	5	5
C.O.D.	mg/L		32	19	40	35
Ammonia Nitrogen	mg/L		0.037	0.05	8.4	0.42
NO3+NO2	mg/L		0.49	0.1	0.36	0.2
Phosphorus	mg/L		0.055	2.3	2.5	0.087
Cyanide	mg/L		<0.005	<0.005	<0.005	<0.005
Sulphide	mg/L		<0.01	<0.01	<0.01	<0.01
Oil & Grease	mg/L		<0.3	<0.3	0.5	<0.3
Phenols	mg/L		<5.0	<5.0	5.0	5.0
Arsenic	mg/L		4	2	2	2
Cadmium	mg/L		0.3	0.7	0.5	0.3
Copper	mg/L		37	230	80	78
Iron	mg/L		710	152500	48900	4000
Lead	mg/L		23	211	52	23
Nickel	mg/L		15	211	56	20
Zinc	mg/L		59	732	250	91
Chromium	mg/L		<5	105	18	<5

* *Bacterial readings in counts per 100 mL*

ANALYSES BY DILLON ENVIRONMENTAL LABORATORY

PARAMETER	units	Minimum Detection Limit	BH3 (0106)
Mercury	ug/L	0.1	0.1
Monocyclic Aromatic Hydrocarbons			
Benzene	ug/L	1.0	Trace
Bromoform	ug/L	1.0	ND
Bromomethane	ug/L	1.0	ND
Bromodichlormethane	ug/L	1.0	ND
sec-Butylbenzene	ug/L	1.0	ND
tert-Butylbenzene	ug/L	1.0	ND
Carbon Tetrachloride	ug/L	1.0	ND
Chlorobenzene	ug/L	1.0	ND
Chloroform	ug/L	1.0	Trace
Chloromethane	ug/L	1.0	ND
Chloroethane	ug/L	1.0	ND
2,4 Chlorotoluene	ug/L	1.0	ND
Dibromochloromethane	ug/L	1.0	ND
1,2 Dichlorbenzene	ug/L	1.0	ND
1,3 Dichlorobenzene	ug/L	1.0	ND
1,4 Dichlorobenzene	ug/L	1.0	ND
1,2 Dichloroethane	ug/L	1.0	Trace
1,1 Dichloroethylene	ug/L	1.0	ND
1,2 Dichloropropane	ug/L	1.0	ND
1,3 Dichloropropylene(E)	ug/L	1.0	ND
1,3 Dichloropropylene(Z)	ug/L	1.0	ND
Ethylbenzene	ug/L	1.0	Trace
Methlylene Chloride	ug/L	1.0	4.0
Tetrachlorethylene	ug/L	1.0	Trace
Toluene	ug/L	1.0	Trace
iso-Propylbenezene	ug/L	1.0	ND
n-Propylbenzene	ug/L	1.0	ND
1,1,1 Trichlorethane	ug/L	1.0	ND
1,1,2 Trichlorethane	ug/L	1.0	ND
Trichloroethylene	ug/L	1.0	Trace
Trichlorofluoromethane	ug/L	1.0	ND
Vinyl Chloride	ug/L	1.0	ND
m & p Xylene	ug/L	1.0	2.0
o Xylene	ug/L	1.0	ND

ND : not detected

The results for the various biological indicators (BOD_5, total and fecal coliform counts) indicated a low level of biological activity in the ground water. The amount of chemical oxygen demand indicated a low concentration of chemically reactive constituents. The low level of microbial activity indicated by the low BOD_5 was confirmed by the low levels of ammonia nitrogen, nitrate/nitrite, phosphorus, cyanide, and sulfide. The oil and grease content of the backfill water was less than the detection limit, as were the total phenols. The heavy metal content was consistent with ground water originating in glacial till.

A number of the parameters were similar to levels present than in the background water quality. Parameters which had higher levels were traceable to activities in the landfill area. The higher BOD_5, COD, ammonia, nitrogen, and phosphorus concentrations in the samples from BH2, BH3, and BH4 were attributable to the breakdown of organic matter in the waste. The higher oil and grease content of the sample from BH3 was attributable to the nearby waste oil pit (see Figure 3.1) as were the higher total phenols in the samples from BH3 and BH4. The heavy metal concentrations in BH4 showed some attenuation of heavy metal concentration downgradient of the waste pits. The significance of these finds is discussed in Section 5.1.

4.3.2 Second Phase of Laboratory Testing

Borehole 3 (BH3) was judged as having the highest potential of contamination due to its proximity to the liquid waste pit. In the second phase of laboratory testing, the duplicate samples from Borehole 3 (BH3) were analyzed for mercury content and monocyclic aromatic hydrocarbon (MAH) scan. Laboratory analyses indicated no evidence of leachate characteristics which would be considered significant.

4.4 Inventory of Typical Biota in the Area

Table 4.3 lists the typical biota found in the area of the Hay River Municipal Landfill. Although the species and groups of species listed are those commonly found in the Hay River area, the list is by no means comprehensive. The degree of sensitivity outlines how chemicals from the leachate could enter the environment. These results are somewhat subjective and are based on the experience of the study team.

TABLE 4.3
SENSITIVITY OF TYPICAL BIOTA TO LEACHATE, HAY RIVER, NWT.

BIOTA	DEGREE OF SENSITIVITY (see below)
VEGETATION	
spagnum moss	1a
grasses	1a
wildflowers	1a
trembling aspen	1a
poplar	1a
black spruce	1a
jack pine	1a
tamarack	1a
INVERTEBRATES	
chironomids	1a,2a
stonefly nymphs	1a,2a
shrimps	1a,2a
mayfly nymphs	1a,2a
FISH	
lake whitefish	1a,2a
broad whitefish	1a,2a
arctic char	1a,2a
chum salmon	1a,2a
walleye	1a,2a
inconnu	1a,2a
northern pike	1a,2a
various forage fish species	1a
MAMMALS: prey species	
snowshoe hare	1a
red squirrel	1a,2a
voles (several species)	1a,2a
beaver	1a,2a
muskrat	1a,2a
MAMMALS: predators	
black bear	1a,2a
grizzly bear	1b,2b
wolverine	1b,2b
mink	1b,2b
otter	1b,2b
wolf	1b,2b
fox	1b,2b

BIOTA	DEGREE OF SENSITIVITY (see below)
MAMMALS: ungulates	
caribou	1b,2b
moose	1b,2b
BIRDS: waterfowl	
canvasback	1b,2b
jaeger	1b,2b
king eider	1b,2b
whistling swan	1b,2b
snow goose	1b,2b
canada goose	1b,2b
mallard	1b,2b
widgeon	1b,2b
common pintail	1b,2b
BIRDS: seabirds	
arctic/common tern	1a,2a
thayers/herring gull	1a,2a
ross' gull	1a,2a
ivory gull	1a,2a
glaucous gull	1a,2a
BIRDS: raptors	
rough-legged hawk	2a
peregrine falcon	2a
gyrfalcon	2a
great grey owl	2a
BIRDS: others	
northern raven	1a,2a
plover (several species)	1a
sandpiper (several species)	1a
phalarope (two species)	1a
spruce grouse	1a
ptarmigan	1a
boreal chickadee	1a
canada jay (whiskeyjack)	1a
sparrow (several species)	1a,2a

DEGREE OF SENSITIVTY
(1a=primary contact-high potential)
(1b=primary contact-low potential)
(2a=secondary contact-high potential)
(2b=secondary contact-low potential)

The means by which the landfill can affect a species varies according to the "lifestyle" of the plant or animal. For some animals, such as ravens, gulls and black bears, the landfill is a food source. Most other species are affected due to the introduction of contaminants into the environment via the leachate from the landfill. By affecting ground water quality, landfills can affect vegetation and everything dependent on that vegetation, either directly or indirectly. Similarly, the flow of ground water contaminated by a landfill site into rivers and streams can affect all the organisms in the water and those dependent on them for food.

5.0 DISCUSSION

5.1 Significance of Results

In order to assess the results of ground water sampling of the Hay River landfill area, several comparisons were made. The results were compared with ground water obtained from an uncontaminated control site, with ground water and river water samples obtained in an earlier study (Yaworsky, 1985) and with several water quality criteria. In general, these comparisons indicated that leachates from the landfill are not significantly impairing the ground water quality in the area.

Although the ground water exceeded the N.W.T. Waterboard Municipal Wastewater Guidelines (1981) for total dissolved solids, calcium, alkalinity, and phenols, it is difficult to draw reliable or valid conclusions from this comparison. However, all other parameters tested were lower than the guidelines. The higher concentrations of major ions found in samples downgradient of the landfill were also present in the control sample. These higher concentrations are typical of ground water from fractured till locations. Also, the impacts on the aquatic environment of the river caused by leachate contaminated ground water would be greatly reduced, due to the substantial dilution which would occur.

The leachate generated and the resultant environmental impact of the landfill is reduced, due to the fact that the landfill is located above the water table. Water infiltration through the unsaturated zone above the water table generates leachate at a much lower rate than waste located below the water table. This acts to slow down the rate at which contaminants enter the ground water.

The types of waste generated at the landfill appeared to closely reflect the commercial activities of the area. Large quantities of hydrocarbon products could be traced to the shipping/transportation and repair industries in Hay River. Animal debris and microbial contamination could be traced to the commercial fishing industry. Paper products are also typical of any community of this size. The higher levels of chemicals could be traced to these products.

5.2 Potential Environmental Impacts

Although, there do not appear to be large amounts of contaminants entering Hay River from the landfill site, the present location of the landfill does not appear to be ideal, in terms of the local fisheries resources, due to the proximity of the landfill to the river. Hay River is quite productive and contains a variety of sport fish species. It is possible that the river could contain sensitive areas where lake whitefish spawn in the autumn, and walleye would also pass through the area during spring spawning runs. Other fish species include inconnu, northern pike, and a variety of forage fish species.

Gulls are seasonal feeders at the landfill and ravens are known to feed year round. Bears have also been observed feeding at the landfill. There is probably a greater chance of stray-domestic animals coming into contact with the landfill than wild land animals, such as wolves, wolverine, and large ungulate species. However, it is possible that species such as foxes and rodents such as squirrels, feed on waste items at the landfill. Foxes and several raptor species would feed on smaller prey items such as rodents.

The evidence of this study does not indicate significant impairment of local ground water quality. However, diligent operating and site use controls are required to minimize this risk of contamination.

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Hay River is a typical moderately sized community in the discontinuous permafrost zone. The waste generation is typical of a moderately sized community in the Northwest Territories.

The Hay River Municipal Landfill consists of an active dumping area, a scrap metal pit, a liquid waste pit, and a number of abandoned pits. Ground water flow in the area is towards the Hay River, northeast of the landfill. The water table is generally 4 to 7 m below the surface. Most of the waste buried in the landfill is situated above the water table.

Leachate emanating from the landfill site was found to be higher in metals, salts, and suspended solids, than background ground water.

The outflow of ground water from the landfill site area into the Hay River is estimated to be typically 1,800 m^3/year. The dilution of seepage from the banks of the Hay River, in the vicinity of the landfill, by the flow of the Hay River is in the order of 2,000,000 to 1.

The quality of leachate generated is typical of a community landfill site. However, in this case, the environmental impacts are minimal since the landfill is above the water table.

The potential environmental effects of the landfill are limited. However, the flow of ground water, contaminated by the landfill site, into the river can affect the organisms in the water and those dependent on them for food. The potential for environmental effects from the landfill can be minimized by prudent operational practises and control of surface drainage at the landfill.

6.2 Recommendations

It may be desirable to continue monitoring the ground water quality by taking samples from the monitoring wells installed for this study on a periodic (eg. yearly) basis. This would provide an indication of any changes in the ground water quality. It may also be desirable to install another monitoring well between the active disposal area and the Hay River, which was inaccessible to the drilling equipment used in this study. Samples obtained from the river, especially during sensitive periods such as fish spawning periods, could also be beneficial to define actual effects.

REFERENCES

Bird and Hale Limited, 1979, "Municipal Refuse Statistics for Canadian Communities of over 100,000 (1976 - 1977)," Environment Canada, Ottawa.

Brown, R. J. E., 1970, "Permafrost in Canada, Its Influence on Northern Development," University of Toronto Press, Toronto.

CCME, 1990, "Interim Environmental Quality Criteria for Contaminated Sites, Ground Water Criteria," Canadian Council of Environment Ministry, Ottawa.

Dupuit, J., 1893, Etudes Theoriques et Practiques sur le Mouvement des Eaux dans les Canaux Decouverts et a Travers les Terrains Permable," Dunod, Paris.

Environment Canada, 1981, "Surface Water Data, Yukon and Northwest Territories - 1980," Inland Waters Directorate, Water Resources Branch, Water Survey of Canada, Ottawa.

Forchneimer, P., 1930, "Hydraulik," Teubner Verlagsgesellschaft, Stuttgart.

Freeze, R. A. and J. A. Cherry, "Ground Water," Prentice Hall Inc., Toronto.

Dillon Limited, 1990, "Recycling Study: Strathcona County," GCG Dillon Limited, Edmonton.

N.W.T. Waterboard, 1981, "Guidelines for Municipal Wastewater Discharges in the Northwest Territories," N.W.T. Water Board, Yellowknife.

Grisak, Cherry, Vonhof, and Blumele, 1976, "Hydrogeologic and Hydrochemical Properties of Fractured Till in the Interior Plains Region," Glacial Till Interdisciplinary Study, Royal Society of Canada, Ottawa.

Harlan, R. L. 1972, "Hydrogeological Reconnaissance - Hay River, N.W.T., Water Disposal Study Site," Water Resources Branch, Environment Canada, Ottawa.

Hvorslev, M. J., 1951, "Time Log and Soil Permeability in Ground Water Observations," U.S. Army Corps. of Engineers Waterways Experimental Station Bulletin 36, Vicksburg, Mississippi.

Institute for Environmental Studies, 1990, unpublished data from an ongoing study of hazardous waste composition, Institute for Environmental Studies, Toronto.

Dillon, 1990, "Winnipeg Waste Minimization Study," M. M. Dillon Limited, Winnipeg.

Quebec Ministry of Environment, 1988, "Guide Standard de Caracterisation de Terrains Contamines," Quebec Ministry of the Environment, Quebec City.

Yaworsky, R. 1985, unpublished report on solid waste disposal at three sites, including Hay River, Environment Canada, Yellowknife.

Stanley, 1990, "(Draft) Yellowknife Solid Waste Study."

Environment Canada, 1979, "Cold Climate Delivery Design Manual."

CCREM, 1989, "Canadian Water Quality Guidelines."

Heinke, G. W. & Wong, J., 1989, "Draft Solid Waste Composition Study for Iqaluit, Pangnirtung and Broughton Island of the Northwest Territories, Department of Municipal and Community Affairs."

Geological Survey of Canada, 1974, Department of Energy Mines and Resources. Map 1370A Geology Great Slave District of Mackenzie.

APPENDIX "A"

BOREHOLE LOGS

DILLON	PROJECT No. 3360	BOREHOLE No.	1
	DATUM	Sheet of	1 of 1
PROJECT	Characterization of Leachate:Hay River Municpal Dump	DATE	7 Sept. 1990
LOCATION	Hay River, N.W.T.	INSPECTOR:	R. Reichelt

DEPTH metres	Elev. Depth m.a.s.l.	Lith.	Description	LABORATORY ANALYSIS Sample No.	Tested for:	Monitor Installation Details
			Elevation top of piezometer: 172.61 m.a.s.l.			
0.0	172.5					Stickup 0.11 m.
			0 - 0.46 m., CLAY: brown, firm, dry, plastic	0101	pH, alkalinity, hardness, anions, conductivity, metals, TOC, total phenols, bacterial analysis, BOD, Oil & Grease, total cyanide	Water level
0.5	172.0		0.46 - 0.91 m., SAND: brown, firm, wet, subangular, coarse - medium grained, fast dilatancy			
1.0	171.6					5.04 m. 50 mm. PVC Pipe Sched.40
1.5			0.91 - 5.18 m., CLAY: gray, firm, damp, plastic slow dilatancy			
2.0				0102	Duplicate sample, not tested	
2.5						
3.0			2.7 m., Clay a/a, with lenses of iron staining			
3.5						
4.0						
4.5						
5.0						
5.5	167.3		5.18 - 8.80 m., CLAY TILL: grey-brown, firm, damp, plastic, 80% clay, 10% silt & sand, 10% pebbles, occasional nodules of glauconite			
6.0						
6.5						3.05 m. 50 mm. #10 Slotted PVC Pipe Sched. 40
7.0						
7.5						
8.0			Bottom of piezometer: 164.4			
8.5						
9.0	163.7		TOTAL DEPTH: 8.80 m.			
9.5						
10.0						Sand packed around piezometer screen, remainder of hole sealed with bentonite
10.5						
11.0						
11.5						*Note: water level in pipe as of 14/10/90*

LEGEND

CLAY	SAND
CLAY TILL	SILT
SANDY TILL	SILTY TILL
BENTONITE HOLEFILL	

DILLON	PROJECT No. 3360	BOREHOLE No.	2
	DATUM	Sheet of	1 of 1
PROJECT	Characterization of Leachate:Hay River Municpal Dump	DATE	7 Sept. 1990
LOCATION	Hay River, N.W.T.	INSPECTOR:	R. Reichelt

DEPTH metres	Elev. Depth m.a.s.l.	Lith.	Description	LABORATORY ANALYSIS Sample No.	Tested for:	Monitor Installation Details
			Elevation of piezometer: 171.843 m.a.s.l.			Stickup 0.515 m.
0.0	171.328					
0.5		SILT	0 - 2.9 m., SILT: tan, firm, damp, non-plastic slow dilatancy, 80% silt, 10% clay, 10% sand	0103	pH, alkalinity, hardness, anions, conductivity, metals, TOC, total phenols, bacterial analysis, BOD, Oil & Grease, total cyanide	
1.0		SILT				5.34 m. 50 mm PVC Pipe Sched.40
1.5		SILT				
2.0		SILT		0104	Duplicate sample, not tested	
2.5		SILT				
3.0	168.4	SILT				
3.5	167.7	SILTY TILL	2.9 - 3.66 m., SILTY TILL: brown, dry, non-plastic, fast dilatancy, 60% silt, 20% sand, 10% clay, 10% pebbles			
4.0		SANDY TILL	3.66 - 6.10 m., SANDY TILL: brown, damp, non-plastic, 20% pebbles,30% sand, 20% silt, 30% clay			
4.5		SANDY TILL				*Water Level* V
5.0		SANDY TILL	4.88 m., Till a/a, wet			
5.5		SANDY TILL				
6.0	165.2	SANDY TILL				
6.5		CLAY TILL	6.10 - 8.90 m., CLAY TILL: brown-grey, firm, wet, semi-plastic, 60% clay, 20% silt, 20% sand, 10% pebbles			3.05 m. 50 mm. #10 Slotted PVC Pipe Sched.40
7.0		CLAY TILL				
7.5		CLAY TILL				
8.0		CLAY TILL				
8.5	163.0	CLAY TILL	TOTAL DEPTH: 8.3 m. Bottom of piezometer: 162.9 m.a.s.l.			
9.0						
9.5						Sand packed around piezometer screen, remainder filled with bentonite
10.0						
10.5						*Note: water level in pipe as of 14/10/90*
11.0						
11.5						

LEGEND

-----	CLAY
-.^.^	CLAY TILL
:^:^:	SANDY TILL
::::::	SAND
,',','	SILT
^,^,^	SILTY TILL
#####	BENTONITE HOLEFILL

DILLON	PROJECT No. 3360	BOREHOLE No.	3
	DATUM	Sheet of	1 of 1
PROJECT	Characterization of Leachate:Hay River Municpal Dump	DATE	7 Sept. 1990
LOCATION	Hay River, N.W.T.	INSPECTOR:	R. Reichelt

DEPTH metres	Elev. Depth m.a.s.l.	Lith.	Description	LABORATORY ANALYSIS Sample No.	Tested for:	Monitor Installation Details
			Elevation top of piezometer: 171.411			Stickup 0.63 m.
0.0	170.779					
0.5			0 - 3.35 m., SILT: tan, firm, dry, non-plastic, slow dilatancy, 80% silt, 10% clay, 10% sand, occasional pebbles	0105	pH, alkalinity, hardness, anions, conductivity, metals, TOC, total phenols, bacterial analysis, BOD, Oil & Grease, total cyanide	
1.0						5.38 m. 50 mm. PVP Pipe Sched.40
1.5						
2.0			1.52 - 2.13, SILT a/a, pebbles more common	0106	Sample tested for Mercury and Volatile Organic Compounds	
2.5						
3.0						
	167.4					
3.5			3.35 - 3.66, SAND: tan, firm, dry, subangular, fine grained, 90% sand, 10% silt			
	167.1					
4.0						
4.5			3.66 - 4.88, CLAY TILL: brown, firm, damp, semi-plastic, 60% clay, 30% sand & silt, 10% pebbles			
5.0	165.9					
			4.88 - 5.49, SAND: green-grey, firm, wet, subangular, fine grained, fast dilatancy, 80% sand, 20% silt & pebbles			*Water Level* V
5.5	165.3					
			5.49 - 8.53, CLAY TILL: grey-green-brown, firm , wet, semi plastic, 60% clay, 20% silt, 10% sand, 10% pebbles			
6.0						3.05 m. 50 mm. #10 Slotted PVC Pipe Sched. 40
6.5						
7.0						
7.5						
8.0						
			Bottom of piezometer: 162.351 m.a.s.l.			
8.5	162.2		TOTAL DEPTH: 8.53 m.			
9.0						
9.5						Piezometer screen packed with sand, remainder filled with bentonite
10.0						
10.5						*Note: water level in pipe as of 14/10/90*
11.0						
11.5						

LEGEND

- ----- CLAY
- -^-^- CLAY TILL
- :^:^: SANDY TILL
- ::::: SAND
- ,',', SILT
- ,^,^, SILTY TILL
- ##### BENTONITE HOLEFILL

DILLON	PROJECT No. 3360	BOREHOLE No.	4
	DATUM	Sheet of	1 of 1
PROJECT	Characterization of Leachate:Hay River Municpal Dump	DATE	7 Sept. 1990
LOCATION	Hay River, N.W.T.	INSPECTOR:	R. Reichelt

DEPTH metres	Elev. Depth m.a.s.l.	Lith.	Description	LABORATORY ANALYSIS Sample No.	Tested for:	Monitor Installation Details
			Elevation top of piezometer: 170.032 m.a.s.l.			Stickup 0.902 m.
0.0	169.13					
0.5		SILT	0 - 4.57 m., SILT: tan, firm, dry, slow dilatancy, 80% silt, 20% clay	0107	pH, alkalinity, hardness, anions, conductivity, metals, TOC, total phenols, bacterial analysis, BOD, Oil & Grease, total cyanide	#######
1.0		SILT				7.98 m. 50 mm PVC Pipe Sched.40 #######
1.5		SILT				#######
2.0		SILT		0108	Duplicate sample, not tested	#######
2.5		SILT				#######
3.0		SILT				#######
3.5		SILT				#######
4.0		SILT				#######
4.5	164.6	SILT				#######
5.0		SAND / SILT	4.57 - 6.40, SILT: a/a; with SAND stringers: tan, firm to loose, wet, subangular, fine grained, fast dilatancy			#######
5.5		SAND / SILT				#######
6.0		SAND / SILT				#######
6.5	162.7	SAND / SILT				#######
7.0		SANDY TILL	6.40 - 7.62, SANDY TILL: brown, firm, wet, semi-plastic, 10% pebbles, 50% sand, 30% silt, 10% clay			Water Level #######
7.5	161.5	SANDY TILL				#######
8.0		CLAY TILL	7.62 - 11.13, CLAY TILL: brown, firm, wet, slow dilatancy, 60% clay, 20% silt, 10% sand, 10% pebbles			:::
8.5		CLAY TILL				:::
9.0		CLAY TILL				3.05 50 mm #10 Slotted PVC Pipe Sched.40 :::
9.5		CLAY TILL				:::
10.0		CLAY TILL				:::
10.5		CLAY TILL				:::
11.0		CLAY TILL	Bottom of piezometer pipe: 158.1 m.a.s.l.			:::
	158.0	CLAY TILL	TOTAL DEPTH: 11.13 m.			
11.5						

LEGEND

------ CLAY	:::::: SAND	##### BENTONITE HOLEFILL	
-^-^- CLAY TILL	,',', SILT		
:^:^: SANDY TILL	^,^,^ SILTY TILL		

Piezometer screen packed with sand remainder filled with bentonite

Note: water level in pipe as of [illegible]

Northwest Territories Environment and Natural Resources

Environmental Protection Division
Environment and Natural Resources
P.O. Box 1320
Yellowknife NT X1A 2L9
Telephone (867) 873-7654
Fax (867) 873-0221

July 9, 2007

MR. CURT SNOOK, P.ENG.
SENIOR PROJECT OFFICER
DEPARTMENT OF PUBLIC WORKS AND SERVICES

Fort Smith Landfarm and Sump

As a follow up to our meeting on May 17, 2007 regarding the Department of Public Works and Services (PWS) intent to transfer control and responsibility for the landfarm area and wet soils sump at the landfill to the Town of Fort Smith, Environment and Natural Resources (ENR) has completed its review of the following two EBA Engineering Consultants Ltd. (EBA) reports:

- 2006 Landfarm and Groundwater Well Monitoring at the Fort Smith Landfarm Facility and the Aurora College Trades Building, Fort Smith, NT (September 28, 2006) and
- Fort Smith Landfarm and Sump Recommendations (November 30, 2006).

Based on these reports, PWS has successfully remediated approximately 17,500 m^3 of hydrocarbon-impacted soil from the Thebacha Campus Trades Building spill. Sampling results confirm the landfarm area meets the Environmental Guideline for Contaminated Site Remediation Industrial Criteria, however, the 3 to $4m^3$ of soil in the adjacent wet soils sump does not. EBA recommends this soil be removed, spread over the landfarm and then sampled. Since the Town of Fort Smith plans to use the sump for future contaminated soil treatment, this minor amount of soil could be incorporated with other soil and dealt with at that time.

ENR has no objections to PWS turning over the facilities to the Town of Fort Smith. Please advise me when this is done, as ENR will have to change the Hazardous Waste Management Facility registration to the Town.

If you have any questions, please give me a call at (867) 873-7645.

Harvey Gaukel
Hazardous Substance Specialist

c: Mr. Jack Bird, Regional Superintendent, South Slave Region

Mackenzie Valley Land and Water Board
7th Floor - 4910 50th Avenue • P.O. Box 2130
YELLOWKNIFE, NT X1A 2P6
Phone (867) 669-0506 • FAX (867) 873-6610

September 17, 2009 File: MV2009L8-0024

Mr. John Holland
Senior Office Administrator
Town of Fort Smith
PO BOX 147
FORT SMITH NT X0E 0P0 Fax: (867) 872-8401

Dear Mr. Holland:

Water Licence Application – Incomplete
Landfarm - Town of Fort Smith

Your Water Licence Application, received on September 2, 2009, has been reviewed and found to be lacking sufficient information to conduct a preliminary screening. In order for this application to be considered complete and forwarded for review, the following information must be submitted to our office:

1. The details of a volume balance and Landfarm sizing that considers expected hydrocarbon contaminated soil and snow to be contained;
2. The details of leachate management that includes but is not limited to: estimation of leachate generated; leachate collection and disposal; and leachate sampling and monitoring;
3. An operational plan that details, but is not limited to: acceptable soil types to be deposited in the Landfarm; remediation standards; and methods and frequency of any soil conditioning to promote remediation;
4. The spatial and temporal monitoring program for soil chemistry within the Landfarm; and
5. Details as to how and when the Town of Fort Smith will incorporate EBA Engineering's recommendations.

This supplementary information must be provided within 90 days otherwise it will be assumed that you do not wish to continue processing your application. Upon receipt of this information, the application will be processed and reviewed in accordance with the *Mackenzie Valley Resource Management Act* and the

.../2

Northwest Territories Waters Act. For further assistance, please refer to the document "Guide for Completing Water Use Applications to the Mackenzie Valley Land and Water Board" which can be found on our website at www.mvlwb.com.

If you have any further questions, please telephone (867) 669-0506 or email permits@mvlwb.com.

Yours sincerely,

for Joyce Mullaney

Jason Ash
Regulatory Officer

Copied to: Darnell McCurdy, District Manager, South Mackenzie District, INAC
Carole Mills, Manager, Water Resources, INAC

Mackenzie Valley Land and Water Board
7th Floor - 4910 50th Avenue
P.O. Box 2130
YELLOWKNIFE NT X1A 2P6
Phone (867) 669-0506
FAX (867) 873-6610

FILE NUMBER: MV2009L8-0024

Date:	September 17, 2009
To:	Mr. John Holland, Senior Office Administrator
Organization:	Town of Fort Smith
Fax Number:	867) 872-8401
Copied To:	Darnell McCurdy, District Manager, South Mackenzie District, INAC Carole Mills, Manager, Water Resources, INAC
From:	Janna for Tyree Mullaney, Regulatory Officer

Number of pages including cover 3

Remarks:

Water Licence Application – Incomplete (Landfarm – Town of Fort Smith)

☐ Enclosures

☐ For your information

☐ For your comment

☐ For your action

☐ For your approval

Delivered by		**Date**
☐	Mail	
☒	Email/Fax	Sept17/09
☐	Hand Delivered	
	Sent by:	JW

Group Send Report

Page : 001
Date & Time: 17-Sep-2009 02:14pm
Line 1 : +8678736610
Line 2 :
Machine ID : MVLWB

Job number	:	622
Date	:	17-Sep 02:11pm
Number of pages	:	003
Start time	:	17-Sep 02:11pm
End time	:	17-Sep 02:14pm

Successful nbrs.

One touch numbers

57	6692720
58	6692716

Fax numbers

☎18678728401

Unsuccessful nbrs. Pages sent

EBA Engineering Consultants Ltd.

Creating and Delivering Better Solutions

LANDFARM OPERATING MANUAL
THEBACHA CAMPUS LANDFARM
FORT SMITH LANDFARM FACILITY
FORT SMITH, NT

0701-00-14393.006

Submitted to:

Department of Public Works & Services
Government of the NWT
Fort Smith, NT

December 2003

P.O. Box 2244, #201, 4916 - 49 Street, Yellowknife, Northwest Territories X1A 2P7
Tel: (867) 920-2287 - Fax: (867) 873-3324
Email: yellowknife@eba.ca - Web Site: www.eba.ca

TABLE OF CONTENTS

1.0 INTRODUCTION

EBA Engineering Consultants Ltd. (EBA) was retained by the Department of Public Works and Services (PW&S) to prepare an Operations Manual for the Thebacha Campus Landfarm (TCL) constructed at the Fort Smith Municipal Landfill (Figure 1 - Site Plan).

In 2001, the landfarm was constructed to be capable of receiving 20,000 cubic metres of hydrocarbon-influenced soil (HIS) resulting from an underground fuel release at the Thebacha Campus of the Aurora College in Fort Smith, NT. The PW&S assumed responsibility for monitoring and directing the operations of the landfarm in late fall of 2001. The landfarm lay dormant through the winter of 2001 - 2002. EBA prepared draft operating guidelines in the spring of 2002 that have been in force through the summer of 2002.

This report provides an overview of the landfarm site evaluation, presents the rationale behind operating guidelines presented herein.

2.0 BACKGROUND

EBA has provided ongoing consultations with respect to the assessment and cleanup of the Thebacha Campus fuel spill since 1998. Characterization of the fuel spill and the hydrocarbon constituents of the spill have been presented in earlier reports (EBA 1996, 1998, and 2000).

In 2000, it was concluded by EBA that landfarming was the most practical method of remediating the large volume of soils influenced by the spill and a landfarm site selection process began in the winter of 2001. The GNWT has not formulated NWT-specific siting guidelines for landfarms and, therefore, the following Alberta Environment (AENV) and Federal Government (FG) criteria were used:

1. Terrain should have slope gradients of less than six per cent (FG) to nine per cent (AENV)
2. Ground surface should be 1 metre (AENV) to 3 metres (FG) above seasonal high water table

3. Site should be greater than 100 metres from a surface water body
4. Site elevation should be above 1 in 10 year-return-event flood level
5. Site should be greater than 60 metres from a residential property line

Following a review of available soil, groundwater and other site conditions for several sites proposed by PW&S, EBA met with the PW&S, the Town of Forth Smith and Aurora College in May 2001 to discuss site options. At that time, it was agreed that lands adjacent to the Fort Smith Landfill site satisfied the above siting criteria, and it was the only site favoured by all of the respective parties.

At the May 2001 meeting, EBA was authorized to carry out a more detailed site assessment. Seven test pits were excavated at the landfarm to assess the local soil stratigraphy. Forest cover at the site had been cut just prior to the meeting and large rows of mounded trees, roots and litter occupied about half the site. Subsurface conditions consisted of interbedded sand, sand with silt, and silt with sand. The top 0.6 metre of soil below ground surface was typically a sand with some silt to silty sand; however, with depth, the siltier beds were noted to be discontinuous presenting a potential for some areas to be more pervious.

To assess the possibility of vertical leaching, a water balance analysis was conducted using climatic data from the Fort Smith Airport and relationships based on research by C.W. Thornwaite and T. R. Mather (1955). For purposes of this discussion, the term "water balance" refers to the difference between the inflow of water at ground surface due to precipitation and the outflow of water expected due to evapotranspiration and infiltration.

Based on the monthly water balance calculations, EBA calculated a substantial moisture deficit for the Fort Smith area from May through to the time of typical freeze-up in mid-October (Figure 2). The greatest monthly deficits occurred during the summer months at a time when landfarming would be most active. These very good drying conditions led EBA to consider the risks of adopting a containment system without a base liner.

Laboratory tests were carried out on stockpiled native soil on site that included particle size distribution, hydraulic conductivity, moisture-density relationship determination and information of the field capacity (Appendix B). Particle (sieve) size testing was also conducted on proposed landfarm soils for comparison to the HIS (Appendix C). These results indicated that the imported hydrocarbon-influenced soils from Thebacha Campus contained silts in similar proportions to the native subgrade soils at the landfarm liner and, therefore, if spread and partially dried, would act as a barrier to infiltration of precipitation if placed with an adequate thickness. Figure 3 shows the influence of lift thickness, the influence of moisture condition of the HIS, and the ability of the HIS to act as a barrier for various intensities of rainfall. A 0.5 metre thick layer of imported HIS was recommended to provide protection against leaching from an intense rainfall event in Fort Smith.

Periodic monitoring was also recommended to check whether operations were achieving the required thickness and to confirm that it was providing adequate protection. Consultations with the fertilizer suppliers and EBA microbiologists indicated that microbiological activity is still strong in soils with as little as seven per cent moisture content. Therefore, dry climatic conditions and the ability to adjust the thickness of HIS indicated that liner-less containment was feasible.

Although a lined facility appeared unwarranted, it was recommended by EBA that a lined cell be constructed to temporarily receive any potential hydrocarbon-saturated soils. A 25 mil reinforced polyethylene liner was installed at the landfarm site and protected with a layer of sand cover. A drainage well was installed at the low point of the liner to permit extraction of any accumulations of hydrocarbons that might drain from the imported HIS.

3.0 LIMITATIONS OF LANDFARM USE

The landfarm was designed as a project-specific facility (finite life) that was intended to be used specifically for the Thebacha Campus program. Although it may be technically feasible to use this facility to landfarm hydrocarbon-influenced soils from other sites, each disposal application should be assessed individually.

Use of this facility to treat any hydrocarbon-influenced soils other than those imported from the Thebacha Campus in 2001 is beyond the scope of EBA's work to date. Closure of the facility is recommended within three years or with the cleanup of the HIS soils imported in 2001, i.e., anticipated before 2006 (five years of operation).

A general overview of landfarming theory and practices is in Appendix A. It provides some rationale for the mechanical, chemical and microbiological measures used in this manual.

4.0 OPERATING PROCEDURES - FORT SMITH LANDFARM FACILITY

The Thebacha Campus Landfarm Facility was constructed at the Fort Smith Municipal Landfill situated approximately 10 km north of the Town of Fort Smith (Figure 1). The landfarm covers an area of 3.5 to 4 ha and an estimated 17,500 m^3 of HIS from the Thebacha Campus of Aurora College were imported to the site in 2001.

To achieve bioremediation of HIS to below regulatory criteria in the least number of summer seasons and reduce the potential for hydrocarbon leaching to the underlying native subgrade, the landfarm must be well managed and monitored. The likelihood of hydrocarbons leaching to the subgrade can be reduced to negligible amounts at any time by increasing the lift thickness of the HIS. If too thick a lift is used, however, the time required to bioremediate the contaminated soils to regulatory criteria will increase significantly.

As the objective of a landfarm operation is to reduce hydrocarbon concentrations to below regulatory criteria in the least amount of time, the optimum operational approach is as follows:

- Spread the hydrocarbon-impacted soil (minimum of thickness of 50 cm), fertilize the hydrocarbon-impacted soil, regularly till or scarify the soil to at least 30 cm, and if needed, water the soil during summer months when the soils naturally tend to be the driest.
- Periodically monitor the progress of the remediation by sampling and testing both the HIS and the underlying native subgrade (for indications of hydrocarbon leaching).
- If the results from monitoring of the native subgrade soils show that hydrocarbons are leaching downward and that this condition is pervasive, then the hydrocarbon-impacted soil should be piled in a thicker lift and spread evenly.

The time to remediate the HIS also depends on the following:

1. The initial hydrocarbon concentrations within the in-place treatment soils
2. The equipment available to do the work
3. The ability of the landfarm operational personnel or contractor (Operator Skills) to both grade and till the soil to maintain the soil moisture content between 30 and 60 per cent of field capacity (seven to 13 per cent water content by weight)

Optimizing the operations procedures is an ongoing process that should be reviewed by qualified personnel at the end of every season. Failure to optimize the program could add several years to the time required to remediate hydrocarbon-influenced soil at the landfarm to the satisfaction of the regulatory authorities.

Remediation of hydrocarbon-impacted soils in the least amount of time requires that the tilling/plowing equipment be capable of reaching depths of 0.3 metre or greater. Large agricultural disc equipment is ordinarily used for this purpose. The equipment selection proposed by the contractors should be approved by PW&S or its representative.

4.1 Landfarm Operation

For maximum efficiency, the landfarm should normally commence operations as soon as the HIS thaws and is trafficable (June) and cease operations close to freeze-up (mid-October).

In 2001, landfarm operations were terminated with the onset of freezing temperatures in October. Although most of the imported HIS soils were end-dumped and spread out, some HIS was end-dumped in piles of up to 1.5 metres high without spreading. In the areas where the HIS was spread, the lift thickness typically ranged from 0.3 metre to 0.5 metre. Operations in 2002 will therefore require the continued spreading of the imported HIS to the minimum required thickness (0.5 metre).

In 2001, the imported soils were systematically placed in the landfarm. Generally, soils in the west half of the landfarm have higher concentrations of hydrocarbons and soils with lower concentrations of hydrocarbons were placed in the eastern half of the landfarm. It is expected, therefore, that the rate of remediation will vary between the east and west halves.

Figure 4 is an annotated schematic of a typical soil column at the landfarm. Landfarm operations should include the following:

Landfarm Subgrade Assessment
(at the start and end of season and following any prolonged period of wet weather)

- Sample underlying native subgrade at five selected control point stations (A, B, C, D, and E). Control stations can be established below potential "hot spot" sampling sites where high hydrocarbon concentrations are suspected.
- Determine moisture content profile for column in native soils.
- Determine if hydrocarbons have influenced landfarm subgrade.

Landfarm Hydrocarbon Soil Spreading and Tilling/Plowing

- Spread imported hydrocarbon–impacted soils to as uniform a layer as possible over the full area of the landfarm. The target layer thickness should be about 0.5 metre. Measure the thickness of the hydrocarbon-impacted soils at 10 or more locations after site grading. After site grading, ponding of water should not occur. It is anticipated that during a high intensity rainfall event, water ponding, runoff and erosion should be negligible. If evidence of ponding is found, or precipitation begins to channel and run off, EBA should be informed so as to prescribe mitigative measures.
- Determine typical hydrocarbon concentrations of the HIS to establish conditions at the start of each landfarming season (see Landfarm Soil and Groundwater Monitoring below).
- Till/plow HIS to a depth of 30 cm during dry site conditions with a frequency of approximately every three weeks (on average). Aerate and condition affected soils using an approved agricultural disc.

Landfarm Fertilizer Application & Moisture Conditioning

- Install a simple rainfall measuring device (standard gauge) at the landfarm, but outside worked area, to check site-specific rainfall. If site-specific information is not possible, daily climatic data from the Fort Smith Airport or Environment Canada should be collected.

- Fertilize the soils once in the spring and once in the fall. Broadcast the fertilizer using a slow release fertilizer (34-17-0) onto the treatment area at a rate of 85 kg/ha (75lb/ac). A quad or tractor mounted broadcaster is acceptable for dispensing the fertilizer. Incorporate the fertilizer application to a depth of at least 30 cm (12 inches) with an approved agricultural disc.
- Determine moisture condition of hydrocarbon-impacted soil.
- The Department of Public Works and Services (PW&S) or its representatives should monitor soil moisture at least every two weeks.
- If the soil moisture content drops below 10 per cent by weight at the 10 to 15 cm depth interval and weather forecasts at that time are for continued dry weather, apply 20 to 25 litres/m^2 of water, evenly spread over the surface of the treatment area. All water applications are to be made before 10:00 a.m. Do not over-water and do not drive on treatment soil with the water truck. Truck traffic will cause compaction that slows the rate of remediation.
- Measure soil moisture content in the same depth interval and at the same locations 24 hours after the water truck application. If moisture contents exceed 16 per cent, the site will be considered over-watered. The contractor should till/plow and dry the soil to 13 per cent (plus or minus two per cent) if over-watering is confirmed.

Landfarm Soil and Groundwater Monitoring

- Following environmentally accepted protocols, collect soil samples for laboratory analysis to determine the progress of hydrocarbon-impacted soil treatment. Soil samples should be collected at the start of the landfarm operation, at mid-season after tilling and fertilizing and at the end of the landfarm season. Samples should include composite samples in the areas of high and low hydrocarbon-impacted soil and soil samples from selected "hot spots" identified at the landfarm.
- Collect composite soil samples from 0 cm to 30 cm below grade from the west side of the landfarm and east side of the landfarm treatment area denoting areas with high and low hydrocarbon concentrations, respectively.
- Collect composite soil samples from 30 cm to 60 cm depth, or to the base of the HIS, from the west side and east sides of the of the landfarm.
- Collect "hot spot" samples at three locations in the treatment area to assess the presence of local high hydrocarbon concentrations in soil.

- Send collected soil and groundwater samples for laboratory analysis at an accredited laboratory for analysis according to the CWS regulatory criteria.
- Confirmatory soil sampling should be done under the supervision of qualified environmental personnel.

Technical Evaluation of Groundwater and HIS Status

- Assess laboratory reported hydrocarbon concentrations in soil samples collected from the landfarm.
- Determine whether landfarm hydrocarbon leaching has affected native subgrade and groundwater below the landfarm. Address remedial measures if hydrocarbon leaching is noted.
- Evaluate the status of hydrocarbon concentrations in the top 30 cm are below the Canada Wide Standards for Petroleum Hydrocarbon in Soil criteria. If soils have been remediated to below regulatory criteria, remove and stockpile the top 30 cm of remediated soil for future industrial use with a dozer or other approved equipment.
- Remediated soil should be stockpiled apart from any contaminated soil stockpile on site. There are no other restrictions on where the soil can be stockpiled on site.
- Redistribute remaining hydrocarbon-impacted soil exceeding the CWS criteria to an even thickness (50 cm or thicker) covering areas of removed soil using a dozer or other approved equipment.
- Review all landfarm inspection records, make necessary repairs and re-assess landfarm operations to optimize remediation of remaining HIS.

4.2 Health and Safety

- Landfarm workers should wear CSA approved hard hats and rubber boots, coveralls, gloves, safety glasses, and a half-mask respirator with organic cartridges.
- No eating, smoking, or drinking is allowed on site.
- Workers handling contaminated soil should wash hands and face after leaving the site.
- No unauthorized access is allowed at the site.

4.3 Record Keeping

- A file should be kept on groundwater sampling for the site. This file should include the groundwater monitoring forms and chemical analysis results supplied by the laboratory.
- A second file should be kept with the landfarm inspection checklist. All repair records should be kept in this file.

5.0 LIMITATIONS OF LIABILITY

Recommendations presented herein are based on a development of a landfarm operating manual as described in Section 1.0. This report has been prepared for the exclusive use of the Department of Public Works and Services, Fort Smith, NT for the specific application described in Section 1.0 of this report. It has been prepared in accordance with generally accepted geo-environmental engineering practices. No other warranty is made, either expressed or implied. Engineering judgement has been applied in developing the recommendations of this report.

For further limitations, reference should be made to the attached General Conditions in Appendix D.

APPENDIX A
FIGURES
APPENDIX C
APPENDIX D

6.0 CLOSURE

We trust that this is sufficient for your present requirements. Should you have any questions or comments, please contact the undersigned.

EBA Engineering Consultants Ltd

REGISTERED PROFESSIONAL ENGINEER
Jan 7/04
M.D. WATSON
LICENSEE
NWT/NU

T.A. (Toivo) Taal, P.Geol.
Hydrogeologist / Hydrologist
Environmental Practice
(Telephone: (867) 920-2287)

M.D. (Mark) Watson, M.Eng., P.Eng.
Senior Geotechnical Engineer
(Direct Line: (780) 451-2130, ext. 277)

reviewed by:
R.B. (Brent) Murphy, M.Sc., P.Geol.
Project Director, NWT/Nunavut
(Telephone: (867) 920-2287)

THE ASSOCIATION OF
PROFESSIONAL ENGINEERS,
GEOLOGISTS and GEOPHYSICISTS
OF THE NORTHWEST TERRITORIES
PERMIT NUMBER
P 018 07/01/04
EBA ENGINEERING
CONSULTANTS LTD.

/wdr

7.0 REFERENCES

CCME 1999. Canadian Soil Quality Guideline for the Protection of Environmental and Human Health, Council of Ministers of the Environment.

CCME 2001. Canada-Wide Standards for Petroleum Hydrocarbons (PHC) in Soil, Canadian Council of Ministers of the Environment, May 2001.

EBA Engineering Consultants Ltd. (EBA) 2001. Environmental Remediation Management Plan, Trades Building Site and Raven Crescent, Thebacha Campus, Aurora College, Fort Smith, Northwest Territories. EBA File: 0701-00-14393.001. Report dated March 2001.

EBA Engineering Consultants Ltd. (EBA) 2000. Environmental Site Assessment, Trades Building, Thebacha Campus, Aurora College, Fort Smith, NWT. EBA File: 0701-00-14393. Report dated April 2000.

Environment Canada 1994 Climate Normals 1961 to 1991, - Northwest Territories, Environment Canada publication.

GNWT 1998. Environmental Guideline for Site Remediation, Department of Resources, Wildlife and Economic Development (RWED), Government of the Northwest Territories, February 1998.

USEPA 1995, How to Evaluate Alternative Cleanup Technologies for Underground Storage Tank Sites: A Guide for Corrective Action Plan Reviewers, EPA 510-B-95-007, (http://www.epa.gov/swerust1/pubs/index.htm#tums).

APPENDIX A

FIGURES

APPENDIX C

APPENDIX D

FIGURES

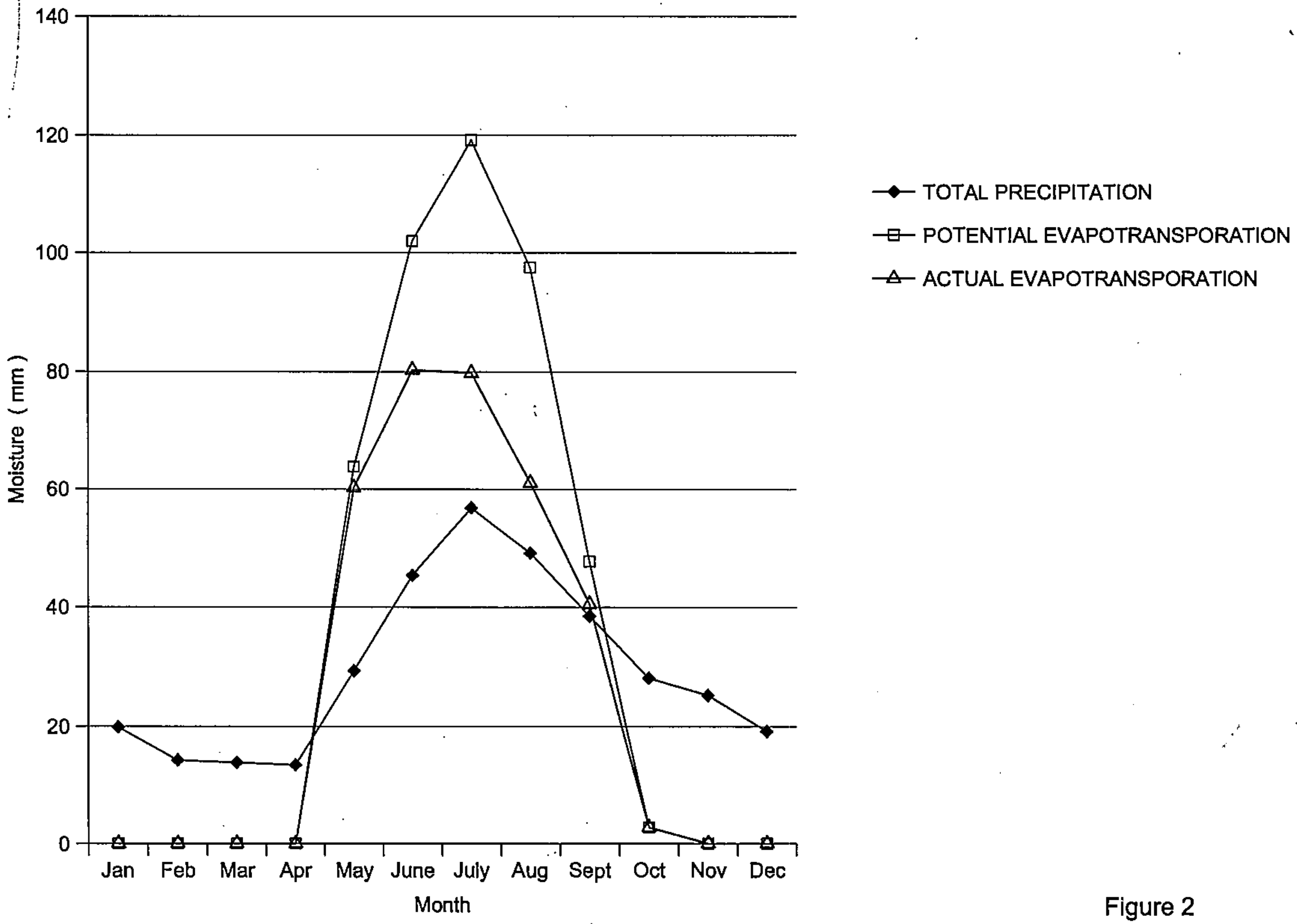


Figure 2

Fort Smith Water Balance

14393R04C.dwg

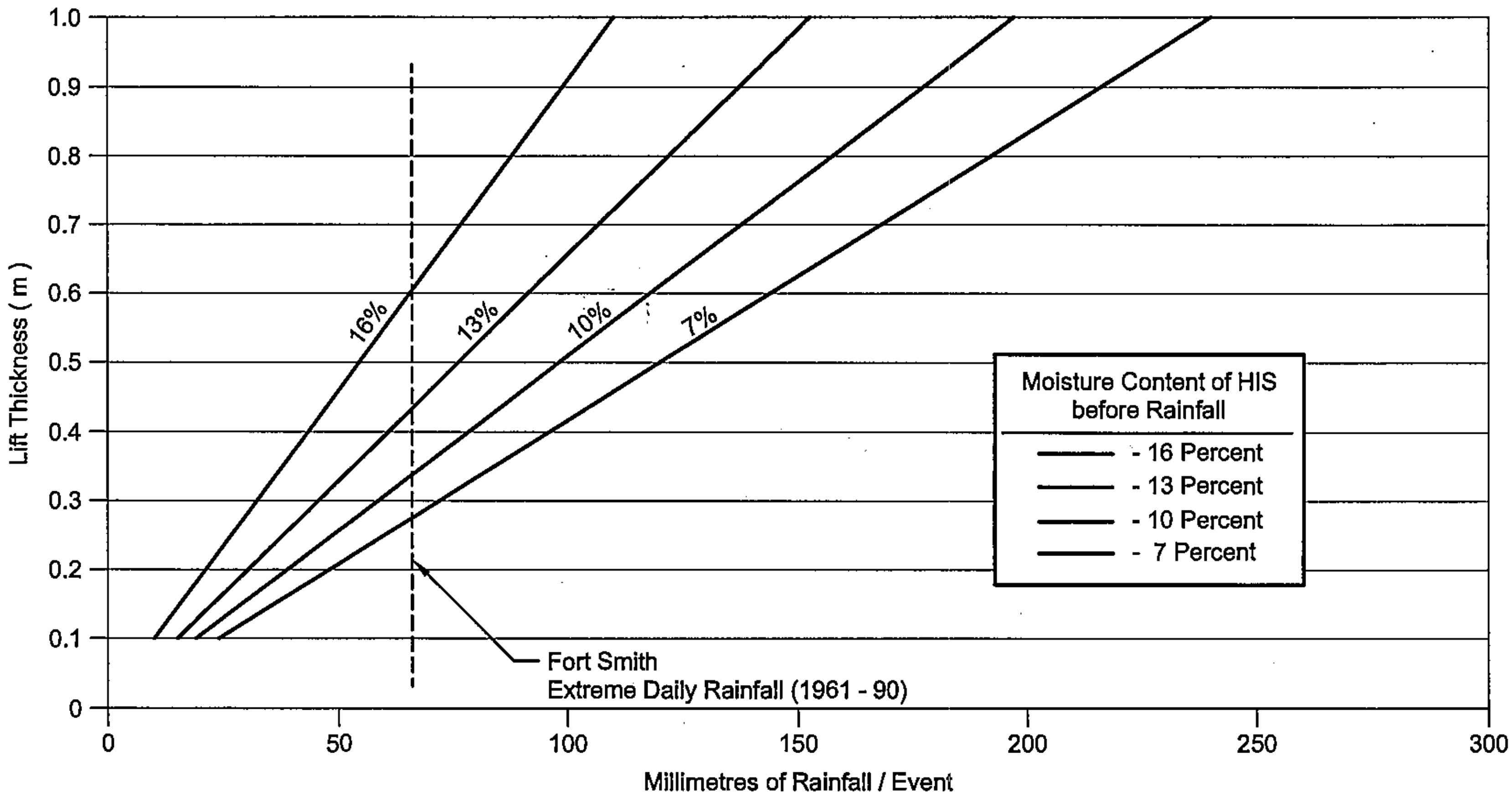


Figure 3
Rainfall Event Tolerance as a
Function of Initial Moisture Content of HIS

14393R03C.dwg

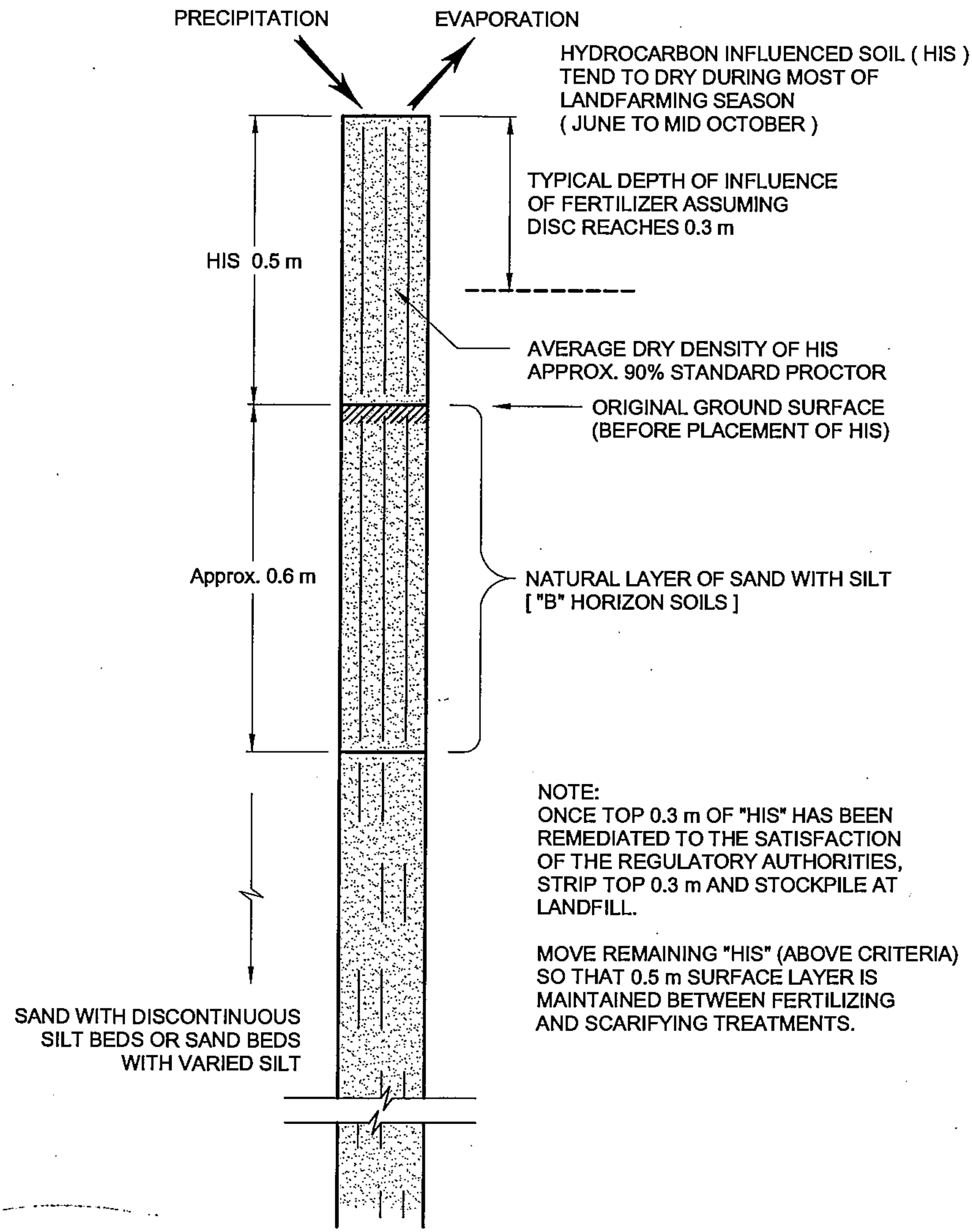


Figure 4

Schematic of Landfarm Soil Profile

14393R05C.dwg

eba

APPENDIX A
APPENDIX B
APPENDIX C
APPENDIX D

APPENDIX A

GENERAL OVERVIEW OF LANDFARMING THEORY AND PRACTICES

APPENDIX B

APPENDIX C

APPENDIX D

General Overview of Landfarming Theory and Practices

1.0 GENERAL PROPERTIES OF PETROLEUM FUELS

A fundamental theoretical concept to the understanding of a landfarming operation is the chemistry of the contaminant(s) to be remediated in the landfarm. The chemistry of a particular compound (contaminant) governs other properties such as the toxicity of the contaminant, the volatility of the contaminant, the mobility of the contaminant and the ability of micro-organisms to biodegrade the contaminant. All of these are discussed in the following sections.

1.1 Chemistry of Hydrocarbon Fuels

Hydrocarbon fuels are classified in the realm of organic chemistry (chemistry of compounds containing carbon). Organic chemistry of the element carbon is different from the chemistry of other elements because of the large number of organic compounds that exist, and many of these compounds can contain very large and complex molecules. The hydrocarbon fuels are derived in nature from deposits of oil and gas, and the majority of fuels manufactured through distillation and cracking of crude oils and tarsands.

The chemistry of carbon atoms is special because these atoms can form large chains or rings with many branches and cross-links. The chemistry of carbon is sufficiently complex that compounds of carbon are divided into families that are based on chemical structure. Two large families generally apply to fuels: aliphatic hydrocarbons and aromatic hydrocarbons.

Aliphatic hydrocarbons include only carbon and hydrocarbon atoms. They can be straight chained, meaning that carbon atoms are linked or bonded with at most two other carbon atoms, or multi-branched involving carbon atoms bonded with three or four other carbon atoms.

Aromatic hydrocarbons also involve exclusively carbon and hydrogen atoms; however, a special structural relationship of the atoms is involved: the benzene ring. A benzene ring is a flat, symmetrical molecule with six carbon atoms in a ring structure.

Benzene rings can also link up with each other to form polyaromatic hydrocarbons. For example, two benzene rings form naphthalene, while a three-ringed benzene structure forms anthracene/phenanthrene. The hydrogen atoms in the benzene ring can be substituted for other elements as well, or with aliphatic hydrocarbons. For instance, a methyl group (CH_3) substituting for a hydrogen atom in a benzene ring is the hydrocarbon compound toluene.

Common constituents of petroleum hydrocarbons are listed in Table 1.

Table 1
Constituents of Common Petroleum Fuels and Related Compounds

Fuels	Distillation Temperature ^{O}C	Aliphatic Constituents	Aromatic Constituents
Gasoline	40 - 205	Highly branches aliphatic with the majority containing between 6 and 12 carbon groups	Benzene, toluene, ethylbenzene and xylenes
Kerosene	175 - 325	Aliphatics with greater than 12 carbon groups	Dimethyl- and methyl-naphthalene, toluene, ethylbenzene and xylenes
Diesel	>275	Aliphatics with greater than 12 carbon groups	Toluene, ethylbenzene, xylenes, phenanthrene, anthracene, substituted naphthalene
Lubricating Oil	Non-volatile liquids	Long chains attached to cyclic structures	Polycyclic aromatic hydrocarbons
Asphalt	Non-volatile solids	Very complex >30 carbon groups	Polycyclic aromatic hydrocarbons

Metals can also be constituents of petroleum with some metal elements, such as vanadium, occurring naturally, while others have been specifically added to the petroleum product such as lead in gasoline (e.g., tetraethyl lead), and other metal elements have accumulated through wear of engine parts in lubricating oils. Hydrocarbon fuels, such as diesel and kerosene, are normally metal free.

1.2 Toxicity of Petroleum Products

Determining the toxicity of petroleum compounds is complex because each fuel is a mixture of thousands of compounds of various structures. Only some of these compounds have been studied in detail by toxicologists and these compounds have usually been studied as the pure compound rather than as a mixture. As a general statement, the toxicity of fuels and related compounds is little understood.

There are a few constituent compounds, primarily aromatic compounds, which have been studied. These are listed in Table 2.

Table 2
Toxicity of Selected Petroleum Product Constituents in Fuel Products

Constituent	Primary Routes of Exposure	Known to Cause Cancer	Non-cancer Causing Effects	Exposure Limit[1] Time Weighted Average 8 hours
Benzene	Inhalation, absorption, ingestion, skin or eye contact	Yes; leukemia	High levels in air cause headaches, tremors, confusion, unconsciousness, and death. Low levels affect immune system and blood cells	25 ppm (inhalation)
Toluene	Inhalation, ingestion, adsorption, skin or eye contact	No	Affects brain and kidneys. High levels cause dizziness, sleepiness, unconsciousness and death. Long-term exposure affects brain functions. High levels of toluene inhaled by mothers can cause neurologic problems in babies	100 ppm (inhalation)
Ethylbenzene	Inhalation, ingestion, adsorption, skin or eye contact	No	Dizziness, fatigue, headache, vertigo, unconsciousness, central nervous system effects, death, liver and kidney problems	100 ppm (inhalation)
Xylenes	Inhalation, ingestion, adsorption, skin or eye contact	No	Dizziness, eye and throat irritation, vomiting, abdominal pain, central nervous system	10 ppm (inhalation)
Naphthalene	Inhalation, skin adsorption, ingestion, skin or eye contact	No	Irritation eyes, headache, confusion, nausea, vomiting, abdominal pain, irritation bladder, profuse sweating, jaundice, hematuria, renal shutdown, dermatitis, optical neurosis, corneal damage	10 ppm (inhalation)
Tetraethyl Lead	Inhalation, skin adsorption, ingestion, skin or eye contact	Yes	Insomnia, lassitude, anxiety, tremor, hyper-reflexia, spasticity, bradycardia, hypertension, hypothermia, pallor, nausea, anorexia, weight loss, confusion, hallucinations, psychosis, mania, convulsions, coma, eye irritation	0.075 mg/m^3 (skin)

1 The Time Weighted Average is the standard exposure allowed for workers to these chemicals for an eight-hour period as recommended by NIOSH.

APPENDIX B APPENDIX C APPENDIX D

1.3 Volatility, Mobility, and Biodegradation of Hydrocarbon Constituents

The volatility, mobility, and ability to biodegrade hydrocarbon constituents of fuels are closely related to the chemical structure of the fuel. The volatility refers to the ability of a chemical to become gaseous at ambient temperatures. The volatility is related to the boiling point of a chemical; those with low boiling points quickly volatize. The mobility and biodegradability of various constituents are also related to the boiling point as chemicals with high mobility and biodegradability also have low boiling points, as summarized in Table 3.

Table 3
Properties of Various Hydrocarbon Constituents

Hydrocarbon Constituents	Volatility	Mobility in Soils/ Groundwater	Biodegradability
Aliphatics $<C_{10}$	High to moderate	High	High
Monoaromatic hydrocarbons	High	High	High
$C_{10}<$ Aliphatics $<C_{20}$	Moderate to low	Moderate to low	Moderate
Napthalenes	Moderate	Moderate	Moderate
Phenanthrene/Anthracene	Low to none	Low	Moderate to low
Other Polyaromatics	None	Very low	Low
Aliphatics $>C_{20}$	None	Very low	Low

2.0 GUIDING PRINCIPLES OF LANDFARM PROCEDURES

2.1 Overview

Landfarming is the process of removing and degrading hydrocarbons in hydrocarbon-impacted soil by spreading the contaminated soil in a thin layer to enhance oxygenation. The effectiveness of landfarming depends on three factors:

- Hydrocarbon-impacted soil characteristics
- Hydrocarbon constituent characteristics
- Climatic conditions

Soil characteristics involve grain size and soil texture, which affects the bulk density of the soil, moisture content and permeability of the soil. The addition of oxygen to the soil by tilling or plowing maintains nutrient distribution and soil moisture within effective ranges. The background soil nutrient composition is also factor as soils can be deficient in essential nutrients for effective biodegradation by soil microbes.

Climatic conditions influence landfarm effectiveness and encompass factors including rainfall, snow, wind effects and temperature. Rain and snowmelt will directly affect the moisture content of the remediating soil and runoff has the potential to cause soil erosion. Landfarm soil erosion can also occur during windy periods particularly during tilling or plowing operations. Wind erosion can be reduced by plowing soil into windrows and applying moisture periodically (EPA 1995). Temperature affects the rate of remediation as bacterial metabolism rates are typically reduced at lower temperatures. Two processes are generally involved in a landfarming cell:

- Volatilization - evaporation
- Biodegradation - breakdown by microbes in the soil

Volatilization refers to the process of hydrocarbons being transferred from the soil to the air, where it is then diluted and broken down further. Volatilization occurs readily to low boiling point hydrocarbons exposed to air in temperatures above 5°C. Lighter hydrocarbon compounds such as gasoline, and to a lesser extent, kerosene and diesel, will volatilize, but heavier hydrocarbons such as lubricating oils and asphalt, will not.

Biodegradation refers to the process where inert soil microbes consume hydrocarbon fuels as a food source and convert the hydrocarbons into soil biomass. Biodegradation can occur readily for certain hydrocarbons if conditions for microbial growth are optimized. The microbes that readily degrade hydrocarbons require moderate temperatures (18°C to 40°C), water (7 to 20% moisture content), oxygen, pH (ranging from 6 to 8 pH units), and nutrients (carbon, nitrogen, hydrogen, oxygen, sulphur, phosphorus, potassium, and magnesium). These microbes also require a non-toxic environment and therefore the concentration and types of contaminants in soil are an important consideration in determining whether biodegradation will occur. Soil microbes in the NWT are adapted to survive these extreme conditions from year to year, although biodegradation does not occur below 0°C.

Microbe nutrients and their associated functions and required concentrations are summarized in Table 4.

Table 4
The Macronutrient Elements, Major Physiological Functions and Growth Requirements

Element	Physiological Function	Required Concentration (Molar)
Carbon	Constituent of organic cellular components; energy source for the cell	>10^{-2} M
Nitrogen	Constituent of proteins, nucleic acids	10^{-3} M
Hydrogen	Constituent of organic matter and water	
Oxygen	Constituent of organic matter and water	
Sulphur	Constituent of proteins and certain co-enzymes	10^{-4} M
Phosphorus	Constituent of nucleic acids, phospholipids, nucleotides and certain co-enzymes	
Potassium	Principle inorganic cation in the cell and a cofactor for certain enzymes co-enzymes	10^{-4} -10^{-3} M
Magnesium	Cofactor for many enzymes, chlorophylls and required for the synthesis of cell walls and membranes	10^{-4} -10^{-3} M

Hydrocarbon fuels are used as the carbon source for the soil microbes. The average hydrocarbon fuel content in the soil should generally be 4% by weight or less for optimum bioremediation.

Fertilizers can be added to improve the nutrient content of the soil. Environment Canada recommends a fertilizer with a carbon:nitrogen:phosphorous:sulphur (C:N:P:S) ratio of 100:10:1:1. Petroleum companies have found through experience that this ratio can be reduced to a C:N:P:S of 100:1:1:0.5.

Hydrocarbons that can be readily biodegraded include gasoline, kerosene, and diesel. In a northern environment, it is more difficult to biodegrade hydrocarbons due to fewer days with optimum temperature conditions, and biodegradation may take several years.

The operational management of the landfarm requires that factors such as soil moisture and nutrient content be maintained within a desirable range. Soil moisture content should be 7% to 20%. In addition, surface water runoff and leachate need to be controlled through soil surface grading. Water accumulation (if any) in the landfarm is normally directed towards and collected in an adjacent sump and re-circulated over the landfarm during dry periods.

2.2 Remediation Guidelines

There are two guidelines that govern remediation of soils at the landfarm:

- Canada Wide Standards for Petroleum Hydrocarbons in Soil (CWS) issued by the Canadian Council of Ministers of the Environment (CCME)
- GNWT Environmental Guidelines for Site Remediation (EGSR)

These guidelines pertain to the levels of hydrocarbons that may remain in soil following remediation as summarized in Table 5.

Table 5
Remediation Criteria for Hydrocarbons Based on Land Use

Parameter	CCME - CWS	CCME - CWS	GNWT
	Industrial	Industrial	Industrial
Organic	Fine-grained Soil	Coarse-grained Soil	
F1 (C6 to C10) (ppm)	660	310	
F2 (>C10 to C16) (ppm)	1500	760	
F3 (>C16 to C34) (ppm)	2500	1700	
F4 (>C34 to C50) (ppm)	6600	3300	
Benzene (ppm)			5
Toluene (ppm)			0.8
Ethylbenzene (ppm)			20
Xylenes (ppm)			20
Total Petroleum Hydrocarbons (ppm)*			2500
Naphthalene (ppm)			--
Phenanthrene (ppm)			--
Benzo(a)anthracene (ppm)			--
Benzo(a)pyrene (ppm)			--
Benzo(p)fluoranthrene (ppm)			--
Dibenz(a,h)anthracene (ppm)			--
Indeno(1,2,3-c,d)pyrene (ppm)			--
Pyrene			--
Inorganic			
Lead (ppm)			1000
Chromium (ppm)			--
Cadmium (ppm)			--
* Total Volatile Hydrocarbons plus Total Extractable Hydrocarbons			

The CWS was adopted by the Government of the Northwest Territories (GNWT) for contaminants related to petroleum products during 2001. The CWS is a remedial standard for hydrocarbon contaminated soil and subsoil occurring in four land use categories: agricultural use, residential/parkland use, commercial use and industrial use. In addition, the standard consists of three Tiers.

The CCME criteria are also applicable in NWT as well as on Federal Crown land.

2.3 Characterizing Contamination for Monitoring

When characterizing petroleum hydrocarbon contaminated soil for either acceptance or for determining whether it has been successfully remediated, the following Table 6 is an example sampling schedule for soils being remediated by landfarming. This table is based on Environment Canada, Conservation and Protection, Technical Guidance on the Land Treatment of Petroleum Hydrocarbon Contaminated Soils at Federal Government Facilities or on Federal Crown Land.

Table 6
Sampling Schedule for Landfarms (Environment Canada)

Volume of Soil (cubic metres)	Number of Samples
1 - 50	3
51 - 500	4
500 - 1000	5
1000 - 2000	6
2000 - 5000	7
Each additional 2000	1 additional

When characterizing petroleum hydrocarbon-contaminated soil, typical laboratory analyses based on the petroleum product source are as shown in Table 7.

Table 7
Analysis Schedule
According to Petroleum Product (Environment Canada)

Petroleum Product	Analysis*
Unleaded gasoline	A,B,H
Regular gasoline, aviation gasoline	A,B,C,H
Fuel oil, diesel fuel, kerosene, jet fuel, mineral oil/spirits, motor oil	A,B,G,H
Petroleum solvents	A,B,F,H
Crude oils, hydraulic fluids*	B,G,H
Waste petroleum products	A,B,C,D,E,F,G,H

* where:
A - Benzene, Ethylbenzene, Toluene, Xylenes (BTEX)
B - Total Petroleum Hydrocarbons (TPH)
C - Lead (for decommissioning)
D - Chromium, Cadmium (for decommissioning)
E - Total Polychlorinated Biphenyls (PCBs) (for decommissioning)
F - Phenols (for decommissioning)
G - Total Polycyclic Aromatic Hydrocarbons (PAHs)
H - Flashpoint and pH (for decommissioning)

2.4 Health and Safety

There are two safety matters at a soil landfarming facility:

- Potential chemical hazards
- Heavy equipment hazards

The potential chemical hazards have been discussed in Section 1.2 of this manual. The chemical hazards are of greatest concern at the beginning of landfarming, when soils are initially spread. Following a short period of bioremediation, these will be reduced with volatilization during soil placement in the landfarm.

APPENDIX B APPENDIX C APPENDIX D

There are four primary ways to be exposed to potential chemical hazards at a landfarm:

- Inhalation
- Ingestion
- Skin contact
- Eye contact

Inhalation is normally the greatest risk; the risk of inhaling these chemicals can be reduced by wearing a respirator (breathing mask with a special organic filter cartridge). The organic filter cartridge will adsorb both contaminants contained in dust, as well as organic vapours.

Ingestion of contaminants normally occurs accidentally, normally when hands, in contact with contaminants, are not washed prior to smoking, eating, and drinking. Smoking, eating, and drinking should be prohibited in the landfarm area and workers at some landfarms are required to scrub down before exiting the landfarm area.

Skin and eye contact with contamination can be prevented by wearing coveralls, rubber safety boots, safety glasses, and gloves to reduce skin exposure when working in a landfarm area.

Heavy equipment, such as loaders, dump trucks, disc and heavy-duty tillers are inherently dangerous and should be operated by competent and experienced workers. Workers should wear hard hats approved by the Canadian Standards Association (CSA) to protect them from side impacts and falling impacts. Heavy equipment should be equipped with backup warning sounds to alert workers to this danger. A trained flag-person should be available at the site to direct truck traffic, if warranted.

Depending on landfarm location, equipment is cleaned prior to leaving the site to remove contamination from the wheels, blades, discs, etc. of the equipment. Discing equipment and tillers can also be cleaned by tilling or discing a small clean area beside the landfarm to loosen off any soil clinging to this equipment. Wash-down water is normally placed on the landfarm soils.

Site workers must be advised as to the dangers of the site and in the use of personal protective equipment. Workers should have heavy construction or farming experience. At least one of the workers should have first aid training. WHMIS and TDG training must be provided to workers at the site.

No access should be granted to unauthorized personnel. The site should be fenced with appropriate warning signs.

In summary:

- Workers should have the following personal protective equipment: CSA approved hard hat and rubber boots, coveralls, gloves, safety glasses, and respirator with organic cartridges
- No eating, smoking or drinking should be allowed on site
- Workers handling contaminated soil should wash hands and face after leaving site
- No unauthorized access is allowed at the site
- The site must be fenced
- At least one employee at the site must have First Aid and Flagman training
- All site workers should be trained in WHMIS and TDG

2.5 Incoming Soil (Entrance Gate Checks)

The volatile and semi-volatile hydrocarbons (light hydrocarbons), such as diesel, gasoline and kerosene, can be readily remediated. Lubricating oils and other heavier hydrocarbons are difficult to remediate.

The characterization of the incoming wastes should follow the sampling and analysis schedules of guidelines set out in Tables 6 and 7 of this manual, respectively.

Hydrocarbon contaminated soils with metals, PCBs, other chlorinated hydrocarbons, polyaromatic hydrocarbons should not be allowed into the landfarm area if these parameters exceed the appropriate CCME criteria. Those contaminants are difficult to remediate and will accumulate in the landfarm due to slower remediation progress.

3.0 OPERATING THE LANDFARM

3.1 Receiving Soil

Soil increases in volume (i.e., bulks up) as it is excavated from its natural condition and transported to a landfarm due to the break up and rearranging of soil particles. Consequently, a "bulking factor" of about 10 to 20% additional volume should be considered for any in-situ estimate of contaminated material to be remediated at a landfarm, which would therefore require a greater surface area than expected if solely based on the in-situ volume estimate. To optimize bioremediation, contaminated soil should be spread to a specified thickness approved by an engineer.

Contaminated soil should be transported directly to the landfarm after excavation to avoid prolonged exposure at the contaminated site. Environmental staff at the landfarm will estimate the volume of contaminated soil on arrival. If the contaminated soil can be segregated into areas of high hydrocarbon-impacted soil and lower hydrocarbon-impacted soil, remediation of the lower hydrocarbon-impacted soil can occur faster, thereby allowing faster removal of the remediated soil from the landfarm.

If excavation and direct transport to the landfarm is not possible, the soil can be stockpiled at the contaminated site until landfarm space is available. Stockpiling of hydrocarbon-contaminated soil should only be done within a bermed area to prevent runoff of contaminants.

3.2 Spreading / Tilling

Soil handling at the landfarm should be under the direction of the environmental staff. The soil should be plowed or tilled as it is spread, and this should continue until all of the soil has been deposited to ensure that the material is well mixed.

During the spring, summer and fall months after spreading, the contaminated soil should ideally be tilled every two weeks. During the winter months, contaminated soil can be stockpiled in the landfarm for spreading and tilling in the spring. Stockpiles should be no higher than five metres.

Farming equipment should be used for tilling, such as a disc or roto-tiller. If a disc is used, the soil should be tilled twice at right angles. If a roto-tiller is used, only one pass is usually sufficient. If farming equipment is not available, it may be necessary to change the way the soil is plowed. For example, if a grader with a ripper blade is all that is available, the plowing will be much less effective. Three or more passes over the soil might be required.

Only the equipment being used to plow the soil (usually a tractor) should ever drive on the landfarm soil, and only during plowing. Trucks or other vehicles should not drive on the landfarm soil as this will compact the soil and prolong the soil remediation time.

The landfarm soil after spreading should be loose and moist, and not hard and dusty. If the landfarm soil is too dry, controlled watering of the soil is recommended prior to tilling. It should not be worked if it is too dry. The landfarm soil should not be tilled during, or immediately following, heavy rain, as this will cause the soil to compact. If the soil is muddy, or sticks to the tires of the tilling equipment, it is too wet to plow.

Access to the landfarm site should be restricted and gates locked except during landfarm operation and monitoring.

3.3 Documentation / Record Keeping

A standard landfarm report form to record landfarm operation is provided in this Appendix. This form can be used to keep track of work undertaken at the site, and the scheduling of follow-up activities. Detailed instructions for landfarm operations are outlined below.

1. Every week, check the landfarm condition, noting if it is:

   - Too dry to plow (dusty, soil is very hard or lumpy, etc.?), or
   - Too wet to plow (muddy, sticks to wheels or boots, etc.?)

2. Do not plow if the soil is too wet or too dry. Complete the landfarm report forms, and make note on the forms that it should be checked again in about seven days. If soil is too dry for a period of two weeks or more, and no rain is forecast, soils should be irrigated.

3. If the soil seems fine, plow or till it.

   - If using a disc or plow, conduct two passes over the site, at right angles to each other, or
   - If using a tiller, conduct one pass over the site

4. Note and flag any hydrocarbon odours from the soil while plowing ('hot spots'). Check a few freshly plowed areas for hydrocarbon odours.

5. Manually check at least five locations to make sure that the equipment is plowing deep enough. Manually dig down to the base of the landfarm, checking for areas where contaminated soil has been packed down below the plowed soil. A ripper blade that

penetrates for the full thickness of the compacted area would work. After breaking up the compacted soil, continue to plow as usual.

6. Complete the landfarm form, noting to check the landfarm again in another week.

7. If there are no noticeable odours from the soil from two plowing sessions, the landfarm should be ready for sampling to determine if the landfarm soil has been remediated to guideline criteria. If soil odour persists after two months of landfarming, additional remediation efforts such as fertilizer application may be required.

8. If confirmatory sampling of the landfarm soil has determined that the soil has been successfully remediated, the soil can be removed and reused. Confirmatory testing should be conducted under the direction of an environmental professional to determine if soil has been successfully remediated.

4.0 MONITORING

Monitoring and record keeping are an essential component of a successful landfarm operation. To determine if a particular soil source has been completely remediated to the applicable guideline criteria, confirmatory sampling and laboratory analysis are required. Landfarm soil can be sampled and analysed when no odour has been detected for two months. The number of samples to be analyzed will depend on the volume of soil, as suggested in the sampling schedule (Table 6).

For sampling hydrocarbon-impacted soils, glass jars with teflon or foil covered lids supplied by the laboratory should be used. The jar should be completely filled with soil with no air pockets and the jar stored in a cooler with ice for transportation to the assigned laboratory for analysis. The soil samples should be analysed according to the analysis schedule in the guidelines. The persistent, or non-degradable compounds such as metals need not be retested, as their levels will not be much different than originally tested. Soil sampling should be conducted under the direction of environmental staff.

If tested soil is within the applicable criteria, the soil can be removed from the landfarm and re-used.

5.0 GROUNDWATER

Groundwater monitoring wells should be installed at the landfarm perimeter, as well as surface water, if applicable. The purpose of the monitoring wells and surface water sampling point is to ensure contamination within the landfarm is not leaching into groundwater or affecting surface water at the site.

Groundwater and surface water, if present, should be tested at least annually. The depth to groundwater must be recorded along with observations such as odour, free product, etc. The well should be purged to three times of its well water volume. Groundwater should be sampled with jars supplied by the laboratory and the samples stored in a cooler with ice until transported to the laboratory. Well monitoring records along with the results should be kept and the results reviewed by environmental staff. The entire landfarm operation should also be reviewed by the environmental staff to ensure operations are being carried out successfully.

6.0 LANDFARM CLOSURE

Soils at the landfarm facility will eventually achieve remediation and require decommissioning. Some steps taken during initial start-up will make the landfarm closure more straightforward. The following guiding principles will simplify the process:

- Soil should not be stockpiled on site without prior consultation with the environmental staff. There is a danger that too much contaminated soil may be accepted than can be treated in a reasonable time frame. If soil is stockpiled on site, it should be contained within soil berm.
- Maintenance of the landfarm, monitoring wells, and other facilities at the site must be ongoing. Landfarm staff should be diligent in inspecting the facilities, so that any required repairs are made promptly.
- Accidental spills outside of designated areas should be promptly cleaned up, reported and inspected.
- There should be minimal disruption to areas outside the landfarm but within the facility, except on a need be basis.
- There must be no other use of the facility, except as a landfarm. No materials other than approved hydrocarbon-contaminated soils should be allowed on site.

APPENDIX B

APPENDIX C

APPENDIX D

APPENDIX B

APPENDIX C

APPENDIX D

EXAMPLE

LANDFARM INSPECTION CHECKLIST

Date Inspected: ____________________ Inspected by: ________________________

Weather: ____________________ Temperature: ________________________

Facilities: Cell Condition __________ Berm Condition ________________ Road Condition __________
Gate ______________ Monitoring Wells ______________ Fence and Gate: ____________
Other ____
Repairs Needed ____

Soil condition: __________ No. of locations inspected: __________ Odour: ______________
Too dry/too wet/ideal ______________ Other : ____________________

Soil transported to site Yes/ No.: ______________ No. of trucks: ________________________
Tonnage: ______________ Estimated Volume: ________________________

Soils tilled or disced: ______________

GUIDANCE DOCUMENT ON FEDERAL INTERIM GROUNDWATER QUALITY GUIDELINES FOR FEDERAL CONTAMINATED SITES

May 2010

Preface

The Federal Contaminated Sites Action Plan (FCSAP) was established to help federal departments, agencies and consolidated Crown corporations (referred to as custodians) address federal contaminated sites, so as to reduce environmental and human health risks as well as federal financial environmental liability associated with the higher risk federal contaminated sites.

The Federal Interim Groundwater Quality Guidelines presented in this report were developed to assist federal custodians in assessing, remediating/risk managing federal contaminated sites funded under the FCSAP. Federal custodians are advised to use these interim guidelines as an interim measure until Canadian groundwater quality guidelines are available.

This report was developed based on a study conducted for Environment Canada by Meridian Environmental Inc. to review existing approaches for deriving groundwater quality guidelines used by other jurisdictions in Canada and other countries, and recommended one of them that can be adapted for use at federal contaminated sites. The study was conducted under the guidance of an Environment Canada working group of experts.

In addition, this document was reviewed by the Expert Support Science Departments of Health Canada and Fisheries and Oceans, and their comments have been considered. Although this report has not yet been reviewed by custodians, it is recommended that these interim guidelines be used at federal sites funded under FCSAP. Custodian comments will be solicited in the renewed FCSAP program after experience has been gained in applying these interim guidelines.

TABLE OF CONTENT

GLOSSARY

Active layer: The soil layer in Northern regions with permafrost that melts in the summer and re-freezes in the fall or winter.

Aquifer: A geologic formation(s) that has the ability to store and/or transmit water, such as to springs. Use of the term is usually restricted to water-bearing formations capable of yielding water in significant quantities sufficient to constitute a usable supply for people's uses.

Background concentration: Representative, naturally occurring level of a contaminant in the environment. Reflects natural geologic variations.
Coarse-grained soil: Soil which contains greater than 50% by mass particles greater than 75 μm mean diameter ($D50 > 75$ μm).

Confined aquifer: A region of soil or rock below the land surface that is saturated with water. There are impermeable material layers above and below it and it is under pressure so that when the aquifer is penetrated by a well, the water will rise above the top of the aquifer.

Dilution factor: A constant applied to groundwater guidelines to address the decrease in concentration as contaminants are transported to surface water due to dilution.

Ecological receptor: A non-human organism potentially experiencing adverse effects from exposure to contaminated media either directly or indirectly (food chain transfer).

Ecosystem: A dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit.

Fine-grained soil: Soil which contains greater than 50% by mass particles less than 75 μm mean diameter ($D50 < 75$ μm).

Groundwater: Subsurface water beneath the water table in fully saturated geologic formations.

Hypolentic zone: Transition zone between groundwater and surface water beneath lakes and wetlands.

Hyporheic zone: Transition zone between groundwater and surface water beneath streams and rivers.

Offset distances: A minimum distance from a receptor where guidelines do not apply, due to limitations in transport models or other invalidated guideline assumptions.

Receptor: A receptor is the person or organism exposed to a chemical. For human health risk assessment, it is common to define a critical receptor as the person expected to experience the most severe exposure (due to age, sex, diet, lifestyle, etc.) or most severe effects (due to state of health, genetic disposition, sex, age, etc.) as a result of that exposure.

Recharge: Process which occurs when the water content of the unsaturated zone becomes high enough to cause excess water to percolate downward to the water table, usually as a result of the infiltration of snow melt or rainwater into surface soils. Using a water balance approach, recharge is equal to the total amount of precipitation less the amount of surface runoff and evapotranspiration.

Pore water: The water occupying the space between particles of sediment or soil.

Solubility: The maximum concentration of a chemical that can be dissolved in water when that water is both in contact and at equilibrium with the pure chemical.

Subsurface: Unconsolidated regolith material above the water table not subject to soil forming processes.

Transition zone: The area where groundwater enters a surface water body.

Unconfined aquifer: A region of saturated ground material not overlain by an impermeable or low-permeability layer such as clay, whose upper water surface (water table) is at atmospheric pressure, and thus is able to rise and fall. These systems allow for the draining of pore water and the subsequent movement of air (or water) to fill the spaces vacated by the moving water.

Water table: Depth below which soil is saturated with groundwater.

1 INTRODUCTION

The Federal Contaminated Sites Action Plan (FCSAP) was established in 2005 as a 15-year program with a commitment of $3.5 billion from the Government of Canada. The program helps federal departments, agencies, and consolidated Crown corporations (referred to as custodians) determine if a site is contaminated and, if so, to what extent. Where appropriate, it provides financial assistance to deal with the environmental and human health risks that these sites may pose.

Federal contaminated sites are generally evaluated using the *Canadian Environmental Quality Guidelines* (CEQG) (CCME 1999) developed by the Canadian Council of Ministers of the Environment (CCME). The CEQGs are primarily risk-based numerical guidelines set at levels at which it is believed that unacceptable adverse effects on environmental or human health will not occur. These were developed for various media: water, soil, and sediments, and biological tissue. For some media (e.g. surface water, soil), there is a multi-tier framework that allows for the application of generic numerical guidelines, the modification of guidelines based on site-specific conditions, or the use of site-specific risk assessment. While the *Canadian Soil Quality Guidelines* (CCME 1999) include consideration of the protection of groundwater for organic chemicals, there are currently no Canadian Environmental Quality Guidelines for groundwater. In the absence of national groundwater guidelines, provincial guidelines are sometimes applied at federal contaminated sites, or in other cases, potable water guidelines, and/or surface water quality guidelines are often applied for groundwater – either directly or with an arbitrary adjustment factor. In recognizing the need for a nationally-consistent approach for assessing and managing groundwater at federal contaminated sites, Environment Canada conducted a study to develop a federal approach that would be based on a critical review and evaluation of existing approaches used by other jurisdictions in Canada and in other countries. Meridian Environmental Inc. conducted such a review for Environment Canada, and recommended Federal Interim Groundwater Quality Guidelines, presented in this report, that should be used by custodians to assess, remediate/risk manage contaminated groundwater at federal sites funded under FCSAP. This report was prepared by the FCSAP Secretariat of Environment Canada and is based on the recommendations provided by Meridian Environmental Inc. in their study.

The Federal Interim Groundwater Quality Guidelines are intended to be used as an interim measure until CEQGs for groundwater are available. Therefore, if a CCME groundwater protocol is developed in the future, guidelines developed under that protocol would supersede the Federal Interim Groundwater Quality Guidelines presented herein. Until such time, the Federal Interim Groundwater Quality Guidelines are to be used in connection with groundwater investigation and remediation activities at federal contaminated sites.

These guidelines are intended as assessment and remediation criteria for contaminated sites, and should not be construed as “pollute up to” levels. The Federal Interim Groundwater Quality Guidelines follow a tiered framework, consistent with the Canadian Soil Quality Guidelines development through the CCME. The tiers are:

- Tier 1: direct application of the generic numerical guidelines; specifically, application of the lowest guideline for any pathway

- Tier 2: allows for the development of site-specific remediation objectives through the consideration of site-specific conditions, by modifying (within limits) the numerical guidelines based on site-specific conditions and focusing on exposure pathways and receptors that are applicable to the site
- Tier 3: use of site-specific risk assessment to develop Site-Specific Remediation Objectives

The Federal Interim Groundwater Quality Guidelines presented in this report have been adopted from other jurisdictions, with some modifications and are based on common risk assessment methods. Quantitative human health and environmental risk assessments involve a number of uncertainties and limitations. As a consequence, the use of the recommendations presented herein may either be overly protective or may not necessarily provide complete protection of human and environmental receptors or prevent damage of property in all circumstances. The generic (i.e. Tier 1) guidelines are not intended for application at all sites without consideration of the sensitivity of the site and its characteristics, as discussed below. However, it is expected that the generic guidelines will be protective of the majority of federal contaminated sites. Sites that are more sensitive than what was assumed for the derivation of the generic guidelines must be assessed at higher tiers; at other sites of lower sensitivity it may be advantageous to proceed to the higher tiers.

This report is organized in six sections. Section 1 provides general background information on the FCSAP program and the Federal Interim Groundwater Quality Guidelines. Section 2 provides general background on groundwater. Section 3 describes the basis of the Federal Interim Groundwater Quality Guidelines. Section 4 describes how the generic numerical guidelines (Tier 1) are to be applied and their limitations. Section 5 explains how these Tier 1 guidelines can be modified for site-specific conditions to generate Tier 2 values. Section 6 provides relevant reference guidance documents that can be used to derive site-specific risk assessment guidelines (Tier 3). The Federal Interim Groundwater Quality Guidelines are provided in Appendix A, for the agricultural, residential/parkland, commercial and industrial land uses. Finally, Appendix B provides the equations and default model parameters that were used to derive the Tier 1 generic numerical guidelines, so that Tier 2 numbers can be derived if required.

2 BACKGROUND ON GROUNDWATER

The term “groundwater”, in its most basic sense, refers to water beneath the ground surface. For purposes of this document, groundwater refers primarily to water beneath the surface of the water table (i.e. in the saturated zone) in either unconsolidated soils (e.g., gravel or sand) or bedrock, including both shallow groundwater and deeper aquifers. Groundwater is part of the hydrologic cycle, and groundwater can be transported to surface water bodies. For contaminated sites, the most important interaction between groundwater and surface water is direct discharge of groundwater into surface water bodies such as streams, lakes or wetlands. Groundwater may also be discharged to the surface (e.g., spring or seepage) and subsequently reach surface water bodies via surface run-off.

The transition between groundwater and surface water is not a sharp or distinct boundary; rather, there is a dynamic transition zone from groundwater to surface water. This transition zone is considered to be an important component of the surface water ecosystem (US EPA 2008). Transition zones beneath streams and rivers are referred to as hyporheic zones, while those beneath lakes and wetlands are referred to as hypolentic zones (US EPA 2008). The transition zone includes the sediment-water interface and sediment beneath and adjacent to the surface water where surface water conditions may affect groundwater and where surface water biota (particularly invertebrates, larvae and microbial communities) spend at least part of their time. The transition zone plays a major role in nutrient and energy cycling in surface water bodies (Hayashi and Rosenberry 2002), and in some cases has been shown to contribute significantly to the biodegradation of contaminants (US EPA 2008). Since groundwater typically has a more stable temperature than surface water, the transition zone can provide a thermal refuge for fish in summer or winter (Hayashi and Rosenberry 2002). The extent of the transition zone can vary over time; since groundwater and surface water often have very different chemical characteristics, the extent can often be determined from water chemistry (Hayashi and Rosenberry 2002).

Groundwater is also present beneath surface water bodies; for purposes of this document, water beneath the hyporheic zone or beneath the hypolentic zone is considered to be groundwater (i.e. the transition zone is not considered as groundwater).

Water within soil pores in the unsaturated zone is referred to herein as pore water. For purposes of this document, water bodies which support macroscopic life (e.g. fish) in subterranean caverns are not considered to be groundwater, but rather would be potential receptors.

In areas of Northern Canada with permafrost, water may also be present at least part of the year in the active layer (the soil layer that thaws during the summer and re-freezes in the fall or winter). This water is also treated as groundwater for purposes of this document. Some of the exposure pathways evaluated herein may not apply for the active layer; these pathways could be excluded on a site-specific basis; the active layer is unlikely to be used as a source of potable water and in many cases may not discharge to nearby surface water bodies. Furthermore, permafrost may also thaw near surface water bodies; this thawed permafrost would also be considered as groundwater for purposes of these guidelines.

The term “aquifer” is used to describe a subsurface formation which can produce enough water when tapped by a well to be useful (e.g., as a drinking water source). Water in aquifers can move either through pores or through fractures. In rare cases, particularly in limestone, fractures may be enlarged to form larger channels or caverns. Aquifers can be unconfined, meaning the water table is present within the unit, or confined, meaning a relatively impermeable layer forms the upper boundary of the aquifer.

3 BASIS FOR THE GUIDELINES

The Federal Interim Groundwater Quality Guidelines have been adopted from other jurisdictions, with some modifications; however, these guidelines have generally been developed using methods consistent with nationally approved protocols published by CCME, and in particular *A Protocol for the Derivation of Environmental and Human Health Soil Quality Guidelines* (CCME 2006) and the *Canada-Wide Standard for Petroleum Hydrocarbons (PHC) in Soil: Scientific Rationale* and *User Guidance* (CCME 2008a, CCME 2008b). The *Guidelines for Canadian Drinking Water Quality* (Health Canada 2008) and the *Canadian Water Quality*

Guidelines for the Protection of Agricultural Water Uses (CCME 1999) were applied for the protection of potable water.

In addition to the Federal Interim Groundwater Quality Guidelines, four other sets of guidelines may be relevant for groundwater at federal contaminated sites:

- The *Guidelines for Canadian Drinking Water Quality* (Health Canada 2008 and available online at www.hc-sc.gc.ca/ewh-semt/water-eau/drink-potab/guide/index-eng.php) apply for potable water sources; the most recent version of the guidelines should be consulted. While they are intended to be applied at the point of exposure (e.g., tap), it is recommended that, at federal contaminated sites, these guidelines be used when investigating groundwater that could be used as a potable water source. The determination of a particular aquifer as a potable water source is often under provincial jurisdiction.

- The *Canadian Water Quality Guidelines for the Protection of Aquatic Life*, summarized in the *Canadian Environmental Quality Guidelines* (CCME 1999 and available online at ceqg-rcqe.ccme.ca/) should be applied to the receiving water body, groundwater within 10 m of a surface water body, and to the groundwater-surface water transition zone (as defined in Section 2).

- The *Canadian Sediment Quality Guidelines for the Protection of Aquatic Life*, summarized in the *Canadian Environmental Quality Guidelines* (CCME 1999 and available online at ceqg-rcqe.ccme.ca/), should be applied for sediments in the groundwater-surface water transition zone for contaminants that are expected to be associated with sediments. If both pore water and bulk sediment samples are collected for comparison with aquatic life and sediment guidelines respectively, both guidelines should be met.

- The *Canadian Water Quality Guidelines for the Protection of Agricultural Water Uses* (CCME 1999). These guidelines protect livestock from contaminated watering sources and protect crops from contaminated irrigation water. Similar to the *Guidelines for Canadian Drinking Water Quality*, the *Canadian Water Quality Guidelines for the Protection of Agricultural Water Uses* are intended to be used when investigating groundwater that could be used a source of irrigation.

The Federal Interim Groundwater Quality Guidelines are based on the consideration of several potential receptors and exposure pathways, including:

- groundwater transport to surface water at least 10 m from the contamination and subsequent exposure of freshwater and marine life
- direct contact of soil organisms with contaminated groundwater
- use of groundwater for irrigation water
- use of groundwater for livestock watering
- groundwater transport to surface water at least 10 m from the contamination and subsequent ingestion by wildlife
- migration of contaminant vapours to indoor air and subsequent inhalation by humans.

- use of groundwater for human consumption (i.e. drinking water)

The generic guidelines are point estimates of a chemical concentration in groundwater associated with an approximate no- to low- effects level based on toxicological information about the chemical, along with a screening-level evaluation of environmental fate and transport and estimated intake rates, or exposure, by potential receptors. The assumed receptor characteristics and fate models are generally the same as those used to derive *Canadian Soil Quality Guidelines* (CCME 2006). Details on the models used and model input parameters applied for guidelines are provided in Appendix B, so that Tier 2 site-specific modification of the guidelines can be performed.

For inorganic substances, the *Canadian Water Quality guidelines for the Protection of Aquatic Life* are applied directly to groundwater, due to the high level of variability in the behaviour of inorganic substances in groundwater and the lack of biodegradation of these substances. Inorganic substances could alternatively be evaluated on a site-specific basis. Additionally, for many organic substances without appropriate groundwater biodegradation rates defined by CCME or other Canadian regulatory agencies, the groundwater quality guidelines are essentially equal to the water quality guidelines for the protection of aquatic life because dispersion alone does not provide significant dilution over the default distance of 10 m. These substances can also be evaluated on a site-specific basis; it should be stressed that applied biodegradation rates should be based on site-specific data or data that conservatively reflect potentially anaerobic degradation in groundwater (not surface water or aerobic degradation rates).

4 APPLICATION OF THE TIER 1 AND TIER 2 NUMERICAL GUIDELINES

At Tier 1, the generic numerical guidelines are directly applied. It is expected that most sites would be addressed using the generic numerical guidelines. The Tier 1 numerical guidelines are presented in Tables 1 to 3 for the agricultural, residential/parkland, commercial and industrial land uses, respectively.

The Tier 2 approach allows for consideration of site-specific conditions by either modifying (within limits) the guidelines based on site-specific conditions and/or removing exposure pathways that may not be applicable to the site.
The columns in Tables 1 to 3 are as follows:

- Lowest Guideline – the lowest guideline available selected from all exposure pathways for that land use.

The existing exposure pathways are:

- Inhalation – the guideline based on indoor inhalation by humans.

- Soil Organisms: Direct Contact – the guideline for direct contact by plants and soil invertebrates, calculated from a Canadian Soil Quality Guideline for these receptors.

- Freshwater Life – the guideline for the protection of freshwater life in a surface water body at least 10 m from the contamination. For soluble organic chemicals, this value is calculated from the *Canadian Water Quality Guideline for the Protection of Life* (freshwater) based on groundwater transport modelling; for other chemicals (e.g., inorganics), it is equal to the *Canadian Water Quality Guideline for the Protection of Aquatic Life* (freshwater).

- Marine Life – the guideline for the protection of marine life in a surface water body at least 10 m from the contamination. These values are calculated the same way as the freshwater life values, but using the *Canadian Water Quality Guideline for the Protection of Aquatic Life* (marine).

- Irrigation – the *Canadian Water Quality Guideline for the Protection of Agricultural Water Uses; Irrigation Water* guideline values are used directly.

- Livestock – the *Canadian Water Quality Guideline for the Protection of Agricultural Water Uses; Livestock Watering* guideline values are used directly.

- Wildlife Watering – the guideline for the protection of wildlife watering in surface water at least 10 m from the contamination.

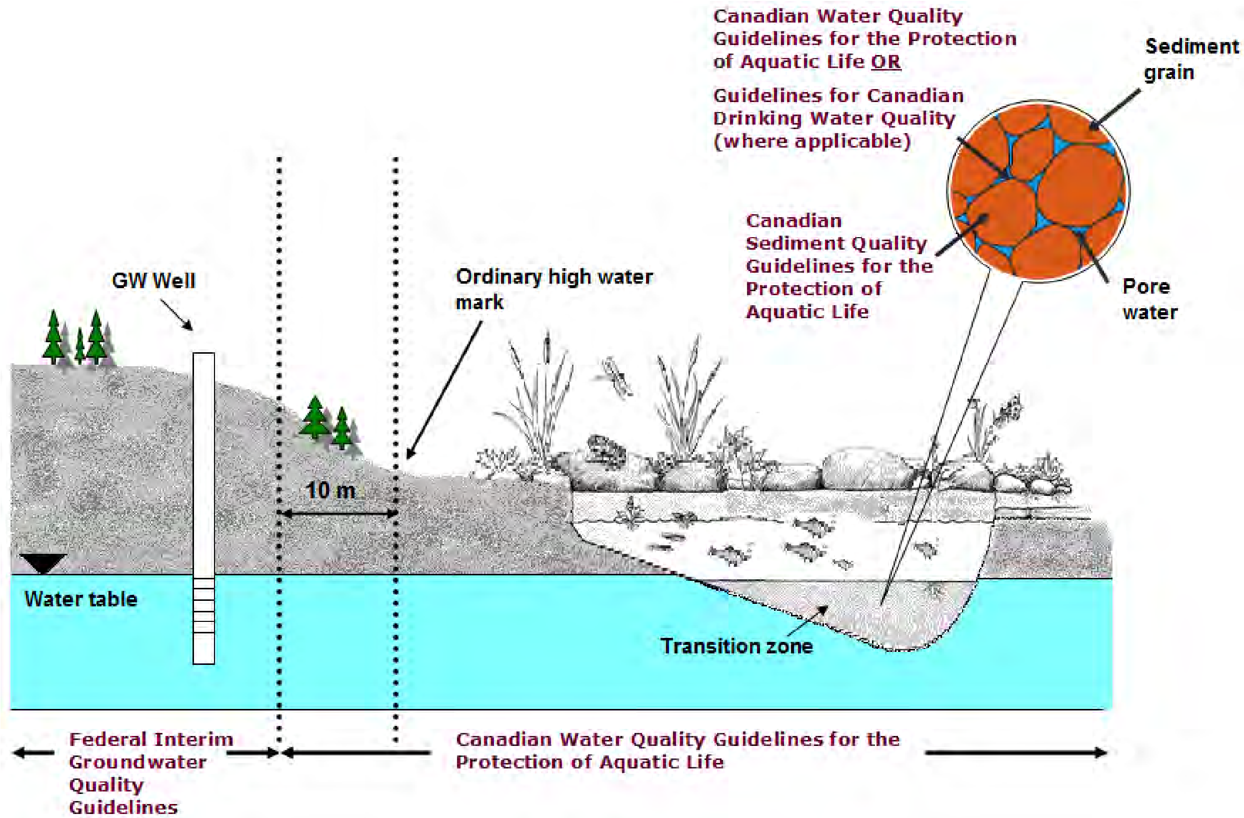
The "lowest guideline" presented in the first two column of Tables 1 to 3 were provided for convenience purposes, and represent the lowest guideline values if all the pathways presented in these tables are present at a site. However, this will often not be the case, and in particular relatively few sites will have both freshwater and marine water bodies nearby; the use of the lowest guideline may therefore result in a guideline that is overly conservative. Further discussion of the applicable pathways is provided in Section 5.2.

It is possible that multiple guidelines will apply at a single location. As a general rule, the following should be applied:

Table 1. Summary of Applicable Groundwater Quality Guidelines

	Federal Interim Groundwater Quality Guidelines	*Canadian **Water** Quality Guidelines for the Protection of Aquatic Life*	*Guidelines for Canadian Drinking Water Quality*	*Canadian **Sediment** Quality Guidelines for the Protection of Aquatic Life*	*Canadian Water Quality Guidelines for the Protection of Agricultural Water Uses*
Groundwater as defined in Section 2 (including the active zone in permafrost areas)	√		√ (where applicable)		√ (where applicable)
Groundwater within 10 m of a water body		√	√ (where applicable)		√ (where applicable)
Groundwater-surface water transition zone		√	√ (where applicable)		√ (where applicable)
Sediment pore water in groundwater-surface water transition zone		√	√ (where applicable)		√ (where applicable)
Sediments in groundwater-surface water transition zone				√ (apply to the sediments)	

The following Figure 1 provides a visual representation of the groundwater and of where the various guidelines would apply near a surface water body.



Note: *Canadian Water Quality Guidelines for the Protection of Agricultural Water Uses* and the *Guidelines for Canadian Drinking Water Quality* may also be applicable where appropriate

Figure 1. Illustration of groundwater cross-section near a surface water body.

4.1 Factors to Consider

In order to apply the numerical Tier 1 and Tier 2 guidelines, the following factors should be considered.

Soil Type Assessment

Groundwater quality guidelines are presented for both coarse (e.g. sand) and fine (e.g. silt or clay) soils. Consistent with *Canadian Soil Quality Guidelines*, coarse soils are defined as having a median particle diameter greater than or equal to 75 µm, while fine soils have a median particle diameter less than 75 µm (CCME 2006). The hydraulic conductivity for coarse soils is typically greater than 33m/year, while the hydraulic conductivity for fine soils is typically less than 33m/year.

Groundwater quality guidelines for coarse soils are generally lower than guidelines for fine soils, and therefore the coarse soil guidelines should be applied unless it can be demonstrated that site soils are fine-grained, with no coarse layers which could potentially govern contaminant migration. Even a relatively thin coarse layer in the saturated zone may govern transport towards downgradient receptors such as surface water bodies. Similarly, a layer of coarse soil beneath a building foundation may govern the transport of vapours into the building. There are a few chemicals, however, for which interim guidelines for the protection of soil organisms are lower for fine soils than coarse soils. Therefore, the lower of the guidelines for coarse and fine soils should be applied unless thorough investigation of site stratigraphy has been undertaken, supported by laboratory classification of the soil type, and it can clearly be demonstrated that the chosen soil type is appropriate.

Distance from Surface Water Bodies
As noted above, the groundwater guidelines as presented in Tables 1 to 3 can only be applied if the groundwater is taken at least 10 m away from the receiving water body. *Canadian Water Quality Guidelines for the Protection of Aquatic Life* are applied within 10 m of a surface water body and to the transition zone, particularly the part of the transition zone where aquatic and benthic organisms may reside. The 10 m lateral offset distance should be applied from the ordinary high water mark or edge of the 1 in 100 year flood zone (see Figure 1). For marine water bodies, the point of compliance should be established on a site-specific basis, taking into consideration the maximum expected high tide mark so as to ensure that there is at least a 10 m lateral separation between the contamination and potential habitat for marine aquatic or benthic organisms. Based on historical practices, it is expected that the extent of the transition zone will not be regularly determined at federal contaminated sites, although site-specific determination is recommended.

Water and Land Use Assessment
In order to apply these numerical guidelines, the appropriate land use should be determined. In many jurisdictions, current uses of groundwater as well as potential future uses must also be considered. The same land uses specified for *Canadian Soil Quality Guidelines* (agricultural, residential/parkland, commercial and industrial) are used for groundwater quality guidelines for consistency, because soil and groundwater are generally investigated together. These land uses are defined as follows (CCME 2006):

- *Agricultural*: where the primary land use is growing crops or tending livestock. This also includes agricultural lands that provide habitat for resident and transitory wildlife and native flora.

- *Residential/Parkland*: where the primary activity is residential or recreational activity; parkland is defined as a buffer between areas of residency, and also includes campground areas, but excludes wild lands such as national or provincial parks.

- *Commercial*: where the primary activity is commercial (e.g., shopping mall) and not residential or manufacturing; access to the site is generally not restricted. This does not include zones where food is grown.

- *Industrial*: where the primary activity involves the production, manufacture, or construction of goods. Access to the site is generally restricted.

Groundwater guidelines are generally less dependent on land use than soil guidelines, because many of the groundwater uses and pathways are independent of human uses of the land. In the event that none of the defined land uses is appropriate for the site, use of the agricultural guidelines is generally conservative.

4.2 Limitations of the Use of the Numerical Guidelines

As discussed above, the numerical guidelines were developed using a specific set of assumptions and models. In some cases, the assumptions used to derive these guidelines may not be protective for particularly sensitive sites. Any of the following conditions may invalidate the assumptions used to develop the Federal Interim Groundwater Quality Guidelines, and therefore would invalidate the use of the numerical groundwater quality guidelines:

Contaminated groundwater within 10 m of a surface water body
For contaminated groundwater within 10 m of a surface water body, accounting for potential seasonal fluctuations in water and the transition zone, the *Canadian Water Quality Guidelines for the Protection of Aquatic Life* should be applied directly.

Groundwater flow to stagnant water bodies
If contaminated groundwater is discharging into a stagnant water body (a water body without significant outflow), persistent contaminants may be concentrated through evaporation. A site-specific risk assessment is normally required in this scenario.

Fractured bedrock or fractured silt/clay
The transport models used to develop the numerical guidelines assume that contaminant transport occurs through unconsolidated soils. If transport between the contaminant source and receptor (e.g. surface water body) is through fractures instead of unconsolidated soils, either a transport distance of zero should be assumed (i.e. the *Canadian Water Quality Guidelines for the Protection of Aquatic Life* should be applied to groundwater), or a site-specific risk assessment should be conducted.

Very coarse textured soils enhancing transport or high groundwater velocity
Very coarse (e.g. gravel) soils may result in enhanced contaminant transport compared to what was assumed in the derivation of the numerical guidelines. Other scenarios resulting in a high groundwater velocity (e.g. tidal influences close to a marine water body) may also enhance contaminant transport. If the Darcy groundwater velocity exceeds $3x10^{-7}$ m/s, the groundwater transport modelling conducted for the numerical guidelines may not be protective of nearby surface water bodies; in this case, a site-specific adjustment of the guidelines will likely be necessary. Similarly, if the soil vapour permeability exceeds $6x10^{-8}$ cm^2, the vapour transport guidelines may need to be adjusted on a site-specific basis.

Contaminated groundwater within 30 cm of a building foundation
The models used to evaluate vapour intrusion are not considered valid if the source of contamination is very close to the building; contaminated groundwater in direct contact with a building in particular is considered to be a high risk situation. In the event that contaminated groundwater is present within 30 cm of a building foundation, a site-specific risk assessment is

normally required.

Earthen Floors or Other Unusual Structural Features
The vapour intrusion model assumes a typical residential or commercial/industrial building with a concrete foundation slab. The presence of a building with an earthen floor within 10 m of groundwater contamination indicates that a site-specific risk assessment is required. Other unusual building features (e.g. unusually low air exchange rate) may need to be addressed in a site-specific risk assessment or site-specific guideline modification.

4.3 Special Considerations on the Application of the Numerical Guidelines

High Natural Background Concentration
In applying the Federal Interim Groundwater Quality Guideline, it is not expected that remediation of a contaminated site would be done to levels below natural background concentrations. However, in some cases where the naturally occurring background concentrations of contaminants are higher than the Federal Interim Groundwater Quality Guideline values, the guideline values may still need to be considered in the development of the risk management approach that would be applied to the site so as to ensure that the site does not continue to pose an unacceptable risk to human health. For example, groundwater in areas with high naturally occurring background chemical concentrations (e.g. arsenic, radon, uranium) may be restricted to non-potable water uses.

Application on First Nation Lands
For contaminated sites on settlement lands, the First Nation has the right to request more stringent standards/guidelines for water quality than those provided in Federal or Territorial laws.

5 CONSIDERATION OF SITE-SPECIFIC CONDITIONS (FOR TIER 2)

The development of site-specific remediation objectives through consideration of site-specific conditions for deriving Tier 2 groundwater quality guidelines, often referred to as “Tier 2 adjustment”, involves the re-calculation of groundwater quality guidelines using the same model and pathways as for the generic guidelines, but adjusting certain stable, readily adjusted parameters in the models or by focusing on the receptors that are applicable to the site to reflect site-specific conditions; or the removal of exposure pathways that are not applicable at a site. These adjustments may be undertaken either for sites where the generic guidelines are not applicable, or for sites where it is believed that site-specific conditions may mitigate exposure for the governing pathway.

5.1 Guidelines Modification based on Site-Specific Conditions

The equations used for site-specific modification of guidelines are presented in Appendix B, along with default model parameters used to derive the generic guidelines. Further guidance on site-specific modification of guidelines, including site characterization requirements, whose parameters can be adjusted, and the adjustment procedures, can be found in the *Alberta Tier 2 Soil and Groundwater Remediation Guidelines* (AENV 2009b) or Appendices C and D of the

Canada-Wide Standard for Petroleum Hydrocarbons (PHC) in Soil: User Guidance (CCME 2008b) and *Guidance Manual for Developing Site-Specific Soil Quality Remediation Objectives for Contaminated Sites in Canada* (CCME 1996).

5.2 Pathways Elimination

To determine the groundwater quality guidelines that would be applied to a site, and thus to select the appropriate Tables 1 to 3, the current and intended federal land uses need to be identified first. Pathways that apply to the site would then be identified, considering both the current site conditions and reasonably anticipated future federal uses of the site. In addition, where potable water sources are present in a contaminated site, the *Guidelines for Canadian Drinking Water Quality* (Health Canada 2008) should be applied. The groundwater quality guidelines that apply at the site would be the lowest of the guidelines for all the applicable pathways.

It should be noted that in some circumstances it may be theoretically possible to screen out all pathways for a particular chemical. It is recommended that at least one pathway should be retained unless a site-specific risk assessment can establish an acceptable concentration, taking into consideration additional factors such as potential free-phase product formation and other hazards from the chemical, and the possibility that remaining concentrations could act as a source of further contamination. It is not the intent of these guidelines to allow for unlimited groundwater contamination in the event that all pathways for which guidelines have been calculated can be eliminated at a site.

Drinking water
The protection of drinking water is addressed separately by the *Guidelines for Canadian Drinking Water Quality* (Health Canada 2008). The drinking water guidelines are applied to groundwater that is used as a potable water source or to groundwater defined as a potential potable water source by the province or other agency with jurisdiction over drinking water issues. This pathway can likely be eliminated for groundwater in the active layer in permafrost areas.

Protection of freshwater/marine life
The protection of freshwater life can be excluded as a consideration for most contaminants if there are no surface water bodies within 500 m of the groundwater contamination. Similarly, marine life guidelines can be excluded if there are no marine water bodies within 500 m. For conservative (i.e. no retardation or biodegradation) solutes in groundwater such as chloride, however, a distance of 500 m may not be adequate in all cases. It is therefore recommended that the protection of aquatic life guidelines be applied if there are water bodies within 10 km of the contamination. It may also be possible to eliminate this pathway if it can be demonstrated that there is no hydrological connection between the contaminated groundwater and nearby surface water bodies, particularly when addressing contamination in the active layer in permafrost areas.

Irrigation water and livestock watering guidelines
The irrigation water and livestock watering guidelines normally only apply with the agricultural land use. They could be excluded if there is no aquifer suitable for this use, and groundwater

contamination is not present within the depth of typical agricultural dugouts (approximately 3 m).

Wildlife watering
The wildlife watering guidelines can be excluded if there are no surface water bodies within 500 m of the groundwater contamination, or 10 km for conservative solutes such as chloride. It may also be possible to eliminate this pathway if it can be demonstrated that there is no hydrological connection between the contaminated groundwater and nearby surface water bodies, particularly when addressing contamination in the active layer in permafrost areas.

Vapour intrusion
The vapour intrusion pathway can only be excluded if there are no occupied buildings present at the site and no potential for future occupied buildings within 30 m of the groundwater contamination.

6 SITE-SPECIFIC RISK ASSESSMENT (TIER 3)

The use of site-specific risk assessment to develop site-specific remediation objectives, which are often referred to as "Tier 3", is generally applied where neither Tier 1 nor Tier 2 guidelines apply, or for large and complex sites.

Site-specific risk assessment, may involve the use of different models and assumptions, and generally requires more site-specific data than application of the generic guidelines or site-specific modification of guidelines. Detailed guidance on site-specific risk assessment is beyond the scope of this document; guidance has been published by agencies such as Health Canada, CCME and several international agencies. Particularly relevant documents include:

- *A Framework for Ecological Risk Assessment: General Guidance*. (CCME 1996).
- *A Framework for Ecological Risk Assessment: Technical Appendices*. (CCME 1997).
- *Federal Contaminated Sites Risk Assessment in Canada Part I: Guidance on Human Health Preliminary Quantitative Risk Assessment* (PQRA). (Health Canada 2004a).
- *Federal Contaminated Sites Risk Assessment in Canada Part II: Health Canada Toxicological Reference Values* (TRVs). (Health Canada 2004b).
- Federal Contaminated Sites Risk Assessment in Canada Part V: Guidance on Human Health Detailed Quantitative Risk Assessment of Chemicals (DQRA). Draft. (Health Canada 2006).
- *A Protocol for the Derivation of Environmental and Human Health Soil Quality Guidelines*. (CCME 2006).
- *Guidance on the Site-Specific Application of Water Quality Guidelines in Canada: Procedures for Deriving Numerical Water Quality Objectives*. (CCME 2003).

APPENDIX A
FEDERAL INTERIM GROUNDWATER QUALITY GUIDELINES

TABLE 1 FEDERAL INTERIM GROUNDWATER QUALITY GUIDELINES
GENERIC GUIDELINES FOR AGRICULTURAL LAND USE[a] (mg/L)

Note: Guidelines for Canadian Drinking Water Quality (Health Canada, 2008) may also apply
Guidelines may not apply if underlying assumptions are not met (see Section 4.2)

	Tier 1		Tier 2											
	Lowest Guideline		Water Use/Exposure Pathway											
			Inhalation		Soil Organisms Direct Contact		Freshwater Life[b]		Marine Life[c]		Irriga-tion[j]	Live-stock[j]	Wildlife Watering	
Parameters	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**	**All**	**All**	**Fine**	**Coarse**
General and Inorganic Parameters														
pH	6.5-8.7	6.5-8.7	-	-	-	-	6.5-9	6.5-9	7-8.7	7-8.7	-	-	-	-
Ammonia	See note e	See note e	-	-	-	-	see note d	see note d	-	-	-	-	-	-
Chloride	100	100	-	-	-	-	230	230	-	-	100	-	-	-
Chlorine	0.002	0.002					0.002 [h,i]	0.002 [h,i]	0.003 [h,i]	0.003 [h,i]				
Cyanide	0.001	0.001	-	-	-	-	0.005	0.005	0.001 [h,i]	0.001 [h,i]	-	-	-	-
Fluoride	0.12	0.12	-	-	-		0.12	0.12	1.5 [h,i]	1.5 [h,i]	1	1	-	-
Nitrate	13	13	-	-	-	-	13	13	16	16	-	-	-	-
Nitrate + Nitrite (as nitrogen)	100	100	-	-	-	-	-	-	-	-	-	100	-	-
Nitrite (as nitrogen)	0.06	0.06	-	-	-	-	0.06	0.06	-	-	-	10	-	-
Sulphate	100	100	-	-	-	-	100 [h,i]	100 [h,i]	-	-	-	1000	-	-
Sulphide (as H_2S)	0.002	0.002	-	-	-	-	0.002	0.002	0.002 [h,i]	0.002 [h,i]	-	-	-	-
Total Dissolved Solids (TDS)	3000	3000	-	-	-	-	-	-	-	-	-	3000	-	-
Metals														
Aluminum	See note e	See note e	-	-	-	-	see note d	see note d	-	-	5	5	-	-
Antimony	1.6	1.6					1.6 [f,i]	1.6 [f,i]						
Arsenic	0.005	0.005	-	-	-	-	0.005	0.005	0.0125	0.0125	0.1	0.025	-	-
Barium	0.5	0.5					2.3 [f,i]	2.3 [f,i]	0.5 [h,i]	0.5 [h,i]				
Beryllium	0.0053	0.0053	-	-	-	-	0.0053 [h,i]	0.0053 [h,i]	0.1 [h,i]	0.1 [h,i]	0.1	0.1	-	-
Boron	0.5	0.5	-	-	-	-	-	-	5 [h,i]	5 [h,i]	0.5	5	-	-
Cadmium	0.000017	0.000017	-	-	-	-	0.000017	0.000017	0.00012	0.00012	0.0051	0.08	-	-
Chromium (Total)	0.0089	0.0089	-	-	-	-	0.0089	0.0089	0.056	0.056	-	0.05	-	-
Cobalt	0.05	0.05	-	-	-	-	-	-	-	-	0.05	1	-	-
Copper	See note e	See note e	-	-	-	-	see note d	see note d	0.002 [h,i]	0.002 [h,i]	0.2	0.5	-	-
Iron	0.3	0.3	-	-	-	-	0.3	0.3	-	-	5	-	-	-
Lead	See note e	See note e	-	-	-	-	see note d	see note d	0.002 [h,i]	0.002 [h,i]	0.2	0.1	-	-
Manganese	0.2	0.2	-	-	-	-	-	-	-	-	0.2	-	-	-
Mercury	0.000016	0.000016	-	-	-	-	0.000026	0.000026	0.000016	0.000016	-	0.003	-	-
Molybdenum	0.073	0.073	-	-	-	-	0.073	0.073	-	-	-	-	-	-
Nickel	See note e	See note e	-	-	-	-	see note d	see note d	0.083 [h,i]	0.083 [h,i]	0.2	1	-	-
Selenium	0.001	0.001	-	-	-	-	0.001	0.001	0.054 [h,i]	0.054 [h,i]	0.02	0.05	-	-
Silver	0.0001	0.0001	-	-	-	-	0.0001	0.0001	0.0015 [h,i]	0.0015 [h,i]	0.02	0.05	-	-
Thallium	0.0008	0.0008	-	-	-	-	0.0008	0.0008	-	-	-	-	-	-
Titanium	0.1	0.1					0.1 [h,i]	0.1 [h,i]						

TABLE 1 FEDERAL INTERIM GROUNDWATER QUALITY GUIDELINES
GENERIC GUIDELINES FOR AGRICULTURAL LAND USE[a] (mg/L)

Note: Guidelines for Canadian Drinking Water Quality (Health Canada, 2008) may also apply
Guidelines may not apply if underlying assumptions are not met (see Section 4.2)

	Tier 1		Tier 2											
	Lowest Guideline		Water Use/Exposure Pathway											
			Inhalation		Soil Organisms Direct Contact		Freshwater Life[b]		Marine Life[c]		Irrigation[j]	Livestock[j]	Wildlife Watering	
Parameters	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**	**All**	**All**	**Fine**	**Coarse**
Uranium	0.01	0.01	-	-	-	-	0.3 [h,i]	0.3 [h,i]	-	-	0.01	0.2	-	-
Vanadium	0.1	0.1	-	-	-	-	-	-	-	-	0.1	0.1	-	-
Zinc	0.01	0.01	-	-	-	-	0.03	0.03	0.01 [h,i]	0.01 [h,i]	1	50	-	-
Hydrocarbons														
Benzene	0.088	0.088	2.8	0.14	100	61	33	0.69	9.8	0.2	-	0.088	6.8	0.14
Toluene	4.9	0.083	NGR	74	82	59	NGR	0.083	NGR	8.9	-	4.9	NGR	180
Ethylbenzene	3.2	3.2	NGR	16	42	20	NGR	41	NGR	11	-	3.2	NGR	NGR
Xylenes	13	3.9	80	3.9	21	31	NGR	18	-	-	-	13	NGR	NGR
Styrene	0.072	0.072	90	4.3	-	-	0.072	0.072	-	-	-	-	-	-
F1	6.5	0.81	19	0.81	6.5	7.1	NGR	9.8	-	-	-	53	NGR	NGR
F2	1.8	1.3	NGR	1.5	1.8	1.8	NGR	1.3	-	-	-	NGR	NGR	NGR
Acenapthene	0.0058	0.0058	NGR	NGR	-	-	0.0058	0.0058	-	-	-	NGR	NGR	NGR
Acenaphthylene	0.046	0.046	-	-	-	-	0.046	0.046	-	-	-	-	-	-
Anthracene	0.000012	0.000012	NGR	NGR	0.025	0.025	0.000012	0.000012	-	-	-	NGR	NGR	NGR
Fluoranthene	0.00004	0.00004	NGR	NGR	0.24	0.24	0.00004	0.00004	-	-	-	NGR	NGR	NGR
Fluorene	0.003	0.003	NGR	NGR	-	-	0.003	0.003	0.012 [h,i]	0.012 [h,i]	-	NGR	NGR	NGR
Methylnaphthalenes	1.5	1.5	150 [f]	24 [f]			1.5 [f,i]	1.5 [f,i]						
Naphthalene	0.0011	0.0011	14	0.6	-	-	0.0011	0.0011	0.0014	0.0014	-	NGR	NGR	NGR
Phenanthrene	0.0004	0.0004	-	-	-	-	0.0004	0.0004	-	-	-	NGR	NGR	NGR
Pyrene	0.000025	0.000025	NGR	NGR	-	-	0.000025	0.000025	-	-	-	NGR	NGR	NGR
Benz[a]anthracene [g]	0.000018	0.000018	-	-	-	-	0.000018	0.000018	-	-	-	NGR	NGR	NGR
Benzo[b+j]fluoranthene [g]	0.00048	0.00048	-	-	-	-	0.00048	0.00048	-	-	-	NGR	NGR	NGR
Benzo[k]fluoranthene [g]	0.00048	0.00048	-	-	-	-	0.00048	0.00048	-	-	-	NGR	NGR	NGR
Benzo[g,h,i]perylene [g]	0.00021	0.00017	-	-	-	-	0.00021	0.00017	-	-	-	-	-	-
Benzo[a]pyrene [g]	0.00001	0.00001	-	-	0.0018	0.0018	0.000017	0.000015	0.00001 [h,i]	0.00001 [h,i]	-	NGR	NGR	NGR
Chrysene [g]	0.0001	0.0001	-	-	-	-	0.0014	0.0014	0.0001 [h,i]	0.0001 [h,i]	-	NGR	NGR	NGR
Dibenz[a,h]anthracene [g]	0.00028	0.00026	-	-	-	-	0.00028	0.00026	-	-	-	NGR	NGR	NGR
Indeno[1,2,3-c,d]pyrene [g]	0.00023	0.00021	-	-	-	-	0.00023	0.00021	-	-	-	-	-	-
Halogenated Aliphatics														
Vinyl chloride	0.018	0.0011	0.018	0.0011	-	-	-	-	-	-	-	-	-	-
1,1-Dichloroethene	0.68	0.039	0.68	0.039	-	-	-	-	-	-	-	-	-	-
cis-1,2-DichloroetheneDichloroethene	12	12	-	-	-	-	12 [f,i]	12 [f,i]	-	-	-	-	-	-
trans-1,2-DichloroetheneDichloroethene	12	12	-	-	-	-	12 [f,i]	12 [f,i]	-	-	-	-	-	-

TABLE 1 FEDERAL INTERIM GROUNDWATER QUALITY GUIDELINES
GENERIC GUIDELINES FOR AGRICULTURAL LAND USE[a] (mg/L)

Note: Guidelines for Canadian Drinking Water Quality (Health Canada, 2008) may also apply
Guidelines may not apply if underlying assumptions are not met (see Section 4.2)

	Tier 1		Tier 2											
	Lowest Guideline		Water Use/Exposure Pathway											
			Inhalation		Soil Organisms Direct Contact		Freshwater Life[b]		Marine Life[c]		Irriga-tion[j]	Live-stock[j]	Wildlife Watering	
Parameters	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**	**All**	**All**	**Fine**	**Coarse**
Trichloroethene (Trichloroethylene, TCE)	0.05	0.02	0.41	0.02	4.4	5	0.27	0.029	-	-	-	0.05	-	-
Tetrachloroethene (Tetrachloroethylene, Perchloroethylene, PCE)	0.11	0.11	2.3	0.11	-	-	0.11	0.11	-	-	-	-	-	-
1,1-Dichloroethane	56	9	56[f]	9[f]	-	-	200[f,i]	200[f,i]	-	-	-	-	-	-
1,2-Dichloroethane	0.005	0.005	0.17	0.01	-	-	0.1	0.1	-	-	-	0.005	-	-
Dichloromethane (Methylene chloride)	0.05	0.05	61	3.4	-	-	0.098	0.098	-	-	-	0.05	-	-
1,1,1,2-Tetrachloroethane	0.038	0.006	0.038[f]	0.006[f]	-	-	9.3[f,i]	9.3[f,i]	-	-	-	-	-	-
1,1,2,2-Tetrachloroethane	0.14	0.022	0.14[f]	0.022[f]	-	-	2.4[f,i]	2.4[f,i]	-	-	-	-	-	-
1,1,1-Trichloroethane	18	4.2	26[f]	4.2[f]	-	-	18[f,i]	18[f,i]	-	-	-	-	-	-
1,1,2-Trichloroethane	9.4	9.4	100[f]	16[f]	-	-	9.4[f,i]	9.4[f,i]	-	-	-	-	-	-
Trichloromethane (Chloroform)	0.0018	0.0018	0.05	0.003	-	-	0.0018	0.0018	-	-	-	0.1	-	-
Tetrachloromethane (Carbon tetrachloride)	0.005	0.00056	0.011	0.00056	-	-	0.013	0.013	-	-	-	0.005	-	-
1,2-Dichloropropane	0.058	0.0093	0.058[f]	0.0093[f]	-	-	5.7[f,i]	5.7[f,i]	-	-	-	-	-	-
1,3-Dichloropropene	0.024	0.0038	0.024[f]	0.0038[f]	-	-	0.24[f,i]	0.24[f,i]	-	-	-	-	-	-
Bromoform	5.2	0.84	5.2[f]	0.84[f]	-	-	29[f,i]	29[f,i]	-	-	-	-	-	-
Bromomethane	0.016	0.002	0.016[f]	0.002[f]	-	-	0.32[f,i]	0.32[f,i]	-	-	-	-	-	-
Bromodichloromethane	67	67	-	-	-	-	67[f,i]	67[f,i]	-	-	-	-	-	-
Dibromochloromethane	0.1	0.1	26	1.1	-	-	-	-	-	-	-	0.1	-	-
Ethylene dibromide	0.021	0.0033	0.021[f]	0.0033[f]	-	-	2.8[f,i]	2.8[f,i]	-	-	-	-	-	-
Chlorinated Aromatics														
Chlorobenzene	0.0013	0.0013	0.3	0.014	-	-	0.0013	0.0013	0.025	0.025	-	-	-	-
1,2-Dichlorobenzene	0.0007	0.0007	116	5.4	-	-	0.0007	0.0007	0.042	0.042	-	-	-	-
1,3-Dichlorobenzene	0.042	0.042	-	-	-	-	0.15	0.15	0.042[h,i]	0.042[h,i]	-	-	-	-
1,4-Dichlorobenzene	0.026	0.026	4.6	0.22	-	-	0.026	0.026	-	-	-	-	-	-
1,2,3-Trichlorobenzene	0.008	0.008	0.8	0.032	-	-	0.008	0.008	-	-	-	-	-	-
1,2,4-Trichlorobenzene	0.024	0.024	0.71	0.028	-	-	0.024	0.024	0.0054	0.0054	-	-	-	-
1,3,5-Trichlorobenzene	0.38	0.015	0.38	0.015	-	-	-	-	-	-	-	-	-	-
1,2,3,4-Tetrachlorobenzene	0.0018	0.0018	NGR	0.14	-	-	0.0018	0.0018	-	-	-	-	-	-
1,2,3,5-Tetrachlorobenzene	0.41	0.017	0.41	0.017	-	-	-	-	-	-	-	-	-	-
1,2,4,5-Tetrachlorobenzene	0.21	0.0088	0.21	0.0088	-	-	-	-	-	-	-	-	-	-

TABLE 1 FEDERAL INTERIM GROUNDWATER QUALITY GUIDELINES
GENERIC GUIDELINES FOR AGRICULTURAL LAND USE[a] (mg/L)

Note: Guidelines for Canadian Drinking Water Quality (Health Canada, 2008) may also apply
Guidelines may not apply if underlying assumptions are not met (see Section 4.2)

	Tier 1		Tier 2											
	Lowest Guideline		Water Use/Exposure Pathway											
			Inhalation		Soil Organisms Direct Contact		Freshwater Life[b]		Marine Life[c]		Irriga-tion[j]	Live-stock[j]	Wildlife Watering	
Parameters	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**	**All**	**All**	**Fine**	**Coarse**
Pentachlorobenzene	0.006	0.006	NGR	0.038	-	-	0.006	0.006	-	-	-	-	-	-
Hexachlorobenzene	0.00052	0.00052	0.029	0.0012	-	-	-	-	-	-	-	0.00052	-	-
Phenols														
2-Chlorophenol	4.4	4.4	-	-	-	-	4.4 [f,i]	4.4 [f,i]	-	-	-	-	-	-
2,4-Dichlorophenol	0.0002	0.0002	NGR	1500	-	-	0.0002	0.0002	-	-	-	-	-	-
2,4-Dimethylphenol	2.1	2.1	-	-	-	-	2.1 [f,i]	2.1 [f,i]	-	-	-	-	-	-
2,4-Dinitrophenol	0.15	0.15	-	-	-	-	0.15 [f,i]	0.15 [f,i]	-	-	-	-	-	-
Phenol	0.002	0.002	73,000	3,700	110	150	0.004	0.004	-	-	-	0.002	-	-
2,4,5-Trichlorophenol	0.063	0.063	-	-	-	-	0.063[f,i]	0.063[f,i]	-	-	-	-	-	-
2,4,6-Trichlorophenol	0.018	0.018	NGR	54	-	-	0.018	0.018	-	-	-	-	-	-
2,3,4,6-Tetrachlorophenol	0.001	0.001	NGR	NGR	-	-	0.001	0.001	-	-	-	-	-	-
Pentachlorophenol	0.0005	0.0005	NGR	NGR	0.87	0.88	0.0005	0.0005	-	-	-	-	-	-
Pesticides														
Aldicarb	0.001	0.001	-	-	-	-	0.001	0.001	0.00015	0.00015	0.055	0.011	-	-
Aldrin	0.003	0.003	-	-	-	-	0.003	0.003	-	-	-	-	-	-
Atrazine and metabolites	0.0018	0.0018	-	-	-	-	0.0018	0.0018	0.01 [h,i]	0.01 [h,i]	0.01	0.005	-	-
Azniphos-methyl	0.00001	0.00001	-	-	-	-	0.00001	0.00001	-	-	-	-	-	-
Bromacil	0.005	0.005	-	-	-	-	0.005	0.005	-	-	-	-	-	-
Bromoxynil	0.00033	0.00033	-	-	-	-	0.005	0.005	-	-	0.00033	0.011	-	-
Captan	0.0013	0.0013	-	-	-	-	0.0013	0.0013	-	-	-	-	-	-
Carbaryl	0.0002	0.0002	-	-	-	-	0.0002	0.0002	0.00032	0.00032	-	1.1	-	-
Carbofuran	0.0018	0.0018	-	-	-	-	0.0018	0.0018	-	-	-	0.045	-	-
Chlordane	0.000004	0.000004	0.17 [f]	0.028 [f]			0.000004 [f,i]	0.000004 [f,i]						
Chlorothalonil	0.00018	0.00018	-	-	-	-	0.00018	0.00018	0.00036	0.00036	0.0058	0.17	-	-
Chlorpyrifos	0.0000035	0.0000035	-	-	-	-	0.0000035	0.0000035	0.000002	0.000002	-	0.024	-	-
Cyanazine	0.0005	0.0005	-	-	-	-	0.002	0.002	-	-	0.0005	0.01	-	-
2,4-D (2,4-Dichlorophenoxyacetic acid) & other phenoxy herbicides	0.004	0.004	-	-	-	-	0.004	0.004	-	-	-	0.1	-	-
DDAC (Didecyl dimethyl ammonium chloride)	0.0015	0.0015	-	-	-	-	0.0015	0.0015	-	-	-	-	-	-
DDT (Dichloro-Diphenyl-Trichloroethane) & metabolites	0.000001	0.000001	-	-	-	-	0.000001	0.000001	-	-	-	0.1	-	-
Deltamethrin	0.0000004	0.0000004	-	-	-	-	0.0000004	0.0000004	-	-	-	-	-	-
Diazinon	0.000003	0.000003					0.000003 [h,i]	0.000003 [h,i]						
Dicamba	0.000006	0.000006	-	-	-	-	0.01	0.01	-	-	0.000006	0.12	-	-

TABLE 1 FEDERAL INTERIM GROUNDWATER QUALITY GUIDELINES
GENERIC GUIDELINES FOR AGRICULTURAL LAND USE[a] (mg/L)

Note: Guidelines for Canadian Drinking Water Quality (Health Canada, 2008) may also apply
Guidelines may not apply if underlying assumptions are not met (see Section 4.2)

	Tier 1		Tier 2											
	Lowest Guideline		Water Use/Exposure Pathway											
			Inhalation		Soil Organisms Direct Contact		Freshwater Life[b]		Marine Life[c]		Irriga-tion[j]	Live-stock[j]	Wildlife Watering	
Parameters	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**	**All**	**All**	**Fine**	**Coarse**
Dichlofop-methyl	0.00018	0.00018	-	-	-	-	0.0061	0.0061	-	-	0.00018	0.009	-	-
Dieldrin	0.000056	0.000056	-	-	-	-	0.000056	0.000056	-	-	-	-	-	-
Dimethoate	0.003	0.003	-	-	-	-	0.0062	0.0062	-	-	-	0.003	-	-
Dinoseb	0.00005	0.00005	-	-	-	-	0.00005	0.00005	-	-	0.016	0.15	-	-
Endosulfan	0.00002	0.00002	-	-	-	-	0.00002	0.00002	-	-	-	-	-	-
Endrin	0.000036	0.000036	-	-	-	-	0.000036	0.000036	-	-	-	-	-	-
Glyphosate	0.065	0.065	-	-	-	-	0.065	0.065	-	-	-	0.28	-	-
Heptachlor epoxide	0.0000038	0.0000038	0.0043	0.00024	-	-	0.0000038	0.0000038	-	-	-	-	-	-
Imidacloprid	0.00023	0.00023	-	-	-	-	0.00023	0.00023	-	-	-	-	-	-
IPBC (3-iodo-2-propynyl butyl carbamate)	0.0019	0.0019	-	-	-	-	0.0019	0.0019	-	-	-	-	-	-
Lindane (γ-hexachlorocyclohexane)	0.00001	0.00001	-	-	-	-	0.00001	0.00001	-	-	-	0.004	-	-
Linuron	0.000071	0.000071	-	-	-	-	0.007	0.007	-	-	0.000071	-	-	-
Malathion	0.0001	0.0001	-	-	-	-	0.0001	0.0001	-	-	-	-	-	-
MCPA	0.000025	0.000025	-	-	-	-	0.0026	0.0026	0.0042	0.0042	0.000025	0.025	-	-
Methoprene	0.00009	0.00009	-	-	-	-	0.00009	0.00009	-	-	-	-	-	-
Methoxychlor	0.00003	0.00003	-	-	-	-	0.00003	0.00003	-	-	-	-	-	-
Metolachlor	0.0078	0.0078	-	-	-	-	0.0078	0.0078	-	-	0.028	0.05	-	-
Metribuzin	0.0005	0.0005	-	-	-	-	0.001	0.001	-	-	0.0005	0.08	-	-
Parathion	0.000013	0.000013	-	-	-	-	0.000013	0.000013	-	-	-	-	-	-
Permethrin	0.000004	0.000004	-	-	-	-	0.000004	0.000004	0.000001	0.000001	-	-	-	-
Picloram	0.029	0.029	-	-	-	-	0.029	0.029	-	-	-	0.19	-	-
Simazine	0.0005	0.0005	-	-	-	-	0.01	0.01	-	-	0.0005	0.01	-	-
Tebuthiuron	0.00027	0.00027	-	-	-	-	0.0016	0.0016	-	-	0.00027	0.13	-	-
Toxaphene	0.0000002	0.0000002	6.4	0.31	-	-	0.0000002	0.0000002	-	-	-	-	-	-
Triallate	0.00024	0.00024	-	-	-	-	0.00024	0.00024	-	-	-	0.23	-	-
Trifluarin	0.0002	0.0002	-	-	-	-	0.0002	0.0002	-	-	-	0.045	-	-
Other Organics														
Acetone	0.33	0.33	11000[f]	1800[f]	-	-	0.33[f,i]	0.33[f,i]	-	-	-	-	-	-
Acridine	0.00005	0.00005	-	-	-	-	0.00005[h,i]	0.00005[h,i]	-	-	-	-	-	-
Aniline	0.0022	0.0022	1,900	87	-	-	0.0022	0.0022	-	-	-	-	-	-
Bis(2-chloroethyl)ether	0.71	0.11	0.71[f]	0.11[f]	-	-	240[f,i]	240[f,i]	-	-	-	-	-	-
Bis(2-chloroisopropyl)ether	2.7	0.43	2.7[f]	0.43[f]	-	-	240[f,i]	240[f,i]	-	-	-	-	-	-
Bis(2-ethyl-hexyl)phthalate	0.016	0.016	NGR	NGR	-	-	0.016	0.016	-	-	-	-	-	-
Chloroaniline, p-	0.01	0.01	-	-	-	-	0.01[f,i]	0.01[f,i]	-	-	-	-	-	-
Dibutyl phthalate	0.019	0.019	NGR	NGR	-	-	0.019	0.019	-	-	-	-	-	-

TABLE 1 FEDERAL INTERIM GROUNDWATER QUALITY GUIDELINES GENERIC GUIDELINES FOR AGRICULTURAL LAND USE[a] (mg/L)

Note: Guidelines for Canadian Drinking Water Quality (Health Canada, 2008) may also apply
Guidelines may not apply if underlying assumptions are not met (see Section 4.2)

	Tier 1		Tier 2											
	Lowest Guideline		Water Use/Exposure Pathway											
			Inhalation		Soil Organisms Direct Contact		Freshwater Life[b]		Marine Life[c]		Irriga-tion[j]	Live-stock[j]	Wildlife Watering	
Parameters	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**	**All**	**All**	**Fine**	**Coarse**
di-n-Butyltin	0.00008	0.00008	-	-	-	-	0.00008 [h,i]	0.00008 [h,i]	-	-	-	-	-	-
Diethylphthalate	0.003	0.003	-	-	-	-	0.003 [f,i]	0.003 [f,i]	-	-	-	-	-	-
Diisopropanolamine	1.6	1.6	-	-	160	160	1.6	1.6	-	-	2	-	-	-
2,4-Dinitrotoluene	0.23	0.23	-	-	-	-	0.23 [f,i]	0.23 [f,i]	-	-	-	-	-	-
Ethylene glycol	190	190	NGR	NGR	9,200	16,000	190	190	-	-	-	-	-	-
Hexachlorobutadiene	0.0013	0.0013	0.031	0.0013	-	-	0.0013	0.0013	-	-	-	-	-	-
Methylmethacrylate	17	0.84	17	0.84	-	-	-	-	-	-	-	-	-	-
Methyl ethyl ketone	120	120	11000 [f]	1700 [f]	-	-	120 [f,i]	120 [f,i]	-	-	-	-	-	-
Methyl isobutyl ketone	350	57	350 [f]	57 [f]	-	-	430 [f,i]	430 [f,i]	-	-	-	-	-	-
Methyl mercury	0.000012	0.000012	-	-	-	-	0.000012 [f,i]	0.000012 [f,i]	-	-	-	-	-	-
MTBE (Methyl tert-butyl ether)	5	0.34	6.1	0.34	-	-	10	10	5	5	-	-	-	-
Monochloramine	0.0005	0.0005					0.0005 [h,i]	0.0005 [h,i]						
Nonylphenol + ethoxylates	0.001	0.001	-	-	0.0081	0.0081	0.001	0.001	0.0007	0.0007	-	-	-	-
Propylene glycol	500	500	-	-	-	-	500	500	-	-	-	-	-	-
Quinoline	0.0034	0.0034					0.0034 [h,i]	0.0034 [h,i]						
Sulfolane	0.5	0.5	-	-	1,700	2,800	50	50	-	-	0.5	-	-	-
Tributyltin	0.000008	0.000008	-	-	-	-	0.000008	0.000008	0.000001	0.000001	-	0.25	-	-
Triethyltin	0.0004	0.0004	-	-	-	-	0.0004 [h,i]	0.0004 [h,i]	-	-	-	-	-	-
Triphenyltin	0.000022	0.000022	-	-	-	-	0.000022	0.000022	-	-	-	0.8	-	-

a – all values adopted from Alberta Environment (AENV) (2009a) unless otherwise specified
b – where AENV (2009a) guideline was not based on the *Canadian Water Quality Guidelines* (CWQG) *for the Protection of Aquatic Life* for freshwater environments (CCME 1999), and a CWQG exists, the groundwater quality guideline was re-calculated based on the CWQG
c – based on *Canadian Water Quality Guidelines* (CWQG) *for the Protection of Aquatic Life* for the marine environments(CCME 1999) and groundwater transport model
d – the freshwater aquatic life guidelines vary depending on water pH, hardness etc. Therefore, see *Canadian Water Quality Guidelines for the Protection of Aquatic Life* (CCME 1999) to determine the appropriate water quality guideline applicable to the site and calculate the groundwater guidelines using formulas provided in Appendix B
e – guideline is the lowest of all applicable pathways
f – adopted from Ontario Ministry of Environment and Energy (OMEE) (1997); may be updated once revised Ontario standards are published
g – for ecological receptors only
h – adopted from BC Contaminated Sites Regulation
i - 10x factor for dilution in surface water was removed from guideline value
j – adopted directly from CCME (1999)
NGR – no guideline required; calculated guideline exceeds solubility limit

TABLE 2 FEDERAL INTERIM GROUNDWATER QUALITY GUIDELINES
GENERIC GUIDELINES FOR RESIDENTIAL/PARKLAND LAND USE[a] (mg/L)

Note: Guidelines for Canadian Drinking Water Quality (Health Canada, 2008) may also apply
Guidelines may not apply if underlying assumptions are not met (see Section 4.2)

	Tier 1		Tier 2							
	Lowest Guideline		Water Use/Exposure Pathway							
			Inhalation		Soil Organisms Direct Contact		Freshwater Life[b]		Marine Life[c]	
	Soil Type									
Parameters	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**
General and Inorganic Parameters										
pH	6.5-8.7	6.5-8.7	-	-	-	-	6.5-9	6.5-9	7-8.7	7-8.7
Ammonia	See note e	See note e	-	-	-	-	see note d	see note d	-	-
Chloride	230	230	-	-	-	-	230	230	-	-
Chlorine	0.002	0.002					0.002 [h,i]	0.002 [h,i]	0.003 [h,i]	0.003 [h,i]
Cyanide	0.001	0.001	-	-	-	-	0.005	0.005	0.001 [h,i]	0.001 [h,i]
Fluoride	0.12	0.12	-	-	-		0.12	0.12	1.5 [h,i]	1.5 [h,i]
Nitrate	13	13	-	-	-	-	13	13	16	16
Nitrite (as nitrogen)	0.06	0.06	-	-	-	-	0.06	0.06	-	-
Sulphate	100	100	-	-	-	-	100 [h,i]	100 [h,i]	-	-
Sulphide (as H_2S)	0.002	0.002	-	-	-	-	0.002	0.002	0.002 [h,i]	0.002 [h,i]
Metals										
Aluminum	See note e	See note e	-	-	-	-	see note d	see note d	-	-
Antimony	1.6	1.6					1.6 [f,i]	1.6 [f,i]		
Arsenic	0.005	0.005	-	-	-	-	0.005	0.005	0.0125	0.0125
Barium	0.5	0.5					2.3 [f,i]	2.3 [f,i]	0.5 [h,i]	0.5 [h,i]
Beryllium	0.0053	0.0053	-	-	-	-	0.0053 [h,i]	0.0053 [h,i]	0.1 [h,i]	0.1 [h,i]
Boron	5	5	-	-	-	-	-	-	5 [h,i]	5 [h,i]
Cadmium	0.000017	0.000017	-	-	-	-	0.000017	0.000017	0.00012	0.00012
Chromium (Total)	0.0089	0.0089	-	-	-	-	0.0089	0.0089	0.056	0.056
Copper	See note e	See note e	-	-	-	-	see note d	see note d	0.002 [h,i]	0.002 [h,i]
Iron	0.3	0.3	-	-	-	-	0.3	0.3	-	-
Lead	See note e	See note e	-	-	-	-	see note d	see note d	0.002 [h,i]	0.002 [h,i]
Mercury	0.000016	0.000016	-	-	-	-	0.000026	0.000026	0.000016	0.000016
Molybdenum	0.073	0.073	-	-	-	-	0.073	0.073	-	-
Nickel	See note e	See note e	-	-	-	-	see note d	see note d	0.083 [h,i]	0.083 [h,i]
Selenium	0.001	0.001	-	-	-	-	0.001	0.001	0.054 [h,i]	0.054 [h,i]
Silver	0.0001	0.0001	-	-	-	-	0.0001	0.0001	0.0015 [h,i]	0.0015 [h,i]
Thallium	0.0008	0.0008	-	-	-	-	0.0008	0.0008	-	-
Titanium	0.1	0.1					0.1 [h,i]	0.1 [h,i]		
Uranium	0.3	0.3	-	-	-	-	0.3 [h,i]	0.3 [h,i]	-	-
Zinc	0.01	0.01	-	-	-	-	0.03	0.03	0.01 [h,i]	0.01 [h,i]
Hydrocarbons										
Benzene	2.8	0.14	2.8	0.14	100	61	33	0.69	9.8	0.2
Toluene	82	0.083	NGR	74	82	59	NGR	0.083	NGR	8.9

TABLE 2 FEDERAL INTERIM GROUNDWATER QUALITY GUIDELINES
GENERIC GUIDELINES FOR RESIDENTIAL/PARKLAND LAND USE[a] (mg/L)

Note: Guidelines for Canadian Drinking Water Quality (Health Canada, 2008) may also apply
Guidelines may not apply if underlying assumptions are not met (see Section 4.2)

	Tier 1		Tier 2							
			Water Use/Exposure Pathway							
	Lowest Guideline		Inhalation		Soil Organisms Direct Contact		Freshwater Life[b]		Marine Life[c]	
	Soil Type									
Parameters	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**
Ethylbenzene	42	11	NGR	16	42	20	NGR	41	NGR	11
Xylenes	21	3.9	80	3.9	21	31	NGR	18	-	-
Styrene	0.072	0.072	90	4.3	-	-	0.072	0.072	-	-
F1	6.5	0.81	19	0.81	6.5	7.1	NGR	9.8	-	-
F2	1.8	1.3	NGR	1.5	1.8	1.8	NGR	1.3	-	-
Acenapthene	0.0058	0.0058	NGR	NGR	-	-	0.0058	0.0058	-	-
Acenaphthylene	0.046	0.046	-	-	-	-	0.046	0.046	-	-
Anthracene	0.000012	0.000012	NGR	NGR	0.025	0.025	0.000012	0.000012	-	-
Fluoranthene	0.00004	0.00004	NGR	NGR	0.24	0.24	0.00004	0.00004	-	-
Fluorene	0.003	0.003	NGR	NGR	-	-	0.003	0.003	0.012 [h,i]	0.012 [h,i]
Methylnaphthalenes	1.5	1.5	150 [f]	24 [f]			1.5 [f,i]	1.5 [f,i]		
Naphthalene	0.0011	0.0011	14	0.6	-	-	0.0011	0.0011	0.0014	0.0014
Phenanthrene	0.0004	0.0004	-	-	-	-	0.0004	0.0004	-	-
Pyrene	0.000025	0.000025	NGR	NGR	-	-	0.000025	0.000025	-	-
Benz[a]anthracene [g]	0.000018	0.000018	-	-	-	-	0.000018	0.000018	-	-
Benzo[b+j]fluoranthene [g]	0.00048	0.00048	-	-	-	-	0.00048	0.00048	-	-
Benzo[k]fluoranthene [g]	0.00048	0.00048	-	-	-	-	0.00048	0.00048	-	-
Benzo[g,h,i]perylene [g]	0.00021	0.00017	-	-	-	-	0.00021	0.00017	-	-
Benzo[a]pyrene [g]	0.00001	0.00001	-	-	0.0018	0.0018	0.000017	0.000015	0.00001 [h,i]	0.00001 [h,i]
Chrysene [g]	0.0001	0.0001	-	-	-	-	0.0014	0.0014	0.0001 [h,i]	0.0001 [h,i]
Dibenz[a,h]anthracene [g]	0.00028	0.00026	-	-	-	-	0.00028	0.00026	-	-
Indeno[1,2,3-c,d]pyrene [g]	0.00023	0.00021	-	-	-	-	0.00023	0.00021	-	-
Halogenated Aliphatics										
Vinyl chloride	0.018	0.0011	0.018	0.0011	-	-	-	-	-	-
1,1-Dichloroethene	0.68	0.039	0.68	0.039	-	-	-	-	-	-
cis-1,2-DichloroetheneDichloroethene	12	12	-	-	-	-	12 [f,i]	12 [f,i]	-	-
trans-1,2-DichloroetheneDichloroethene	12	12	-	-	-	-	12 [f,i]	12 [f,i]	-	-
Trichloroethene (Trichloroethylene, TCE)	0.27	0.02	0.41	0.02	4.4	5	0.27	0.029	-	-
Tetrachloroethene (Tetrachloroethylene, Perchloroethylene, PCE)	0.11	0.11	2.3	0.11	-	-	0.11	0.11	-	-
1,1-Dichloroethane	56	9	56 [f]	9 [f]	-	-	200 [f,i]	200 [f,i]	-	-
1,2-Dichloroethane	0.1	0.01	0.17	0.01	-	-	0.1	0.1	-	-

TABLE 2 FEDERAL INTERIM GROUNDWATER QUALITY GUIDELINES GENERIC GUIDELINES FOR RESIDENTIAL/PARKLAND LAND USE[a] (mg/L)

Note: Guidelines for Canadian Drinking Water Quality (Health Canada, 2008) may also apply Guidelines may not apply if underlying assumptions are not met (see Section 4.2)

	Tier 1		Tier 2							
	Lowest Guideline		Water Use/Exposure Pathway							
			Inhalation		Soil Organisms Direct Contact		Freshwater Life[b]		Marine Life[c]	
	Soil Type									
Parameters	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**
Dichloromethane (Methylene chloride)	0.098	.098	61	3.4	-	-	0.098	0.098	-	-
1,1,1,2-Tetrachloroethane	0.038	0.006	0.038[f]	0.006[f]	-	-	9.3[f,i]	9.3[f,i]	-	-
1,1,2,2-Tetrachloroethane	0.14	0.022	0.14[f]	0.022[f]	-	-	2.4[f,i]	2.4[f,i]	-	-
1,1,1-Trichloroethane	18	4.2	26[f]	4.2[f]	-	-	18[f,i]	18[f,i]	-	-
1,1,2-Trichloroethane	9.4	9.4	100[f]	16[f]	-	-	9.4[f,i]	9.4[f,i]	-	-
Trichloromethane (Chloroform)	0.0018	0.0018	0.05	0.003	-	-	0.0018	0.0018	-	-
Tetrachloromethane (Carbon tetrachloride)	0.011	0.00056	0.011	0.00056	-	-	0.013	0.013	-	-
1,2-Dichloropropane	0.058	0.0093	0.058[f]	0.0093[f]	-	-	5.7[f,i]	5.7[f,i]	-	-
1,3-Dichloropropene	0.024	0.0038	0.024[f]	0.0038[f]	-	-	0.24[f,i]	0.24[f,i]	-	-
Bromoform	5.2	0.84	5.2[f]	0.84[f]	-	-	29[f,i]	29[f,i]	-	-
Bromomethane	0.016	0.002	0.016[f]	0.002[f]	-	-	0.32[f,i]	0.32[f,i]	-	-
Bromodichloromethane	67	67	-	-	-	-	67[f,i]	67[f,i]	-	-
Dibromochloromethane	26	1.1	26	1.1	-	-	-	-	-	-
Ethylene dibromide	0.021	0.0033	0.021[f]	0.0033[f]	-	-	2.8[f,i]	2.8[f,i]	-	-
Chlorinated Aromatics										
Chlorobenzene	0.0013	0.0013	0.3	0.014	-	-	0.0013	0.0013	0.025	0.025
1,2-Dichlorobenzene	0.0007	0.0007	116	5.4	-	-	0.0007	0.0007	0.042	0.042
1,3-Dichlorobenzene	0.042	0.042	-	-	-	-	0.15	0.15	0.042[h,i]	0.042[h,i]
1,4-Dichlorobenzene	0.026	0.026	4.6	0.22	-	-	0.026	0.026	-	-
1,2,3-Trichlorobenzene	0.008	0.008	0.8	0.032	-	-	0.008	0.008	-	-
1,2,4-Trichlorobenzene	0.024	0.024	0.71	0.028	-	-	0.024	0.024	0.0054	0.0054
1,3,5-Trichlorobenzene	0.38	0.015	0.38	0.015	-	-	-	-	-	-
1,2,3,4-Tetrachlorobenzene	0.0018	0.0018	NGR	0.14	-	-	0.0018	0.0018	-	-
1,2,3,5-Tetrachlorobenzene	0.41	0.017	0.41	0.017	-	-	-	-	-	-
1,2,4,5-Tetrachlorobenzene	0.21	0.0088	0.21	0.0088	-	-	-	-	-	-
Pentachlorobenzene	0.006	0.006	NGR	0.038	-	-	0.006	0.006	-	-
Hexachlorobenzene	0.029	0.0012	0.029	0.0012	-	-	-	-	-	-
Phenols										
2-Chlorophenol	4.4	4.4	-	-	-	-	4.4[f,i]	4.4[f,i]	-	-
2,4-Dichlorophenol	0.0002	0.0002	NGR	1500	-	-	0.0002	0.0002	-	-
2,4-Dimethylphenol	2.1	2.1	-	-	-	-	2.1[f,i]	2.1[f,i]	-	-
2,4-Dinitrophenol	0.15	0.15	-	-	-	-	0.15[f,i]	0.15[f,i]	-	-

TABLE 2 FEDERAL INTERIM GROUNDWATER QUALITY GUIDELINES
GENERIC GUIDELINES FOR RESIDENTIAL/PARKLAND LAND USE[a] (mg/L)

Note: Guidelines for Canadian Drinking Water Quality (Health Canada, 2008) may also apply
Guidelines may not apply if underlying assumptions are not met (see Section 4.2)

	Tier 1		Tier 2							
	Lowest Guideline		Water Use/Exposure Pathway							
			Inhalation		Soil Organisms Direct Contact		Freshwater Life[b]		Marine Life[c]	
	Soil Type									
Parameters	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**
Phenol	0.004	0.004	73,000	3,700	110	150	0.004	0.004	-	-
2,4,5-Trichlorophenol	0.063	0.063	-	-	-	-	0.063[f,i]	0.063[f,i]	-	-
2,4,6-Trichlorophenol	0.018	0.018	NGR	54	-	-	0.018	0.018	-	-
2,3,4,6-Tetrachlorophenol	0.001	0.001	NGR	NGR	-	-	0.001	0.001	-	-
Pentachlorophenol	0.0005	0.0005	NGR	NGR	0.87	0.88	0.0005	0.0005	-	-
Pesticides										
Aldicarb	0.001	0.001	-	-	-	-	0.001	0.001	0.00015	0.00015
Aldrin	0.003	0.003	-	-	-	-	0.003	0.003	-	-
Atrazine and metabolites	0.0018	0.0018	-	-	-	-	0.0018	0.0018	0.01 [h,i]	0.01 [h,i]
Azniphos-methyl	0.00001	0.00001	-	-	-	-	0.00001	0.00001	-	-
Bromacil	0.005	0.005	-	-	-	-	0.005	0.005	-	-
Bromoxynil	0.005	0.005	-	-	-	-	0.005	0.005	-	-
Captan	0.0013	0.0013	-	-	-	-	0.0013	0.0013	-	-
Carbaryl	0.0002	0.0002	-	-	-	-	0.0002	0.0002	0.00032	0.00032
Carbofuran	0.0018	0.0018	-	-	-	-	0.0018	0.0018	-	-
Chlordane	0.000004	0.000004	0.17 [f]	0.028 [f]			0.000004 [f,i]	0.000004 [f,i]		
Chlorothalonil	0.00018	0.00018	-	-	-	-	0.00018	0.00018	0.00036	0.00036
Chlorpyrifos	0.0000035	0.0000035	-	-	-	-	0.0000035	0.0000035	0.000002	0.000002
Cyanazine	0.002	0.002	-	-	-	-	0.002	0.002	-	-
2,4-D (2,4-Dichlorophenoxyacetic acid) & other phenoxy herbicides	0.004	0.004	-	-	-	-	0.004	0.004	-	-
DDAC (Didecyl dimethyl ammonium chloride)	0.0015	0.0015	-	-	-	-	0.0015	0.0015	-	-
DDT (Dichloro-Diphenyl-Trichloroethane) & metabolites	0.000001	0.000001	-	-	-	-	0.000001	0.000001	-	-
Deltamethrin	0.0000004	0.0000004	-	-	-	-	0.0000004	0.0000004	-	-
Diazinon	0.000003	0.000003					0.000003 [h,i]	0.000003 [h,i]		
Dicamba	0.01	0.01	-	-	-	-	0.01	0.01	-	-
Dichlofop-methyl	0.0061	0.0061	-	-	-	-	0.0061	0.0061	-	-
Dieldrin	0.000056	0.000056	-	-	-	-	0.000056	0.000056	-	-
Dimethoate	0.0062	0.0062	-	-	-	-	0.0062	0.0062	-	-
Dinoseb	0.00005	0.00005	-	-	-	-	0.00005	0.00005	-	-
Endosulfan	0.00002	0.00002	-	-	-	-	0.00002	0.00002	-	-
Endrin	0.000036	0.000036	-	-	-	-	0.000036	0.000036	-	-
Glyphosate	0.065	0.065	-	-	-	-	0.065	0.065	-	-

TABLE 2 FEDERAL INTERIM GROUNDWATER QUALITY GUIDELINES
GENERIC GUIDELINES FOR RESIDENTIAL/PARKLAND LAND USE[a] (mg/L)

Note: Guidelines for Canadian Drinking Water Quality (Health Canada, 2008) may also apply
Guidelines may not apply if underlying assumptions are not met (see Section 4.2)

	Tier 1		Tier 2							
			Water Use/Exposure Pathway							
	Lowest Guideline		Inhalation		Soil Organisms Direct Contact		Freshwater Life[b]		Marine Life[c]	
	Soil Type									
Parameters	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**
Heptachlor epoxide	0.0000038	0.0000038	0.0043	0.00024	-	-	0.0000038	0.0000038	-	-
Imidacloprid	0.00023	0.00023	-	-	-	-	0.00023	0.00023	-	-
IPBC (3-iodo-2-propynyl butyl carbamate)	0.0019	0.0019	-	-	-	-	0.0019	0.0019	-	-
Lindane (γ-hexachlorocyclohexane)	0.00001	0.00001	-	-	-	-	0.00001	0.00001	-	-
Linuron	0.007	0.007	-	-	-	-	0.007	0.007	-	-
Malathion	0.0001	0.0001	-	-	-	-	0.0001	0.0001	-	-
MCPA	0.0026	0.0026	-	-	-	-	0.0026	0.0026	0.0042	0.0042
Methoprene	0.00009	0.00009	-	-	-	-	0.00009	0.00009	-	-
Methoxychlor	0.00003	0.00003	-	-	-	-	0.00003	0.00003	-	-
Metolachlor	0.0078	0.0078	-	-	-	-	0.0078	0.0078	-	-
Metribuzin	0.001	0.001	-	-	-	-	0.001	0.001	-	-
Parathion	0.000013	0.000013	-	-	-	-	0.000013	0.000013	-	-
Permethrin	0.000004	0.000004	-	-	-	-	0.000004	0.000004	0.000001	0.000001
Picloram	0.029	0.029	-	-	-	-	0.029	0.029	-	-
Simazine	0.01	0.01	-	-	-	-	0.01	0.01	-	-
Tebuthiuron	0.0016	0.0016	-	-	-	-	0.0016	0.0016	-	-
Toxaphene	0.0000002	0.0000002	6.4	0.31	-	-	0.0000002	0.0000002	-	-
Triallate	0.00024	0.00024	-	-	-	-	0.00024	0.00024	-	-
Trifluarin	0.0002	0.0002	-	-	-	-	0.0002	0.0002	-	-
Other Organics										
Acetone	0.33	0.33	11000[f]	1800[f]	-	-	0.33[f,i]	0.33[f,i]	-	-
Acridine	0.00005	0.00005	-	-	-	-	0.00005[h,i]	0.00005[h,i]	-	-
Aniline	0.0022	0.0022	1,900	87	-	-	0.0022	0.0022	-	-
Bis(2-chloroethyl)ether	0.71	0.11	0.71[f]	0.11[f]	-	-	240[f,i]	240[f,i]	-	-
Bis(2-chloroisopropyl)ether	2.7	0.43	2.7[f]	0.43[f]	-	-	240[f,i]	240[f,i]	-	-
Bis(2-ethyl-hexyl)phthalate	0.016	0.016	NGR	NGR	-	-	0.016	0.016	-	-
Chloroaniline, p-	0.01	0.01	-	-	-	-	0.01[f,i]	0.01[f,i]	-	-
Dibutyl phthalate	0.019	0.019	NGR	NGR	-	-	0.019	0.019	-	-
di-n-Butyltin	0.00008	0.00008	-	-	-	-	0.00008[h,i]	0.00008[h,i]	-	-
Diethylphthalate	0.003	0.003	-	-	-	-	0.003[f,i]	0.003[f,i]	-	-
Diisopropanolamine	1.6	1.6	-	-	160	160	1.6	1.6	-	-
2,4-Dinitrotoluene	0.23	0.23	-	-	-	-	0.23[f,i]	0.23[f,i]	-	-
Ethylene glycol	190	190	NGR	NGR	9,200	16,000	190	190	-	-
Hexachlorobutadiene	0.0013	0.0013	0.031	0.0013	-	-	0.0013	0.0013	-	-
Methylmethacrylate	17	0.84	17	0.84	-	-	-	-	-	-
Methyl ethyl ketone	120	120	11000[f]	1700[f]	-	-	120[f,i]	120[f,i]	-	-

TABLE 2 FEDERAL INTERIM GROUNDWATER QUALITY GUIDELINES GENERIC GUIDELINES FOR RESIDENTIAL/PARKLAND LAND USE[a] (mg/L)

Note: Guidelines for Canadian Drinking Water Quality (Health Canada, 2008) may also apply
Guidelines may not apply if underlying assumptions are not met (see Section 4.2)

	Tier 1		Tier 2							
			Water Use/Exposure Pathway							
	Lowest Guideline		Inhalation		Soil Organisms Direct Contact		Freshwater Life[b]		Marine Life[c]	
	Soil Type									
Parameters	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**
Methyl isobutyl ketone	350	57	350 [f]	57 [f]	-	-	430 [f,i]	430 [f,i]	-	-
Methyl mercury	0.000012	0.000012	-	-	-	-	0.000012 [f,i]	0.000012 [f,i]	-	-
MTBE (Methyl tert-butyl ether)	5	0.34	6.1	0.34	-	-	10	10	5	5
Monochloramine	0.0005	0.0005					0.0005 [h,i]	0.0005 [h,i]		
Nonylphenol + ethoxylates	0.001	0.001	-	-	0.0081	0.0081	0.001	0.001	0.0007	0.0007
Propylene glycol	500	500	-	-	-	-	500	500	-	-
Quinoline	0.0034	0.0034					0.0034 [h,i]	0.0034 [h,i]		
Sulfolane	50	50	-	-	1,700	2,800	50	50	-	-
Tributyltin	0.000008	0.000008	-	-	-	-	0.000008	0.000008	0.000001	0.000001
Triethyltin	0.0004	0.0004	-	-	-	-	0.0004 [h,i]	0.0004 [h,i]	-	-
Triphenyltin	0.000022	0.000022	-	-	-	-	0.000022	0.000022	-	-

a – all values adopted from Alberta Environment (AENV) (2009a) unless otherwise specified
b – where AENV (2009a) guideline was not based on the *Canadian Water Quality Guidelines* (CWQG) *for the Protection of Aquatic Life* for freshwater environments (CCME 1999), and a CWQG exists, the groundwater quality guideline was re-calculated based on the CWQG
c – based on *Canadian Water Quality Guidelines* (CWQG) *for the Protection of Aquatic Life* for the marine environments(CCME 1999) and groundwater transport model
d – the freshwater aquatic life guidelines vary depending on water pH, hardness etc. Therefore, see *Canadian Water Quality Guidelines for the Protection of Aquatic Life* (CCME 1999) to determine the appropriate water quality guideline applicable to the site and calculate the groundwater guidelines using formulas provided in Appendix B
e – guideline is the lowest of all applicable pathways
f – adopted from Ontario Ministry of Environment and Energy (OMEE) (1997); may be updated once revised Ontario standards are published
g – for ecological receptors only
h – adopted from BC Contaminated Sites Regulation
i - 10x factor for dilution in surface water was removed from guideline value
j – adopted directly from CCME (1999)
NGR – no guideline required; calculated guideline exceeds solubility limit

TABLE 3 FEDERAL INTERIM GROUNDWATER QUALITY GUIDELINES
GENERIC GUIDELINES FOR COMMERCIAL AND INDUSTRIAL LAND USES[a] (mg/L)

Note: Guidelines for Canadian Drinking Water Quality (Health Canada, 2008) may also apply
Guidelines may not apply if underlying assumptions are not met (see Section 4.2)

	Tier 1		Tier 2							
	Lowest Guideline		Water Use/Exposure Pathway							
			Inhalation		Soil Organisms Direct Contact		Freshwater Life[b]		Marine Life[c]	
	Soil Type									
Parameters	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**
General and Inorganic Parameters										
pH	6.5-8.7	6.5-8.7	-	-	-	-	6.5-9	6.5-9	7-8.7	7-8.7
Ammonia	See note e	See note e	-	-	-	-	see note d	see note d	-	-
Chloride	230	230	-	-	-	-	230	230	-	-
Chlorine	0.002	0.002					0.002[h,i]	0.002[h,i]	0.003[h,i]	0.003[h,i]
Cyanide	0.001	0.001	-	-	-	-	0.005	0.005	0.001[h,i]	0.001[h,i]
Fluoride	0.12	0.12	-	-	-		0.12	0.12	1.5[h,i]	1.5[h,i]
Nitrate	13	13	-	-	-	-	13	13	16	16
Nitrite (as nitrogen)	0.06	0.06	-	-	-	-	0.06	0.06	-	-
Sulphate	100	100	-	-	-	-	100[h,i]	100[h,i]	-	-
Sulphide (as H_2S)	0.002	0.002	-	-	-	-	0.002	0.002	0.002[h,i]	0.002[h,i]
Metals										
Aluminum	See note e	See note e	-	-	-	-	see note d	see note d	-	-
Antimony	1.6	1.6					1.6[f,i]	1.6[f,i]		
Arsenic	0.005	0.005	-	-	-	-	0.005	0.005	0.0125	0.0125
Barium	0.5	0.5					2.3[f,i]	2.3[f,i]	0.5[h,i]	0.5[h,i]
Beryllium	0.0053	0.0053	-	-	-	-	0.0053[h,i]	0.0053[h,i]	0.1[h,i]	0.1[h,i]
Boron	5	5	-	-	-	-	-	-	5[h,i]	5[h,i]
Cadmium	0.000017	0.000017	-	-	-	-	0.000017	0.000017	0.00012	0.00012
Chromium (Total)	0.0089	0.0089	-	-	-	-	0.0089	0.0089	0.056	0.056
Copper	See note e	See note e	-	-	-	-	see note d	see note d	0.002[h,i]	0.002[h,i]
Iron	0.3	0.3	-	-	-	-	0.3	0.3	-	-
Lead	See note e	See note e	-	-	-	-	see note d	see note d	0.002[h,i]	0.002[h,i]
Mercury	0.000016	0.000016	-	-	-	-	0.000026	0.000026	0.000016	0.000016
Molybdenum	0.073	0.073	-	-	-	-	0.073	0.073	-	-
Nickel	See note e	See note e	-	-	-	-	see note d	see note d	0.083[h,i]	0.083[h,i]
Selenium	0.001	0.001	-	-	-	-	0.001	0.001	0.054[h,i]	0.054[h,i]
Silver	0.0001	0.0001	-	-	-	-	0.0001	0.0001	0.0015[h,i]	0.0015[h,i]
Thallium	0.0008	0.0008	-	-	-	-	0.0008	0.0008	-	-
Titanium	0.1	0.1					0.1[h,i]	0.1[h,i]		
Uranium	0.3	0.3	-	-	-	-	0.3[h,i]	0.3[h,i]	-	-
Zinc	0.01	0.01	-	-	-	-	0.03	0.03	0.01[h,i]	0.01[h,i]
Hydrocarbons										
Benzene	9.8	0.2	19	1.8	540	350	33	0.69	9.8	0.2
Toluene	240	0.083	NGR	NGR	240	200	NGR	0.083	NGR	8.9

TABLE 3 FEDERAL INTERIM GROUNDWATER QUALITY GUIDELINES
GENERIC GUIDELINES FOR COMMERCIAL AND INDUSTRIAL LAND USES[a] (mg/L)

Note: Guidelines for Canadian Drinking Water Quality (Health Canada, 2008) may also apply
Guidelines may not apply if underlying assumptions are not met (see Section 4.2)

	Tier 1		Tier 2							
	Lowest Guideline		Water Use/Exposure Pathway							
			Inhalation		Soil Organisms Direct Contact		Freshwater Life[b]		Marine Life[c]	
	Soil Type									
Parameters	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**
Ethylbenzene	150	41	NGR	NGR	150	110	NGR	41	NGR	11
Xylenes	74	18	NGR	48	74	120	NGR	18	-	-
Styrene	0.072	0.072	NGR	51	-	-	0.072	0.072	-	-
F1	9.9	9.1	NGR	9.1	9.9	11	NGR	9.8	-	-
F2	3.1	1.3	NGR	17	3.1	3.1	NGR	1.3	-	-
Acenapthene	0.0058	0.0058	NGR	NGR	-	-	0.0058	0.0058	-	-
Acenaphthylene	0.046	0.046	-	-	-	-	0.046	0.046	-	-
Anthracene	0.000012	0.000012	NGR	NGR	0.32	0.32	0.000012	0.000012	-	-
Fluoranthene	0.00004	0.00004	NGR	NGR	0.86	0.86	0.00004	0.00004	-	-
Fluorene	0.003	0.003	NGR	NGR	-	-	0.003	0.003	-	-
Methylnaphthalenes	1.5	1.5	150 [f]	24 [f]			1.5 [f,i]	1.5 [f,i]		
Naphthalene	0.0011	0.0011	NGR	7	-	-	0.0011	0.0011	0.0014	0.0014
Phenanthrene	0.0004	0.0004	-	-	-	-	0.0004	0.0004	-	-
Pyrene	0.000025	0.000025	NGR	NGR	-	-	0.000025	0.000025	-	-
Benz[a]anthracene [g]	0.000018	0.000018	-	-	-	-	0.000018	0.000018	-	-
Benzo[b+j]fluoranthene [g]	0.00048	0.00048	-	-	-	-	0.00048	0.00048	-	-
Benzo[k]fluoranthene [g]	0.00048	0.00048	-	-	-	-	0.00048	0.00048	-	-
Benzo[g,h,i]perylene [g]	0.00021	0.00017	-	-	-	-	0.00021	0.00017	-	-
Benzo[a]pyrene [g]	0.000017	0.000015	-	-	0.0066	0.0066	0.000017	0.000015	-	-
Chrysene [g]	0.0014	0.0014	-	-	-	-	0.0014	0.0014	-	-
Dibenz[a,h]anthracene [g]	0.00028	0.00026	-	-	-	-	0.00028	0.00026	-	-
Indeno[1,2,3-c,d]pyrene [g]	0.00023	0.00021	-	-	-	-	0.00023	0.00021	-	-
Halogenated Aliphatics										
Vinyl chloride	0.12	0.013	0.12	0.013	-	-	-	-	-	-
1,1-Dichloroethene	4.5	0.49	4.5	0.49	-	-	-	-	-	-
cis-1,2-DichloroetheneDichloroethene	12	12	-	-	-	-	12 [f,i]	12 [f,i]		
trans-1,2-DichloroetheneDichloroethene	12	12	-	-	-	-	12 [f,i]	12 [f,i]		
Trichloroethene (Trichloroethylene, TCE)	0.27	0.029	2.8	0.25	73	83	0.27	0.029	-	-
Tetrachloroethene (Tetrachloroethylene, Perchloroethylene, PCE)	0.11	0.11	16	1.3	-	-	0.11	0.11	-	-
1,1-Dichloroethane	56	9	56 [f]	9 [f]	-	-	200 [f,i]	200 [f,i]		

TABLE 3 FEDERAL INTERIM GROUNDWATER QUALITY GUIDELINES GENERIC GUIDELINES FOR COMMERCIAL AND INDUSTRIAL LAND USES[a] (mg/L)

Note: Guidelines for Canadian Drinking Water Quality (Health Canada, 2008) may also apply Guidelines may not apply if underlying assumptions are not met (see Section 4.2)

	Tier 1		Tier 2							
	Lowest Guideline		Water Use/Exposure Pathway							
			Inhalation		Soil Organisms Direct Contact		Freshwater Life[b]		Marine Life[c]	
	Soil Type									
Parameters	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**
1,2-Dichloroethane	0.1	0.1	1.2	0.13	-	-	0.1	0.1	-	-
Dichloromethane (Methylene chloride)	0.098	0.098	410	43	-	-	0.098	0.098	-	-
1,1,1,2-Tetrachloroethane	0.038	0.006	0.038[f]	0.006[f]	-	-	9.3[f,i]	9.3[f,i]	-	-
1,1,2,2-Tetrachloroethane	0.14	0.022	0.14[f]	0.022[f]	-	-	2.4[f,i]	2.4[f,i]	-	-
1,1,1-Trichloroethane	18	4.2	26[f]	4.2[f]	-	-	18[f,i]	18[f,i]	-	-
1,1,2-Trichloroethane	9.4	9.4	100[f]	16[f]	-	-	9.4[f,i]	9.4[f,i]	-	-
Trichloromethane (Chloroform)	0.0018	0.0018	0.35	0.04	-	-	0.0018	0.0018	-	-
Tetrachloromethane (Carbon tetrachloride)	0.013	0.0068	0.078	0.0068	-	-	0.013	0.013	-	-
1,2-Dichloropropane	0.058	0.0093	0.058[f]	0.0093[f]	-	-	5.7[f,i]	5.7[f,i]	-	-
1,3-Dichloropropene	0.024	0.0038	0.024[f]	0.0038[f]	-	-	0.24[f,i]	0.24[f,i]	-	-
Bromoform	5.2	0.84	5.2[f]	0.84[f]	-	-	29[f,i]	29[f,i]	-	-
Bromomethane	0.016	0.002	0.016[f]	0.002[f]	-	-	0.32[f,i]	0.32[f,i]	-	-
Bromodichloromethane	67	67	-	-	-	-	67[f,i]	67[f,i]	-	-
Dibromochloromethane	250	10	250	10	-	-	-	-	-	-
Ethylene dibromide	0.021	0.0033	0.021[f]	0.0033[f]	-	-	2.8[f,i]	2.8[f,i]		
Chlorinated Aromatics										
Chlorobenzene	0.0013	0.0013	2.2	0.18	-	-	0.0013	0.0013	0.025	0.025
1,2-Dichlorobenzene	0.0007	0.0007	NGR	64	-	-	0.0007	0.0007	0.042	0.042
1,3-Dichlorobenzene	0.042	0.042	-	-	-	-	0.15	0.15	0.042[h,i]	0.042[h,i]
1,4-Dichlorobenzene	0.026	0.026	32	2.6	-	-	0.026	0.026	-	-
1,2,3-Trichlorobenzene	0.008	0.008	6.9	0.33	-	-	0.008	0.008	-	-
1,2,4-Trichlorobenzene	0.024	0.024	6.1	0.29	-	-	0.024	0.024	0.0054	0.0054
1,3,5-Trichlorobenzene	3.3	0.15	3.3	0.15	-	-	-	-	-	-
1,2,3,4-Tetrachlorobenzene	0.0018	0.0018	NGR	NGR	-	-	0.0018	0.0018	-	-
1,2,3,5-Tetrachlorobenzene	NGR	0.16	NGR	0.16	-	-	-	-	-	-
1,2,4,5-Tetrachlorobenzene	NGR	0.08	NGR	0.08	-	-	-	-	-	-
Pentachlorobenzene	0.006	0.006	NGR	0.44	-	-	0.006	0.006	-	-
Hexachlorobenzene	0.21	0.014	0.21	0.014	-	-	-	-	-	-
Phenols										
2-Chlorophenol	4.4	4.4	-	-	-	-	4.4[f,i]	4.4[f,i]	-	-
2,4-Dichlorophenol	0.0002	0.0002	NGR	NGR	-	-	0.0002	0.0002	-	-

TABLE 3 FEDERAL INTERIM GROUNDWATER QUALITY GUIDELINES GENERIC GUIDELINES FOR COMMERCIAL AND INDUSTRIAL LAND USES[a] (mg/L)

Note: Guidelines for Canadian Drinking Water Quality (Health Canada, 2008) may also apply
Guidelines may not apply if underlying assumptions are not met (see Section 4.2)

	Tier 1		Tier 2							
	Lowest Guideline		Water Use/Exposure Pathway							
			Inhalation		Soil Organisms Direct Contact		Freshwater Life[b]		Marine Life[c]	
	Soil Type									
Parameters	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**
2,4-Dimethylphenol	2.1	2.1	-	-	-	-	2.1 [f,i]	2.1 [f,i]	-	-
2,4-Dinitrophenol	0.15	0.15	-	-	-	-	0.15 [f,i]	0.15 [f,i]	-	-
Phenol	0.004	0.004	NGR	45,000	110	150	0.004	0.004	-	-
2,4,5-Trichlorophenol	0.063	0.063	-	-	-	-	0.063[f,i]	0.063[f,i]	-	-
2,4,6-Trichlorophenol	0.018	0.018	NGR	540	-	-	0.018	0.018	-	-
2,3,4,6-Tetrachlorophenol	0.001	0.001	NGR	NGR	-	-	0.001	0.001	-	-
Pentachlorophenol	0.0005	0.0005	NGR	NGR	2.2	2.2	0.0005	0.0005	-	-
Pesticides										
Aldicarb	0.001	0.001	-	-	-	-	0.001	0.001	0.00015	0.00015
Aldrin	0.003	0.003	-	-	-	-	0.003	0.003	-	-
Atrazine and metabolites	0.0018	0.0018	-	-	-	-	0.0018	0.0018	0.01 [h,i]	0.01 [h,i]
Azniphos-methyl	0.00001	0.00001	-	-	-	-	0.00001	0.00001	-	-
Bromacil	0.005	0.005	-	-	-	-	0.005	0.005	-	-
Bromoxynil	0.005	0.005	-	-	-	-	0.005	0.005	-	-
Captan	0.0013	0.0013	-	-	-	-	0.0013	0.0013	-	-
Carbaryl	0.0002	0.0002	-	-	-	-	0.0002	0.0002	0.00032	0.00032
Carbofuran	0.0018	0.0018	-	-	-	-	0.0018	0.0018	-	-
Chlordane	0.000004	0.000004	0.17 [f]	0.028 [f]			0.000004 [f,i]	0.000004 [f,i]		
Chlorothalonil	0.00018	0.00018	-	-	-	-	0.00018	0.00018	0.00036	0.00036
Chlorpyrifos	0.0000035	0.0000035	-	-	-	-	0.0000035	0.0000035	0.000002	0.000002
Cyanazine	0.002	0.002	-	-	-	-	0.002	0.002	-	-
2,4-D (2,4-Dichlorophenoxyacetic acid) & other phenoxy herbicides	0.004	0.004	-	-	-	-	0.004	0.004	-	-
DDAC (Didecyl dimethyl ammonium chloride)	0.0015	0.0015	-	-	-	-	0.0015	0.0015	-	-
DDT (Dichloro-Diphenyl-Trichloroethane) & metabolites	0.000001	0.000001	-	-	-	-	0.000001	0.000001	-	-
Deltamethrin	0.0000004	0.0000004	-	-	-	-	0.0000004	0.0000004	-	-
Diazinon	0.000003	0.000003					0.000003 [h,i]	0.000003 [h,i]		
Dicamba	0.01	0.01	-	-	-	-	0.01	0.01	-	-
Dichlofop-methyl	0.0061	0.0061	-	-	-	-	0.0061	0.0061	-	-
Dieldrin	0.000056	0.000056	-	-	-	-	0.000056	0.000056	-	-
Dimethoate	0.0062	0.0062	-	-	-	-	0.0062	0.0062	-	-
Dinoseb	0.00005	0.00005	-	-	-	-	0.00005	0.00005	-	-

TABLE 3 FEDERAL INTERIM GROUNDWATER QUALITY GUIDELINES
GENERIC GUIDELINES FOR COMMERCIAL AND INDUSTRIAL LAND USES[a] (mg/L)

Note: Guidelines for Canadian Drinking Water Quality (Health Canada, 2008) may also apply
Guidelines may not apply if underlying assumptions are not met (see Section 4.2)

	Tier 1		Tier 2							
	Lowest Guideline		Water Use/Exposure Pathway							
			Inhalation		Soil Organisms Direct Contact		Freshwater Life[b]		Marine Life[c]	
	Soil Type									
Parameters	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**
Endosulfan	0.00002	0.00002	-	-	-	-	0.00002	0.00002	-	-
Endrin	0.000036	0.000036	-	-	-	-	0.000036	0.000036	-	-
Glyphosate	0.065	0.065	-	-	-	-	0.065	0.065	-	-
Heptachlor epoxide	0.0000038	0.0000038	0.051	0.002	-	-	0.0000038	0.0000038	-	-
Imidacloprid	0.00023	0.00023	-	-	-	-	0.00023	0.00023	-	-
IPBC (3-iodo-2-propynyl butyl carbamate)	0.0019	0.0019	-	-	-	-	0.0019	0.0019	-	-
Lindane (γ-hexachlorocyclohexane)	0.00001	0.00001	-	-	-	-	0.00001	0.00001	-	-
Linuron	0.007	0.007	-	-	-	-	0.007	0.007	-	-
Malathion	0.0001	0.0001	-	-	-	-	0.0001	0.0001	-	-
MCPA	0.0026	0.0026	-	-	-	-	0.0026	0.0026	0.0042	0.0042
Methoprene	0.00009	0.00009	-	-	-	-	0.00009	0.00009	-	-
Methoxychlor	0.00003	0.00003	-	-	-	-	0.00003	0.00003	-	-
Metolachlor	0.0078	0.0078	-	-	-	-	0.0078	0.0078	-	-
Metribuzin	0.001	0.001	-	-	-	-	0.001	0.001	-	-
Parathion	0.000013	0.000013	-	-	-	-	0.000013	0.000013	-	-
Permethrin	0.000004	0.000004	-	-	-	-	0.000004	0.000004	0.000001	0.000001
Picloram	0.029	0.029	-	-	-	-	0.029	0.029	-	-
Simazine	0.01	0.01	-	-	-	-	0.01	0.01	-	-
Tebuthiuron	0.0016	0.0016	-	-	-	-	0.0016	0.0016	-	-
Toxaphene	0.0000002	0.0000002	75	2.9	-	-	0.0000002	0.0000002	-	-
Triallate	0.00024	0.00024	-	-	-	-	0.00024	0.00024	-	-
Trifluarin	0.0002	0.0002	-	-	-	-	0.0002	0.0002	-	-
Other Organics										
Acetone	0.33	0.33	11000[f]	1800[f]	-	-	0.33 [f,i]	0.33 [f,i]	-	-
Acridine	0.00005	0.00005	-	-	-	-	0.00005 [h,i]	0.00005 [h,i]	-	-
Aniline	0.0022	0.0022	13,000	1,000	-	-	0.0022	0.0022	-	-
Bis(2-chloroethyl)ether	0.71	0.11	0.71 [f]	0.11 [f]	-	-	240 [f,i]	240 [f,i]	-	-
Bis(2-chloroisopropyl)ether	2.7	0.43	2.7 [f]	0.43 [f]	-	-	240 [f,i]	240 [f,i]	-	-
Bis(2-ethyl-hexyl)phthalate	0.016	0.016	NGR	NGR	-	-	0.016	0.016	-	-
Chloroaniline, p-	0.01	0.01	-	-	-	-	0.01 [f,i]	0.01 [f,i]	-	-
Dibutyl phthalate	0.019	0.019	NGR	NGR	-	-	0.019	0.019	-	-
di-n-Butyltin	0.00008	0.00008	-	-	-	-	0.00008 [h,i]	0.00008 [h,i]	-	-
Diethylphthalate	0.003	0.003	-	-	-	-	0.003 [f,i]	0.003 [f,i]	-	-
Diisopropanolamine	1.6	1.6	-	-	160	160	1.6	1.6	-	-

TABLE 3 FEDERAL INTERIM GROUNDWATER QUALITY GUIDELINES GENERIC GUIDELINES FOR COMMERCIAL AND INDUSTRIAL LAND USES[a] (mg/L)

Note: Guidelines for Canadian Drinking Water Quality (Health Canada, 2008) may also apply
Guidelines may not apply if underlying assumptions are not met (see Section 4.2)

	Tier 1		Tier 2							
	Lowest Guideline		Water Use/Exposure Pathway							
			Inhalation		Soil Organisms Direct Contact		Freshwater Life[b]		Marine Life[c]	
	Soil Type									
Parameters	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**	**Fine**	**Coarse**
2,4-Dinitrotoluene	0.23	0.23	-	-	-	-	0.23 [f,i]	0.23 [f,i]	-	-
Ethylene glycol	190	190	NGR	NGR	9,200	16,000	190	190	-	-
Hexachlorobutadiene	0.0013	0.0013	0.22	0.015	-	-	0.0013	0.0013	-	-
Methylmethacrylate	120	10	120	10	-	-	-	-	-	-
Methyl ethyl ketone	120	120	11000 [f]	1700 [f]	-	-	120 [f,i]	120 [f,i]	-	-
Methyl isobutyl ketone	350	57	350 [f]	57 [f]	-	-	430 [f,i]	430 [f,i]	-	-
Methyl mercury	0.000012	0.000012	-	-	-	-	0.000012 [f,i]	0.000012 [f,i]	-	-
MTBE (Methyl tert-butyl ether)	5	4.3	40	4.3	-	-	10	10	5	5
Monochloramine	0.0005	0.0005					0.0005 [h,i]	0.0005 [h,i]		
Nonylphenol + ethoxylates	0.001	0.001	-	-	0.0081	0.0081	0.001	0.001	0.0007	0.0007
Propylene glycol	500	500	-	-	-	-	500	500	-	-
Quinoline	0.0034	0.0034					0.0034 [h,i]	0.0034 [h,i]		
Sulfolane	50	50	-	-	1,700	2,800	50	50	-	-
Tributyltin	0.000008	0.000008	-	-	-	-	0.000008	0.000008	0.000001	0.000001
Triethyltin	0.0004	0.0004	-	-	-	-	0.0004 [h,i]	0.0004 [h,i]	-	-
Triphenyltin	0.000022	0.000022	-	-	-	-	0.000022	0.000022	-	-

a – all values adopted from Alberta Environment (AENV) (2009a) unless otherwise specified
b – where AENV (2009a) guideline was not based on the *Canadian Water Quality Guidelines* (CWQG) *for the Protection of Aquatic Life* for freshwater environments (CCME 1999), and a CWQG exists, the groundwater quality guideline was re-calculated based on the CWQG
c – based on *Canadian Water Quality Guidelines* (CWQG) *for the Protection of Aquatic Life* for the marine environments(CCME 1999) and groundwater transport model
d – the freshwater aquatic life guidelines vary depending on water pH, hardness etc. Therefore, see *Canadian Water Quality Guidelines for the Protection of Aquatic Life* (CCME 1999) to determine the appropriate water quality guideline applicable to the site and calculate the groundwater guidelines using formulas provided in Appendix B
e – guideline is the lowest of all applicable pathways
f – adopted from Ontario Ministry of Environment and Energy (OMEE) (1997); may be updated once revised Ontario standards are published
g – for ecological receptors only
h – adopted from BC Contaminated Sites Regulation
i - 10x factor for dilution in surface water was removed from guideline value
j – adopted directly from CCME (1999)
NGR – no guideline required; calculated guideline exceeds solubility limit

APPENDIX B
MODELS, EQUATIONS AND DEFAULT MODEL PARAMETERS USED TO CALCULATE TIER 1 GUIDELINES

This appendix provides the equations and default model parameters used to derive most of the generic groundwater guidelines; these same equations and model parameters should be used as the starting point for site-specific modification in the derivation of Tier 2 guidelines. All equations presented herein were adopted from Alberta Environment (AENV) (AENV 2009a, 2009b) unless otherwise specified.

For more comprehensive guidance on using the models presented herein, including which parameters can be adjusted at Tier 2, appropriate ranges within which these parameters can be adjusted, and data requirements to support Tier 2 adjustment, refer to Appendices C and D of the *Canada-Wide Standard for Petroleum Hydrocarbons in Soil: User Guidance* (CCME, 2008b).

B.1 Human Exposure Pathways

Vapour Inhalation

Groundwater guidelines protective of the indoor infiltration and inhalation pathway were calculated using the equations from the CCME (2006) protocol adapted for groundwater.

Consistent with the approach taken in CCME (2008a), an adjustment factor of 10 is applied in the equations below for petroleum hydrocarbons (including benzene, toluene, ethylbenzene and xylenes), to account for empirical evidence that measured indoor air concentrations are typically lower by at least an order of magnitude than concentrations predicted from the models below. The adjustment factor takes the value of 1 for all other chemicals, reflecting the lack of any empirical data to support such a factor for these chemicals. Default parameter values are summarized in Tables 4 to 8. Separate calculations are made for carcinogens and non-carcinogenic chemicals.

Groundwater Guidelines for Non-Carcinogens

$$GWQG_I = \frac{(TC - C_a) \times SAF \times DF_i \times AF}{H' \times ET \times 10^3}$$

Where:

Where:	$GWQG_I$	=	groundwater quality guideline for indoor infiltration (mg/L);
	TC	=	tolerable concentration (mg/m^3);
	C_a	=	background air concentration (mg/m^3);
	SAF	=	allocation factor (dimensionless);
	DF_i	=	dilution factor from soil gas to indoor air (calculated below);
	AF	=	adjustment factor (10, hydrocarbons; 1, all other chemicals);
	H’	=	dimensionless Henry’s Law Constant (dimensionless);
	ET	=	exposure term (dimensionless);
	10^3	=	conversion factor from m^3 to L; and,

Groundwater Guidelines for Carcinogens

$$GWQG_I = \frac{RsC \times DF_i \times AF}{H' \times ET \times 10^3}$$

Where:	$GWQG_I$	=	groundwater quality guideline for indoor infiltration (mg/L);
	RsC	=	risk-specific concentration (mg/m^3);
	DF_i	=	dilution factor from soil gas to indoor air (calculated below);
	AF	=	adjustment factor (10, hydrocarbons; 1, all other chemicals);
	H'	=	dimensionless Henry's Law Constant (dimensionless);
	ET	=	exposure term (dimensionless);
	10^3	=	conversion factor from m^3 to L; and,

Note that in contrast to the CCME (2006) protocol, an exposure term of 0.2747 was used for commercial and industrial land use for carcinogens.

Dilution Factor Calculation

The dilution factor (DF_i) was calculated as follows:

$$DF_i = \frac{1}{\alpha}$$

Where:	DF_i	=	dilution factor from soil gas concentration to indoor air concentration (unitless); and,
	α	=	attenuation coefficient (unitless; see derivation below).

$$\alpha = \frac{\left(\frac{D_T^{eff} A_B}{Q_B L_T}\right) exp\left(\frac{Q_{soil} L_{crack}}{D_{crack} A_{crack}}\right)}{exp\left(\frac{Q_{soil} L_{crack}}{D_{crack} A_{crack}}\right) + \left(\frac{D_T^{eff} A_B}{Q_B L_T}\right) + \left(\frac{D_T^{eff} A_B}{Q_{soil} L_T}\right)\left[exp\left(\frac{Q_{soil} L_{crack}}{D_{crack} A_{crack}}\right) - 1\right]}$$

where:

α	=	attenuation coefficient (dimensionless);
D_T^{eff}	=	effective porous media diffusion coefficient (cm^2/s);
A_B	=	building area (cm^2);
Q_B	=	building ventilation rate (cm^3/s);
L_T	=	distance from contaminant source to foundation (cm);
Q_{soil}	=	volumetric flow rate of soil gas into the building (cm^3/s);
L_{crack}	=	thickness of the foundation (cm);
D_{crack}	=	effective vapour diffusion coefficient through the crack (cm^2/s); and,
A_{crack}	=	area of cracks through which contaminant vapours enter the building (cm^2).

Calculation of D_T^{eff}:

$$D_T^{eff} \approx D_a \times \left(\frac{\theta_a^{10/3}}{\theta_t^2} \right)$$

Where: D_T^{eff} = overall effective porous media diffusion coefficient based on vapour-phase concentrations for the region between the source and foundation (cm^2/s);

D_a = diffusion coefficient in air (cm^2/s);

θ_a = soil vapour-filled porosity (dimensionless); and,

θ_t = soil total porosity (dimensionless).

Note that this equation assumes that the dominant form of diffusion is through air and therefore cannot be applied to scenarios where diffusion in water may become a dominant form of the transport equation. Therefore, moisture content must always be set to an unsaturated condition in order to apply this equation.

For Tier 1 and Tier 2 guideline adjustments where more than 1 stratum exists, the calculation of D_T^{eff} must be based on the most conservative stratum in zone of contaminant migration (e.g., the stratum with the highest diffusion coefficient must be used). An exception is allowed for sites where a surficial fine grained deposit exists over a coarse grained deposit. In the event that

1. Sufficient borehole information is provided to support the presence of a continuous fine grained layer over the entire site,
2. Sufficient borehole information is provided to support estimation of the minimum thickness of the fine grained layer and
3. The minimum thickness of the fine grained layer is at least 1 m deeper than the depth of typical excavations at the site in the event of construction and at least 1 m deeper than the maximum depth of basements or potential basements at the site

then the fine grained layer can be applied to the calculation of D_T^{eff}. However, the depth to the contaminant layer or the groundwater cannot be set at a depth greater than the minimum thickness of the layer.

For more detailed site specific risk assessments and in the event that sufficient data is available to determine continuous presence of several layers and minimum and maximum thickness of these layers, it may be possible to estimate the effective diffusion coefficient based on a combination of all layers present at the site. However, this requires a site specific risk assessment and is not allowed for simple model changes at Tier 2.

Where site-specific risk assessments are used, and in the event that there is more than one soil type through which the contaminant must diffuse, D_T^{eff} can be calculated separately for each soil stratum (stratum-specific diffusion coefficients are referred to as D_i^{eff} below) and averaged using the following equation:

$$D_T^{eff} = \frac{L_T}{\sum D_i^{eff} L_i}$$

Where:	D_T^{eff}	=	overall effective porous media diffusion coefficient based on vapour-phase concentrations for the region between the source and foundation (cm^2/s);
	D_i^{eff}	=	effective porous media diffusion coefficient for stratum 'i', calculated as above;
	L_T	=	distance from contaminant source to foundation (cm); and,
	L_i	=	thickness of stratum 'i' through which the contaminant travels.

Calculation of D_{crack}:

D_{crack} is calculated in exactly the same way as D_T^{eff}, with the exception that the assumption is made that the soil material in the cracks is dry (CCME, 2006a), and accordingly, the air filled porosity is the same as the total porosity, and the equation becomes:

$$D_{crack} \approx D_a \times \left(\frac{\theta_t^{10/3}}{\theta_t^2} \right)$$

Where:	D_{crack}	=	effective porous media diffusion coefficient in floor cracks (cm^2/s);
	D_a	=	diffusion coefficient in air (cm^2/s);
	θ_t	=	total porosity for underlying soil (dimensionless).

In this equation, it is always assumed that the soil properties are based on the properties of the soil surrounding the building foundation.

Calculation of Q_B:

$$Q_B = \frac{L_B W_B H_B ACH}{3{,}600}$$

Where:	Q_B	=	building ventilation rate (cm^3/s);
	L_B	=	building length (cm);
	W_B	=	building width (cm);
	H_B	=	building height (cm 3);
	ACH	=	air exchanges per hour (h^{-1}); and,
	3,600	=	conversion factor from hours to seconds.

Calculation of Q_{soil}:

$$Q_{soil} = \frac{2\pi \Delta P k_v X_{crack}}{\mu \, ln\left[\frac{2Z_{crack}}{r_{crack}}\right]}$$

Where	Q_{soil}	=	volumetric flow rate of soil gas into the building (cm^3/s);
	ΔP	=	pressure differential ($g/cm \cdot s^2$);
	k_v	=	soil vapour permeability to vapour flow (cm^2) for soil adjacent to building foundation;
	X_{crack}	=	length of idealized cylinder (cm);
	μ	=	vapour viscosity (0.000173 g/cm·s; CCME, 2006a);
	Z_{crack}	=	distance below grade to idealized cylinder (cm); and,
	r_{crack}	=	radius of idealized cylinder (cm; calculated as A_{crack}/X_{crack}).

B.2 Ecological Exposure Pathways

Direct Contact by Soil organisms

Groundwater guidelines based on direct contact by soil organisms for non-polar organic compounds and salts are based on soil quality guidelines for this pathway:

Non-polar organic compounds

$$GWQG_{DC} = SQG_{DC} \frac{\rho_b}{\theta_w + \left(K_{oc} \times f_{oc} \times \rho_b\right) + \left(H' \times \theta_a\right)}$$

Where:	$GWQG_{DC}$	=	groundwater remediation guideline protective of direct contact with plants and soil invertebrates in areas of shallow groundwater (mg/L);
	SQG_{DC}	=	soil quality guideline protective of direct contact with plants and soil invertebrates (mg/kg);
	ρ_b	=	dry soil bulk density (g/cm^3);
	θ_w	=	moisture-filled porosity (dimensionless);
	K_{oc}	=	organic carbon partition coefficient (L/kg);
	f_{oc}	=	fraction of organic carbon (g/g);
	H'	=	dimensionless Henry's Law Constant (dimensionless); and,
	θ_a	=	vapour-filled porosity (dimensionless).

Salt Compounds

Salt compounds do not interact significantly with soil organic carbon, are not present to a significant extent in the vapour phase, and are present in pore water or loosely bound to clay mineral surfaces. These guidelines are presented in terms of the electrical conductivity (in dS/m) of a saturated paste of the soil. The groundwater guideline for this exposure pathway for salts is calculated from the AENV (2001b) ecological soil contact soil quality guidelines, for coarse and fine soils, using the following equation. It is assumed that the water content of the soil in a saturated paste sample may be approximated by the total porosity of the soil.

$$GWQG_{DC} = SQG_{DC} \frac{1{,}000\rho_b}{\theta t}$$

where:

$GWQG_{DC}$	=	groundwater remediation objective protective of ecological soil contact in surface soil (μS/cm);
SQG_{DC}	=	soil quality guideline for salts protective of eco-soil contact (2 dS/m, agricultural and residential; 4 dS/m commercial and industrial);
1,000	=	conversion factor from dS/m to μS/cm (dimensionless);
ρ_b	=	dry soil bulk density (g/cm^3); and,
θ_t	=	total porosity (dimensionless).

It should be noted that this calculation only applies to the groundwater quality guideline that is calculated for soil-based ecological receptors and cannot be used to screen any other pathways or receptors. It should also be noted that the above calculation only applies to the total ionic concentration in the soil. All pathways and receptors, including soil ecological pathways and receptors, must still be screened for potential effects from exposure of the individual ions that comprise the total electrical conductivity regardless of calculations from this equation.

B.3 Groundwater Transport

Lateral groundwater transport (e.g. to a nearby surface water body) is modelled using a transport model and equations from the CCME (2006) protocol. At this time, transport modelling for inorganic substances is not conducted due to the uncertainties associated with the partitioning of metals between the adsorbed and dissolved phase and the lack of biodegradation of these substances; transport of inorganic substances could be assessed on a site-specific basis where appropriate.

For the protection of aquatic life or wildlife watering, it is assumed that there is a minimum 10 m lateral separation between the point of measurement and the surface water body; this distance can be modified at Tier 2. The model used to calculate the groundwater guidelines for these water uses is simply the lateral transport part of the CCME (2006) model used to calculate the corresponding soil guideline.

The groundwater remediation guideline protective of aquatic life and wildlife watering is calculated using the following equations.

$$GWQG_{GR} = SWQG \times DF4$$

where:

$GWQG_{GR}$	=	groundwater quality guideline protective of groundwater pathways (mg/kg);
$SWQG_{FL}$	=	corresponding surface water quality guideline (aquatic life, or

wildlife watering) (mg/L);
DF4 = dilution factor for lateral transport (L/kg).

Assumptions implicit in the model include the following:

- the soil is physically and chemically homogeneous;
- depletion of the contaminant source is not considered (*i.e.*, infinite source mass);
- contaminant is not present as a free phase product;
- groundwater aquifer is unconfined;
- groundwater flow is uniform and steady;
- co-solubility and oxidation/reduction effects are not considered;
- attenuation of the contaminant in the saturated zone is assumed to be one-dimensional with respect to sorption-desorption, dispersion, and biological degradation;
- dispersion in groundwater is assumed to occur in the longitudinal and transverse directions only and diffusion is not considered;
- dilution of the plume by groundwater recharge down-gradient of the source is not included.

Dilution Factor 4
Dilution factor 4 (DF4) from the CCME (2006) model accounts for the processes of dispersion and biodegradation as groundwater travels downgradient from beneath the source of contamination, and is the ratio of the concentration of a chemical in groundwater beneath the source, to the concentration in groundwater at a distance (10 m for generic aquatic life and wildlife watering guidelines) downgradient of the source. For distances less than 10 m, a value of 1 should be used for DF4. Consistent with CCME (2008a,b), the time independent (steady state) version of the equation to calculate DF4 was used:

$$DF4 = \frac{2}{\exp(A) \times [erf(C) - erf(D)]}$$

$$A = \frac{x}{2D_x}\left\{1 - \left(1 + \frac{4L_s D_x}{v}\right)^{1/2}\right\}$$

$$C = \frac{y + Y/2}{2\left(D_y x\right)^{1/2}}$$

$$D = \frac{y - Y/2}{2\left(D_y x\right)^{1/2}}$$

$$L_s = \frac{0.6931}{t_{1/2s}} \times \exp(-0.07d)$$

$$v = \frac{V}{\theta_t R_s}$$

$$R_s = 1 + \frac{\rho_b K_{oc} f_{oc}}{\theta_t}$$

$$D_x = 0.1x$$

$$D_y = 0.01x$$

where:

DF4	=	dilution factor 4 (dimensionless);
erf	=	the error function;
A	=	dimensionless group A (dimensionless);
C	=	dimensionless group C (dimensionless);
D	=	dimensionless group D (dimensionless);
x	=	lateral distance between source and receptor (m);
D_x	=	dispersivity in the direction of groundwater flow (m);
L_s	=	decay constant (1/year);
v	=	velocity of the contaminant (m/year);
y	=	distance to receptor perpendicular to groundwater flow (m);
Y	=	source width (m);
D_y	=	dispersivity perpendicular to the direction of groundwater flow (m);
$t_{1/2s}$	=	decay half-life of contaminant in saturated zone of aquifer (years);
d	=	water table depth (m);
V	=	Darcy velocity in groundwater (m/year);
θ_t	=	total soil porosity (dimensionless) in the aquifer;
R_s	=	retardation factor in saturated zone (dimensionless);
ρ_b	=	dry soil bulk density in the aquifer (g/cm^3);
K_{oc}	=	organic carbon partition coefficient (mL/g); and,
f_{oc}	=	fraction organic carbon (g/g) in the aquifer.

It should be noted that the decay half-life is assumed to be infinite unless a value has been approved by the CCME. Most published half-life data reflect aerobic conditions or surface water/surface soil, and may be unconservative for potentially anaerobic groundwater conditions. Site-specific half-lives may be considered in a site-specific risk assessment.

B.4 Model Input Parameters

Table 4: Model Input Parameters for Human Receptor Characteristics[a]

Parameter	Symbol	Infant (0 – 6 mo)	Toddler (7 mo - 4 y)	Child (5 – 11 y)	Teen (12 – 19 y)	Adult (20+ y)
Body Weight (kg)	BW	8.2	16.5	32.9	59.7	70.7
Air Inhalation Rate (m^3/d)	IR	2.1	9.3	14.5	15.8	15.8
Water Ingestion Rate (L/d)	WIR	0.3	0.6	0.8	1.0	1.5

a – from CCME 2006

Table 5: Soil and Hydrogeological Model Input Parameters[a]

Parameter	Symbol	Soil Type	
		Coarse-grained	Fine-grained
Saturated Hydraulic Conductivity (m/y)	K_H	320	32
Hydraulic Gradient	i	0.028	0.028
Recharge (Infiltration rate) (m/y)	I	0.28	0.20
Organic Carbon Fraction (g/g)	foc	0.005	0.005
Soil Bulk Density (g/cm3)	ρ_b	1.7	1.4
Water Content (Mw/Ms)	M_W/M_S	0.07	0.12
Total Soil Porosity	n	0.36	0.47
Vapour-Filled Porosity	θ_a	0.241	0.302
Moisture-Filled Porosity	θ_w	0.119	0.168
Soil Vapour Permeability (cm2)	k_v	$6x10^{-8}$	10^{-9}

a – from CCME 2008a

Table 6: Model Input Parameters for Site Characteristics[a]

PARAMETER	SYMBOL	VALUE
Contaminant Source Width (m)	Y	10
Contaminant Source Depth (m)	Z	3
Contaminant Source Length (m)	X	10
Distance to Surface Water (m)	x	10
Distance to Potable Water User (m)	x	0
Distance to Agricultural Water User (m)	x	0
Distance from Groundwater to Building Slab (cm)	L_T	30
Depth to Groundwater (water table) (m)	d	3
Depth of unconfined aquifer (m)	d_a	5

a – from CCME 2006

Table 7: Model Input Parameters for Building [a]

Parameter	Symbol	Residential Basement	Residential Slab-On-Grade	Commercial Slab-On-Grade
Building Length (cm)	L_B	1225	1225	2000
Building Width (cm)	W_B	1225	1225	1500
Building Substructure Area (cm^2)	A_B	$2.7x10^6$	$1.5x10^6$	$3.0x10^6$
Mixing Height (cm)[a]	H_B	360	360	300
Thickness of Building Foundation (cm)	L_{crack}	11.25	11.25	11.25
Depth Below Grade of Foundation (cm)	Z_{crack}	244	11.25	11.25
Area of Crack (cm^2)	A_{crack}	1790	994.5	1846
Length of Idealized Cylinder (cm)	X_{crack}	4900	4900	7000
Air Exchanges per Hour (1/h)	ACH	0.5	0.5	0.9
Pressure Differential ($g/cm\text{-}s^2$)	ΔP	40	40	20

a – from CCME 2008a

Table 8: Model Input Parameters for Livestock and Wildlife Receptor Characteristics[a]

Parameter	Symbol	Unit	Livestock (Cow)	Wildlife (Meadow Vole)
Body Weight	BW	kg	550	0.017
Soil Ingestion Rate	SIR	kg/d	0.747	0.000058
Water Ingestion Rate	WIR	L/d	100	0.00357

a – from AENV (2008a)

B.5 Chemical-Specific Parameters

A variety of chemical physical-chemical and toxicological parameters are also needed for guideline calculation. The physical-chemical parameters applied to derive the generic guidelines have been summarized in AENV (2008a) and OMEE (1997). Human toxicological parameters should be based on the latest guidance from Health Canada.

REFERENCES

AENV. 2001. *Salt Contamination Assessment & Remediation Guidelines*. Pub no.: T/606.

AENV. 2009a. *Alberta Tier 1 Soil and Groundwater Remediation Guidelines*.

AENV. 2009b. *Alberta Tier 2 Soil and Groundwater Remediation Guidelines*.

CCME. 1996. *A Framework for Ecological Risk Assessment: General Guidance. The National Contaminated Sites Remediation Program*. PN 1195.

BC (British Columbia). 1996. *BC Regulation 375/96: Contaminated Sites Regulation*.

CCME. 1997. *A Framework for Ecological Risk Assessment: Technical Appendices*. PN 1274.

CCME. 1999. *Canadian Environmental Quality Guidelines. Canadian Council of Ministers of the Environment*. Publication No. 1299.

CCME. 2003. *Guidance on the Site-Specific Application of Water Quality Guidelines in Canada: Procedures for Deriving Numerical Water Quality Objectives*.

CCME. 2006. *A Protocol for the Derivation of Environmental and Human Health Soil Quality Guidelines*. PN 1332.

CCME. 2008a. *Canada-Wide Standard for Petroleum Hydrocarbons (PHC) in Soil: Scientific Rationale*. Supporting Technical Document. PN 1399.

CCME. 2008b. *Canada-Wide Standard for Petroleum Hydrocarbons (PHC) in Soil: User Guidance*. Prepared by O'Connor Associates Environmental Inc. (2001) and Meridian Environmental Inc. (2001, 2007) for Canadian Council of Ministers of the Environment. PN 1398.

Environment Canada. 2006. *Ecological Risk Evaluation Framework for Federal Contaminated Sites: Guidance for ERE Level 1 (Custodial Department Input Section)*. Version 2.2.

Hayashi, M. and Rosenberry, D. O. 2002. *Effects of ground water exchange on the hydrology and ecology of surface water*. Ground Water 40(3): 309-316.

Health Canada. 2004a. *Federal Contaminated Site Risk Assessment in Canada, Part I: Guidance on Human Health Preliminary Quantitative Risk Assessment* (PQRA).

Health Canada. 2004b. *Federal Contaminated Site Risk Assessment in Canada, Part II: Health Canada Toxicological Reference Values* (TRVs).

Health Canada. 2006. *Federal Contaminated Sites Risk Assessment in Canada Part V: Guidance on Human Health Detailed Quantitative Risk Assessment*. Contaminated Sites Division.

Health Canada. 2008. *Guidelines for Canadian Drinking Water Quality. Federal-Provincial-Territorial Committee on Drinking Water of the Federal-Provincial-Territorial Committee on Health and the Environment*.

OMEE (Ontario Ministry of Environment and Energy). 1997. *Rationale for the Development and Application of Generic Soil, Groundwater and Sediment Criteria for Use at Contaminated Sites in Ontario*. Standards Development Branch.

US EPA. 2008. *Evaluating Ground-Water/Surface-Water Transition Zones in Ecological Risk Assessments*. Office of Solid Waste and Emergency Response. EPA-540-R-06-072.

Mackenzie Valley Land and Water Board
7th Floor - 4910 50th Avenue
P.O. Box 2130
YELLOWKNIFE NT X1A 2P6
Phone (867) 669-0506
FAX (867) 873-6610

APPLICATION FOR A NEW WATER LICENCE, AMENDMENT OF LICENCE, OR RENEWAL OF LICENCE.

Application/Licence No:
(amendment or renewal only)

1. Name and Mailing Address of Applicant	**2. Address of Head Office in Canada if Incorporate**
Town of Fort Smith	
P.O. Box 147 Fort Smith	
Northwest Territories X0E 0P0	
Telephone: 867-872-8400	Telephone:
Fax: 867-872-8401	Fax:

3. Location of Undertaking (describe and attach a map, indicating watercourses and location of any proposed waste deposits).

Latitude 60° 01'00" N   Longitude 112° 02'49" W

4. Description of Undertaking (describe and attach plans)

Landfarm for soil remediation. See attached technical memorandum and other information.

5. Type of Undertaking.

1. Industrial		5. Agriculture	
2. Mining and Milling		6. Conservation	
3. Municipal		7. Recreation	
4. Power		8. Miscellaneous	X

6. Water Use

To obtain water		Flood control	
To cross a watercourse		To divert water	
To modify the bed or bank of a watercourse		To alter the flow of, or store water	

Other (describe):

7. Quantity of water involved (litres per second, litres per day or cubic meter per year), including both quantity to be used and quality to be returned to source.

N/A

8. **Waste deposited (quantity, quality, treatment and disposal)**

Unknown future quantities of hydrocarbon-impacted soil to be treated at the landfarm

9. **Other persons or properties affected by this Undertaking (give name, mailing address and location). Attach a list if necessary.**

10. **Predicted environmental impacts of Undertaking and proposed mitigation.**

There is the potential for hydrocarbons to leave the site and enter surrounding soil or groundwater. Proposed mitigation includes the use of existing geomembrane liner and groundwater monitoring – see attached documents for description.

11. **Contractors and sub-contractors (names, addresses and functions). Attach a list if necessary.**

12. **Studies undertaken to date. Attach a list if necessary.**

See attached technical memorandum (AECOM) under "Landfarm Operation & Maintenance During Current Operating Period"

13. **Proposed time schedule.**

Start date: ______________ Completion date: ______________

Name (print): John Holland Signature: John Holland

Title (print): Senior Admin Officer Date: August 25/09

Please make all cheques payable to "Receiver General of Canada"

FOR OFFICE USE ONLY

Application Fee Amount: $__________ **Receipt No:** __________

Water Use Deposit Amount: $__________ **Receipt No:** __________

AECOM

AECOM
17203 103rd Avenue, Edmonton, AB, Canada T5S 1J4
T 780.488.6800 F 780.488.2121 www.aecom.com

Memorandum

Date:	July 31, 2009
To:	Mackenzie Valley Land and Water Board
From:	Ken Johnson, AECOM
Project Number:	112336
Subject:	Fort Smith Landfarm – Background for Water Licence Application

Distribution:

The purpose of this technical memorandum is to describe the Fort Smith Landfarm Facility to support the Town of Fort Smith's application for a Class B Water Licence for this facility. The memo will cover the landfarm site layout, past operation, and future operational plans.

Landfarm Infrastructure Description

A landfarm facility was constructed by the GNWT Department of Public Works and Services (Public Works) in 2000, to remediate hydrocarbon-impacted soil excavated from under the Fort Smith campus of Aurora College.

The landfarm is located west of the Town of Fort Smith along the Fort Smith Highway (see Figure 1). On the east side of the site is a lined (geomembrane liner) wet soil sump, which covers a surface area of approximately 2,700 m^2 (28 m x 97 m). The main landfarm area is adjacent to the sump on the west side of the site, and covers roughly 30,000 m^2. See Figure 2 and the *Landfarm Cell Dimensions and Soil Stockpile Locations* drawing, EBA 2006.

There are six (6) groundwater monitoring wells located on the north, west and south sides of the site. See Figure 3 for locations.

Landfarm Operation & Maintenance During Current Operating Period

The Fort Smith landfarm has been managed by GNWT Public Works since its construction. Approximately 17,500 m^3 of excavated soil from under the College was spread over the landfarm area to promote natural attenuation and bioremediation of the soil. The lined sump is meant to detain site runoff (although contaminated soil is currently piled in this location, as described below).

Reports that have been prepared about the landfarm over this period include:

- EBA Engineering Consultants Ltd., *Letter Re: Fort Smith Landfarm and Sump Recommendations*, November 30, 2006.
- Earth Tech (Canada) Inc., *Groundwater Monitoring Program Evaluation – Fort Smith Municipal Landfill*, May 2006.
- IEG Environmental, *2005 Solid Waste Facility Surveillance Network Monitoring, Fort Smith NT*, February 2006.
- EBA Engineering Consultants Ltd., *Letter Report Re: 2005 Landfarm and Groundwater Well Monitoring at the Fort Smith Landfarm Facility and the Aurora College Trades Building, Fort Smith, NT*, July 11, 2005.
- Earth Tech (Canada) Inc., *Fort Smith Solid Waste Facility, Surveillance Network Monitoring*, September 2004.

Various samples have been taken of the soil in the landfarm and the surrounding groundwater. An EBA Engineering letter report dated July 2005 gives a description of landfarm soil and groundwater monitoring that was done in summer 2005. The 2005 landfarm sampling program concluded that soil in the Fort Smith landfarm was below GNWT standards for industrial land-use soil, and the facility had not impacted the surrounding groundwater.

The wells surrounding the landfarm have been monitored as part of the Solid Waste Disposal Facility sampling for the Town of Fort Smith's water licence Surveillance Network Program. Monitoring of wells around the landfarm and solid waste landfill occurred in 2001 (EBA), 2004 (Earth Tech) and 2005 (IEG) – see Appendix A for a summary of the results. The 2004 Earth Tech report indicated that the landfarm facility was not impacting the surrounding groundwater, since no sign of hydrocarbon, mineral oil and grease, or BTEX contamination was observed in surface or groundwater samples. IEG Environmental found similar results based on the water licence SNP sampling done in 2005.

While the original purpose of the site was to remediate a single load of soil from the Fort Smith College, additional dumping of contaminated material has occurred. This material is currently piled in the lined wet soil sump.

Future Operation of Landfarm

The landfarm facility is being transferred from Public Works to the Town of Fort Smith (the Town). The Town will continue to use the sump and landfarm for soil remediation, as there is potential for the Town to accept hydrocarbon-impacted soil from other parties in the future.

There are five existing borehole wells surrounding the landfarm facility for groundwater monitoring. The Town will continue to monitor hydrocarbons in the groundwater using these wells.

The attached EBA Engineering letter dated November 30, 2006 contains some recommendations for the future use of the Fort Smith landfarm site. EBA recommended that the Town remove soil in the sump and spread it over the landfarm, install 3 groundwater monitoring wells close to the sump, and conduct appropriate monitoring of the site. The Town will act on these recommendations at some point in the future.

The soil remediation objectives for the landfarm will be as shown in the ENR *Environmental Guideline for Contaminated Site Remediation*. This document lists remediation criteria in mg/kg of petroleum hydrocarbons (PHC), depending on the type of soil (coarse or fine grained) and the Land Use planned for the remediated soil.

The Town of Fort Smith will need to be registered with the Department of Resources, Wildlife and Economic Development's Environmental Protection Service (EPS) as the receiver of a hazardous waste (hydrocarbon-impacted soil). The GNWT Environment and Natural Resources (ENR) document "Guideline for the General Management of Hazardous Waste in the NWT" outlines the responsibilities of generators, carriers, and receivers of hazardous waste materials. All three parties must be registered so that waste manifests can be completed for soil transported to the landfarm. In addition, the Town may need to register the landfarm site.

Conclusions and Recommendations

The Fort Smith landfarm has been used to treat a single load of hydrocarbon-impacted soil under the management of GNWT Public Works. Thus far, the facility has not had a negative impact on the surrounding groundwater, based on monitoring by EBA and Earth Tech.

The Town of Fort Smith will be able to make good use of the landfarm site in the future, and will undertake the appropriate soil and groundwater monitoring. Actions will be needed to address the recommendations in the EBA report.

KRJ:cm
Encl.

July 31, 2009

Figure 1. Fort Smith Landfarm Location

Base Image © Google Earth, 2007

July 31, 2009

Figure 2. Fort Smith Landfarm Site Plan

Base Image © Google Earth, 2007

July 31, 2009

Figure 3. Fort Smith Landfarm Monitoring Wells

AECOM

Appendix A

Past Sampling Results
Fort Smith Landfarm & Solid Waste Disposal Facility

Samples were taken by EBA Engineering (2001), Earth Tech (2004) and IEG Environmental (2005)

These results were compiled for the Fort Smith Municipal Landfill Groundwater Monitoring Program Evaluation (Earth Tech 2006)

TABLE 2: GROUNDWATER RESULTS FOR PETROLEUM HYDROCARBONS AND MINERAL OIL AND GREASE

Benzene
(mg/L)

	Mar-2001	Oct-2001	Jun-2004	Sep-2004	Aug-2005	Oct-2005
BH-1A	<0.0005	-	<0.001	<0.002	<0.0005	<0.0005
BH-1B	-	-	<0.001	<0.002	<0.0005	<0.0005
BH-2	<0.0005	-	<0.001	<0.002	<0.0005	<0.0005
BH-3	<0.0005	-	<0.001	<0.002	<0.0005	<0.0005
BH-4	<0.0005	-	<0.001	<0.002	<0.0005	<0.0005
BH-5	<0.0005	-	<0.001	<0.002	<0.0005	<0.0005
BH-6	<0.0005	-	<0.001	<0.002	<0.0005	<0.0005
BH-7	<0.0005	-	<0.001	<0.002	<0.0005	<0.0005
BH-8	-	-	-	<0.002	-	-
BH-9	<0.0005	-	-	<0.002	<0.0005	<0.0005
BH-10	<0.0005	-	-	<0.002	<0.0005	<0.0005
MW-101	-	-	<0.001	<0.002	<0.0005	<0.0005
MW-102	-	-	<0.001	<0.002	<0.0005	<0.0005
MW-103A	-	-	<0.001	<0.002	<0.0005	<0.0005
MW-103B	-	-	<0.001	<0.002	<0.0005	<0.0005
MW-104	-	-	<0.001	<0.002	<0.0005	<0.0005

note: CCME Freshwater Aquatic Life Guideline for benzene is 0.37 mg/L

Toluene
(mg/L)

	Mar-2001	Oct-2001	Jun-2004	Sep-2004	Aug-2005	Oct-2005
BH-1A	<0.0005	-	<0.001	<0.002	<0.0005	<0.0005
BH-1B	-	-	<0.001	<0.002	<0.0005	<0.0005
BH-2	<0.0005	-	<0.001	<0.002	<0.0005	<0.0005
BH-3	<0.0005	-	<0.001	<0.002	<0.0005	<0.0005
BH-4	<0.0005	-	<0.001	<0.002	<0.0005	<0.0005
BH-5	<0.0005	-	<0.001	<0.002	<0.0005	<0.0005
BH-6	<0.0005	-	<0.001	<0.002	<0.0005	<0.0005
BH-7	<0.0005	-	<0.001	<0.002	<0.0005	<0.0005
BH-8	-	-	-	<0.002	-	-
BH-9	<0.0005	-	-	<0.002	<0.0005	<0.0005
BH-10	<0.0005	-	-	<0.002	<0.0005	<0.0005
MW-101	-	-	<0.001	<0.002	<0.0005	<0.0005
MW-102	-	-	<0.001	<0.002	<0.0005	<0.0005
MW-103A	-	-	<0.001	<0.002	<0.0005	<0.0005
MW-103B	-	-	<0.001	<0.002	<0.0005	<0.0005
MW-104	-	-	<0.001	<0.002	<0.0005	<0.0005

note: CCME Freshwater Aquatic Life Guideline for toluene is 0.09 mg/L

Ethylbenzene
(mg./L)

	Mar-2001	Oct-2001	Jun-2004	Sep-2004	Aug-2005	Oct-2005
BH-1A	<0.0005	-	<0.001	<0.002	<0.0005	<0.0005
BH-1B	-	-	<0.001	<0.002	<0.0005	<0.0005
BH-2	<0.0005	-	<0.001	<0.002	<0.0005	<0.0005
BH-3	<0.0005	-	<0.001	<0.002	<0.0005	<0.0005
BH-4	<0.0005	-	<0.001	<0.002	<0.0005	<0.0005
BH-5	<0.0005	-	<0.001	<0.002	<0.0005	<0.0005
BH-6	<0.0005	-	<0.001	<0.002	<0.0005	<0.0005
BH-7	<0.0005	-	<0.001	<0.002	<0.0005	<0.0005
BH-8	-	-	-	<0.002	-	-
BH-9	<0.0005	-	-	<0.002	<0.0005	<0.0005
BH-10	<0.0005	-	-	<0.002	<0.0005	<0.0005
MW-101	-	-	<0.001	<0.002	<0.0005	<0.0005
MW-102	-	-	<0.001	<0.002	<0.0005	<0.0005
MW-103A	-	-	<0.001	<0.002	<0.0005	<0.0005
MW-103B	-	-	<0.001	<0.002	<0.0005	<0.0005
MW-104	-	-	<0.001	<0.002	<0.0005	<0.0005

note: CCME Freshwater Aquatic Life Guideline for ethylbenzene is 0.002 mg/L

Xylenes
(mg/L)

	Mar-2001	Oct-2001	Jun-2004	Sep-2004	Aug-2005	Oct-2005
BH-1A	<0.0005	-	<0.001	<0.006	<0.0005	<0.0005
BH-1B	-	-	<0.001	<0.006	<0.0005	<0.0005
BH-2	<0.0005	-	<0.001	<0.006	<0.0005	<0.0005
BH-3	<0.0005	-	<0.001	0.007	<0.0005	<0.0005
BH-4	<0.0005	-	<0.001	0.007	<0.0005	<0.0005
BH-5	<0.0005	-	<0.001	<0.006	<0.0005	<0.0005
BH-6	<0.0005	-	<0.001	<0.006	<0.0005	<0.0005
BH-7	<0.0005	-	<0.001	<0.006	<0.0005	<0.0005
BH-8	-	-	-	<0.006	-	-
BH-9	<0.0005	-	-	<0.006	<0.0005	<0.0005
BH-10	<0.0005	-	-	<0.006	<0.0005	<0.0005
MW-101	-	-	<0.001	<0.006	<0.0005	<0.0005
MW-102	-	-	<0.001	<0.006	<0.0005	<0.0005
MW-103A	-	-	<0.001	<0.006	<0.0005	<0.0005
MW-103B	-	-	<0.001	<0.006	<0.0005	<0.0005
MW-104	-	-	<0.001	0.004	<0.0005	<0.0005

Mineral Oil and Grease
(mg/L)

	Mar-2001	Oct-2001	Jun-2004	Sep-2004	Aug-2005	Oct-2005
BH-1A	-	-	<1	<5	-	-
BH-1B	-	-	<1	<5	-	-
BH-2	-	-	<1	<5	-	-
BH-3	-	-	<1	<5	-	-
BH-4	-	-	<1	<5	-	-
BH-5	-	-	<1	<5	-	-
BH-6	-	-	<1	<5	-	-
BH-7	-	-	<1	<5	-	-
BH-8	-	-	-	<5	-	-
BH-9	-	-	-	<5	-	-
BH-10	-	-	-	<5	-	-
MW-101	-	-	<1	<5	-	-
MW-102	-	-	<1	<5	-	-
MW-103A	-	-	<1	<5	-	-
MW-103B	-	-	<1	<5	-	-
MW-104	-	-	<1	<5	-	-

Total Extractable Hydrocarbons
(mg/L)

	Mar-2001	Oct-2001	Jun-2004	Sep-2004	Aug-2005	Oct-2005
BH-1A	<0.1	-	<0.01	<0.05	0.06	<0.05
BH-1B	-	-	<0.01	<0.05	<0.05	<0.05
BH-2	<0.1	-	<0.01	<0.05	<0.05	<0.05
BH-3	<0.1	-	<0.01	<0.05	0.06	<0.05
BH-4	<0.1	-	<0.01	<0.05	<0.05	<0.05
BH-5	<0.1	-	<0.01	<0.05	<0.05	<0.05
BH-6	<0.1	-	<0.01	<0.05	0.05	<0.05
BH-7	<0.1	-	<0.01	<0.05	0.11	<0.05
BH-8	-	-	-	<0.05	-	-
BH-9	<0.1	-	-	<0.05	<0.05	<0.05
BH-10	<0.1	-	-	<0.05	<0.05	<0.05
MW-101	-	-	<0.01	<0.05	<0.05	<0.05
MW-102	-	-	<0.01	<0.05	<0.05	<0.05
MW-103A	-	-	<0.01	<0.05	0.07	<0.05
MW-103B	-	-	<0.01	<0.05	<0.05	<0.05
MW-104	-	-	<0.01	<0.05	<0.05	<0.05

Total Volatile Hydrocarbons
(mg/L)

	Mar-2001	Oct-2001	Jun-2004	Sep-2004	Aug-2005	Oct-2005
BH-1A	<0.05	-	<0.01	0.003	<0.1	<0.1
BH-1B	-	-	<0.01	0.002	<0.1	<0.1
BH-2	<0.05	-	<0.01	<0.002	<0.1	<0.1
BH-3	<0.05	-	<0.01	0.006	<0.1	<0.1
BH-4	<0.05	-	<0.01	<0.002	<0.1	<0.1
BH-5	<0.05	-	<0.01	<0.002	<0.1	<0.1
BH-6	<0.05	-	<0.01	<0.002	<0.1	<0.1
BH-7	<0.05	-	<0.01	<0.002	<0.1	<0.1
BH-8	-	-	-	<0.002	-	-
BH-9	<0.05	-	-	<0.002	<0.1	<0.1
BH-10	<0.05	-	-	<0.002	<0.1	<0.1
MW-101	-	-	<0.01	<0.002	<0.1	<0.1
MW-102	-	-	<0.01	<0.002	<0.1	<0.1
MW-103A	-	-	<0.01	<0.002	<0.1	<0.1
MW-103B	-	-	<0.01	<0.002	<0.1	<0.1
MW-104	-	-	<0.01	0.003	<0.1	<0.1

AECOM

Base Image © Google Earth, 2007

July 31, 2009

Appendix A. Fort Smith Landfill Monitoring Wells

AECOM

Appendix B

EBA Engineering Consultants Letter of Recommendations

(appendix flysheet.doc)

File: Y22100002

November 30, 2006

Mr. Curt Snook, P.Eng. Project Officer
Department of Public Works and Services
Government of Northwest Territories
P.O. Box 390
199 McDougal Road
Fort Smith, NT
XOE 0P0

Re: Fort Smith Landfarm and Sump Recommendations

Dear Mr Snook:

EBA Engineering Consultants Ltd (EBA) is pleased to provide this letter of recommendations regarding the current state and future uses of the landfarm area and sump located west of the Fort Smith airport (Figure 1). These recommendations are based on the meeting held between EBA and the Government of Northwest Territories Public Works and Services (Public Works) on November 21, 2006.

1.0 BACKGROUND:

Mr. Matthew Barnette, and Mr. Patrick Kramers of EBA met with Mr. Curt Snook of Public Works and Mr. Bill Reimer formerly of Public Works to discuss the current state and future plans of the Fort Smith landfarm facility. A detailed plan of the landfarm and sump are attached as Figure 2. The landfarm and sump were initially constructed to remediate hydrocarbon impacted soils excavated from the Fort Smith College Trades Building in 2000. EBA understands that the sump was only used for one load of soil during the excavation and the Town of Fort Smith would like to continue to use the area for landfarming after the sump (and the landfarm) is handed over by Public Works. The two main topics discussed during the meeting between EBA and Public Works were the existence of impacted soils within the sump and recommendations for the future use of the landfarm and sump by the Town of Fort Smith.

EBA Engineering Consultants Ltd.
p. 867.920.2287 • f. 867.873.3324
PO Box 2244 • 201, 4916 - 49 Street • Yellowknife, Northwest Territories X1A 2P7 • CANADA

2.0 RECOMMENDATIONS

Based on the results of the meeting between EBA and Public Works, EBA has recommended the following with respect to the impacted material in the sump area and future use of the landfarm and sump after the area is handed over to the Town of Fort Smith.

2.1 IMPACTED SOIL IN SUMP

Since its construction in 2000, EBA and Public Works understand that additional dumping of contaminated material in the sump has occurred without the consent of Public Works. EBA sampled and analyzed a composite sample from the sump in September, 2006. Analytical results of the sample collected indicated an exceedance in the F2 hydrocarbon fraction (EBA file: 1740202, report dated September 28, 2006). EBA's recommendation for the treatment of this material was as follows:

- Excavate the impacted soil in sump.
- Spread impacted soil over landfarm.
- Collect five (5) confirmatory samples to confirm that all impacted material has been excavated from the sump.

2.2 FUTURE CONSIDERATIONS FOR USE OF LANDFARM AND SUMP BY THE TOWN OF FORT SMITH

It is understood that the Town of Fort Smith will use the landfarm facility and the sump located within after Public Works hands over the site. Future considerations are indicated below:

- EBA recommends that three (3) groundwater monitoring wells be installed surrounding the sump and continual monitoring of groundwater be carried out until closure of the site to ensure there are no hydrocarbon impacts on groundwater as a result of activities in the sump.
- EBA understands that the landfarm area (including sump) was initially designed for short-term use and Public Works has only deposited one load of hydrocarbon contaminated soil from the 2000 excavation in the sump. EBA recommends that following the transfer of the landfarm and the sump from Public Works to the Town of Fort. Smith, appropriate monitoring (soil/groundwater, annual/monthly) is conducted as per appropriate guidelines.

3.0 CLOSURE

We trust these recommendations suit your needs. A copy of EBA's Terms and Conditions are attached. Should you have any questions, please do not hesitate to contact the undersigned at your convenience.

Sincerely;

EBA Engineering Consultants Ltd.

Prepared by:

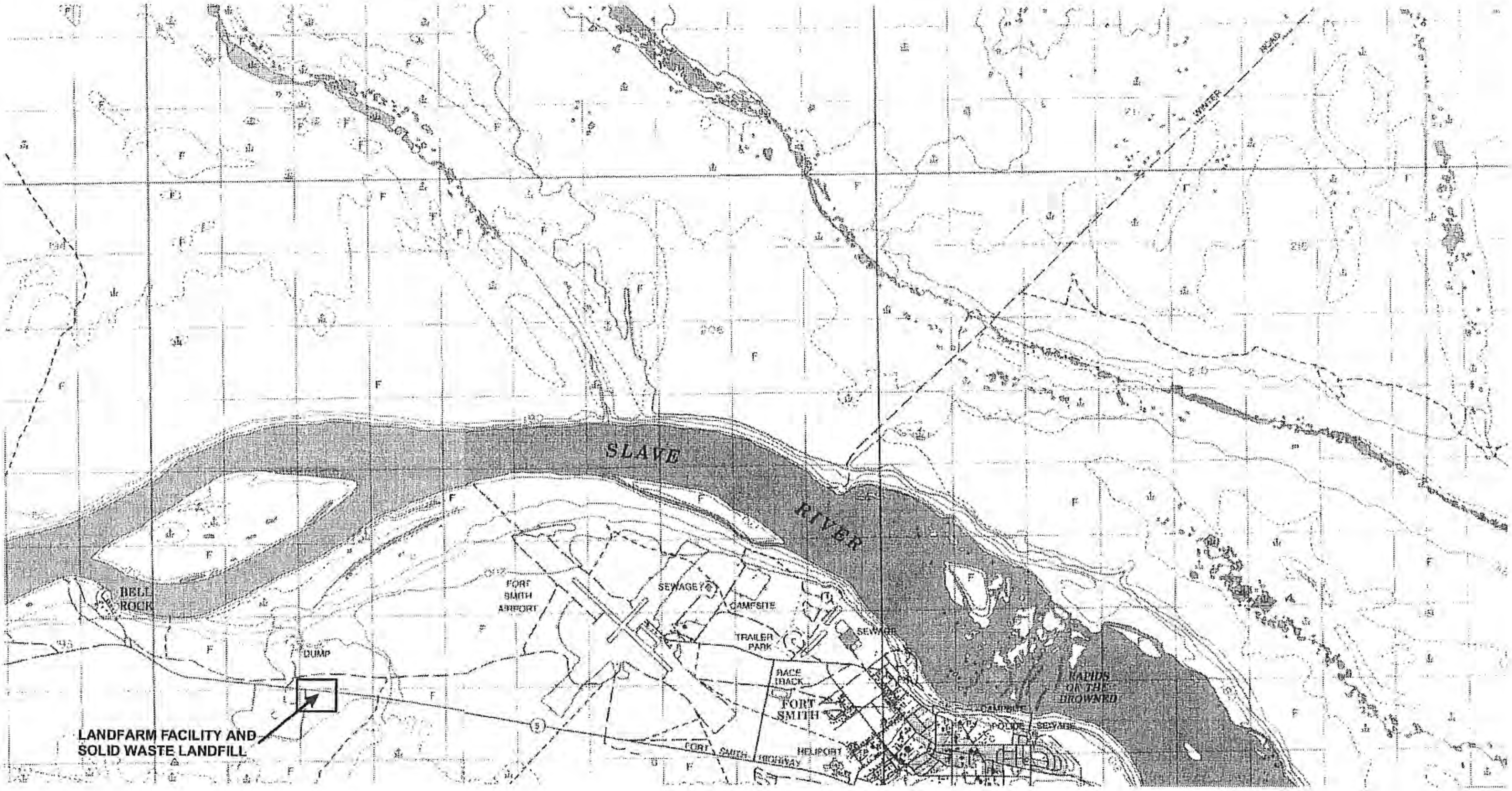
Patrick Kramers, B.Sc.
Environmental Scientist
Direct (867) 766-3728 x. 105
pkramers@eba.ca

Reviewed by:

Nov 30/2006

David Das, Ph.D, P.Eng
Project Director, NWT/Nunavut
Direct (867) 766-3728 x. 121
ddas@eba.ca

Figure 1 – Site Location Plan
Figure 2 – Landfarm Cell Dimensions and Soil Stockpile Locations, August 2006
Terms and Conditions



0 4,000

APPROXIMATE SCALE (metres)

CLIENT

Department of Public Works and Services, Government of the NWT, Fort Smith, NWT

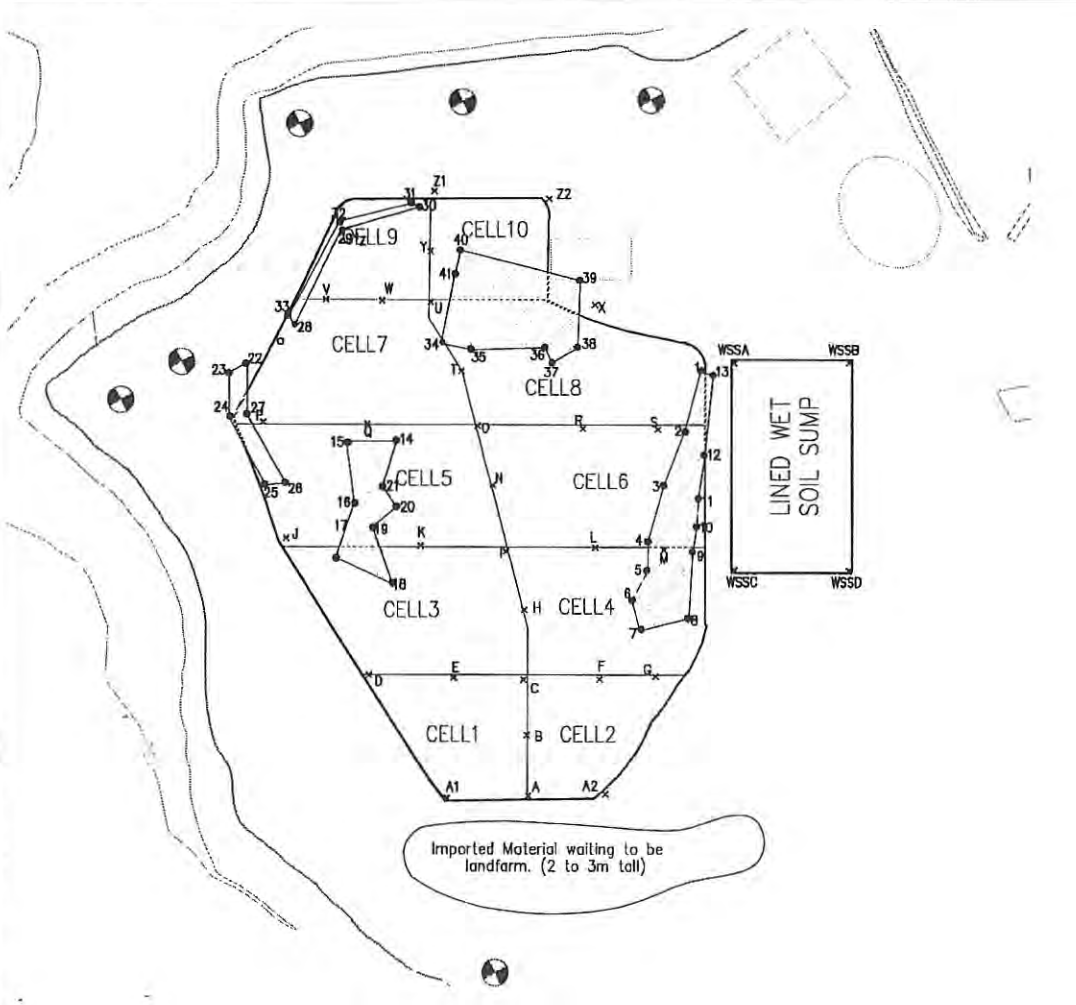
EBA Engineering Consultants Ltd.

Landfarm and Sump Recomendations
Fort Smith, NWT.

Site Plan Location

PROJECT NO./FILE NO.	DWN	CKD	REV
Y22100002 Y22100002701a.cdr	TK	PK	1
OFFICE	DATE		
EBA-EDM	November 30, 2006		

Figure 1



Soil Stockpile Dimensions and Locations at Landfill Landfarm					
Waypoint	Northing	Easting	Waypoint	Northing	Easting
1	6653735	441713	22	6653740	441547
2	6653705	441705	23	6653735	441538
3	6653678	441695	24	6653713	441538
4	6653650	441687	25	6653679	441556
5	6653635	441687	26	6653680	441566
6	6653621	441679	27	6653714	441547
7	6653606	441683	28	6653773	441573
8	6653612	441707	29	6653820	441596
9	6653644	441709	30	6653831	441635
10	6653657	441711	31	6653833	441631
11	6653672	441712	32	6653824	441595
12	6653693	441715	33	6653777	441570
13	6653732	441719	34	6653767	441617
14	6653717	441605	35	6653764	441631
15	6653710	441580	36	6653765	441665
16	6653679	441584	37	6653758	441668
17	6653652	441575	38	6653765	441680
18	6653639	441603	39	6653796	441681
19	6653667	441593	40	6653810	441626
20	6653677	441605	41	6653797	441623
21	6653687	441598			

Landfarm Cell Dimensions					
Waypoint	Northing	Easting	Waypoint	Northing	Easting
A	6653610	441639	N	6653696	441632
A1	6653634	441600	O	6653709	441629
A2	6653602	441675	P	6653727	441554
B	6653629	441644	Q	6653716	441610
C	6653464	441650	R	6653698	441665
D	6653668	441589	S	6653693	441698
E	6653650	441630	T	6653740	441624
F	6653639	441672	U	6653773	441612
G	6653630	441694	V	6653786	441574
H	6653664	441648	W	6653775	441595
I	6653681	441641	X	6653766	441687
J	6653703	441550	Y	6653813	441632
K	6653686	441611	Z	6653821	441594
L	6653670	441657	Z1	6653839	441645
M	6653661	441689	Z2	6653844	441699

Wet Soil Sump Dimensions		
Waypoint	Northing	Easting
WSSA	6653714	441740
WSSB	6653706	441766
WSSC	6653617	441716
WSSD	6653609	441745

LEGEND:

- X - LANDFARM CELL DIMENSIONS
- ● - SOIL STOCKPILE DIMENSIONS AND LOCATIONS
- ⊗ - MONITORING WELL LOCATIONS

0 50
Scale: (metres)

CLIENT

Department of Public Works & Services,
Government of The NWT,
Fort Smith, NWT

EBA Engineering Consultants Ltd.

Landfarm and Sump Recommendations
Fort Smith, NWT.

Landfarm Cell Dimensions and Soil Stockpile Locations
August, 2006

PROJECT NO./FILE NO.	DWN	CKD	REV
Y22100002 Y22100002T01a.dwg	TK	PK	1
OFFICE EBA-EDM	DATE November 30, 2006		

FIGURE 2

ENVIRONMENTAL REPORT – GENERAL CONDITIONS

This report incorporates and is subject to these "General Conditions".

1.0 USE OF REPORT

This report pertains to a specific site, a specific development, and a specific scope of work. It is not applicable to any other sites, nor should it be relied upon for types of development other than those to which it refers. Any variation from the site or proposed development would necessitate a supplementary investigation and assessment.

This report and the assessments and recommendations contained in it are intended for the sole use of EBA's client. EBA does not accept any responsibility for the accuracy of any of the data, the analysis or the recommendations contained or referenced in the report when the report is used or relied upon by any party other than EBA's client unless otherwise authorized in writing by EBA. Any unauthorized use of the report is at the sole risk of the user.

This report is subject to copyright and shall not be reproduced either wholly or in part without the prior, written permission of EBA. Additional copies of the report, if required, may be obtained upon request.

2.0 LIMITATIONS OF REPORT

This report is based solely on the conditions which existed on site at the time of EBA's investigation. The client, and any other parties using this report with the express written consent of the client and EBA, acknowledge that conditions affecting the environmental assessment of the site can vary with time and that the conclusions and recommendations set out in this report are time sensitive.

The client, and any other party using this report with the express written consent of the client and EBA, also acknowledge that the conclusions and recommendations set out in this report are based on limited observations and testing on the subject site and that conditions may vary across the site which, in turn, could affect the conclusions and recommendations made.

The client acknowledges that EBA is neither qualified to, nor is it making, any recommendations with respect to the purchase, sale, investment or development of the property, the decisions on which are the sole responsibility of the client.

2.1 INFORMATION PROVIDED TO EBA BY OTHERS

During the performance of the work and the preparation of this report, EBA may have relied on information provided by persons other than the client. While EBA endeavours to verify the accuracy of such information when instructed to do so by the client, EBA accepts no responsibility for the accuracy or the reliability of such information which may affect the report.

3.0 LIMITATION OF LIABILITY

The client recognizes that property containing contaminants and hazardous wastes creates a high risk of claims brought by third parties arising out of the presence of those materials. In consideration of these risks, and in consideration of EBA providing the services requested, the client agrees that EBA's liability to the client, with respect to any issues relating to contaminants or other hazardous wastes located on the subject site shall be limited as follows:

1. With respect to any claims brought against EBA by the client arising out of the provision or failure to provide services hereunder shall be limited to the amount of fees paid by the client to EBA under this Agreement, whether the action is based on breach of contract or tort;
2. With respect to claims brought by third parties arising out of the presence of contaminants or hazardous wastes on the subject site, the client agrees to indemnify, defend and hold harmless EBA from and against any and all claim or claims, action or actions, demands, damages, penalties, fines, losses, costs and expenses of every nature and kind whatsoever, including solicitor-client costs, arising or alleged to arise either in whole or part out of services provided by EBA, whether the claim be brought against EBA for breach of contract or tort.

4.0 JOB SITE SAFETY

EBA is only responsible for the activities of its employees on the job site and is not responsible for the supervision of any other persons whatsoever. The presence of EBA personnel on site shall not be construed in any way to relieve the client or any other persons on site from their responsibility for job site safety.

5.0 DISCLOSURE OF INFORMATION BY CLIENT

The client agrees to fully cooperate with EBA with respect to the provision of all available information on the past, present, and proposed conditions on the site, including historical information respecting the use of the site. The client acknowledges that in order for EBA to properly provide the service, EBA is relying upon the full disclosure and accuracy of any such information.

6.0 STANDARD OF CARE

Services performed by EBA for this report have been conducted in a manner consistent with the level of skill ordinarily exercised by members of the profession currently practicing under similar conditions in the jurisdiction in which the services are provided. Engineering judgement has been applied in developing the conclusions and/or recommendations provided in this report. No warranty or guarantee, express or implied, is made concerning the test results, comments, recommendations, or any other portion of this report.

7.0 EMERGENCY PROCEDURES

The client undertakes to inform EBA of all hazardous conditions, or possible hazardous conditions which are known to it. The client recognizes that the activities of EBA may uncover previously unknown hazardous materials or conditions and that such discovery may result in the necessity to undertake emergency procedures to protect EBA employees, other persons and the environment. These procedures may involve additional costs outside of any budgets previously agreed upon. The client agrees to pay EBA for any expenses incurred as a result of such discoveries and to compensate EBA through payment of additional fees and expenses for time spent by EBA to deal with the consequences of such discoveries.

8.0 NOTIFICATION OF AUTHORITIES

The client acknowledges that in certain instances the discovery of hazardous substances or conditions and materials may require that regulatory agencies and other persons be informed and the client agrees that notification to such bodies or persons as required may be done by EBA in its reasonably exercised discretion.

9.0 OWNERSHIP OF INSTRUMENTS OF SERVICE

The client acknowledges that all reports, plans, and data generated by EBA during the performance of the work and other documents prepared by EBA are considered its professional work product and shall remain the copyright property of EBA.

10.0 ALTERNATE REPORT FORMAT

Where EBA submits both electronic file and hard copy versions of reports, drawings and other project-related documents and deliverables (collectively termed EBA's instruments of professional service), the Client agrees that only the signed and sealed hard copy versions shall be considered final and legally binding. The hard copy versions submitted by EBA shall be the original documents for record and working purposes, and, in the event of a dispute or discrepancies, the hard copy versions shall govern over the electronic versions. Furthermore, the Client agrees and waives all future right of dispute that the original hard copy signed version archived by EBA shall be deemed to be the overall original for the Project.

The Client agrees that both electronic file and hard copy versions of EBA's instruments of professional service shall not, under any circumstances, no matter who owns or uses them, be altered by any party except EBA. The Client warrants that EBA's instruments of professional service will be used only and exactly as submitted by EBA.

The Client recognizes and agrees that electronic files submitted by EBA have been prepared and submitted using specific software and hardware systems. EBA makes no representation about the compatibility of these files with the Client's current or future software and hardware systems.

TOWN OF FORT SMITH
Post Office Box 147, Northwest Territories, X0E 0P0

PERSEVERANCE

Dec 4, 2009

MacKenzie Valley Land and Water Board
7th Floor - 4910 50th Ave PO Box 2130
Yellowknife, NT X1A 2P6

Mackenzie Valley Land & Water Board
File ____________
JAN 0 4 2010
Application # MV2009L8-0024
Copied To LC / Reg

Attn: Jason Ash

Dear Mr. Ash

Thank you for your letter of Sept. 17 regarding the landfarm at the Fort Smith Municipal Landfill.

I will address your itemized requests for information as follows:

Item One - Details of volume and landfarm sizing

- **This landfarm was previously constructed in 2001 by the GNWT. Approx. 17,500 cubic meters of hydrocarbon impacted soil from the Arctic College Compound was transported to the landfarm and was then successfully treated in the following few seasons. This amount of impacted soil was unprecedented and is not expected to re-occur therefore the present facility is of more than ample size for anticipated volumes. Only local contaminated soils and aggregates would be accepted.**

Item Two - Leachate management

- **A soil berm encloses the existing facility which is located on a very large flat area. A geotextile membrane lined containment pond was also previously constructed. This**

area is tapered from ground level to a depth of approx. 2m and is complete with a vented sump collection area. No leachate has ever been observed in this pond area. Groundwater monitoring wells surround the facility and despite years of use all collected samples have shown less than detectable limits for BTEX or petroleum hydrocarbons in the F1 - F2 range.

Item Three - Operation plan

- **See attached from Waste Works(Reflects the Town of Fort Smith Operations Planning)**

Item Four - Spatial and temporal plan

- **See attached from Alberta Environment and Environment Canada(All relative areas will reflect in Town of Fort Smith operations)**

Item Five - EBA Engineering recommendations

- **2.1 The Town will excavate the soils in the sump and spread over an area of the landfarm as soon as possible in the spring of 2010. All soils would be remediated to industrial standards by accepted land farming methods. This farming would continue, as required, until the desired and required results have been achieved. Before any soil would be considered as remediated it would have to be tested and accepted by either ENR or an engineering firm's personnel. Either Municipal DPW equipment and personnel and/or contracting the same local contractor and his equipment, that the GNWT utilized, would be accessed in order to meet these standards.**

- **2.2 There are presently fourteen groundwater monitoring wells strategically placed both around and throughout the** landfill. Four of these wells are located so as to monitor the landfarm facility alone. Considering the previous volume of impacted soil and the monitoring results, The Town of Fort Smith strongly submits that the present network of monitoring wells is sufficient in design, construction and location to fully and effectively describe the groundwater quality and conditions beneath the facility.

I feel assured that this information plus the attachments will sufficiently address your concerns. Please do not hesitate to contact me. Thank you.

Yours truly,

Don Webb

Don Webb
Director of Public Works and Planning

cc: file, attachments

WASTEWORKS

HAY RIVER
PETROLEUM CONTAMINATED SOILS
TREATMENT FACILITY

OPERATIONS PLAN

November 2003

Prepared by WasteWorks Inc.
(800) 667-0444

Based on the Hazardous Waste Receiver Registration # NTR 000023 and October 21, 2003 Addendum from GNWT Environmental Protection Service.

Table of Contents

Introduction

The Hay River Treatment Facility (HRTF) is designed to remediate petroleum-contaminated soil (PCS). Contaminated soils are delivered to the facility and stored in the lined, run-off controlled treatment cell. Access to the HRTF is controlled, and hours of operation are 10:00 – 18:00 daily. Other hours of operation by appointment only.

The Hay River Treatment Facility is located within the Hay River Municipal Solid Waste (MSW) Disposal Facility. Access to the facility is through the yard of the MSW facility. The Town of Hay River and WasteWorks have a partnership in place to share the access, though the control and management of the HRTF are the exclusive purvey of WasteWorks Inc.

Characteristics of the facility

- One bermed storage and treatment cell. The treatment cell is constructed with 0.6 m clay liner. Storage and treatment cells are constructed completely above ground and graded to direct precipitation to the leachate control pond.
- The main leachate storage pond is designed with an HDPE liner underlain by low-conductivity native clay.
- Sub-soil berms surrounding the site divert clean water from running on to the facility.
- Treatment capacity of 25,000 metric tonnes (mt) at one time
- PCS for remediation shall be placed in windrows, piles or spread in thin lifts as conditions dictate.
- PCS shall be held in the treatment area until the PCS has been cleared for use as clean alternative cover for the Town of Hay River MSW landfill based on current CCME guidelines.
- Weigh scales at the NTCL and Town of Hay River works yards will be used for the detailed tracking of inventory processed.
- The HRTP is within the Hay River MSW Facility which is gated and locked outside of operating hours.

Construction of the treatment cell

- The liner is constructed of native low permeability compacted clay with a permeability not exceeding 1×10^{-7} cm/s.
- Compaction meets or exceeds 95% of the standard proctor maximum dry density of the material.
- Moisture content of the liner material is +/- 1% - 5% of optimal.
- The material selected for liner construction does not contain organic matter, frozen lumps, weeds, sod, roots, stumps or any other unsuitable liner material.
- The material selected for liner construction contains less than ten percent by volume of stone or rock fragments larger than 100 mm.

- The treatment pad dimensions are 50 m x 100m.

Employees and Responsibilities

Site manager

The site manager is responsible for the development and implementation of standard operating procedures on site. The site manager oversees the operations at the HRTF and co-ordinates communication with the GNWT Environmental Protection Service (EPS) and Department of Indian and Northern Affairs (DIAND) on issues pertaining to the operation and monitoring programs. The site manager designs the treatment program for specific remediation projects.

Site supervisor

The site supervisor is responsible for the day to day operations at the HRTF. These include implementing the treatment program in place for each waste project and ensuring the acceptance and screening program is executed according to WasteWorks standard operating procedures. The supervisor is also the first responder to any emergencies on site and will co-ordinate any action with emergency response teams.

Material handling procedure

Every project destined for treatment at the Hay River Treatment Facility (HRTF) is subject to the waste acceptance and screening program (see Waste Acceptance procedures).

Approved projects are delivered to the facility in bulk. Trucks are weighed at either 1) the GNWT highway scale at Enterprise (for out of town projects), 2) NTCL scale located at the NTCL cargo dock on Vale Island or 3) the Town of Hay River truck scales located at the Town Yard in Hay River. Tickets are issued for each load recording the gross, net and tare weights of the vehicles. The contaminated soil is delivered to Initial Receiving Area on the west side of the Treatment Cell. Debris or rocks are removed by handpicking, mechanized rock pickers or by screening, depending on the quality and quantity of waste.

Initial Receiving Area

All incoming waste will be initially dumped in the west side of the treatment cell and moved with a tracked dozer or excavator either into biopiles or spread in a 15 cm lift. If waste is accepted in an emergency situation, prior to the receipt of independent, third party analytical, the project is directed to the Initial Receiving Area. If necessary, confirmatory samples are taken to ensure the suitability of the soil for the facility.

Treatment Cell

All soil treatment takes place in the treatment cell. Depending on the type and quantity of waste, soil may be either placed in windrows, biopiles, or spread in thin lifts for maximum aeration. Treatment and processing takes place with heavy equipment available on site. This includes excavators, rubber tire loaders, power roto-tillers and crawler tractors.

Waste Tracking and Monitoring

Depending on the characteristics and level of contamination of the soil, a treatment schedule is estimated. The remediation process may be evaluated on site with PID monitors, in addition to sampling and analysis of the waste at independent, third party laboratories. Frequency of monitoring depends on the time of year, and the availability of cell space for more waste. Testing of the material may include:

- CCME total hydrocarbons (F1 to F4)
- Other parameters depending on the waste site history

Treatment results are kept on file at the WASTEWORKS Calgary Office, and at the facility shack at the HRTF.

Treatment Objectives

For release of the waste as alternative cover to the Town of Hay River Landfill, all contaminated soils must meet the NWT criteria for alternative cover for MSW landfills or the CCME criteria for Industrial sites. The final release analysis is reviewed by the HRTF Manager, and the Manager of Operations for WASTEWORKS. Copies of the release report are forwarded to the Town of Hay River Director of Public Works prior to release of the material.

Description of treatment process

Petroleum Contaminated Soils (PCS) eligible for treatment include a variety of soil matrices that are suitable for treatment through the enhancement of hydrocarbon breakdown. The breakdown of the contaminants is achieved through aeration activities including discing, turning the piles, processing with an ALLU excavator attachment. Treatment may also include the addition of suitable amendments to enhance the natural activity of indigenous hydrocarbon degrading micro organisms.

Waste Acceptance Procedures

The Hay River Treatment Facility is permitted to accept petroleum-contaminated soil suitable for bioremediation treatment.

Common sources of acceptable waste include:

- Service station decommission projects
- Truck spills and roll overs
- Aboveground and underground tank fuel storage tank leaks
- Other fuel or similar-type hydrocarbon contaminated soils

Prohibited wastes include:

- Biomedical wastes
- Explosive waste
- Radioactive waste
- Waste that is unsuitable for bioremediation
- Waste that does not meet the definition of soils

The industrial waste generator is responsible for providing the waste generating process information, independent analysis and supporting documentation required to make a reasonable assessment of the suitability of their waste for acceptance at the HRTF. At a minimum, the following information about each waste disposal project will be collected prior to approval and acceptance of the waste:

- Generator name / Location / Contact information;
- Waste type / Description / Process history / Quantities;
- Physical properties / Chemical characteristics;
- Laboratory reports / Material Safety Data Sheets / Process knowledge letters
- Generator certification

The Waste Approvals Group at WasteWorks reviews the information supplied by the generator and approves or rejects the waste. Each approved project is issued an approval code unique to a particular waste stream, location, and generator. Each load of approved waste delivered to the landfill must be accompanied by a 'Waste Docket'. This multiple copy form identifies the unique waste approval code, the generator, the transporter, and the intended disposal facility. These waste dockets will be distributed throughout the disposal event to these same identified parties, and will serve to provide waste chain of custody documentation and waste disposal certification.

Waste screening at the facility

Employees are trained to look for evidence of potentially unacceptable wastes. Such evidence includes the following:

- Wastes with strong and unusual odours
- Sludges
- Any load with unusual or unfamiliar paperwork

If a waste is delivered that is of concern at the facility, or is considered suspicious, the following procedure will be implemented:

- A waste discrepancy report will be completed. This report contains information with respect to the nature of the waste, where it came from and the generator's name and telephone number.
- The load will be directed a quarantine area located in the treatment cell.
- The facility supervisor will be notified immediately, and the customer may be contacted to obtain further information or clarification of the nature of the waste.
- Confirmatory samples will be taken.

If, after confirmatory samples, the waste is deemed unacceptable for treatment the generator will be immediately advised. An alternate action plan will then be developed, taking into account the specifics of the waste. Alternative disposal plans will include shipment to a Class II landfill in Alberta or the Swan Hills Hazardous Waste Treatment Facility in Alberta.

Surface Water and Leachate Management

Surface water at the HRTF can be categorized in two ways;

1. Non-Impacted Water ("clean")
This water is the result of precipitation falling on non-impacted areas of the disposal site. These areas would include roads, clean soil stockpiles, and unused areas among others. This water is considered clean water, and will not have come into contact with any of the waste stockpiled on the pad.

2. Impacted Water ("leachate")
This water is the result of precipitation falling on or draining near impacted soil. This water may or may not be impacted by the waste material it contacts.

Clean surface water

All clean surface water is diverted from the HRTF by one (1) metre sub-soil berms surrounding the facility.

Impacted water

The site is designed and managed in such a way as to prevent the loss or discharge of impacted water into the surrounding environment. The generation of impacted water is minimized by prohibiting the disposal of bulk liquids and by managing the surface water.

The following activities may be used to manage the impacted water:

- Impacted water is re-applied to impacted soil using a sprinkler system. This will allow for re-absorption of the water into the soil. This process enhances the treatment process, and helps to control any dust from contaminated soil piles.
- Excess impacted water may be treated with an on-site water treatment plant that is installed within the treatment pad.
- Impacted water is sent for disposal at an approved facility off site.
- If the quality is sufficient, impacted water is used for dust control on the treatment pad.

Modifications to the management plan may be warranted from time to time as site conditions change, new technologies are developed or regulations change.

All discharged water will meet CCME criteria for background water quality.

Closure plan

Final closure of the soil treatment facility will involve the decommissioning of the clay lined bioremediation cell, the lined impacted water run-off pond, and the removal of fencing and security installations associated with the site.

Final closure and decommissioning of the landfill will begin with the release of any soil remaining in treatment for use as alternate daily cover in the adjacent MSW landfill. In the event that closure of the facility is required before all contaminated soil has completed the treatment program, the waste will be transported to a suitable facility for further treatment or secure disposal.

Following release or removal of all soil from the treatment facility, the clay liner of the bioremediation cell will be excavated and stockpiled. The clay will be ultimately used as a low permeability final capping layer for landfill cells. Long term monitoring of the landfill area will continue during the active life of the adjacent landfill disposal facility and following the final closure of the landfill. As the soil treatment facility is not the end disposal site for any waste, there are no long term effects expected following decommissioning of the facility.

Safety and Emergency Response Plans

The operations at the HRTF involve the use of heavy equipment to process the waste stored for remediation on the pads, and of heavy truck traffic. The wastes handled on site consist of soils with varying levels of hydrocarbon contamination. The only liquids handled include the clean and impacted runoff water storage ponds.

The HRTF is operated in conjunction with the WASTEWORKS Occupational Health and Safety Program. All personnel on site are required to wear basic personal protective equipment: hard hat, high visibility vest or striping, safety footwear. Other PPE requirements are specific to the tasks undertaken by the employees on site.

Refer to the HAZCO Occupational Health and Safety Manual

Emergency Contact Information for Hay River Treatment Facility

Police	(867) 874-6555
Fire	(867) 874-2222
Ambulance	(867) 874-9333
WASTEWORKS 24 hour Emergency	1-800-667-0444

Fire Prevention and Control

The purpose of this plan is to provide information to landfill employees in the event that a fire occurs at or near the landfill. Specifically, the plan establishes who is responsible for various aspects of the fire control procedure.

General Guidelines

DO NOT PANIC, the greatest danger lies not in fighting the fire, but in the panic that arises from a fire. Spend a few minutes getting a grip of the situation. Go through the steps of notifying the appropriate authorities and follow the basic steps in the fire control plan.

- Notify any other nearby employees.
- Notify the Site Manager immediately. Follow his instructions.
- Notify the Fire Department. Tell them the location and type of fire and whether it looks like it will spread out of the immediate area.
- Notify surrounding property owners, particularly if it appears that the fire could spread beyond the facility.
- When the Fire Department arrives, follow their instructions.
- Do not fight a fire alone.
- Do not place yourself or others in danger while fighting the fire.

Electrical Storms

During any electrical storm, office personnel and scale checkers should stay indoors. While indoors, keep away from doors, windows, radiators, stoves, metal pipes, sinks or other metallic objects. Disconnect electrical appliances such as computers and radios. Do not handle any electrical equipment or the telephone.

Outside workers should relocate to an indoor location, staying away from any metal objects such as fences, metal pipes, or rails that may conduct electricity. Heavy equipment operators should get off and away from their equipment and move indoors. If not possible, stay inside the cab and move to an area of lower elevation.

If you are in a vehicle, stay there, as it will provide protection from lightning. Pull away from any trees or other objects that have the potential to fall on the vehicle.

Extreme Winds or Tornadoes

During high windstorms (potentially occurring between May and September) take shelter immediately. If heavy equipment operators cannot evacuate, move to lower elevations. Workers can take shelter underneath the weigh scale, or underneath the compactor. Do not stay in the scale trailer or the workshop in the case of a tornado. As a last resort, lie flat on the ground in a ditch, excavation or culvert.

Spill Response Plan

For the purposes of this plan, a spill is the accidental or purposeful discharge of a liquid waste (listed herein) or contaminated soil in a location or manner that will allow it being washed, carried, or flow into a natural or man-made watercourse that could potentially result in groundwater or surface water contamination now or in the future.

Most potential spill sources will only be present during normal facility working hours. As a result, adequate personnel and equipment is available to respond to any spill-related emergency. With equipment at the facility, it is possible to respond immediately to the site of any spill for necessary spill containment and cleanup. The immediate requirement will be to construct temporary earth berms around the spill area to contain any free liquids. The on site crew will then initiate other necessary control and cleanup measures as directed by the Site Manager and the Hazardous Material Response Team (if applicable).

The Spill Response Plan addresses spills of:

- Fuels and oils from landfill equipment
- Soils contaminated with any of the above
- Liquids from the storage ponds

ALBERTA ENVIRONMENT

ENVIRONMENTAL PROTECTION AND ENHANCEMENT ACT

CODE OF PRACTICE FOR THE LAND TREATMENT AND DISPOSAL OF SOIL CONTAINING HYDROCARBONS

Published in ... 2001

Monitoring Requirements

9(1) A person responsible for Class I land treatment of SCH must install and operate a groundwater monitoring system and conduct a soils sampling program in accordance with subsections 9(2) through 9(7).

(2) At a minimum, the groundwater monitoring system must include:
- (a) one groundwater monitoring well immediately upgradient of the land cells; and
- (b) two groundwater monitoring wells downgradient of the land cells, one of which is located immediately adjacent to the land treatment area.

(3) Groundwater monitoring wells referred to in subsection 9(2) must be:
- (a) designed to meet the requirements in Appendix Two of the *Guidelines for Land Treatment of Industrial Wastes* published by Alberta Environment;
- (b) protected from damage; and
- (c) locked except when being sampled.

(4) Any groundwater monitoring well referred to in subsection 9(2) that is no longer able to produce representative groundwater samples must be repaired or replaced before the next scheduled sampling date.

(5) From each groundwater monitoring well referred to in subsection 9(2), representative water samples must be collected and analyzed in accordance with Table 3.

Table 3 - Ground Water Monitoring

Sample Type and Number	Frequency	Parameter
One representative sample from each groundwater monitoring well	Before commencement of operations and at closure	• PH • major ions (Ca^{2+}, Mg^{2+}, NH_4^+, Na^+, K^+, Cl^-, NO_3^-, and SO_4^{2-}) • metal scan • electrical conductivity • total dissolved solids • benzene, toluene, ethylbenzene, and xylene • total petroleum hydrocarbons (purgeables and extractables or F1+F2+F3+F4 CCME fractions), and • water levels
	Annually and at closure	• pH, • benzene, toluene, ethylbenzene, and xylene • total petroleum hydrocarbons (purgeables and extractables or F1+F2+F3+F4 CCME fractions), • methyl *tert*-butyl ether, and • water levels

(6) A person responsible for Class I land treatment of SCH must collect and analyze representative soil samples in accordance with Table 4.

Table 4 - Soil Monitoring

Sample Type and Number	Frequency	Parameter
Five samples per hectare upon which SCH will or has been applied. This includes • four random core samples, and • one composite sample resulting from the combination of at least 20 samples of the surface soil The samples are to be taken from • the uppermost 15 centimeters of soil, or • the depth of incorporation and impact of SCH whichever is deeper.	Before commence-ment of operations and at closure	• pH • major ions (Ca^{2+}, Mg^{2+}, NH_4^+, Na^+, K^+, Cl^-, NO_3^-, and SO_4^{2-}) • metal scan • electrical conductivity • benzene, toluene, ethylbenzene, and xylene, and • total petroleum hydrocarbons (purgeables and extractables or F1+F2+F3+F4 CCME fractions)
	Annually and at closure	• pH, • benzene, toluene, ethylbenzene, and xylene • total petroleum hydrocarbons (purgeables and extractables or F1+F2+F3+F4 CCME fractions), and • methyl *tert*-butyl ether, and

Analytical Methods

10(1) Collection and analyses of samples required by this Code of Practice must be in accordance with the following:

(a) for waters samples:

(i) the *Standard Methods for Examination of Water and Wastewater*, 19th edition, as amended, published by the American Public Health Association, American Water Works Association, and Water Environment Federation;

(ii) the *Methods Manual for Chemical Analysis of Water and Waste* (1996) published by Alberta Environment, as amended;

(iii) any other equivalent method accepted in writing by the Director.

(b) for soil and SCH samples:

(i) the most recent edition of the *Reference Method for the Canada Wide Standard for Petroleum Hydrocarbon in Soil – Tier I Method*;

(ii) the most recent edition *of Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*, SW-846, U.S. EPA;

(iii) the most recent edition of *Manual on Soil Sampling and Methods of Analyses*, published by the Canadian Society of Soil Science; or

(iv) any other equivalent method specified in writing by the Director.

ENVIRONMENT CANADA
CONSERVATION AND PROTECTION

TECHNICAL GUIDANCE ON THE LAND TREATMENT OF PETROLEUM HYDROCARBON CONTAMINATED SOILS AT FEDERAL GOVERNMENT FACILITIES OR ON FEDERAL CROWN LAND

I. BACKGROUND

Based on both frequency of occurrence and associated volumes of contaminated material, sites contaminated with petroleum products represent the single largest problem which federal government departments face in dealing with contaminated sites located at facilities which they operate or on federal crown land for which they have custodial responsibilities.

Given that petroleum products can be fairly readily degraded biologically, land treatment of excavated petroleum contaminated soil has and continues to be a popular clean-up technology.

While the effectiveness of land treatment technologies in dealing with petroleum contaminated soils has been demonstrated, when improperly designed or operated, such practices have contributed to the creation of new problems at sites that were previously uncontaminated.

For these reasons, the Office of Waste Management has prepared this document, under the auspices of the National Contaminated Sites Remediation Program, to provide general guidance to federal government departments on the application of land treatment technologies to clean up petroleum hydrocarbon contaminated soil.

It should be noted that these guidelines are not intended to serve as a comprehensive set of design and operational specifications, which to a large extent are dependent on such factors as the nature and quantity of soils, the level of contamination, land use, accessibility and climatic conditions, etc. Further, while the aim of these guidelines is to minimize potential environmental impacts associated with establishing and operating land treatment facilities as defined herein, conformance with these guidelines does not in itself constitute compliance with relevant statutes and regulations which deal with the protection of human health and the environment.

It should lastly be noted that a number of other in-situ and ex-situ treatment/destruction technologies exist that have been shown to be effective in dealing with petroleum hydrocarbon contaminated soil. These guidelines should in no way be viewed as indicating a preference toward land treatment over these other technologies.

II GENERAL

1. For the purpose of these guidelines the following definitions apply:

   a) "land treatment" means the land-based treatment of excavated petroleum hydrocarbon contaminated soil through volatilization and/or bioremediation and shall include such technologies commonly referred to as landfarming, soil piles, soil venting/extraction and soil composting and any combination thereof;

   b) "land treatment facility" means any site located at a federal government facility or on federal crown land in Canada at which land treatment is carried out;

   c) "petroleum hydrocarbon contaminated soil" means any naturally occurring earth material that has been contaminated by petroleum products and "contaminated soil" shall have the same meaning, and;

   d) "period of active land treatment" means those times of the year during which the mean daily temperature of the contaminated soil is at 5° Celsius or above.

2. Unless in house capability exists, it is strongly recommended that the services of a qualified environmental consultant be engaged to oversee the establishment, operation and decommissioning of a land treatment facility.

III SITING

1. When siting a land treatment facility, it is recommended that the following locations be avoided:

   a) land having a slope greater than 6%;

   b) land which is less than 3 meters above the seasonal high water table of an aquifer which serves as a source of potable water;

   c) within 100 meters of a surface water body;

   d) land identified as being within a 50 year floodplain; or

   e) within 60 meters of residential property lines or buildings.

IV DESIGN AND OPERATING REQUIREMENTS

1. Prior to the establishment of a land treatment facility a detailed set of design plans and specifications should be prepared which, unless site specific conditions indicate otherwise, incorporate the following requirements:

    a) a natural or engineered soil berm and impermeable liner system to restrict leachate migration;

    b) a means of collecting and holding contaminated run-off water and leachate;

    c) a means of controlling dust from and precipitation infiltration into the land treatment facility;

    d) no less than two monitoring wells located down gradient of the site to monitor possible impact on groundwater quality;

    e) a means to capture and treat fugitive volatile organic compounds (VOC) in air emissions from the land treatment facility when it is situated in an area designated as a "high tropospheric ozone region" by the relevant provincial/territorial jurisdiction.

2. Access to the site should be restricted through fencing or other suitable means and signs warning of the potential hazard adequately posted around the site.

3. Prior to the placement of excavated contaminated soil in the land treatment facility:

    a) the contaminated soil in question should be characterized with respect to quantity and level of contamination and a treatability study carried out to determine the feasibility of remediating the contaminated soil to an acceptable level that meets appropriate criteria as set forth in CCME's Interim Environmental Quality Criteria for Contaminated Sites;

    b) a detailed set of operational procedures should be prepared which identifies:

        - the recommended frequency and method of soil tillage; and

        - the type and application rate of any land treatment amendments i.e. water, air, lime, nutrients, or inoculum which may be required; and

    c) a health and safety plan should be developed which addresses both site workers and, where applicable, nearby inhabitants.

4. When characterizing petroleum hydrocarbon contaminated soil, the number of composite samples required should be based on the schedule provided in Table 1:

TABLE 1 - SAMPLING SCHEDULE

Volume of Soil (cubic metres)	Number of Composite Samples*
1 - 50	1
51 - 500	2
500 - 1000	3
1000 - 2000	4
2000 - 5000	5
each additional 2000	1 additional

* where a composite sample should consists of no less than 3 representative grab samples.

5. When characterizing petroleum hydrocarbon contaminated soil, the analysis should be based on the nature of petroleum contamination as shown in Table 2:

TABLE 2 - ANALYSIS SCHEDULE

Petroleum Product	*Analysis
*Unleaded gasoline	*A, B,
*Regular Gasoline, Aviation Gasoline	*A, B, C
*Fuel Oil, Diesel Fuel, Kerosene, Jet Fuel, Mineral Oil/Spirits, Motor Oil	*A, B, G
*Petroleum Solvents	*A, B, F
Crude Oils, Hydraulic Fluids	*B, G
*Waste Petroleum Products	*A, B, C, D, E, F, G

*Where A - Benzene, Ethylbenzene, Toluene, Xylene (BTEX)
B - Total Petroleum Hydrocarbons (TPH)
C - Lead
D - Chromium, Cadmium
E - Polychlorinated Biphenyls (PCB's)
F - Phenols
G - Polycyclic Aromatic Hydrocarbons (PAHs)

V MONITORING AND RECORD KEEPING REQUIREMENTS

1. For the purpose of monitoring the performance of the land treatment process, soil samples should be taken no less frequently than once every four months, during the period of active land treatment, until analytical results are below acceptable levels as set forth in the CCME's Interim Environmental Criteria for Contaminated Sites.

2. For the purpose of monitoring for potential impact of the facility on groundwater quality, groundwater samples should be taken from the down gradient monitoring wells no less frequently than twice per year and analyzed for indicators of petroleum hydrocarbon contamination. Should analytical results indicate groundwater contamination associated with the land treatment facility, corrective action should be taken as soon as possible.

3. Accurate records should be maintained by the Department having responsibility for the land treatment facility which contain the following information:

   a) a detailed description of the size and location of the land treatment facility;

   b) quantitative and qualitative data on the soil treated at the site;

   c) monitoring data as set forth above; and

   d) the final destination of the treated soil and its intended use.

VI DECOMMISSIONING

1. Prior to the decommissioning of a land treatment facility, a plan should be prepared which:

   a) outlines removal procedures for any remaining soil and all other works at the site i.e. liners, drainlines, etc.;

   b) identifies the nature and level of any residual contamination that will remain on the site; and

   c) identifies the intended use of the site once the land treatment facility has been decommissioned.

2. The land treatment facility should be decommissioned in accordance with the above noted plan and associated records retained by the responsible Department.

Questions or comments on these guidelines should be directed to:

Mr. Tom Foote
Senior Program Engineer
National Contaminated Site Remediation Program
Office of Waste Management
Environment Canada
Ottawa, Ontario
K1A 0H3

Tel: (819) 953-1117
Fax: (819) 953-0509

or your nearest Environment Canada Regional Office:

Dr. Colin Duerden
EP- Atlantic Region
Fifth Floor, Queen Square
45 Alderny Drive
Halifax, NS
B2Y 2N6

Tel: (902) 426-9044
Fax: (902) 426-3897

Mr. Andre Pelletier
EP - Quebec Region
1179 de Bleury Street
Montreal, Quebec
H3B 3H9

Tel: (514) 283-4684
Fax: (514) 283-4423

Mr. Dale Cameron
EP - Ontario Region
49 Camelot Drive
Ottawa, Ontario
K1A 0H3

Tel: (613) 952-8674
Fax: (613) 952-8995

Roy Nixon
EP Western and Northern Region
Twin Attria # 2, 2nd Floor
4999 - 98th Avenue
Edmonton, AB
T6B 2X3

Tel: (403) 468-8032
Fax: (403) 495-2615

Mr. Richard Glue
EP - Pacific and Yukon Region
224 West Esplanade
Vancouver, BC
V7M 3H7

Tel: (604) 666-5566
Fax: (604) 666-7294

Rhonda Miller - MVLWB

From:	Rebecca Chouinard [rchouinard@mvlwb.com]
Sent:	July-06-11 5:04 PM
To:	permits@mvlwb.com; 'Lynn Boettger - MVLWB'; 'Kathy Racher'; 'Zabey Nevitt - MVLWB'; jdonihee@mross.com
Subject:	FW: ENR intervention response - Water License application #MV2011L3-001
Attachments:	Chemical Characterization of Leachate from Northwest Territories Municipal Dumps - Hay River Municipal Dump.pdf; AB Code of Practice for Landfills.pdf; AB Standards for Landilffs.pdf; AB Waste Control Regulation.pdf; Chemical Characterization of Leachate from Northwest Territories Municipal Dumps - Coppermine Municipal Dump.pdf; MV2009L8-0024_Town_Fort_Smith_Response_to_IR_Dec04-09.pdf; ENR_FInal_Intervention_Fort_Smith AWL 2011.pdf; ENR_PWS_Ft Smith_Landfarm_2007_07_09_LRT.pdf; Ft Smith Landfarm_Application Deemed Incomplete.pdf; Ft Smith_Landfarm_OM_Nov_2004.pdf; Guidance Fed Interim GW guidelines ENG_2010 May.pdf; MV2009L8-0024_Application_for_Water_Licence_Sept_02-09.pdf

This just in…

Rebecca Chouinard
Regulatory Manager
Mackenzie Valley Land and Water Board
7th Floor, 4922 48th St, PO Box 2130 | Yellowknife, NT | X1A 2P6
ph 867.766.7459 | fax 867.873.6610|cell 867.446.0442
rchouinard@mvlwb.com | www.mvlwb.com

From: Terri Bugg [mailto:Terri_Bugg@gov.nt.ca]
Sent: Wednesday, July 06, 2011 4:59 PM
To: rchouinard@mvlwb.com
Subject: FW: ENR intervention response - Water License application #MV2011L3-001

Hi Rebecca,

Kathleen is out town so here is our submission as indicated below…

Thx..

From: Terri Bugg
Sent: Wednesday, July 06, 2011 4:57 PM
To: 'kgraham@mvlwb.com'
Cc: Todd Paget; Patrick Clancy
Subject: ENR intervention response - Water License application #MV2011L3-001

Hi Kathleen,

Please find attached ENR's written intervention response and additional supporting documents with respect to the above file. Let me know if you have any other questions.

Thanks!

____

Terri Bugg
Environmental Assessment Analyst
Land and Water Unit
Environment and Natural Resources
Government of the NWT
Box 1320
Yellowknife NWT X1A 2L9

867.920.6593 (p)
867.873.0221 (f)
terri_bugg@gov.nt.ca