Water

City of Iqaluit

West 40 Landfill Drainage Management Review

Prepared by:

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Project Number:

60221928

Date:

September 16, 2011

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September 16, 2011

Paul Clow
Project Officer
City of Iqaluit
Box 460
Iqaluit, NU XOA 0H0

Dear Mr Clow:

Project No: 601221928

Regarding: West 40 Landfill Drainage Management Review

Enclosed for your reference is a report which reviews the current landfill drainage management at the West 40 Landfill in Iqaluit, NU. The report reviews historical sample test results from landfill runoff retention and detention ponds on site and compares the results to appropriate regulatory guidelines. Options which have been examined by the City of Iqaluit for the future treatment of landfill runoff are presented and commented on. Recommendations are provided for the collection, treatment, and appropriate effluent quality criteria.

Should you have any questions or concerns please do not hesitate to call the undersigned at (780) 453 0910.

Sincerely,
AECOM Canada Ltd.

Ken Johnson, P.Eng
Senior Planner and Engineer
Ken.Johnson@aecom.com

XX:xx
Encl.
cc:

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Executive Summary

The City of Iqaluit's Water Licence states that the City is required to collect, monitor and control the discharge of runoff from the West 40 Landfill site and adjacent Sludge Management Facility. The City currently employs a surface water management system to divert off-site surface runoff from entering the site, and to collect on-site surface runoff for a controlled discharge into the environment. The landfill site relies on the local permafrost regime to provide a low permeability barrier to control the subsurface runoff.

In 2006 the City upgraded the landfill's drainage management system by constructing two berm structures, three on-site detention ponds and an off-site retention pond. The berm structures create a continuous ditch system for surface runoff collection and controlled movement on site. On-site runoff water drains into detention ponds around the site and then into a larger on-site retention pond where the water is stored until it is decanted as a controlled discharge into a marine environment. In 2010 the City of Iqaluit purchased a tube filtration system and has been filtering the retention pond water through this device prior to discharge.

The historical sampling results from the landfill runoff between 2004 and 2011 show that the water is consistently over the maximum allowable concentration limits for iron, manganese and zinc as listed in the Guidelines for the Discharge of Treated Municipal Wastewater in the Northwest Territories. There are no specific guidelines in place for landfill surface runoff water in Nunavut. In the absence of specific guidelines, the most appropriate benchmark for comparing sample results are the Guidelines for the Discharge of Treated Municipal Wastewater in the Northwest Territories, as well as limits established from other Nunavut Water Licences.

The City of Iqaluit has examined treatment options which could be applied to the landfill runoff, including wetland treatment, mechanical treatment (membrane bioreactor technology) and physical-chemical treatment with filtration. The City has completed a conceptual design for a constructed wetland that would treat the runoff by utilizing the natural processes of wetland vegetation, soils and soil microbial populations to degrade and store contaminants. The City has also completed a review of Membrane Bioreactor Technology which combines filtration and a suspended growth bioreactor to treat the runoff. Most recently the City advanced a turnkey proposal on physical-chemical treatment applying a Geotube® filtration system to remove precipitated solids.

The City initiated a filtration process in 2010 to determine the practicality and the potential treatment of the runoff by filtration alone. The 2010 sampling results of the filtered runoff suggest some contaminant removal, however the 2011 sampling results are inconclusive. The next phase of the trial process for the City will be applying chemical treatment in advance of the physical filtration process.

Table of Contents

List of Tables

Appendices

1. Introduction

The City of Iqaluit Water Licence No. 3AM-IQA0611 Type “A” (valid until July 15, 2012) requires that the City of Iqaluit collect, monitor and control discharge of the runoff from the West 40 Landfill site and adjacent Sludge Management Facility. Currently the City of Iqaluit sends approximately 30,000 cubic meters of compacted waste to the landfill annually (estimate provided by Landfill Foreman September 2011). In 2007 AECOM calculated that the volume of winter runoff water generated from the landfill would be approximately 7,700 m^3 and that the summer runoff would be 6,600 m^3. The West 40 Landfill currently employs a surface water management system to divert off-site surface runoff from entering the site, and to collect on-site surface runoff for a controlled discharge into the environment. The landfill site relies on the local permafrost regime to provide a low permeability barrier to control the subsurface runoff.

2. Current Site Conditions

2.1 Current Drainage Management Plan

In 2006 the City of Iqaluit upgraded the West 40 landfill to improve drainage management. The current landfill drainage management system on site is based on a system of berms, ditches, detention ponds and a retention pond. A figure showing the landfill operating conditions can be located in Appendix A.

A berm structure on site diverts off-site runoff around the site and divert on-site runoff into a ditch collection system. The perimeter berm structures provide the infrastructure for a continuous ditch system for surface runoff management. On-site runoff control ditches drain to several control ponds (refer to Appendix A for locations). In 2006 three new drainage control ponds were constructed on site, increasing the total number of control ponds to 4 with an approximate total volume of 3000 m^3. The control ponds provide a point where runoff may be sampled and transferred to the retention pond.

The runoff retention pond was constructed in 2006 and has approximately 5000 m^3 of storage volume. The retention pond provides storage before the runoff is decanted into the receiving water system. Upon notification of the regulatory authorities the water is currently either decanted from the retention pond directly or decanted after filtration. In 2010 the City of Iqaluit purchased a tube filtration system and has been filtering the retention pond water through this device before the water enters the receiving environment.

Appendix B contains a photo presentation of the current landfill drainage management system on site.

The City of Iqaluit is continuing to make capital improvements to the drainage management system associated with the West 40 landfill. Construction has been awarded for the expansion of the perimeter berm on the east side of the site to provide a larger berm structure, and an impermeable membrane on the interior face of the berm.

Associated with the capital improvements have been operational improvements the drainage management. The landfill operating staff has taken steps to minimize the generation of on-site runoff by initiating removal of clean snow from the landfill site. The removal of snow ultimately reduces the amount of on-site runoff.

2.2 Summary of Historical Landfill Water Sampling Data

Twelve water samples taken from the retention pond, detention ponds and landfill runoff between 2004 and 2011 were provided by the City of Iqaluit and reviewed by AECOM. Currently there are no specific guidelines for the discharge of landfill surface runoff in Nunavut so the sample results were compared to limits for discharge from a sewage lagoon from the City of Iqaluit Water Licence (2006) and the Guidelines for the Discharge of Treated Municipal Wastewater in the Northwest Territories (GDTMWNWT).

All twelve samples throughout the time period tested exceeded the limits for iron, manganese and zinc. Table 1 presents the maximum and minimum sample results for these three parameters compared to the guideline limit. The June 2006 sample results from the retention pond exceeded the limits for iron, manganese and zinc as well as for BOD_5, TSS, aluminum, copper and lead. All other samples analyzed were below the limits for BOD_5, TSS, aluminum, copper and lead.

Table 1. Comparison of GDTMWNWT Limit and Maximum and Minimum Sample Results

	GDTMWNWT Limit	Maximum Sample Result	Minimum Sample Result
Iron	0.3 mg/L	122 mg/L INAC Results July 30, 2009	2.3 mg/L Detention Pond May 9, 2006
Maganese	0.05 mg/L	1.61 mg/L Retention Pond #2 May 23 2011	0.61 mg/L Retention Pond Sample #1 May 3 2010
Zinc	0.5 mg/L	15.0 mg/L Control Pond 2007	0.5 mg/L INAC Results July 30, 2009

Full summary sample results are located in Appendix C.

3. Review and Recommendation of Discharge Criteria

3.1 Origin of Effluent Quality Criteria for Landfill Runoff

The current water license in place for the City of Iqaluit was issued on May 15, 2006 (License No. 3AM-IQA0611 Type “A”) and will expire in July 15, 2012. Within this license there is a condition (Part E, Item 17) which states that the City must submit a report “that will include a discussion of available treatment options, proposed discharge criteria, … and a monitoring program”. In response to this condition of the current license, the City retained Earth Tech as an Engineering Consultant in 2008 to meet the reporting requirements.

In June 2008 Earth Tech completed the report entitled City of Iqaluit – Water License Monitoring Program. The report identified parameters that should be tested for and also recommended the frequency of sampling of both the detention ponds and the retention pond associated with the landfill runoff management system. Table 2 lists the parameters from the report. The report was reviewed and supported by Environment Canada and Indian and Northern Affairs Canada. The report did not recommend any specific limits (maximum allowable concentrations) on the parameters to be monitored.

Table 2. Landfill Runoff Monitoring Parameters and Frequency as Recommended in 2008 Water Licence Monitoring Program Report

Parameter	Earth Tech's Recommendation on Sampling Frequency
Detention Ponds	
pH	Annually
Turbidity	Annually
Total suspended solids	Annually
BOD_5	Annually
COD	Annually
TOC	Annually
Retention Pond	
pH	Annually
Turbidity	Annually
Total suspended solids	Annually
BOD_5	Annually
COD	Annually
TOC	Annually
Ammonia nitrogen	Annually
TKN	Annually
Total phosphorous	Annually
Full Metal Scan + Hg	Annually
Total Coliform	Annually
Fecal Coliform	Annually
BTEX	Annually
PCBs	Annually

The full 2008 City of Iqaluit Water License Monitoring Program report is presented in Appendix D.

3.2 Sampling Criteria from Other Jurisdictions

The West 40 Landfill discharges into a marine environment, for this reason it is not appropriate to consult or compare sampling guidelines and criteria developed for surface water discharge situations with data from the West 40 Landfill runoff.

The Canadian Council of Ministers of the Environment (CCME) have guidelines for the discharge of water into marine environments for the protection of aquatic life. The criteria outlined in CCME's Water Quality Guidelines for The Protection of Aquatic Life lists guidelines for select metal parameters and petroleum hydrocarbon parameters. The CCME guidelines were developed in a national context for receiving environments across Canada.

The CCME Water Quality Guidelines for the Protection of Aquatic Life are located in Appendix E.

3.3 Applicable Sampling Parameters and Maximum Allowable Concentrations

It is most applicable to compare landfill runoff water sample results from the West 40 Landfill with the Guidelines for the Discharge of Treated Municipal Wastewater in the Northwest Territories (GDTMWNWT) (Season: Summer, 150-600Lcd, marine/bay receiving environment). The GDTMWNWT criteria are the current effluent quality guidelines referenced in the City of Iqaluit's Water Licence.

Another applicable reference is a water licence issued by the Nunavut Water Board to Defense Construction Canada for a DEW Line remediation project (licence number 1BR-DYE0914). This water licence lists guidelines that apply to discharge events associated with demolition rinse water, water from dewatering contaminated soil areas, contact water and potential seepage from a non-hazardous waste disposal facility and other monitoring stations at the site (Cape Dyer, Dye-M).

The City of Iqaluit's Water Licence issued in 2006 lists guidelines for water and waste disposal. The guidelines listed in this licence are for discharge of a municipal wastewater treatment lagoon and can be used as a reference when establishing appropriate guidelines for the discharge of landfill runoff.

Table 3 compares the parameters and maximum allowable concentrations from the three appropriate references discussed above.

Table 3. Appropriate Parameters and Maximum Allowable Concentrations for Comparison with West 40 Landfill Runoff Sampling Results

Parameter	Maximum Allowable Concentration	Source
pH	6 to 9	2009 Cape Dyer WL & 1992 GDTWNWT
Oil and Grease	5	2009 Cape Dyer WL
Arsenic (total)	0.1	2009 Cape Dyer WL
Cadmium (dissolved)	10	2009 Cape Dyer WL
Chromium (dissolved)	0.1	2009 Cape Dyer WL & 1992 GDTWNWT
Cobalt (dissolved)	0.5	1992 GDTWNWT
Copper (dissolved)	0.2	2009 Cape Dyer WL & 1992 GDTWNWT
Lead (dissolved)	0.05	2009 Cape Dyer WL & 1992 GDTWNWT
Mercury (total)	0.0006	2009 Cape Dyer WL & 1992 GDTWNWT
Nickel (dissolved)	0.3	1992 GDTWNWT
PCB (total)	1	2009 Cape Dyer WL
Zinc (total)	0.5	2009 Cape Dyer WL & 1992 GDTWNWT
Benzene	0.37	2009 Cape Dyer WL
Toluene	0.002	2009 Cape Dyer WL
Ethylbenzene	0.09	2009 Cape Dyer WL
BOD (5 Day)	120	1992 GDTWNWT & 2006 City of Iqaluit WL
TSS	180	2006 City of Iqaluit WL
Aluminum (total)	2	1992 GDTWNWT
Barium (total)	1	1992 GDTWNWT
Boron (dissolved)	5	1992 GDTWNWT
Cyanide (total)	0.1	1992 GDTWNWT
Fluoride (dissolved)	5	1992 GDTWNWT
Iron (dissolved)	0.3	1992 GDTWNWT
Maganese (dissolved)	0.05	1992 GDTWNWT

Methylene Blue Active Substances (MBAS)	5	1992 GDTWNWT
Molybdenum (total)	0.2	1992 GDTWNWT
Selenium (total)	0.05	1992 GDTWNWT
Silver (total)	0.1	1992 GDTWNWT
Suplhate (dissolved)	500	1992 GDTWNWT
Sulphide (dissolved)	0.5	1992 GDTWNWT
Tin (total)	5	1992 GDTWNWT

Note: 2009 Cape Dyer WL refers to the 2009 Cape Dyer DEW Line Remediation Water Licence
2006 City of Iqaluit WL refers to the City of Iqaluit 2006 Water Licence

4. Landfill Water Treatment Options

The City of Iqaluit has examined treatment options which may be applied to the landfill runoff water in the future. Currently none of the option listed below have been pursed further than the conceptual design and planning stage.

4.1 Constructed Wetland Treatment (Earth Tech Conceptual Design Report 2007)

4.1.1 Overview of Constructed Wetland Technology

In 2007 Earth Tech (now AECOM) was retained by the City of Iqaluit to develop a conceptual plan for a wetland treatment system for the West 40 Landfill. The full report is attached as Appendix F. It was determined that a constructed wetland system was most appropriate wetland configuration because of the runoff volumes and cold climate conditions. Constructed wetlands are engineered systems that are designed and constructed to utilize the natural functions of wetland vegetation, soils and soil microbial populations to treat contaminants in wastewater streams. As wastewater flows slowly through a wetland, pollutants are removed through physical, chemical and biological processes. The physical processes include entrapment, sedimentation and adsorption. The biological processes include nitrification and denitrification, the uptake of nutrients and metals by plants and by organisms that occupy the bedding media. Constructed wetlands are advantageous to natural wetland systems because they can be specifically engineered for particular wastewater characteristics, they have lower lifecycle costs, and they may be operated with less labor and power. It is important to note that wetland technology is still in a developing phase, and it is not possible to predict the ultimate performance of a wetland system.

4.1.2 Proposed Details of a Constructed Wetland Structure for the West 40 Landfill

The conceptual design report recommended that a subsurface horizontal flow wetland system be designed to treat the surface runoff from the landfill site. Subsurface flow wetlands involve passing the wastewater substrate through gravel or organic soil based systems. The large surface area of the media and plant roots provides space for microbial activity to degrade contamination. Media based wetland systems have high efficiencies at removing biodegradable organic matter and nitrate-nitrogen. Subsurface flow systems are below ground and work ideally in colder climates. Subsurface wetlands are preferred because they reduce odor and bug problems and reduce the potential for human contact with contaminated wastewater.

The proposed wetland treatment system would be located adjacent to the existing landfill site. The available and optimal location is the area east of the runoff retention pond which is sloped west to east. This land is currently under the control of another jurisdiction, therefore the City would have to negotiate for the use of this land for the wetland system. The wetland would be in operation from June to October. The proposed wetland would have a subsurface flow with permeable soil matrix growing medium. Landfill runoff would be introduced via a perforated head pipe to a gravel flow dispersion trench.

The wetland system would be developed in two phases. Phase 1 would have 7,700 m^3 treatment capacity to meet the 2007 current discharge quality requirements. Phase 2 would have a 6,600 m^3 treatment capacity for the future process improvements. The cost estimated to implement a constructed wetland at the site in 2007 for Phase 1 was $273,770 and for Phase 2 was $268,437.

4.2 Membrane Bioreactor Technology (2007 Earth Tech Letter Report)

4.2.1 Overview of Membrane Bioreactor Technology

Membrane bioreactors (MBRs) combine the membrane filtration process with a suspended growth bioreactor to degrade contaminants. The 2007 Earth Tech (now AECOM) report on Membrane Bioreactor Technology prepared for the City of Iqaluit outlines a mechanical treatment option for the treatment of runoff from the West 40 Landfill. An immersed MBR was recommended as the most appropriate MBR technology because of the lower energy demand when compared to side stream MBR configurations. To treat the West 40 Landfill runoff an anoxic and aerobic tank would be required in front of the MBR for nitrogen removal. The MBR system would be able to produce effluent that is well below any guideline limits.

The MBR would only be in operation for the summer months (120 days) and would require proper storage and maintenance work during the winter months. Commissioning the MBR for each season would be a difficult task.

The order of magnitude cost estimate prepared in 2007 for an MBR for only one season of operation was 2.4 million dollars (including a 40% contingency allowance for construction and engineering services). MBRs are associated with high capital and operation/maintenance costs.

Appendix G contains the full Membrane Bioreactor Report.

4.3 WESATech Geotube® Physical – Chemical Treatment System (WESATech Proposal)

WESA Technologies (WESATech) is an Ontario based company which focuses on the design and implementation of water and wastewater treatment systems. In 2010 WESATech prepared a proposal for the City of Iqaluit to implement a physical – chemical treatment system using a Geotube® filtration system for the West 40 landfill runoff to meet specified effluent discharge criteria.

4.3.1 Overview of WESATech Geotube® Physical-Chemical Treatment System

The WESATech Geotube® physical-chemical treatment process involves chemical treatment, solid filtration and neutralization all carried out continuously. The landfill runoff properties are characterized initially and the contaminants which require removal are identified. A chemical treatment process is designed to precipitate the contaminants from solution and to flocculate the contaminants into larger filterable particles. The Geotube® then works as a physical barrier to remove suspended solids. The solids that remain in the Geotube® can be returned to the landfill or transported for disposal at an appropriate facility. The Geotube® system can be stored in a shipping container and commissioned each time it is required to be used.

In the 2010 proposal the contaminants requiring removal from the West 40 Landfill runoff were iron, manganese and zinc. A two-stage chemical treatment step was proposed by WESATech. In the first chemical step calcium hydroxide solution would be added to raise the pH of the runoff water to induce the precipitation of the metals. In the second chemical treatment stage aluminum sulphate and polymer were added to flocculate the metals into larger particles. The chemical treatment stages were air mixed to promote the oxidation of the iron and manganese in the solution, which leads to precipitation. The filtered water then entered a final neutralization step were the pH was adjusted to between 7 and 8 using hydrochloric acid.

The cost of the WESATech Geotube® equipment (pumps, tanks, Geotube®, piping, fittings, and chemicals for one season and transportation) to Iqaluit was estimated to be $75,000. This amount does not include the cost of manpower on site. The cost of a WESATech operator was estimated to be $1000/day. For the 2010 discharge event the cost of operator time and expenses per seasonal treatment and discharge event would be $25,000. Supplies for seasonal treatment events were estimated to be $10,000.

The complete WESATech proposal is included as Appendix H.

4.4 Tube Filtration System Currently in Use at the West 40 Landfill

The City of Iqaluit has purchased and utilized a tube filtration system on two discharge events from the retention pond. The first event was in July 2010 and the second event was in June 2011. The tube filter used by the City has a nominal pore size of 450 microns. The pore size decreases during operation as the tube captures suspended solids. The City has not used any chemical pretreatment on the runoff. As proposed by WESATech, pretreatment could enhance contaminant removal through the flocculation of dissolved contaminants.

The performance of the tube filter in removing contaminants based upon the very limited sampling in 2010 (unfiltered discharge versus filtered discharge) is encouraging with substantial reductions in aluminum, iron, zinc and turbidity reported by the City of Iqaluit (2010 NTWWA conference presentation). The results reported by the City in 2011 do not show significant signs of contaminant removal which suggests that the City may wish to consider chemical pretreatment in the future as part of the tube filtration process.

5. Conclusions and Recommendations

5.1 Collection and Control of Landfill Runoff

The landfill runoff management system has been designed and constructed for the collection and control of off-site runoff (clean) and on-site runoff (contaminated) water. The on-site runoff is controlled so that water drains into a series of detention ponds on site and is then transferred to one retention pond off-site for storage prior to being discharged into the environment. Prior to any discharges the City consults and notifies the regulatory authorities. Modifications to the collection system are currently being completed by the City to improve the management of the on-site runoff.

5.2 Treatment of Landfill Runoff

The City has investigated potential treatment processes which may be applied to the landfill runoff, including wetland treatment, membrane treatment and WESATech Geotube® physical-chemical treatment. Based upon the capital cost of the three options, the membrane treatment option is not financially viable for the City. The wetland treatment option may be financially viable; however negotiation is required with the current land owner. Negotiation could take a considerable amount of time and may not be successful, depending upon the stakeholders involved. The City has implemented a physical filtration process on a trial basis. The performance of filtration alone for the treatment of the landfill runoff has been inconclusive; therefore it is recommended that the City advance the use of a chemical treatment in advance of the filtration process. The WESATech Geotube® physical-chemical proposal is financially viable for the City and operationally practical for the City staff.

5.3 Effluent Quality Criteria for Treated Runoff

The City has completed an investigation into the appropriate parameters that should be tested for and a frequency of testing for the landfill runoff management system. This investigation was reviewed and supported by Environment Canada and Indian and Northern Affairs Canada. The City should continue to monitor for the parameters recommended in the 2008 Water License Monitoring Report. The Guidelines for the Discharge of Treated Municipal Wastewater in the NWT have been developed for arctic locations discharging into a marine environment, and are the most applicable standards of concentration limits to apply to the City of Iqaluit's discharge from the retention pond at the landfill. The Cape Dyer water licence has criteria that may also be used to supplement the GDTMWNWT in cases where a standard does not exist.

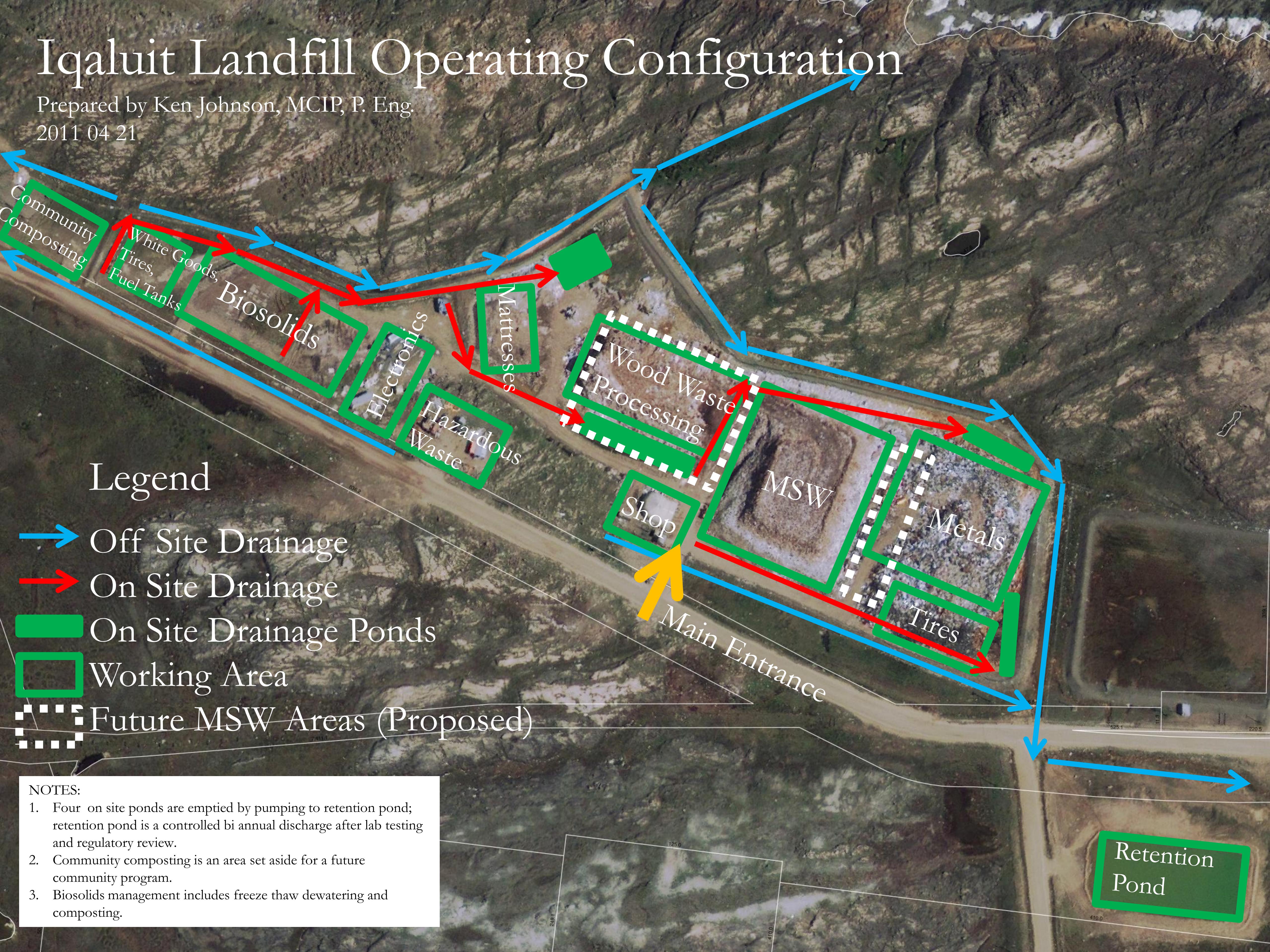
Appendix A

West 40 Landfill Drainage Management Review

Landfill Operating Conditions

Iqaluit Landfill Operating Configuration

Prepared by Ken Johnson, MCIP, P. Eng.
2011 04 21



NOTES:

1. Four on site ponds are emptied by pumping to retention pond; retention pond is a controlled bi annual discharge after lab testing and regulatory review.
2. Community composting is an area set aside for a future community program.
3. Biosolids management includes freeze thaw dewatering and composting.

Appendix B

West 40 Landfill Drainage Management Review

Photo Presentation of Current Landfill Drainage Management System

On site runoff **detention** pond on northeast side of landfill site. Runoff is naturally flows from this pond to runoff **detention** pond at south west corner.

On site runoff **detention** pond at south east corner of landfill site. Runoff drains from this pond to runoff **detention** pond at south west corner.

AECOM

On site runoff detention pond at south west corner of landfill site. Runoff is pumped from this pond to runoff **retention** pond.

Runoff **retention** pond , south of landfill site, receives runoff from landfill detention pond . Retention pond is sample and discharge twice each year.

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Off site runoff management control system on southeast side of the landfill site (view to south)

Off site runoff management control system on southeast side of the landfill site (view to north)

Off site runoff management control system on south of the landfill site (view to west)

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Off site runoff management control system on north side of the landfill site (view to northwest)

Discharge to minor wetland of off site runoff management control system on north side of the landfill site (view to south east)

AECOM

Appendix C

West 40 Landfill Drainage Management Review

Landfill Water Sample Testing Results

City of Iqaluit West 40 Landfill Water Historical Water Sampling Results

PARAMETER	UNITS	2011-08-09 Retention Pond #1	2011-06-21 Retention Pond	2011-06-23 Retention Pond #2	2011-06-24 Retention Pond #3	2010-06-03 Retention Pond Sample #1	2010-06-10 Retention Pond Sample #2	2010-06-10 Retention Pond Sample #3	2009-07-30 INAC Results	2008-06-09 Detention Pond	2007 Retention Pond	2007 Control Pond	2006-06 Control Pond	2004-07 Runoff Sample Results	IQALUIT WATER LISCENCE 2006 DISCHARGE CRITERIA AVE.	GRAB	GUIDELINES FOR THE DISCHARGE OF TREATED MUNICIPAL WASTEWATER IN THE NWT (1)
INORGANICS																	
Alkalinity (Total as CaCO3)	mg/L									98	99	110	474				
Biochemical Oxygen Demand	mg/L	70	5	11	11	8	5	5		16	11	19	269	5.2	120	180.0	120
Chloride (Dissolved)	mg/L									90	110	249	249	215			
Conductivity	umho/cm									824	1050	1180	2050	1667.0			
Chemical Oxygen Demand	mg/L		75	70	80	63	60	63									
Hardness (CaCO3)	mg/L									280	410	480	660				
N-NH3 (Ammonia)	mg/L	3.74	5.81	6.01	4.77	4.03	3.85	4.00		2.40	2.54	4.00		4.42			
Nitrite (N)	mg/L									0.02	0.04	ND	<0.02	<0.2			
Nitrate (N)	mg/L									ND	ND	ND	<0.05	<0.2			
Nitrite +Nitrate	mg/L									ND	ND	ND	<0.07				
Oil and Grease	mg/L													2.00			
pH		7.99	7.65	8.01	8.01	7.74	7.84	7.96		7.9	7.20	7.10	7.52	7.41	6-9		6-9
Sulphate (Dissolved)	mg/L									179	293	307	307.0	398.0			500
Total Dissolved Solids	mg/L									516	610	682	1130				
Total Kjeldahl Nitrogen	mg/L	7.16	9.44	8.21	7.57	5.36	6.11	5.90					20.7				
Total Organic Carbon	mg/L	26.6	25.5	24.8	23.6	20.7	23.1	21.7		18.6	26.5	41.9					
Total Inorganic Carbon	mg/L									20	24	27					
Total Phosphorus	mg/L	0.04	0.05	0.04	0.14	0.13	0.07	0.08		0.05	0.2	0.2	0.8	0.3			
Total Suspended Solids	mg/L	9	11	14	177	54	15	14		15	20	29	868	32.0	180	270	180
Turbidity	NTU	8.9	31.6	39.1	55.4	26.1	27.8	28.8		14.7	40	53					
METALS																	
Aluminum	mg/L	0.07	0.04	0.05	0.22	0.26	0.08	0.08		0.29	0.21	0.11	5.01	0.05			2
Antimony	mg/L	0.0006	0.0007	0.006	<0.0005	0.0009	0.0009	0.0009	0.002	0.001	0.0016	0.0032	0.0238	0.0051			
Arsenic	mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0	ND	0.002	0.0030	0.018	0.002			0.05
Barium	mg/L	0.03	0.03	0.04	0.03	0.02	0.03	0.03	0.57	0.021	0.03	0.05	0.12	0.04			1
Beryllium	mg/L	<0.0005	<0.0005	<0.0005	<0.0005	<0.001	<0.001	<0.001	0	ND	ND	ND	<0.0002	<0.001			
Bismuth	mg/L									ND	ND	ND	<0.001	<0.001			
Boron	mg/L	0.97	0.99	0.82	0.69	0.43	0.59	0.60	0.31	0.30	0.39	0.48	1.06	0.71			5
Bromide	mg/L												203	166			
Cadmium	mg/L	<0.0001	0.0006	0.0006	0.0006	0.0011	0.0011	0.0011	0.0001	0.0005	0.0019	0.0048	0.0024	0.0024			0.005
Calcium	mg/L	147	122	128	123	112	146	144		100	150	200	203	166			
Chromium	mg/L	0.009	0.006	0.007	0.005	0.003	0.006	0.035	0.008	ND	ND	ND	0.0241	<0.005			0.1
Cobalt	mg/L	0.0014	0.0015	0.0014	0.0018	0.0022	0.0023	0.0024	0.010	0.0032	0.0057	0.0038	0.0024	0.0055			0.1
Copper	mg/L	0.002	0.011	0.011	0.011	0.027	0.027	0.027	0.01	0.006	0.023	0.058	0.294	0.023			0.2
Iron	mg/L	1.52	3.28	3.68	4.98	4.05	4.03	4.08	122	2.3	4.30	7.50	12.8	8.86			0.3
Lead	mg/L	<0.001	0.002	0.002	0.002	0.004	0.003	0.003	0.002	0.0019	0.007	0.022	0.099				0.05
Lithium	mg/L									0.012	0.015	0.024	0.020				
Manganese	mg/L	0.68	1.48	1.61	1.34	0.61	0.78	0.81		0.84	1.10	1.00	1.02	0.90			0.05
Magnesium	mg/L	26	18	22	22	13	19	18		11	12	11	49				
Mercury	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0001				0.1	<0.0001			0.0006
Molybdenum	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005		0.002	0	0	<0.002	0.006			0.2
Nickel	mg/L	0.010	0.011	0.012	0.010	0.012	0.013	0.013	0.013	0.008	0.011	0.014	0.0226	0.016			0.3
Potassium	mg/L	30	22	26	22	16	19	19		9.5	11	13	61.7	36.8			
Selenium	mg/L	<0.01	<0.005	<0.005	<0.005	<0.01	<0.01	<0.01	0.002	ND	ND	ND	0.0009	<0.002			0.05
Silicon	mg/L	4.9	2.3	2.5	2.7	1.7	2.3	2.3		1.3	1.5	1.4	9.4	-			
Silver	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.001	ND	ND	0.0001	0.0006	<0.0001			0.1
Sodium	mg/L	172	112	132	122	70	103	103		41	41	40	207	125			
Strontium	mg/L	0.914	0.813	0.920	0.761	0.499	0.841	0.853		0.600	0.770	1.100	1.010	0.86			
Thallium	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0005	ND	ND	ND	<0.00001	<0.00005			
Tin	mg/L									ND	ND	ND	0.02	0.001			5
Titanium	mg/L	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01		0.02	0.008	ND	0.382	<0.005			
Uranium	mg/L			0.004	0.006				0.005	0.0003	0.0003	0.0002	<0.001	<0.0001			
Vanadium	mg/L	0.006	0.004			0.003	0.003	0.003	0.019	0.002	0.001	ND	0.010	-			
Zinc	mg/L	0.05	1.9	1.57	1.6	2.0	1.8	1.7	0.5	2.5	6.90	15.0	0.763	15.2			0.5
Zirconium	mg/L									ND			0.005				
MICROBIOLOGICAL																	
Background	CFU/100mL										4200	3500					
Total Coliforms	CFU/100mL		10			190	250	280			500.00	300.00					
Fecal Coliforms	CFU/100mL		<10			7	12	3			20.00	<10	<1				
VOLATILE ORGANIC COMPOUNDS																	
Benzene	ug/L		<0.5			<0.5	<0.5	<0.5									
Ethylbenzene	ug/L		<0.5			<0.5	<0.5	<0.5									
m/p-xylene	ug/L		<1.0			<1.0	<1.0	<1.0									
o-xylene	ug/L		<0.5			<0.5	<0.5	<0.5									
Toluene	ug/L		<0.5			<0.5	<0.5	<0.5									
VOC SURROGATES																	
Toluene-d8	%		102			98	95	95									
Polychlorinated Biphenyls - PCBs																	
Phenols	mg/L												4.42				
Polychlorinated Biphenyls (PCBs)	ug/L		<0.1	<0.02	<0.02	<0.1	<0.1	<0.1									

Notes:
(1) Guidelines for the Discharge of Treated Municipal Wastewater in the NWT, 1992 (Season: Summer, 150-600 Lcd) (Receiving Env: Marine/Bay).

City of Iqaluit Landfill Storage Retention Pond Decant Historical Water Sampling Results

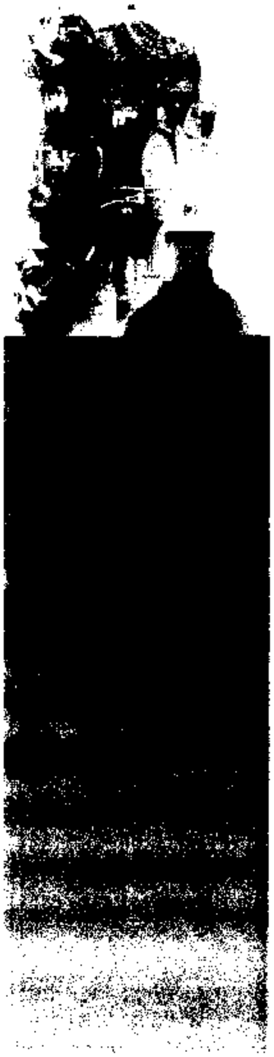
PARAMETER	UNITS	2011-06-22 Start	2011-06-23 Mid	2011-06-24 End	2010-07-27 Start	2010-07-27 End	2010-06-03 Start	2010-06-10 Mid	2010-06-10 End	2008-06-09	IQALUIT WATER LISCENCE 2006 DISCHARGE CRITERIA AVE.	GRAB	GUIDELINES FOR THE DISCHARGE OF TREATED MUNICIPAL WASTEWATER IN THE NWT (1)
INORGANICS													
Alkalinity (Total as CaCO3)	mg/L												
Biochemical Oxygen Demand	mg/L	5	11	11	11	9	8	5	5	16	120	180.0	120
Chloride (Dissolved)	mg/L												
Conductivity	umho/cm												
Chemical Oxygen Demand	mg/L	75	70	80	83	75	8	5	5	16			
Hardness (CaCO3)	mg/L												
N-NH3 (Ammonia)	mg/L	5.81	6.01	4.77	3.21	3.33	4.03	3.85	4				
Nitrite (N)	mg/L												
Nitrate (N)	mg/L				<0.1	<0.1	<0.1						
Nitrite +Nitrate	mg/L												
Oil and Grease	mg/L												
pH		7.65	8.01	8.08	8.11	8.15	7.74	7.84	7.96	7.9	6-9		6-9
Sulphate (Dissolved)	mg/L												500
Total Dissolved Solids	mg/L												
Total Kjeldahl Nitrogen	mg/L	9.44	8.21	7.57	6.61	4.86	5.36	6.11	5.9				
Total Organic Carbon	mg/L	25.5	24.8	23.6	23.4	23.8	20.7	23.1	21.7	18.6			
Total Inorganic Carbon	mg/L												
Total Phosphorus	mg/L	0.05	0.04	0.14	0.05	0.05	0.13	0.07	0.08	0.05			
Total Suspended Solids	mg/L	11	14	177	14	12	54	15	14	15	180	270	180
Turbidity	NTU	31.6	39.1	55.4	6.9	6.4	26.1	27.8	28.8	14.7			
METALS													
Aluminum	mg/L	0.04	0.05	0.22	0.02	0.02	0.26	0.08	0.08				2
Antimony	mg/L	0.0007	0.0006	<0.0005	0.0008	0.0008	0.0009	0.0009	0.0009				
Arsenic	mg/L	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1				0.05
Barium	mg/L	0.03	0.04	0.03	0.03	0.03	0.02	0.03	0.03				1
Beryllium	mg/L	<0.0005	<0.0005	<0.0005	<0.001	<0.001	<0.001	<0.001	<0.001				
Bismuth	mg/L												
Boron	mg/L	0.99	0.82	0.69	0.77	0.75	0.43	0.59	0.6				5
Bromide	mg/L												
Cadmium	mg/L	0.0006	0.0006	0.0006	<0.0001	<0.0001	0.0011	0.0011	0.0011				0.005
Calcium	mg/L	122	128	123	185	184	112	146	144				
Chromium	mg/L	0.006	0.007	0.005	0.002	0.007	0.003	0.006	0.035				0.1
Cobalt	mg/L	0.0015	0.0014	0.0018	0.0015	0.0015	0.0022	0.0023	0.0024				0.1
Copper	mg/L	0.011	0.011	0.011	0.004	0.003	0.027	0.027	0.027				0.2
Iron	mg/L	3.28	3.68	4.98	0.54	0.52	4.05	4.03	4.08				0.3
Lead	mg/L	0.002	0.002	0.002	<0.001	<0.001	0.004	0.003	0.003				0.05
Lithium	mg/L												
Manganese	mg/L	1.48	1.61	1.34	0.38	0.37	0.61	0.78	0.81				0.05
Magnesium	mg/L	18	22	22	27	27	13	19	18				
Mercury	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001				0.0006
Molybdenum	mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005				0.2
Nickel	mg/L	0.011	0.012	0.01	0.009	0.009	0.012	0.013	0.013				0.3
Potassium	mg/L	22	26	22	29	30	16	19	19				
Selenium	mg/L	<0.005	<0.005	<0.005	<0.01	<0.01	<0.01	<0.01	<0.01				0.05
Silicon	mg/L	2.3	2.5	2.7	3.1	3	1.7	2.3	2.3				
Silver	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001				0.1
Sodium	mg/L	112	132	122	161	162	70	103	103				
Strontium	mg/L	0.813	0.92	0.761	1.33	1.27	0.499	0.841	0.853				
Thallium	mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001				
Tin	mg/L												5
Titanium	mg/L	<0.01	0.004	0.006	<0.01	<0.01	0.01	<0.01	<0.01				
Uranium	mg/L												
Vanadium	mg/L	0.004	0.004	0.006	<0.001	<0.001	0.003	0.003	0.003				
Zinc	mg/L	1.9	1.57	1.6	0.06	0.05	2	1.8	1.7				0.5
Zirconium	mg/L												
MICROBIOLOGICAL													
Background	CFU/100mL												
Total Coliforms	CFU/100mL	10					190	250	280				
Fecal Coliforms	CFU/100mL	<10					7	12	3				
VOLATILE ORGANIC COMPOUNDS													
Benzene	ug/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5						
Ethylbenzene	ug/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5						
m/p-xylene	ug/L	<1	<1	<1	<1	<1	<1						
o-xylene	ug/L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5						
Toluene	ug/L	<0.5	<0.5	<0.5	<0.5	0.8	<0.5						
VOC SURROGATES													
Toluene-d8	%	102			100	100	95	95	98				
Polychlorinated Biphenyls - PCBs													
Phenols	mg/L												
Polychlorinated Biphenyls (PCBs)	ug/L	<0.1	<0.002	<0.002	<0.1	<0.1	<0.1	<0.1	<0.1				

Notes:
(1) Guidelines for the Discharge of Treated Municipal Wastewater in the NWT, 1992 (Season: Summer, 150-600 Lcd) (Receiving Env: Marine/Bay).

Appendix D

West 40 Landfill Drainage Management Review

City of Iqaluit Water License Monitoring Program



City of Iqaluit
Water Licence Monitoring Program

EarthTech

City of Iqaluit
Water Licence Monitoring Program

Prepared for:
City of Iqaluit
City Hall
P.O. Box 460
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June 2008
Project No. 99602

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF APPENDICES

1.0 INTRODUCTION

1.1 Background

The City of Iqaluit is located at the south end of Baffin Island, on Frobisher Bay at 64° 31'N latitude and 68° 31'W longitude, in a region of continuous permafrost with a typical arctic climate. The community has only four months when the average monthly temperature is above freezing.

The city has a population of approximately 6,200 with a predicted increase in population to 11,300 in 2022. The infrastructure municipal facilities are currently operated under the Water Licence (File No: 3AM-IQA0611) issued by the Nunavut Water Board (NWB) in 2006. Based on the requirements of the Water Licence, one of the most important responsibilities of the City of Iqaluit is to monitor the quantity and quality of the "water" associated with potable water supply, sewage treatment and solid waste management to protect public health and the environment.

In 2007, the City of Iqaluit retained Earth Tech (Canada), Inc. to provide services for preparing the "water" monitoring plan. The primary purpose of the monitoring plan is to help the City of Iqaluit identify appropriate water quality parameters to be monitored and sampling locations for the collection of representative samples. This monitoring plan will be submitted to the NWB for approval before it is applied for water monitoring in the City.

1.2 Scope and Objectives

It is very important for the City of Iqaluit to comply with the Water Licence for operating and monitoring the municipal facilities (i.e. water treatment, wastewater treatment, landfill etc.) properly. The water monitoring programme, once in place, will provide the appropriate framework for the City to achieve compliance associated with the water sampling requirements in the water licence.

Overall, the primary objective of the project is to develop a cost-effective compliance monitoring plan for:

- Protection against adverse impacts on public health from physical, chemical and biological hazards;
- Environment protection; and Compliance with Water Licence regulation and guidelines.

The Monitoring plan for the City of Iqaluit has been prepared based on the following key tasks:

- Identification of current criteria for water monitoring presented in Water Licence;
- Identification of the gap between the requirements of the Water Licence and the practical needs of Iqaluit for water monitoring;
- Recommendations of appropriate water quality parameters for Iqaluit;
- Confirmation of the sampling points for the recommended monitoring; and
- Preparation of final monitoring plan based upon NWB feedback.
- Organization of the Report.

The remainder of the report has been organized in the following sections:

- Section 2.0: Municipal Facilities and "Water" Characteristics. The treatment process and operation strategy of the drinking water treatment plant (WTP), wastewater treatment plant (WWTP) and solid waste management facility are briefly introduced in this section. In addition, the characteristics of "water", associated with water treatment, sewage disposal and landfill management, are also summarized;

- Section 3.0: Identification of the Water Monitoring Criteria and Locations. This section compares the requirements of the Water Licence applied for the City of Iqaluit with some standards and guidelines published by some organizations or government branches. Also, some suggestions and comments regarding the monitoring criteria required by the Water Licence are discussed.

- Section 4.0: Budget for Sampling. An annual budget for monitoring (sampling and analysis) is presented based on laboratory quotations from several commercial laboratories which the City of Iqaluit could use for sample analysis.

2.0 MUNICIPAL FACILITIES AND "WATER" CHARACTERISTICS

2.1 Water Treatment Facility (WTP)

The City of Iqaluit's water treatment plant (WTP) was initially commissioned in the 1960s, with Lake Geraldine Lake used as the raw water source. Due to the limited treatment capacity, the main treatment process of the WTP was upgraded between 2002 to 2004. After the upgrade, the treatment capacity of the WTP was increased to approximately 9,500 m^3 day^{-1} based on a projected population of 11,300 in 2021.

The upgraded treatment facility consists of the following processes:

- Lake Geraldine dam structure and valve chamber;
- Raw water intake pipeline and tempering system (upgraded in 1999);
- Plant inlet flow control valve;
- Ultraviolet (UV) pre-disinfection (one duty and one standby);
- Flocculation tanks (to be used for flocculation only when coagulation is required in future);
- Dual media rapid gravity filters and filter backwash and "filter to waste" storage tanks;
- Chemical (chlorine gas, zinc orthophosphate, hydrofluorosilicic acid and caustic soda) dosing systems; and
- Treated water clearwells (west clearwell and east clearwell).

Normally, raw water is drawn from the dam on the Geraldine Lake and flows to the WTP through a 250 mm main by gravity. Upon entering the WTP, the raw water is metered and controlled by a flow control valve. The raw water then flows through either of the UV reactors to inactivate pathogens. Downstream of the UV equipment the water flows through a set of flocculation tanks (these tanks will only be required to operate as flocculation tanks in the event that future coagulation is required to meet the final water quality targets), or through a flocculation tank bypass line on to the filters. From the filters the filtered water flows into the contact chamber where chlorine gas (for residual disinfection) is injected to the water along with hydrofluorosilic acid (for fluoridation) and caustic soda (for pH adjustment). The treated flow from the contact chamber can then be diverted to either of the clearwells or into the filter backwash chamber. Zinc orthophosphate (for pipeline corrosion protection) is added before the treated water is delivered to the distribution system or an off-site reservoir. The "filter to waste" storage tank is used for accepting the filter ripening flow, of which the quality is usually above the regulatory requirements, generated by filters after backwash cycles.

This drinking water treatment process is automatically controlled by a Plant Control System (PCS) and requires minimal intervention unless there is an alarm indicated. Monitoring, fine-tuning and scheduled maintenance of the WTP operating systems provide reliability and dependability with reduced system malfunctions and breakdowns.

2.2 Wastewater Treatment Facility (WWTP)

The City of Iqaluit has historically used a primary sewage lagoon for its wastewater treatment. To improve the wastewater treatment efficiency and achieve effluent quality requirements, the City initiated construction of a new WWTP. In 1998, the city awarded a design-build contract for a new WWTP.

The design-build contractor proposed the use of an aerated membrane bioreactor (MBR) process for the wastewater treatment. In this proposed treatment process, the wastewater, after flowing through the preliminary treatment screens, is treated by a MBR system, in which most organic contaminants are degraded by microorganisms, and the treated wastewater and biomass are separated by membranes. Then, the filtrate from the membranes may be discharged to the surface water, and waste sludge generated in the treatment process may be dewatered and transferred to the landfill site for disposal.

However, due to design and construction problems, the MBR wastewater treatment process was never commissioned. In 2002, Earth Tech (Canada), Inc. conducted a detailed investigation of the WWTP, and recommended that the City reconfigure the facility to use a conventional biological wastewater treatment process to replace the MBR process. Following that, CH2M Hill developed a workable conceptual design in 2003 and Earth Tech carried out the conversion and expansion work from 2004 to 2006.

The major treatment facilities of the conventional biological treatment process (phase 1 and phase 2) consist of:

- Wastewater lift station;
- Preliminary treatment headworks (screening and grit removal);
- Primary filter (Salness filter);
- Activated-sludge aeration tanks and aeration systems (phase 2);
- Secondary clarifiers (phase 2);
- Waste sludge dewatering system (phase 2); and
- Others (chemical storage, pH adjustment, disinfection equipment).

The construction and commissioning of the new conventional biological WWTP is being carried out two phases. Phase 1 of the WWTP, the preliminary treatment process, was commissioned in May 2006, and phase 2, the biological treatment process, is scheduled for implementation within the next 5 to 10 years. The major facility equipment in phase 1 was designed for a peak flow of 14,400 m^3 day^{-1} with a service population of 12,000; the remaining equipment in phase 1 were designed for a peak flow of 9,600 m^3 day^1 with a service population of 8,000.

Currently, the raw wastewater enters the plant through an existing 300 mm gravity sewer main into the influent pumping chamber, where a basket screen catches any solids that have a diameter greater than 75 mm. The raw wastewater is then pumped and metered up to the coarse screens by which the particles larger than 5 mm are removed. The wastewater from the coarse screens is further screened to 300 micron particle size by fine screens and then flows by gravity into the retention channel. This primary effluent flows through the retention channel, under an underflow weir (to contain any floatable flammables), then over an overflow weir and finally out through the outfall to the Koojesse Inlet.

The sludge from the screens and the primary filter is compacted and dewatered to a solids content of approximately 20%, and dropped into a the dump trailer which is periodically emptied at the landfill site. The sludge is dewatered further by freeze-thaw over the course of one winter, and composted at the landfill site.

2.3 Landfill Facility

The City of Iqaluit produces approximately 10,000 m^3 of compacted waste which enters the landfill annually, including residential, commercial and industrial wastes. Recycling is currently limited to the collection and diversion of aluminium cans. The current landfill facility was constructed on the south end of the West 40 Dump Site #3 in 1995 and expanded to the north in 2001. Further construction work in manage the site drainage was completed in 2006.

The waste disposal techniques at the landfill include compaction and covering with wood waste fill. The area method is used for the landfill operation, and includes placing waste above grade against a perimeter berm, compacting the waste using a wheeled loader and covering the waste using a wood waste material. The mulch, developed from wood construction waste, is a 250 to 300 mm layer that is placed over the waste and prevents wind blown material.

The landfill does not have an impermeable liner system to control the subsurface runoff; it relies on the local permafrost regime to provide a low permeability barrier to control the subsurface runoff. To control the surface discharge of runoff from the landfill site to the receiving environment, a surface water control system for both on-site and off-site drainage was completed in 2006.

The landfill surface runoff management system consists of a series of continuous ditches associated primarily with the perimeter berm structure of the landfill facility. The system is used to divert the "off-site" surface runoff and "on-site" surface runoff, essentially keeping the clean "off-site" water "clean" and keeping the potentially contaminated "on-site" surface runoff from leaving the landfill site. The "on-site" surface runoff is collected in several control ponds through the ditches and then pumped to a retention pond. The retention pond is discharged annually after testing and notification to the regulatory authorities.

3.0 IDENTIFICATION OF THE WATER MONITORING CRITERIA

3.1 Drinking Water Monitoring Criteria

3.1.1 Raw Water

Table 3.1 presents the water quality parameters and testing frequency that are required by the Water Licence (File No: 3AM-IQA0611) and recommended by Earth Tech for the raw water supply from Lake Geraldine Reservoir at the City of Iqaluit's WTP prior to treatment.

Table 3.1 Raw Water Monitoring Criteria and Frequency

Parameters Required by Water Licence	Required Frequency by Water Licence	Earth Tech's Recommendation
Routine Parameters		
Acidity	Monthly	Not recommended
Alkalinity	Monthly	Monthly
Bicarbonate	Monthly	Quarterly
Carbonate	Monthly	Quarterly
Chloride	Monthly	Quarterly
Conductivity	Monthly	Monthly
Hardness	Monthly	Quarterly
Hydroxide	Monthly	Quarterly
ORP	Monthly	Not recommended
pH	Monthly	Weekly
Sulphate	Monthly	Quarterly
TDS	Monthly	Monthly
TSS	Monthly	Monthly
TOC	Monthly	Monthly
TIC	Monthly	Not recommend
Temperature	Monthly	Weekly
Turbidity	Monthly	Weekly
Potable Water Parameters		
Fecal coliforms	Monthly	Quarterly
Total ICP metals	Monthly	Quarterly
Dissolved ICP metals	Monthly	Quarterly
Additional Parameters		
UV transmittance	N/A	Monthly
Color	N/A	Quarterly
Total coliforms	N/A	Quarterly
Giardia Lamblia	N/A	Quarterly
Cryptosporidium	N/A	Quarterly

As presented in **Table 3.1**, the Water Licence requires the City to monitor all of these listed parameters monthly. However, from the point view of operation of a WTP, some of these parameters may need to be monitored more frequently and some less frequently. Based on the importance of these parameters specific to the City of Iqaluit's WTP, different monitoring frequencies ranging from daily to annually are recommended as listed in **Table 3.1**. The reasoning behind these recommendations is discussed in the following paragraphs.

Parameters not recommended: Acidity, ORP and TIC.

The acidity of raw water can be directly or indirectly reflected by pH and alkalinity, which are recommended for routine monitoring. ORP monitoring is usually needed for water containing a relatively high concentration of a redox-active species, which may have some adverse effects on pipelines. The water quality of Lake Geraldine is good and there are no such redox-active species observed currently. Since many important parameters related to inorganic components, such as metals, chloride, carbonate, etc., are recommended for routine monitoring, TIC, as an overall index of the inorganic matters present in water, is not necessary. Acidity, ORP and TIC are not recommended during the normal operation of the WTP, although these parameters are to be monitored if some unusual condition arises.

Weekly monitored parameters: pH, Temperature and Turbidity.

These three parameters have significant effects on the performance of the existing water treatment process at the WTP. For example, raw water pH and temperature have great impacts on the chlorine concentration and contact time for the disinfection of treated water. Turbidity is very important for the operation of coagulation, flocculation and filtration. In addition, UV disinfection is also affected significantly by turbidity. The higher the turbidity of water in a UV reactor, the more UV light is attenuated. This means that higher UV doses will be required to achieve reliable disinfection levels when the turbidity is high. Under the current operating conditions, it is recommended to monitor these parameters weekly; if and when the coagulation and flocculation process is applied, it would be better to measure these parameters on a daily basis.

Monthly monitored parameters: Alkalinity, Conductivity, TDS, TSS, TOC and Fecal coliform.

The alkalinity of a water is its ability to neutralize an acid and is due to its CO_3^{2-}, HCO^{3-} and OH^- content. This is an index of the buffering capacity of water and if it is too low, the pH value could be changed significantly during the treatment. TDS and conductivity are used directly or indirectly to estimate the dissolved solids concentration in water. Both of them have certain correlations with the parameter of hardness. Water with high TDS usually tastes bitter, salty or metallic and sometimes, it may have some unpleasant odours. TSS is used to indicate the suspended solids present in water and it can usually affect the performance of some treatment processes, such as UV disinfection, coagulation, flocculation and filtration. TOC, indicating the concentration of organics present in water, is another important parameter for the WTP operator to monitor. In addition, TOC can also be used to estimate the generation of some organic disinfection by-products (DBPs), such as THMs and HAAs. Due to the importance of these parameters to the operation of the WTP, it is recommended to monitor them monthly in the first one or two years after the monitoring program is applied and then, to optimize the monitoring costs, these parameters could be monitored quarterly if the raw water quality, confirmed by the results obtained in the first one or two years, is good enough for the operation of the WTP. The reason that these parameters are recommended to be monitored at least quarterly is that the water quality of Lake Geraldine could have a variation due to the transition between different seasons, such as the runoff in spring. Some of these parameters may need to be monitored more frequently if some unusual condition of the WTP requires doing so.

Quarterly monitored parameters: Hardness, Bicarbonate, Carbonate, Chloride, Hydroxide, Sulphate, Total ICP Metals, Dissolved ICP metals and Fecal Coliforms.

Compared with the parameters discussed above, the focus of this group of parameters is more on the suitability of raw water to be used as a source for the WTP rather than the effects of raw water on the operation of the WTP treatment process. Since the water of Lake Geraldine is characterized to be good for drinking water treatment by the WTP, it is recommended to monitor these parameters (except Fecal Coliforms) quarterly in the first one or two years after the monitoring program is applied. If these parameters are in acceptable ranges and there is no significant contaminant source affecting the water quality of Lake Geraldine, these parameters could be monitored annually. If these parameters are monitored annually, it is recommended to monitor them alternatively in warm seasons and cold seasons. For the fecal coliforms, it is quite important for the public health and safety and it is recommended to monitor this parameter quarterly for the first two years after the monitoring program is applied; the monitoring frequency can then be reduced if the observed results are stable and no significant contamination source is around the drinking water source.

Additional parameters: UVT, Color, Total Coliforms, *Giardia Lamblia*, and *Cryptosporidium*.

Since a UV reactor is used for pre-disinfection at this WTP, the UV transmittance (UVT) of raw water becomes very important for the performance of the UV reactor. The lower the UVT of the raw water, the less effective UV light can get to the target pathogens and therefore, the more pathogens could pass through the UV reactor. To ensure the UV reactor is working under design conditions, it is recommended to monitor the raw water UVT at least monthly. Color is another important parameter for the monitoring of raw water quality and it is usually regulated as an aesthetic parameter by many regulatory authorities. The current treatment process of the WTP has minor capability for the removal of color. Therefore, the raw water color monitoring is recommended at least quarterly in the first one or two years after monitoring program is applied. In warm seasons, the raw water color may need to be monitored more frequently if it has been observed to experience a significant variation during this time. However, if the color is always observed far below the regulatory requirement, it may be monitored annually in the following years for economic purposes. Total coliforms, *Giardia Lamblia* and *Cryptosporidium* are three important biological parameters for any water treatment plant to monitor, to protect the public from biohazards. It is recommended to monitor these three biological parameters quarterly for the first two years after the water monitoring program is applied and then, if these biological parameters are within acceptable ranges, the monitoring frequency may be reduced to annually.

3.1.2 Treated Water

There are no specific requirements for the quality of treated water in the Water Licence. However, it is more important for the protection of public health to monitor the quality of treated water than it is to monitor the quality of raw water. Therefore, some important parameters are recommended hereinafter for the monitoring of treated water quality. The *Guidelines for Canadian Drinking Water Quality* (March 2007) published by Health Canada on behalf of the Federal-Provincial-Territorial Committee on Drinking Water was used as a reference in the following discussion.

Generally speaking, the parameters required for monitoring the quality of treated water can be categorized as microbiological, physical, chemical (inorganic, organic, disinfectant and disinfectant by-products (DBP)) and radiological parameters. Since most drinking water sources have very low radioactive contaminants, the radiological parameters in most WTPs are not monitored in routine operation. Lake Geraldine is recognized as a good drinking water source and no radioactive contamination has been observed. Therefore, to reduce the operation cost, the City of Iqaluit does not need to monitor the radioactive parameters routinely unless such kind of contamination is suspected in Lake Geraldine. The inorganic and organic chemical parameters of treated water to be monitored primarily depend on the raw water quality. The parameters of disinfectant and DBPs are monitored based on the species of disinfectant applied at the WTP and organics present in the raw water. Physical and microbiological parameters are usually monitored in most WTPs to protect the public from aesthetic and pathogenic problems. **Table 3.2** summarizes the microbiological and physical parameters and the guideline limitations required by Health Canada.

Table 3.2 Treated Water (in WTP) Monitoring Parameters and Frequency

	Limitations Required by Health Canada	Recommended Monitoring Frequency
Microbiological Parameters		
Fecal coliforms	0 CFU/100mL	Quarterly
Total coliforms	0 CFU/100mL	Quarterly
Heterotrophic plate count	No numerical guideline[1]	Twice per year
Giardia Lamblia	No numerical guideline[2]	Dependent on the raw water
Cryptosporidium	No numerical guideline[2]	Dependent on the raw water
Enteric viruses	No numerical guideline[3]	Dependent on the raw water
Turbidity	0.3/1.0/0.1 NTU[4]	Weekly
Physical Parameters[5]		
Color	≤ 15 TCU	Quarterly
pH	6.5 – 8.5	Weekly
Temperature	≤ 15 °C	Weekly
Total dissolved solids	≤ 500 mg/L	Monthly
Taste and Odor	Inoffensive	Not recommended
Chemical Parameters		
Free and/or total chlorine		Weekly
THM formation potential	0.08 mg/L[6]	Annually
HAA formation potential	0.06 mg/L[6]	Annually

Note:
1. No MAC is specified for HPC bacteria currently; but increases in HPC concentration above baseline levels are considered undesirable;
2. If the presence of these protozoa is observed or suspected in drinking water sources, the WTP should achieve at least a 3-log reduction in and/or inactivation of cysts and oocysts, unless source water quality requires a greater log reduction and/or inactivation;
3. Where treatment is required, the WTP should achieve at least a 4-log reduction and/or inactivation of viruses;
4. Requirements listed in the table are based on conventional treatment/slow sand or diatomaceous earth filtration/membrane filtration;
5. All limits of physical parameters listed in Table 3.2 are aesthetic objectives or operational guidance values; and
6. Maximum contaminant levels required by USEPA.

3.1.3 Microbiological Parameters

As shown in **Table 3.2**, Health Canada has set relatively stringent requirements on treated water for microbiological parameters. For the treated water produced by the City of Iqaluit's WTP, the parameters of E. *coli*, total coliforms and turbidity should be monitored on a routine schedule. To reduce the operation cost, turbidity of treated water is recommended to be monitored at least weekly (daily measurement is preferred); E. *coli* and total coliforms should be monitored no less frequently than those done in raw water of the WTP (quarterly for the first two years and then annually if possible). Generally speaking, Heterotrophic Plate Count (HPC) does not have health effects; it is an index to reflect the variety of bacteria present in water. The lower the HPC, the better maintained the water system is. Therefore, to monitor the maintenance condition of the water system it would be better to determine the HPC level in treated water twice per year. The threat from *Giardia Lamblia* and *Cryptosporidium* against public health and safety has attracted great attention in North America since several fatal illnesses caused by drinking water contaminated by these protozoa were reported in recent years. Although there are currently no specific MACs required for these protozoa, Health Canada has set strict reduction and/or inactivation requirements for the water treatment process if possible contamination by these protozoa is suspected or known in the drinking water source. According to *the City of Iqaluit Water Treatment Plant Design Report* dated September 2001, the current treatment process at the City's WTP should be able to achieve at least a 3-log removal of *Giardia* and *Cryptosporidium*, which is a minimum requirement for a WTP without source water assessment for these parasites. Therefore, at the moment, it is important for the City's WTP to monitor the *Giardia* and *Cryptosporidium* levels in the raw water; the treatment redundancy for *Giardia* and *Cryptosporidium* can then be determined based on the obtained raw water data. If the City of Iqaluit has watershed protection plan in place it may not be necessary to monitor these protozoa levels in treated water routinely. For enteric viruses, as long as the water treatment facilities, especially filtration and chlorination, are operated properly, it should be able to achieve at least a 4-log removal at this WTP. Therefore, it is more important to monitor the parameters (chlorine residual, contact time, turbidity etc.) which can indicate the operational status of treatment facilities, than to determine the level of enteric viruses present in treated water. Due to this reason, it is not considered necessary to monitor the enteric viruses routinely in treated water.

3.1.4 Physical Parameters

Regarding the physical parameters listed in **Table 3.2**, they do not cause health risks but aesthetic problems for human consumption in most cases. Very similar aesthetic objectives or operational guidance values are regulated by both Health Canada and USEPA. Of these parameters, Odour and Taste are two very subjective parameters and are easy to be detected. So, it is not necessary to collect some specific water samples for odour and taste analysis in normal conditions. However, operators may need to check for these two aesthetic parameters in routine operation, especially in algal blooming period. Temperature and pH are two basic parameters for treated water; they may affect the chlorine disinfection process and cause pipeline corrosion and some aesthetic problems. It is recommended to determine these parameters at least weekly. For TDS and Color in treated water, they should be monitored as frequently as TDS and Color in raw water.

3.1.5 Chemical Parameters

Chemical parameters monitored in treated water can be categorized as inorganic, organic, disinfectant and disinfection by-product (DBP). As described previously, the City of Iqaluit's WTP currently uses UV irradiation for pre-disinfection, and chlorine gas for secondary disinfection and disinfection residual kept in potable water distribution systems. Many academic researchers have indicated that no significant DBPs could be generated by UV disinfection. For chlorination, some harmful DBPs, such as trihalomethanes (THMs) and haloacetic acids (HAAs), can be produced. The following parameters regarding the disinfectant and DBP in treated water are recommended to be monitored:

- Free chlorine concentration or total chlorine concentration in treated water before entering potable water distribution systems at least weekly (daily is preferred);
- THMs formation potential (FP) at least annually; it is recommended to analyze the THMs FP alternatively in warm seasons and cold seasons if it is monitored annually;
- HAAs formation potential (FP) at least annually; it is recommended to analyze the HAAs FP alternatively in warm seasons and cold seasons if it is monitored annually; and
- UV reactors should be checked routinely according to both the operation manual, and the requirements to make sure that reactors are working properly and appropriate UV doses can be delivered to the water.
- Inorganic chemical parameters include metals and anions. All of these parameters are quite important for the public safety and health and Health Canada has strict requirements on these parameters. Since there has been no systematic analysis conducted before for these parameters in treated water at the WTP, it is recommended to:
- Conduct a full metal scan[1] (for total concentrations) quarterly in the first two years of the Water Licence applied; the analysis frequency then can be reduced to annually (alternatively in warm seasons and cold seasons) if the metals are within the regulatory required ranges and the determined metal concentrations do not have significant variations; and
- Conduct a anion scan[2] quarterly in the first two years of the Water Licence applied; the analysis frequency then can be reduced to annually (alternatively in warm seasons and cold seasons) if the anions are within the regulatory required ranges and the determined anion concentrations do not have significant variations.

Generally speaking, the purpose of monitoring the dissolved metals (such as Aluminium, Iron, Calcium, and Manganese) in drinking water is to study the effects of these dissolved ions on the performance of some specific treatment units (such as membrane filtration, softening and coagulation). Therefore, monitoring these dissolved metals does not have significant meaning for the current treatment process at the WTP. If the total concentrations of metals can achieve the regulatory requirements, it may not be necessary to routinely monitor the dissolved metals.

[1] Including Aluminium, Arsenic, Antimony, Barium, Boron, Calcium, Cadmium, Copper, Iron, Lead, Magnesium, Manganese, Mercury, Nickel, Potassium, Silver, Sodium, Zinc, etc.
[2] Including Chloride, Cyanides, Fluoride, Nitrates, Nitrites, Phosphates, Sulphates, etc.

3.1.6 Potable Water in Distribution Systems

The Water Licence does not mention the requirements for the monitoring of potable water in potable water distribution systems. Due to the possibility that treated water supplied by the WTP could be contaminated in potable water distribution systems, it is also important to monitor the quality of potable water in distribution systems. The following parameters are suggested to be monitored:

- Temperature and pH. These two basic water quality parameters are usually related to many important reactions of water chemistry. It is recommended to monitor them at least weekly;

- Free chlorine residual and/or total chlorine residual concentration. This is an important parameter indicating the residual disinfection ability of the potable water in distribution systems. It is recommended to monitor this parameter at least weekly;

- THM and HAA concentrations. Sometimes, due to the presence of some organics (TOC) in treated water, significant amounts of THMs and/or HAAs could be generated in distribution systems after a long contact time of the organics with chlorine. It is recommended to monitor the THM and HAA concentrations at least annually;

- Turbidity. It is used to monitor the possibility of potable water in distribution systems contaminated by surface runoff and it is suggested to monitor the potable water turbidity at least weekly; and

- Fecal coliform, total coliform and HPC. These parameters are used to monitor the potable water in distribution systems contaminated by human and animal fecal wastes. Quarterly determination of these parameters is recommended to protect the public from these microbiological threats.

Table 3.3 summarizes the parameters which are recommended to be monitored in potable water distribution systems of the City.

Table 3.3 Treated Water (In Distribution Systems) Monitoring Parameters and Frequency

Recommended Parameters	Recommended Monitoring Frequency
Temperature	Weekly
pH	Weekly
Free and/or total chlorine residual	Weekly
THMs concentration	Annually
HAAs concentration	Annually
Turbidity	Weekly
Fecal coliforms	Quarterly
Total coliforms	Quarterly
HPC	Quarterly

3.2 Wastewater Monitoring Criteria

3.2.1 Influent to the WWTP

Only a primary treatment process is operated at the City of Iqaluit's WWTP currently and domestic sewage is the major wastewater treated at the WWTP. In order to achieve the discharge requirements required by NWB, a secondary biological treatment process may be added to the WWTP in the future. To protect the wastewater treatment process from damage, especially microorganisms in secondary treatment process, and to ensure that contaminants contained in wastewater influent are under the design loading rate of treatment facilities, some important influent parameters are usually monitored in the routine operation of most WWTPs. **Table 3.4** lists the parameters required by the Water Licence and recommended by Earth Tech to be monitored in the influent of the City's WWTP.

Table 3.4 WWTP Influent Monitoring Parameters and Frequency

	Required By Water Licence	Earth Tech's Recommendation
Biological Parameters		
Biochemical oxygen demand	Annually	Quarterly
Total coliforms	Annually	Quarterly
Fecal coliforms	Annually	Quarterly
Nutrient Parameters		
Ammonia nitrogen	Annually	Quarterly
Nitrate nitrogen	Annually	Not recommended
Nitrite nitrogen	Annually	Not recommended
Total phosphorus	Annually	Quarterly
Orthophosphate	Annually	Not recommended
Other Parameters		
Total suspended solids	Annually	Quarterly
Temperature	Annually	Biweekly
Conductivity	Annually	Not recommended
pH	Annually	Biweekly
ICP Parameters		
A full metals scan (total conc.)	Annually	Not recommended
Site Specific Parameters		
Chlorinated paraffins	Annually	Not recommended
LC50 Bioassay	Annually	Not recommended
New Added Parameters		
COD	N/A	Annually
TKN	N/A	Annually

As shown in **Table 3.4**, the Water Licence requires the WWTP to monitor these listed parameters in its influent annually. Based on the current operating condition and future development of the WWTP, the following recommendations, as presented in **Table 3.4**, are suggested for the WWTP:

Parameters not recommended: Nitrate nitrogen, Nitrite nitrogen, Orthophosphate, Conductivity, ICP metals, Chlorinated paraffins and LC50 bioassay.

The concentrations of NO_3-N, NO_2-N and orthophosphate in wastewater are usually used to monitor the nitrification, denitrification and phosphorus removal processes in a microbiological treatment process for nutrient removal. As described previously, it is just a primary treatment process operated at the City's WWTP, and there are no significant microbiological activities expected to occur during this phase. So, currently to monitor these three parameters in wastewater influent has no meaning. However, after the WWTP is upgraded to a secondary treatment process with biological nutrient removal sectors, these parameters may need to be monitored routinely based on some samples collected in relevant microbiological cells. Conductivity in influent usually is not a concern for wastewater treatment and it can be ignored in normal conditions. Metals, especially some heavy metals, have significant adverse effects on microorganisms in secondary biological treatment process. To keep microorganisms healthy and ensure the WWTP is running properly, Environment Canada has regulated the contaminant limits of industrial waste (including various metals) discharged to municipal sewers. In addition, the Department of Sustainable Development, Environmental Protection Service, Nunavut, also published detailed requirements on the industrial wastewater discharged to local sewage systems. However, for the current primary treatment process, it is not essential to routinely monitor the concentrations of various metals in the influent of the WWTP. Similarly, chlorinated paraffins and LC50 bioassay, though they may need to be monitored in the effluent of the WWTP to protect the receiving water from toxic contaminations, do not affect the current treatment process significantly and presently are not recommended for routine monitoring in the influent of the WWTP.

Quarterly monitored parameters: Total coliform, Fecal coliform, BOD5, Ammonia nitrogen, Total phosphorus and TSS.

No regulations specifically limit the numbers of total coliforms or fecal coliforms present in the influent of a WWTP; however, in order to have a basic understanding of the influent quality and performance of the wastewater treatment facilities, it is recommended to monitor these two parameters in the influent routinely at the City's WWTP. Since the numbers of total coliforms and fecal coliforms in wastewater could vary significantly in different seasons, the City of Iqaluit should monitor these parameters quarterly instead of annually. BOD_5, ammonia nitrogen and total phosphorus are some important parameters indicating the organic and nutrient concentrations contained in wastewater; however, they do not have significance for the current primary physical treatment process of the WWTP. In consideration of the future upgrade of the WWTP, it would be better to routinely collect the influent BOD_5, NH_3-N and TP data from now on for the design and operation of future secondary biological treatment process. TSS is another important parameter for the influent quality of WWTP, and it may significantly affect the performance of both primary and secondary treatment processes. Therefore, it is recommended to be monitored quarterly.

Biweekly monitored parameters: Temperature and pH.

These two basic water quality parameters are easy to measure and important to the operation of a WWTP. For example, both temperature and pH can affect the microorganism behaviours in a biological treatment process; also, the wastewater temperature and pH can be significantly related to the corrosion of plumbing fixtures of the primary treatment process. Therefore, it is recommended to monitor these parameters on a biweekly basis.

Other recommended parameters: COD and TKN.

Chemical oxygen demand (COD) is used to measure the oxygen equivalent of the organic material in wastewater that can be oxidized chemically using dichromate in an acid solution. Total Kjeldahl nitrogen (TKN) is the total of the organic and ammonia nitrogen in wastewater. Both COD and TKN in the influent wastewater do not have significant meanings for the current primary treatment process. However, the concentration of COD, combined with the influent BOD_5, is usually used to evaluate the possibility of wastewater treatment by biological means: TKN, combined with NH_3-N, usually can be used for the estimation of organic nitrogen loading in wastewater, which is important to biological nutrient removal process. Therefore, it is recommended to monitor these two parameters in the influent wastewater annually for the design and operation of future biological treatment process applied at the WWTP.

3.2.2 Effluent from the WWTP

As indicated by Nunavut Water Board Reasons for Decision including Record of Proceedings dated May 2006, Sewage Treatment Plant Investigation dated December 2002 and City of Iqaluit Wastewater Treatment Plant Completion Study dated October 2003, the effluent of the City's WWTP, with the current primary treatment facilities, is hard-pressed to achieve the limits of discharge quality required by NWB. Also, there is a concern that the WWTP effluent which is being discharged to receiving water may not comply with the Fisheries Act. Based on the requirements of the Water License issued by NWB and the current operating condition of the WWTP, the monitoring parameters and frequency of sampling for the WWTP effluent are recommended and summarized in **Table 3.5**. The reasons for recommendations of these parameters are discussed after the Table.

Table 3.5 WWTP Effluent Monitoring Parameters and Frequency

	Required Frequency by Water Licence	Earth Tech's Recommendation
Biological Parameters		
Biochemical oxygen demand	Bi-monthly	Quarterly
Total coliform	Bi-monthly	Quarterly
Fecal coliform	Bi-monthly	Quarterly
Nutrient Parameters		
Ammonia nitrogen	Bi-monthly	Quarterly
TKN	N/A	Quarterly
Nitrate nitrogen	Bi-monthly	Not recommended
Nitrite nitrogen	Bi-monthly	Not recommended
Total phosphorus	Bi-monthly	Quarterly
Orthophosphate	Bi-monthly	Not recommended
Other Parameters		
Total suspended solids	Bi-monthly	Quarterly
Temperature	Bi-monthly	Quarterly
Conductivity	Bi-monthly	Not recommended
pH	Bi-monthly	Quarterly
ICP Parameters		
A full metals scan (total conc.)	Quarterly	Annually
Site Specific Parameters		
Chlorinated paraffins	Annually	Annually
LC50 Bioassay	Annually	Annually

Quarterly monitored parameters: BOD_5, Total coliforms, Fecal coliforms, Ammonia nitrogen, Total phosphorus, Total suspended solids, Temperature and pH.

The effluent BOD_5 and total suspended solids are two important parameters which are usually required by regulatory authorities to meet certain discharge qualities. Currently, a primary mechanical treatment process is operated at the wastewater treatment facility. Normally, a primary treatment process has a certain capacity to physically remove the influent BOD_5 and TSS and the treatment efficiency is usually very stable under certain operating conditions. So, these two parameters are recommended for monitoring at a quarterly basis. In addition, the existing treatment process is expected to have a minor capacity for the removal of ammonia nitrogen, total phosphorus, fecal coliforms and total coliforms; however, it is necessary to routinely determine these parameters as they provide information on nutrients and pathogens discharged from the WWTP to receiving water bodies. As these parameters in influent have been recommended to be monitored routinely, it is recommended to monitor them in effluent less frequently (quarterly) than bi-monthly required by the Water License.

Temperature and pH are two easily measured and commonly monitored parameters at most wastewater treatment facilities. A WWTP effluent with unacceptable temperature and pH values usually causes adverse effects on the plants and animals in receiving water bodies. To ensure the effluent temperature and pH are in normal ranges, the City should monitor these two parameters quarterly.

Annually monitored parameters: Full metal scan, Chlorinated paraffins and LC50 bioassay.

Some metals, especially heavy metals, may have significant adverse impacts on microorganisms and aquatic organisms. The chlorinated paraffins are classified as toxic to aquatic organisms and have been recognized as a possible carcinogen to humans. An LC50 bioassay is usually used to reflect the toxicity of wastewater to aquatic organisms. As these parameters were not monitored during previous operation of the WWTP, it is absolutely necessary to monitor these parameters to ensure the effluent quality can achieve the requirements of *Fisheries Act*. However, the primary wastewater treated at the WWTP is domestic sewage and under normal conditions, there is low probability that domestic wastewater will contain such high levels of toxic contaminants. Therefore, in this report, these parameters are recommended for monitoring on an annual basis. If there are no significant such toxic contaminants detected in the effluent, the monitoring frequency can be reduced based on a reasonable basis.

Not recommended parameters: Nitrite nitrogen, Nitrate nitrogen, Orthophosphate and Conductivity.

Although these parameters, such as NO_2-N, NO_3-N and PO_4-P, are very important for a biological nutrient removal treatment process, they do not have significant meanings for the currently operated mechanical treatment process at the WWTP. The parameter of conductivity is not a very important parameter for the effluent quality of a WWTP and it is not routinely monitored at most WWTPs. In addition, as a full metal scan of the wastewater effluent is recommended to be conducted on an annual basis, this report does not recommend routine monitoring of the effluent conductivity.

3.3 Landfill Monitoring Criteria

The current Water License only includes some general requirements for the landfill runoff and it does not address specific monitoring parameters and frequency. According to *Nunavut Water Board: Reasons for Decision Including Record of Proceedings* dated May 2006, there was a concern regarding environmental contamination by runoff from the landfill facility. This file documented that the City would propose a weekly sampling frequency for pH, Electrical conductivity, metals, BTEX, and Fractional hydrocarbon analysis and a monthly sampling frequency for phenols, PAHs and PCBs; when the drainage improvements are complete, the sampling frequency would be reduced to monthly for pH, Electrical conductivity, metals, BTEX, and Fractional hydrocarbon analysis and annually for phenols, PAHs and PCBs.

From 2004 to 2007, some samples were collected from the runoff of the landfill site and parameters such as BOD_5, TOC, nutrients, solids, anions, and metals were analyzed. Based on the comparison of these sampling reports, it can be concluded that:

Some parameters (BOD_5, TSS, and some metals) of the landfill runoff in detention pond significantly exceed the MWWE guidelines, and the direct discharge into environment from the detention pond may need to be controlled; and

The quality of runoff in retention pond is significantly better than that in detention pond; most of the parameters in retention pond are within the MWWE guidelines except for total iron, manganese and zinc concentrations which slightly exceed the guidelines.

Based on the historical sampling results and NWB's requirements, the monitoring parameters and frequency for the landfill runoff are recommended as shown in **Table 3.6**. The reasons for the monitoring recommendations are discussed in following paragraphs.

3.3.1 Monitoring Parameters In Detention Ponds

According to *Iqaluit Landfill Improvements* dated August 2006, detention ponds of the landfill facility are primarily used to collect the landfill "on-site" runoff and protect the "off-site" runoff from contamination. With a short retention time in detention ponds, the collected "on-site" runoff streams are directed to the retention pond where the wastewater is cleaned by holding for a long retention time. From this point of view, the "on-site" runoff collected in detention ponds is similar to the raw wastewater of a WWTP. Since the waste streams are treated primarily in the retention pond, some basic parameters are recommended for annual monitoring of the "on-site" runoff collected in detention ponds.

3.3.2 Monitoring Parameters In Retention Pond

The wastewater held in the retention pond has been annually discharged to the environment. It is important to ensure the discharge quality of the wastewater is within the regulatory requirements. Therefore, more detailed water quality parameters in the retention pond are recommended for routine monitoring. As BTEX and PCBs are concerns in the leachate of the landfill facility, it is also necessary to routinely monitor these two parameters. It is recommended to monitor these parameters before the discharge of each year. If the wastewater in the retention pond is discharged more than once per year, it is also necessary to monitor these parameters before each discharge.

Table 3.6 Landfill Runoff Monitoring Parameters and Frequency

	Earth Tech's Recommendation
Detention Ponds	
pH	Annually
Turbidity	Annually
Total suspended solids	Annually
BOD_5	Annually
COD	Annually
TOC	Annually
Retention Pond	
pH	Annually
Turbidity	Annually
Total suspended solids	Annually
BOD_5	Annually
COD	Annually

	Earth Tech's Recommendation
TOC	Annually
Ammonia nitrogen	Annually
TKN	Annually
Total phosphorus	Annually
Full Metal Scan + Hg	Annually
Total coliform	Annually
Fecal coliform	Annually
BTEX	Annually
PCBs	Annually

3.3.3 Monitoring Parameters for Sewage Sludge

The current Water License does not include requirements for the sludge monitoring with regard to parameters and frequency. Since sewage sludge treatment is an inherent part of the landfill management, sampling and testing should be required as part of the sludge management plan.

Table 3.7 Sewage Sludge Monitoring Parameters and Frequency

	Earth Tech's Recommendation
pH	Twice during summer
Total solids	Twice during summer
TKN	Annually
Total phosphorus	Annually
Full Metal Scan	Every second year
Total coliforms	Annually
Fecal coliforms	Twice during summer

4.0 BUDGET FOR SAMPLING

Based on the monitoring parameters and sampling frequency recommended in the previous section, the sampling cost per year is estimated and summarized in **Table 4.1**. It should be noted that:

- The budgetary cost is primarily based on cost information provided by Bodycote Testing Group (Ottawa). Sampling bottles, coolers, freezer packs and forms would be provided at no additional cost;
- "Temperature" of all samples should be determined immediately on-site;
- It is assumed that a total of 100 hours of manpower is required to collect and send all samples every year and $40.00 per hour is used for the estimation of manpower cost; and
- The shipping cost of sampling supplies and samples mainly depends on the weight and/or the volume of the shipment. Due to the variation of the amount of samples collected each time, the shipping cost will also vary significantly; therefore the cost presented is for budgeting purposes only.

Table 4.1 Budgetary Costs For The Monitoring

			Sampling cost
1.	**Sample Analysis Budget**		
	1.1	Drinking Water	
		WTP Raw water	$ 4,500
		WTP Treated water	$ 3,500
		Distribution system	$ 2,000
		Sub-total	$ 10,000
	1.2	Wastewater	
		WWTP Influent	$ 1,000
		WWTP Effluent	$ 1,000
		Sub-total	$ 2,000
	1.3	Landfill	
		Detention pond	$ 200
		Retention pond	$ 800
		Sludge	$ 1,000
		Sub-total	$ 2,000
2.	**Other costs**		
	Manpower		$ 4,000
	Sampling supplies		No extra cost
	Shipping		$ 2,000
3.	**Total sampling cost**		$ 20,000

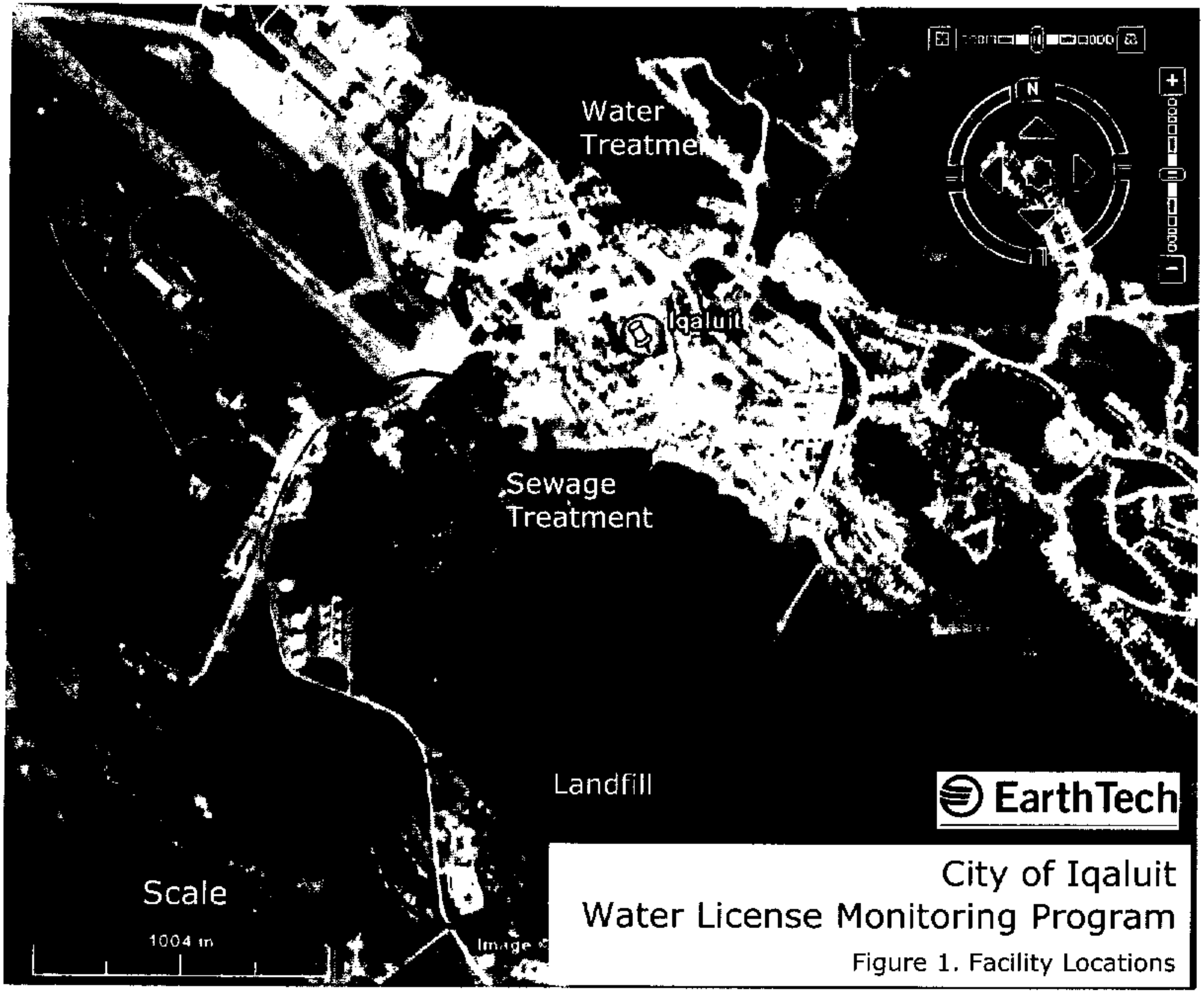
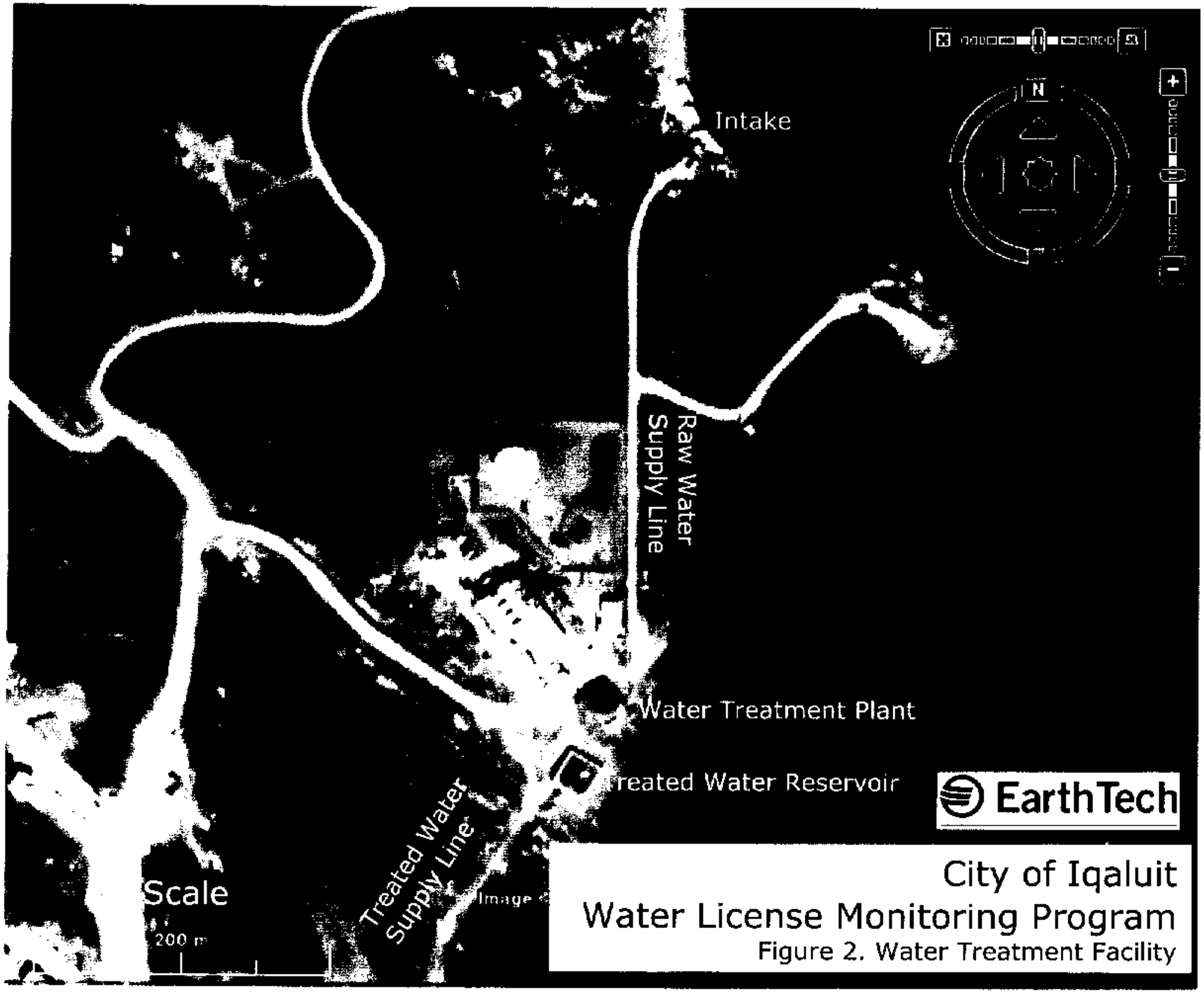
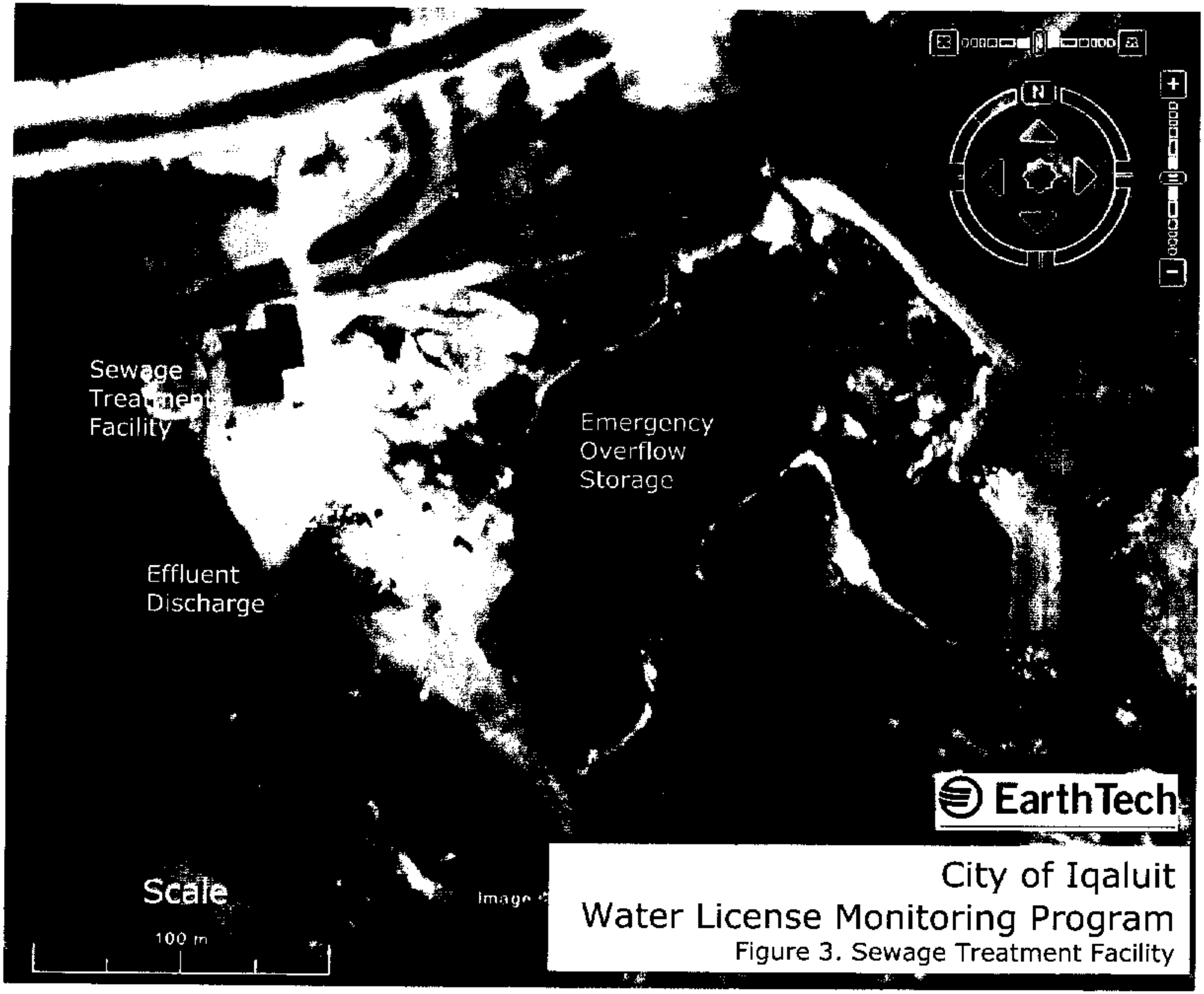


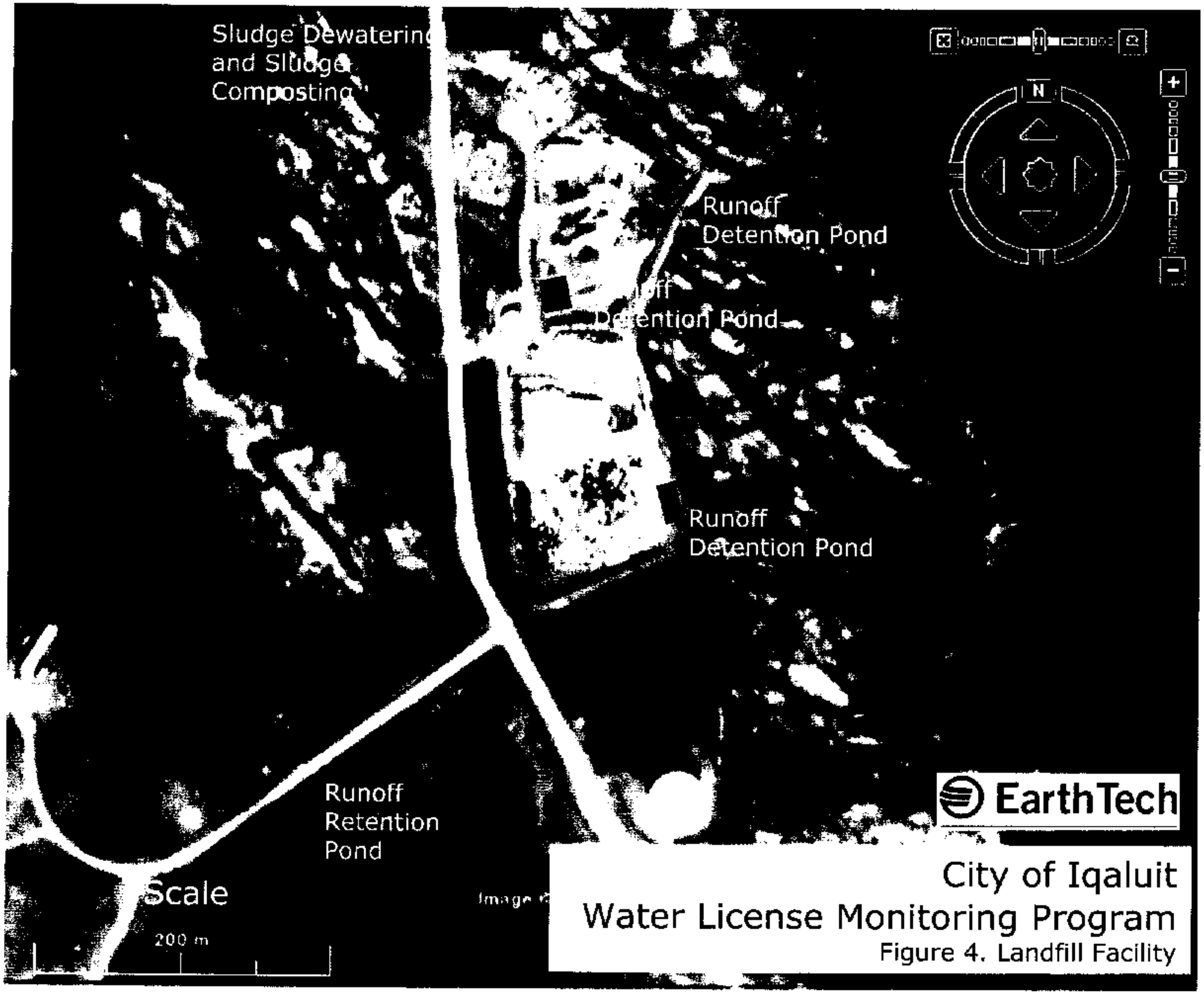
Figure 1. Facility Locations



City of Iqaluit
Water License Monitoring Program
Figure 2. Water Treatment Facility



City of Iqaluit
Water License Monitoring Program
Figure 3. Sewage Treatment Facility

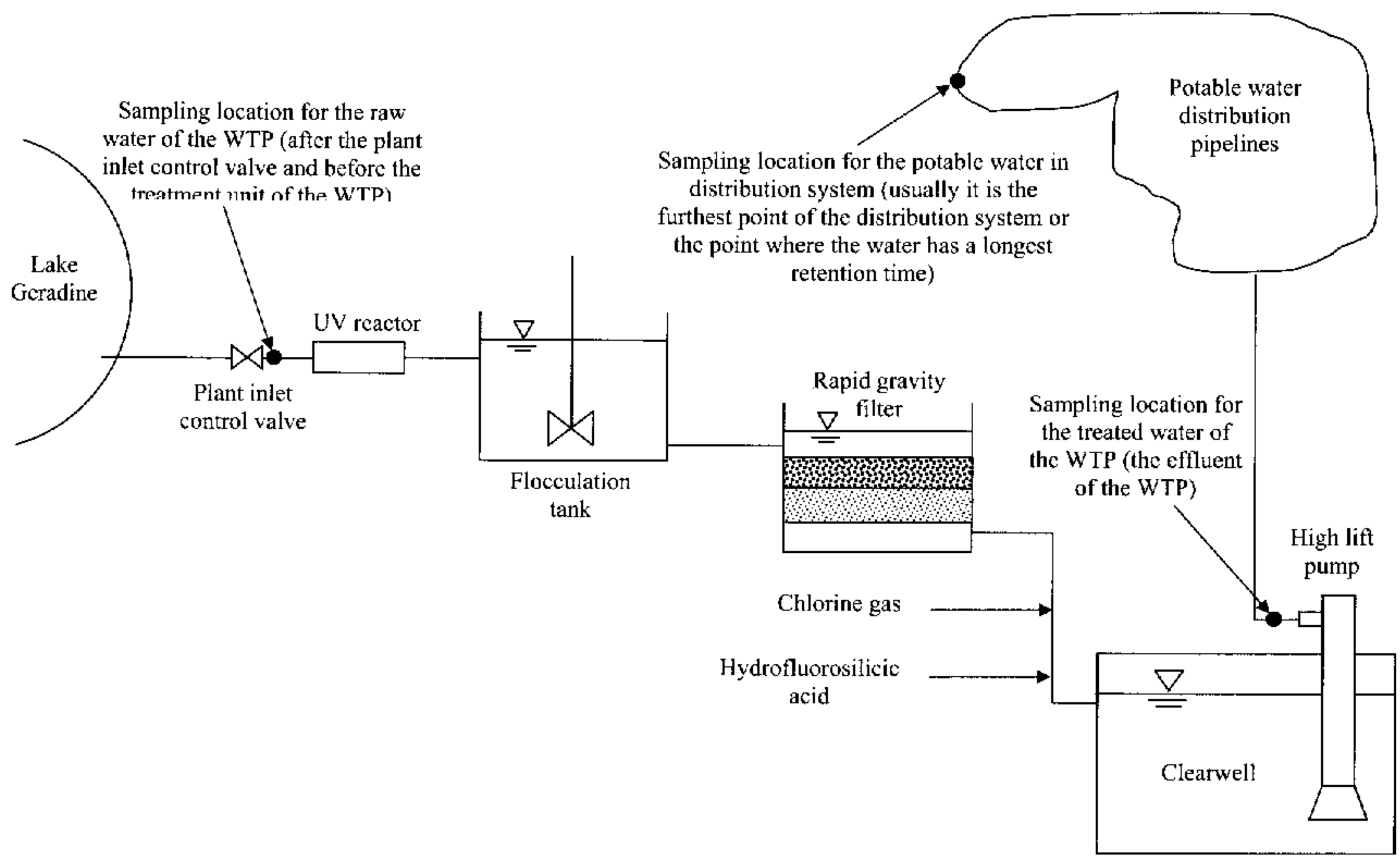


City of Iqaluit
Water License Monitoring Program
Figure 4. Landfill Facility

APPENDIX A

SAMPLING LOCATIONS FOR THE WATER TREATMENT FACILITY

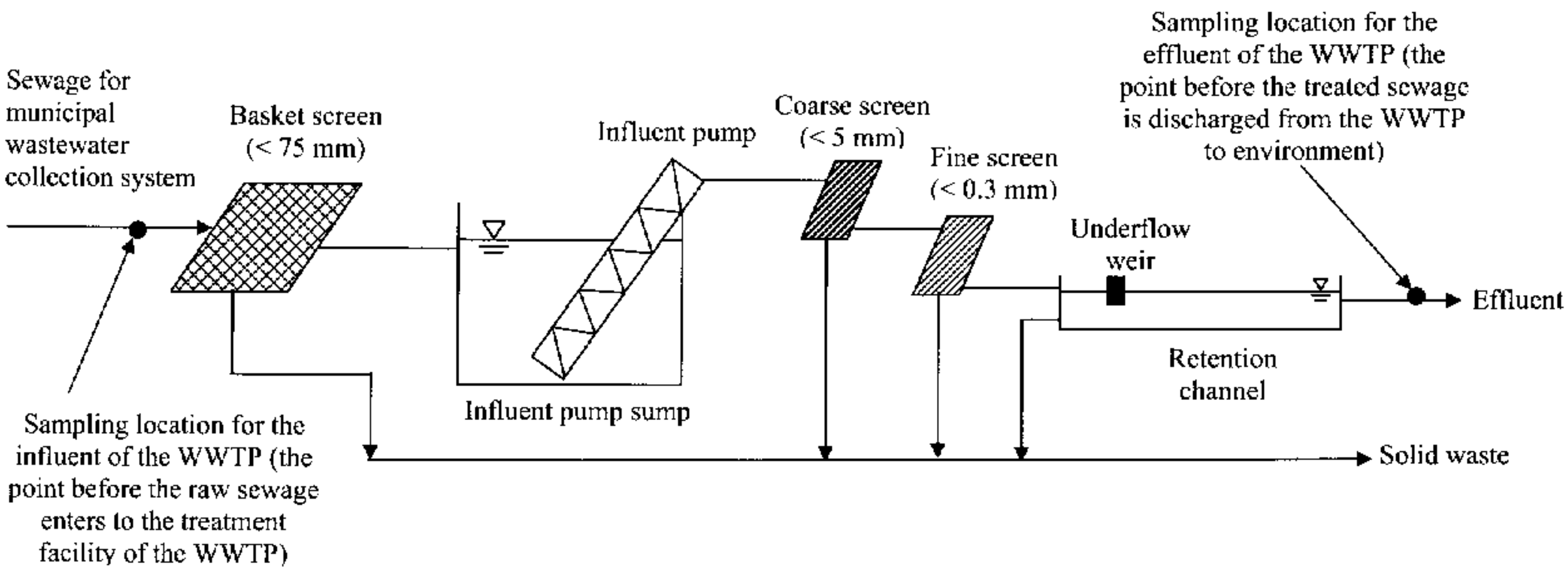
Schematic sampling locations for the Water Treatment Facility



APPENDIX B

SAMPLING LOCATIONS FOR THE SEWAGE TREATMENT FACILITY

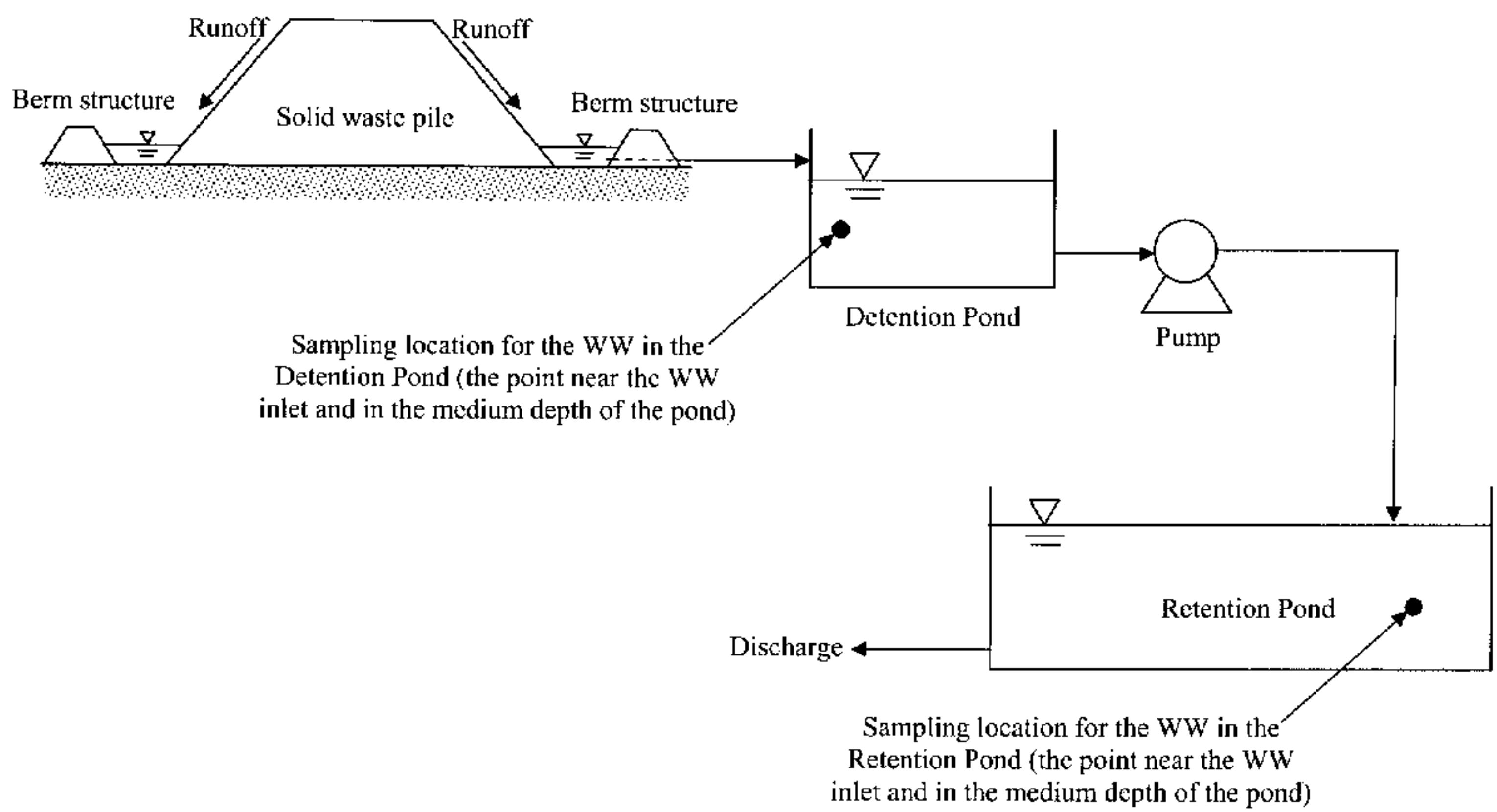
Schematic sampling locations for the Sewage Treatment Facility



APPENDIX C

SAMPLING LOCATIONS FOR THE LANDFILL FACILITY

Schematic sampling locations for the Landfill Facility



Appendix E

West 40 Landfill Drainage Management Review

Canadian Environmental Quality Guidelines Summary Table

Canadian Environmental Quality Guidelines Summary Table

Users are advised to consult the Canadian Environmental Quality Guidelines introductory text, factsheet, and/or protocols for specific information and implementation guidance pertaining to each environmental quality guideline.

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
1,1,1-Trichloroethane **CASRN** 71556	Organic Halogenated aliphatic compounds Chlorinated ethanes	*No data*	Insufficient data	1991	*No data*	Insufficient data	1991
1,1,2,2-Tetrachloroethene PCE (Tetrachloroethylene) **CASRN** 127184	Organic Halogenated aliphatic compounds Chlorinated ethenes	*No data*	**110**	1993	*No data*	**Insufficient data**	1993
1,1,2,2-Tetrachlorethane **CASRN** 79345	Organic Halogenated aliphatic compounds Chlorinated ethanes	*No data*	Insufficient data	1991	*No data*	Insufficient data	1991
1,1,2-Trichloroethene TCE (Trichloroethylene) **CASRN** 790106	Organic Halogenated aliphatic compounds Chlorinated ethenes	*No data*	**21**	1991	*No data*	Insufficient data	1991
1,2,3,4-Tetrachlorobenzene **CASRN** 634662	Organic Monocyclic aromatic compounds Chlorinated benzenes	*No data*	**1.8**	**1997**	*No data*	**Insufficient data**	1997
1,2,3,5-Tetrachlorobenzene	Organic Monocyclic aromatic compounds Chlorinated benzenes	*No data*	**Insufficient data**	1997	*No data*	**Insufficient data**	1997

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		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
1,2,3-Trichlorobenzene **CASRN** 87616	Organic Monocyclic aromatic compounds Chlorinated benzenes	No data	**8**	1997	No data	**Insufficient data**	1997
1,2,4,5-Tetrachlorobenzene	Organic Monocyclic aromatic compounds Chlorinated benzenes	No data	**Insufficient data**	1997	No data	**Insufficient data**	1997
1,2,4-Trichlorobenzene **CASRN** 120801	Organic Monocyclic aromatic compounds Chlorinated benzenes	No data	**24**	**1997**	No data	5.4	1997
1,2-Dichlorobenzene **CASRN** 95501	Organic Monocyclic aromatic compounds Chlorinated benzenes	No data	**0.7**	1997	No data	**42**	1997
1,2-Dichloroethane **CASRN** 1070602	Organic Halogenated aliphatic compounds Chlorinated ethanes	No data	**100**	1991	No data	**Insufficient data**	1991
1,3,5-Trichlorobenzene	Organic Monocyclic aromatic compounds Chlorinated benzenes	No data	**Insufficient data**	1997	No data	**Insufficient data**	1997
1,3-Dichlorobenzene **CASRN** 541731	Organic Monocyclic aromatic compounds Chlorinated benzenes	No data	**150**	1997	No data	**Insufficient data**	1997
1,4-Dichlorobenzene **CASRN** 106467	Organic Monocyclic aromatic compounds Chlorinated benzenes	No data	**26**	1997	No data	**Insufficient data**	1997
1,4-Dioxane		NRG	NRG	2008	NRG	NRG	2008
3-Iodo-2-propynyl butyl carbamate IPBC **CASRN** 554065360	Organic Pesticides Carbamate pesticides	No data	**1.9**	1999	No data	No data	No data
Acenaphthene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	No data	**5.8**	1999	No data	Insufficient data	1999

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		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Acenaphthylene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	*No data*	*No data*	1999	*No data*	*No data*	1999
Acridine PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	*No data*	**4.4**	1999	*No data*	Insufficient data	1999
Aldicarb **CASRN** 116063	Organic Pesticides Carbamate pesticides	*No data*	**1**	1993	*No data*	**0.15**	1993
Aldrin	Organic Pesticides Organochlorine compounds	*No data*	~~**0.004**~~	1987	*No data*	*No data*	*No data*
Aluminium	Inorganic	*No data*	**Variable**	1987	*No data*	*No data*	*No data*
Ammonia (total)	Inorganic Inorganic nitrogen compounds	*No data*	**Table**	2001	*No data*	*No data*	*No data*
Ammonia (un-ionized) **CASRN** 7664417	Inorganic Inorganic nitrogen compounds	*No data*	**19**	2001	*No data*	*No data*	*No data*
Aniline **CASRN** 62533	Organic	*No data*	**2.2**	1993	*No data*	Insufficient data	1993
Anthracene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	*No data*	**0.012**	1999	*No data*	Insufficient data	1999
Arsenic **CASRN** none	Inorganic	*No data*	**5**	1997	*No data*	**12.5**	1997
Atrazine **CASRN** 1912249	Organic Pesticides Triazine compounds	*No data*	**1.8**	1989	*No data*	*No data*	*No data*
Benzene **CASRN** 71432	Organic Monocyclic aromatic compounds	*No data*	**370**	1999	*No data*	**110**	1999
Benzo(a)anthracene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	*No data*	**0.018**	1999	*No data*	Insufficient data	1999

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		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Benzo(a)pyrene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	No data	**0.015**	1999	No data	Insufficient data	1999
Boron	Inorganic	29,000µg/L or 29mg/L	1,500µg/L or 1.5mg/L	2009	NRG	NRG	2009
Bromacil **CASRN** 314409	Organic Pesticides	No data	**5**	1997	No data	Insufficient data	1997
Bromoxynil	Organic Pesticides Benzonitrile compounds	No data	**5**	1993	No data	Insufficient data	1993
Cadmium **CASRN** 7440439	Inorganic	No data	**Equation**	1996	No data	**0.12**	1996
Captan **CASRN** 133062	Organic Pesticides	No data	**1.3**	1991	No data	No data	No data
Carbaryl **CASRN** 63252	Organic Pesticides Carbamate pesticides	3.3	0.2	2009	5.7	0.29	2009
Carbofuran **CASRN** 1564662	Organic Pesticides Carbamate pesticides	No data	**1.8**	1989	No data	No data	No data
Chlordane	Organic Pesticides Organochlorine compounds	No data	~~**0.006**~~	1987	No data	No data	No data
Chlorothalonil **CASRN** 1897456	Organic Pesticides	No data	**0.18**	1994	No data	**0.36**	1994
Chlorpyrifos **CASRN** 2921882	Organic Pesticides Organophosphorus compounds	0.02	0.002	2008	NRG	0.002	2008
Chromium, hexavalent (Cr(VI)) **CASRN** 7440473	Inorganic	No data	**1**	1997	No data	**1.5**	1997
Chromium, trivalent (Cr(III)) **CASRN** 7440473	Inorganic	No data	**8.9**	1997	No data	**56**	1997
Chrysene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	No data	Insufficient data	1999	No data	Insufficient data	1999

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		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Colour **CASRN** N/A	Physical	No data	**Narrative**	1999	No data	**Narrative**	1999
Copper	Inorganic	No data	**Equation**	1987	No data	No data	No data
Cyanazine **CASRN** 2175462	Organic Pesticides Triazine compounds	No data	**2**	**1990**	No data	No data	No data
Cyanide	Inorganic	No data	**5 (as free CN)**	1987	No data	No data	No data
Debris **CASRN** N/A	Physical	No data	No data	No data	No data	**Narrative**	1996
Deltamethrin **CASRN** 52918635	Organic Pesticides	No data	0.0004	1997	No data	Insufficient data	1997
Deposited bedload sediment	Physical Turbidity, clarity and suspended solids Total particulate matter	No data	Insufficient data	1999	No data	Insufficient data	1999
Di(2-ethylhexyl) phthalate **CASRN** 117817	Organic Phthalate esters	No data	**16**	1993	No data	Insufficient data	1993
Di-n-butyl phthalate **CASRN** 84742	Organic Phthalate esters	No data	**19**	1993	No data	Insufficient data	1993
Di-n-octyl phthalate **CASRN** 117840	Organic Phthalate esters	No data	Insufficient data	1993	No data	Insufficient data	1993
Dibromochloromethane	Organic Halogenated aliphatic compounds Halogenated methanes	No data	**Insufficient data**	1992	No data	**Insufficient data**	1992
Dicamba **CASRN** 1918009	Organic Pesticides Aromatic Carboxylic Acid	No data	**10**	1993	No data	No data	No data
Dichloro diphenyl trichloroethane; 2,2-Bis(p-chlorophenyl)-1,1,1-trichloroethane DDT (total)	Organic Pesticides Organochlorine compounds	No data	~~**0.001**~~	1987	No data	No data	No data
Dichlorobromomethane	Organic Halogenated aliphatic compounds Halogenated methanes	No data	**Insufficient data**	1992	No data	**Insufficient data**	1992
Dichloromethane Methylene chloride **CASRN** 75092	Organic Halogenated aliphatic compounds Halogenated methanes	No data	**98.1**	1992	No data	Insufficient data	1992

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		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Dichlorophenols	Organic Monocyclic aromatic compounds Chlorinated phenols	No data	**0.2**	1987	No data	No data	No data
Diclofop-methyl **CASRN** 51338273	Organic Pesticides	No data	6.1	1993	No data	No data	No data
Didecyl dimethyl ammonium chloride DDAC **CASRN** 7173515	Organic Pesticides	No data	**1.5**	1999	No data	Insufficient data	1999
Diethylene glycol **CASRN** 111466	Organic Glycols	No data	**Insufficient data**	1997	No data	Insufficient data	1997
Diisopropanolamine DIPA **CASRN** 110974	Organic	No data	**1600**	**2005**	No data	**Insufficient data**	2005
Dimethoate **CASRN** 60515	Organic Pesticides Organophosphorus compounds	No data	**6.2**	1993	No data	Insufficient data	1993
Dinoseb **CASRN** 88857	Organic Pesticides	No data	0.05	1992	No data	No data	No data
Dissolved gas supersaturation **CASRN** N/A	Physical	No data	Narrative	1999	No data	Narrative	1999
Dissolved oxygen DO **CASRN** N/A	Inorganic	No data	**Variable**	1999	No data	**>8000 & Narrative**	1996
Endosulfan	Organic Pesticides Organochlorine compounds	0.06	0.003	2010	0.09	0.002	2010
Endrin	Organic Pesticides Organochlorine compounds	No data	~~**0.0023**~~	1987	No data	**No data**	No data
Ethylbenzene **CASRN** 100414	Organic Monocyclic aromatic compounds	No data	**90**	1996	No data	**25**	1996
Ethylene glycol **CASRN** 107211	Organic Glycols	No data	**192 000**	1997	No data	Insufficient data	1997
Fluoranthene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	No data	**0.04**	1999	No data	Insufficient data	1999

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		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Fluorene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	No data	**3**	1999	No data	Insufficient data	1999
Fluoride	Inorganic	No data	**120**	2002	No data	**NRG**	2002
Glyphosate **CASRN** 1071836	Organic Pesticides Organophosphorus compounds	No data	**65**	1989	No data	No data	No data
Heptachlor Heptachlor epoxide	Organic Pesticides Organochlorine compounds	No data	~~**0.01**~~	1987	No data	No data	No data
Hexachlorobenzene	Organic Monocyclic aromatic compounds Chlorinated benzenes	No data	**Insufficient data**	1997	No data	**Insufficient data**	1997
Hexachlorobutadiene HCBD **CASRN** 87683	Organic Halogenated aliphatic compounds	No data	**1.3**	1999	No data	No data	No data
Hexachlorocyclohexane Lindane	Organic Pesticides Organochlorine compounds	No data	**0.01**	1987	No data	No data	No data
Imidacloprid **CASRN** 13826413		No data	**0.23**	2007	No data	**0.65**	2007
Inorganic Mercury **CASRN** 7439976	Inorganic	No data	**0.026**	2003	No data	**0.016**	2003
Iron	Inorganic	No data	**300**	1987	No data	No data	No data
Lead	Inorganic	No data	**Equation**	1987	No data	No data	No data
Linuron **CASRN** 41205214	Organic Pesticides	No data	**7**	1995	No data	No data	1995
Methoprene **CASRN** 40596698		No data	**0.09 (Target Organism Management value: 0.53)**	2007	No data	Insufficient data	2007
Methyl tertiary-butyl ether MTBE **CASRN** 1634044	Organic Non-halogenated aliphatic compounds Aliphatic ether	No data	**10 000**	2003	No data	**5 000**	2003

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		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Methylchlorophenoxyacetic acid (4-Chloro-2-methyl phenoxy acetic acid; 2-Methyl-4-chloro phenoxy acetic acid) MCPA **CASRN** 94746	Organic Pesticides	No data	**2.6**	1995	No data	**4.2**	1995
Methylmercury	Organic	No data	**0.004**	2003	No data	NRG	2003
Metolachlor **CASRN** 51218452	Organic Pesticides Organochlorine compounds	No data	**7.8**	1991	No data	No data	No data
Metribuzin **CASRN** 21087649	Organic Pesticides Triazine compounds	No data	**1**	1990	No data	No data	No data
Molybdenum	Inorganic	No data	**73**	1999	No data	No data	No data
Monobromomethane Methyl bromide	Organic Halogenated aliphatic compounds Halogenated methanes	No data	**Insufficient data**	1992	No data	**Insufficient data**	1992
Monochlorobenzene **CASRN** 108907	Organic Monocyclic aromatic compounds Chlorinated benzenes	No data	**1.3**	1997	No data	**25**	1997
Monochloromethane Methyl chloride	Organic Halogenated aliphatic compounds Halogenated methanes	No data	**Insufficient data**	1992	No data	**Insufficient data**	1992
Monochlorophenols	Organic Monocyclic aromatic compounds Chlorinated phenols	No data	**7**	1987	No data	No data	No data
Naphthalene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	No data	**1.1**	1999	No data	**1.4**	1999
Nickel	Inorganic	No data	**Equation**	1987	No data	No data	No data
Nitrate **CASRN** 14797558	Inorganic Inorganic nitrogen compounds	No data	**13 000**	2003	No data	**16 000**	2003

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		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Nitrite	Inorganic Inorganic nitrogen compounds	No data	**60 NO_2-N**	1987	No data	No data	No data
Nonylphenol and its ethoxylates **CASRN** 84852153	Organic Nonylphenol and its ethoxylates	No data	**1**	2002	No data	**0.7**	2002
Nutrients		No data	**Guidance Framework**	2004	No data	**Guidance framework**	2007
Pentachlorobenzene **CASRN** 608935	Organic Monocyclic aromatic compounds Chlorinated benzenes	No data	**6**	1997	No data	**Insufficient data**	1997
Pentachlorophenol PCP	Organic Monocyclic aromatic compounds Chlorinated phenols	No data	**0.5**	1987	No data	No data	No data
Permethrin **CASRN** 52645531	Organic Pesticides Organochlorine compounds	No data	**0.004**	2006	No data	**0.001**	2006
Phenanthrene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	No data	**0.4**	1999	No data	Insufficient data	1999
Phenols (mono- & dihydric) **CASRN** 108952	Organic Aromatic hydroxy compounds	No data	**4**	1999	No data	No data	No data
Phenoxy herbicides 2,4 D; 2,4-Dichlorophenoxyacetic acid	Organic Pesticides	No data	**4**	1987	No data	No data	No data
Phosphorus	Inorganic	No data	**Guidance Framework**	2004	No data	**Guidance Framework**	2007
Picloram **CASRN** 1918021	Organic Pesticides	No data	**29**	1990	No data	No data	No data
Polychlorinated biphenyls PCBs	Organic Polyaromatic compounds Polychlorinated biphenyls	No data	~~**0.001**~~	1987	No data	~~**0.01**~~	1991
Propylene glycol **CASRN** 57556	Organic Glycols	No data	**500 000**	1997	No data	Insufficient data	1997
Pyrene PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	No data	**0.025**	1999	No data	Insufficient data	1999

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		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
pH	Inorganic Acidity, alkalinity and pH	No data	**6.5 to 9.0**	**1987**	No data	**7.0 to 8.7 & Narrative**	1996
Quinoline PAHs	Organic Polyaromatic compounds Polycyclic aromatic hydrocarbons	No data	**3.4**	1999	No data	Insufficient data	1999
Reactive Chlorine Species total residual chlorine, combined residual chlorine, total available chlorine, hypochlorous acid, chloramine, combined available chlorine, free residual chlorine, free available chlorine, chlorine-produced oxidants	Inorganic Reactive chlorine compunds	No data	**0.5**	1999	No data	**0.5**	1999
Salinity	Physical	No data	No data	No data	No data	**Narrative**	1996
Selenium	Inorganic	No data	**1**	1987	No data	No data	No data
Silver	Inorganic	No data	**0.1**	1987	No data	No data	No data
Simazine **CASRN** 122349	Organic Pesticides Triazine compounds	No data	**10**	1991	No data	**No data**	No data
Streambed substrate	Physical Turbidity, clarity and suspended solids Total particulate matter	No data	**Narrative**	1999	No data	**Narrative**	1999
Styrene **CASRN** 100425	Organic Monocyclic aromatic compounds	No data	**72**	1999	No data	No data	No data
Sulfolane Bondelane **CASRN** 126330	Organic Organic sulphur compound	No data	**50 000**	2005	No data	Insufficient data	2005
Suspended sediments TSS	Physical Turbidity, clarity and suspended solids Total particulate matter	No data	**Narrative**	1999	No data	**Narrative**	1999
Tebuthiuron **CASRN** 34014181	Organic Pesticides	No data	**1.6**	1995	No data	Insufficient data	1995
Temperature	Physical Temperature	No data	**Narrative**	1987	No data	**Narrative**	1996

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		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Tetrachloromethane Carbon tetrachloride **CASRN** 56235	Organic Halogenated aliphatic compounds Halogenated methanes	No data	**13.3**	1992	No data	Insufficient data	1992
Tetrachlorophenols	Organic Monocyclic aromatic compounds Chlorinated phenols	No data	**1**	1987	No data	No data	No data
Thallium	Inorganic	No data	**0.8**	1999	No data	No data	No data
Toluene **CASRN** 108883	Organic Monocyclic aromatic compounds	No data	**2**	1996	No data	**215**	1996
Toxaphene	Organic Pesticides Organochlorine compounds	No data	~~**0.008**~~	1987	No data	No data	No data
Triallate **CASRN** 2303175	Organic Pesticides Carbamate pesticides	No data	**0.24**	1992	No data	No data	No data
Tribromomethane Bromoform	Organic Halogenated aliphatic compounds Halogenated methanes	No data	**Insufficient data**	1992	No data	**Insufficient data**	1992
Tributyltin	Organic Organotin compounds	No data	**0.008**	1992	No data	**0.001**	1992
Trichloromethane Chloroform **CASRN** 67663	Organic Halogenated aliphatic compounds Halogenated methanes	No data	**1.8**	1992	No data	Insufficient data	1992
Trichlorophenols	Organic Monocyclic aromatic compounds Chlorinated phenols	No data	**18**	1987	No data	No data	No data
Tricyclohexyltin	Organic Organotin compounds	No data	Insufficient data	1992	No data	Insufficient data	1992
Trifluralin **CASRN** 1582098	Organic Pesticides Dinitroaniline pesticides	No data	**0.2**	1993	No data	No data	No data

CCME Comments or questions? Contact us at info@ccme.ca

Users are advised to consult the Canadian Environmental Quality Guidelines introductory text, factsheet, and/or protocols for specific information and implementation guidance pertaining to each environmental quality guideline.

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Triphenyltin	Organic Organotin compounds	*No data*	**0.022**	1992	*No data*	*No data*	1992
Turbidity	Physical Turbidity, clarity and suspended solids Total particulate matter	*No data*	**Narrative**	1999	*No data*	**Narrative**	1999
Uranium **CASRN** 7440-61-1	Inorganic	33	15	2011	**NRG**	**NRG**	2011
Zinc	Inorganic	*No data*	**30**	1987	*No data*	*No data*	*No data*

Chemical name	Chemical groups
No Chemicals with Data	

CCME Comments or questions? Contact us at info@ccme.ca

Canadian Environmental Quality Guidelines Summary Table

Users are advised to consult the Canadian Environmental Quality Guidelines introductory text, factsheet, and/or protocols for specific information and implementation guidance pertaining to each environmental quality guideline.

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Aluminium	Inorganic	No data	**Variable**	1987	No data	No data	No data
Ammonia (total)	Inorganic Inorganic nitrogen compounds	No data	**Table**	2001	No data	No data	No data
Arsenic **CASRN** none	Inorganic	No data	**5**	1997	No data	**12.5**	1997
Benzene **CASRN** 71432	Organic Monocyclic aromatic compounds	No data	**370**	1999	No data	**110**	1999
Boron	Inorganic	29,000µg/L or 29mg/L	1,500µg/L or 1.5mg/L	2009	NRG	NRG	2009
Cadmium **CASRN** 7440439	Inorganic	No data	**Equation**	1996	No data	**0.12**	1996
Copper	Inorganic	No data	**Equation**	1987	No data	No data	No data
Ethylbenzene **CASRN** 100414	Organic Monocyclic aromatic compounds	No data	**90**	1996	No data	**25**	1996
Iron	Inorganic	No data	**300**	1987	No data	No data	No data
Lead	Inorganic	No data	**Equation**	1987	No data	No data	No data
Nickel	Inorganic	No data	**Equation**	1987	No data	No data	No data
Nitrate **CASRN** 14797558	Inorganic Inorganic nitrogen compounds	No data	**13 000**	2003	No data	**16 000**	2003
Nitrite	Inorganic Inorganic nitrogen compounds	No data	**60 NO_2-N**	1987	No data	No data	No data
Phenols (mono- & dihydric) **CASRN** 108952	Organic Aromatic hydroxy compounds	No data	**4**	1999	No data	No data	No data

Comments or questions? Contact us at info@ccme.ca

Users are advised to consult the Canadian Environmental Quality Guidelines introductory text, factsheet, and/or protocols for specific information and implementation guidance pertaining to each environmental quality guideline.

		Water Quality Guidelines for the Protection of Aquatic Life					
		Freshwater			Marine		
		Concentration (µg/L)	Concentration (µg/L)	Date	Concentration (µg/L)	Concentration (µg/L)	Date
Chemical name	Chemical groups	Short Term	Long Term		Short Term	Long Term	
Phosphorus	Inorganic	*No data*	**Guidance Framework**	2004	*No data*	**Guidance Framework**	2007
Polychlorinated biphenyls PCBs	Organic Polyaromatic compounds Polychlorinated biphenyls	*No data*	~~**0.001**~~	1987	*No data*	~~**0.01**~~	1991
Selenium	Inorganic	*No data*	**1**	1987	*No data*	*No data*	*No data*
Silver	Inorganic	*No data*	**0.1**	1987	*No data*	*No data*	*No data*
Thallium	Inorganic	*No data*	**0.8**	1999	*No data*	*No data*	*No data*
Toluene **CASRN** 108883	Organic Monocyclic aromatic compounds	*No data*	**2**	1996	*No data*	**215**	1996
Turbidity	Physical Turbidity, clarity and suspended solids Total particulate matter	*No data*	**Narrative**	1999	*No data*	**Narrative**	1999
Uranium **CASRN** 7440-61-1	Inorganic	33	15	2011	**NRG**	**NRG**	2011
Zinc	Inorganic	*No data*	**30**	1987	*No data*	*No data*	*No data*

Chemical name	Chemical groups
No Chemicals with Data	

Appendix F

West 40 Landfill Drainage Management Review

City of Iqaluit Landfill Runoff Wetland Treatment Conceptual Design Report

City of Iqaluit
Landfill Runoff - Wetland Treatment
Conceptual Design Report

Prepared for:

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City of Iqaluit
P.O. Box 460
Iqaluit, Nunavut, X0A 0H0

Prepared by:

Earth Tech (Canada) Inc.
17203 – 103rd Avenue
Edmonton, AB T5S 1J4

February 21, 2007

Project No. 93107-04

Table of Contents

Section 1 Introduction

Section 2 Existing Conditions

Section 3 Wetland Systems

Section 4 Design Criteria

Section 5 Conceptual Design

Section 6 Recommendations & Implementation

References

List of Figures

List of Tables

SECTION 1

INTRODUCTION

BACKGROUND

The water license No. 3AM-IQA0611 Type "A" (Valid till May 15, 2011) issued to the City of Iqaluit by Nunavut Water Board, requires that the City of Iqaluit manage, collect and monitor the runoff from the West 40 Landfill site and adjacent Sludge Management Facility.

The City of Iqaluit produces approximately 10,000 cubic meters of compacted waste, which enters the landfill annually, including residential, commercial and industrial wastes. The landfill applies a surface water management system to divert off-site surface runoff from entering the site, and collect on-site surface runoff for a controlled discharge into the environment. West 40 landfill site development relies on the local permafrost regime to provide a low permeability barrier to control the subsurface runoff.

The on-site surface runoff is comprised of contaminated surface runoff originating from the melt water from the spring freshet and runoff from summer precipitation. The surface runoff sampling results in June 2006 suggest that the landfill runoff needs to be appropriately managed, and direct discharge into the environment should be controlled. The most feasible means to manage the landfill surface runoff is to treat runoff using an engineered solution. Wetland treatment of the runoff is an appropriate option for Iqaluit because of its passive mode, low maintenance requirements, and cost effectiveness in comparison with other available technologies. This process has been successfully applied to landfill runoff treatment in Southern Canada. The precedent for northern wetland systems was established by the Town of Fort Smith landfill wetland system, which was the first instant where a wetland treatment of landfill runoff has been incorporated into a northern community water licence (2003).

PROJECT SCOPE & OBJECTIVES

Earth Tech (Canada) Inc. was retained by the City of Iqaluit in 2006 for the "Solid Waste Disposal Facility (Landfill) Improvements" project. The scope of the project was to provide engineering consulting services for the management of the landfill surface runoff. Runoff collection and storage improvements were constructed in 2006. The next phase of the project is to engineer a runoff treatment process.

The first phase of the runoff treatment work is to develop a conceptual plan for a constructed wetland to treat on-site surface runoff from West 40 Landfill site.

This report addresses the following scope and objectives:

- To confirm the seasonal on-site surface runoff volume;
- To develop a wetland treatment concept to meet discharge guidelines;
- To evaluate the financial and technical considerations for these processes;
- To provide recommendations for the City of Iqaluit to implement a runoff treatment solution.

This report documents the conceptual level assessment of landfill runoff generation and wetland treatment suitable for the cold climate conditions. To assist with the completion of this report, the following background information was reviewed. The other documents cited in the report are listed in the Section References.

1. The average weather condition during 1971 to 2000 from Environment Canada (Appendix A).
2. The historical runoff quality parameter data and current water sampling data (Appendix B).
3. The Guidelines for the Discharge of Treated Municipal Wastewater in the Northwest Territories, 1992.
4. Nunavut Water Board Water Licence: City of Iqaluit, No.3AM-IQA0611 TYPE “A”, issued by Indian and Northern Affair Canada (INAC).

SECTION 2

EXISTING CONDITIONS

The existing on-site surface runoff management system consists of a series of continuous perimeter ditches associated primarily with perimeter berm structures (see Figure 2-1). The on-site runoff control ditches drain to several runoff control ponds. Two dedicated runoff storage ponds serve the existing landfill operating area, and two dedicated runoff storage ponds serve the landfill expansion area (see Figure 2-2). The ponds provide a control area where the runoff may be sampled and pumped into a runoff retention pond. The surface runoff in the retention pond will be pumped to the proposed runoff wetland area for treatment during the frost free period every year.

Figure 2-1. Continuous ditches formed with a perimeter berm structure to control on-site and off-site surface runoff at the West 40 landfill site in Iqaluit.

CLIMATE

Weather conditions influence wetland processes and the treatment performance, especially in cold climates. The engineering limitations in the design of constructed wetlands (CWs) in cold climates are the ice formation, hydrology and temperature effects on the biological and microbiological mediated treatment processes. However, these limitations may be overcome by design and operation of the system.

The average monthly temperatures in Iqaluit vary from 2.2 to 7.7 degree Celsius from June through September and -4.4 to -28 degree Celsius from October through May based on Environment Canada data in the period of 1971 to 2000. The average annual precipitation is 198 mm of rainfall and 236 cm of snowfall for a mean annual precipitation total of 412 mm. **Appendix A** presents detailed Canadian Climate Normals for Iqaluit from 1971 to 2000. Figure 2-3 shows the average monthly temperature from 1971 to 2000. The frost free period ranges from middle May to early September.

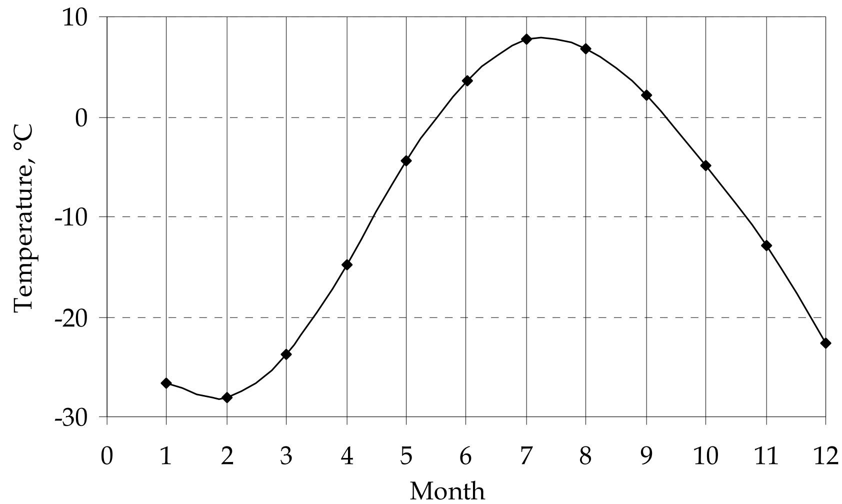

Figure 2-3. Average monthly temperature in Iqaluit from 1971 to 20000

LANDFILL RUNOFF CHARACTERIZATION

Landfill runoff sampling at the landfill site was completed in 2004 and 2006. The 2004 sampling was collected by the City of Iqaluit, and the 2006 sampling was completed by Earth Tech (Canada) Inc. The report "Runoff Sample Analysis – Comparison of 2004 and 2006 Samples" prepared on July 31, 2006 provides a detailed comparison of the 2004 and 2006 results (**Appendix B**).

The sampling results shows that the concentrations of many of the parameters have increased over the past two years, especially Aluminum (Al) concentration in 2006 increased to 5.01 mg/L from 0.048 mg/L detected in 2004 sample. The major parameters exceeding the Guidelines for the Discharge of Treated Municipal Wastewater in the Northwest Territories (1992) in 2006 sampling event are Biochemical Oxygen Demand (BOD_5), Total Suspended Solid (TSS) and metal contents including Aluminum, Iron, Copper, Lead, Manganese and Zinc.

DRAINAGE CONTROL PONDS AND RETENTION POND

Four drainage control ponds are located in the landfill area at West 40 Landfill site (see Figure 2-2). An existing pond was augmented by three new ponds in 2006. The total volume of these control ponds is approximately 3000 m³. A runoff retention pond was also constructed in 2006 as the area where accumulated runoff in the control ponds may be pumped to (Figure 2-4). The volume of the retention pond is approximately 5000 m³. Figure 2-5 shows a runoff control pond and Figure 2-6 shows the retention pond.

Figure 2-5. Runoff control pond (October 2006)

Figure 2-6. Drainage retention pond (October 2006)

The runoff retention pond was constructed in original ground with a compacted base. The base materials are typically loamy sands based on the grain size distribution. The loamy sand is a poorly graded material with limited permeability, and has significant fractions of silt and gravel sized materials (see Figure 2-7).

CONTAMINANT REMOVAL IN THE RETENTION POND

A portion of the runoff contaminants may be reduced by sedimentation and infiltration in the retention pond. Sedimentation of the suspended particulate matter to the base of the retention pond may occur in the quiescent conditions of the pond.

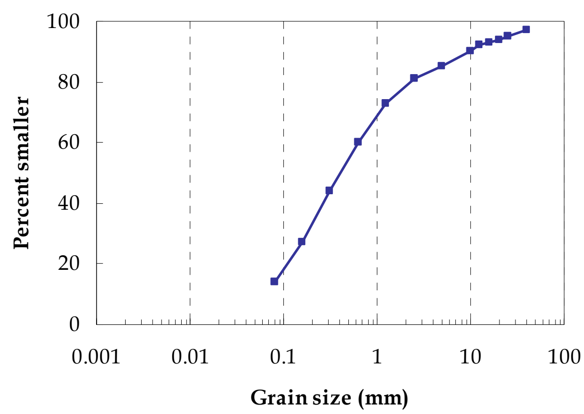

Figure 2-7. Grain size distribution of compacted base in the runoff retention pond

Infiltration into the base of the pond is another mechanism for the reduction of contaminants in the retention pond. The loamy sand base material has the capacity to allow the runoff to flow through the material and the contaminants reduced. The mechanisms of filtration, biodegradation and absorption/adsorption in the soil may reduce contaminants. Contaminant migration into the active layer may be limited by the permafrost regime, the permeability of the base material, and the removal mechanisms in the soil material.

AVAILABLE LAND AREA FOR WETLAND TREATMENT

The proposed wetland treatment area is located east of the runoff retention pond. The slope in the proposed wetland location is generally from west to east (see Figure 2-4), which provides a positive drainage slope by gravity for the proposed wetland. The actual slope required for the wetland depends on the hydraulic conductivity of selected bedding materials. The existing elevations of the runoff retention pond and the proposed wetland area are summarized in Table 2-1.

Table 2-1. Elevations of the proposed wetland location

Location	Elevation (m)	Notes
Top of runoff retention pond	13.5	
Bottom of runoff retention pond	11.0	
Inlet of wetland area	11.0	
Outlet of wetland area	9.0	Can be further extended to elevation of 7.0 m if more wetland area needed.

SECTION 3

WETLAND SYSTEMS

Both natural and constructed wetland systems have been used to treat a variety of wastewaters including runoff from landfills. The use of constructed wetland, rather than natural wetlands, may be preferred because constructed systems may be specifically engineered for the particular wastewater characteristics. Constructed wetlands allow a greater degree of control of substrate, vegetation types, flow characteristics, and flexibility in sizing. Constructed wetlands are engineered systems that have been designed and constructed to utilize the natural functions of wetland vegetation, soils, and their microbial populations to treat contaminants in various wastewater streams. Constructed wetlands also have significantly lower lifecycle costs than conventional treatment systems, and may be operated using less power and less labor.

Constructed wetlands are categorized into two main groups: surface flow (SF) and subsurface flow (SSF). Figure 3-1 shows the detail of typical constructed wetland cells for SF and SFF. Factors to be considered include land area availability, capital cost, runoff composition concentrations, and the potential public health risks. Unlike a natural wetland system in which hydrology is largely fixed by the tolerance limits of the existing plant community, a constructed wetland may be designed to regulate water depth and retention time based on the influent quality.

This section will discuss two options for a constructed wetland system for the treatment of on-site surface runoff generated from the Iqaluit landfill site. The advantages and disadvantages of the options will also be discussed in this section. Section 4 will discuss the design criteria for wetland treatment of runoff in Iqaluit, and the mechanisms for removal of contaminants by wetland treatment.

OPTION 1: SURFACE FLOW WETLAND

A constructed SF wetland is a shallow, engineered pond (about 30 cm deep) that is planted with local emergent and rooted vegetation. Runoff is introduced at one end and flows across the wetland area to the discharge point.

The emergent plants of SF wetlands are not harvested to remove nutrients. Instead, the natural assimilative capacity of the microbial flora (bacteria and fungi) that attach to the plants, provides efficient and reliable removal of biodegradable organics and nitrogen (ammonia and nitrate). Metals and phosphorus may be sequestered in plant materials and wetland sediments. Most of the treatment is a function of the microbial, physical and chemical action rather than plant uptake; therefore, these processes may occur during cold weather.

OPTION 2: SUBSURFACE FLOW WETLAND

SSF wetlands are gravel or organic soil based systems, in which the wastewater substrate passes through the permeable media. The flow is subsurface in and around the roots of the wetland plants. Flow through the media may also be horizontal flow, referred as subsurface horizontal-flow wetland; or vertically downward, referred as subsurface vertical-flow wetland. The large surface area of the media and the plant roots provides sites for microbial activity, and SSF systems use many of the same emergent plant species as SF systems.

SSF wetland systems have better performance in cold weather because most of the treatment occurs below the ground surface where the treatment processes are less affected by cold air temperatures. In addition, media based systems have relatively low in maintenance requirements and are less likely to have odor and mosquito problems in comparison with SF wetlands. When properly designed, media based wetland systems have high removing efficiency rates for biodegradable organic matter and nitrate-nitrogen.

A consideration that makes the SSF system attractive is the reduced potential for human contact with partially treated wastewater, which reduces public health concerns.

SELECTION OF WETLAND PROCESS

The advantage and disadvantage of SF wetland and SSF wetland are compared in Table 3-1. As previously discussed, on-site surface runoff is collected and stored in the runoff retention pond before discharge to the wetland. The suspended solids will be reduced by sedimentation in the retention pond (as discussed in section 2), therefore, the clogging may not be a significant operational problem for subsurface flow (SSF) wetlands. Since the wetland may be only operated during the frost free period every year in Iqaluit, the snow or ice insulation of SF wetland is not an advantage over SSF system.

There are some general considerations for the design of a constructed wetland, and every wetland system is site-specific and the assistance of an experienced wetland designer is critical to the success of a wetland project. Some key components to consider are:

- Available land area
- Available vegetation
- Available soil materials
- Contaminant removal objectives
- Operating window dictated by freezing conditions
- Hydraulic retention time (HRT)
- Gravity flow availability
- Nuisance controls (i.e. mosquito and odour control)
- Maintenance and self-sustainability

Table 3-1. Comparison of surface flow and subsurface flow wetlands

Wetlands	Advantages	Disadvantages
Surface flow	• Minimal clogging problems • Air stripping potential of organic toxic contents • Snow/ice cover as an insulation	• More area than SSF • Potential air quality degradation
Subsurface flow	• Less area need than SF • Better contact between soil and water • Greater thermal protection than SF	• Tendency of plugging of pore space • Higher cost than SF for a certain pollutant mass removal

For Iqaluit, the proposed wetland treatment system will be located adjacent to the existing landfill site. The available and optimal location is the area east of the runoff retention pond, which is sloped from west to east. An existing stream just north of this area may be used for effluent discharge. The runoff stored in the retention pond will be pumped to the wetland inlet by setting up a potable pump over the berm structure.

As stated in Section 2, the average temperature from June to September is approximately 5ºC with an average daytime high of 11.6 ºC and an average overnight low of -0.4 ºC. The construction of a SSF system will reduce or eliminate the potential of the runoff freezing. Layers of snow, ice, and organic materials will provide an insulating barrier to the cold. This may help to extend the wetland operation period from May to October.

To meet the perspective discharge criteria, it is important to design the wetland system with a hydraulic retention time (HRT) sufficient to reduce the organic contaminant and nitrogen concentrations under cold water temperature conditions. This will require additional land area as compared to a system operated with a warmer water temperature. The minimum HRT is 7 to 10 days for SF wetlands and 2 to 4 days for SSF wetlands. Based upon this criterion, the land area required for a SF wetland system will be at least twice as large as a SSF wetland system.

The porous media of SSF wetland will provide more contact area between contaminants and microbes/medium particles. The contaminants will first partition from the liquid phase into the solid phase, and then be absorbed by the plant roots. The SSF wetland systems have a higher removal efficiency for biodegradable organic matter and nitrate-nitrogen than SF wetland system in comparing the areal removal rate constant (Kadlec and Knight 1996).

Considering the advantages and disadvantages listed in Table 3-1, and the local conditions in Iqaluit, a SSF wetland system is recommended for Iqaluit landfill surface runoff treatment process. This conclusion is supported by the conceptual process information from Riparia Aquatic Ltd., a wetland treatment specialist. The technical memo from Riparia regarding the wetland conceptual design for the City of Iqaluit is presented in **Appendix C**.

SECTION 4
DESIGN CRITERIA

WATER QUALITY PARAMETERS

Wetland performance may be characterized by contaminant concentration reduction, by mass reduction or by areal load reduction. There are no guidelines for treated landfill surface runoff in Nunavut. The benchmark conditions on the treated discharge are the discharge limits for Sewage Lagoon effluents of the City of Iqaluit Water Licence issued by NWB, 2006. The major parameters are summarized in Table 4-1.

Table 4-1. Proposed treated wetland outflow water quality parameters

Parameters	Limits of Water Licence	Maximum Concentration of Any Grab Sample
BOD_5 (mg/L)	120	180
TSS (mg/L)	180	270
Oil and Grease	No visible sheen	

The following paragraphs discuss the removal potential of major contaminants contained in the runoff by constructed wetlands in general.

TOTAL SUSPENDED SOLIDS

Suspended solids are principally removed in a wetland system by physical filtration processes. Both surface flow (SF) and subsurface flow (SSF) wetland systems effectively remove suspended solids from contaminated water. Suspended solids within SSF system may block the pores or bedding media, and as a result, will decrease the hydraulic conductivity or the flow through the system, especially near the inlet.

ORGANICS - BOD

Organic matter is removed in the wetland systems by deposition and filtration for settleable BOD, and by microbial metabolism for soluble BOD. The removal efficiencies for BOD_5 vary significantly depending on the organic loading rates, dissolved oxygen concentration, water temperature, bedding media and plant species. The oxygen sources for these reactions are important for the efficient removal of organic matters. The major oxygen source in surface flow wetlands is aeration at the water surface. However, the water mixing at the surface will be reduced by the vegetation and snow or ice cover. Oxygen conveyed through the plant root system supports the aerobic microbial activity adjacent to roots. The average temperature from June to September of 5ºC in Iqaluit will lower biological activity, which ultimately means a decreased oxygen transfer efficiency and lower biochemical activity. This may be compensated by providing a longer hydraulic retention time and a lower hydraulic loading rate for the proposed wetland.

METALS

Metals are removed by cation exchange to wetland sediments, precipitation as insoluble salts and plant uptakes. The major concerned metals are Iron, Zinc, Copper, Aluminum and Lead in Iqaluit, based on the 2006 sampling results. The average removals of these metals were reported in the range of 50 to 90 percent by constructed wetlands in the literature.

NUTRIENTS – N & P

The reduction of nutrients, nitrogen (N) and phosphorus (P) requires the longest hydraulic retention time of any of the anticipated pollutants. The phosphorus concentration measured in 2006 sampling event was 0.8 mg/L, which is lower than the Canadian Guideline 1.0 mg/L. For most wetland treatment, P is not regarded as an important pollutant; however, P is a required supplement to support biological processes.

The total nitrogen concentration was measured 20.7 mg/L as Kjeldahl Nitrogen (TKN) for the 2006 sampling event, which includes organic nitrogen and ammonia. The nitrite (NO_2^- -N) and nitrate (NO_3^- -N) are less than 0.07 mg/L, which is not a concern. The NWT guidelines (1992) do not provide a discharge limit on the ammonia, however, ammonia in wastewater effluent may be deleterious to fish in the receiving water body if the concentration is more than 0.2 mg/L. A certain level of ammonia removal is expected from a SSF wetland. However, it is not possible to achieve high total nitrogen removal in cold climate constructed wetland without adding supplemental oxygen for nitrification, and carbon sources for denitrification.

HYDRAULIC DESIGN PARAMETERS

The retention pond provides storage for runoff generated from landfill site during the period of October through May. It is anticipated that the wetland treatment for the retention pond accumulation will be operated during the frost free period of June through September.

SURFACE RUNOFF VOLUME

Based on the monthly precipitation from November through May (8 months), the average total precipitation is 161 mm. The total landfill area (existing and new area) is approximately 48,000 m^2; therefore, the anticipated total volume of runoff generated from snowfall is approximately

7,700 m^3. During the summer and fall months (June through October), the anticipated surface runoff volume is approximately 6,600 m^3 (Table 4-2), assuming that 50% precipitation will retain in the runoff control ponds and retention pond.

A significant portion of the summer and fall runoff will infiltrate into the landfill subsurface, therefore, the surface runoff volume generated will be much less than the amount shown in Table 4-2. Assuming fifty percent (50%) of rainfall precipitation accumulates into surface runoff, the runoff control ponds and the retention pond have enough capacity for storing the surface runoff from landfill site for spring runoff. The actual runoff resulting from summer and fall precipitation and stored in the control ponds and the retention pond may be monitored as part of the on-going facility operations. Summer runoff may be directed through the wetland with retention.

Table 4-2. Surface Runoff Volume Projection at Landfill Site (1971 to 2000)

	November to May	June to October
Precipitation (mm)	161	252 *
Estimated runoff volume (m^3)	7,700	6,600

Note: * 50% precipitation was used to estimate the runoff volume.

HYDRAULIC RETENTION TIME (HRT)

Hydraulic retention time for constructed wetlands is typically in the range of 1 to 10 days. The HRT for the proposed SSF wetland system is 4 days to maximize the removal of the contaminants based on the local conditions, as recommended by Riparia (Appendix C) and Alberta Environment guidelines.

HYDRAULIC LOADING RATE

Hydraulic loading rate is a primary design factor for constructed wetlands. The selection of an appropriate design loading rate should be based on several factors, including treatment objectives, wetland used for levels of treatment, wetland types (SF or SSF), and safety factors. Since constructed wetlands technology is a variable science, the facility may be conservatively designed with low loading rates. The average loading rates for wetland treatment of municipal wastewater is approximately 3 cm/day. Considering the cold climate and runoff parameters at the landfill site, the proposed design hydraulic loading rate is 2.5 cm/day.

SECTION 5
CONCEPTUAL DESIGN

Based on the information in the preceding sections of this report, it is possible to develop a conceptual design for the selected SSF wetland. The design of the wetland will include the sizing of wetland, a pumping system to pump runoff from the retention pond to the wetland, the plant selection suitable for the local climate and removal of contaminants, bedding materials, and the reduction of suspended materials in the retention pond.

The proposed approach to the facility design is to complete a pilot study to determine the performance of the wetland system. A series of sampling tests will be needed to determine the surface runoff water characteristics in the retention pond and the wetland itself over the duration of the wetland operating season.

CONCEPTUAL DESIGN OPTIONS

Based on the discussion in Section 4, the estimated surface runoff volumes are 7,700 m^3 from November to May and 6,600 m^3 for June to October. Runoff testing to meet the guidelines of NWT, may provide some flexibility in the discharge strategies. The potential total runoff treatment needs for the wetland may be up to 14,300 m^3 per year.

It should be pointed out that these volume numbers are based on the following assumptions:

- Average precipitation will occur as the statistics from Environment Canada.
- All the snow runoff will be collected and stored in the drainage control ponds and the retention pond.
- Fifty percent of summer rainfall runoff will filtrate into the landfill area and 50% will flow into the control ponds.
- There is no peak factor selected due to the buffer capacity of the retention pond.

Table 5-1 compares the referred guidelines for the proposed wetland discharge with Environment Canada guidelines and Alberta Environment guidelines. The current discharge limits for BOD_5 and TSS from Sewage Lagoon in Water Licence of the City of Iqaluit are the same as those in NWT guidelines. The more strict guidelines may be warranted within the next 10 or 20 years. In 2005, Yukon government prepared Draft Interim Guidelines for Community Wastewater Discharges, which is intended to help communities in the planning of new and upgraded sewage treatment systems to comply with the Canada-wide Strategy. The Canada-wide Strategy for wastewater discharge will include all the provinces and territories.

Based on the above assumptions, the proposed wetland system may be implemented as follows:

- Phase 1 surface runoff volume 7,700 m^3 with phase 2 expansion (6,600 m^3) in the future.

Table 5-1. Comparison of Guidelines of Treated Wastewater Discharge in Canada

Guidelines	NWT Guidelines [3]	Yukon Interim Guidelines [7]	Environment Alberta [4]	Environment Canada [5]
BOD_5, mg/L	120	45	25 [1]	20
TSS, mg/L	180	60	25 [1]	25
TP, mg/L	Site specific	-	1 [2]	1 [6]
NH_3^+-N, mg/L	-	-	Site specific	-
Fecal coli., cfu/100 mL	-	20,000	200	400
Iron, mg/L	0.3	-	-	-
Zinc, mg/L	0.5	-	-	-
Aluminum, mg/L	2.0	-	-	-
Lead, mg/L	0.05	-	-	-

[1] Population < 20,000;
[2] Populations > 20,000;
[3] Guidelines for the Discharge of Treated Municipal Wastewater in the NWT, 1992 (Season: Summer, 150-600 Lcd, Receiving Environment: Marine/Bay);
[4] Standards and Guidelines for Municipal Waterworks, Wastewater and Storm Drainage System, Alberta Environment, 2006;
[5] Guidelines for Effluent Quality and Wastewater Treatment at Federal Establishments, 1976, Report EPS-1-EC-76-1, Federal Activities Environmental Branch;
[6] Applicable when phosphorus removal is required.
[7] Draft 2005 Interim Guidelines for Communities Wastewater Discharge, Yukon Environment, 2005.

CONSTRUCTED WETLAND STRUCTURE

The proposed wetland will be a subsurface flow wetland with permeable soil matrix growing medium as discussed in Section 3. Runoff will be introduced via perforated head pipe to a gravel flow dispersion trench. Runoff will permeate through the side of the flow spreader trench, through a peat bed, then into the permeable medium. The sacrificial peat bed will buffer the wetland against spike concentrations of contaminants (Figure 5-1). Since there is a slope from the inlet to the discharge point of the proposed wetland area, the SSF will be designed as a horizontal subsurface flow. The design slope will be calculated based on the anticipated hydraulic conductivity of available materials for the bedding media. At the outlet of the wetland, another gravel trench will be placed with a perforated pipe. The treated runoff may then be discharged to a stream on the northeast corner of proposed SSF wetland (See Figure 2-4).

NATURE IN ACTION

The ability of wetlands to remove contaminants from water relies on the emergent plants, which play a key role in a wetland treatment process. Plants provide an oxygen source to help sustain aerobic conditions in the wetland, and plant roots provide passages for water to filtrate through the bedding media.

As water slowly flows through a wetland, pollutants are removed through physical, chemical, and biological processes. The physical processes include entrapment, sedimentation and adsorption. The biological processes include nitrification and denitrification, the uptake of nutrients and metals by plants, and by organisms that occupy on the bedding media. The different species of organisms and plants may have markedly different success depending on factors such as type and toxicity of individual pollutant, water level and temperature.

WETLAND SIZING

The performance of a constructed wetland for contaminant removal often depends on the proper interaction among hydraulic retention time (HRT) and flow, contaminant compositions, vegetation and seasonal temperatures. It is difficult to determine the exact area needed for effective treatment of runoff since specific hydraulic and pollution fluctuations, as well as varying local climatic conditions have to be taken into consideration. There are two methods to estimate the preliminary area for the constructed wetland. One method is to use the model based on reaction kinetics developed by Kadlec and Knight (1996). The other method is to calculate the land area required using the selected hydraulic loading rate. **Appendix D** illustrates the model and calculation used in this report to estimate the land area required for wetland construction.

PHASE 1: RUNOFF 7,700 M^3

Reaction Model Method of Area Determination

Kadlec and Knight provided a model to determine the preliminary area requirements based on desired effluent quality, first areal rate constants and background limits of the contaminants. To achieve a conservative estimate of land area required, modeling was conducted on BOD and TSS. The other factors can be used in modeling are TP, TN, ammonia, and organic nitrogen. However, the sampling programs conducted in 2004 and 2006 shown that the results of these parameters are below the guidelines of NWT, 1992. **Appendix D** presents the detail calculation using this model.

The land area calculated is 840 m^2 to meet the BOD discharge guideline 120 mg/L. Should the BOD discharge concentration be 45 mg/L (as in 2005 Yukon Interim), the area required is 2,070 m^2.

Hydraulic Loading Rate Method of Area Determination

The hydraulic loading rate is assumed to be 2.5 cm/day (0.025 m^3/m^2/day) for optimal removal efficiency (as discussed in Section 4). Therefore, the area estimated for surface runoff treatment during average 105 frost free days is

$$(7700\ m^3) / (105\ days) / (0.025\ m^3/m^2/d) = 2940\ m^2$$

The land area required for a SSF wetland system to treat 7,700 m^3 of surface runoff, as sampled in June 2006, is approximately 2,940 m^2.

PHASE 2: ADDITIONAL 6,600 M³ TO A TOTAL OF 14,300 M³

Reaction Model Method of Area Determination

As the same method used in Phase 1, the required land area is 720 m^2 for a 120 mg/L BOD discharge limitation. If the discharge limit of BOD is 45 mg/L, the total land required for a wetland treatment system will be 1,770 m^2 to meet the BOD discharge guideline.

Hydraulic Loading Rate Method of Area Determination

The hydraulic loading rate is assumed to be 2.5 cm/day (0.025 m^3/m^2/day) for optimal removal efficiency. Therefore, the area needed for surface runoff during average 105 frost free days is

$$(6600\ m^3) / (105\ days) / (0.025\ m^3/m^2/d) = 2520\ m^2$$

The wetland sizing estimated by above two methods was quite different. The land area required to treat 6,600 m^3 of runoff is estimated to be 2,520 m^2 by selecting larger land area. This wetland system will also meet the land area required for the future BOD discharge limit as discussed above.

MODEL COMPARISONS

Comparing the reaction model method with hydraulic loading rate method, the difference for the calculated land area to treat the same runoff volume is significant. The calculated land area by the reaction model method is the area required to treat BOD to meet the effluent guidelines as indicated in Appendix D, BOD is the governing parameter based upon its larger area requirement.

The temperature has significant effect on the reaction rate model based on van't Hoff Arrhenius equation, where K_{T1} and K_{T2} are first-order rate constants at temperature T1 and T2 (see Appendix D).

$$K_{T1} = K_{T2} \cdot \theta^{(T1-T2)}$$

The rate constant and temperature coefficient in the calculation are based on the broad range of study results, not specifically for the cold climate. Therefore, these parameters may not represent the actual biochemical reaction and rate constants in the proposed wetland system, particularly the temperature coefficient, θ.

The land area requirement calculated from hydraulic loading rate is much larger than the land area calculated from the reaction model. In order to be conservative, the larger land area requirements will be applied to the proposed wetland system during the conceptual design. The pilot study results will allow for an optimization of the wetland system based upon the local conditions.

CONCEPTUAL LEVEL COST ESTIMATE

A conceptual level cost estimate of various components has been completed for the two phases of the wetland (Table 5-2). The spreadsheet showing the breakdown of this cost estimate is presented in **Appendix E**. The total construction cost for both phases does not include capital for land acquisition since it is assumed that the land for the wetland is the property of City of Iqaluit.

Table 5-2. Cost Estimation of Proposed Wetland System

Wetland Component	Phase 1	Phase 2
Wetland Construction	$ 176,550	$ 173,425
Vegetation	$ 9,000	$ 8,316
Pumping system	$ 10,000	$ 10,000
Engineering contingency (40%)	$ 78,220	$ 76,696
Total construction cost estimate	**$ 273,770**	**$ 268,437**

SECTION 6

RECOMMENDATIONS & IMPLEMENTATION

RECOMMENDATIONS

It was recommended that the subsurface flow wetland system be designed to treat the surface runoff from the landfill site of Iqaluit, as discussed in Section 3. Horizontal flow may be designed to utilize the slope of the wetland area.

Based on the information presented in this report, Iqaluit may develop the wetland system for the treatment of landfill on-site surface runoff in two phases. Phase 1 will have a 7,700 m^3 treatment capacity to meet the current discharge quality requirement. Phase 2 will have a 6,600 m^3 treatment capacity for the future process improvements. During the pilot operation, by collecting the water quality parameters of the wetland influent and discharge, the operation of the wetland treatment system will be monitored and evaluated for the need of Phase 2 expansion.

It is important to point out that wetland technology is still in a developing phase, and it is not possible to predict the ultimate wetland performance.

IMPLEMENTATION

The conceptual design for Iqaluit West 40 Landfill site surface runoff provides a practical and valuable solution for the management and protection of water bodies surround the landfill site. Following the recommendations made within this report, the next steps are:

1) Submit the conceptual design report for regulators' review;
2) Monitoring the quality of runoff contained in control ponds and the retention pond;
3) Complete preliminary engineering for the pilot program (Phase 1) for the proposed wetland treatment;
4) Complete detailed design and tendering for Phase 1 and construction;
5) Operate the Phase 1 facility and monitor results;
6) Plan for facility optimization based on Phase 1 results.

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Appendix A

City of Iqaluit Weather Climate Normals

from Environment Canada

(1971 - 2000)

Climate Normals for City of Iqaluit from 1971 to 2000

(Data adapted from Environment Canada)

Temperature: Temperature:	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Daily Average (°C)	-26.6	-28	-23.7	-14.8	-4.4	3.6	7.7	6.8	2.2	-4.9	-12.8	-22.7	
Standard Deviation	5	3.8	3.7	2.6	2.1	1.7	1	0.9	1.1	2.5	3.6	4.7	
Daily Maximum (°C)	-22.5	-23.8	-18.8	-9.9	-0.9	6.8	11.6	10.3	4.7	-2	-8.9	-18.5	
Daily Minimum (°C)	-30.6	-32.2	-28.6	-19.6	-7.8	0.3	3.7	3.3	-0.4	-7.7	-16.7	-26.9	
Extreme Maximum (°C)	3.9	4.4	3.9	7.2	13.3	21.7	**25.8**	25.5	17.2	7.3	5.6	3.4	
Date (yyyy/dd)	1958/21	1965/22	1955/19	1981/23	1954/30	1955/22+	**2001/28**	1991/08	1964/03+	1981/05	1952/19	2001/29	
Extreme Minimum (°C)	-45	**-45.6**	-44.7	-34.2	-26.1	-10.2	-2.8	-2.5	-12.8	-27.1	-36.2	-43.4	
Date (yyyy/dd)	1953/24+	**1967/10+**	1991/01	1983/10	1949/02	1978/02	1961/03	1996/31	1965/30	1978/30	1978/18+	1993/30	
Rainfall (mm)	0.1	0	0	0.2	2.8	24.7	59.2	64.8	41.5	4.5	0.5	0	
Snowfall (cm)	22.8	16.8	25.3	32.4	25.1	9.8	0.1	0.8	13.7	34.9	32.4	21.7	
Precipitation (mm)	21.1	15	21.8	28.2	26.9	35	59.4	65.7	55	36.7	29.1	18.2	
Average Snow Depth (cm)	22	23	25	29	18	2	0	0	0	6	16	20	13
Median Snow Depth (cm)	21	23	25	28	16	1	0	0	0	6	15	19	13
Snow Depth at Month-end (cm)	23	25	29	27	10	0	0	0	1	10	21	21	14
Extreme Daily Rainfall (mm)	2.5	2	0.5	5.1	11.7	28.4	**52.8**	48.2	40.4	23.3	11.9	0.5	
Date (yyyy/dd)	1958/21	1963/03	1958/09	1950/20	1986/14	1961/30	**1968/14**	1995/08	1979/01	1985/24	1955/01	1963/16	
Extreme Daily Snowfall (cm)	30.7	**32.2**	24.6	21.8	29.5	19.2	3.6	6.2	21.3	20.6	27.9	21.8	
Date (yyyy/dd)	1958/18	**1981/12**	1973/08	1973/07	1965/09	1984/09	1970/08	1981/29	1946/26	1961/08	1960/24	1951/03	
Extreme Daily Precipitation (mm)	30.7	27.4	23.9	23.9	27.4	30.2	**52.8**	48.2	40.4	27.2	27.9	21.8	
Date (yyyy/dd)	1958/18	1981/12	1953/29	1973/07	1965/09	1980/06	**1968/14**	1995/08	1979/01	1985/25	1960/24	1951/03	
Extreme Snow Depth (cm)	57	74	69	**86**	86	43	1	3	15	33	52	48	
Date (yyyy/dd)	1977/15+	1956/27	1963/01+	**1958/30**	1958/01+	1987/02	1978/01+	1957/24+	1992/29	1961/29+	1989/27	1958/23	

Appendix B

Surface On-site Runoff Wastewater

Quality Data and Report

City of Iqaluit
Solid Waste Disposal Facility (Landfill) Improvements

Runoff Sample Analysis – Comparison of 2004 and 2006 Samples

July 31, 2006

INTRODUCTION

Earth Tech (Canada) Inc. was retained by the City of Iqaluit for the "Solid Waste Disposal Facility (Landfill) Improvements" project. The scope of the project is to provide engineering consulting services for the landfill expansion, and onsite and offsite drainage improvements.

According to the City's Water License (3AM-IQA0611 Type "A; valid till May 15, 2011), the City has to submit an annual report to the Nunavut Water Board highlighting the collection and analysis of samples from a specified location at landfill. As a part of the project scope/license requirement, Earth Tech collected a sample of runoff in duplicate from the City's landfill on June 28, 2006.

This report provides a summary of sample results, and their comparison with the 2004 sample results. The purpose is to determine the change in runoff quality over the time.

SAMPLING HISTORY

The 2004 sample was collected by the City (Geoff Baker, Manager of Capital Projects) on July 6, and was shipped on the same day to the PSC Analytical Services, Ontario. Figure 1 shows the location of sampling points.

The 2006 sample was collected in duplicate by Earth Tech on June 28 from the sampling point that corresponds to "× 103" on Figure 1. The samples were transported to Edmonton on the same day, and delivered at the Norwest Labs (Edmonton) on the morning of June 29.

SAMPLING DATA AND DISCUSSION

Table 1 presents a summary of the sample results. The results are compared with the Guidelines for the Discharge of Treated Municipal Wastewater in the Northwest Territories, 1992, considering values for summer season with a rate of 150-600 Lcd and a marine/bay as the receiving environment.

CONCLUSIONS AND RECOMMENDATIONS

The results show that the concentrations of two thirds of measured runoff parameters are within the MWWE Guidelines. The concentrations of many of the parameters have increased over the past two years. The parameters that currently exceed the MWWE Guidelines are TSS, BOD_5, $Fe_{dissolved}$, Al_{total}, Cu_{total}, Pb_{total}, Mn_{total} and Zn_{total}.

The most significant increase is in the Al_{total} concentration, which has increased over 100 times from the concentration detected in the 2004 sample. Other significant increases have occurred in the concentration of TSS, BOD_5, Cu_{total}, Sn_{total} and V_{total}. It should be noted that the results comparison is based upon no consideration of the potential errors in 2004 sample results arising from no sample preservation before shipping to the laboratory, and high temperature at the time of receiving by the laboratory (9°C).

Overall, the historic runoff sample results suggest that the landfill runoff needs to be appropriately managed, and direct discharge into the environment should be controlled.

Table B-1. Comparison of runoff samples in 2004 and 2006

Runoff Discharge Parameter	Units	Runoff Sample Results		MWWE Guidelines[1]
		Jul-04	Jun-06	
pH	pH units	7.41	7.52	6.5 - 8.5[2]
Specific Conductivity	µmoh/cm	1667.0	2050.0	
Iron (dissolved), Fe^-	mg/L	0.2	0.7	0.3*
Chloride, Cl^-	mg/L	215.0	249.0	
Nitrite Nitrogen, NO_2-N	mg/L	<0.2	<0.02	
Nitrate Nitrogen, NO_3-N	mg/L	<0.2	<0.05	
Ammonia Nitrogen, NH_3-N	mg/L	4.42		
Kjeldahl Nitrogen (TKN)	mg/L		20.7	
Phosphate, PO_4^{-3}	mg/L	<0.1	0.8	
Sulphate, SO_4^{-2}	mg/L	398.0	307.0	500.0*
Sulfur, S	mg/L		105.0	
Phenols	mg/L	4.42		
Mercury, Hg	mg/L	<0.0001	0.0001	0.0006
Biochemical Oxygen Demand, BOD_5	mg/L	5.2	269	120.0
Oil and Grease	mg/L	2		
Total Suspended Solids, TSS	mg/L	32.0	868.0	180.0
Total Dissolved Solids (Calc.), TDS	mg/L		1330.0	
Hardness	mg/L		660.0	
Silver, Ag_{total}	mg/L	<0.0001	0.0006	0.1
Aluminum, Al_{total}	mg/L	0.048	5.01	2.0
Antimony, Sb_{total}	mg/L	0.0051	0.0238	
Arsenic, As_{total}	mg/L	0.002	0.018	0.05
Boron, B_{total}	mg/L	0.71	1.06	5.0*
Barium, Ba_{total}	mg/L	0.035	0.12	1.0*
Beryllium, Be_{total}	mg/L	<0.001	<0.0002	
Bismuth, Bi_{total}	mg/L	<0.001	<0.001	
Bromide, Br	mg/L	2.3		
Calcium, Ca_{total}	mg/L	166	203	
Cadmium, Cd_{total}	mg/L	0.0024	0.0024	0.005*
Cobalt, Co_{total}	mg/L	0.0055	0.0024	0.1*
Copper, Cu_{total}	mg/L	0.0229	0.294	0.2*
Chromium, Cr_{total}	mg/L	<0.005	0.0241	0.1
Iron (total), Fe_{total}	mg/L	8.86	12.8	
Lead, Pb_{total}	mg/L	0.0191	0.0993	0.05*
Lithium, Li_{total}	mg/L		0.02	
Magnesium, Mg_{total}	mg/L	26.7	49±	
Manganese, Mn_{total}	mg/L	0.903	1.02	0.05*
Molybdenum, Mo_{total}	mg/L	0.006	<0.001	0.2
Nickel, Ni_{total}	mg/L	0.016	0.0226	0.3*
Phosphorous, P_{total}	mg/L	0.25	0.8	Site-Specific
Potassium, K_{total}	mg/L	36.8	61.7	
Sodium, Na_{total}	mg/L	125.0	207.0	
Selenium, Se_{total}	mg/L	<0.002	0.0009	0.05

Runoff Discharge Parameter	Units	Runoff Sample Results		MWWE Guidelines[1]
		Jul-04	Jun-06	
Silicon, Si_{total}	mg/L		9.42	
Strontium, Sr_{total}	mg/L	0.8600	1.0100	
Tin, Sn_{total}	mg/L	0.001	0.02	5.0
Titanium, Ti_{total}	mg/L	<0.005	0.382	
Thallium, Tl_{total}	mg/L	<0.00005	<0.0001	
Uranium, U_{total}	mg/L	<0.0001	<0.001	
Vanadium, V_{total}	mg/L	<0.0005	0.01	
Zinc, Zn_{total}	mg/L	15.2	0.763	0.50
Zirconium, Zr_{total}	mg/L		0.005	

Notes:

[2] Water License requirement.

* Dissolved content.

the concentration of runoff discharge parameter exceeds the MWWE guidelines.

no specific guidelines are available.

no results are available.

Appendix C

Technical Memo

Iqaluit Landfill Leachate Treatment Wetland Cell Conceptual Design

By Riparia Aquatic, Wetland and Shoreland Environments

Date:	October 12, 2006	Project #:	93107-04
To:	Ken Johnson	cc:	

From: Bernie Amell
Riparia Aquatic, Wetland and Shoreland Environments
#202, 403 - 30th Ave NE, Calgary AB T2E 9B3

Subject: Iqaluit Landfill Leachate Treatment Wetland Cell Conceptual Design

The following are my recommendations based on available site area of 2000 sq m.

Limiting issues will be temperature and high BOD loads. High nutrient loads are not anticipated. Advice by Earth Tech that heavy metals and other industrial chemicals are not evident.

Leachate should be stored in a pond area throughout the cold period. Releases to the treatment wetland would be pumped, when the leachate is at 5 degrees C. Propose creating a subsurface flow wetland with 0.5m deep permeable soil growing medium. Permeable medium will be mix of sand, fine gravel and peat. Local sedges and wetland mosses will be established on the surface.

Leachate would be introduced via perforated header pipe to gravel flow spreader trench wrapped with geotextile. Liquid will permeate into the side of the flow spreader trench, through a “sacrificial” peat bed of 3 meters width, then into the permeable medium. The sacrificial bed will buffer the main wetland against spike concentrations of hazardous materials.

The subgrade and surface of the permeable medium will be sloped to induce horizontal flow within the soil voids, without liquid emerging to surface. Slope will be calculated when information on locally available materials allows estimation of hydraulic conductivity. At the downstream end there will be another gravel trench wrapped with geotextile and with a perforated weeping tile pipe. This will drain to the recirculation/release vault. A small pump in this vault may continuously recirculate 1/2 volume of the leachate, providing an opportunity entrain atmospheric oxygen to improve BOD removal performance of the system. The remaining half volume will be released as treated leachate.

Capacity Calculations

12 weeks (84 days) of flow
Permeable soil medium assumed to have 25% voids @ 0.5m depth = 0.125 m^3 liquid/m^2 wetland area
Desirable 4 day hydraulic retention time (HRT).
84 / 4 = 21 cycles per year
21 X 0.125 = 2.625 m^3 / m^2 net hydraulic loading per treatment bed surface area
Subtract assumed net precipitation/evaporation per bed area (0.325 m) = 2.3 m^3 net hydraulic loading per year

If 2000 m^2 area is available, assume 75% as effective treatment bed area, then
total treated capacity = 1500 X 2.3 = 3450 m^3 leachate per year.

Please verify the basis of my assumptions – and provide other feedback.
Thanks!

Appendix D

Wetland Sizing

Subsurface Flow (SSF) Treatment Wetland
Preliminary Feasibility Calculation Sheet

Phase 1
(BOD limit = 120 mg/L)

Location: **City of Iqaluit West 40 Landfill Site**

Runoff Volume, m^3 7,700

Design Flow, m^3/d Q= 73

		TSS	BOD	TP	TN	NH_4^+-N	Org-N
Influent Concentration	Ci =	868	269	0.8	20.7	4.42	16.21
Target Effluent Concentration	Ce =	180	120				
Wetland background limit, mg/L	C* =	62	18	0.05	2	0	1.5

for TSS, C* = 7.8 + 0.063Ci

for BOD, C* = 3.5+0.053Ci

Areal rate constant **@ 20^{o}C**, m/yr.	k =	3000	180	12	27	18	17
Required wetland area, ha	A =	0.0017	0.0134				

$$A = \left[\frac{0.0365 \times Q}{k}\right] \times \ln\left(\frac{C_i - C^*}{C_e - C^*}\right)$$

maximum calculated area from above boxes (Amax) = 0.013 ha

= 134 m^2

	θ =	1.050	1.130	1.000	1.050		
Areal rate constant **@ 5^{o}C**, m/yr.	k =	1443	29	12	13		
Required wetland area, ha	A =	0.0036	0.0836				

maximum calculated area from above boxes (Amax) = 0.084 ha

= 836 m^2

use van't Hoff Arrhenius equation: $K_{T1} = K_{T2} \cdot \theta^{(T1-T2)}$

Effluent concentration, mg/L

via k-C* model	Co @ maximum area =	62	78	1	17	4	18

$$C_o = C^* + (C_i - C^*)\exp\left[-\frac{kA_{max}}{0.0365 \times Q}\right]$$

Subsurface Flow (SSF) Treatment Wetland
Preliminary Feasibility Calculation Sheet

Phase 2
(BOD limit = 120 mg/L)

Location: **City of Iqaluit West 40 Landfill Site**

Runoff Volume, m^3: 6,600

Design Flow, m^3/d: Q= 63

		TSS	BOD	TP	TN	NH_4^+-N	Org-N
Influent Concentration	Ci =	868	269	0.8	20.7		
Target Effluent Concentration	Ce =	180	120				
Wetland background limit, mg/L	C* =	62	18	0.05	2	0	1.5

for TSS, C* = 7.8 + 0.063Ci

for BOD, C* = 3.5+0.053Ci

Areal rate constant **@ 20°C**, m/yr.	k =	3000	180	12	27	18	17
Required wetland area, ha	A =	0.0015	0.0115				

$$A = \left(\frac{0.0365 \times Q}{k}\right) \times \ln\left(\frac{C_i - C^*}{C_e - C^*}\right)$$

maximum calculated area from above boxes (Amax) = 0.011 ha

= 115 m^2

	θ =	1.050	1.130	1.000	1.050		
Areal rate constant **@ 5°C**, m/yr.	k =	1443	29	12	13		
Required wetland area, ha	A =	0.0031	0.0717				

maximum calculated area from above boxes (Amax) = 0.072 ha

= 717 m^2

use van't Hoff Arrhenius equation: $$K_{T1} = K_{T2} \cdot \theta^{(T1-T2)}$$

Effluent concentration, mg/L

via k-C* model	Co @ maximum area =	62	78	1	16	0	2

$$C_o = C^* + (C_i - C^*)\exp\left(-\frac{kA_{max}}{0.0365 \times Q}\right)$$

Subsurface Flow (SSF) Treatment Wetland
Preliminary Feasibility Calculation Sheet

Phase 1
(BOD limit = 45 mg/L)

Location: **City of Iqaluit West 40 Landfill Site**

Runoff Volume, m^3: 7,700

Design Flow, m3/d: Q= 73

		TSS	BOD	TP	TN	NH_4^+-N	Org-N
Influent Concentration	Ci =	868	269	0.8	20.7	4.42	16.21
Target Effluent Concentration	Ce =	45	45				
Wetland background limit, mg/L	C* =	62	18	0.05	2	0	1.5

for TSS, C* = 7.8 + 0.063Ci

for BOD, C* = 3.5+0.053Ci

		TSS	BOD	TP	TN	NH_4^+-N	Org-N
Areal rate constant @ **20°C**, m/yr.	k =	3000	180	12	27	18	17
Required wetland area, ha	A =	-	0.0330				

$$A = \left(\frac{0.0365 \times Q}{k}\right) \times \ln\left(\frac{C_i - C^*}{C_e - C^*}\right)$$

maximum calculated area from above boxes (Amax) = 0.033 ha

= 330 m^2

		TSS	BOD	TP	TN	NH_4^+-N	Org-N
	θ =	1.050	1.130	1.000	1.050		
Areal rate constant @ **5°C**, m/yr.	k =	1443	29	12	13		
Required wetland area, ha	A =	-	0.2066				

maximum calculated area from above boxes (Amax) = 0.207 ha

= 2066 m^2

use van't Hoff Arrhenius equation: $K_{T1} = K_{T2} \cdot \theta^{(T1-T2)}$

Effluent concentration, mg/L

		TSS	BOD	TP	TN	NH_4^+-N	Org-N
via k-C* model	Co @ maximum area =	62	42	0	10	4	18

$$C_o = C^* + (C_i - C^*)\exp\left(-\frac{kA_{max}}{0.0365 \times Q}\right)$$

Subsurface Flow (SSF) Treatment Wetland
Preliminary Feasibility Calculation Sheet
Phase 2
(BOD limit = 45 mg/L)

Location: **City of Iqaluit West 40 Landfill Site**

Runoff Volume, m^3 6,600

Design Flow, m3/d Q= 63

		TSS	BOD	TP	TN	NH_4^+-N	Org-N
Influent Concentration	Ci =	868	269	0.8	20.7	4.42	16.21
Target Effluent Concentration	Ce =	45	45				
Wetland background limit, mg/L	C* =	62	18	0.05	2	0	1.5

for TSS, C* = 7.8 + 0.063Ci

for BOD, C* = 3.5+0.053Ci

Areal rate constant @ **20°C**, m/yr.	k =	3000	180	12	27	18	17
Required wetland area, ha	A =	-	0.0283				

$$A = \left[\frac{0.0365 \times Q}{k}\right] \times \ln\left(\frac{C_i - C^*}{C_e - C^*}\right)$$

maximum calculated area from above boxes (Amax) = 0.028 ha

= 283 m^2

	θ =	1.050	1.130	1.000	1.200		
Areal rate constant @ **5°C**, m/yr.	k =	1443	29	12	2		
Required wetland area, ha	A =	-	0.1771				

maximum calculated area from above boxes (Amax) = 0.177 ha

= 1771 m^2

use van't Hoff Arrhenius equation: $K_{T1} = K_{T2} \cdot \theta^{(T1-T2)}$

Effluent concentration, mg/L

via k-C* model	Co @ maximum area =	62	42	0	20	4	18

$$C_o = C^* + (C_i - C^*)\exp\left[-\frac{kA_{max}}{0.0365 \times Q}\right]$$

Appendix E

Conceptual Level Cost Estimation

Conceptual Level Cost Estimation

			Phase 1		Phase 2	
Runoff Volume	m^3		7700		6600	
land area required	m^2		2934		2518	
	Unit	Unit Price	Quantity	Extension	Quantity	Extension
Common excavation to waste disposal	m^3	$ 15.00	3000	$ 45,000	2520	$ 41,580
Control Berm	m^3	$ 20.00	410	$ 8,200	380	$ 8,360
Ditch	m	$ 40.00	300	$ 12,000	250	$ 11,000
Bedding materials						
Permeable Medium (mix of sand, fine gravel and peat)	m^3	$ 50.00	1500	$ 75,000	1260	$ 75,600
Gravel	m^3	$ 40.00	75	$ 3,000	70	$ 3,360
Peat	m^3	$ 30.00	150	$ 4,500	130	$ 3,900
Geotextile	m^2	$ 5.00	270	$ 1,350	250	$ 1,375
Culvert 200 mm	m	$ 150.00	50	$ 7,500	50	$ 8,250
Mobilization				$ 20,000		$20,000
Subtotal				**$ 176,550**		**$ 173,425**
Vegetation	m^2	$ 3.00	3000	$ 9,000	2520	$ 8,316
Pump and temporary piping				$ 10,000		$ 10,000
Subtotal				**$ 195,550**		**$ 191,741**
Engineering Contingency (40%)				$ 78,220		$ 76,696
Total				**$ 273,770**		**$ 268,437**

Notes:

Assume 20% increase of the base price for all the components at Phase 2.

Appendix G

West 40 Landfill Drainage Management Review

Membrane Bioreactor Technology Report

City of Iqaluit Landfill Surface Runoff Treatment -
Membrane Bioreactor Technology

Prepared by Earth Tech Canada, April 24, 2007
Ken Johnson, M.A.Sc., P.Eng., Project Manager

Introduction

Earth Tech has prepared this letter report at the request of the City of Iqaluit regarding the use of mechanical wastewater treatment technology for treating the West 40 landfill runoff. The purpose of this letter report is to provide information for the City to compare with the proposed wetland treatment system. In March 2007, Earth Tech Canada submitted a Conceptual Design Report recommending the use of subsurface flow wetland system for landfill runoff treatment.

The Membrane Bioreactor (MBR) technology was chosen as an alternative process because it represents an advanced biological and membrane coupled process that has been successfully applied for the treatment of a wide range of industrial and municipal wastewaters (Stephenson et al., 2000). The applications include old or stabilized landfill leachates, as it may be the case with landfill runoff from the West 40 Landfill site.

This letter report is intended to develop the basis for the conceptual design of the MBR system and to illustrate the system process along with order of magnitude capital and operational costs.

MBR Process

MBR technology offers an alternative process which replaces two stages of the conventional activated sludge process (ASP) (biotreatment and settlement) with a single, integrated suspended growth biological reactor and membrane clarification step. Using membranes in biological wastewater treatment reactors offers the potential to overcome operational problems experienced with conventional ASP treatment, such as:

1. relatively large land areas for the bioreactors,
2. downstream solids separation by sedimentation, increasing the land area further,
3. the requirement to equalize hydraulic and organic loadings to maintain a constant treated effluent quality, and
4. inhibition of the solids settling process by “bulking”, i.e. the inhibition of sedimentation by filamentous microorganisms,

In addition, MBR technology consistently produces a high quality effluent. The high biomass concentration in the reactor reduces both bioreactor tank size and sludge production, and enables influent of varying quality to be treated while maintaining a disinfected final effluent. Furthermore, an increased rate of nitrification may be achieved since a large amount of slow-growing nitrifying bacteria may be retained in the aeration tank.

MBR Configuration

The MBR process may be configured with the membrane unit located either external to the bioreactor (SideStream - SS) or mounted directly within it (submerged or IMmersed - IM) (see Figure 1).

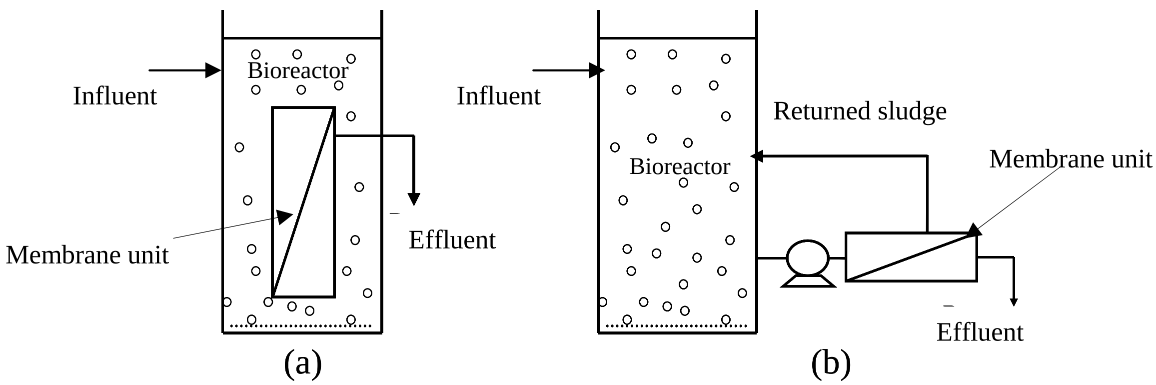

Figure 1. Two MBR configurations: (a) immersed (Im) and (b) Sidestream (SS).

In the SS configuration, a high cross flow fluid velocity (between 2 and 4.5 m/s) provided by a recirculation pump reduces the deposition of suspended solids at the membrane surface. Although this configuration is simple and provides more direct control of fouling of the membrane, the energy demand is relatively high. This configuration has the longest history and is primarily used for industrial wastewater treatment. From the early 1990s, Im MBR systems have been introduced and preferred to SS configuration for treating municipal wastewater on a larger scale. The IM configuration relies on coarse bubble aeration to produce in-tank recirculation and reduces fouling of the membrane. Although the energy demand of the IM system may be up to 2 orders of magnitude lower than that of SS systems, IM systems operate at a low flow, demand more membrane area, and rely on coarse bubble aeration. The membranes themselves may have tubular or flat configuration. Membranes used for MBR application have pore sizes ranging from the ultrafiltration (UF) range (0.01 to 0.1 µm) to microfiltration (MF) range (from 0.1 µm up to 1 µm).

A hollow fiber UF membrane system may be appropriate as a proposed membrane system for Iqaluit landfill runoff treatment.

Water quality parameters and design considerations

A common basis of design for MBRs during the treatment of landfill runoff are Volumetric Loading Rates (VLRs) for carbonaceous material (measured as COD) and ammonia nitrogen, along with “fouling” potential indexes of organic and inorganic contaminants. Since none of these parameters are available in the existing laboratory analyses of the landfill runoff, the quality was assumed to be similar to a typical old landfill leachate. Runoff sampling results from July 2004 and June 2006 were compared to old landfill leachate matrices shown in literature reviews. (Table 1).

Table 1. Average leachate runoff quality vs. key characteristics of old leachates.

Parameter	***City of Iqaluit Runoff***	***Robinson (1995)***	***Irene and Lo (1996)***	***Urbini et al. (1999)***
pH	7.5	7.5	7.9 – 8.1	8
BOD (mg/L)	120 – 180	260	160	150
TSS (mg/L)	180 – 270	ND*	ND*	ND*
NH_4^+ (mg/L)	4.42	5 – 370	26 – 557	10 – 40
Metal values (mg/L)	0.09 – 15	0.1 – 26.5	0.7 – 24	0.03 – 25.9
Chlorides (mg/L)	215 – 250	70 – 2,780	2 – 119	180 – 2,650

ND*: No available data.

Experiences of MBRs treating old leachates show that a membrane flow of 5 L/m^2/h is common and have a low impact on membrane fouling (Alvarez-Vazquez et al., 2004). Therefore, 5 L/m^2/h was chosen as the membrane flux value of the proposed conceptual design. A hydraulic retention time (HRT) value of 5 days was also chosen to counteract the biological impact on the biomass at low operating temperatures in Iqaluit. Such a HRT lies slightly above reported data for old leachate treatment where contaminant removals of up to 80% for COD have been observed at HRTs between 2 – 3 days. It is expected that only a partial reduction of nitrogen compounds may be achieved due to the low operating temperatures. Metals and TSS will be completely removed as they will either be assimilated by the biomass or physically retained by the membrane.

Bioreactor volume

According to the calculations shown in the Conceptual Design Report for Wetland Treatment, leachate runoff volumes are estimated to be 7,700 m^3 for Phase 1. Such flow is to be treated during summer periods, thus a period of 120 days was selected to perform the total treatment of the runoff. The MBR capacity will be approximately 65 m^3/d; therefore, a total bioreactor volume basin of 325 m^3 is required to conform to the predetermined 5 days HRT.

Membrane surface area

The required membrane surface area is calculated considering the most critical conditions of peak influent flow and lowest temperature. Because the influent flow is fixed, temperature becomes the dictating design factor. A minimum water temperature of 5°C was used for the operating period, along with a correction factor for water viscosity at that temperature. The membrane area is 755 m^2 to comply with a 5 $L/m^2/h$ flux, corresponding to 24 membrane modules with individual areas of 31.6 m^2 per module.

MBR configuration schematic

The proposed MBR corresponds to the immersed (IM) configuration, and a general schematic showing the complete process is shown in Figure 2. The system is integrated with anoxic and aerobic reactor tanks for nitrogen removal.

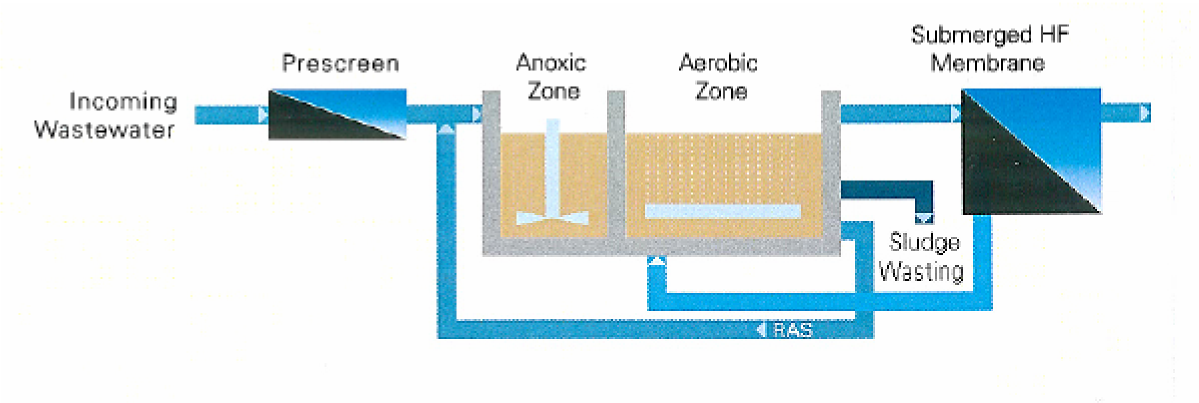

Figure 2. Immersed MBR configuration, including nitrogen removal steps.

Cost Estimate

The cost estimate for the MBR system treating Iqaluit landfill runoff have been projected based on previous old leachate experiences, and are an "order of magnitude" estimates only for one season of operation (i.e. 120 days) (Table 2). The estimate is 2.4 million dollars including a 40% contingency allowance for construction and engineering services.

The capital costs are equipment costs including membrane modules, feed pumps, permeate/recirculation pumps and chemical cleaning pumps, blowers, air diffusers, mixers, valves, fittings, controls and control panel with remote access capabilities. In order to obtain more detailed costs and to recommend spare parts and membrane replacements; membrane cleaning frequency, and volumes of chemicals and nutrients needed, a comprehensive chemical and physical analysis of the leachate runoff matrix would be required.

Due to the simplicity of operation for MBRs, manpower requirements are similar or even less than a conventional wastewater treatment plant. The cost for manpower to the cost associated with one 8 hour shift in a 40-hour week for one operator for the annual operating period of 120 days. One operator is sufficient to fulfill with standard operational and maintenance needs of the MBR, such as valve replacements, water sampling, nutrient dosing, data collection and in situ membrane chemical cleaning. Major events such as ex-situ membrane cleaning or membrane replacements will require anywhere from 2 to 4 operators.

Table 2. Estimated costs of the proposed immersed MBR system

Item No.	Component	Estimated cost (Million $)
1	Complete MBR system	1.6
2	Operation and maintenance costs and operator time	0.1
3	Contingency allowance (40%)	0.7
4	Total estimate	2.4

Note: Item 2 includes electrical and mechanical standard spare parts replacement, chemical reagents for periodical cleaning and nutrient dosing.

Summary

The proposed MBR system will produce wastewater effluent exceeding the discharge guideline for the landfill runoff treatment in Iqaluit, provided the MBR system is operated and maintained as required from the manufacture specifications. However, the City will face challenges associated with the MBR system for landfill runoff treatment.

Challenge 1 – Higher capital costs and operation/maintenance costs

Challenge 2 – The maintenance of MBR system during the off-season, since the MBR system will be only operating from a period of 120 days per year. The membrane system needs to be well maintained during 245 days of the rest of the year.

Challenge 3 – The treatment of wasted sludge. Normally, the costs associated with sludge treatment for the MBR could be in the same order of magnitude as the capital cost of MBR system itself.

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Appendix H

West 40 Landfill Drainage Management Review

WESATech Proposal Iqaluit Landfill Runoff

WESA Technologies Inc.
The Tower, The Woolen Mill, 4 Cataraqui Street
Kingston, Ontario, Canada K7K 1Z7
Tel: 613-531-2725 Fax: 613-531-1852
Email: wesaking@wesa.ca www.wesa.ca

City of Iqaluit
Attn: Meagan Leach
Director of Engineering and Sustainability
PO Box 460
Iqaluit, NU
X0A 0H0

Dear Ms. Leach,

WESA Technologies is pleased to submit a proposal to design, build and operate a small treatment facility to manage the volume of water contained in the Iqaluit landfill runoff detention pond. The objective of this exercise is to reduce the volume contained in the pond by treating and discharging it to the environment. The primary treatment goal is to reduce the concentration of the iron, manganese and zinc. This will be achieved through pH adjustment and coagulation.

Design and Process

The proposed design will consist of a two-stage chemical treatment, solid filtration and neutralization step, all carried out in a continuous process. The treatment of 5000m^3 will be conducted within a 3 week period. A process flow diagram of our proposed treatment facility is attached.

In the first chemical treatment stage, a calcium hydroxide solution (lime, CaOH) will be added to raise the pH of the runoff water to 10.5 – 11.5 in order to induce the precipitation of the metals. Further, the first and second chemical treatment stages are air mixed to promote the oxidation of the iron and manganese in the solution. The oxidation of these metals leads to their precipitation out of the solution. In the second chemical treatment stage, aluminum sulfate (Alum, $KAl(SO_4)_2$) and polymer (Magnafloc® 338) will be added to flocculate the precipitated metals into larger, filterable particles. The effluent from the second chemical treatment stage is clarified by filtration using a Geotube® to remove suspended solids. The metal solid waste will be contained within the Geotube® and can be returned to the pond or appropriately containerized and transported for disposal at a suitably engineered facility. The filtered water will enter a final neutralization tank to achieve a pH between 7 and 8. This final pH adjustment will be conducted with the addition of hydrochloric acid (HCl). While the plant is in operation, we will be monitoring for the three parameters of concern in the discharge; total iron concentration, total zinc concentration and total manganese concentration, as well as pH and Total Suspended Solids (TSS).

Cost

The cost for the associated plant equipment and consumables (pumps, tanks, Geotube®, piping, fittings, and chemicals for one season) and its transportation is estimated to be $75,000. This does not include the cost of manpower (time and expenses on site). Also, this does not cover the cost of field analytical equipment or sample analysis at a water testing laboratory. From the city of Iqaluit, we will require

WESAtech
A Better Environment For Business

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Email: wesaking@wesa.ca www.wesa.ca

a shipping container to store all the required gear over the winter season as well as a power supply to operate the electrical equipment. This system can readily be commissioned seasonally to treat the spring and fall landfill runoff volumes projected over the next few years with a treatment cost of $10,000 for consumables for each additional treatment event. The treatment system will be operated by two people. WESA Technologies will provide an operator ($1000/day plus expenses). The Municipality of Iqaluit can provide an additional support person to assist with the operation of the plant and to be trained in the treatment process or WESA Technologies can provide a second operator.

Cost Summary

Initial Capital Cost: $75,000
Operator Time and Expenses per Seasonal Treatment and Discharge Event: $25,000
Supplies for Subsequent Season Treatment Event: $10,000
All prices exclude applicable taxes.

Schedule

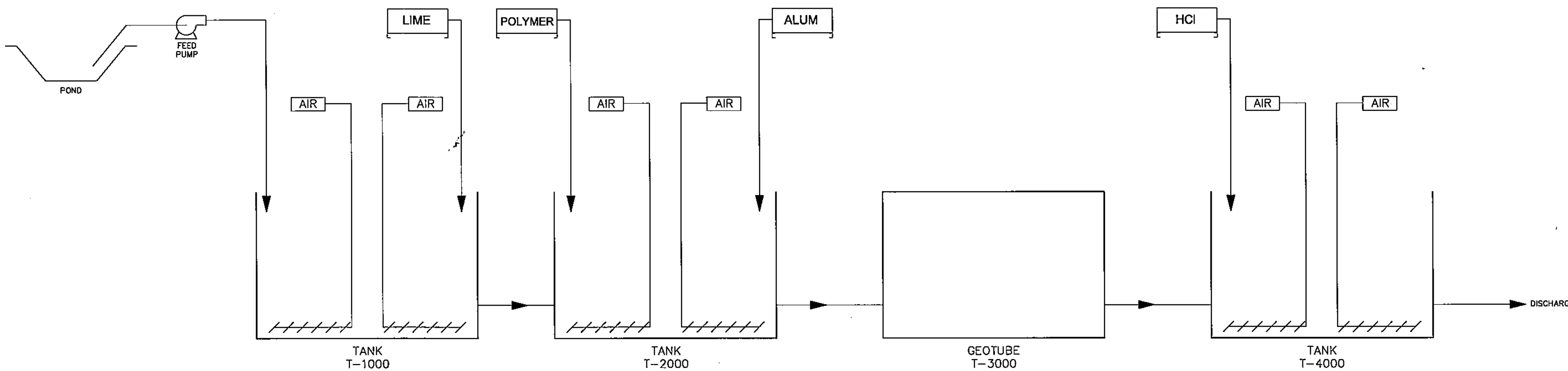
Upon approval, equipment and supplies will be airlifted to Iqaluit within 2 weeks. Construction and commissioning will proceed immediately and is anticipated to be ready to discharge within one week. Discharge will only commence with the approval of the regulatory agents.

Thank you for contacting WESA Technologies to provide support to AECOM and the Municipality of Iqaluit in resolving their landfill runoff discharge concerns. We hope that this provides sufficient information to support your decision to proceed with this innovative and effective time sensitive solution to the current retention pond capacity and landfill runoff discharge issue. Please feel free to contact me if you require any additional information or clarification.

Regards,

Harry Marshall CET
President, WESA Technologies Inc.

Wayne Ingham, PhD
Principal, WESA Inc.



1 **PROCESS FLOW DIAGRAM**
Scale: N.T.S.

NOT FOR CONSTRUCTION

REV	DESCRIPTION	DATE	APPROVED
A	DRAFT	201007-22	HM

REVISIONS

WESA Technologies Inc.
The Tower, The Woolen Mill
Kingston, Ontario, Canada
K7K 1Z7
Tel: 613-531-2725

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CLIENT:	PWGSC
PROJECT TITLE:	Iqaluit Landfill Leachate Treatment
DRAWING NAME:	
DRAWING TITLE:	Simplified Process Flow Diagram
PO #:	
SCALE:	AS NOTED
PROJECT MANAGER:	H.MARSHALL
PROJECT NUMBER:	WT-////
DESIGNED BY:	DSc/HM
DRAWN BY:	R.E.M.
VERIFIED BY:	HM
REVISION:	C
DRAWING No:	P-1