City of Iqaluit
Landfill Runoff - Wetland Treatment
Conceptual Design Report

Prepared for:

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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.

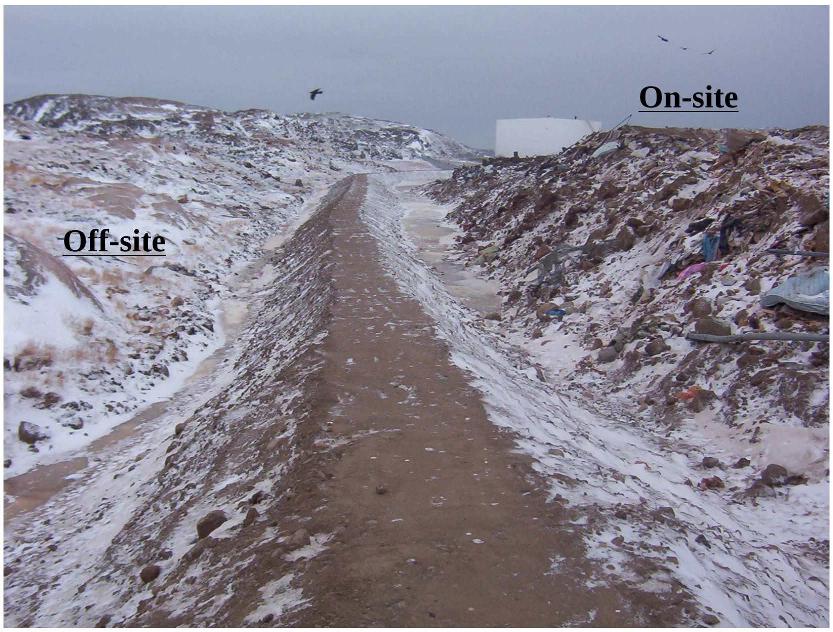

Figure 2-1. Continuous ditches formed with a perimeter berm structure to control on-site and off-site surface runoff at the West 40 landfill site in Iqaluit.

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.

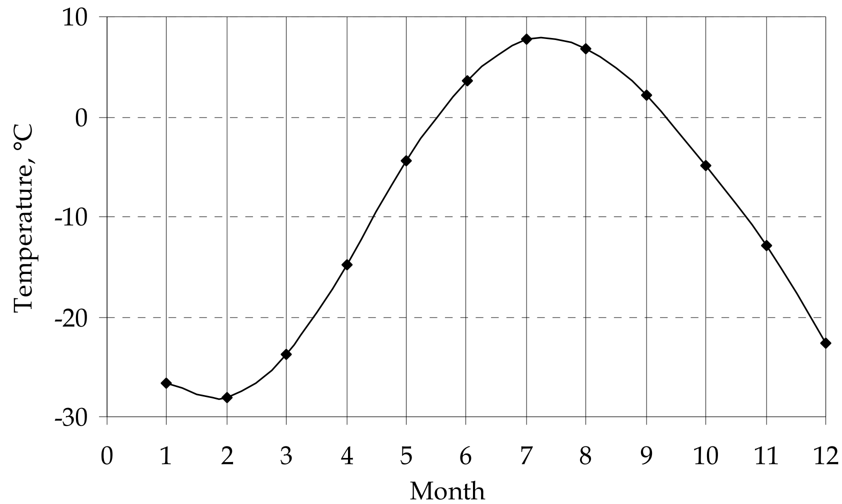

Figure 2-3. Average monthly temperature in Iqaluit from 1971 to 20000

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 m^3. 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 m^3. 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).

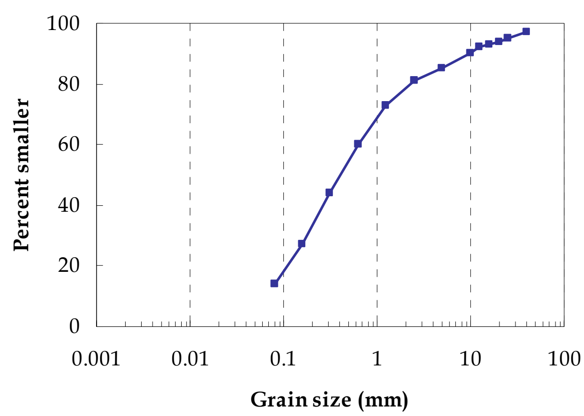

Figure 2-7. Grain size distribution of compacted base in the runoff retention pond

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.

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

		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 =	0.0017	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

		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 =	0.0036	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

		TSS	BOD	TP	TN	NH_4^+-N	Org-N
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 @ **20ºC**, 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 @ **5ºC**, 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

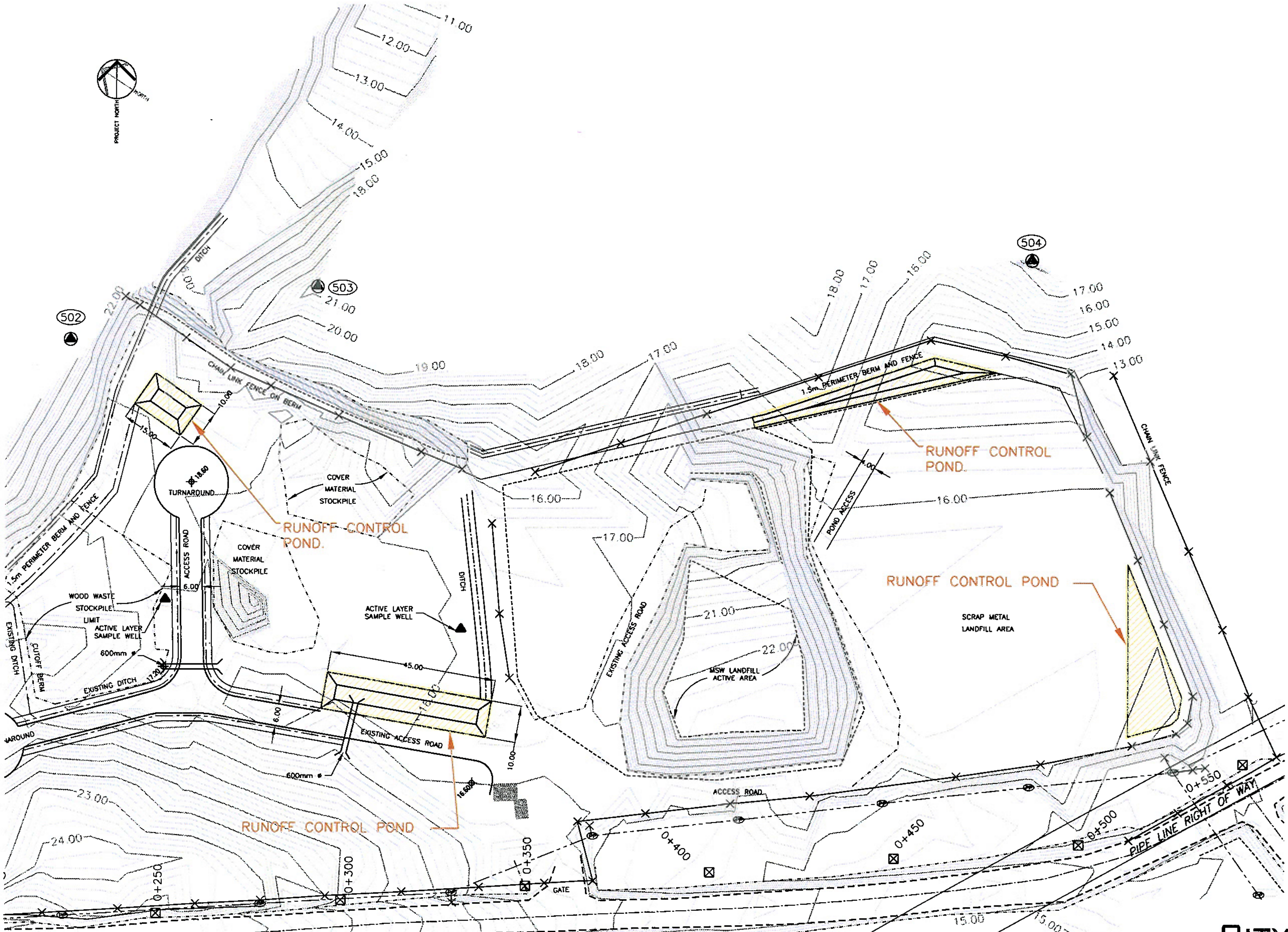
Conceptual Level Cost Estimation

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:

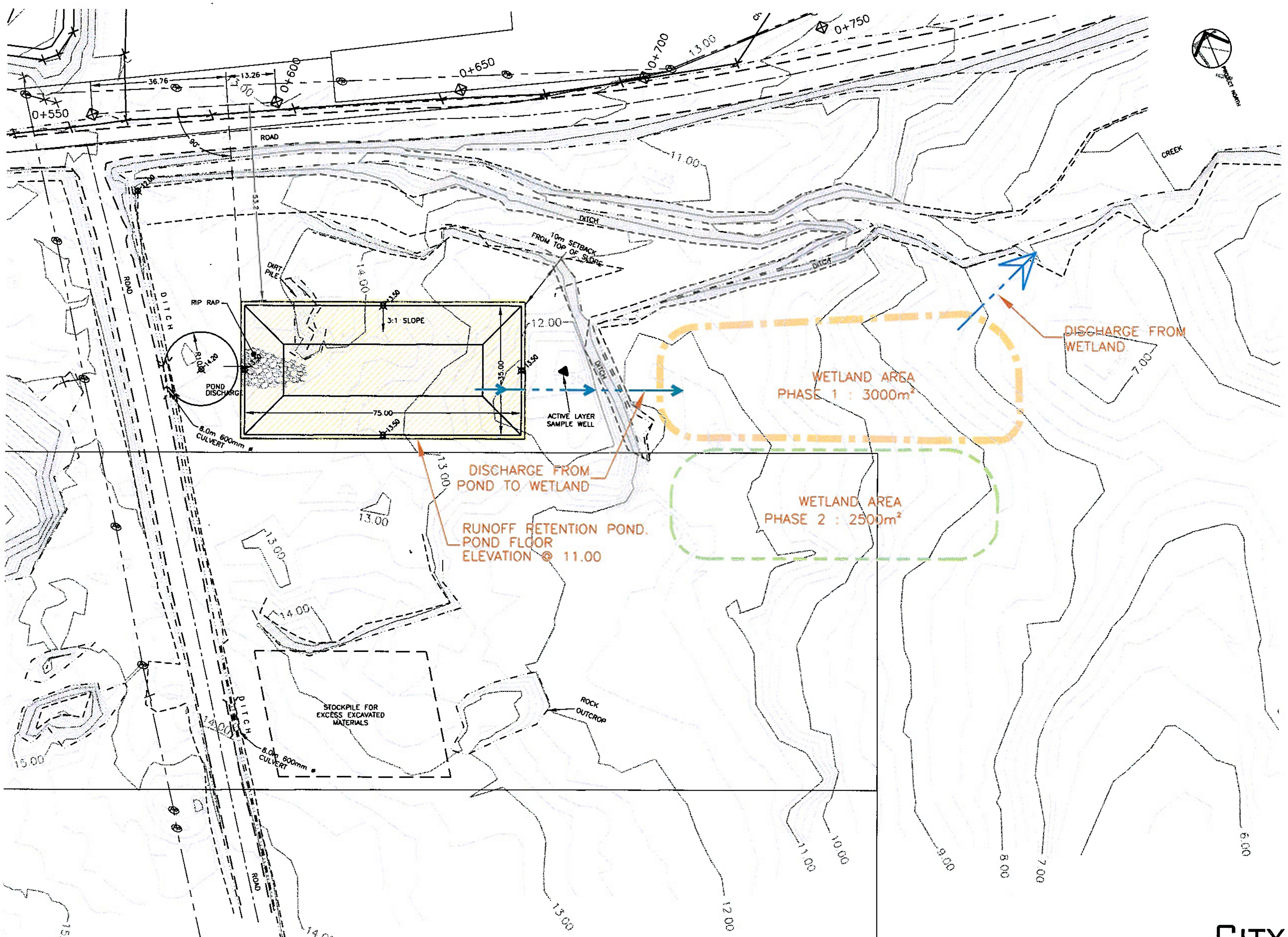
Assume 20% increase of the base price for all the components at Phase 2.



Date: February 2007
Not to Scale

EarthTech
A tyco International Ltd. Company

City of Iqaluit
Landfill Runoff Treatment -2007
EXISITNG RUNOFF CONTROLL PONDS
Figure 2-2



Date: FEBRUARY 2007
Not to Scale

EarthTech
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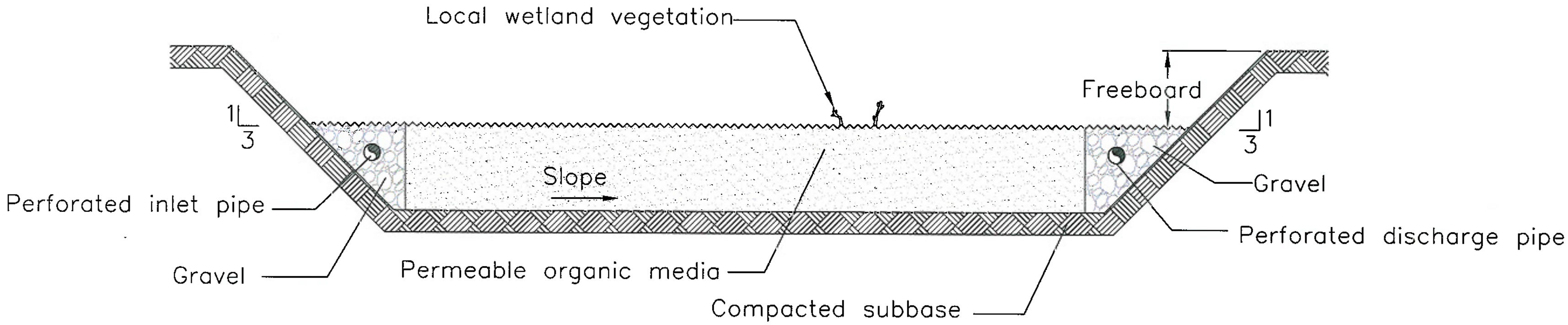
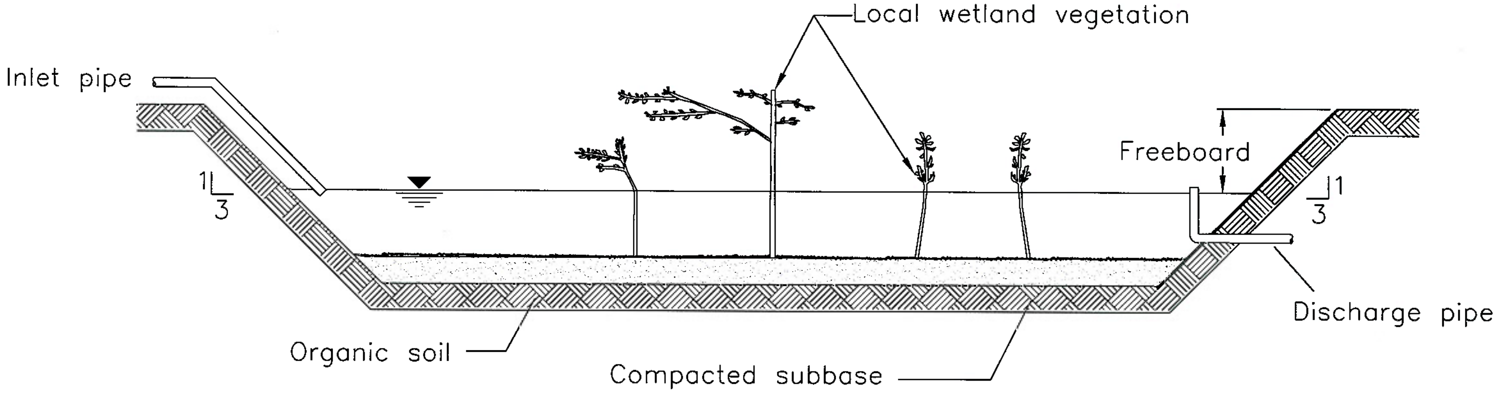
CITY OF IQALUIT
LANDFILL RUNOFF TREATMENT -2007
RUNOFF RETENTION POND AND PROPOSED WETLAND AREA
FIGURE 2-4



SUBSURFACE FLOW



SURFACE FLOW

Date: February 2007
Not to Scale

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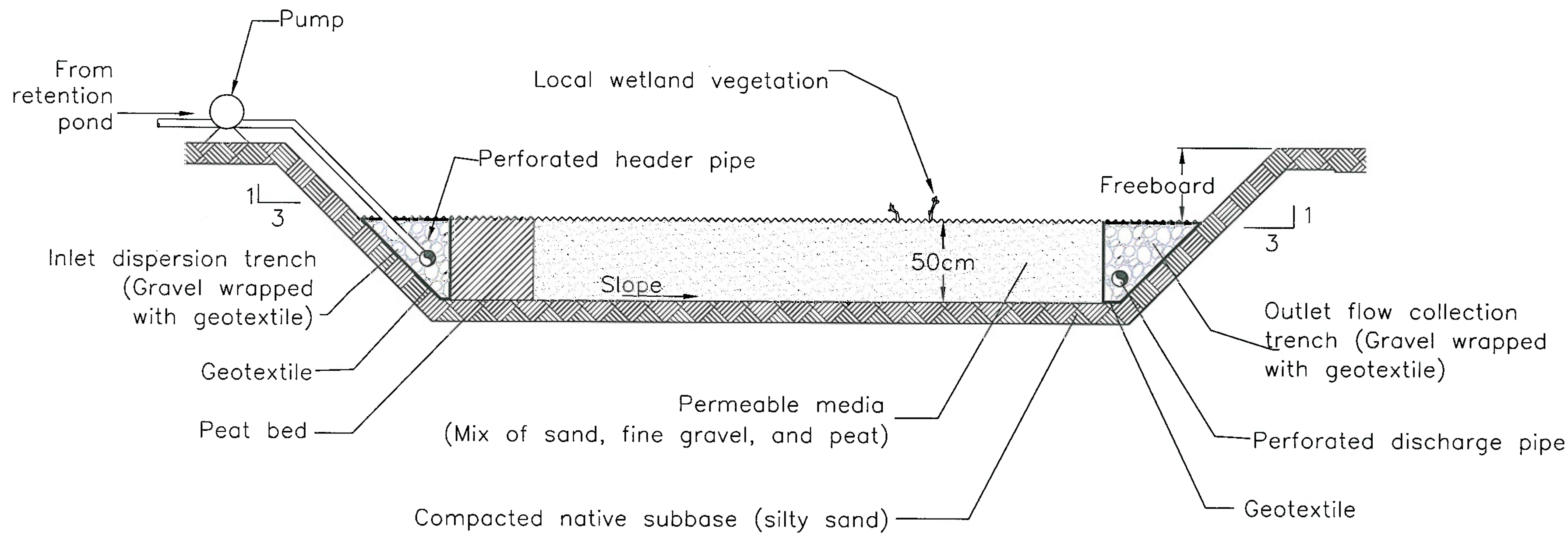
CROSS-SECTIONS OF CONSTRUCTED WETLAND PROCESSES

FIGURE 3-1



Date: February 2007
Not to Scale

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CITY OF IQALUIT
LANDFILL RUNOFF TREATMENT - 2007
CROSS-SECTION OF PROPOSED WETLAND
FIGURE 5-1

PLOT BY: BASHIR, SHAKEEB LAST SAVED: 21/2/2007 10:54 AM L:\work\83000\83107\02a-CAD\WAT\Wetland conceptual design\Figure 5-1 proposed wetland.dwg PLOT DATE: 21 February 2007