Igloolik Sewage Lagoon

Prepared for:

The Hamlet of Igloolik,
Nunavut, Canada

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TABLE OF CONTENTS

LIST OF APPENDICES

1. INTRODUCTION

1.1 PROJECT UNDERSTANDING

Ferguson Simek Clark was contracted to complete a planning study for the Igloolik Sewage Treatment Systems for Community Government and Transportation, (CG&T), Government of Nunavut. The purpose of this study is to:

- Collect all relevant engineering and geotechnical reports, specifications, and drawings for review
- Travel to Igloolik for consultation with Hamlet representatives and to discuss the project with CG&T representatives
- Inspect and survey the lagoon to determine storage capacity
- Prepare a planning report that outlines various options for consideration to meet the 20 year needs of the community with each option including a Class D life cycle cost analysis
- Consultation with regulatory agencies to ensure rapid acceptance of plans

1.2 REVIEW OF PREVIOUS DOCUMENTS

In 1997, Oliver Mangione, McCalla & Associates, (OMM), were retained to determine the impact of an immediate population increase of 179 persons in 1999. At the time, a two-cell lagoon was in place with an estimated storage of 14,900 m^3. An expansion of the site to include a new lagoon cell was designed by OMM and later built.

1.3 SITE VISIT

On September 12, 2001 Nick Arnatsiaq (SAO of Igloolik) met with Kelly Henderson, B. Tech (Env.) and James Perry of FSC and toured the sewage lagoon site. On September 13-14, 2001, James Perry and Kelly Henderson completed a topographic survey of the existing structures.

The sewage lagoon is located immediately south of the municipal landfill. The cell nearest to the honey bag pit will be referred to as Cell 1 and the cells will be numbered sequentially with the cell nearest the municipal waste site being Cell 4. The system was designed as an exfiltration lagoon. In this design, sewage discharged to the lagoon in winter would freeze and be retained. In the spring the sewage would melt and liquid would exfiltrate. Sewage solids would be retained in the lagoon. Exfiltrated liquid discharges over a wetland area where additional treatment is provided. The lagoon had been drained recently. There was still liquid within the cells, Nick Arnatsiaq commented that the cells do not empty completely.

The sewage lagoon is a series of three active cells and one inactive cell that are composed of local granular material. The material appears to be fragmented siltstone, generally 75 mm minus. There are serious erosion issues with most of the cells; they all have steep interior and exterior slopes (1.3:1 - 2.3:1). There is also prevalent longitudinal cracking around the rims of the cells (up to 0.3 m wide a 5+ m long).

The berms have varying exfiltration capacity. Cell 1 appears to have limited drainage capacity and is pumped out at summers end, Cell 2 drains and has active drainage channels, and Cell 3 drains very well and has an active drainage channel. The drainage channels are either 1 or 2 m wide dug trenches (as seen on design drawing). There is no obvious ponding in the drainage area between the lagoon and the ocean with the exception of the drainage channels.

The current series of three cells have a working volume of approximately 17,000 m^3. The Hamlet of Igloolik has an estimated sewage production of 66,000 m^3/year. The current exfiltration system has 26% capacity by annual volume. The sewage lagoon is approximately 2 km from the hamlet and 0.4 km from the ocean. The wetland, comprised of mosses, grasses and sedges, appears to be healthy and flourishing.

The cells are near maximum capacity. A fourth cell has been built and it is in the process of being commissioned. Cell 4 will have a working volume of between 1,500 m^3 and 2,000 m^3. Nick Arnatsiaq was informed that Cell 4 should not be used until the Nunavut Water Board had granted approval.

2. COMMUNITY INFORMATION

2.1 General

Igloolik is located on Igloolik Island, in the Foxe Basin lowlands, at 69°23′ N latitude and 81°46′ W longitude. It is bounded on the north by the Fury and Hecla Straits and separated from the Melville Peninsula to the south by Hooper Inlet. Igloolik is 362-air km northeast of Repulse Bay and 1641 air km northeast of Yellowknife.

2.2 Geology and Terrain

The glaciation that shaped the landscape retreated from this region five thousand years ago. The Island is composed of a dolomitic conglomerate, with sandstone, dolostone and siltstone interspersed throughout. Predominant features on the Island are the east and west ridges.

Igloolik is very low, heavily ponded and has extensive tidal foreshore flats. Most deposits on the surface make up a thin layer on the Palaeozoic beds, with raised beaches being the most common features. Any drift deposits are subject to extensive frost action. Permafrost is present throughout the active layer, averaging 0.7 m in depth.

2.3 Vegetation

Mosses, lichens, and grasses are the predominant vegetation species found.

2.4 Climate

Igloolik's Arctic summer rarely lasts longer than three months. A true arctic desert location, precipitation in snowfall averages 19.1 cm per year. July mean high and low temperatures are 7.8° C and 3.3° C. January mean high and low temperatures are -23.3° C and -32.8° C. The winds are generally north and annually average 21 km/h.

2.5 General Demographic Information

The population of Igloolik is projected to increase at a rate of 3% per capita. This rate was determined through the change in population between the census years of 1981 and 1996. The population of Igloolik was determined to be 746 during the 1981 census and 1174 during the

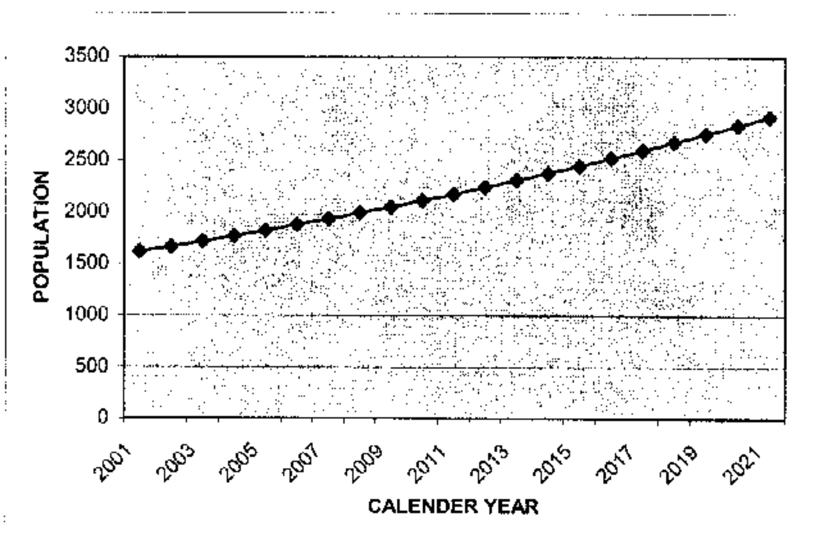
1996 census. The current population is estimated to be 1,500 (1,620 with the addition of 120 due to the decentralization of the Nunavut government). Projections estimate that the population will reach 1,768 by 2004 and 2,376 by the year 2014.

This projection is higher than the rate projected by OMM. Their projection included the immediate increase of 179 persons projected at 2.5% after 2011. OMM's 2019 projection was 2,498; the projection by FSC is 2754. These projections are made from the population information provided by Nicolas Arnatsiaq on October 2, 2001. For this report, FSC will retain our projection methodology.

Figure 2.1 Population Projections for the Hamlet of Igloolik

Calendar Year	Population
1996	1292
2001	1618
2006	1875
2011	2174
2016	2520
2021	2922

Figure 2.2 Population Projection Graph for the Hamlet of Igloolik



3. BACKGROUND

3.1 WATER SUPPLY AND TREATMENT

Prior to the construction of the new reservoir, three sources were used for potable water, depending upon seasonality:

1. Airstrip Lake from late May to July following the spring thaw. The recharge was not sufficient to supply the community year-round. The lake freezes to the bottom in winter.

2. North Lake was the source from July to September. Its use was limited due to its shallow depth.

3. East Lake was used during the winter. It is 3 - 6 m deep, 2.4 km long, and has a large capacity. However, it is only accessible by winter road across Turton Bay.

The present source of water is surface runoff entering South Lake and Airport Lake, at a point about 3.5 km from the community. The intake screen at South Lake is positioned approximately 2 m below the surface of the lake. The system to fill the reservoir near Airport Lake is used only during the summer months. A portable pump used to pump water to the pump house has replaced the skid-mounted portable pump house that was used for this task previously.

The truck fill station contains a Wallace and Tiernan Series A-745 hypochlorinator and other equipment. Fluoridation injection equipment was installed in 1990 to provide fluoride solution to the raw water en route to the reservoir. Currently, the GN does not fluoridate the water supply.

3.2 WATER STORAGE AND DISTRIBUTION

In 1979-80, a water reservoir designed to provide an accessible year-round water supply, was built beside Airport Lake. The reservoirs capacity was increased by blasting in 1991-2.

Water is pumped 2 km from the South Lake pump house to the reservoir, located near the airstrip; the water mixes with the water from Airport Lake. Although the watersheds are relatively small, sufficient annual recharge is available to supply the Hamlet over a 20 year period. The estimated capacity of the reservoir is 76,265,000 L. A pumping station and truck fill point are located at the reservoir.

All water used in Igloolik is supplied by a trucked system. Individuals who melt snow for their drinking water supplement the delivered drinking water supply to some extent.

Water delivery is provided by the Hamlet using three water trucks, a 1986 model (4546 L), a 1988 model (5683 L) and a 1992 model (6819 L). Homes with pressure systems receive water every other day, while the three remaining homes using bagged sewage service receive water twice per week. Water is trucked approximately 3.5 km from the fill point to the residential area. All water deliveries are metered.

3.3 Solid Waste Collection and Disposal

Garbage is stored in wooden boxes in front of each home prior to collection. At least twice per week, a two-person crew uses the Ford model F-350 stake truck to collect wastes. The same vehicle is used to collect bagged sewage wastes twice per week. Each year the community participates in a spring cleanup.

The solid waste management site is located 1.5 km north of the community. The site has separate modified landfill (10,000 m^2) and bulky metal waste areas (15,000 m^2). When possible, wastes are burned daily. Once per year the site is compacted and covered with gravel.

3.4 Sewage Generation Projections

The "GN - CG&T Water & Sewage Facilities Capital Program: Standards and Criteria" developed by the Department of Municipal and Community Affairs (MACA) provides a model for sewage generation by a community. The Water Use Planning Guidelines developed by MACA estimate the increase in municipal water use to be approximated with the following model:

Table 3.1 Design Total Community Water Use Estimates

Total Community Population	Total Water Use per Capita
0 to 2,000	RWU x (1.0 + (0.00023 x Population))
2,000 to 10,000	RWU x (1.0 + (0.323 x Ln(Population)))
Over 10,000	RWU x 2.0

Where:

RWU = Residential Water Use (Lcpd)

Ln = Natural Logarithm

The RWU value is estimated to be 90 Lpcd for communities with populations lower than 2,000. For populations of the range of 2,000 to 10,000, the RWU value is estimated to be 220 Lpcd. The model for populations in the range of 2,000 to 10,000 assumes the development of a piping system. This may not be a reality for Igloolik and significantly increases the required size of the sewage system.

Therefore, for this report, the equation for a population lower than 2,000 and RWU of 90 Lpcd will be used. This sewage projection assumes 100% water use entering the sewage stream.

There is no obvious runoff to the lagoon to be considered. Precipitation will be assumed to equal evaporation.

Table 3.2 Sewage Generation Projections

Census Population	1292	Residential Water Use	90 Lpcd
Census Year	1996	Sludge Generation Rate	50 g/cd
% Population Increase	3		

Planning Year	Calendar Year	Total Population	Projected Water Use (Lpcd)	Projected Volume (Litres/day)	Projected Volume (Litres/year)	Projected Sludge Volume (m^3/yr)	Accumulated Sludge Volume (m^3)
	1996	1292	116.7	150,834	55,054,324	24	24
	1997	1331	117.5	156,426	57,095,669	24	48
	1998	1371	118.4	162,252	59,221,987	25	73
	1999	1412	119.2	168,321	61,437,274	26	99
	2000	1454	120.1	174,646	63,745,732	27	125
0	2001	1618	123.5	199,777	72,918,540	30	155
	2002	1666	124.5	207,444	75,717,125	30	185
	2003	1716	125.5	215,444	78,636,879	31	216
	2004	1768	126.6	223,791	81,683,704	32	249
	2005	1821	127.7	232,504	84,863,815	33	282
5	2006	1875	128.8	241,599	88,183,763	34	316
	2007	1932	130.0	251,097	91,650,448	35	351
	2008	1990	131.2	261,017	95,271,142	36	388
	2009	2049	132.4	271,379	99,053,513	37	425
	2010	2111	133.7	282,207	103,005,640	39	464
10	2011	2174	135.0	293,523	107,136,045	40	503
	2012	2239	136.4	305,353	111,453,712	41	544
	2013	2307	137.7	317,721	115,968,118	42	586
	2014	2376	139.2	330,656	120,689,258	43	630
	2015	2447	140.7	344,185	125,627,675	45	674
15	2016	2520	142.2	358,341	130,794,495	46	720
	2017	2596	143.7	373,155	136,201,458	47	768
	2018	2674	145.4	388,660	141,860,951	49	816
	2019	2754	147.0	404,893	147,786,053	50	867
	2020	2837	148.7	421,892	153,990,566	52	919
20	2021	2922	150.5	439,696	160,489,065	53	972

3.5 SIZING THE SEWAGE TREATMENT SYSTEM

Proper sizing of the sewage treatment system was one of the primary focuses of this report. Igloolik, like many other Nunavut communities, uses exfiltration ponds as part of the sewage treatment system. An exfiltration pond is an area that uses permeable earthen structures (berms). During the winter months, the structures hold wastewater as ice and confine it to a determined location. As the ice melts, liquid exfiltrates through the permeable earthen structures. This at once attenuates the flow and provides a reduction in the organic loading to downstream processes, through the retention of organic solids within the pond. Organic removal through the permeable structure is generally about 40%. In contrast, a sewage lagoon is designed to store wastewater, and treat it aerobically with bacteria and algae.

The exfiltration pond alternatives that will be presented are designed for seven month icepack sewage storage.

Sewage lagoon alternatives were designed with either 12 or 10 month sewage storage. Lined lagoons are designed to have year round storage of sewage, with controlled discharge onto the wetlands during the summer.

All options are designed for 20 year discharge estimates. Each option is based on incremental growth model for the sewage treatment system and is therefore a series of ponds or lagoons instead of a single large pond or lagoon.

This would enable the Hamlet of Igloolik to have a schedule of construction to implement at defined intervals. The current system has a calculated 3 month storage with no report of overflow or breaching. Drawing B-1 shows the current system.

3.6 DISCHARGE TO WETLANDS

3.6.1 BACKGROUND ON WETLANDS

Wetlands sewage treatment is a web of complex physical and biological processes. Sedimentation, absorption of pollutants in the surface soils, nutrient uptake by plants, and the oxidation of compounds by microorganisms are some of the processes that effect the treatment.

The plants within a wetland act as natural purifiers trapping and binding pollutants in the mud and roots. The plants also provide a media to which bacteria can cling as it grows. These bacteria, many identical to those present in a mechanical sewage treatment plant, remove carbon and nutrients from the water. Finally, the thin layer of now clean water allows sunlight to penetrate deeply, thus, killing some pathogenic organisms and reducing the number of microorganisms in the water.

3.6.2 Sewage Characteristics

The Nunavut Water Board projects raw sewage characteristics based on the per capita rates shown in Table 3.3.

Influent into the wetland will have already been treated in the exfiltration pond; therefore it is assumed that the contaminant concentrations can be reduced by 40%. All further calculations will be made using the adjusted contaminant calculations in Table 3.4.

3.6.3 Treatment Requirements

3.6.3.1 Hydraulic Loading

With the apparent success of wetlands treatment in the NWT, Yukon and other jurisdictions, the Government of the Northwest Territories commissioned a study of the potential use of wetlands for the treatment of municipal wastewater in the NWT. Doku and Heinke's (1993) study reviewed the use of natural and constructed wetlands in northern and southern wetlands and identified preliminary design considerations. Doku and Heinke recommended that hydraulic and organic loading rates should not exceed 100 to 200 m^3/ha.d and 8 kg BOD_5/ha.d.

There are no climate normals for Igloolik at Environment Canada. The closest community to Igloolik with climate normals information is Hall Beach; therefore this information will be used. The appended climate normals indicate that ice will be accumulated for 8 months and the duration of the melt period is 60 days.

For the FSC calculations below, the daily sewage generation value was obtained from the 20 year design sewage generation volume within Table 3.2. The wetlands at Igloolik are not constructed wetlands but natural wetlands; consequently it cannot be assumed that the entire potential wetland area will be used to treat the effluent from the exfiltration ponds. The potential wetland area is the area between the exfiltration ponds and the ocean.

The conservative estimate used for the hydraulic loading rates is 50% of the potential wetland area will be naturally used. Evaporation and sublimation were not included in these calculations. All calculations for hydraulic loading and contaminant loading are appended.

Table 3.3 Raw Sewage Quality Projection

Residential Water Use per capita	90 Litres
BOD	45 Grams
TSS	48 Grams
T-PO4	2.3 Grams
TKN	12 Grams
FC	9.50E+10

Planning Year	Calendar Year	Total Population	Projected Water Use (Lpcd)	BOD (mg/L)	TSS (mg/L)	T-PO4 (mg/L)	TKN (mg/L)	FC (#/dL)
	1996	1292	116.7	386	411	20	103	8.E+09
	1997	1331	117.5	383	409	20	102	8.E+09
	1998	1371	118.4	380	405	19	101	8.E+09
	1999	1412	119.2	378	403	19	101	8.E+09
	2000	1454	120.1	375	400	19	100	8.E+09
0	2001	1618	123.5	364	389	19	97	8.E+09
	2002	1666	124.5	361	386	18	96	8.E+09
	2003	1716	125.5	359	382	18	96	8.E+09
	2004	1768	126.6	355	379	18	95	8.E+09
	2005	1821	127.7	352	376	18	94	7.E+09
5	2006	1875	128.8	349	373	18	93	7.E+09
	2007	1932	130	346	369	18	92	7.E+09
	2008	1990	131.2	343	366	18	91	7.E+09
	2009	2049	132.4	340	363	17	91	7.E+09
	2010	2111	133.7	337	359	17	90	7.E+09
10	2011	2174	135	333	356	17	89	7.E+09
	2012	2239	136.4	330	352	17	88	7.E+09
	2013	2307	137.7	327	349	17	87	7.E+09
	2014	2376	139.2	323	345	17	86	7.E+09
	2015	2447	140.7	320	341	16	85	7.E+09
15	2016	2520	142.2	316	338	16	84	7.E+09
	2017	2596	143.7	313	334	16	84	7.E+09
	2018	2674	145.4	309	330	16	83	7.E+09
	2019	2754	147	306	327	16	82	6.E+09
	2020	2837	148.7	303	323	15	81	6.E+09
20	2021	2922	150.5	299	319	15	80	6.E+09

Table 3.4 Sewage Characteristics After Pre-treatment

Contaminant	Sewage Characteristic after pre-treatment (mg/L)
BOD	179.4
TSS	191.4
T-PO4	9
TKN	48
FC	3.79E+9

Table 3.5 Summary of Calculated Hydraulic Loading Rates

TIME PERIOD	TOTAL DAILY HYDRAULIC LOADING RATE (m^3/d/ha)			
	OPTION 1	OPTION 2	OPTION3	OPTION4
JULY TO AUGUST	110	134	175	106
SEPTEMBER TO OCTOBER	28	24	41	27
NOVEMBER TO JUNE	FROZEN	FROZEN	FROZEN	FROZEN

When compared to Heinke (1993), the FSC calculations exceed 100-200 m3/day/ha during July and August for Options #1-3.

The organic or contaminant loading rate was calculated by the following equation:

Contaminant load (kg/d) = [(hydraulic load) – (rainfall)]*contaminant concentration

Table 3.6 Summary of Calculated Contaminant Loading Rates

TIME PERIOD	TOTAL DAILY CONTAMINANT LOADING RATE BOD (kg/d*ha)			
	OPTION 1	OPTION 2	OPTION 3	OPTION 4
JULY TO AUGUST	17.5	21.9	29.2	16.9
SEPTEMBER TO OCTOBER	3.5	4.4	5.8	3.4
NOVEMBER TO JUNE	FROZEN	FROZEN	FROZEN	FROZEN

When compared to Heinke *et al.* (1993), the FSC calculations exceed 8 kg BOD_5/day/ha for every option during July and August.

3.6.3.2 Alberta Environmental Protection Guidelines

Alberta (1998) has published a set of guidelines that use spreadsheets and arithmetic algorithms, based on a 20° C rate constant, to define the area of a wetland and its expected effluent quality.

$$A = 0.0365Q/k \bullet \mathrm{Ln}\,(C_i - C^*)/(C_e - C^*)$$

Where A = required area
Q = Design Flow
k = Rate constant for a given temperature
C_i = Influent Concentration
C_e = Target Effluent Concentration
C^* = Wetland Background Concentration
for BOD, $C^* = 7.8 + 0.063C_i$
for TSS, $C^* = 3.5 + .053C_i$

Based on this model the predicted effluent concentration is determined by the model

$$C_o = C^* + (C_i - C^*)\exp(-kA/0.0365Q)$$

Alberta's guidelines have not been proven in northern climates. In addition, they are designed for an average temperature of 20°C. One must be conservative in applying these guidelines, as Igloolik's average summer temperature is assumed to approximate Hall Beach's at 5.5°C.

Assuming that biological production rate is decreased by half as the temperature decreases from 20° to 10 °C, then again by half as temperature decreases to 5°C , the algorithms have been applied to the Igloolik situation and are appended.

Assuming that biological production rate is decreased by half as the temperature decreases from 20° to 10 °C , then again by half as temperature decreases to 5°C, the results of the model is compared to Dillon (1998) data and conditions.

Table 3.7 Comparison of Dillon (1998) to Alberta Model

	BOD_5 Removal Rate	TSS Removal Rate	Faecal Coliform Removal Rate
Dillon (1998)	90	90	100
Alberta Model	92	93	100

As the results are similar, the Alberta model shows promise, however, there remains insufficient empirical data to develop specific correction factors. However, we are confident that the Alberta model can be applied to indicate future conditions at Igloolik.

Similarly, the algorithms are applied to the Igloolik situation for the 20 year projection. The summary of the results follow in Table 3.8 and the calculations are appended.

Certainly, empirical wetland data would be preferable, however, none is available for Igloolik. In the absence of such data, or tested models, it is FSC's judgement that the Alberta model, in conjunction with the more conservative Heinke recommendations, can provide confidence in selecting wetlands as a treatment process for use in Igloolik.

3.7 DISCUSSION OF RESULTS

Using the adapted Alberta model, the calculation of BOD and TSS effluent concentrations fall below those outlined by the Nunavut Water Board Guidelines.

The Heinke (1993) guidelines and the modified Alberta Guidelines show that wetlands at Igloolik have merit. Wetlands therefore will be incorporated into our planning options.

Table 3.8 Summary of Results from Alberta Guidelines Calculations at 5°C

Option Number	Wetland Area (ha)	BOD [Ci] (mg/L)	TSS [Ci] (mg/L)	Nunavut Water Board Guideline		BOD Co (mg/L)	TSS Co (mg/L)
				BOD (mg/L)	TSS (mg/L)		
1	22.5	179.4	191.4	100	120	34.3	19.1
2	18	179.4	191.4	100	120	45	19.1
3	13.5	179.4	191.4	100	120	60.6	19.1
4	23.3	179.4	191.4	100	120	33.2	19.1

4. OPTIONS FOR IGLOOLIK SEWAGE TREATMENT

4.1 Option 1: 12 Month Lined Storage With Sludge Storage Area

Shown in Drawing No. B-2, in this option, a series of five cells will be constructed on the site of the existing lagoon. The berms would be built using the material from the existing berms. The sewage lagoon would be lined with a Bentomat ST liner. This will provide annual storage of wastewater with a controlled summer discharge over the wetlands to the ocean. The lagoons will be sized for the 20 year design volumes. A sludge farm area is incorporated at mid point. The cells are designed to allow staged construction.

4.2 Option 2: 10 Month Lined Storage With Sludge Storage Area

Shown in Drawing No. B-3, in this option, a series of four cells will be constructed on the site of the existing lagoon. The berms would be built using the material from the existing berms. The sewage lagoon would be lined with a Bentomat ST liner. This will provide storage for seasonal (10 month) storage of wastewater with a controlled summer discharge to the wetlands. The lagoons will be sized for the 20 year design volumes. A sludge farm area is incorporated at mid point. The cells are designed to allow staged construction.

4.3 Option 3: 7 Month Storage Exfiltration Ponds With Sludge Storage Area

Shown in Drawing No. B-4, in this option, a series of three exfiltrating ponds will be constructed on the site of the existing lagoon. The berms would be built using the material from the existing berms. The new ponds will be sized for 7 months of storage at the 20 year design volumes. This will provide storage for winter storage of wastewater and ice, with an uncontrolled summer discharge to the wetlands. A sludge farm area is incorporated at mid point. The cells are designed to allow staged construction.

The need for a sludge storage area will be accessed five years after construction. Section 5.2.3 separates the cost of the lagoon cells and the sludge storage area since they will be completed independently.

4.4 Option 4: 7 Month Storage Exfiltration Ponds Retaining the Current Ponds With Sludge Storage Area

Shown in Drawing No. B-5, in this option, a series of three exfiltrating ponds are built in addition to the existing structures. In contrast to Option 6, this option retains the current structures so that investment is not lost. The existing structures will also be upgraded to maximize their current capacity. The total volume of all the ponds will be sized for 7 months of storage at the 20 year design volumes. This will provide seasonal storage of wastewater and ice, with an uncontrolled summer discharge to the wetlands. A sludge farm area is incorporated at mid point. The new ponds would be located adjacent to the existing structures, thus, allowing for staged construction.

4.5 Option 5: RBC and building

Shown in Drawing No. B-6, in this option, the sewage lagoon is decommissioned and replaced with a Rotating Biological Contactor.

4.6 Inclusion/Exclusion of Sludge Storage Area

Options 1 through 4 all include a designed sludge storage area. Under the revised Nunavut Water Board Guidelines (2001), the sludge would have to be removed if it became toxic when compared to the CCME guidelines, or if it interferes with the working zones and degrades effluent quality.

The cost involved with the removal of sludge is in the order of the cost to build another cell. As seen in Figure 4.1, the 20 year percentage/volumes are quite low, but will be slightly higher in cells that are in continuous use, opposed to those that have been added through staged construction. For planning purposes, we have included a sludge storage area in each of the options.

Figure 4.1 Sludge Per Volume Calculations

	AVERAGE VOLUME %	AVERAGE DEAD ZONE VOLUME %
OPTION 1	0.49%	2.46%
OPTION 2	0.59%	2.95%
OPTION 3	0.98%	4.92%
OPTION 4	0.98%	4.92%

5. MODIFIED K-T ANALYSIS

In order to evaluate potential alternatives objectively, we have used a decision making tool called a modified Kepner-Tregoe analysis or a weighted factor analysis. This method involves two distinct steps, which are outlined as follows.

5.1 INITIAL SCREENING

The initial screening process involves the creation of constraints, which each option/alternative must meet. Only options/alternatives that meet each constraint will be included in the final analysis.

- Must meet the Public Health Act
- Must meet Nunavut Water Board Acts and Regulations
- Must meet 20 year storage

The results are shown in Table 5.1

Table 5.1 – Results of Initial Screening

	PUBLIC HEALTH ACT	NUNAVUT WATER BOARD	20 YEAR STORAGE
OPTION 1	PASS	PASS	PASS
OPTION 2	PASS	PASS	PASS
OPTION 3	PASS	PASS	PASS
OPTION 4	PASS	PASS	PASS
OPTION 5	PASS	PASS	PASS

5.2 Cost Analysis for Remaining Options

5.2.1 Option 1: 12 Month Lined Storage With Sludge Storage Area

OPTION 1: 12 MONTH LINED STORAGE WITH SLUDGE STORAGE AREA				
5 – 225 m x 100 m LINED CELLS WITH 1 50 x 100 m SLUDGE STORAGE AREAS				
COST ITEMS	COST/UNIT	UNIT	TOTAL	TOTAL
IMPORTED MATERIAL	$35.00	CUBIC METRE	151645.0	$5,307,575.00
ON SITE MATERIAL	$15.00	CUBIC METRE	-	-
BENTOMAX ST LINER	$6.00	SQUARE METRE	141000.0	$846,000.00
SCREENED MATERIAL	$50.00	CUBIC METRE	84600.0	$4,230,000.00
SHIPPING	$300.00	TONNE	955.8	$286,740.00
ENGINEERING AND CONTINGENCY	40%	N/A		$4,268,126.00
TOTAL COST				$14,938,441.00
LAGOON BERM SPECIFICATIONS				
Average height of exterior berm*			4.1	METRE
Average area of exterior berm			68.9	SQUARE METRE
Length of berm			1375.0	METRE
Area of exterior berms			94710.0	CUBIC METRES
Average height of interior berms			3.3	METRE
Average are of interior berms			31.7	SQUARE METRE
Length of berm			500.0	METRE
Area of interior berms			15840.0	CUBIC METRES
Area of berm			110550.0	CUBIC METRES
Area of screened liner material			84600.0	CUBIC METRES
Area of general liner cover			28200.0	CUBIC METRES
Area of old berms			29000.0	CUBIC METRES
Area of stripping			41125.0	CUBIC METRES
Area to be removed			70125.0	CUBIC METRES
Exterior berms are to be 99 m high, 4.5 m wide at the top with 3:1 slopes				
Interior berms are to be 99 m high, 3 m wide at the top with 2:1 slopes				
Liner depth to be 0.8 m (0.3 m of liner base, 0.3 m of screened cover and 0.2 m of general fill cover)				
*Heights calculated on 10 m stationing on design drawing				

5.2.2 OPTION 2: 10 MONTH LINED STORAGE WITH SLUDGE STORAGE AREA.

OPTION 2: 10 MONTH LINED STORAGE WITH SLUDGE STORAGE AREA				
4 225 m x 100 m LINED CELLS WITH 1 50 x 100 m SLUDGE STORAGE AREA				
COST ITEMS	COST/UNIT	UNIT	TOTAL	TOTAL
IMPORTED MATERIAL	$35.00	CUBIC METRE	119570.0	$4,184,950.00
ON SITE MATERIAL	$15.00	CUBIC METRE	-	-
BENTOMAX ST LINER	$6.00	SQUARE METRE	114000.0	$684,000.00
SCREENED MATERIAL	$50.00	CUBIC METRE	68400.0	$3,420,000.00
SHIPPING	$300.00	TONNE	672.6	$201,780.00
ENGINEERING AND CONTINGENCY	40%	N/A		$3,396,292.00
TOTAL COST				$11,887,022.00
LAGOON BERM SPECIFICATIONS				
Average height of exterior berm			4.1	METRE
Average area of exterior berm			68.9	SQUARE METRE
Length of berm			1150.0	METRE
Area of exterior berms			79212.0	CUBIC METRES
Average height of interior berms			3.3	METRE
Average are of interior berms			31.7	SQUARE METRE
Length of berm			400.0	METRE
Area of interior berms			12672.0	CUBIC METRES
Area of berm			91884.0	CUBIC METRES
Area of screened liner cover			68400.0	CUBIC METRES
Area of general liner cover			22800.0	CUBIC METRES
Area of old berms			29000.0	CUBIC METRES
Area of stripping			33250.0	CUBIC METRES
Area to be moved			62250.0	CUBIC METRES
Exterior berms are to be 99 m high, 4.5 m wide at the top with 3:1 slopes				
Interior berms are to be 99 m high, 3 m wide at the top with 2:1 slopes				
Liner depth to be 0.8 m (0.3 m of liner base, 0.3 m of screened cover and 0.2 m of general fill cover)				
*Heights calculated on 10 m stationing on design drawing				

5.2.3 OPTION 3: 7 MONTH STORAGE EXFILTRATION POND BUILT IN PLACE OF EXISTING SITE WITH OPTION FOR SLUDGE STORAGE AREA

OPTION 3: 7 MONTH STORAGE EXFILTRATION POND 3 225 m x 100 m EXFILTRATING PONDS				
COST ITEMS	COST/UNIT	UNIT	TOTAL	TOTAL
IMPORTED MATERIAL	$35.00	CUBIC METRE	8414.1	$294,493.55
ON SITE MATERIAL	$15.00	CUBIC METRE	43375.0	$650,625.00
ENGINEERING AND CONTINGENCY	40%	N/A		$117,797.42
TOTAL COST				$1,062,915.97
LAGOON BERM SPECIFICATIONS				
Average height of exterior berm			3.3	METRE
Average area of exterior berm			48.3	SQUARE METRE
Length of berm			942.0	METRE
Area of exterior berms			45453.1	CUBIC METRES
Average height of interior berms			3.3	METRE
Average are of interior berms			31.7	SQUARE METRE
Length of berm			200.0	METRE
Area of interior berms			6336.0	CUBIC METRES
Area of berm			51789.1	CUBIC METRES
Area of old berms			29000.0	CUBIC METRES
Area of stripping			14375.0	CUBIC METRES
Area to be removed			43375.0	CUBIC METRES
Exterior berms are to be 98.2 m high, 4.5 m wide at the top with 3:1 slopes Interior berms are to be 98.2 m high, 3 m wide at the top with 2:1 slopes *Heights calculated on 10 m stationing on design drawing				

OPTION 3 SLUDGE STORAGE AREA 50 m X 100 M SLUDGE STORAGE AREA				
COST ITEMS	COST/UNIT	UNIT	TOTAL	TOTAL
IMPORTED MATERIAL	$35.00	CUBIC METRE	3000.0	$105,000.00
ON SITE MATERIAL	$15.00	CUBIC METRE	2763.0	$41,445.00
ENGINEERING AND CONTINGENCY	40%	N/A		$42,000.00
TOTAL COST				$188,445.00

5.2.4 OPTION 4: 7 MONTH STORAGE EXFILTRATION POND WITH SLUDGE STORAGE AREA

OPTION 4: 7 MONTH STORAGE EXFILTRATION POND WITH SLUDGE STORAGE AREA				
3 215 M X 100 M EXFILTRATING PONDS WITH 1 SLUDGE STORAGE AREA IN ADDITION TO EXISTING CELLS				
COST ITEMS	COST/UNIT	UNIT	TOTAL	TOTAL
IMPORTED MATERIAL	$35.00	CUBIC METRE	33483.7	$1,171,929.03
ON SITE MATERIAL	$15.00	CUBIC METRE	13625.0	$204,375.00
ENGINEERING AND CONTINGENCY	40%	N/A		$468,771.61
TOTAL COST				$1,845,075.64
LAGOON BERM SPECIFICATIONS				
Average height of exterior berm			3.3	METRE
Average area of exterior berm			48.3	SQUARE METRE
Length of berm			845.0	METRE
Area of exterior berms			40772.7	CUBIC METRES
Average height of interior berms			3.3	METRE
Average are of interior berms			31.7	SQUARE METRE
Length of berm			200.0	METRE
Area of interior berms			6336.0	CUBIC METRES
Area of berm			47108.7	CUBIC METRES
Area of stripping			13625.0	CUBIC METRES
Exterior berms are to be 98.2 m high, 4.5 m wide at the top with 3:1 slopes				
Interior berms are to be 98.2 m high, 3 m wide at the top with 2:1 slopes				
*Heights calculated on 10 m stationing on design drawing				

OPTION 4 SLUDGE STORAGE AREA				
50 m X 100 M SLUDGE STORAGE AREA				
COST ITEMS	COST/UNIT	UNIT	TOTAL	TOTAL
IMPORTED MATERIAL	$35.00	CUBIC METRE	3000.0	$105,000.00
ON SITE MATERIAL	$15.00	CUBIC METRE	2763.0	$41,445.00
ENGINEERING AND CONTINGENCY	40%	N/A		$42,000.00
TOTAL COST				$188,445.00

5.2.5 Option 5: RBC and Building

OPTION 5: RBC AND BUILDING				
COST ITEMS	COST/UNIT	UNIT	TOTAL	TOTAL
RBC AND BUILDING	$2,000,000.00	N/A	1.00	$2,000,000.00
ENGINEERING AND CONTINGENCY	40%	N/A		$800,000.00
TOTAL COST				$2,800,000.00
O&M Costs 12%/Year				$240,000.00

5.3 Options Analysis

The final process consists of evaluating each option on a set of objectives that has been deemed the 'want' criteria.

The want criteria are a list of objectives that are weighted according to their importance to the decision to be made. Each option is then ranked against these criteria and scores assigned based on the ranking multiplied by the weight of the criteria. The weighted scores for the various options are added to provide a total score for each option.

The total score for different options can be compared to provide an indication of which option best meets the stated objectives for a new solid waste disposal system.

The following "want" objectives have been established for this project:

1. Lowest Capital Cost
2. Lowest O&M Costs
3. Lowest Net Present Value (NPV)
4. Can meet the general conditions (Section 36(3)) of the *Fisheries Act*
5. Ease of lagoon cleanout
6. Frequency of lagoon cleanout

5.3.1 Selecting Weights

A binary choice decision model was used to generate preliminary weighting for each objective.

In this model, only two objectives are considered at a time, the more important objective receiving a "1" and the other a "0". When all objectives are considered the scores are summed and the results placed in descending order. The highest-ranking objective is then assigned a "10". Others receive a lesser weight.

The following table shows the decision process.

Table 5.2 - Binary Decision Model to Assign Weights to Objectives

	CAPITAL COST	O&M COST	CONSTUCT STAGE	NPV	EASE OF CLEANOUT	FREQUENCY OF CLEANOUT	FISHERIES ACT	SUM	ASSIGNED WEIGHT
O&M COST	1	-	1	1	1	1	1	6	10
CAPITAL COST	-	0	1	1	1	1	1	5	9
NPV	0	0	1	-	1	1	1	4	8
CONSTRUCTION STAGING			-		1	1	1	3	7
FISHERIES ACT	0	0	0	0	1	1	-	2	6
EASE OF CLEANOUT	0	0	0	0	-	1	0	1	5
FREQUENCY OF CLEANOUT	0	0	0	0	0	-	0	0	4

5.3.2 Scoring

1. **Lowest O&M Costs**

The lowest O&M cost will be scored "10". Others will be scored based on percentage.

2. **Lowest Capital Cost**

The lowest capital cost will be scored "10". Others will be scored on percentage.

3. **Lowest Net Present Value**

The lowest Net Present Value will be scored "10". Others will be scored on percentage.

4. **Construction Staging Opportunities**

Over 10 years – 10
Over 5 years – 7
Over 2 years – 3
Cannot be staged - 0

5. **Meets Fisheries Act**

Always - 10

Except in the spring - 5
Does not – 0

6. Ease of Cleanout

In service (continued use during clean out) – 10
Not in service - 0

7. Frequency of Cleanout

Never – 10
10 years 5
5 years – 0

5.4 RESULTS

Table 5.3 shows the results of the modified K-T Analysis

	WEIGHT	OPTION 1		OPTION 2		OPTION 3		OPTION 4		OPTION 5	
		SCORE	W*S	SCORE	W*S	SCORE	W*S	SCORE	W*S	SCORE	W*S
LOWEST O&M COST	10	0.9	9.5	1.2	11.9	10.0	100.0	6.4	64.3	3.0	30.5
LOWEST CAPITAL COST	9	0.8	7.5	1.1	9.5	10.0	90.0	6.2	55.4	4.5	40.2
LOWEST NPV	8	1.3	10.3	1.6	12.9	10.0	80.0	7.1	56.5	1.9	14.9
CONSTRUCTION STAGING	7	7	49	3	21	3	21	7	49	0	0
FISHERIES ACT	6	10.0	70.0	10.0	70.0	5.0	35.0	5.0	35.0	0.0	0.0
EASE OF CLEANOUT	5	10.0	60.0	10.0	60.0	10.0	60.0	10.0	60.0	10.0	60.0
FREQUENCY OF CLEANOUT	4	5.0	25.0	5.0	25.0	5.0	25.0	0.0	0.0	10.0	50.0
	TOTAL		231.3		210.3		411		320.2		195.6

6. CONCLUSIONS

1. From the K-T Analysis, Option 3 was the highest scoring option. Option 3 is a series of 3 exfiltrating cells that are built in place of the existing site with or without an attached sludge retention area. This option is less expensive than Option 4 because the berms for this system are primarily built from the existing berms and stripped material. Such a design provides some construction staging opportunities, however, not as many as in Option 4.

2. Option 4 was the second highest scoring in the K-T Analysis. Option 4 is a series of exfiltrating ponds are built in addition to the existing sewage lagoon. This Option provides the greatest flexibility in construction staging opportunities, but fails on capital cost alone.

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