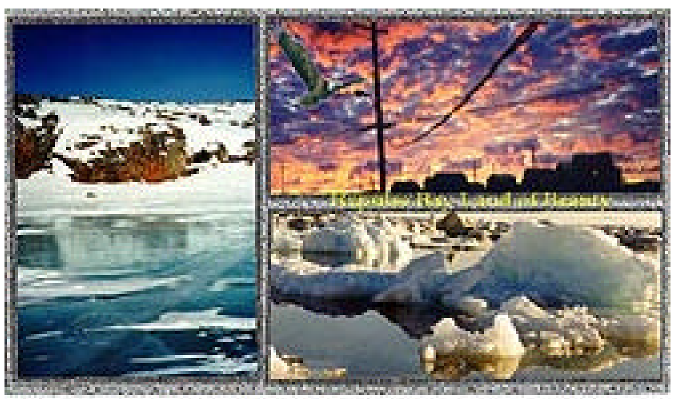
Final Report

Repulse Bay Sewage Treatment and Solid Waste
Repulse Bay, Nunavut

prepared for:

Department of Community Government & Transportation
P.O. Box 490
Rankin Inlet, NU
X0C 0G0



prepared by:

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4910 53rd Street
Yellowknife, NT
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FSC Project Number: 2001-1050

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1. INTRODUCTION

1.1 PROJECT UNDERSTANDING

Ferguson Simek Clark was contracted to complete a planning study for the Repulse Bay Sewage Treatment Systems and Solid Waste Disposal Sites for Community Government and Transportation, Government of Nunavut. The purpose of this study is to:

- Determine if the existing sewage treatment and solid waste site meet 20-year demand;
- Submit the designs for the new sewage disposal site and solid waste site if necessary;
- Investigate 4 potential solid waste sites identified by Vance Consulting and for any other sites that appear feasible; and
- Use modified KT Analysis to recommend a preferred alternative for approval by the client and Hamlet.

1.2 COMMUNITY INFORMATION

1.2.1 GENERAL

The Hamlet of Repulse Bay, located on the northern shore of Repulse Bay, is on the south shore of the Rae Isthmus. Geographic coordinates are 66°32′ N latitude and 86°15′ W longitude, Repulse Bay is 443-air km southeast of Taloyoak and 1,424-air km northeast of Yellowknife.

1.2.2 GEOLOGY AND TERRAIN

The Hamlet is located at the northern tip of Roes Welcome Sound in the Churchill Structural Province. The terrain is composed primarily of Precambrian granite gneiss. Foliation and structural lineaments of the bedrock have a visible north-north-west trend. Pleistocene glaciation was prominent in the region and the structural lines of weakness were eroded rapidly during this period. Formerly a relatively level plateau, the land was cut up into a series of steep-sided, narrow valleys and ridges. These blocks begin at the coast where they form narrow deep fiords that point toward the northwest.

The geomorphology of the area is extremely rugged and access inland is difficult. Extensive breakage of bedrock fluting created many marshy depressions. During deglaciation, the area was isostatically depressed, allowing coastal waters to rework the glacial till. Very little soil covers the ridges of bedrock; silty sands and gravel constitute the limited soil layers present.

Repulse Bay is well within the continuous permafrost zone and permafrost-created landforms such as solifluction lobes and patterned ground are clearly visible. Since the permafrost table lies near the ground surface, only very limited thawing of the active layer takes place in summer.

1.2.3 VEGETATION

The climate and soil of Repulse Bay can support mosses, lichens, and some flowering plants. The sewage treatment area supports a sedge meadow. Plant communities in wetter portions consist mostly of wetland grasses and sedges. Pond areas have some emergent macrophites.

1.2.4 CLIMATE

Repulse Bay receives an average of 15.0 cm of rainfall and 58.2 cm of snowfall per year. Mean annual precipitation totals 20.6 cm. July mean high and low temperatures are 15.7° C and 5.8° C. January mean high and low temperatures are -29.4° C and -36.4° C. The winds are generally from the north and annually average 23 km/h.

1.2.5 COMMUNITY HISTORY AND ECONOMY

Repulse Bay is the homeland of the Iglulik Inuit. The first European arrivals in 1741 and 1746 would lead to the formation of a prosperous whaling industry. Inuit guides and skippers were often hired on to European crews. In 1853, Dr. John Rae traveled by dogsled from his base at Repulse Bay in an effort to complete the survey of the Boothia Peninsula.

The Hudson Bay Company established the first trading post in 1916, shortly after whaling began to lessen. Revillion Freres, a French trading company, followed in 1923. The Roman Catholic Mission was established in 1932. Modern development started in the early 1960's with the introduction of rental homes. Government services, a community co-op and a housing association were set up in 1968. The Community Council was formed the following year.

Repulse, a very traditional community, is sensitive to new development. Marine mammal harvesting, hunting, fishing, trapping, carving sales, arts and handicrafts are the main economic opportunities available to the Hamlet. The historic sites, bird nesting areas, and natural beauty contribute to the tourism industry, as does the Inuit artwork. Businesses in the community include fur buyers, general retailers, food sales, service stations, hotels, outfitters, restaurants and amusement centres.

Repulse Bay gained Hamlet status on July 1, 1978. The traditional name of the Community is "Naujat", meaning 'seagull resting place'.

1.2.6 TRANSPORTATION AND ACCESS

The GNWT and the Hamlet jointly operate a 1,036 m x 30 m certified Arctic 'C' gravel runway. Facilities include the terminal building, weather/communications equipment, and navigation aids. Scheduled flight service is available through Calm Air Ltd. via Rankin Inlet/Churchill.

Marine Transportation is provided by Sealift. Facilities include a beach landing and pushout south of the community. High cliffs limit expansion of these facilities.

There is no direct road access to Repulse Bay. Within the community there are approximately 8.9 km of gravel surface roads. Calcium chloride is applied annually to 4.5 km of road to act as a dust suppressant and surface-stabilizing agent.

1.2.7 HOUSING

The number of private occupied dwellings increased 23.6% between 1986 and 1991. As of 1994, the Housing Corporation owned 76 housing units. The Housing Assistance Program, the Alternative Housing Program, and Government Lease-to-Own units have accounted for 14 new homes in the community.

1.2.8 COMMERCIAL ACCOMODATION

The Aivilik Lodge accommodates seven guests and the Naujat Co-op Hotel accommodates thirteen.

1.2.9 RECREATION AND CULTURAL ACTIVITIES

Recreational facilities include a gymnasium, built in 1986, and an arena, built in 1991/92. The Community also has a playground and a playfield. Repulse Bay has an Active Recreation Committee.

1.2.10 EDUCATIONAL FACILITIES

Tusarvik School teaches grades K-9. Six teachers and three classroom assistants are on staff. The Repulse Bay Education Council is the local education authority.

1.2.11 HEALTH FACILITIES

The health centre (747 m^2), built in 1983, houses two medical beds, one bassinet, and one crib. Two nurses, one therapist, and one community health representative are on staff.

1.2.12 FIRE PROTECTION FACILITIES

Fire protection consists of a twelve-person volunteer fire brigade. Equipment includes a 1980 International 625 g/min. triple combination pumper, a fire siren, and a telephone alarm system. The community has a firehall (116 m^2).

1.2.13 OTHER SERVICES AND MUNICIPAL SERVICES

RCMP services are available from Coral Harbour. The Community Social Services Office has a staff of two; services include the Youth Justice Committee.

Mail is delivered three times per week. NorthwesTel local and long distance telephone service, CBC Radio and CBC Television are available through the Anik satellite system. There is also a community radio station. Other television channels include CTV, Cancom and CHCH. NWTPC provides 690 kW of diesel-generated power to the Hamlet.

Other infrastructure funded by Municipal and Community Affairs programs includes staff housing, the Hamlet office (with six offices), a three-bay parking garage (196 m^2), and a three-bay maintenance garage (246 m^2).

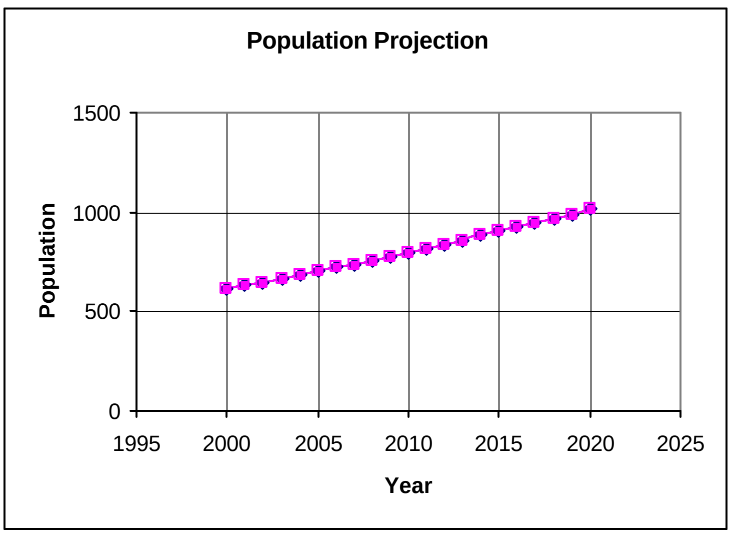
1.2.14 GENERAL DEMOGRAPHIC INFORMATION

The population of Repulse Bay, 615 (2000), is anticipated to grow at an average rate of 2.5% over the next twenty years. Projections estimate that the population will be 702 in 2005 and 1012 in 2021. The population is largely Inuit.

Table 1.1: Population projections for the Hamlet of Repulse Bay

Calendar Year	Population
2000	615
2005	702
2010	797
2015	903
2020	1012

Figure 1.1: Population projection for the Hamlet of Repulse Bay



Source: www.stats.gov.nu.ca

2. BACKGROUND

2.1 PREVIOUS STUDIES

2.1.1 DILLON, SUPP. REPORT TO EVALUATION OF ALTERNATIVES, OCTOBER 1984

Dillon's report was a supplementary report to be read in conjunction with " Repulse Bay – Water Supply, Sewage and Solid Waste Disposal – Evaluation of Alternatives" March 1980. This referenced report was unavailable for review. Essentially this report recommended what is now the existing dump site and sewage disposal site.

2.1.2 DILLON, PLANNING STUDY, JUNE 1984

This was a pre-design engineering study to develop alternatives and recommendations for water supply & distribution, sewage collection & treatment and solid waste management. This report furthered earlier works that were submitted in 1979 and 1980. The report made a number of recommendations. The following are a summary of some applicable/relevant recommendations to this work:

- Sewage disposal system should be designed to handle tanker truck contents and honey bags separately.
- Honey bags should be collected separately from garbage.
- Sewage disposal systems should be located adjacent to the existing garbage disposal site. The system should include the following:
    - Access roadway with truck turnaround;
    - Discharge point at top of valley wall;
    - Gravity sluice of pipe half sections;
    - Solids retention pit;
    - Discharge ditch from retention pit to lagoon; and
    - Sewage lagoon with a floatables containment berm and relief pipes.

- The existing garbage disposal site should be operated in a manner that the site is properly closed before a new disposal site is prepared.

- New site should have an area exclusively for bulky waste.

2.1.3 DPW, DESIGN AND OPERATIONS CONCEPT REPORT, SEPTEMBER 1990

This was a study carried out by DPW on behalf of MACA to provide engineering services for the design and construction of new sewage and solid waste facilities in Repulse Bay. The report outlined the following requirements:

- Modified Landfill Area method. Required area for landfill of 18,000 m^2 (depth of 900 mm). Required area for Bulky Waste of 1,000 m^2.

- Construction of a sluice, solids retention pit and floatables containment berm.

- Required volume for honey bag disposal of 90 m^2.

2.1.4 DPW, DESIGN AND OPERATIONS CONCEPT REPORT, MARCH 1993

This report is essentially a continuation of the report that was prepared in September of 1990. The required landfill area increased slightly to 20,000 m^2. The height of the landfill would be 1.5 m to accommodate a volume of 30,000 m^3. The report also outlined operation methods and maintenance schedules.

2.1.5 UMA, DESIGN AND OPERATIONS CONCEPT REPORT, MARCH 1994

This report recommended that the existing solid waste facility be re-developed to appropriately handle the various wastes produced by the community. UMA did not feel that the proximity to the airport created a problem with birds. They did feel that the situation should be monitored prior to any further development to quantify if there is a problem or not. It was noted in the site visit report (Sept. 2, 1993) that it was thought that a bird was struck by an airplane earlier that year. An alternate site along the water road could also be developed.

UMA recommended monitoring of the effluent produced by the wetland system. The main reason would be to determine the seasonal variation of effluent quality and to determine the long-term performance of the system. This information would aid in determining if a lagoon type structure should be developed. UMA referenced an offset requirement of 365 m for lagoons from airports, it was noted that the existing system is 400 m.

2.1.6 DILLON, WETLANDS SEWAGE TREATMENT SYSTEM IMPACT ASSESSMENT, JUNE 1998

Dillon (1998) reported on a sampling program at three communities using tundra wetlands for the purpose of further developing the understanding of these systems, the expected effluent, the development of desirable site characteristics, and design parameters. The communities were Baker Lake, Chesterfield Inlet, and Repulse Bay. This report found that the treated sewage discharge to Repulse Bay does not appear to be impacting the marine environment.

2.2 WATER SUPPLY AND TREATMENT

In the past, the water supply had been obtained from a small lake approximately 2 km from the community. A pump was used to draw water from the source to the truck. Disinfection consisted of adding calcium or sodium hypochlorite directly to the truck.

A pre-design study completed in 1984 investigated potential permanent water supply sources. When the truckfill facility was in the planning stages, the community expressed a strong desire to have the water supplied from Nuviq Luktujuq Lake, a much larger lake approximately 4 km from the community.

In 1988, a new intake/truckfill facility was constructed. The site consists of a natural boulder deposit between a bedrock ridge and Nuviq Luktujuq Lake. The boulder deposit extends into the lake to form a flat, shallow shelf that rapidly drops off at a point 35 m from shore. A gravel pad has been placed at the termination of the access road at the top of the rock ridge. The surface area is covered with cobbles and stones, ranging from approximately 100 - 400 mm in size.

Water is drawn into the twin inclined shaft intake casings through vertically mounted drum screen intakes located at a depth of approximately 5 m. Submersible pumps (one duty and one standby), located inside the casings about 6 m from the intakes, are mounted on skids and can be removed from the casings for servicing by means of a wire pull arrangement. The 100 mm diameter heat traced HDPE discharge lines are carried inside the 300 mm diameter, 60 m long HDPE casings. The intake casings are insulated, ballasted and protected by a granular berm and rip-rap. The pumps are capable of filling the trucks at 1000 L/min.

The pre-engineered, skid-mounted pumphouse, 3.5 m x 7.6 m, is divided into two rooms. One room contains the hypochlorination equipment and the steel discharge line from the intake to the truckfill arm. The other contains twin 10 kW diesel electric generators (one duty, one standby). As there is no outside source of power, one of the gensets is always operating to prevent freezing of the intakes and to heat the building.

Pump maintenance requires pulling the pump and discharge pipe from the casing. While requiring more time for removing similar pumps from wetwells, this task has been performed successfully by local labour in many communities. Difficulties have occurred in the past due to mechanical damage; the casing itself can become crushed by ice. Proper bedding and cover of the casing minimizes the frequency of this occurrence.

A hypochlorinator kit provides disinfection of the raw water. It consists of a pump (48 L/h), two mixing tanks, a mixer and an injector. A chlorine test kit and a spare chemical feed pump are available.

2.3 WATER STORAGE AND DISTRIBUTION

The community's water storage is Nuviq Luktujuq Lake. The pumphouse draws water directly from the lake. While the pumphouse facility is designed for maximum truckfill rate of 1000 L/min., the actual capacity is dependent upon the lake level at any given time. During commissioning, the actual flow rate was approximately 1250 L/min.

A truckfill heat trace is installed to thaw the truckfill arm. The arm is removable to facilitate repair or replacement in case of damage.

In the event of the duty pump failing, the standby or alternate pump can be selected by the truck driver simply by switching to the alternate pump on the "PUMP1/PUMP2" switch on the driver's control panel.

Repulse Bay is now under a fully trucked water distribution system operated by the Hamlet Council. Water is delivered using a 1994 model F-800 8172 L truck. All water deliveries are metered.

2.4 SOLID WASTE VOLUME PROJECTIONS

There is no published information on waste volumes in Repulse Bay. Relying on data from other communities in this region, the following table of estimated solid waste volumes was prepared.

The following assumptions were made to prepare this table:

- Yearly Per capita volume described by Heinke and Wong (1990) is 0.014 m^3 /person/day.
- The per capita population growth rate is 2.5% per year.
- The waste will compact by 50% in the landfill.
- The cover material required is 20% of the compacted volume.

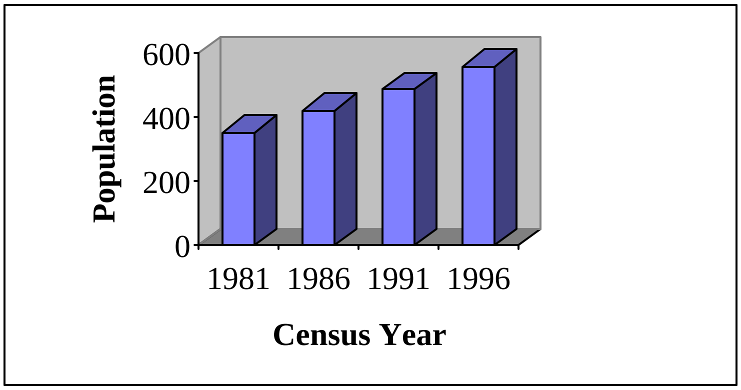
Table 2.1 Solid Waste Projections for the Community of Repulse Bay

Year	Pop.	Solid Waste Volume	Compacted Volume	
		cu.m.	cu.m.	
2001	630	3219	1610	
2002	648	3311	1656	
2003	664	3393	1697	
2004	682	3485	1743	
2005	702	3587	1794	
2006	720	3679	1840	
2007	738	3771	1886	
2008	757	3868	1934	
2009	777	3970	1985	
2010	797	4073	2036	
2011	818	4180	2090	
2012	838	4282	2141	
2013	858	4384	2192	
2014	881	4502	2251	
2015	903	4614	2307	
2016	928	4742	2371	
2017	949	4849	2425	
2018	970	4957	2478	
2019	990	5059	2529	
2020	1012	5171	2586	
2021	1033	5279	2639	
			44189	Sub-Total
			8838	Cover Material
			53026	**Total Volume Required [m3]**

2.5 SEWAGE GENERATION PROJECTIONS

The community population projections published by the Government of Nunavut indicate an average community growth rate of 2.5% for the Hamlet. Figure 2.1 indicates the census population tallies from previous years.

Figure 2.1 Population Increase in the Hamlet of Repulse Bay



The Municipal and Community Affairs (MACA) planning guidelines suggest that the increase in the projected per capita water use in a community should be modelled through the following equations.

(1) RWU x (1.0 + (0.00023 x Population)) **Population <2000**

(2) RWU x (-1.0 + (0.323 x Ln (Population)) **2000<Population<10,000**

(3) RWU x 2 **Population >10,000**

The RWU or residential water use is estimated to be 90 litres per capita (lpcd) for populations lower than 2000. The RWU is estimated to be 220 lpcd for populations greater than 2000.

Ln is the natural logarithm.

Equation 1 assumes that the population is using a delivery system to transfer water to the population. Equation 2 assumes the development of a piping system to transfer the water to members of a community.

Utilizing these modelling equations, the sewage generation was projected for the community of Repulse Bay for a 20-year span from the year 2001 to 2021 (Table 2.2). The assumption that the volume of sewage created is equal to the water consumed is inherent in the table. The sludge generation rate was taken to be 0.035 Lpcd.

Table 2.2 Sewage Generation Projections for the Hamlet of Repulse Bay

Year	Pop.	Water Consumption	Sewage Volume	Sludge Volume	Accumulated Sludge
		cu.m.	cu.m.	cu.m.	cu.m.
2001	630	23694	23694	80	80
2002	648	24459	24459	83	163
2003	664	25144	25144	85	248
2004	682	25918	25918	87	335
2005	702	26784	26784	90	425
2006	720	27569	27569	92	517
2007	738	28358	28358	94	611
2008	757	29197	29197	97	708
2009	777	30086	30086	99	807
2010	797	30981	30981	102	909
2011	818	31927	31927	104	1013
2012	838	32834	32834	107	1120
2013	858	33747	33747	110	1230
2014	881	34805	34805	113	1343
2015	903	35824	35824	115	1458
2016	928	36991	36991	119	1577
2017	949	37979	37979	121	1698
2018	970	38973	38973	124	1822
2019	990	39927	39927	126	1948
2020	1012	40982	40982	129	2077
2021	1033	41996	41996	132	2209

3. SOLID WASTE DISPOSAL SYSTEM

3.1 CURRENT PRACTICES

Solid waste collection occurs five days per week. Burning of wastes in oil drums is not practiced generally, save for some retailers. Once per year in July or August, the community participates in a spring clean up.

The modified landfill site is located 1.2 km northeast of the community across from the airstrip, just north of the sewage truck dumping point. Solid waste is stored on a sloping 12,000 m^2 unfenced site, where used oil supplies (in summer) are used in a weekly controlled burn. Once each month, the solid waste is compacted. Bulky wastes are stored at a separate 16,000 m^2 site.

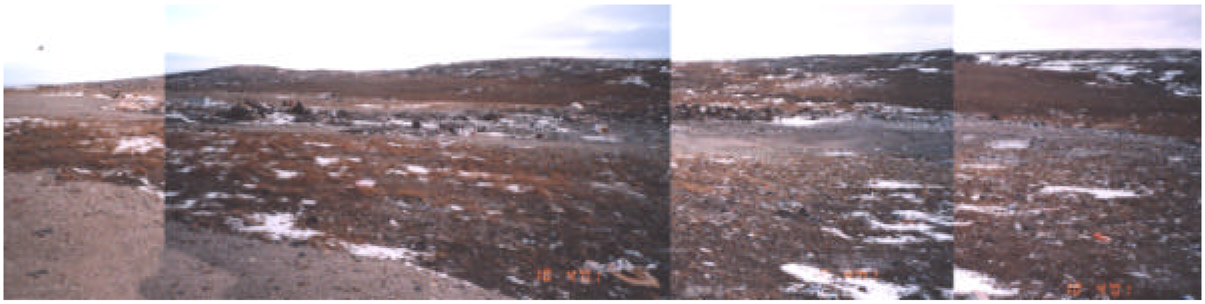
The Hamlet owns one garbage truck. It is a compactor that rests upon a Ford truck. Garbage is collected five days per week. The Hamlet charges for the garbage pick-up service. Rates vary depending on the classification of the pick-up. Residential units are charged $25/month. Government and Community buildings are charged $75/month. Commercial buildings are charged $250/month.

Residents place garbage into a 45 gallon drum outside their homes. The garbage truck picks up the garbage and hauls it to the dumpsite. The garbage is placed onto the ground near the perimeter of the covered area. Garbage is burned periodically. The burns are not scheduled by the Hamlet but completed as necessary. The garbage is compacted on a semi-regular basis. The compacted garbage is covered every two years with a layer of granular material. The site is expanding to the East. The Southern edge is encroaching onto the area utilized for wetlands treatment.

The hamlet maintains a separate area for large, bulky items. The area is immediately north of the existing general drop-off area. Waste is separated into the following categories: metal waste, old vehicles, old recreational vehicles (snowmobiles, all terrain vehicles), culverts, piping, heating oil tanks, waste oil, septic tanks. The Hamlet is proficient in keeping this area in a neat, organized manner.

Local building projects frequently drop off salvageable materials at the general drop-off area. Locals are free to pick up this discarded material for their personal use. There is no specific area that is marked out as a salvage area.

The existing general drop-off area sprawls over approximately 12,000 m^2. There is no fencing around the general area. There is no signage at the general area. The predominant North winds have scattered litter into the discharge area of the sewage wetlands. The following photo was taken from atop the sewage discharge area.



3.2 RECOMMENDATION

During the community consultation some concerns were expressed over the location of the bulky waste site. It was felt that it should be relocated because it is now visible from a new subdivision that is being developed to the north of the airport.

It was also discovered in the past that the community had tried to deal with sealift operators to remove the metal waste for recycling in facilities in the south. These attempts failed because the hamlet could not come to an agreement with the shipping companies over fair compensation for the work.

The recommendation for the bulky waste area is to decommission the existing site. Items that can be disposed of within the decommissioned solid waste facility should be. The community should attempt to ship out all metal waste and waste oils etc. in the near future. A new bulky waste area should be developed in the decommissioned solid waste area. This pattern should be repeated over time. Recycling of metal waste and developing bulk waste facilities in areas of decommissioned solid waste areas.

4. SANITARY WASTEWATER TREATMENT SYSTEM

4.1 CURRENT PRACTICES

A typical sewage pump-out truck is used to collect sewage from residences with holding tanks, discharging the waste at a dumping point 0.5 km east of the community. The sewage wetland is south of the landfill area in the same valley. The sewage drop off point adjoins the landfill area. Garbage has found its way to the discharge stream down the valley. The discharge point is delineated by two concrete footings with a steel beam positioned loosely between the footings. A steel 'sluice' leads down hill from the concrete footings. The discharge makes its way down the valley to the ocean.

	
Steel Sluice at Sewage Dropoff Point	Top of Sewage Dropoff Structure

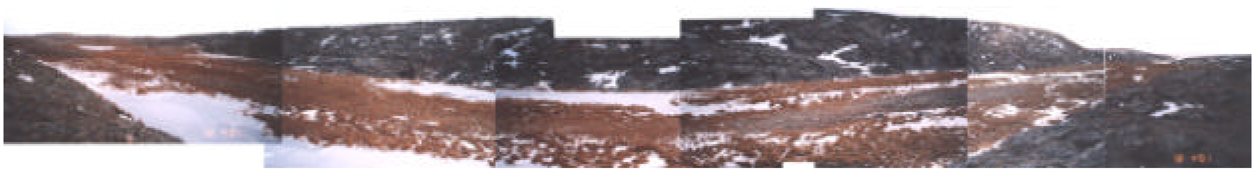
Treatment is by the natural wetlands method. Wetlands treatment is a web of complex physical and biological processes. Sedimentation, absorption of pollutants in the surface soils, nutrient uptake by plants, and the oxidation of compounds by microorganisms are some of the processes that effect the treatment.

From the dumping point, the sewage flows 1.4 km through a series of ponds and thickly vegetated areas before entering Hudson Bay. Sampling and analysis carried out in the summers of 1993 and 1994 showed the wetlands treatment to be very effective. BOD_5 levels of <10 mg/L and ammonia levels of <0.08 mg/L were recorded just above the point where the effluent entered the Bay. Dillon (1998) found that the wetland removed, during July, August and September, an average of 88% of the BOD_5, 87% of the TSS, 95% of ammonia, 74% of the total Phosphorus and 100% of the Fecal Coliform.

One residence in town relies on honeybags. This is contrary to the wishes of the Hamlet. The residence will no longer be provided with the service after October 15th of 2001. All other buildings and homes rely on sewage pumpout. The cost for providing this service is included in the cost for providing water.

The following photo shows the length of the wetland system. On the left side of the picture is the sewage drop-off point. On the right side of the picture is the outlet to Hudson Bay. The wetland system is confined on the east and west side by exposed bedrock. The valley varies in width on average it is approximately 50 m wide. There are three main ponds through which the effluent travels en route to the outlet at Hudson Bay. The Dillon (1998) report the active treatment area can vary from 6.4 ha (entire valley) in the spring to 2.3 ha later in the summer.

The predominant vegetation types within the bedrock domain are milfoil, sedges and grasses.



4.2 EFFLUENT QUALITY

Dillon (1998) reports the following removal rates:

BOD_5	88%
Suspended Solids	87%
Ammonia	95%
Total Phosphorus	94%
Faecal Coliform	100%

4.3 WETLANDS MODELLING

4.3.1 BACKGROUND

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.

It was Dillon's (1998) observation that treatment occurs with native species, and that the spring freshet passed before the sewage stored as ice began to melt. Instead, the majority of the sewage is slowly released to the wetland as the ice melts, thus, receiving full treatment. However, the contaminants go with the first 10% to 30% of the flow (Gao, 1996)

4.3.2 SEWAGE CHARACTERISTICS

The Nunavut Water Board projects raw sewage characteristics based on the per capita rates shown in Table 4.1. The Nunavut Water Board projection demonstrates that sewage quality parameters decrease in value as a result of the dilution due to the increase in water use.

Table 4.1 Sewage Characteristic 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 #

Year	Pop.	Water Consumption	BOD	TSS	T-PO4	TKN	FC
		Lpcd	mg/L	mg/L	mg/L	mg/L	#/dL
2001	630	103	437	466	22	116	9.2E+09
2002	648	103	435	464	22	116	9.2E+09
2003	664	104	434	463	22	116	9.2E+09
2004	682	104	432	461	22	115	9.1E+09
2005	702	105	430	459	22	115	9.1E+09
2006	720	105	429	458	22	114	9.1E+09
2007	738	105	427	456	22	114	9.0E+09
2008	757	106	426	454	22	114	9.0E+09
2009	777	106	424	452	22	113	9.0E+09
2010	797	106	423	451	22	113	8.9E+09
2011	818	107	421	449	22	112	8.9E+09
2012	838	107	419	447	21	112	8.8E+09
2013	858	108	418	445	21	111	8.8E+09
2014	881	108	416	443	21	111	8.8E+09
2015	903	109	414	442	21	110	8.7E+09
2016	928	109	412	440	21	110	8.7E+09
2017	949	110	410	438	21	109	8.7E+09
2018	970	110	409	436	21	109	8.6E+09
2019	990	110	407	434	21	109	8.6E+09
2020	1012	111	406	433	21	108	8.6E+09
2021	1033	111	404	431	21	108	8.5E+09

4.3.3 TREATMENT REQUIREMENTS

4.3.3.1 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. Doku and Heinke also stated that the critically used design parameter is the hydraulic loading rate, while the organic loading rate is used as a check to ensure that the aerobic conditions necessary for microbial activity prevail in a wetland system.

Dillon (1998) revised Doku and Heinke's design recommendations to; 18 to 400 m^3/ha.d for the hydraulic loading criteria..

There are no climate normals for Repulse Bay at Environment Canada. There is climate normals information for 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 4.1. The size of the wetland used for the calculations is 6.4 ha, the full area of the valley and the size of the wetland in the spring.

Evaporation and sublimation were not included in these calculations. Calculations for hydraulic loading are appended.

Table 4.2 Hydraulic loading summary

Duration	Hydraulic Loading Rate (m^3/d.ha)
During Melt (July & August)	97.2
After Melt (September & October)	20.5

The hydraulic loading rates during the melt period, and after the melt period, fall within the Doku and Heinke recommendation of 100 to 200 m^3/ha.d.

4.3.3.2 Organic Loading

The organic loading calculations are similar to the hydraulic loading calculations, Hall Beach climate normals and the 6.4 ha wetland will be used in addition to the sewage generation characteristics in Table 4.1.

Evaporation and sublimation were not included in these calculations. Calculations for organic loading are appended.

Table 4.3 Organic Loading Summary

Duration	BOD_5 Loading Rate (kg/d.ha)
During Melt (July & August)	36.4
After Melt (September & October)	7.3

The organic loading rate calculated during the melt period is higher then the suggested design values from both Doku and Heinke, 8 kg BOD_5/ha.d and revised by Dillon, 0.6 to 15 kg BOD_5/ha.d.

4.3.3.3 Alberta Environmental Protection Guidelines

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

$$A = 0.0365Q/k \bullet \ln (C_i - C^*)/(C_e - C^*)$$

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.

FSC has been collecting whatever data is available on wetlands and comparing the results to the Alberta model. Repulse Bay's average summer temperature is assumed to be 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 results of the model is compared to Dillon's 1998 data and conditions.

Table 4.4 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 model shows promise, however, there remains insufficient empirical data to develop specific correction factors. However, we are confident that they can be applied to indicate the future conditions at Repulse Bay.

The algorithms are applied to the Repulse Bay situation for the 20 year projection. The summary of the results follow and the calculations are appended.

Table 4.5 Alberta Environmental Protection Guidelines Summary

Wetland area	BOD Ci	TSS Ci	Nunavut Water Board Guidline BOD	Nunavut Water Board Guidline TSS	BOD Co	TSS Co
(ha)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
6.4	431	404	100	120	63	33

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

4.4 Discussion

The hydraulic loading rates fall within those recommended by Heinke and Dillon. Over time, increased hydraulic loading may cause some erosion and channelling which will reduce the effectiveness of the wetland. The situation should be monitored annually and if necessary, permeable granular berms installed to spread water across the available area(s).

The organic loadings rates are higher during the spring than those recommended, however, modelling suggests that NWB effluent requirements should still be meet in year 20.

All of the consequences of higher than suggested organic loading rates are manageable if detected early. Anaerobic conditions may occur within the wetland. These conditions would not stop treatment; just slow it down and take away from the aesthetic value of the wetland. In the worst case, some plants may die, potentially causing blockage and short-circuiting. The site should be monitored annually for early signs of anaerobic conditions.

A winter storage exfiltration pond could be considered to reduce organic loading. The contaminant concentrations, including BOD_5, are reduced approximately by 40%. The organic loading rate during the melt period would then be about 22 kg/ha/d, still slightly higher than recommended, but showing promise in the model.

The wetland at Repulse Bay is a natural system and subject to natural variability caused by temperature, sunlight intensity, rainfall, and the like. As a result, effluent quality may vary annually.

4.5 Recommendations

The following improvements should be implemented to the existing sewage disposal system.

- Litter and any other solid waste should be removed from the wetland area.
- Bollards and wheel stops should be installed to prevent trucks from backing off of the drop-off area.
- Signage should be placed not only at the discharge facility but also along the wetland route the effluent follows on its path to the ocean.
- The wetland should be monitored for early signs of erosion or channelling and anaerobic conditions.

5. SOLID WASTE OPTIONS

5.1 OVERVIEW

The main concern with the Sewage & Solid Waste system in Repulse Bay is the increased potential for bird/plane incidents due to the proximity of the Solid Waste disposal area to the existing airport facility. As well, there is a minor concern that the bulky waste disposal area is visible from the new subdivision area built to the North of the runway.

There are two alternatives available to remedy the situation. They are as follows:

- Do nothing;
- Close out existing Solid Waste site and develop a new site.

There are three alternative sites that were observed as potential locations for a new solid waste landfill facility. These sites were numbered 1, 2 and 3. Their location relative to the community can be seen in the figure on the next page.

5.2 SOLID WASTE DISPOSAL OPTIONS

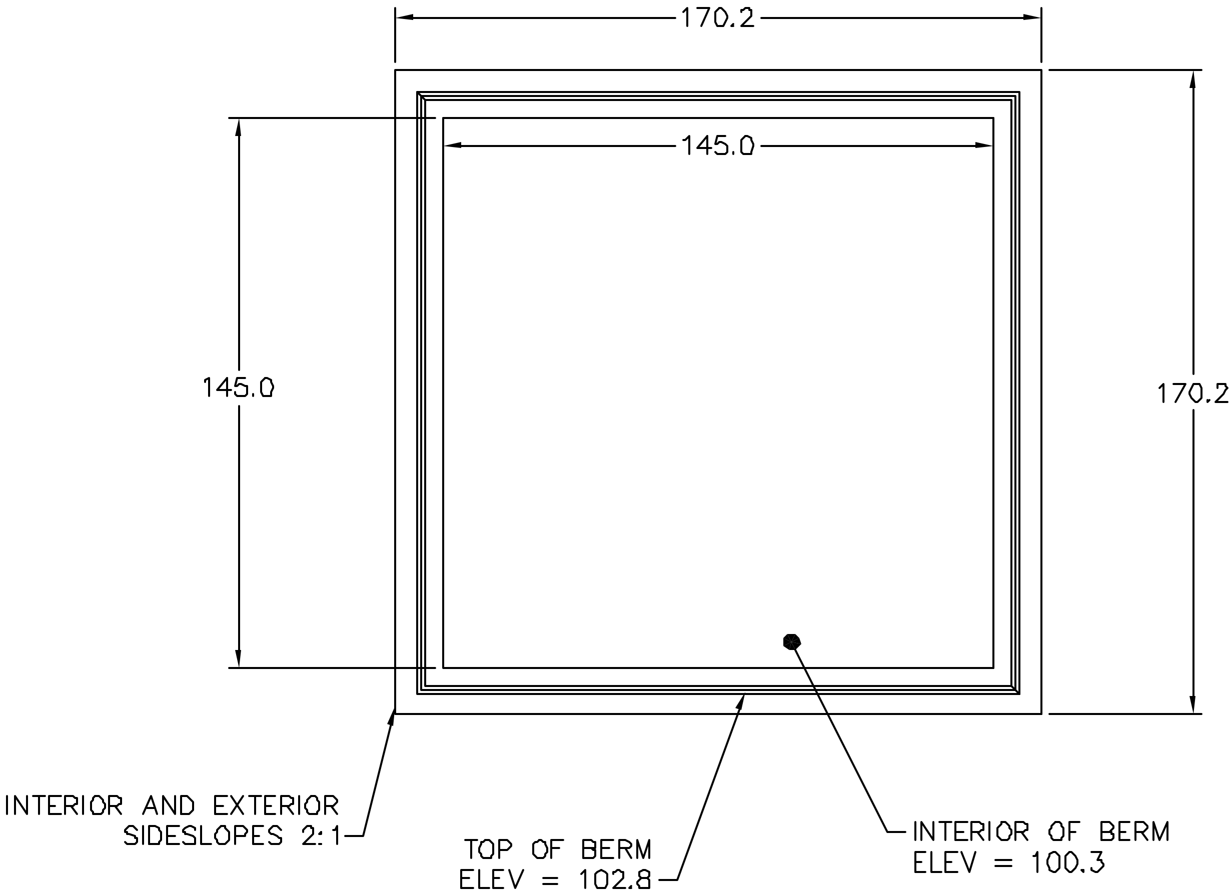
There are several acceptable methods of disposal for municipal garbage that are acceptable for use in the North today, including:

- Modified landfill;
- Sanitary Landfill;
- Landfill with burning;
- Incineration; and
- Baling.

These options will be examined in the following sections.

5.2.1 MODIFIED LANDFILL

The modified landfill is very similar to the open dump/landfill. The difference lies in the planning and operation of the facility. Modified landfill sites require careful planning in their operation to ensure that they are utilized efficiently so that they can maximize their service life within the design period. Garbage



NOTES:

1. EXISTING GROUND ELEVATION = 100.0
2. FENCING TO BE PLACED AT MIDPOINT OF THE TOP OF THE BERM. 622 lin.m. PLUS 6m SLIDING GATE.
3. DOES NOT ACCOUNT FOR ACCESS ROAD DEVELOPMENT.
4. VOLUME DEVELOPED IN REPORT, SECTION 2.4

Site Volume Table: Unadjusted

Site	Stratum	Surf1	Surf2	Cut cu.m	Fill cu.m	Net cu.m	Method
145							
	intvol145	int145bot	top145	0	56271	56271 (F)	Composite
	145base	base145	145x145	0	19286	19286 (F)	Composite

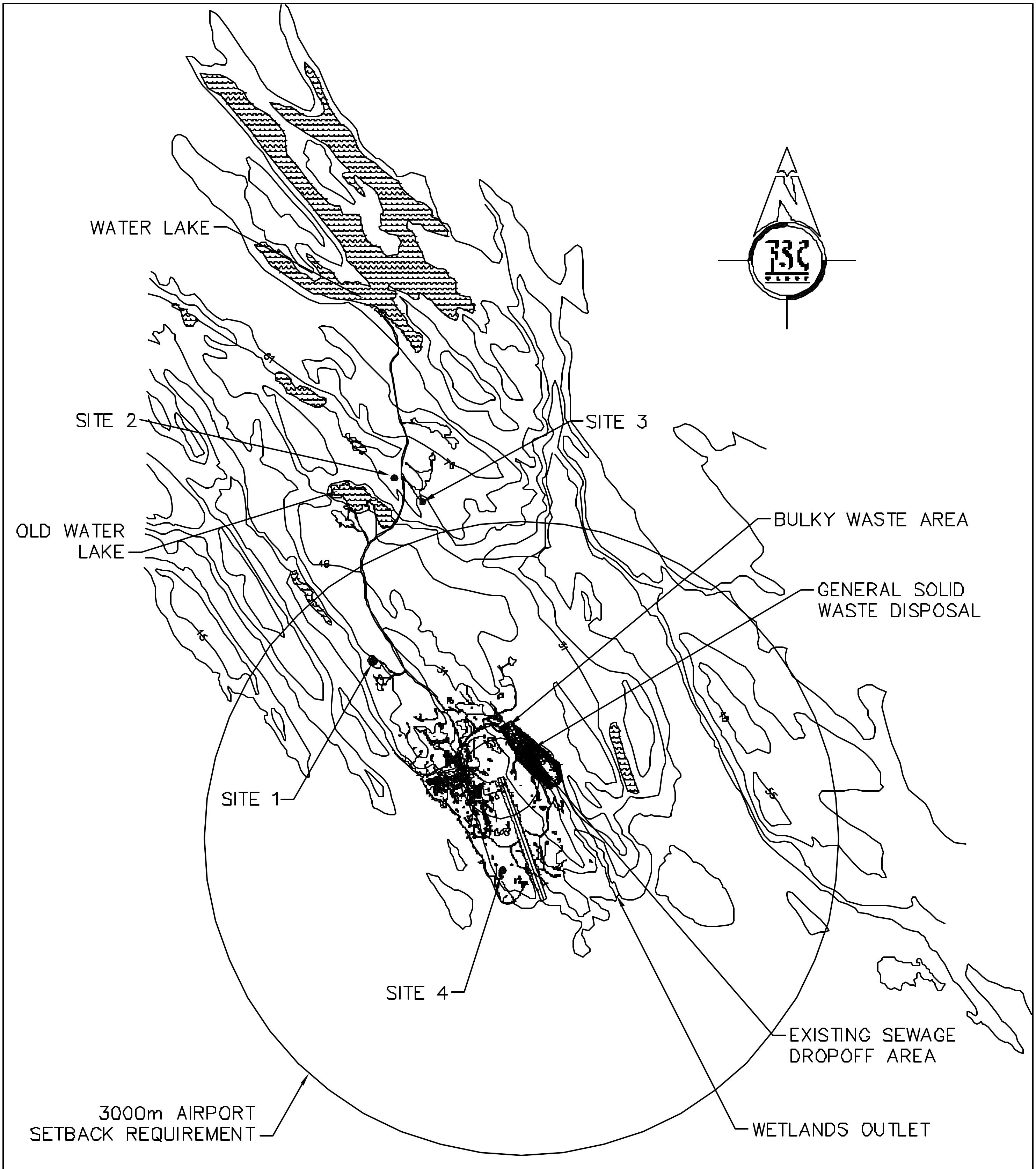
FSC GROUP

JOB TITLE
SEWAGE & SOLID WASTE STUDY

REPULSE BAY, NUNAVUT

DRAWING TITLE
BERM IN FLAT AREA 157 x 157 x 2.5m OPTION 2

DESIGNED BY	SCALE 1:2000
DRAWN BY WM	DATE DEC/2001
CHECKED BY	CLIENT JOB NO.
FSC FILE NO. landfill.dwg	FSC PROJECT NO. 2001-1050
SHEET OF	DRAWING NO 2



FSC GROUP	JOB TITLE	DRAWING TITLE		
FERGUSON SIMEK CLARK	SEWAGE AND SOLID WASTE IMPROVEMENTS	OVERALL SITE LOCATIONS	DESIGNED BY WM	SCALE 1:50000
			DRAWN BY WM	DATE NOV.2001
			CHECKED BY RK	CLIENT JOB NO.
			FSC FILE NO. SITES.DWG	FSC PROJECT NO. 2001-1050
	REPULSE BAY, NUNAVUT		SHEET OF	DRAWING NO 1

is disposed of in pre-determined locations, compacted and covered at more frequent intervals than the open dump style. A separate area for bulky and hazardous wastes is required.

5.2.2 LANDFILL WITH BURNING

This type of landfill is an extension of the open dump/landfill. Burning is used to reduce the volume of the garbage to extend the life of the landfill. Much of the waste generated in small northern communities is combustible. This enables a significant reduction in the volume of the garbage.

Although burning is currently used in the community its use has fallen out of favour with regulatory officials. Open burning increases the risk of injury to workers and the public from explosions of discarded aerosol cans. This increases the liability of the community. It also creates concerns due to the potential effects on the health of workers and the public, incomplete combustion creates air pollution concerns, hazardous material deposited with municipal waste could be released into the atmosphere, etc.

Burning will not be considered further in this report.

5.2.3 SANITARY LANDFILL

This type of landfill requires daily compaction and cover with soil. It is a labour intensive operation that requires a high level of supervision. The sanitary landfill has been widely accepted as the standard disposal infrastructure type in southern locales with populations greater than 5,000. It requires access to cheap and extensive amounts of fill. Due to the equipment time commitment required and the lack of fill material in the community this option will not be discussed further.

5.2.4 INCINERATION

Essentially, incineration is a combustion process that breaks down waste into inert, easily transportable material. This process generally provides complete combustion of the material unlike open burning. This alleviates a number of the health and liability concerns with incineration versus open burning. It does not however eliminate them; improperly maintained incinerators can release persistent organic pollutants and heavy metals into the atmosphere. Incineration also virtually eliminates problems associated with bird control.

Incinerators in the past have been typically complex systems requiring a relatively high degree of specialization to maintain equipment in peak running conditions. High capital costs for the equipment and equally high costs for replacement parts have made this option less desirable than other simpler more cost effective methods. Improvements have been developed that may make this option more suitable in this type of application.

Because there will be no waste available that could be considered as food by birds and/or other wildlife, it may be possible to construct an incineration facility at the same location as the current solid waste facility.

It is noted that several provinces do not allow burning of MSW. Other provinces are planning to ban MSW burning in the future.

5.2.5 BALING

The City of Yellowknife currently operates a baling facility for disposal of its municipal waste. There are positive attributes for utilizing this technology which include: reduced cover material thickness, longer landfill life due to increased compaction of refuse, enhanced material recycling costs.

Essentially a baling system consists of a baler machine located in an enclosed building with a dumping area, typically a concrete floor. The garbage trucks deposit their bins on the concrete floor and a loader pushes the refuse into a loader bin. The baler takes the garbage and presses it hydraulically and ties it with wire. These bales can be stacked within the landfill.

However, these operations have considerable capital costs and associated operation and maintenance costs. For these reasons this option will not be discussed any further in this report.

6. POTENTIAL SOLID WASTE DISPOSAL SITES

6.1 SITE ONE

This site was 975 m from the tank farm to the access road along water road. The road leading from water road to the area is about 225 m in length. The area is naturally shielded from view from the water road by a bedrock outcrop. The area itself is bounded on the sides by bedrock outcrops. The far end of the site drops off into an inlet of the ocean.

While the general topography of the area lends itself to being an appropriate site for a modified landfill, there are other factors that render the area undesirable for such a solid waste site. Primarily the site is directly north of the community. Odors from the site will propagate into the Hamlet on a regular basis due to the predominant north winds.

The location of this site allows it to be suitable to be a potential site for an incineration unit. However, the predominant winds in the area would blow emissions towards the community. It is unlikely that this would be acceptable to the community. It is likely that there is enough space to accommodate a bulky waste area. This location is blocked from view from the water lake road by a large bedrock outcrop. This is the only site out of the three that does not have a potential conflict with the airport's flight path. The site is, however, within the 3km radius of the airport.

As well, the site is 900 m overland from the nearest community development. The community is growing in the direction of this site. It is reasonable to expect that the community will encroach on the site in the future. This site will not be discussed further.

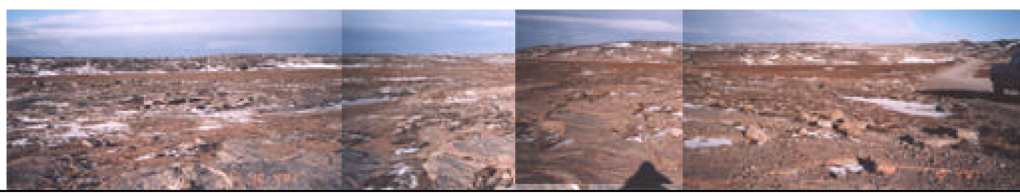
Panoramic View to the North

6.2 SITE TWO

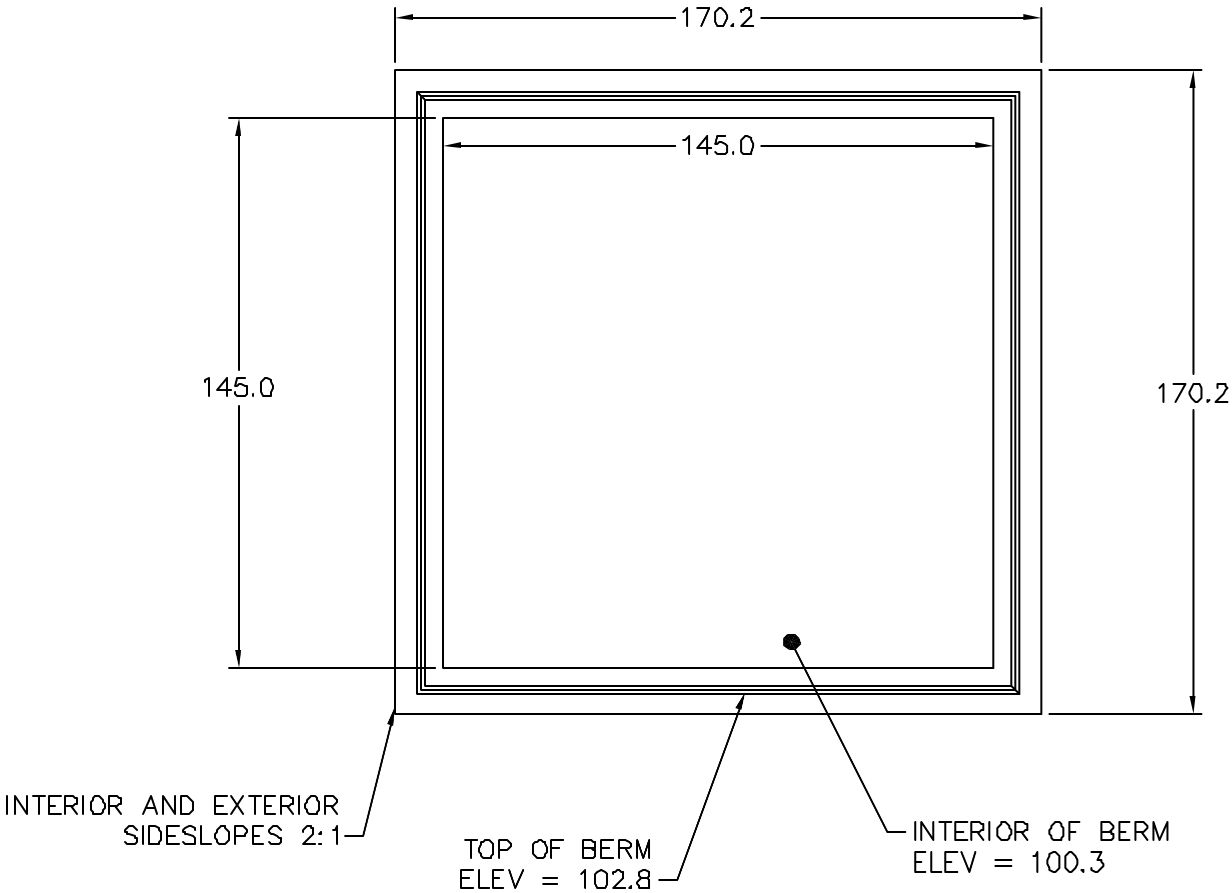
The second site is approximately 3 km by road out of town along water lake road. It is on the North side of the road immediately adjacent to it. The area is quite large and is bounded by a bedrock outcrop on the Northwest side. The terrain is relatively flat with some short bedrock outcrops.

The extensive area available for a solid waste site and distance from the community makes this area appealing. The area however is outside the 3km distance minimum from the airport and lies within close proximity to the flight path zone of the airport. The site is lower than bedrock outcrops to the south of the site. As such it does not protrude into the take-off / approach surface of the airport.

This area is relatively flat. Bedrock is predominant in this area. The area is immediately adjacent to the water road. These features reduce the potential development costs of any buildings or other facilities in this area. As such, it is likely that a modified landfill would not be accepted by the community and would be regarded as an eyesore. A sketch of the proposed layout and cost estimate can be viewed in the following pages.



Panoramic view to the North



NOTES:

1. EXISTING GROUND ELEVATION = 100.0
2. FENCING TO BE PLACED AT MIDPOINT OF THE TOP OF THE BERM. 622 lin.m. PLUS 6m SLIDING GATE.
3. DOES NOT ACCOUNT FOR ACCESS ROAD DEVELOPMENT.
4. VOLUME DEVELOPED IN REPORT, SECTION 2.4

Site Volume Table: Unadjusted

Site	Stratum	Surf1	Surf2	Cut cu.m	Fill cu.m	Net cu.m	Method
145							
	intvol145	int145bot	top145	0	56271	56271 (F)	Composite
	145base	base145	145x145	0	19286	19286 (F)	Composite

FSC GROUP

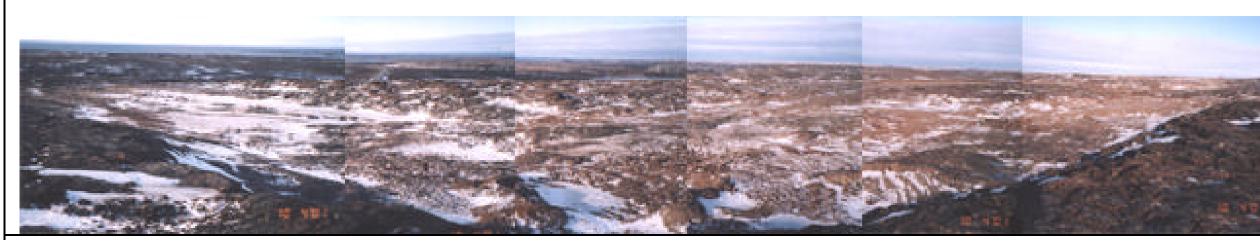
JOB TITLE SEWAGE & SOLID WASTE STUDY REPULSE BAY, NUNAVUT	DRAWING TITLE BERM IN FLAT AREA 157 x 157 x 2.5m OPTION 2	DESIGNED BY	SCALE 1:2000
		DRAWN BY WM	DATE DEC/2001
		CHECKED BY	CLIENT JOB NO.
		FSC FILE NO. landfill.dwg	FSC PROJECT NO. 2001-1050
		SHEET OF	DRAWING NO 2

6.3 SITE THREE

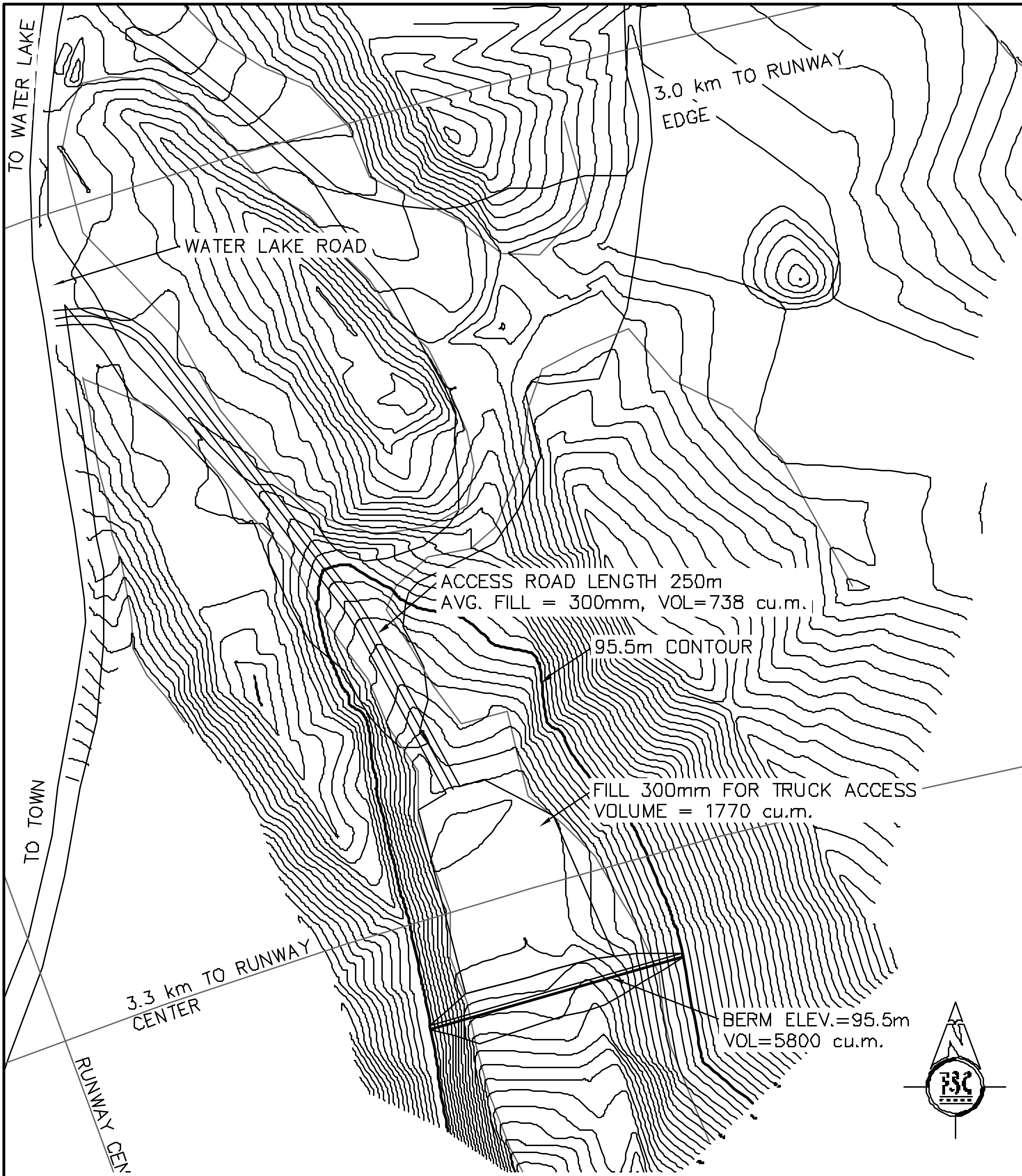
The third site is the same distance from the community by road as site 2. It is South of the water lake road, directly opposite from site 2. It is approximately 2.7 km from the end of the runway. The site is approximately 3.3 km from the geographical center of the runway. The terrain of the area is similar to Site 1. Large bedrock outcrops form a boundary on the east and west sides of the area. The south end drops off down into a valley. Access is at the north end. A bedrock outcrop hides the area from view from the road. The developed site would not rise above the peak elevation of the adjacent bedrock outcrops. As such it does not protrude into the take-off / approach surface of the airport.

Drainage from this valley runs down a steep slope at the Southeast end of the valley into another large sweeping area. This area drains away from the old water lake into an inlet off of the ocean. This inlet runs out to the ocean just East of the outlet for runoff from the existing solid waste disposal area. There is sufficient volume in the valley to handle the projected 20 years of solid waste.

This site would likely be acceptable to the community. The site meets the minimum 3 km setback from the airport depends on your interpretation of the requirement. The site lies approximately 3.3 km from the geographical center of the runway.



Panoramic View from North Ridge



FSC GROUP FERGUSON SIMEK CLARK	JOB TITLE SEWAGE AND SOLID WASTE IMPROVEMENTS REPULSE BAY, NUNAVUT	DRAWING TITLE SITE 3	DESIGNED BY WM	SCALE 1:4000
			DRAWN BY WM	DATE NOV.2001
			CHECKED BY RK	CLIENT JOB NO.
			FSC FILE NO. OPTIONS.DWG	FSC PROJECT NO. 2001-1050
			SHEET OF	DRAWING NO 3

6.4 SITE FOUR

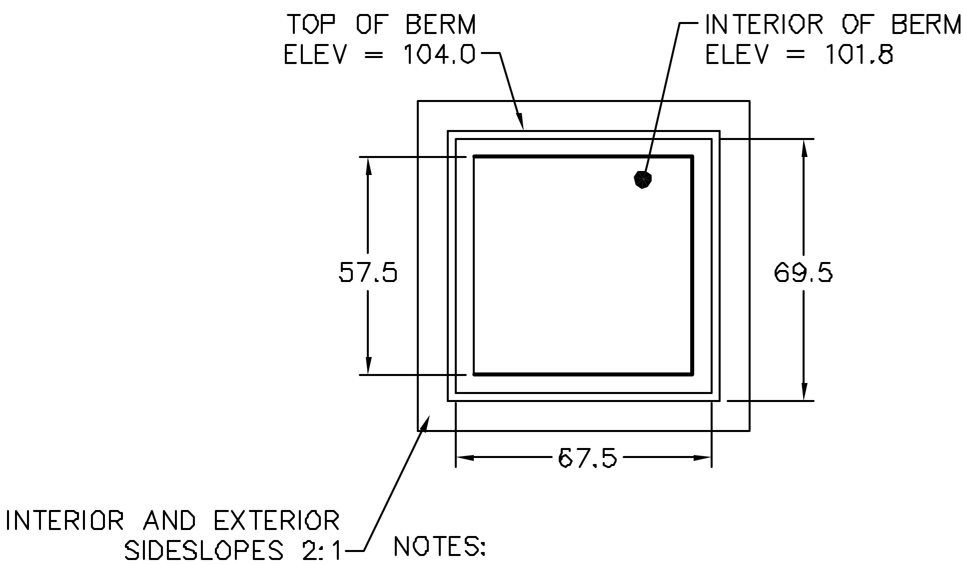
This site was not visited during the tour of the community. This site was not discussed with any of the local community representatives. At the time of the visit incineration was not considered as an option for dealing with the solid waste generated by the community. Some investigation into the feasibility and cost of an incinerator facility was completed after the site visit.

The incineration unit requires electrical power and produces minimal emissions. The site was selected due to its proximity to the town. This will reduce the cost of providing power. As well, the predominantly north winds will blow the emissions away from the community. The system is not complex, company representatives reported that individuals with HVAC experience would be able to maintain the unit.

This option will require the extension of an existing road by approximately 222 m in length. A new building will be required to house the facility. An ash deposit site will also require development. Volume reduction rates of 90% are achievable. An ash deposit area with a volume of approximately 9000 m^3 would be required to handle the 20 year projected waste production.

This option also allows for the possibility of heat recovery. This is an additional capital cost to install additional equipment. It would reduce O&M requirements for the building that the unit is housed in. As well, the incineration unit could be fitted to dispose of waste oils, fuel, etc.

This system has been installed in northern locations with success. Literature produced by the company is presented in an appendix to this report.



NOTES:

1. EXISTING GROUND ELEVATION = 100.0
2. AVERAGE DEPTH OF FILL FROM EXISTING GROUND TO BASE OF INTERIOR STORAGE = 1.5m
2. VOLUME OF GRANULAR MATERIAL TO BUILD, 15580 cu.m.
3. INTERIOR VOLUME AVAILABLE = 9786cu.m.
4. VOLUME DEVELOPED IN REPORT, SECTION 2.4, 90% REDUCTION RATE.

Site Volume Table: Unadjusted

Site	Stratum	Surf1	Surf2	Cut cu.m	Fill cu.m	Net cu.m	Method
ASH							
	ashberm	ashbase	ASHBERM	0	15580	15580 (F)	Composite
	ashstore	ashstorage	ashtop	0	9786	9786 (F)	Composite

FSC GROUP	JOB TITLE SEWAGE & SOLID WASTE STUDY REPULSE BAY, NUNAVUT	DRAWING TITLE ASH WASTE DISPOSAL 57.5 x 57.5 x 2.5m	DESIGNED BY	SCALE 1:2000
			DRAWN BY WM	DATE DEC/2001
			CHECKED BY	CLIENT JOB NO.
			FSC FILE NO. landfill.dwg	FSC PROJECT NO. 2001-1050
			SHEET OF	DRAWING NO 4

7. OPTIONS EVALUATION

In order to evaluate potential remediation options objectively, we have used a decision making tool called a weighted factor analysis. This tool/method is a modification of the Kepner-Tregoe analysis. It involves two distinct steps, which are outlined as follows:

7.1 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 requirement; and
- **Must** not impede on future growth of community

7.2 OPTIONS ANALYSIS

If an option passes our initial screening process it will be included in our final evaluation process. 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 objectively 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. Acceptable to the community; and

5. Maximum distance from airport.

7.2.1 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 7.1 - Binary Decision Model to Assign Weights to Objectives

	Capital Cost	O&M Cost	NPV	Community Acceptance	Distance to Airport	Total	Assigned Weight
Capital Cost	-	0	1	1	0	**2**	8
O&M Cost	1	-	1	1	0	**3**	9
NPV	0	0	-	1	0	**1**	7
Community Acceptance	0	0	0	-	0	**0**	6
Distance to Airport	1	1	1	1	-	**4**	10

7.2.2 SCORING

1. Lowest Capital Costs

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

2. Lowest O&M Cost

The lowest O&M 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. Locations Acceptable to the Community

Locations to which the community would be receptive to - 10

Locations to which the community may be receptive to - 5

Locations to which the community will not be receptive to - 0

5. Distance to the Airport

The site, which is the furthest away from the airport will be scored "10". Others will be scored based on percentage of the distance. It should be noted that the incineration option is a different type of operation than the landfill. While it is a solid waste facility, all refuse is dropped off inside of an enclosed structure. The ash produced by the system is inert and unusable to animals for food. As such, the required 3.0km separation may not be applicable to this system. As such, the score for this option will not be based on distance but will be scored a five.

7.2.3 RESULTS

The following table shows the results of the modified K-T Analysis:

		Option 2		Option 3		Option 4	
Want	**Weight**	**Score**	**W*S**	**Score**	**W*S**	**Score**	**W*S**
Lowest O&M Cost	9	9.7	87.0	10	90.0	6.1	55.1
Lowest Capital Cost	8	6.2	49.8	10	80.0	4.1	32.6
Lowest NPV	7	7.3	51.3	10	70.0	4.7	33.2
Acceptable To Community	6	5	30.0	10	60.0	5	30.0
Distance From Airport	10	10	100.0	9	90.4	5	50.0
Total			**318.1**		**390.4**		**201.0**

Legend:

	Capital	Annual O&M	NPV	Dist.2 Airport	
Option 2	$2,999,518	$133,670	$4,429,879	3650	Site Two
Option 3	$1,866,207	$129,250	$3,249,271	3300	Site Three
Option 4	$4,584,529	$210,944	$6,841,780	420	Incinerator

8. CONCLUSIONS AND RECOMMENDATIONS

8.1 SUMMARY OF OPTIONS

8.1.1 LANDFILLING

Two landfilling options were examined, at sites 2 and 3. They have estimated costs of construction and operations as follows:

Option	Capital Cost	Annual O&M
2	$2,999,518	$133,670
3	$1,866,207	$129,250
4	$4,584,529	$210,944

The preferred landfilling option is at site 3. It is cheaper to develop and operate. As well, it is likely to be the option most acceptable to the community. It is slightly closer to the airport than option two but is outside the 3km-offset requirement. It is further away from the flight path than option 2.

8.1.2 INCINERATION

Incineration without waste heat recovery was examined. The capital and operating costs were found to be significantly higher than the landfilling options. Incineration would eliminate many environmental concerns with respect to contamination from the waste that is disposed in landfill. As well, it greatly reduces the area required for disposal of waste. Solid waste volume reductions of 90% are achievable.

8.2 DISCUSSION AND ANALYSIS

Landfilling and incineration are both adequate methods of dealing with solid waste in northern communities. In this case the capital cost and O&M cost of the incineration unit render it unappealing.

Two landfill sites were examined. While there is ample area for future expansion at site two, it is more expensive to develop and maintain this site. As well, this site would not likely receive support from the community.

Site three is the option with the least cost to construct and operate. It would be relatively simple to construct. It is capable of handling the 20 year projected garbage production of the community. It is likely to receive more support than any of the other options due to its 'hidden' location.

All options require the decommissioning of the existing solid waste facility. The cost estimates allowed for reshaping and compaction of the existing garbage to allow for natural drainage through the area.

The existing site is too close to the sewage waste disposal area. Garbage is strewn across the waterways, which is not acceptable.

All options require the bulky waste area to be decommissioned. It is recommended that the community develop a metal waste-recycling program. Metal waste should be shipped out in conjunction with sealift delivery. It is also recommended that the new bulky waste disposal area be relocated to atop the decommissioned solid waste site.

9. SITE 3 PHASED COST

Due to the nature of this project, a portion of the capital cost could be phased over the next several years. Site 3 was chosen by the K-T Analysis to be the best option for a new solid waste site at Repulse Bay and therefore the cost for construction of this project and decommissioning the existing solid waste site can be phased over the next four years.

The construction of site 3 does not need to take place all at once. One quarter of the site could be built in 2002. Once this portion is complete, the existing solid waste site should begin to be decommissioned. The first 300 mm layer of cover over the waste should be applied in 2002. The following year the final layer of 300 mm cover can be applied. The existing solid waste site will then be completely decommissioned in 2003.

Once the existing solid waste site is abandoned, the bulky waste can be moved to that site in 2004. The following year the abandoned bulky waste site should be cleaned up and decommissioned. All spills and stains should be scraped and deposited in the solid waste site. Then the site should be covered with 300 mm of general fill as required to bring the site to positive drainage.

The following table, Table 9.1, is the detailed phased cost plan.

Table 9.1 Phased Cost 2002-2005

2002

Capital Component	Unit Cost	Unit	Quantity	Extension
General fill, ¼ of the new site	$60	m^3	1837	$110,198
Granular fill, ¼ of the new site	$75	m^3	56	$4,191
Access road, new site	$188	m	250	$47,063
Close out Solid Waste (300 mm)	$60	m^3	3600	$216,000
Subtotal				**$377,451**
Engineering & Contingency @ 40%				$150,980
Total				**$528,431**

2003

Capital Component	Unit Cost	Unit	Quantity	Extension
Close out Solid Waste (300 mm)	$60	m^3	3600	$216,000
Fencing, ¼ of new site	$150	M	31	$4,650
Subtotal				**$220,650**
Engineering & Contingency @ 40%				$88,260
Total				**$308,910**

2004

Capital Component	Unit Cost	Unit	Quantity	Extension
Move Bulky Waste to New Site	$8,480	day	10	$84,800
Subtotal				**$84,800**
Engineering & Contingency @ 40%				$33,920
Total				**$118,720**

2005

Capital Component	Unit Cost	Unit	Quantity	Extension
Cover abandoned Bulky Waste Site (300 mm)	$60	m^3	4714	$282,840
Spill clean up allowance	$10,000	lump	1	$10,000
Subtotal				**$292,840**
Engineering & Contingency @ 40%				$117,136
Total				**$409,976**

Table 9.2 Phased Cost Summary

Remaining Capital Component for New Site	Unit Cost	Unit	Quantity	Extension
General fill, ¾ of new site	$60	m^3	5,510	$330,592.50
Granular fill ¾ of new site	$75	m^3	168	$12,571.88
Fencing, ¾ of new site	$150	m^3	94	$14,100
Subtotal				**$357,264.38**
Engineering and contingencies				$142,905.75
2002-2005 Total				$1,366,037
Total				**$1,866,207.00**

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Appendix A
Wetlands Calculations

Daily Hydraulic Load, Repulse Bay

Daily sewage generation (m3/d)	116
Duration of pond storage (months)	8
Melt period (months)	2
After melt period and before freeze (months)	2
Rainfall during melt period(mm)	41.7
Rainfall after melt period (mm)	14.8
Size of wetland (ha)	6.4
Pond Storage (m3)	27721.05
Ice pack melt (m3/day)	462.0175
Rainfall rate over wetland during melt (m3/d)	44
Rainfall rate over wetland after melt (m3/d)	16
Total daily hydraulic load during melt (m3/d)	622
Total daily hydraulic load after melt (m3/d)	131

Heinke requires 100 -200 (m3/d/ha)

Total hydraulic load during melt per ha	**97 (m3/d/ha)**
Total hydraulic load after melt per ha	**21 (m3/d/ha)**

Daily Contaminant Load, Repulse Bay

Total hydraulic load during melt (m3/d)	622	
Total hydraulic load after melt (m3/d)	131	
Rainfall rate over wetland during melt (m3/d)	44.5	
Rainfall rate over wetland after melt (m3/d)	15.8	
BOD concentration (mg/L)	404	
TSS concentration (mg/L)	431	
T-PO4 concentration (mg/L)	21	
TKN concentraion (mg/L)	108	
FC concentration (#/dl)	8.52E+09	
Size of wetland (hydraulic loading calculation, ha)	6.4	
Contaminant load during melt (kg/d)		
BOD contaminant load (kg/d)	233.2	**36.43**
TSS contaminant load (kg/d)	248.7	38.86
T-PO4 contaminant load (kg/d)	11.9	1.86
TKN contaminant load (kg/d)	62.2	9.72
FC contaminant load (#/d)	4.9E+09	7.69E+08
Contaminant load after melt		
BOD contaminant load (kg/d)	46.6	**7.29**
TSS contaminant load (kg/d)	49.7	7.77
T-PO4 contaminant load (kg/d)	2.4	0.37
TKN contaminant load (kg/d)	12.4	1.94
FC contaminant load (#/d)	9.8E+08	1.54E+08

Heinke's recommendation 8 kg/d/ha for BOD

Alberta Guidelines, Repulse Bay

Surface Flow Wetland Treatment

Design Flow m3/d	Q =	622					
		TSS	BOD	TP	TN	NH4-N	FC
Wastewater Characterization	Ci	404	431	21	108	80	8.52E+09
Target Effluent Quality	Ce	120	100	2	4	2	10000
Wetland Background Input	C* =	33.23684	26.32586	0.05	2	0	100

for TSS, C* = 7.8 + 0.063Ci
for BOD, C* = 3.5 + 0.053Ci

Area Rate Constant @20oC	k =	1000	34	12	22	18	77
Required Wetland Area	A =	0.03	1.137	4.459	4.094	4.653	4.029

Models $A = \frac{0.0365 * Q}{k} * \ln \left| \frac{Ci - C^*}{Ce - C^*} \right|$

Available Area 6.4

Projected Effluent Quality	**Co**	**33.24**	**26.35**	**0.75**	**2.21**	**0.50**	**1.03E+02**

$Co = C^* + [Ci - C^*] \exp \left| \frac{- kAmax}{0.0365 * Q} \right|$

Overall % removal	91.768	93.881	96.371	97.944	99.374	100.000

10C

Area rate constant, k, has been divided by 2 from 20C value

Alberta Environment Wetlands Calculations

Surface Flow Wetland Treatment

Design Flow m3/d Q = 622.0019

		TSS	BOD	TP	TN	NH4-N	FC
Wastewater Characterization	Ci	403.7593	430.6766	20.63659	107.6691	80	8.52E+09
Target Effluent Quality mg/l	Ce	120	100	2	4	2	10000
Wetland Background Input	C* =	33.23684	26.32586	0.05	2	0	100

for TSS, C* = 7.8 + 0.063Ci
for BOD, C* = 3.5 + 0.053Ci

		TSS	BOD	TP	TN	NH4-N	FC
Area Rate Constant @10oC	k =	500	17	6	11	9	38.5
Required Wetland Area, ha	A =	0.07	2.274	8.918	8.188	9.305	8.059

Models $A = \frac{0.0365 * Q}{k} * \ln \left| \frac{Ci - C^*}{Ce - C^*} \right|$

Available Area 6.4

		TSS	BOD	TP	TN	NH4-N	FC
Projected Effluent Quality	**Co**	**33.24**	**29.68**	**3.84**	**6.76**	**6.33**	**1.65E+05**

$Co = C^* + [Ci - C^*] \exp \left| \frac{- kAmax}{0.0365 * Q} \right|$

	TSS	BOD	TP	TN	NH4-N	FC
Overall % removal	91.768	93.109	81.376	93.725	92.090	99.998

5C

Area rate constant, k, has been divided by 2 from 10C value

Alberta Environment Wetlands Calculations

Surface Flow Wetland Treatment

Design Flow m3/d Q = 622.0019

		TSS	BOD	TP	TN	NH4-N	FC
Wastewater Characterization	Ci	404	431	21	108	80	8.52E+09
Target Effluent Quality mg/l	Ce	120	100	2	4	2	10000
Wetland Background Input	C* =	33.23684	26.32586	0.05	2	0	100

for TSS, C* = 7.8 + 0.063Ci
for BOD, C* = 3.5 + 0.053Ci

		TSS	BOD	TP	TN	NH4-N	FC
Area Rate Constant @5oC	k =	250	8.5	3	5.5	4.5	19.25
Required Wetland Area, ha	A =	0.13	4.548	17.836	16.376	18.611	16.117

Models $A = \frac{0.0365*Q}{k} * \ln \left| \frac{Ci - C^*}{Ce - C^*} \right|$

Available Area 6.4

		TSS	BOD	TP	TN	NH4-N	FC
Projected Effluent Quality	**Co**	**33.24**	**63.15**	**8.89**	**24.42**	**22.50**	**3.75E+07**

$$Co = C^* + [Ci - C^*] \exp \left| \frac{- kAmax}{0.0365*Q} \right|$$

	TSS	BOD	TP	TN	NH4-N	FC
Overall % removal	91.768	85.337	56.936	77.321	71.876	99.560

Appendix B
Cost Calculations

Option 2
Site Two

Capital Component	Unit Cost	Unit	Quantity	Extension
Earthworks				
General Fill	$60	cu.m.	18299	$1,097,940
Granular Fill	$75	cu.m.	1850	$138,750
Fencing	$150	lin.m.	562	$84,300
Close-out Bulky Waste Area	$377,640	lump	1	$377,640
Close-out Solid Waste Area	$432,000	lump	1	$432,000
Spill clean up allowance, Bulky Waste	$10,000	lump	1	$10,000
New Access Road	$188	lin.m.	10	$1,883
Subtotal				$2,142,513
Engineering & Contingency @ 40%				$857,005
Total				$2,999,518

O&M Component	Unit Cost	Unit	Quantity	Extension
Fencing Repair	$40.00	lin.m.	562	$22,480
Berm Maintenance	$100.00	lin.m.	520	$52,000
Waste Compaction	$30,000.00	lump	1	$30,000
Access Road Clearing & Maintenance	$219.00	lin.m.	10	$2,190
Cover material	$60.00	cu.m.	450	$27,000
Total				$133,670

Construct berm 157x157, depth of 2.5m.

Relocate existing bulky waste area to closed-out Solid Waste Area.

Year	i = 8%	
1	1	$133,670
2	0.925925926	$123,769
3	0.85733882	$114,600
4	0.793832241	$106,112
5	0.735029853	$98,251
6	0.680583197	$90,974
5	0.630169627	$84,235
8	0.680583197	$90,974
9	0.540268885	$72,218
10	0.500248967	$66,868
11	0.463193488	$61,915
12	0.428882859	$57,329
13	0.397113759	$53,082
14	0.367697925	$49,150
15	0.340461041	$45,509
16	0.315241705	$42,138
17	0.291890468	$39,017
18	0.270268951	$36,127
19	0.250249029	$33,451
20	0.231712064	$30,973
Sum Annual Costs		$1,430,361
Capital Cost		$2,999,518
Net Present Value		$4,429,879

Option 3

Site Three- Phased cost plan

Capital Component	**Unit Cost**	**Unit**	**Quantity**	**Extension**
Earthworks				
General Fill	$60	cu.m.	7346.5	$440,790
Granular Fill	$75	cu.m.	223.5	$16,763
Fencing	$150	lin.m.	125	$18,750
Close-out Bulky Waste Area	$377,640	lump	1	$377,640
Close-out Solid Waste Area	$432,000	lump	1	$432,000
New Access Road	$188	lin.m.	250	$47,063
Subtotal				$1,333,005
Engineering & Contingency @ 40%				$533,202
Total				$1,866,207

O&M Component	**Unit Cost**	**Unit**	**Quantity**	**Extension**
Fencing Repair	$40.00	lin.m.	125	$5,000
Berm Maintenance	$100.00	lin.m.	125	$12,500
Waste Compaction	$30,000.00	lump	1	$30,000
Access Road Clearing & Maintenance	$219.00	lin.m.	250	$54,750
Cover material	$60.00	cu.m.	450	$27,000
Total				$129,250

Construct berm 157x157, depth of 2.5m.

Relocate existing bulky waste area to closed-out Solid Waste Area.

Year	i = 8%	
1	1	$129,250
2	0.9259259	$119,676
3	0.8573388	$110,811
4	0.7938322	$102,603
5	0.7350299	$95,003
6	0.6805832	$87,965
5	0.6301696	$81,449
8	0.6805832	$87,965
9	0.5402689	$69,830
10	0.500249	$64,657
11	0.4631935	$59,868
12	0.4288829	$55,433
13	0.3971138	$51,327
14	0.3676979	$47,525
15	0.340461	$44,005
16	0.3152417	$40,745
17	0.2918905	$37,727
18	0.270269	$34,932
19	0.250249	$32,345
20	0.2317121	$29,949
Sum Annual Costs		$1,383,064
Capital Cost		$1,866,207
Net Present Value		$3,249,271

Site Three - Phased Cost Plan

2002

Capital Component	Unit Cost	Unit	Quantity	Extension
Close out Solid Waste (300 mm)	$60	cu.m.	3600	$216,000
General fill 1/4 of the new site	$60	cu.m.	1837	$110,198
Granular fill 1/4 of the new site	$75	cu.m.	56	$4,191
Access road new site	$188	lin.m.	250	$47,063
Subtotal				$377,451
Engineering & Contingency @ 40%				$150,980
Total				$528,431

2003

Capital Component	Unit Cost	Unit	Quantity	Extension
Close out Solid Waste (300 mm)	$60	cu.m.	3600	$216,000
Fencing, new site	$150	lin.m.	31	$4,650
Subtotal				$220,650
Engineering & Contingency @ 40%				$88,260
Total				$308,910

2004

Capital Component	Unit Cost	Unit	Quantity	Extension
Move Bulky Waste to New Site	$8,480	day	10	$84,800
Subtotal				$84,800
Engineering & Contingency @ 40%				$33,920
Total				$118,720

Unit cost based on $1000/2 trucks & 2 loaders

1 load every two hours, 4 labourers at $120 / day. 8 hours per day.

2005

Capital Component	Unit Cost	Unit	Quantity	Extension
Cover Bulky waste site (300 mm)	$60	cu.m.	4714	$282,840
Spill clean up allowance	$10,000	lump	1	$10,000
Subtotal				$292,840
Engineering & Contingency @ 40%				$117,136
Total				$409,976

Remaining Capital Component for new site	Unit Cost	Unit	Quantity	Extension
General fill 3/4 of site	$60	cu.m.	5,510	$330,592.50
Granular fill 3/4 of site	$75	cu.m.	168	$12,571.88
Fencing, new SW site	$150	lin.m.	94	$14,100.00
Sub total				$357,264.38
Engineering and contingencies				$142,905.75
2002-2005 Total				$1,366,037
Total				**$1,866,207.00**

Option 4
Incinerator

Capital Component	Unit Cost	Unit	Quantity	Extension
Earthworks				
General Fill	60	cu.m.	1528	$91,680
Granular Fill	75	cu.m.	80	$6,000
Fencing	$150	lin.m.	0	$0
Close-out Bulky Waste Area	$367,640	lump	1	$367,640
Close-out Solid Waste Area	$432,000	lump	1	$432,000
New Access Road	$374	lin.m.	222	$83,084
Building	$3,520	sq.m.	360	$1,267,200
Eco Waste Equipment				
Oxidiser	$724,500	lump	1	$724,500
Waste Loading Equip.	$74,200	lump	1	$74,200
Ash Removal Unit	$78,000	lump	1	$78,000
Subtotal				$3,124,304
Engineering & Contingency @ 40%				$1,249,721
Total				$4,374,025
O&M Component	**Unit Cost**	**Unit**	**Quantity**	**Extension**
Incinerator	$92.64	tonne	1010	$93,566
Berm Maintenance	$100.00	lin.m.	0	
Access Road Clearing	$219.00	lin.m.	222	$48,618
Cover material	$60.00	cu.m.	90	$5,400
Building (5% of capital)	5.00%		$1,267,200	$63,360
Total				$210,944

Relocate existing bulky waste area to closed-out Solid Waste Area.
New access road average fill = 0.6m meter.
Average tonnage of waste over the 20 year projection, 240 kg/cu.m.

Year	i = 8%	
1	1	$210,944
2	0.9259259	$195,319
3	0.8573388	$180,851
4	0.7938322	$167,454
5	0.7350299	$155,050
6	0.6805832	$143,565
5	0.6301696	$132,931
8	0.6805832	$143,565
9	0.5402689	$113,967
10	0.500249	$105,525
11	0.4631935	$97,708
12	0.4288829	$90,470
13	0.3971138	$83,769
14	0.3676979	$77,564
15	0.340461	$71,818
16	0.3152417	$66,498
17	0.2918905	$61,573
18	0.270269	$57,012
19	0.250249	$52,789
20	0.2317121	$48,878
Sum Annual Costs		$2,257,251
Capital Cost		$4,374,025
Net Present Value		$6,631,276

Initial Screening

(KT Must Analysis)

	Option 1	**Option 2**	**Option 3**	**Option 4**	**Option 5**
Facility Must Meet the Public Health Act	pass	pass	pass	pass	pass
Facility Must Meet Nunavut Water Board Requirements	pass	pass	pass	pass	pass
System Must Meet 20 Year Requirement	pass	pass	pass	pass	fail
System Must Not Impede future growth of the community	fail	pass	pass	pass	pass

Legend:

Process	**Description**
Option 1	Site One, Modified Landfill & Bulky Waste Area, Decommission Existing Site
Option 2	Site Two, Modified Landfill & Bulky Waste, Decommission Existing Site
Option 3	Site Three, Modified Landfill & Bulky Waste, Decommission Existing Site
Option 4	Site Four, Incinerator, Bulky Waste at Site Three, Decommission Existing Site
Option5	Do Nothing

Options Analysis

(KT Want Analysis)

Want	Weight	Option 2 Score	Option 2 W*S	Option 3 Score	Option 3 W*S	Option 4 Score	Option 4 W*S
Lowest O&M Cost	9	9.7	87.0	10	90.0	6.1	55.1
Lowest Capital Cost	8	6.2	49.8	10	80.0	4.1	32.6
Lowest NPV	7	7.3	51.3	10	70.0	4.7	33.2
Acceptable To Community	6	5	30.0	10	60.0	5	30.0
Distance From Airport	10	10	100.0	9	90.4	5	50.0
Total			**318.1**		**390.4**		**201.0**

Legend:

	Capital	Annual O&M	NPV	Dist.2 Airport	
Option 2	$2,999,518	$133,670	$4,429,879	3650	Site Two
Option 3	$1,866,207	$129,250	$3,249,271	3300	Site Three
Option 4	$4,584,529	$210,944	$6,841,780	420	Incinerator

Appendix C
Eco Waste Product Information

Appendix D
Hall Beach Climate Normals