Coral Harbour Sewage Lagoon and Solid Waste Site Improvements

prepared for:

The Government of Nunavut
Community Government & Transportation

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TABLE OF CONTENTS

1. INTRODUCTION 1

1.1 PROJECT UNDERSTANDING 1
1.2 COMMUNITY INFORMATION 1
1.2.1 General *1*
1.2.2 Geology and Terrain *2*
1.2.3 Vegetation *2*
1.2.4 Climate *2*
1.2.5 Community History And Economy *2*
1.2.6 Transportation And Access *3*
1.2.7 Housing *3*
1.2.8 Commercial Accomodation *3*
1.2.9 Recreation And Cultural Activities *3*
1.2.10 Educational Facilities *4*
1.2.11 Health Facilities *4*
1.2.12 Fire Protection Facilities *4*
1.2.13 Other Services And Municipal Services *4*
1.2.14 General Demographic Information *4*

2. BACKGROUD 6

2.1 PREVIOUS STUDIES 6
2.1.1 W.L. Wardrop & Assoc., Addendum No. 1 to Cost Effective Analysis Water Supply, Sewage & Solid Waste Disposal, Coral Harbour, NWT, February 1983 .... *6*
2.1.2 GNWT - DPW, Design & Operations Concept Report, October 1992 .... *6*
2.1.3 UMA Engineering Ltd., Design & Operations Concept Report, March 1994 .... *7*
2.1.4 Arctic Environmental Services Ltd., Review of the Natural Wetlands Sewage Disposal system at Coral Harbour, March 1995 .... *8*
2.2 WATER SUPPLY AND TREATMENT 9
2.3 WATER STORAGE AND DISTRIBUTION 10
2.4 SOLID WASTE VOLUME PROJECTIONS 10
2.5 SEWAGE GENERATION PROJECTIONS 11

3. SOLID WASTE DISPOSAL SYSTEM 13

3.1 CURRENT PRACTICES 13

4. SANITARY WASTEWATER TREATMENT SYSTEM 16

4.1 CURRENT PRACTICES 16
4.2 WETLANDS MODELING 17
4.2.1 Purpose *17*
4.2.2 Background *18*
4.2.3 Sewage Characteristics *18*
4.2.4 Treatment Requirements *20*
Table 4.2 Hydraulic loading summary *20*
Table 4.4 Comparison of Dillon 1998 to Alberta Model, for Repulse Bay NU *22*
Table 4.5 Alberta Environmental Protection Guidelines Summary *22*
Table 4.6 Comparison between Arctic Environmental data and Alberta Model *23*
4.3 DISCUSSION 23

5. SOLID WASTE OPTIONS 25

5.1 OVERVIEW 25

5.2 SOLID WASTE DISPOSAL OPTIONS 25
5.2.1 Modified Landfill 25
5.2.2 Landfill with burning 26
5.2.3 Sanitary Landfill 26
5.2.4 Incineration 26
5.2.5 Baling 27

6. POTENTIAL SOLID WASTE DISPOSAL OPTIONS 28

6.1 LOCATION OF SITES 28
6.2 OPTION 1: UPGRADE EXISTING SITE 28
6.3 SITE ONE 30
6.4 OPTION 2: SITE TWO 31
6.5 OPTION 3: SITE THREE 32
6.6 OPTION 4: SITE FOUR 33

7. OPTIONS EVALUATION 34

7.1 INITIAL SCREENING 34
7.2 OPTIONS ANALYSIS 35
7.2.1 Selecting Weights 35
7.2.2 Scoring 36
7.2.3 Results 36

8. CONCLUSIONS AND RECOMMENDATIONS 38

8.1 SUMMARY OF OPTIONS 38
8.1.1 Cost 38
8.2 DISCUSSION AND ANALYSIS 38
8.3 RECOMMENDATION 39
8.3.1 Solid Waste Disposal 39
8.3.2 Sewage Disposal 39

Draft

1. INTRODUCTION

1.1 PROJECT UNDERSTANDING

Ferguson Simek Clark was contracted to complete a planning study for the Coral Harbour Sewage Treatment Systems and Solid Waste Disposal Sites for the Department of Community Government and Transportation, Government of Nunavut. The following examines the purpose of this study as per its division into two sections:

- Sewage Disposal and Treatment:
  - Site Inspection of the proposed new access road, sewage truck dumpsite and retention pond;
  - Development of a design concept for approval by the client and the Hamlet;
  - Development of a close-out plan for the existing sewage dumpsite;
  - Provide site surveys as required to design the proposed access road, dumpsite, and retention pond and to close-out the existing site; and
  - Submission of the design for the access road, dumpsite and retention pond, and close-out plan for the existing site for approval by the regulatory agencies.
- Solid Waste Disposal Area:
  - The development of design concepts for a new solid waste disposal site for approval by the client and Hamlet. Our planning will include the area immediately northward of the existing site;
  - Development of a close-out plan for the existing solid waste site for approval by the client and the Hamlet;
  - Provide site surveys as required to complete the design of the new solid waste site and to close-out the existing site; and
  - The submission of the design concept for the new solid waste site and close-out plans for approval by regulatory agencies.

1.2 COMMUNITY INFORMATION

1.2.1 GENERAL

Coral Harbour is located at South Bay, in the Boothia-Foxe Lowland Ecoregion, on the southern end of Southampton Island. Located at 64°08′ N and 83°10′ W, it is 720 km west of Iqaluit and 1,560 km north-east of Yellowknife.

1.2.2 Geology and Terrain

Linear bedrock ridges run in an approximate north to south direction spaced about 400 m apart. Palaeozoic marine limestone constitutes virtually all of the bedrock in the area. The seasonal effects of frost shattering and surface water runoff have resulted in a blanket of irregular, angular gravel and the flushing of fine material from ridges. The subsequent deposition of fines has occurred in low-lying areas. Where the rock is not exposed at the surface, the ground is usually covered with a thin layer of brown, fibrous peat. True soil development is limited to marshy areas.

The active layer of permafrost is up to 2 m below the surface during the late summer months. Weakly developed polygonal patterned ground is evident in virtually all the areas devoid of vegetation.

1.2.3 Vegetation

Mosses and lichens are common throughout the region. Flowering plants fare better in low-lying wetland, while lichens characterize drier areas. Graminoids, brown mosses, and willows up to 30 cm in height are found in the wetter areas.

1.2.4 Climate

Coral Harbour receives an average of 14.1 cm of rainfall and 131.9 cm of snowfall per year. Mean annual precipitation totals 27 cm. July mean high and low temperatures are 13.1° C and 4.2° C. January mean high and low temperatures are -25.5° C and -33.8° C. Winds are generally northwest and annually average 20.2 km/h.

1.2.5 Community History and Economy

The Coral Harbour area was first inhabited by the Sallirmiut Inuit, descendants of the Thule. These people made stone, whale, and turf homes, wore bearskin clothes and used flint-headed weapons. These characteristics are atypical of other coastal Inuit groups. On his 1612 voyage, Sir Thomas Button's expedition became the first Europeans to reach Southampton Island. The area began economically in the 1860's as a whaling base, continuing until 1920. All but five of the Sallirmiut perished from disease brought over by the whalers; the tribe is now extinct.

The settlement was established by the Hudson Bay Company, which opened a post in 1925. An Inuk started the Anglican Mission at the same time, and a Roman Catholic Mission opened in 1927. During the Second World War, an airfield was opened by the R.C.A.F. and the U.S.A.F. 15 km from the present community. The site served as a refueling stop and hospital staging area. At this time the community was divided into north and south camps. In 1948, the MOT took over the airfield, and the DEW-Line operation saw an increase in its use. A school was built in 1950. The federal administrator arrived in 1959 and the first nursing station was built in 1963.

Today the economy is based on marine mammal and polar bear resources. Some residents are employed at the airfield or the weather station, while others work in private enterprise. Tourism opportunities consist of sport fishing, arts and crafts sales, and the carving of walrus ivory. Private business is associated mainly with the tourism industry.

Coral Harbour gained hamlet status on April 1, 1972. A traditional name for the Hamlet is "Salliq", meaning 'islands in the south'.

1.2.6 TRANSPORTATION AND ACCESS

The GN and the Hamlet jointly operate the 1,524 m x 31 m certified Arctic 'C' gravel runway. Other facilities and services include the air terminal building, weather/communications equipment, and navigational aids. Scheduled flight service is available. An unlicensed water aerodrome provides floatplane access. Break-up is in July and freeze-up in October.

Marine transportation is provided by barge. Facilities include a beach landing for shallow draft only and a pushout at Snafu Beach, five km west of the community.

There is no direct road access to Coral Harbour. Within the community there are approximately 20.9 km of roads. Calcium chloride is applied annually to 4.6 km of road to act as a dust suppressant and surface-stabilizing agent.

1.2.7 HOUSING

The number of occupied private dwellings increased 36.5% between 1986 and 1991. As of 1994, the Housing Corporation owned 100 housing units. The Housing Assistance Program, the Alternative Housing Program, and Government Lease-to-Own units have accounted for 39 new homes in the community.

1.2.8 COMMERCIAL ACCOMODATION

The Esungark Motel accommodates six and Leonie's Place accommodates twelve guests.

1.2.9 RECREATION AND CULTURAL ACTIVITIES

The school gymnasium was built in 1977. The community hall, built in 1989, includes a curling rink and arena. There are also two playgrounds and a playfield. Coral Harbour has an active recreation committee.

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1.2.10 Educational Facilities

Atausiunsuarniq School teaches grades K-12. Sixteen teachers and three language specialists are on staff.

1.2.11 Health Facilities

The health centre (983 m^2), built in 1986, houses six medical beds, two bassinets and one crib. Two nurses, one therapist, and one community health representative are employed.

1.2.12 Fire Protection Facilities

A ten-person volunteer fire brigade uses a 1980 International Superior triple combination pumper (625 g/min capacity) to fight fires. The community has a firehall (149 m^2).

1.2.13 Other Services And Municipal Services

The RCMP detachment staffs one officer. The Community Social Services Office, with a staff of two, overlooks the Youth Justice Committee.

Mail is delivered twice 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. The Rankin Inlet NPC area office provides 1,290 kW of diesel-generated power.

Other infrastructure funded by Community Government and Transportation programs includes staff housing, a community office (315 m^2), a two-bay maintenance garage (228 m^2), and two three-bay parking garages (143 m^2 and 140 m^2).

1.2.14 General Demographic Information

Based on discussions with hamlet officials the current population in 2001 is between 750 and 800. The population by ethnic distribution is 95% Inuit and 5% non-aboriginal. The population by age and sex distribution is as follows: 0-4 (19%), 5-14 (25%), 15-64 (54%), 65+ (2%); 50% male and 50% female. The Government of Nunavut has published population projections for the community. These will be used for the remainder of this report.

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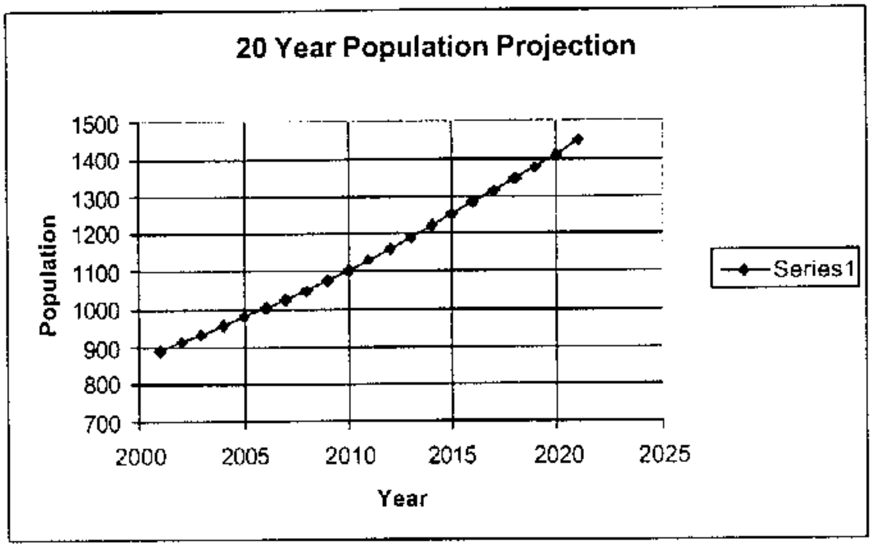
Table 1.1: Population projections for the Hamlet of Coral Harbour

Calendar Year	Population
2001	888
2006	1003
2011	1128
2016	1281
2021	1445

Source: www.stats.gov.nu.ca

Figure 1.1 Population projection for the Hamlet of Coral Harbour



2. BACKGROUD

2.1 Previous Studies

2.1.1 W.L. Wardrop & Assoc., Addendum No. 1 to Cost Effective Analysis Water Supply, Sewage & Solid Waste Disposal, Coral Harbour, NWT, February 1983

This report was written to provide additional information relating to a draft report that was submitted in 1981. This document does not re-iterate much of what was presented in the draft report but refers the reader to it. Much of the report concentrated on alternative water distribution and supply analysis.

This report was written prior to acceptance of wetlands as an acceptable means of sewage disposal. It discusses the option of utilizing an ocean outfall. 60% of the residences were on a pumpout system. Honeybags were disposed with municipal waste. The report suggested the construction of berms or dykes around the sewage dumping point. The report noted that rock ridges at the existing site prevent surface runoff to either the Post River or the community. As well, the existing site acts as a natural lagoon due to its depression like features.

There were no concerns with the existing solid waste disposal area. The system in use today is virtually identical to what was in place twenty years ago. The report suggested periodic covering of solid wastes, burning to reduce volume and segregation of bulky wastes.

Concerns over the existing facilities were limited to the fact that the same road accessed the sewage disposal, water supply and solid waste facilities. The concern was for the potential contamination of the reservoir due to spillage by a transport vehicle.

2.1.2 GNWT - DPW, Design & Operations Concept Report, October 1992

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 Coral Harbour. The report referenced the Wardrop study. The report determined the following:

- At the time of the site visit in 1991 the current solid waste site was found to be adequate for use by the community. The disposal area can be expanded to the existing sewage disposal area upon completion of the proposed sewage disposal lagoon.
- Bulky waste was not organized and was disposed at two different locations. A better system needed to be developed.
- A honey bag disposal cell should be created with a volume of 220 cu.m.

- A new sewage lagoon should be constructed. Dimensions as follows: area – 15000 sq.m., depth of 4m, crest width of 4m. Two locations were discussed. The first in the existing pond, only a berm constructed on the downstream end was required. The second location was about 300m further north of the existing site. A sewage flume should be constructed along with a truck turnaround area. The community preferred site two.

2.1.3 UMA ENGINEERING LTD., DESIGN & OPERATIONS CONCEPT REPORT, MARCH 1994

This was a study carried out by UMA on behalf of MACA to review previous work and studies done on the sewage and solid waste systems and to develop designs, procedures and schedules, estimates and locations to expand or improve the existing facilities. The report determined the following:

Recommended against discharging sewage to the ground. Discharge area should have appropriate access, discharge controls and discharge into a lagoon area. Honeybags should be separated from the municipal waste stream. Concern from operators that the disposal area is too steep.

Solid waste: current practices appropriate for site and conditions. Major deficiency is site organization and lack of means to control windblown material. Burning is practiced and although discouraged it is an effective means of volume reduction. Operators reported that their main problem is incomplete burning of the waste.

Did not recommend mechanical treatment for the following reasons: extreme operating conditions for temperature, extreme geographic distance and limited access for maintenance, intermittent high strength waste water generation, limited availability of trained operating personnel.

Discussed two potential sites that were outlined in the 1992 report further. Ocean 2500m away from the sites. Utilizing the existing pond (6000 sq.m.) would minimize construction this pond is connected to a second pond (26000 sq.m.). Environmental evaluation suggests that the current system can handle the projected 20-year loading, however monitoring of the system is recommended.

The second site would require the construction of containment berms and 300m of access road construction. The location is just to the north of the existing site. The discharge could either exfiltrate through the berm, or through an engineered drain or overflow.

The development of site one for a sewage drop-off facility was recommended. It was not felt that the construction of an engineered lagoon would result in a significant increase in effluent quality. It would aid in retaining solids. An effluent monitoring program should be developed.

For solid waste the report determined that there was no risk to aircraft from bird activity at the drop-off facility. An inspection by the GNWT in 1991 determined the existing facility was adequate. Expansion to the East was not recommended due to the numerous ponds in the area.

Expansion to the West was promoted it stated that overland flow to the community would be impeded by a bedrock ridge and road to the south (likely the old airport road).

A 20-year solid waste volume of 54,100 cu.m. was projected. The existing initial development projected volume remaining was 7000 cu.m. Expansion to create an area 250m x 70m was recommended. Only fencing along the North edge of the landfill was recommended. It was felt that the perpendicular access road through the facility would serve as a roadblock. Development of an organized bulky waste site was recommended on the south end of the development.

Various setback criteria were presented. Landfills require a 450m setback from areas of human habitation. A 90m setback to a public road allowance may not be applicable because the road is not a legally defined right of way.

2.1.4 Arctic Environmental Services Ltd., Review of the Natural Wetlands Sewage Disposal System at Coral Harbour, March 1995

This was a study done on behalf of Municipal and Community Affairs. It was commenced in the summer of 1994. Its main purpose was to demonstrate the effectiveness of this particular natural sewage treatment system. As well, it was to point out any innovations that could be incorporated to allay any public health concerns.

A number of vegetation species can be found along the flow route. In lowland organic areas: cotton grass tussocks, Labrador tea, arctic willow, sedge and peat moss, cranberry, daisies and other grasses. In bedrock areas: lichens and mosses.

Surface area of ponds along flow route:

Pond 1 & 2, Surface Area=5000, Catchment Area=48500, average depth 1m, estimated retention time (UMA) 94 days

Pond 3, Surface Area=25900, Catchment Area=74000, depth = 2.3m, estimated retention time (UMA) 236 days

Pond 4, Surface Area=3300, Catchment Area=29500, depth = 1m

There are five alternative drainage routes that could be available if the disposal location were relocated further north along the existing road. This allows for additional expansion in the future if additional disposal capacity is ever required.

Enhancement options discussed were applicable only if the system is not performing well or if there is an existing health hazard concern. One option is to increase retention times by modifying existing natural impoundments or constructing artificial impoundments. Another option is to improve the source dump location with respect to bank erosion protection or operator protection against sewage sprayback. There is little need to enhance the operation of the wetlands disposal system beyond making improvements at the front end.

Wastewater analysis indicates that there are no heavy metals present. It is noted that the landfill has a negative water quality influence that will likely increase over time as the landfill grows and wastes accumulate.

The system is effective within a short distance from the dump source location. Ninety percent of the biological breakdown occurs within the first 300 meters of distance along the flow route. Final effluent is of a good quality 600m from the dump source. There is no reason to enhance the effectiveness of the current waste flow pattern.

Loading capacity was not quantified. It was stated that the system should be sufficient to handle sewage loads to a point well beyond the year 2000. The system should be monitored to see if it is continuing to be effective.

The report recommended that the perimeter of the sewage flow route should be marked by signage.

2.2 WATER SUPPLY AND TREATMENT

Kigulik Lake, located 2.9 km west of the community, was the former winter source for water. Weather-related access closures and the seasonal deterioration of its water quality forced the community to search for a more reliable source.

The source chosen was the Post River. This fast-flowing river contained adequate capacity for the Hamlet. The water is of good to excellent chemical quality for domestic use. Based on chemical analysis the water is very clear, soft, weakly buffered, and low in dissolved solids.

However, concerns for winter reliability remained. To resolve this concern a reservoir and truckfill system were constructed near the river. Now a permanent supply line from the river is used to fill the reservoir each summer. Water is pumped from the river at a point 2 km northwest of the community. The pumphouse is a wood frame building equipped with a skid-mounted portable diesel pump system. The water is drawn from a point 20 m from shore and pumped 1500 m to the reservoir.

For treatment, water is drawn from the reservoir and chlorinated in the pumphouse by a hypochlorinator. The pipe that carries the water from the pumphouse to the truckfill arm has chlorine injected into it when the trucks are being filled.

Comparison of the chemical analysis for raw and treated water samples to the Guidelines for Canadian Drinking Water Quality shows the parameters tested to be below the recommended limits. Microbiological analysis of treated water shows that batch chlorination eliminates or greatly reduces the number of bacterial species present in raw water samples.

2.3 Water Storage And Distribution

Water for domestic use is stored in a rock-blast reservoir, located approximately 1 km northwest of the community. The reservoir, completed in 1980, has a usable storage capacity of 25,200,000 L. The reservoir was expanded in the late 1990's. This expansion doubled the storage capacity of the community.

Submersible pumps located inside twin 100 mm diameter HDPE intake lines pump the water from the reservoir. The intake lines are heat-traced and are carried inside 250 mm diameter HDPE pipes which are themselves protected by 75 mm of polyurethane insulation and a 400 mm HDPE outer casing. The casings are supported by an 80 m long inclined rock slope which has been blasted out of the side of the reservoir. The upper ends of the casings enter the truckfill pumphouse at floor level.

The truckfill pumphouse, a 3.5 m x 4.7 m pre-engineered building, houses the hypochlorinator. A steel pipe carries the water from the intake lines through the pumphouse and into the truckfill arm. A similar small pre-engineered building located beside the pumphouse houses an emergency generator.

The truckfill rate is 900 L/min. Water is delivered by the hamlet's 8172 L capacity truck. Each residence receives a delivery three days per week. Tanks sizes vary from 225 L to 2250 L for residences. The nursing station, school, hotel, and government staff quarters contain larger tanks ranging from 1362 L to 4540 L in capacity. All water deliveries are metered.

2.4 Solid Waste Volume Projections

There is no published information on waste volumes in Coral Harbour. 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 cu.m/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 Coral Harbour

Year	Pop.	Solid Waste Volume	Compacted Volume	
2001	888	4538	2450	
2002	911	4655	2514	
2003	933	4768	2575	
2004	955	4880	2635	
2005	978	4998	2699	
2006	1003	5125	2768	
2007	1024	5233	2826	
2008	1049	5360	2895	
2009	1078	5509	2975	
2010	1101	5626	3038	
2011	1128	5764	3113	
2012	1158	5917	3195	
2013	1187	6066	3275	
2014	1219	6229	3364	
2015	1250	6388	3449	
2016	1281	6546	3535	
2017	1312	6704	3620	
2018	1345	6873	3711	
2019	1376	7031	3797	
2020	1410	7207	3892	
2021	1445	7384	3987	
			66312	Sub-Total
			13262	Cover Material
			79575	**Total Volume Required [cu.m.]**

2.5 SEWAGE GENERATION PROJECTIONS

The 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 + (0.0023 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.

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 Coral Harbour 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 Coral Harbour

Year	Pop.	Water Consumption	Sewage Volume	Sludge Volume	Accumulated Sludge
2001	888	35129	35129	113	113
2002	911	36197	36197	116	230
2003	933	37226	37226	119	349
2004	955	38263	38263	122	471
2005	978	39354	39354	125	596
2006	1003	40549	40549	128	724
2007	1024	41561	41561	131	855
2008	1049	42774	42774	134	989
2009	1078	44192	44192	138	1127
2010	1101	45327	45327	141	1267
2011	1128	46668	46668	144	1411
2012	1158	48172	48172	148	1559
2013	1187	49638	49638	152	1711
2014	1219	51271	51271	156	1867
2015	1250	52868	52868	160	2026
2016	1281	54479	54479	164	2190
2017	1312	56105	56105	168	2358
2018	1345	57851	57851	172	2529
2019	1376	59507	59507	176	2705
2020	1410	61361	61361	180	2885
2021	1445	63244	63244	185	3070

3. SOLID WASTE DISPOSAL SYSTEM

3.1 Current Practices

Employees of the hamlet collect garbage five days per week. A Ford truck modified with a compactor on the back is used to collect the garbage. The hamlet foreman estimates that the truck is capable of hauling 5000 lbs of garbage in one trip. Each residence has a 205L drum in front of it to contain the trash until pickup. There are approximately 177 residences in the community.

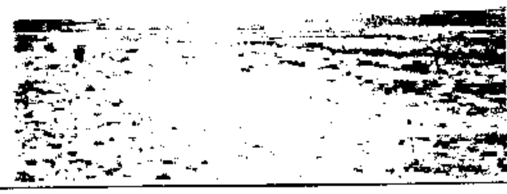
Garbage truck loading at hotel.

The garbage is hauled to the existing solid waste management site. It is located 2.5 km northwest of the community on the east side of a gravel ridge. The truck deposits the garbage at the edge of the covered portion of the landfill. A wheeled loader pushes the garbage over the edge of the slopes every two weeks. Combustible waste at the disposal site is burned weekly. At the end of each summer a cat compacts the garbage that has accumulated. Every two years the uncovered garbage is covered and compacted.

Garbage truck and loader at work.

The existing solid waste disposal site covers an area of approximately 7,300 sq.m. There is no fencing at the site. This is one of the largest contributing factors to the amount of windspread litter observed around the site. The community usually performs a clean up of the litter every two or three years. There is room for expansion to the north and east. This area is wet and boggy throughout the summer months and would be difficult to work with.

View of Site from the North



Wind Blown Litter

The area to the west of the existing site is in use as a bulky waste disposal area. The bulky waste in this area is old vehicles and tires. The Hamlet does not want any more development in this area for fear of contamination of the Post River. Hamlet workers are in the process of relocating the bulky waste to an area southeast of the landfill site. Old appliances are stored 500m north of the solid waste site.

Large metal waste items are discarded within the municipal waste area. These items include old tanks, culverts, barrels, etc. The presence of these items with municipal wastes reduces the compaction potential of the refuse and thus decreases the service life of the existing facility. Any future developments should include a more organized approach to the disposal of metal items that are not typical of the household garbage stream.

Vehicle Disposal Area South of Landfill Site

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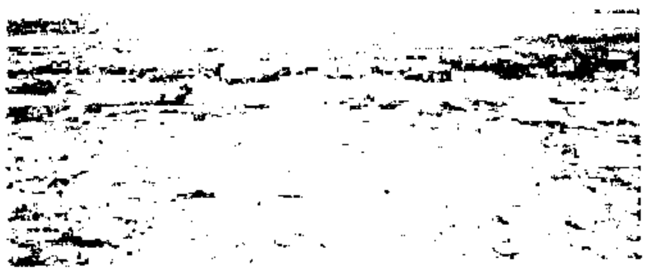
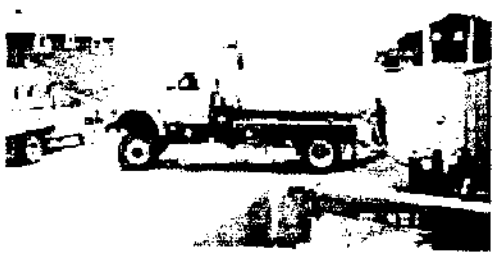
	
Bulky Waste West of Site	Discarded Tires

The hamlet foreman expressed some concerns. Waste oil, antifreeze, transmission fluid, etc. is stored in an area near the hamlet shop. The Hamlet does not have a disposal procedure for these wastes. The loader operator must be careful when pushing garbage over the side of the slopes to avoid puncturing the machine's tires. The foreman would like to have fencing installed in the future to minimize the effects of wind on the landfill.

4. SANITARY WASTEWATER TREATMENT SYSTEM

4.1 Current Practices

The Hamlet provides sewage tank pump out service for the community. The Hamlet owns and operates two 1500-gallon sewer trucks. An older 1200-gallon truck is available for back up. All houses are pumped out each day. Some homes have opted to receive pump out service only 3 to 5 times per week. The sizes of the holding tanks in the community vary from 750 to 1000 gallons. Of the 177 residences in the community, 150 are currently in service. Sewage service is provided 7 days per week.



Hamlet Sewer Truck

Sewage Drop Off Location

Sewage Spillway

Sewage Drop Off Location

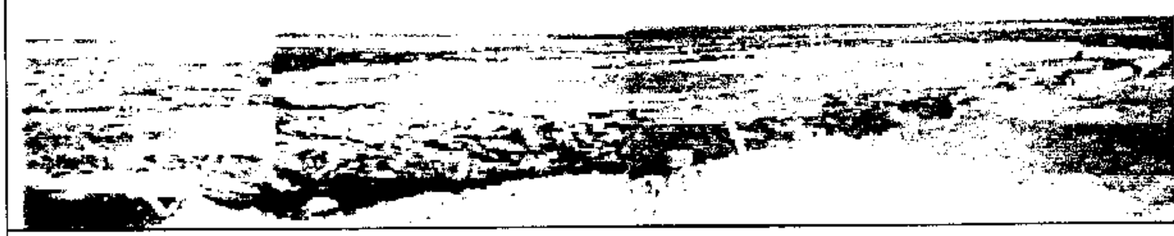
The sewage is transported to a sewage drop off area 2.8 km northwest of the community. The sewage is treated by the natural wetlands method. The total area covered by the overland treatment system is 10.5 ha. The wetlands consist of four shallow ponds with an area of 7 ha. The remaining

3.5 ha are covered by soils from 2 - 15 mm in thickness. Cotton grasses and sedges are the major vegetation species that grow in the soils. The highly treated water is discharged to Hudson Bay. The sewage wetlands run in a predominantly southeasterly direction towards the ocean. As such it runs through the toe of the expanding solid waste facility.

The discharge point is a pushout adjacent to the access road. It is setup to allow the operator to discharge in three different directions, depending on the wind direction. There are no bollards or signage to indicate the area is a sewage disposal area. Some logs were placed to act as a wheel stop for the operators.

During the winter months, sewage is stored in the upper reaches of the wetlands in the form of an ice mound.

There are no residences in town that rely on honeybags. All buildings and homes rely on sewage pumpout. The cost for providing this service is included in the cost for providing water. Residents will utilize honeybags for camping trips. These are disposed of along with the municipal waste. The hamlet foreman finds this method of disposal acceptable.



Panoramic view of sewage drop of point and primary lagoon.

4.2 Wetlands Modeling

4.2.1 Purpose

The purpose of wetland modeling for Coral Harbour is to determine if the existing wetlands are sufficient to meet the 20- year demand of the community. Models will be compared to empirical data collected in Coral Harbour and other northern communities.

If the modeling proves the wetlands to be insufficient then a close out plan for the sewage dump site will be required.

4.2.2 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.

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.

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.

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, 1998)

4.2.3 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.

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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	865	108	417	445	21	111	8.80E+07
2002	888	108	415	443	21	111	8.77E+07
2003	911	109	413	441	21	110	8.73E+07
2004	933	109	412	439	21	110	8.69E+07
2005	955	110	410	437	21	109	8.65E+07
2006	978	110	408	435	21	109	8.62E+07
2007	1003	111	406	433	21	108	8.58E+07
2008	1024	111	405	432	21	108	8.54E+07
2009	1049	112	403	430	21	107	8.50E+07
2010	1078	112	401	427	20	107	8.46E+07
2011	1101	113	399	426	20	106	8.42E+07
2012	1128	113	397	423	20	106	8.38E+07
2013	1158	114	395	421	20	105	8.34E+07
2014	1187	115	393	419	20	105	8.29E+07
2015	1219	115	391	417	20	104	8.24E+07
2016	1250	116	388	414	20	104	8.20E+07
2017	1281	117	386	412	20	103	8.15E+07
2018	1312	117	384	410	20	102	8.11E+07
2019	1345	118	382	407	20	102	8.06E+07
2020	1376	118	380	405	19	101	8.02E+07
2021	1410	119	378	403	19	101	7.97E+07

4.2.4 TREATMENT REQUIREMENTS

4.2.4.1 Hydraulic Loading

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.

The appended climate normals for Coral Harbour from Environment Canada 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 4.2. The size of the wetland used for the calculations is the current wetland 10.5 ha.

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

Table 4.2 Hydraulic loading summary

	Hydraulic Loading Rate (m^3/d/ha)
During Melt (June & July)	100
After Melt (September & October)	28

The hydraulic loading rates fall within those recommended by Heinke and Dillon.

4.2.4.2 Organic Loading

The organic loading calculations are similar to the hydraulic loading calculations, the climate normals and the 10.5 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

	BOD_5 Loading Rate
	(kg/d/ha)
During Melt (June & July)	30.2
After Melt (August &September)	6.1

The organic loading rate calculated during the melt period is higher than 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.

The organic loadings rates are higher during the spring than those recommended, however, modelling suggests that NWB effluent requirements should still be met 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. Such a pond will reduce BOD and TSS by approximately 40%. The organic loading rate during the melt period would then be about 18 kg/ha.d, still slightly higher than recommended, but showing promise in the model.

4.2.4.3 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 fully tested in northern climates. FSC has been collecting available data on northern wetlands and comparing the results to the Alberta model. To apply the Alberta model to the north it was assumed 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. These assumptions were compared for Repulse Bay to the results obtained in Dillon's 1998 data. Coral Harbour's average summer temperature is 8°C.

Table 4.4 Comparison of Dillon 1998 to Alberta Model, for Repulse Bay NU

	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 Coral Harbour.

The algorithms are applied to the Coral Harbour situation for the 20-year projection. A summary of the results follows and the calculations are appended.

Table 4.5 Alberta Environmental Protection Guidelines Summary

Wetland area	BOD Ci	TSS Ci	Nunavut Water Board Guidline BOD	TSS	BOD Co	TSS Co
(ha)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
10.5	378	403	100	120	58	33

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

4.2.4.4 Arctic Environmental Services Report

In 1995 Arctic Environmental Services Ltd. (AES) completed a review of the wetlands in Coral Harbour. Sampling was done during August and September. AES compared their data to a study done in 1994 by Dillon Engineering at Chesterfield Inlet. From this comparison AES determined that natural systems are effective within a rather short distance from the dumping source location and an active biological system is working, with monthly variations, during June, July, August and September.

Another conclusion of the AES review is that dilution is prevalent in the system at Coral Harbour. The wetland area is 70 % ponds with depths of approximately 1 m and as deep as 2.3 m. Dilution was evident by the sharp drops in readings between 150 m and all other downstream readings.

The data collected at the outlet of the wetland was used to compare to the Alberta model. The effect of dilution is also noticeable in the following comparison.

Table 4.6 Comparison between Arctic Environmental data and Alberta Model

	BOD	TSS	P	TKN	FC
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(#/dL)
Arctic - Aug 20, Site 9	3.5	59	0.06	1.6	70
Arctic - Sept 15, Site 8	3.9	16	0.9	4.4	130
Alberta model	58	33	9	24	4.13E+05
Alberta model- background values	3.5	7.5	0.05	2	100

The AES values for BOD, Phosphorous (P), Total Nitrogen (TKN) and Fecal Coliform (FC) are approximately equal to the background concentrations for these contaminants in a wetland according to the Alberta model.

The AES results show a BOD/TSS ratio of 0.06 and 0.24 respectively. In contrast the Alberta model suggests a BOD/TSS ratio of 0.47. The AES results suggest a significant amount of inorganic suspended solids in the wetland effluent. This further suggests flow rates and volumes that mobilize solids within the system. From a regulatory point of view TSS can be either organic or inorganic. It would therefore be advantageous to reduce the inorganic TSS as much as possible. Inorganic TSS reduction may be achieved by reducing the velocity of the flow with flow-attenuating berms. The Volatile Suspended Solids (VSS)/TSS ratio should be monitored to determine the ratio of inorganic and organic TSS within the system.

The flow-attenuating berms would also reduce erosion and channelling as the hydraulic loading increases over time. The situation should be assessed annually.

4.3 Discussion

The purpose of this modelling is to determine if, based on models and accumulated empirical data, the current wetlands at Coral Harbour will meet the 20-year demands of the community.

While the modeling is inexact at this time, we are confident in suggesting that the Alberta model provides the worst-case scenario.

Based on all of the data presented above, we conclude that the wetlands at Coral Harbour will be sufficient for the next 20 years. Therefore, a close out plan will not be required.

The wetland at Coral Harbour 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.

5. SOLID WASTE OPTIONS

5.1 Overview

The main concern with the Sewage & Solid Waste system in Coral Harbour is the dispersion of litter due to the effects of wind. As well, there is a perception that the water that drains from this area flows into the community.

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

- Do nothing;
- Expand and improve the existing Solid Waste site; or
- Close out existing Solid Waste site and develop a new site.

There is one alternative site that was observed to be a potential location for a new solid waste landfill facility. Alternatively this site could be utilized as a location for a sewage disposal facility.

5.2 Solid Waste Disposal Options

There are several methods of disposal for municipal garbage that are used 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 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.

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

Incinerators are ideal for locations in which landfills area not economical. This could be for many reasons: lack of available land, lack of fill material, etc. This is not the case in Coral Harbour. There is an abundance of land available that can be developed economically. As well, the community has a vast supply of well-graded granular material. Discussions with the hamlet foreman indicate that the community has the ability to develop roadways of good quality with limited resources. For these reasons an incineration facility will not be considered further in this report.

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 OPTIONS

6.1 LOCATION OF SITES

Figure 6.1 indicates the location of the various sites that are discussed in this report. Figure 6.2 indicates the overland drainage pathways in the area of concern. Figure 6.3 indicates the existing solid waste facility disposal areas.

6.2 OPTION 1: UPGRADE EXISTING SITE

Discussions with hamlet staff indicate that there are no pressing concerns with regards to the existing site location. The site is not within the 8km setback requirement of the airport. The toe(s) of the site are beginning to encroach on waterways that are part of the drainage pathway of the sewage wetland.

The current area of the site is insufficient to meet the 20-year demand of the community, however there is an 8,000 sq.m area available for expansion. With this additional area the solid waste site will last until 2007. The expansion does not meet the 20-year requirements of the community but it should still be considered as a short tem option for solid waste management. By expanding as far as possible on the existing site the capital cost of closing out the site and constructing a new site including a road will be deferred.

Before implementing this option improvements to the site need to be made. A fence should be installed surrounding the entire site to prevent windblown litter and to keep the public from contacting the MSW. As this site will only be active for another five years the cost of installing a permanent fence is not feasible. A temporary fence, such as a snow fence, would be adequate. Also a general clean up is required.

The site management practices will include the modified area method on the expanded area of the site. The depth of the active layer limits the depth to 0.5 m from the surface. The covered waste on the existing site will be the berm that the waste is compacted against. Please see Figure 6.4. Calculations were done to determine the extended lifespan of the site if another berm was built on top of the existing waste. The increase in lifespan did not outweigh the additional berm cost.

Concerns have been expressed with runoff or leachate entering the wetland from the solid waste site. The AES wetland study addressed this concern by sampling the effluent from the solid waste site that enters the wetland. The conclusion of the study determined that the solid waste site has a negative water quality influence on the wetland. FSC reviewed the empirical data collected by AES and have concluded differently. The AES study viewed the wetland as a freshwater receiving body and therefore subject to CCME Guidelines for Freshwater Aquatic Life.

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FSC believes the wetland should be designated as a unit process of the sewage treatment. As a unit process the concern would be if the vegetation within the wetland could no longer function under the contaminant loading. Therefore FSC compared the effluent from the solid waste site to the CCME guidelines for Irrigation. The solid waste site effluent does meet the CCME guidelines for Irrigation and therefore should not have a negative effect on the plant life in the wetlands.

As mentioned in the Wetland Modeling Discussion section, the wetland effluent meets the Nunavut Water Board guidelines and is therefore sufficiently treating all influents. Calculations were done to determine the yearly amount of runoff associated with the solid waste site. The amount of runoff is 7% of the yearly sewage generation. When added into the Alberta wetland model, the wetland is large enough to continue treating the influents to meet the Nunavut Water Board guidelines for the 20-year design period.

A solid waste site should always be used to its maximum potential to reduce the amount of contaminated sites surrounding the community. Once a site is used for solid waste disposal, even with proper close out, it may never again be suitable for human occupation. For this reason even though expanding the solid waste site does not meet the 20-year requirements of the community it should still be implemented before a new site is commissioned.

6.3 Site One

The other site in consideration is in the same general vicinity of the existing sewage and solid waste disposal areas. There is an existing road that goes further north of these facilities. This road eventually becomes a trail for all-terrain vehicles.

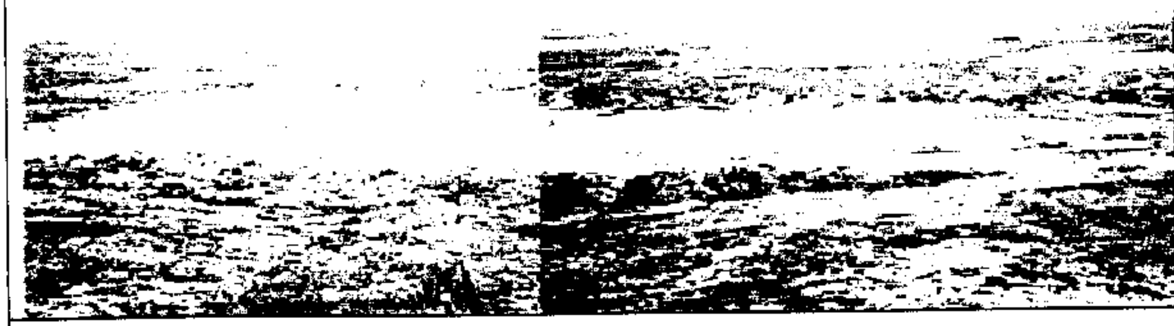
This site is located adjacent to an area that appears to have been used as a borrow source for a sand-like granular material. During the site visit the area appeared to be well drained. A large bedrock outcrop is present in the area. The site under consideration is the area between the existing road and the bedrock outcrop.

Aerial photography and available mapping of the area indicate ponding in the area. Consultation with Hamlet staff suggests this site wet and boggy in the spring. This site will not be considered further.

View of Site One

6.4 OPTION 2: SITE TWO

Another site in consideration is in the same general vicinity as site one. The site is on the east side of the bedrock outcrop. The area appears to be the new location for granular cover materials. During the site visit Mr. Pudlat indicated that this area would be preferential for development because drainage would not be towards the community.



View of Site Two

6.5 Option 3: Site Three

Site three has been selected based on aerial photography and existing mapping. The area covers what appears to have been a borrow source for the community to produce cover material for the existing solid waste disposal site. During the site visit it appeared as though the community has discontinued use of this area and has been extending its borrow area further to the north.

The majority of the area has had the organic material stripped to expose the underlying granular material. The area also appears to be well drained. The existing digital mapping indicates that the majority of the area covered by the structure's footprint is not swampy.

View of Site Three

6.6 Option 4: Site Four

This site is located between site two and three. Site Four was selected because it does not encroach on the drainage area of the wetland, avoids borrow sources and fits the natural contours of the topography.

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

Table 7.1 Must Option 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	fail	pass	pass	pass	fail
System Must Not Impede future growth of the community	pass	pass	pass	pass	pass

Legend:

Process	Description
Option 1	Upgrading Existing Site
Option 2	Site Two, Modified Landfill & Bulky Waste, Decommission Ex isting Site
Option 3	Site Three, Modified Landfill & Bulky Waste, Decommission Existing Site
Option 4	Site Four, Modified Landfill & Bulky Waste, Decommission Existing Site
Option 5	Do Nothing

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System Must Not Impede future growth of the community	pass	pass	pass	pass	pass

Legend:

Process	Description
Option 1	Upgrading Existing Site
Option 2	Site Two, Modified Landfill & Bulky Waste, Decommission Ex isting Site
Option 3	Site Three, Modified Landfill & Bulky Waste, Decommission Existing Site
Option 4	Site Four, Modified Landfill & Bulky Waste, Decommission Existing Site
Option 5	Do Nothing

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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

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 7.2 - 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	9
O&M Cost	1	-	1	1	0	3	10
NPV	0	0	-	1	0	1	8
Community Acceptance	0	0	0	-	0	0	7

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

7.2.3 Results

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

Table 7.3 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	10	9.3	92.9	10	100.0	10.0	100.0
Lowest Capital Cost	9	8.73	78.5	10.00	90.0	8.35	75.2
Lowest NPV	8	8.9	71.1	10	80.0	8.8	70.5
Acceptable To Community	7	10	70.0	5	35.0	7.5	52.5
Total			219.7		205.0		198.1

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Legend:

	Capital	Annual O&M	NPV
Option 2: Site Two	$5,981,836	$239,145	$8,540,853
Option 3: Site Three	$5,219,410	$222,063	$7,595,638
Option 4: Site Four	$6,248,550	$222,063	$8,624,778

8. CONCLUSIONS AND RECOMMENDATIONS

8.1 Summary of Options

8.1.1 Cost

Expanding and improving the existing site and three landfilling options north of the existing site were examined. They have estimated costs of construction and operations as follows:

	Capital	Annual O&M
Option 1: Upgrading Existing Site	$168,574	$68,500
Option 2: Site Two	$5,981,836	$239,145
Option 3: Site Three	$5,219,410	$222,063
Option 4: Site Four	$6,248,550	$222,063

The option that was chosen by the K-T Analysis is Option 2.

The reason for the higher O&M cost for Option 2 compare to the other new site options is the need for a longer access road.

The main item driving capital cost for Options 2-4 is the quantity of granular material. It is possible that the design quantities could be reduced through further optimization of the landfill to the existing topography.

8.2 Discussion and Analysis

Even though expanding the existing site does not meet the 20-year requirements of the community it should still be implemented. The capital cost for a new site can be deferred another five years and the current site will be used to it's potential.

One new landfill area was examined during the site visit. This area was chosen due to its recognition in past work. Access to the area has already been constructed but would require improvement if this area were to be developed to replace the existing solid waste disposal area.

Sites two, three and four overlap each other and cover an area of approximately 8.3 ha. This combined area could meet the demands of the community for the next 40 to 50 years. Sites three and four have the shortest access roads. Site three could be developed first and then the solid waste site could expand from site three to sites four and two. Once site three is covered with granular material, the solid waste underneath will have the advantage of being packed even more by heavy machinery running over it to get to the next site.

8.3 RECOMMENDATION

8.3.1 SOLID WASTE DISPOSAL

1) It is recommended that Option 1 be developed pending discussions with the community. Option 1 maximizes the existing site and defers capital spending another 5 years.

2) In 2007 it is recommended that site three be commissioned as the first site for the solid waste facility.

3) Currently, garbage is strewn across the wetland waterways. This is not acceptable. With improvements to the site including fencing and better waste management operations windblown litter problems should be eliminated.

4) All options require the bulky waste area to be reorganized. It is recommended that the bulky wastes are properly sorted and stored.

5) It is recommended that the community develop a metal waste-recycling program to avoid placement of oversized waste with the municipal solid waste and extend the life of the proposed expanded and improved landfill. Metal waste should be shipped out in conjunction with sealift delivery.

8.3.2 SEWAGE DISPOSAL

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

1) Discarded barrels and other litter should be removed from the sewage site.

2) The drop-off area should be reconstructed with a retaining wall to avoid erosion in the future. The retaining wall should also be oriented as the existing drop-off facility to allow the operators to discharge in three distinct directions depending on the direction of the wind.

3) Bollards and wheel stops should be installed to prevent trucks from backing off of the drop-off area.

4) 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.

5) The TSS/VSS ratio of the wetland effluent should be monitored. Flow-attenuating berms should be installed as required.

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Appendix 1

Wetlands Calculations

To calculate daily hydraulic load rate input highlighted values

Daily sewage generation (m3/d)	168
Duration of pond storage (months)	8
Melt period (months)	2
After melt period and before freeze (months)	2
Rainfall during melt period(mm)	121
Rainfall after melt period (mm)	73
Size of wetland (ha)	10.5
Pond Storage (m3)	40332.88
Ice pack melt (m3/day)	672.2147
Rainfall rate over wetland during melt (m3/d)	212
Rainfall rate over wetland after melt (m3/d)	128
Total daily hydraulic load during melt (m3/d)	1052
Total daily hydraulic load after melt (m3/d)	296

* for this project, wetland is natural and area shown is the actual area reduced by 50%

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

Total hydraulic load during melt per ha	**100 (m3/d/ha)**
Total hydraulic load after melt per ha	**28 (m3/d/ha)**

No imputs needed, all values taken from other worksheets

Total hydraulic load during melt (m3/d)	1052	
Total hydraulic load after melt (m3/d)	296	
Rainfall rate over wetland during melt (m3/d)	211.8	
Rainfall rate over wetland after melt (m3/d)	127.8	
BOD concentration (mg/L)	378	
TSS concentration (mg/L)	403	
T-PO4 concentration (mg/L)	19	
TKN concentraion (mg/L)	101	
FC concentration (#/dl)	7.97E+07	
Size of wetland (hydraulic loading calculation, ha)	10.5	
Contaminant load during melt (kg/d)		**Contaminant load during melt (kg/d/ha)**
BOD contaminant load (kg/d)	317.3	**30.21**
TSS contaminant load (kg/d)	338.4	32.23
T-PO4 contaminant load (kg/d)	16.2	1.54
TKN contaminant load (kg/d)	84.6	8.06
FC contaminant load (#/d)	6.7E+07	6.38E+06
Contaminant load after melt		**Contaminant load after melt (kg/d/ha)**
BOD contaminant load (kg/d)	63.5	**6.04**
TSS contaminant load (kg/d)	67.7	6.45
T-PO4 contaminant load (kg/d)	3.2	0.31
TKN contaminant load (kg/d)	16.9	1.61
FC contaminant load (#/d)	1.34E+07	1.28E+06

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

Alberta Environment Wetlands Calculations

Surface Flow Wetland Treatment

Design Flow m3/d Q = 1052

		TSS	BOD	TP	TN	NH4-N	FC
Wastewater Characterization	Ci	403	378	19	101	80	7.97E+07
Target Effluent Quality	Ce	120	100	2	4	2	10000
Wetland Background Input	C* =	33.1719	23.5106	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 @20oC	k =	1000	34	12	22	18	77
Required Wetland Area	A =	0.06	1.731	7.326	6.805	7.869	4.485

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

Available Area 10.5

		TSS	BOD	TP	TN	NH4-N	FC
Projected Effluent Quality	**Co**	**33.17**	**23.54**	**0.77**	**2.24**	**0.58**	**1.00E+02**

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

	TSS	BOD	TP	TN	NH4-N	FC
Overall % removal	91.763	93.764	95.993	97.774	99.272	100.000

Calculations including MSWS effluent

Alberta Environment Wetlands Calculations

Surface Flow Wetland Treatment

Design Flow m3/d Q = 1065

		TSS	BOD	TP	TN	NH4-N	FC
Wastewater Characterization	Ci	403	378	19	101	80	7.97E+07
Target Effluent Quality	Ce	120	100	2	4	2	10000
Wetland Background Input	C* =	33.1719	23.5106	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 @20oC	k =	1000	34	12	22	18	77
Required Wetland Area	A =	0.06	1.752	7.417	6.889	7.967	4.540

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

Available Area 10.5

		TSS	BOD	TP	TN	NH4-N	FC
Projected Effluent Quality	**Co**	**33.17**	**23.55**	**0.80**	**2.26**	**0.62**	**1.00E+02**

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

	TSS	BOD	TP	TN	NH4-N	FC
Overall % removal	91.763	93.763	95.840	97.756	99.226	100.000

10C

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

Alberta Environment Wetlands Calculations

Surface Flow Wetland Treatment

		TSS	BOD	TP	TN	NH4-N	FC
Design Flow m3/d	Q =	1065.02					
Wastewater Characterization	Ci	402.728	377.558	19.2974	100.682	80	7.97E+07
Target Effluent Quality mg/l	Ce	120	100	2	4	2	10000
Wetland Background Input	C* =	33.1719	23.5106	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 =	0.11	3.504	14.834	13.778	15.933	9.081

Models $A = \frac{0.0365 \cdot Q}{k} \cdot \ln \left| \frac{Ci - C^*}{Ce - C^*} \right|$ Available Area 10.5

		TSS	BOD	TP	TN	NH4-N	FC
Projected Effluent Quality	**Co**	**33.17**	**27.10**	**3.86**	**7.06**	**7.04**	**2.53E+03**

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

		TSS	BOD	TP	TN	NH4-N	FC
Overall % removal		91.763	92.823	80.015	92.991	91.205	99.997

5C

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

Alberta Environment Wetlands Calculations

Surface Flow Wetland Treatment

		TSS	BOD	TP	TN	NH4-N	FC
Design Flow m3/d	Q =	1065.02					
Wastewater Characterization	Ci	402.728	377.558	19.2974	100.682	80	7.97E+07
Target Effluent Quality mg/l	Ce	120	100	2	4	2	10000
Wetland Background Input	C* =	33.1719	23.5106	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 =	0.23	7.008	29.667	27.556	31.866	18.161

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

Available Area: 10.5

		TSS	BOD	TP	TN	NH4-N	FC
Projected Effluent Quality	**Co**	**33.17**	**59.15**	**8.61**	**24.34**	**23.73**	**4.40E+05**

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

		TSS	BOD	TP	TN	NH4-N	FC
Overall % removal		91.763	84.333	55.385	75.827	70.344	99.448

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 = 1052.02

		TSS	BOD	TP	TN	NH4-N	FC
Wastewater Characterization	Ci	402.728	377.558	19.2974	100.682	80	7.97E+07
Target Effluent Quality mg/l	Ce	120	100	2	4	2	10000
Wetland Background Input	C* =	33.1719	23.5106	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 =	0.11	3.461	14.653	13.610	15.739	8.970

Models $A = \frac{0.0365*Q}{k} * \ln\left|\frac{Ci - C*}{Ce - C*}\right|$ Available Area 10.5

		TSS	BOD	TP	TN	NH4-N	FC
Projected Effluent Quality	**Co**	**33.17**	**26.90**	**3.78**	**6.87**	**6.83**	**2.23E+03**

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

	TSS	BOD	TP	TN	NH4-N	FC
Overall % removal	91.763	92.875	80.406	93.172	91.465	99.997

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 =   1052.02

		TSS	BOD	TP	TN	NH4-N	FC
Wastewater Characterization	Ci	402.728	377.558	19.2974	100.682	80	7.97E+07
Target Effluent Quality mg/l	Ce	120	100	2	4	2	10000
Wetland Background Input	C* =	33.1719	23.5106	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 =	0.22	6.922	29.305	27.219	31.477	17.940

Models $A = \frac{0.0365*Q}{k} * \ln\left|\frac{Ci - C*}{Ce - C*}\right|$ Available Area   10.5

		TSS	BOD	TP	TN	NH4-N	FC
Projected Effluent Quality	**Co**	**33.17**	**58.15**	**8.52**	**23.93**	**23.37**	**4.13E+05**

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

	TSS	BOD	TP	TN	NH4-N	FC
Overall % removal	91.763	84.597	55.827	76.230	70.786	99.482

Appendix 2

Cost Calculations

Option 1

Upgradin existing site

Capital Component	Unit Cost	Unit	Quantity	Extension
Upgrade site				
Temporary Fencing	$25	lin.m.	317	$7,925
Clean-up	$5,000	lump	1	$5,000
Additional berms	$15	cu.m	3,071	$46,065
Close out solid waste				
Cover required	$35	cu.m.	4,342	$151,970
Close-out Bulky Waste Area				
Move bulky waste	$50,000	lump	1	$50,000
Scraping,moving and replacing granula	$70	cu.m.	2,264	$158,480
Subtotal				$419,440
Engineering & Contingency @ 40%				$167,776
Total				$587,216

O&M Component	Unit Cost	Unit	Quantity	Extension
Temporary Fencing Repair	$25.00	lin.m.	64	$1,600
Waste Compaction	$30,000.00	lump	1	$30,000
Access Road Clearing & Maintenance	$219.00	lin.m.	0	$0
Cover material	$50.00	cu.m.	285	$14,250
Total				$45,850

Year	i = 8%	
1	1	$45,850
2	0.8573388	$39,309
3	0.8573388	$39,309
4	0.7938322	$36,397
5	0.7350299	$33,701
6	0.6805832	$31,205
Sum Annual Costs		$225,772
Capital Cost		$587,216
Net Present Value		$812,988

Additional berm material will be taken from the fill scraped from the bottom of the expanded area in the modified area method.

Close-out cover is for existing solid waste site

Bulky Waste Sites, New Abandoned Vehicle, Existing abandoned vehicle, Tires and Appliances will all be closed out and relocated to the existing solid waste site. This can be done gradually over the next five years.

O&M

Most of the cover material will be taken from the material scraped from the closed out bulky waste sites.

Cover material in O&M component consists of extra granular needed.

Option 2
Site Two

Capital Component	Unit Cost	Unit	Quantity	Extension
Earthworks				
Berm				
Granular Fill	$50	cu.m.	53710	$2,685,500
Fencing	$150	lin.m.	748	$112,200
Turnaround	$50	cu.m.	1,000	$50,000
Close-out Solid Waste Area				
Cover required	$35	cu.m.	3,735	$130,725
New Access Road	$80.00	lin.m.	293	$23,440
Culvert	$200.00	lin.m.	8	$1,600
Subtotal				$3,003,465
Engineering & Contingency @ 40%				$1,201,386
Total				$4,204,851

O&M Component	Unit Cost	Unit	Quantity	Extension
Fencing Repair	$40.00	lin.m.	748	$29,920
Berm Maintenance	$100.00	lin.m.	748	$74,800
Waste Compaction	$30,000.00	lump	1	$30,000
Access Road Clearing & Maintenance	$219.00	lin.m.	325	$71,175
Cover material	$50.00	cu.m.	665	$33,250
Total				$239,145

Year	i = 8%	
1	1	$239,145
2	0.9259259	$221,431
3	0.8573388	$205,028
4	0.7938322	$189,841
5	0.7350299	$175,779
6	0.6805832	$162,758
5	0.6301696	$150,702
8	0.6805832	$162,758
9	0.5402689	$129,203
10	0.500249	$119,632
11	0.4631935	$110,770
12	0.4288829	$102,565
13	0.3971138	$94,968
14	0.3676979	$87,933
15	0.340461	$81,420
16	0.3152417	$75,388
17	0.2918905	$69,804
18	0.270269	$64,633
19	0.250249	$59,846
20	0.2317121	$55,413
Sum Annual Costs		$2,559,017
Capital Cost		$4,204,851
Net Present Value		$6,763,868

Construct berm 185x185, depth of 2.5m from floor of enclosure
New access road average fill = 0.6m meter.
Close out of Expanded Solid Waste Area with 600 mm of fill. Bulky waste site can then be expanded to this site.

Option 3

Site Three

Capital Component	Unit Cost	Unit	Quantity	Extension
Earthworks				
Berm				
Granular Fill	$50	cu.m.	42943	$2,147,150
Fencing	$150	lin.m.	748	$112,200
Turnaround	$50	cu.m.	1,000	$50,000
Close-out Solid Waste Area				
Cover required	$35	cu.m.	3,735	$130,725
New Access Road	$80.00	lin.m.	215	$17,200
Culvert	$200.00	lin.m.	8	$1,600
Subtotal				$2,458,875
Engineering & Contingency @ 40%				$983,550
Total				$3,442,425

O&M Component	Unit Cost	Unit	Quantity	Extension
Fencing Repair	$40.00	lin.m.	748	$29,920
Berm Maintenance	$100.00	lin.m.	748	$74,800
Waste Compaction	$30,000.00	lump	1	$30,000
Access Road Clearing & Maintenance	$219.00	lin.m.	247	$54,093
Cover material	$50.00	cu.m.	665	$33,250
Total				$222,063

Year	i = 8%	
1	1	$222,063
2	0.9259259	$205,614
3	0.8573388	$190,383
4	0.7938322	$176,281
5	0.7350299	$163,223
6	0.6805832	$151,132
5	0.6301696	$139,937
8	0.6805832	$151,132
9	0.5402689	$119,974
10	0.500249	$111,087
11	0.4631935	$102,858
12	0.4288829	$95,239
13	0.3971138	$88,184
14	0.3676979	$81,652
15	0.340461	$75,604
16	0.3152417	$70,004
17	0.2918905	$64,818
18	0.270269	$60,017
19	0.250249	$55,571
20	0.2317121	$51,455
Sum Annual Costs		$2,376,228
Capital Cost		$3,442,425
Net Present Value		$5,818,653

Construct berm 185x185, depth of 2.5m from floor of enclosure
New access road average fill = 0.6m meter.
Close out of Expanded Solid Waste Area with 600 mm of fill. Bulky waste site can then be expanded to this site.

Option 4
Site Four

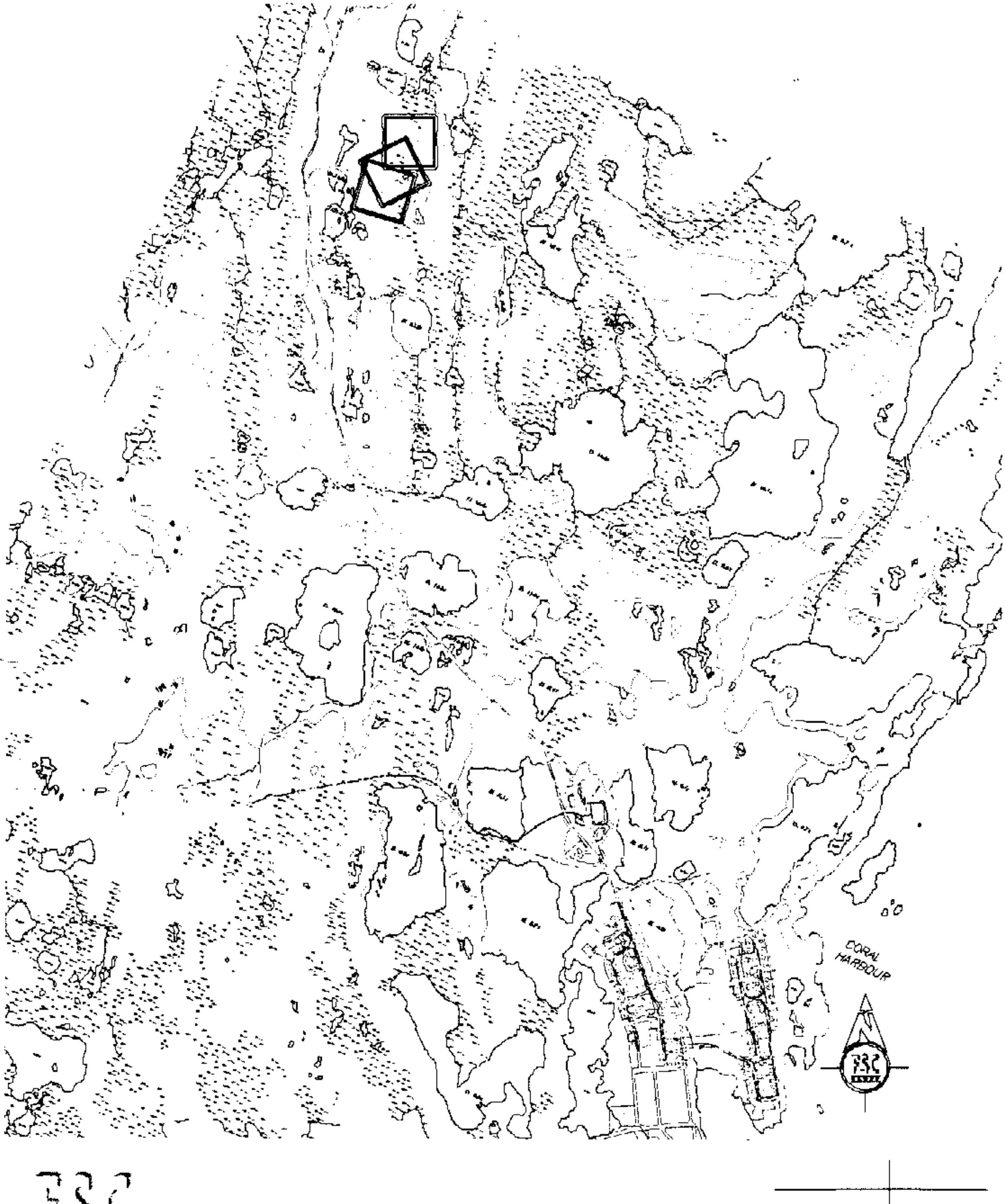
Capital Component	Unit Cost	Unit	Quantity	Extension
Earthworks				
Berm				
Granular Fill	$50	cu.m.	57645	$2,882,250
Fencing	$150	lin.m.	748	$112,200
Turnaround	$50	cu.m.	1,000	$50,000
Close-out Solid Waste Area				
Cover required	$35	cu.m.	3,735	$130,725
New Access Road	$80.00	lin.m.	215	$17,200
Culvert	$200.00	lin.m.	8	$1,600
Subtotal				$3,193,975
Engineering & Contingency @ 40%				$1,277,590
Total				$4,471,565

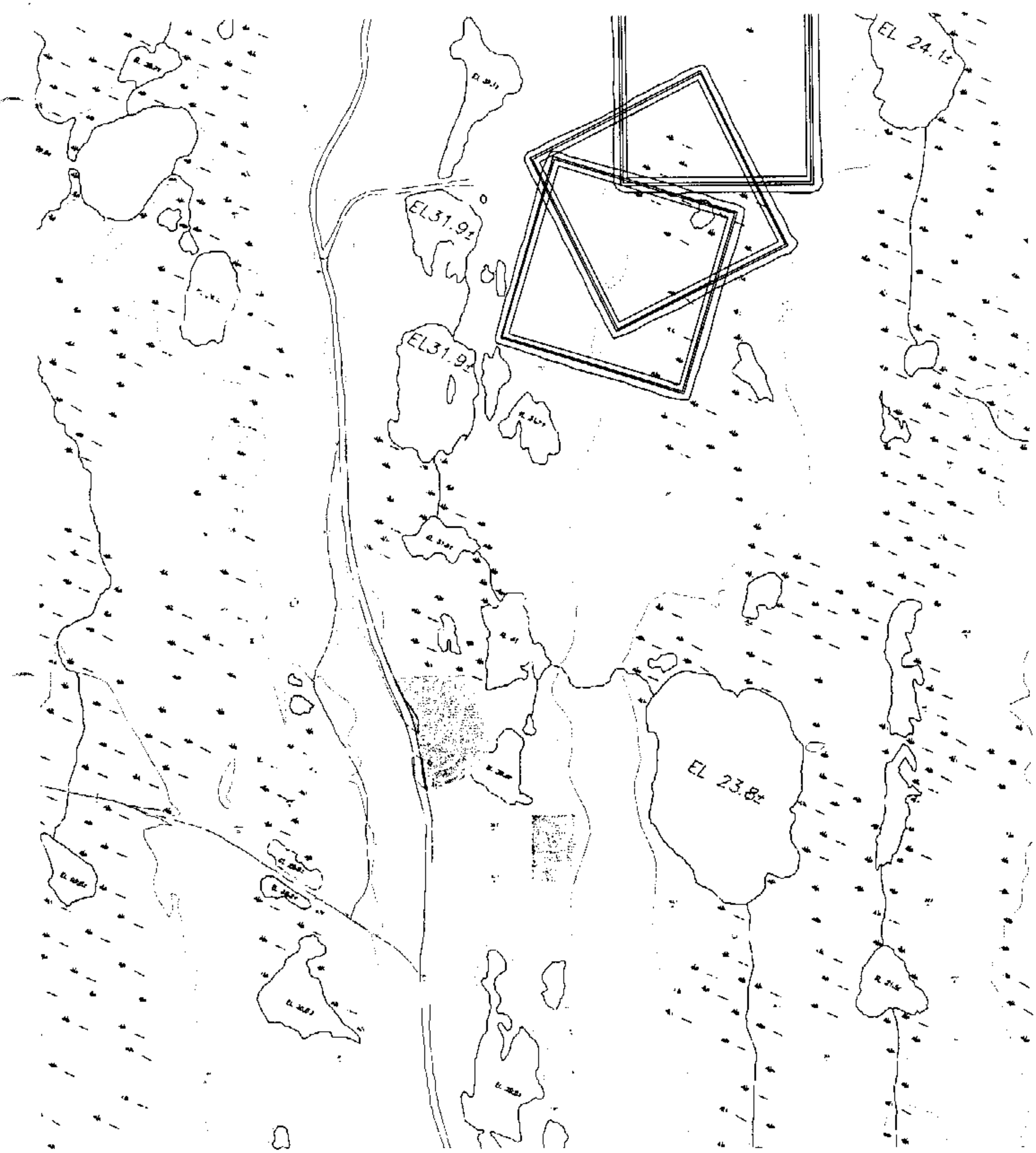
O&M Component	Unit Cost	Unit	Quantity	Extension
Fencing Repair	$40.00	lin.m.	748	$29,920
Berm Maintenance	$100.00	lin.m.	748	$74,800
Waste Compaction	$30,000.00	lump	1	$30,000
Access Road Clearing & Maintenance	$219.00	lin.m.	247	$54,093
Cover material	$50.00	cu.m.	665	$33,250
Total				$222,063

Year	i = 8%	
1	1	$222,063
2	0.9259259	$205,614
3	0.8573388	$190,383
4	0.7938322	$176,281
5	0.7350299	$163,223
6	0.6805832	$151,132
5	0.6301696	$139,937
8	0.6805832	$151,132
9	0.5402689	$119,974
10	0.500249	$111,087
11	0.4631935	$102,858
12	0.4288829	$95,239
13	0.3971138	$88,184
14	0.3676979	$81,652
15	0.340461	$75,604
16	0.3152417	$70,004
17	0.2918905	$64,818
18	0.270269	$60,017
19	0.250249	$55,571
20	0.2317121	$51,455
Sum Annual Costs		$2,376,228
Capital Cost		$4,471,565
Net Present Value		$6,847,793

Construct berm 185x185, depth of 2.5m from floor of enclosure
New access road average fill = 0.6m meter.
Close out of Expanded Solid Waste Area with 600 mm of fill. Bulky waste site can then be expanded to this site.


CORAL HARBOUR
N


CORAL HARBOUR



FSC

EXISTING GARBAGE PILE

USE MATERIAL TO
BUILD NEW BERMS

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FSC