Government of Nunavut

Design Brief
Sewage Wetland Upgrade,
Whale Cove, Nunavut

Type of Document
Final

Project Name
Whale Cove Sewage Wetland Upgrade

Project Number
OTT-00201369-A0

Prepared By:

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Date Submitted
September 2012

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NT/NU Association of Professional Engineers and Geoscientists

Date Submitted:
September 2012

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1 Introduction

Exp Services Inc. (**exp**) was retained by the Department of Community and Government Services (CGS), Government of Nunavut (GN), to review the existing sewage lagoon and complete the detail planning and design for the Sewage Wetland Upgrade, for the Hamlet of Whale Cove (Hamlet), Nunavut.

As per the Terms of Reference (TOR) of this project, to keep pace with the growth of the community, there is a need to provide proper disposal of sewage to wetland.

1.1 Background

The Hamlet's existing sewage treatment facility is located approximately 450 metres to the southwest of the community as shown on Figure 1.1 – Location Plan. It is comprised of a single cell lagoon developed within the depression of an existing lake, and a natural wetlands draining directly to the ocean. Berms were constructed along the east and west banks to increase the holding capacity of the lagoon. According to Whale Cove Solid Waste and Sewage Disposal, Design and Operations Report that was prepared by DPW&H in August 1988, "The natural drainage appears to be occurring at the east and west ends of the lake, water appears to drain overland as well as underground through fractures in rock and between big boulders at the east end back to the community".

The first condition assessment done for the Whale Cove sewage lagoon was completed by FSC in 2001. The 2001 review noted that the lagoon was originally a natural pond or lake, which was not drained of water before it began to be used as a sewage lagoon. It was also noted in 2001 that there was seepage from the lagoon on both the west and east berms. Wastewater samples were taken by FSC at various locations east and west of the lagoon. Testing has shown very little contamination, and BOD, TSS, F. Coliform values were well below the acceptable limits. The FCS 2001 study concluded that making the lagoon impervious was not desirable given the contamination values were low. The study estimated that the lagoon would meet the community needs until 2015 to 2020.

1.2 Regulatory Issues

The Hamlet operates the Sewage treatment facility under its existing Water Licence Number 3BM-WHA0914 issued by the Nunavut Water Board (NWB). Under this licence, the NWB has identified conditions to be addressed in the Hamlet of Whale Cove's include:

- Effluent standards for sewage treatment should meet the parameters set in the "Guidelines for the discharge of treated municipal wastewater in the Northwest Territories"
- The discharge point from the Sewage Lagoon is renewed as the Final Discharge Point and will be where effluent quality limits must be met.
- A freeboard of at least 1.0 metre, or as recommended by a qualified geotechnical engineer and as approved by the Board in writing, for all dams, dykes or other structures intended to contain, withhold, divert or retain water or wastes.

Issues identified within the inspection report were:

- One metre freeboard not maintained as required under the Dam Safety Guideline.
- Effluent draining from the lagoon to the northeast, toward the Hamlet.

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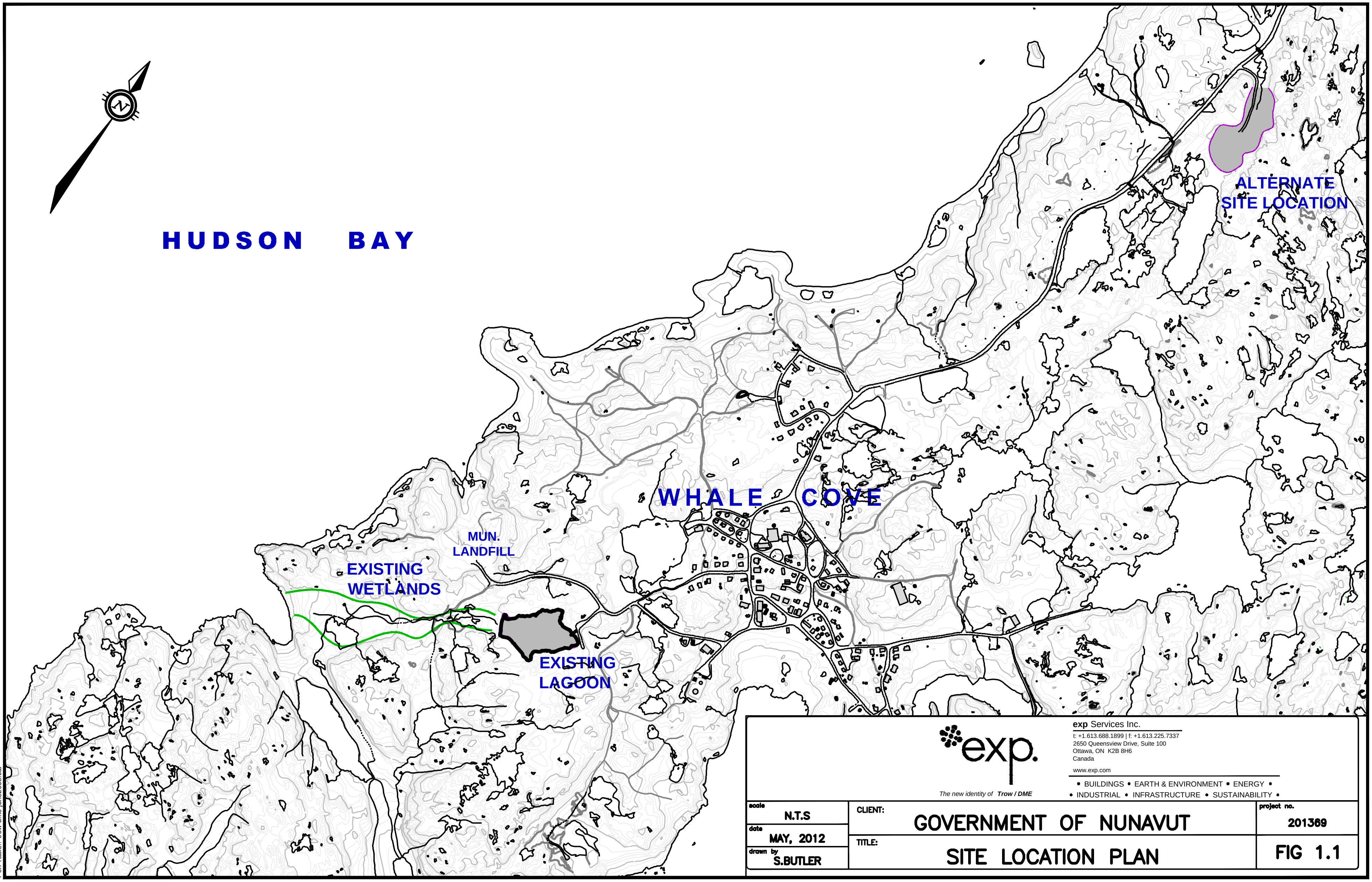

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scale N.T.S	CLIENT: GOVERNMENT OF NUNAVUT	project no. 201369
date MAY, 2012	TITLE: SITE LOCATION PLAN	FIG 1.1
drawn by S.BUTLER		

1.3 Scope of Services

The scope of services to be undertaken as part of the detail planning and design for the new sewage lagoon and the decommissioning of the Hamlet's existing sewage treatment facility included the following:

1. Travel to Whale Cove to gather information on the existing site known from the conditions imposed by Nunavut Water Board Water Licence, INAC & DFO Inspection Report.
2. Design a Sewage Holding Cell and indicate the source of material.
3. The existing Wetland Sewage treatment area shall also be assessed to insure compliance.
4. The report / design shall be prepared to meet the requirements of NWB, INAC, DE (NU) & DFO.
5. Assessment Study should be conducted with any alternate to produce the gravel by crushing and mixing to produce proper gravel for different applications.
6. The design shall address any environmental and wild life impacts.
7. The design shall indicate the quantity based on the specifications for different applications (embankment, Sub-base, Base, Surface and Concrete Aggregate).
8. The Study shall also indicate the materials available in existing pits and other potential sources.
9. The design shall address concerns of NWB Licence.
10. Any other issues indicated in Water Licence.
11. Drawings & O&M manuals to meet NWB requirements.
12. Address anything else missing.

2 System Requirements

2.1 General

The proposed sewage treatment facility must meet the long term needs of the Hamlet, as well as the regulatory requirements of the Hamlet's water licence. The "Water and Sewage's Facility Capital Program Standards and Criteria" as provided by the CGS, indicates the design horizon for sewage lagoons is to be between 15 – 20 years. As per the direction of the CGS, the design horizon for the Sewage Lagoon shall be 20 years, until the year 2032.

2.2 Population

The population projections for this project will be based on "Nunavut: Community Population Projections" as published by the Nunavut Bureau of Statistics, June 24, 2010. The Nunavut Bureau of Statistics provide projected populations of the Nunavut communities to the year 2036. The table below summarizes the population projections to the year 2032.

Table 2.1: Population Projections

Planning Year	Year	Population
	2009	388
	2010	394
	2011	400
0	**2012**	**406**
1	2013	412
2	2014	419
3	2015	426
4	2016	433
5	**2017**	**439**
6	2018	446
7	2019	453
8	2020	460
9	2021	467
10	**2022**	**472**
11	2023	477
12	2024	482
13	2025	488
14	2026	494
15	**2027**	**500**
16	2028	506
17	2029	512
18	2030	518
19	2031	525
20	**2032**	**532**

2.3 Sewage Generation

To determine the volume of sewage the facility must treat, the sewage generation rate for the community must be determined. Sewage generation rates are generally assumed to be equal to the water consumption rates for a community, with the water consumption rate being the total of the residential and non-residential water consumption. The "Water and Sewage Facility Capital Program Standards and Criteria" provide the following design values and formulae for estimating the water consumption and therefore the sewage generation rates for communities.

The residential water usage (RWU) for a community is based on the method of water delivery and sewage collection in the community. The litres per capita water usage rates for the different methods of water delivery and sewage collection are summarized in the Table 2.2.

Table 2.2 - Residential Water Usage

Service Method	Residential Water Usage (RWU)
Trucked water and sewage	90 lpcd
Piped water and sewage	225 lpcd
Piped water supply and truck sewage pump out	110 lpcd
Trucked water delivery and individual septic fields	100 lpcd

The Hamlet has a trucked water and sewage system, therefore the RWU for the community from Table 2.2 is equal to 90 lpcd.

The non-residential water usage by a community tends to increase with increases in the population. To determine the total community water usage the Residential Water Usage is adjusted based on population to provide a Total Water Usage Per Capita (TWUC). The Total Water Usage Per Capita, including residential and non residential activities IS estimated based on the equations in Table 2.3.

Table 2.3 - Total Community Water Usage

Community Population	Total Water Use Per Capita
0 – 2,000	RWU x (1.0 + 0.00023 x Population)
2,000 – 10,000	RWU x [-1.0 + {0.323 x Ln(Population)}]
Over 10,000	RWU x 2.0

The daily water consumption, and therefore the sewage generated by the community, is based on the design population of **532** for the year ***2032***, and the TWUC is calculated to be:

TWUC = RWU x (1.0 + 0.000323 x Population)
= 90 x (1 + 0.000323 x Population)
= 90 x (1.172)
= 105.48 lcpd or **105.5 lpcd**

Based on a TWUC rate of 105.5 lpcd, the daily sewage generation rate, estimated for the year 2032, for the entire community of Whale Cove is equal to 56,126 litres per day (lpd). This is equal to a yearly sewage generation rate of **18,802 m^3** (based on an 11-month period, allowing for one (1) month of decanting).

2.4 Regulatory Requirements

The proposed sewage treatment facility will have to meet the effluent quality standards as set out in the Hamlet's water licence. The Hamlet is operating under water licence # 3BM-WHA0914 Issued June 10, 2009 by the Nunavut Water Board, as required under the Nunavut Lands Claim Agreement and the Nunavut Waters Act. The effluent quality standards set out in the water licence are summarized in the Table 2.5.

Table 2.5 – Effluent Quality Standards

Parameters	Maximum Average Concentration
BOD_5	120 mg/L
Total suspended solids (TSS)	180 mg/L
Faecal coliforms	1×10^6 CFU/100 mL
Oil and grease	No visible sheen
pH	Between 6 and 9

3 Site Investigation

In August & September 2011, detailed site investigation(s) was undertaken, including the following:

1. Site inspection
2. Topographic survey
3. Geotechnical investigation
4. Wetlands assessment
5. Environmental Assessment

3.1 Site Inspection

As part of the site investigation an inspection of the existing facility was undertaken on August 15th and 16th, 2011. This inspection noted the following:

- The existing sewage treatment facility includes a natural lake which has been modified through the construction of an earth berm along its natural southwest outlet at its end, and a smaller earth berm along the northeast end near the truck discharge point.
- The berm to the northeast end of the sewage lagoon is intended to prevent flow from the lagoon back towards the Hamlet.
- The presence of lush green vegetation in the drainage course to the northeast of the sewage lagoon appears to indicate that this berm is experiencing some seepage.
- The lagoon is intended to drain through the berm at the southwest corner of the lagoon through seepage to natural wetlands, approximately 650 m long which outlets to the ocean.
- The wetlands appear to be very lush and it appears it is very successful at treating the sewage released to it.
- The areas to the northwest and southeast of the lagoon are extremely rugged and composed mainly of bare rock.
- The berm to the southwest was not overtopping, however, had limited freeboard and would not meet the requirements of the one metre freeboard as per the Dam Safety Guidelines.
- Due to the natural topography there is very limited opportunity to construct an additional sewage lagoon cell in the proximity of the existing facility.
- Sampling program was undertaken, and samples were sent to the Laboratory.
- Alternative sites for the location of the sewage treatment facility were examined along the road to the airport, but those sites were considered to be traditional fishing grounds and berry picking grounds for the local community.
- After consultation with the Hamlet Council it was recommended that an emphasis be placed on the potential for rehabilitation / remediation of the existing facility to meet the concerns and conditions of the Water Board and provide the long term sewage disposal requirements of the Hamlet.
- Four old, abandoned gravel sources were visited along with the current gravel pit.
- Gravel is a scarce commodity within the Hamlet and any major construction will require a quarrying program.

3.2 Topographic Survey

A topographic survey of the existing facility, including the existing lagoon and wetlands area was undertaken. Sonar was used to map ground elevations under water.

The survey of the existing facility reaffirmed the information provided in the background report with regards to the location and size of the various components of the facility. The existing facility is shown on Figure 3-1.

Survey information was used to calculate the storage volumes at various water elevations.

The survey crew, in conjunction with the wetlands specialist, mapped out the limits of the existing wetlands treatment.

3.3 Geotechnical Investigation

As part of the site investigation, a geotechnical investigation was carried out by **exp.** The geotechnical factual report resulting from this investigation has been issued November 14th, 2011 under a separate cover. The following summarizes the findings and recommendations from this report.

The existing sewage lagoon was constructed in a low lying area of a valley, by building berms across it. The area is reported to be on existing water body. The alternate site of a new lagoon is located in an active quarry approximately 2 km north of the Hamlet.

The investigation has revealed that fill extends to 1.2 m to 1.5 m in the crest of the berms. The fill is underlain by sand and gravel, sandy silt, sandy gravel and silty sand to 7.2 m (Elevation 13.9 m) to 5.7 m (Elevation 16.2 m). Drilling on the sides of the valley away from the berms found a surficial veneer of sand and gravel 0.4 m to 0.9 m thick is underlain by bedrock. The bedrock was identified as dolomite of good to excellent quality. Depth of permafrost at the berm locations was established at 5.7 m. It is considered that the permafrost had degraded over the years since the area used to be a pond prior to its conversion into sewage lagoon.

Investigation at the potential alternative location of the new sewage lagoon encountered 1.5 m of surficial sand which was underlain by sandy gravel to the entire depth investigated i.e. 3.7 m depth, Elevation 12.5 m. Permafrost was not encountered to the depth investigated.

A detailed description of the subsoil conditions encountered at the two sites is given in the report.

The above and other related considerations have been discussed in greater detail in the geotechnical report.

3.4 Wetlands Assessment

In junction with the upgraded sewage lagoon, the treatment of raw sewage from the lagoon will be combined with the utilization of wetland treatment as a final polishing. The proposed system will be similar to the existing system already established. The area used as wetlands for the Whale Cove treatment facility is a vegetated filterstrip wetland.

The upgraded sewage lagoon and the area between the lagoon and the ocean will be incorporated into the sewage treatment process as shown in Figure 3.2 - Wetlands. The existing wetlands area is approximately 3.6 hectare in size with an average slope of 2.7%. The well established native vegetation community will be used and alterations or modifications to the plant community composition are not necessary to increase removal of contaminants. The plant species present, which include willows, grasses, sedges and mosses, are suitable for the phytofiltration processes that will reduce BOD and TSS.

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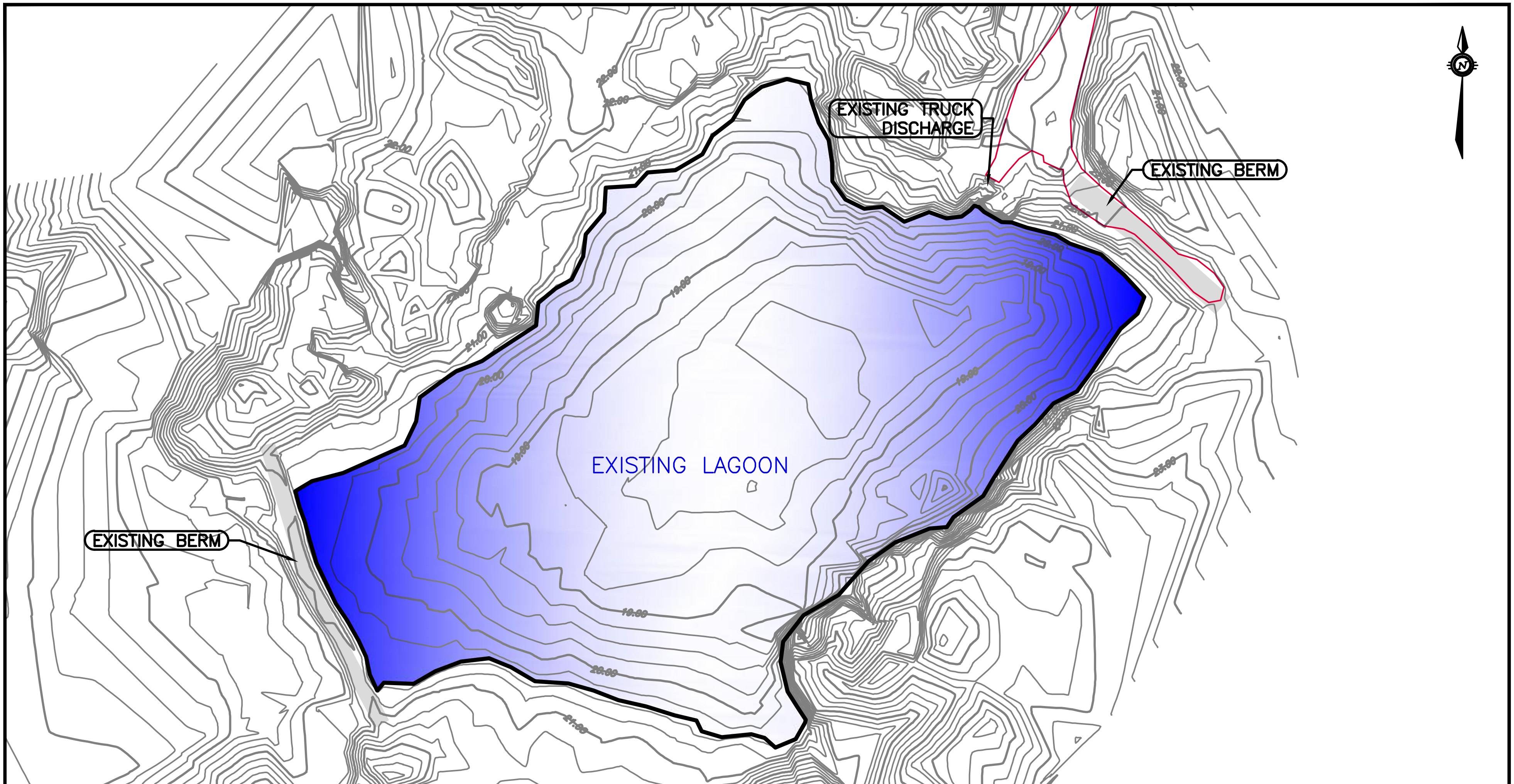

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scale: N.T.S	CLIENT: GOVERNMENT OF NUNAVUT	project no.: OTT-00201369-A0
date: MAY, 2012	TITLE: EXISTING FACILITY	FIG 3.1
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date MAY 2012	TITLE:	
drawn by S.BUTLER	WETLANDS	FIG 3.2

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3.5 Environmental Assessment

As part of the site investigation, **exp** completed a Screening Level Environmental Assessment (SLEA) under the *Canadian Environmental Assessment Act* (CEAA) in order to complete the detailed planning design for the sewage wetland upgrade. The objective of the SLEA is to identify and document the environmental effects of the proposed project components, and to determine the need to mitigate the adverse effects and modify the project plan, or recommend further assessment by a review panel.

The Environmental Assessment has been issued under a separate cover. The following summarizes the findings of that report.

All of the vegetation observed at the Site or expected to be present at the Site, are highly adapted to the extreme conditions of the subarctic region. Various species are also adapted to disturbed Sites, including fireweed. As such, the composition of the vegetation community observed to be present at the Site is considered suitable for the proposed upgrade and expansion of the existing sewage treatment system for the Hamlet of Whale Cove.

In general, the extent of disturbance at the Site is considered minimal. There is light, widespread evidence of colonizing plant species at various areas of the Site, and light, localized evidence of human encroachment, including some tracks or trails, and recreational activities. However, given the low evidence of disturbance at the Site, the proposed upgrade and expansion of the existing long term sewage treatment system is not expected to significantly alter the existing environment.

All of the wildlife observed at the Site or expected to be present at the Site, are highly adapted to the extreme conditions of the subarctic region. Various species are also adapted to disturbed Sites, including arctic ground squirrels and Canada geese. As such, the composition of the wildlife community observed to be present at the Site is considered suitable for the proposed upgrade and expansion of the existing long term sewage treatment system for the Hamlet.

The SLEA revealed that the proposed upgrades and expansion of the existing long term sewage treatment system for the Hamlet will have net positive effects on the community. This project will not have significant long term negative effects on the environment or local wildlife. Most effects are related to the construction activities, and are short term. All potential effects can be mitigated by applying suitable mitigation measures.

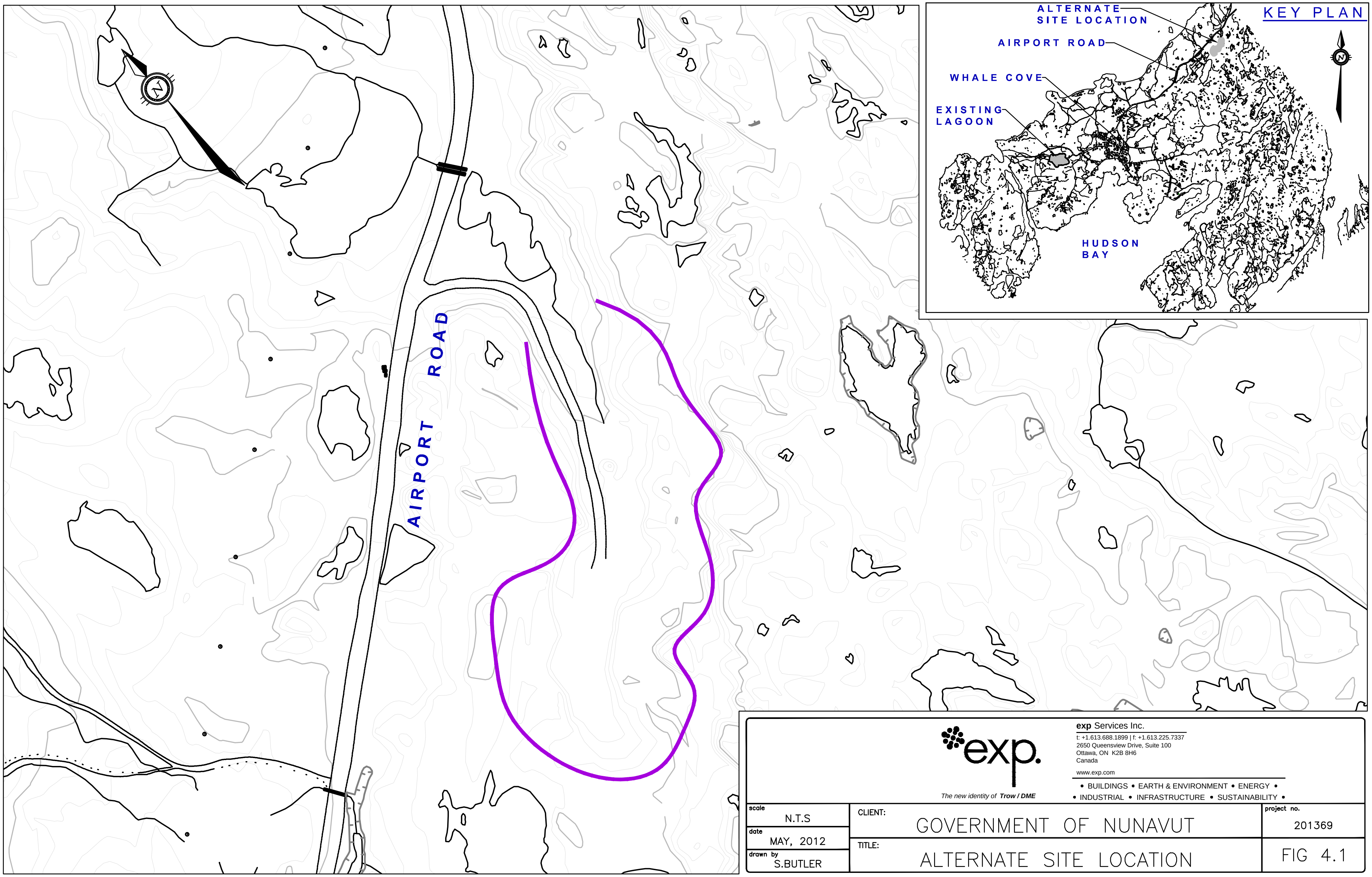
4 Alternative Sites

4.1 Alternative Sites

As part of the site visit, a meeting was held with the Town Foreman in which the Town Foreman was requested to show the project team the alternative sites for the location of a sewage treatment facility. Many sites were visited along the Airport Road, however this area is considered to be traditional fishing and berry picking grounds for local community. The Hamlet Foreman concluded that the existing site was the best location. The Hamlet Council, during a meeting with representatives of CGS and **exp**, was against the location of a new sewage treatment facility along the road to the airport and favoured maintaining the sewage lagoon to the southeast of the community in the vicinity of the existing facility. Minor concerns were expressed with regards to the rare occurrence of odour from the existing lagoon. The alternative sites identified are shown on Figure 4.1 Alternative Sites.

4.2 Site Evaluation

Based on the meeting with Council and the Town Foreman, as well as the review of the local area for alternate sites, it is recommended that an emphasis be placed on the potential for rehabilitation / remediation of the existing facility to meet the concerns and conditions of the Water Board and provide the long term sewage disposal requirements of the Hamlet.



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date MAY, 2012			
drawn by S.BUTLER	TITLE: ALTERNATE SITE LOCATION		FIG 4.1

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5 Detail Design

5.1 Lagoon Size

The proposed sewage lagoon system for Whale Cove is operated as a storage cell system. Storage cell lagoon systems must store the sewage generated from the end of one decanting cycle to the start of the next, plus precipitation and runoff which would enter the lagoon from the lagoon watershed.

5.1.1 Sewage Generated

It is proposed that the Whale Cove lagoon be decanted over a 30 day period from between mid to late August and mid to late September. Therefore, the required storage period for the new sewage lagoon will be for 335 days (approximately 11 months). Based on the projected population of 532 and the sewage generation rate of 105.5 lcpd, the total required storage for sewage is 18,802 m^3.

5.1.2 Precipitation Data

Whale Cove sewage lagoon was originally developed within the depression of an existing water body. The lagoon watershed area, as shown in figure 5.1, is calculated using the Topographic Survey data. The watershed area is calculated to be 47,500 m^2.

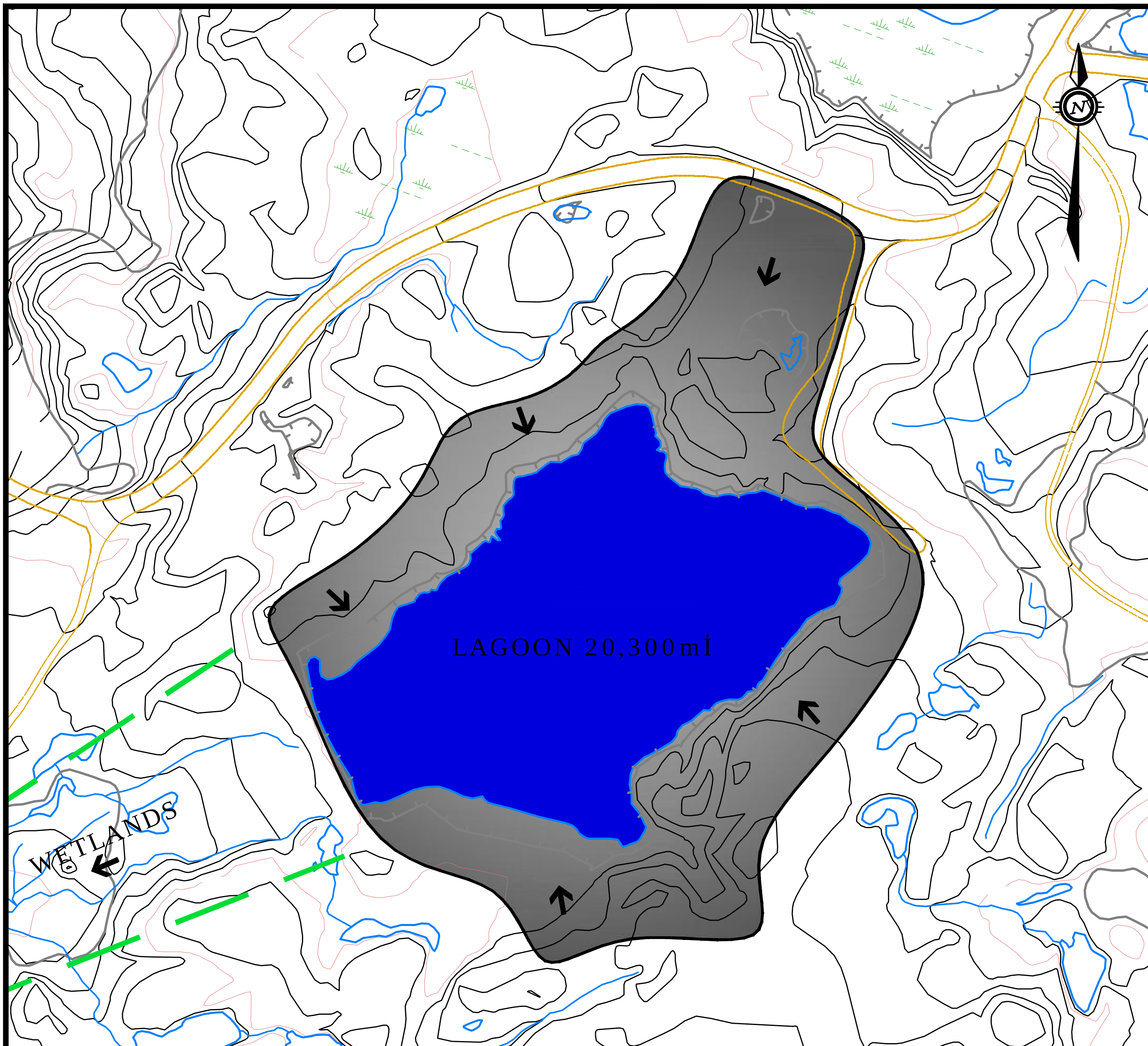
To calculate the flow generated from the watershed area, historic precipitation data was obtained from the Environment Canada website for Rankin Inlet which is considered sufficient to represent Whale Cove Climate Normals. The information is presented in Table 5.1 below.

Table 5.1 – Rankin Inlet Climate Normals

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Temperature (°C)													
Daily Average	-31.9	-30.1	-25	-16.3	-5.9	4.2	10.4	9.5	3.4	-5.3	-17.8	-26.7	-11
Daily Maximum	-28.3	-26.2	-21	-11.7	-2.4	7.9	14.9	13	5.8	-2.4	-13.9	-22.9	-7.3
Daily Minimum													
Precipitation (mm)													
Rainfall	0	0.1	0	1	7.4	25	39.5	57.3	39.2	11.9	0.1	0	181.5
Snowfall	67	93	129	136	115	49	0	3	46	231	209	119	1197
Precipitation	6.6	8.9	12.6	14.3	18.4	29.8	39.5	57.6	43.8	34.6	19.8	11.3	297.1

Using 0.2971 m of annual precipitation over the watershed area of 47,500 m^2, the volume of water that must be stored from the sewage lagoon watershed is 14,112 m^3 per year.

A portion of the total precipitation is taken up in evapotranspiration, the sum of the evaporation and plant transpiration from the land. Given the short summer season, and limited vegetation, it is recommended that evapotranspiration not be considered in sizing this facility.



LAGOON & WATERSHED
AREA = 47,500mļ
WATERSHED VOLUME
PRECIPITATION /YEAR 181.5mm RAIN
PRECIPITATION /YEAR 119.7cm SNOW
AVERAGE PRECIPITATION 0.3012m/YEAR
YEARLY WATERSHED VOLUME
14,300mį

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date MAY, 2012	TITLE: LAGOON WATERSHED	FIG 5.1
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5.1.3 Sewage Sludge Accumulation

The sewage lagoon must provide storage for solids (sludge) which accumulation in the sewage lagoon. There is very limited data regarding the operational behaviour of lagoons in arctic environments. Due to this lack of data, various assumptions, which are summarized as follows, were used to develop an estimate of sludge accumulation rates.

1. Individual suspended solids contribution is assumed to be 90 grams/capita/day. This is based upon the rate of suspended solids typically found in municipal sewage.
2. A complex set of mechanisms is responsible for removal of contaminants in a lagoon. These mechanisms include sedimentation, aerobic oxidation and anaerobic sludge volume reduction, which reduce the solids contribution from influent sewage. The biological processes also create solids in the forms of bio-mass (bio-solids). It has been assumed that the net outcome of the various biological processes that both create and reduce solids leads to a rate of sludge contribution at the same rate as the individual suspended solids contribution.
3. The sludge that accumulates in the lagoon is made up of sedimented suspended solids and a large amount of water. These solids remain undisturbed in the bottom of the lagoon for several years. This provides the opportunity for gravity thickening of these solids over a protracted period of time. For the purposes of these calculations it has been assumed that an ultimate sludge density of 10% will be achieved.

The preceding assumptions lead to an annual per capita rate of sludge accumulation of 32.85 kg/capita that represents a per capita volume of 0.329m^3.

The following table summarizes the rate of sludge accumulation anticipated in Whale Cove.

Table 5.2 – Sludge Accumulation Anticipated in Whale Cove

Year	Population	Sludge Generated	Sludge Accumulated
2012	**406**	134	134
2013	412	136	270
2014	419	138	408
2015	426	140	548
2016	433	142	690
2017	**439**	144	834
2018	446	147	981
2019	453	149	1130
2020	460	151	1281
2021	467	154	1435
2022	**472**	155	1590
2023	477	157	1747
2024	482	159	1906
2025	488	161	2067
2026	494	163	2230
2027	**500**	165	2395
2028	506	166	2561
2029	512	168	2729
2030	518	170	2899
2031	525	173	3072
2032	**532**	175	3247

The working volume of the proposed lagoon in Clyde River is 32,914 m^3. Ongoing sludge accumulation over the life of the facility would account for an additional storage requirement of 3,247 m^3. Therefore the total storage requirement is 36,161 m^3.

5.2 Lagoon System

As previously discussed, the rehabilitated lagoon system for the Hamlet must meet the storage requirements for the design horizon of 2032. As well it must address the regulatory concerns of maintaining the one metre freeboard on the earth berms and eliminating the seepage of effluent back towards the Hamlet.

As shown in section 5.1, the storage requirements for the lagoon includes 18,802 m^3 of storage for sewage and 14,112 m^3 of precipitation for at total of 32,914 m^3 of active storage. In addition to the active storage volume, the sewage lagoon will have to provide a dead zone for the collection and storage of sewage sludge of 3,274 m^3.

The traditional approach of providing a lined cell to prevent seepage from the sewage lagoon is not practical in the case of the Whale Cove facility as the facility is an existing lake with a watershed draining into it. The lining of a natural body of water is difficult is it has an irregular base which requires substantial levelling to provide a firm bearing surface for the liner. In addition, the liner requires substantial ballast due to buoyancy forces from water accumulating under the liner in a naturally occurring depression. For these reasons the lining of the existing facility was not considered as a viable option.

The second common approach for providing an impervious berm section in the Arctic is the use of a liner keyed into either bedrock or permafrost. In these systems the permafrost or bedrock in the bottom of the lagoon system provides an impervious layer throughout the bottom of the system with the liner providing the impervious barrier within the berms. The two impervious systems are tied together through keying the liner into the bedrock or permafrost.

The geotechnical investigation of the Whale Cover berm did not encounter bedrock within the depth of the borehole of 6 m and revealed the berm was in a thawed condition to a depth of over 5 m. As part of the geothermal investigation of the facility, it was concluded that the continuous seepage of water through the berm has driven the permafrost to a depth greater than normally anticipated within the Whale Cove area. Due to the lack of presence of bedrock and the extreme depth of permafrost in the existing berm, it was deemed impractical to utilize the system of liner keyed into the bedrock or permafrost as a method of making the existing berm impervious. Therefore this alternative was not pursued as an alternative for making the sewage lagoon berm impervious.

As the traditional method of creating an impervious sewage lagoon in the Arctic was deemed impractical or unfeasible for the Whale Cove sewage lagoon an innovative alternative was required. Working with Naviq Consulting (Naviq), **exp** investigated two alternatives to create the impervious surface. The first of these alternatives was to create an ice dam within the existing berm through the installation of thermosyphons. The extent of geothermal modelling detailed in the geothermal report authored by Naviq, entitled *Geothermal Modelling of Lagoon Containment Structures, Whale Cove, Nunavut* revealed that the constant seepage of effluent through the existing berm required a very close spacing of approximately 2 m for the vertical thermosyphons to generate the ice dam within the berm. Consultation with the Arctic Foundations Inc. (AFI) indicated that this would be a very expensive alternative as each vertical thermosyphon would require its own radiator. Recommendations from AFI indicated that horizontal thermosyphons would be more cost effective. Although the use of horizontal thermosyphons would be more cost effective, it would still require installation at a relatively close spacing. This alternative would also require the thermosyphons to be installed to depths that would be technically challenging given the available equipment.

Given the challenges and costs associated with installation of thermosyphons, **exp** and Naviq developed an alternative for a hybrid thermosyphon-liner system. This system will incorporate a liner installed on the back side or dry side of the slope excavated approximately to the top of the permafrost level. By installing the liner on the back side of the slope it will make installation of the liner easier and more cost effective. The issue of ensuring an impervious barrier between the liner and the permafrost will be addressed through the installation of a horizontal thermosyphon along the bottom of the liner key trench.

Thermodynamic modelling of the thermosyphon indicated that it should generate a frozen zone of approximately 2 m diameter. This artificially generated frozen zone would ensure an impervious system between the existing permafrost and the liner, thus ensuring an impervious berm and eliminating the seepage of sewage back towards the Hamlet.

To meet the requirements of storage volumes within the sewage lagoon it was determined the liquid level within the lagoon would have to be increased to 21.1 m. This would require increasing the height of the existing berms to provide a 1 m freeboard, plus the construction of three small berms as shown on Figure 5.2. The geotechnical investigation and visual inspection of the area indicated that all three new berms could utilize a system of a liner keyed into bedrock which is present at or near the surface of the proposed berms.

The existing berm, which outlets to the existing wetlands exhibits similar characteristics as the berm which is to the north east. The geotechnical investigation did not indicate bedrock at or near the surface or within the depth where it could be utilized to be incorporated into an impervious surface. Due to the continuous seepage of effluent through the berm the depth of permafrost is relatively deep, therefore the alternatives for rehabilitation of this berm include implementing a similar system of liner and horizontal thermosyphon or allowing the berm to remain as a pervious berm. As the sewage lagoon system has a substantial and very effective wetlands below, it is recommended that the existing berm be raised to provide the required storage with a 1 m freeboard, and the berm continue to be a pervious.

5.3 Decanting Methods

One of the significant challenges in the operation of a sewage lagoon in a northern location is the process of decanting or emptying the lagoon. The three methods that are commonly used are:

1. Seepage cell lagoon design
2. Provision of a discharge pipe through the berm
3. Pumping over the berm

5.3.1 Seepage Cell Design

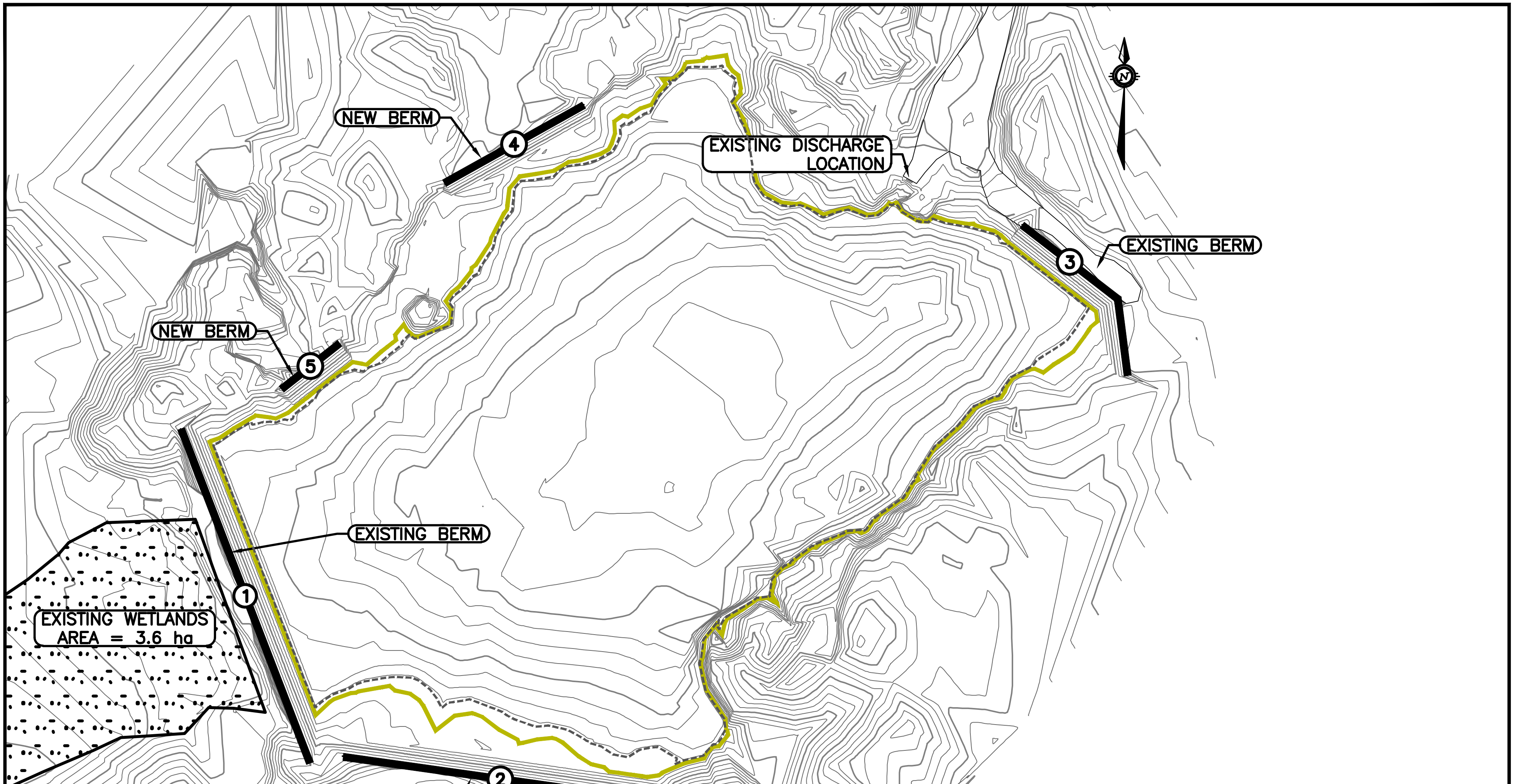
Many lagoons in the north depend on the permeability of their berms to allow the sewage to seep or leak out during the summer. This method does not allow for the control of the time or rate of decanting and therefore does not allow control over when sewage is released to the wetlands or ensure full decanting of the lagoon.

5.3.2 Discharge Pipe

For lagoons that are designed to be impermeable a decanting method must be installed. The installation of a discharge pipe and valve through the berm is common in southern locations with continuous discharge. In storage lagoons in northern locations, the discharge pipe is only used seasonally, and pipe and valve arrangement are installed through a frozen berm. This tends to require the pipe and valve have to be thawed prior to their use which has caused operational concerns, and in some instances has proven impossible.

5.3.3 Pumping

Pumping the effluent from the lagoon is the most operator demanding alternative, however is also the most dependable. It requires the pumps to be installed and removed each year, and during operation must be checked on a regular basis. It also has the added operational cost for fuel. The operation of a pump is a relatively dependable operation, and in the case of failure, a relatively easy system to repair or replace. Pumps also provide a very good method for controlling the time and rate of discharge which is important for lagoons which use a wetlands as a secondary or additional treatment.



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scale N.T.S	CLIENT: GOVERNMENT OF NUNAVUT	project no. OTT-00201369-A0
date MAY, 2012	TITLE: PROPOSED BERM LOCATION – AUG.	FIG 5.2
drawn by S.BUTLER		

Filename: p:\projects\civil engineering services\201000\ott-00201369-a0 - sewage lagoon wetland upgrade - whale cove - gn\reports\design brief\2012-05-29-fig 5.2-storagecalcs.dwg
Last Saved: 5/29/2012 11:46:44 AM
Last Plotted: 5/29/2012 11:47:34 AM Plotted by: butlers
Pen Table:: exp-64.ctb

5.3.4 Recommended Decanting Method

It is recommended that pumping be the method used for the decanting of the Whale Cove lagoon. The Whale Cove system includes a wetlands treatment system with the lagoons providing retention and treatment and the wetlands additional treatment or polishing. The performance of the lagoon is dependent on retention time and the wetlands performance is dependent on the time and rate of discharge. Seepage cell construction does not allow for sufficient control over the time and rate of discharge, and therefore are not suitable for this application. The installation of piped discharges poses operational challenges, primarily thawing of the pipe at the time of discharge. They are also more prone to freeze and may not be recoverable which would result in a costly repair or abandonment of the system. Although pumping is the most operator dependent, it provides the best control over the release time and release rate, and is easiest to repair or replace as the system is accessible.

5.4 Sludge Management

Effluent quality will guide when a sludge management program is implemented. Monitoring of the effluent from the lagoon will indicate when the performance of the lagoon starts to degrade. Degradation of the performance of a lagoon is normally caused by sludge accumulation and will be the indicator to desludge the lagoon.

Prior to disposal, the sludge must be tested to ensure the disposal method chosen is safe and environmentally responsible. Sludge removed from the lagoons can be disposed of in a separate cell constructed at the landfill site. The sludge will be covered with granular material and allowed to freeze.

6 Sewage Treatment

The proposed Whale Cove Sewage Treatment Facility will be comprised of a storage lagoon and a vegetated filterstrip wetlands. The treated sewage will be released over a period of 4 weeks late in the summer for further treatment in a downstream wetland. It is desirable that discharge to the wetlands occur prior to the end of warmer weather to maximize the opportunity for treatment.

6.1 Influent Characteristics

The characteristics of sewage generated in a community are dependent on the type of installation and sanitary facilities within the community. The Hamlet's water and sewage system is comprised of holding tanks and a trucked delivery and collection system. The waste generated from this arrangement is considered to be "Moderately Diluted Wastewater", as per the Cold Climate Utility Manual. Table 6.1 - Characteristics of Basic Wastewater Categories is an excerpt from the Cold Climate Utilities Manual, summarizing the characteristics of moderately diluted wastewater.

Table 6.1 – Characteristics of Wastewater

Parameter	Units	Moderately Diluted
BOD_5	mg/L	460
COD	mg/L	1000
Suspended Solids	mg/L	490

6.2 Sewage Lagoon

There are several removal mechanisms within a sewage lagoon, including sedimentation and bio-chemical oxidation. Sedimentation will remove BOD_5 and suspended solids through settling. An annual detention lagoon provides a good opportunity for sedimentation due to the large volume and long detention time. Sedimentation provides typical removals of 35% and 65% of BOD_5 and Suspended Solids respectively in a short time frame (Ontario MOE Guidelines for the Design of Sewage Treatment Works, July 1984, see excerpt in Appendix A). The remaining BOD_5 and suspended solids is in dissolved or colloidal form, and some other removal mechanism must be applied. The natural processes within the lagoon will result in bio-chemical removal of the dissolved and colloidal fraction. The BOD_5 reduction from a lagoon can be predicted using the following first order relationship.

$$C_e = C_i e^{-Kt}$$

Where:

C_e = Effluent concentration (mg/L)

C_1 =Influent concentration (mg/L)

K = BOD_5 removal rate constant (day^{-1})

t = Residence time in lagoon (days)

The rate constant is temperature dependent. The impact of temperature is estimated using the following relationship:

$$K = K_{20}\Theta^{T-20}$$

Where:

K = Rate constant at stipulated temperature (day^{-1})

K_{20} = Rate constant at 20˚C (day^{-1})

Θ = Temperature activity coefficient

T = Temperature (˚C)

The temperature activity coefficient (Θ) for various sewage treatment processes falls in the range of 1.00 to 1.10, with higher values indicating greater sensitivity to changing temperature. Values in the range of 1.04 to 1.10 are reported as typical for aerated lagoons. The lagoon under consideration is a facultative lagoon. A value of 1.08 has been assumed for this coefficient.

The BOD_5 removal rate coefficient for lagoons typically falls in the range of 0.25 to 0.50. Operating conditions for lagoons in harsh climates vary from those in Southern Canada. Specifically, they experience long periods of low activity due to low temperatures and ice cover. The sewage treated has higher than typical strength. There is limited data regarding the performance of lagoons in harsh climates. For these reasons, it was felt appropriate to use a conservative value for the removal rate coefficient. For this analysis a value of 0.10 has been assumed.

Based on the influent characteristics reported in Section 6.1, the influent sewage strength has been assumed to be 460 mg/L BOD_5. Table 6.2 summarizes the treatment levels based on the assumptions stated above for various treatment times, different primary removal rates and a range of temperatures:

Table 6.2 - Effluent BOD5 Following Bio-Chemical Oxidation

Treatment Time (Days)	Temperatures		
	1°C	2°C	4°C
30	149	141	125
45	105	97	80
60	74	67	52

Based upon the above, 45 days of treatment will provide sufficient treatment to meet the requirements of the Hamlet's water licence for the levels of BOD_5.

This initial removal of suspended solids results in the removal of a portion of the BOD_5. The remaining contaminants are in soluble and colloidal forms. The colloidal materials represent the remaining suspended solids. Subsequent to initial sedimentation, removal is achieved by bio-chemical oxidation. The colloidal fraction is converted into various gasses and microbial cells. The resulting microbial cells settle, further reducing suspended solids through the removal of the colloidal fraction. Typically, suspended solids are reduced to a level comparable to the BOD_5 through the various biological removal mechanisms. This is evidenced by the performance that is typical of lagoons in Southern Canada where effluent quality for seasonal discharge lagoons is reported as 25 mg/L BOD_5 and 30 mg/L suspended solids (Ontario MOE Guidelines for the Design of Sewage Treatment Works, July 1984). For the purpose of estimating the levels of suspended solids at the time of release, the levels will be assumed to be 20% higher than the levels of BOD_5 as per the general performance of lagoons in Southern Canada.

The quality of the effluent released from the sewage lagoon is summarized in Table 6.3 assuming a 45 day treatment period with an average temperature of 2°C.

Table 6.3 – Effluent Quality from the Lagoon

Parameter	Units	Effluent from Lagoon
BOD_5	mg/L	97
TSS	mg/L	172* 116**

*Based solely on reductions from sedimentation
** Includes removal of colloidal fraction of TSS through bio-chemical oxidation

6.3 Wetlands Treatment

Treatment of raw sewage in the new sewage lagoon in Whale Cove will be combined with the utilization of a vegetated filterstrip wetland as a final polishing step. The vegetated area between the lagoon and shoreline will be incorporated into the sewage treatment process. The filterstrip wetland area is 3.6 hectares in size with an average slope of 2.7 %. Treatment of the pre-treated sewage in the filterstrip wetland area will include removal of TSS, BOD, nutrients and pathogens. A detailed description and estimates of treatment of the Whale Cove Wetlands is provided in the Wetlands Assessment report prepared under a separate cover as part of this project.

Sampling of the wetlands influent and effluent showed a BOD_5 removal rate between 82-99%. For the purpose of this analysis a rate of 80% removal of BOD_5 will be assumed.

Sampling of the wetlands influent and effluent showed a TSS removal rate between 93-97%. For the purpose of this analysis a rate of 90% removal of TSS will be assumed.

Pathogen removal in the filterstrip wetland is expected to be near 100% as pathogen survival is very limited outside of host organisms.

Nitrogen and phosphate reduction is estimated to be around 80%. Temperature fluctuations are not expected to change reduction of contaminants or nutrients significantly.

The estimated performance of the filterstrip wetland is shown in Table 6.4.

Table 6.4 – Effluent Quality from the Wetlands

Parameter	Units	Influent from Lagoon	Removal	Effluent from Wetlands
BOD_5	mg/L	97	80%	19
TSS	mg/L	172* 116**	90%	17* 12**

*Based solely on reductions from sedimentation in the lagoon
** Includes removal of colloidal fraction of TSS through bio-chemical oxidation in the lagoon

The filterstrip wetland, which will be receiving pre-treated sewage from the newly constructed sewage lagoon, is expected to successfully remove BOD, TSS, pathogens and nitrogen compounds and phosphate before the wastewater enters the ocean. Existing native vegetation and microorganisms will be the main contributors to the reduction in contaminants and nutrients.

6.4 Sewage System Treatment Summary

The predicted level of treatment provided by the proposed sewage treatment system meets or exceeds the requirements of the Hamlet's water licence. Table 6.5 summarizes the levels of treatment predicted from the sewage treatment system in comparison to the water licence criteria.

Table 6.5 – Summary of Treatment Levels

Parameter	Units	Criteria	Influent	Effluent from Lagoon	Effluent from Wetland†
BOD_5	mg/L	100	460	97	19
TSS	mg/L	120	490	172* 116**	17* 12**
FC	#/100ml	1×10^6	1×10^7	1×10^6	<100,000

† Based on average treatment levels – as per the Wetlands Assessment report
* Based solely on reductions from sedimentation
** Includes removal of colloidal fraction of TSS through bio-chemical oxidation

7 Monitoring and Compliance Points

7.1 Effluent Monitoring and Compliance

Monitoring the operation of the system will be accomplished through the establishment of three sampling points, one of which will also be the compliance point. Sampling will provide information regarding the performance of the system and help identify any degradation to the treatment provided. Sampling points will be established at the truck discharge points, pump discharge, and at the end of the wetlands. It is purposed that the wetlands be integrated into the treatment facility, therefore the compliance point will be relocated from the discharge point of the lagoon to the sampling point at the end of the wetlands. Table 7.1 provides coordinates of the sampling points, which will be confirmed upon construction by hand held GPS units. A sampling protocol shall be as summarized in Table 7.2.

Table 7.1 – Sampling Points Coordinates

SNP#	Description	Latitude	Longitude	Comment
1	Truck Discharge	62° 10’ 07.96”	92° 35’ 14.51”	
2	Lagoon Pump Discharge	62° 10’ 04.23”	92° 35’ 28.94”	
3	End of Wetlands	62° 09’ 56.70”	92° 35’ 02.04”	Compliance Point

Table 7.2 – Sampling Frequency

SNP#	Description	Frequency
1	Truck Discharge	Yearly
2	Lagoon Pump Discharge	Twice Yearly – start and end decanting
3	End of Wetlands	Twice Yearly – start and end decanting

8 Granular Supply

During the site visit of August 2011, **exp** staff visited several existing or abandoned granular supplies within close proximity to the Hamlet as identified by Hamlet staff. Based upon the site visit it was concluded that available granular material is very limited and as such adds a high value to the Hamlet. It was also concluded that it would be extremely difficult to extract or obtain sufficient quantities of granular material from the sites identified without greatly depleting the available material for the Hamlet's municipal needs. Therefore it is recommended that an alternative of pouring material be undertaken.

In addition as part of the site visit in August 2011, **exp** staff visited the site of an existing quarry adjacent to the Hamlet's solid waste disposal site. This site appears to have sufficient available material which could be quarried and crushed to be used for the expansion of the Hamlet's wastewater disposal facility. It is anticipated that a quarry permit would have to be obtained by the Hamlet from the GN to facilitate access to this site.

9 Cost Estimate

A Class C capital cost estimate has been prepared for the Whale Cove wastewater treatment facility. The works included in the cost estimate include the following:

- Expansion of the existing berm to the east of the facility
- Expansion of the existing berm outletting to the wetlands
- Construction of three new berms to facilitate increased capacity for the sewage lagoon
- Improvements to the truck discharge area
- Development of a decanting system
- Creation of sludge handling cell

A detailed breakdown of the costs is included in Appendix B and includes a 20% contingency allowance. The estimated costs for the construction of the Whale Cove wastewater treatment facility, including the works listed above is $1,500,000.

10 Conclusions and Recommendations

The following summarizes the conclusions and recommendations put forth in this report for the preliminary design for the Hamlet's wastewater treatment facility.

1. The existing wastewater treatment facility for the Hamlet will not meet the long term requirements of the Hamlet.
2. The existing wastewater treatment facility for the Hamlet has regulatory issues, including sewage seeping through the north east berm and draining back towards the Hamlet, as well as inadequate freeboard provided on the water retaining structures within the sewage lagoon.
3. The rehabilitated facility must not only meet the long term requirements for the Hamlet but must address the two regulatory issues.
4. The design horizon for the project is twenty years.
5. The population projection for the year 2032, the design horizon for the project is 532 persons.
6. The sewage generation rate for the population at the design horizon is 105.5 l/c/d.
7. A review of potential alternate sites as identified by the Hamlet did not identify any site which would be preferable to the existing site.
8. The Hamlet recommendation was for the expansion and rehabilitation of the existing facility as opposed to moving the facility to an alternate site.
9. The existing facility is a natural body of water in which outlets have been dammed-up to provide an increased storage capacity.
10. As the facility is a natural body of water there is a portion of land adjacent to the facility that drains into the sewage lagoon. Any expanded and rehabilitated facility will have to also contain surface runoff. It is proposed that the facility will require eleven months storage based on a thirty day decanting period.
11. Sewage generated over the eleven month period for the design horizon population of 532 at a sewage generation rate of 105.5 l/c/d is 18,802 m^3.
12. It is estimated that the Hamlet's sewage lagoon will also be required to retain 14,112 m^3 of precipitation runoff based upon a total watershed area of 47,500 m^2 and an annual precipitation rate of 297.1 cm per year. In addition the facility will need to store solids in the form of sludge. It is estimated that a total of 3,247 m^3 of sludge will be accumulated over the twenty year life of the facility.
13. The rehabilitated facility will be required to provide a minimum of 36,161 m^3 of storage to allow for sewage generation, precipitation and sludge storage.
14. Due to the topography of the existing facility, and its location in a natural occurring body of water, it is concluded that the use of traditionally fully lined sewage lagoon system is impractical due to the preparatory work that would be required, and the efforts to ballast the liner against uplift forces from buoyancy forces generated below the liner.
15. Due to the geotechnical conditions within the locations of the existing berms, it was determined that it was impractical to use a liner system in the berms keyed into permafrost from bedrock to form the impervious surface lagoon.

16. Based on thermal dynamic modelling of the earth berms, a system including a liner in the back slope of the berm to the north east of the lagoon with a thermal siphon located along the base of the liner would create an impervious barricade at this location. It is proposed that the berm to the south west be maintained as a permeable berm as there exists a large wetlands below it which sampling has indicated that it is very effective in treating any effluent that seeps through the berm. The south west berm would be increased to provide a minimum 1m freeboard as required. The area to the south west of the sewage lagoon will continue to act as a filterstrip wetlands and will provide polishing to the effluent prior to release to the environment. An environmental assessment undertaken concluded that although there is potential for negative impacts to the project either due to construction or operations, these negative impacts can be mitigated through proper design and construction procedures. The project overall provides a benefit primarily through the improved treatment of the Hamlet's sewage. It is recommended that effluent monitoring be undertaken at the discharge point to the sewage lagoon and at the end of the wetlands, with a compliance point located at the end of the wetlands. This means that the capital costs of construction of the new facility will be approximately $1,500,000.
17. The estimated final quality of the effluent at the compliance point, i.e. the end of the wetlands meets or exceeds the effluent requirements of 120 mg/L BOD_5 and 100 mg/L TSS and faecal coliforms of less than 100,000.

Appendix A – Excerpt from Ontario MOE Guidelines for the Design of Sewage Treatment Works, July 1984,

With each new plant, or major expansion of an existing plant, the designer is, therefore, requested to economically compare the waste treatment and sludge treatment alternatives before finalizing the overall process.

Primary sedimentation treatment offers low cost suspended solids and BOD_5 removal, especially in cases where the raw sewage contains a high proportion of settleable solids, as is often the case with sewage containing significant food processing, or similar wastes.

As shown in Table 6.1, primary sedimentation tanks used for phosphorus precipitation with normal strength municipal wastewaters exhibit BOD_5 and suspended solids removals of 65 and 85 per cent, respectively. Without chemical addition for phosphorus removal, the BOD_5 and suspended solids reductions would be 35 and 65 per cent, respectively. With secondary treatment plants, the use of the secondary clarifiers for phosphorus removal has been the most common approach. This has been at least partially due to the reduced chemical requirements when the secondary units are used for phosphorus removal. In view of the potential for increased BOD_5 and suspended solids removals when the primaries are used for phosphorus removal, there may be circumstances when consideration should be given to their use rather than the secondaries for phosphorus removal. Such circumstances might include the following:

- where economic evaluation shows the process to be more cost effective despite the higher chemical costs;

TABLE 6.1

SEWAGE TREATMENT PROCESSES AND TYPICAL EFFLUENT QUALITY

PROCESS	EFFLUENT PARAMETERS (mg/L)			
	TOTAL BOD_5	SS	TOTAL PHOSPHORUS (as P)	FREE AMMONIA (as N)
PRIMARY				
- Without P Removal	110	70	5.0	20
- With P Removal	90	30	1.0	20
CONVENTIONAL A.S.				
- Without P Removal	15	15	3.5	17
- With P Removal	15	15	1.0	17
- With P Removal And Filtration	10	5	0.3	17
- With Nitrification	15	15	3.5	3.0
CONTACT STABILIZATION				
- Without P Removal	20	20	3.5	17
- With P Removal	20	20	1.0	17
EXTENDED AERATION				
- Without P Removal	15	15	3.5	3.0
- With P Removal	15	15	1.0	3.0
- With P Removal And Filtration	5	5	0.3	3.0
CONTINUOUS DISCHARGE LAGOON				
- Without P Removal	25	30	6.0	
- With P Removal	25	30	1.0	
SEASONAL RETENTION LAGOON				
- Without P Removal	25	30	6.0	
- With P Removal By Batch Chemical Dosage	15	20	1.0/0.5	
- With P Removal By Continuous Chemical Dosage	25	30	1.0	
PRE-AERATION LAGOON (Aerobic - Facultative Type)				
- Without P Removal With 4-5 Days Retention Time	60	100	6.0	

NOTE :

1. The above values are based on typical raw sewage with Total BOD_5 = 170 mg/L, Soluble BOD_5 = 50%, SS = 200 mg/L, P = 7 mg/L, NH_4^+ = 20 mg/L.

Appendix B – Cost Estimate

ITEM	DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	TOTAL PRICE
1	**Mobilization / Demobilization Phase 1**	L.S.	1	$600,000.00	$600,000.00
2	**a)** Supply and deliver silt fence including wood stake	m	665	$4.00	$2,660.00
	b) Installation of silt fence including wood stake and trenching	m	665	$4.00	$2,660.00
3	Supply,deliver and place granular material to construct new berms	cu.m	1500	$65.00	$97,500.00
4	Supply,deliver and place granular material to stabilize the existing berms	cu.m	400	$65.00	$26,000.00
5	**a)** Supply and deliver liner for proposed berm	m.sq.	1190	$14.00	$16,660.00
	b) Installation of liner for proposed lagoon including sand bedding, sand cover, and anchor trench	m.sq.	1190	$30.00	$35,700.00
6	**a)** Supply and deliver materials for spillway structure	ea	1	$4,500.00	$4,500.00
	b) Installation of spillway structure	ea	1	$10,000.00	$10,000.00
7	Supply**,** deliver and place granular material to construct new access road	m.sq.	370	$65.00	$24,050.00
8	Supply**,** deliver and place granular material to construct truck turning pad	cu. m	1510	$65.00	$98,150.00
9	Supply, deliver and place 150mm of granular A material to top road and turn for truck discharge point	sq.m.	1201	$65.00	$78,065.00
10	**a)** Supply and deliver piping for inlet structure including 200 dia. HDPE series 100 pipe, concrete block and pipe support	ea	1	$8,000.00	$8,000.00
	b) Installation of piping for inlet structure	ea	1	$5,000.00	$5,000.00
11	**a)** Supply and deliver piping for outlet structure including 150 dia. HDPE series 100 pipe and wood support	ea	1	$4,000.00	$4,000.00
	b) Installation of piping for outlet structure	ea	1	$3,000.00	$3,000.00
12	**a)** Supply and deliver piping for outlet structure including 300 dia. HDPE series 100 pipe c/w concrete block	m	65	$160.00	$10,400.00
	b) Installation of piping for outlet structure	m	65	$80.00	$5,200.00
13	**a)** Supply and deliver 600mm dia. nestable pipe including pressure treated wood post and lag bolt	m	50	$220.00	$11,000.00
	b) Installation of 600mm dia. nestable pipe including pressure treated wood post and lag bolt	m	50	$110.00	$5,500.00
14	**a)** Supply and deliver truck discharge structures, including erosion protection and bollards	ea	1	$40,000.00	$40,000.00
	b) Installation of truck discharge structures, including erosion protection and bollards	ea	1	$25,000.00	$25,000.00
15	Supply, deliver and install boulder barriers	ea	36	$50.00	$1,800.00

ITEM	DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	TOTAL PRICE
16	**a)** Supply and deliver horizontal thermosyphons	ea	2	$10,000.00	$20,000.00
	b) Installation of horizontal thermosyphons	ea	2	$2,500.00	$5,000.00
17	**a)** Supply and deliver thermistor casing c/w data logger	ea	4	$7,000.00	$28,000.00
	b) Installation of thermistor c/w data logger	ea	4	$2,500.00	$10,000.00
18	**a)** Supply and deliver seepage monitoring tubes	ea	4	$500.00	$2,000.00
	b) Installation of seepage monitoring tubes	ea	4	$1,500.00	$6,000.00
19	**a)** Supply and deliver signage	ea	8	$350.00	$2,800.00
	b) Installation of signage	ea	8	$200.00	$1,600.00
20	**a)** Supply and deliver pump including engine, wheel kit 150mm dia. Hose, pressure gauge, ball valve, flange and coupling	ea	1	$75,000.00	$75,000.00
	b) Installation of pump including engine, wheel kit, 150mm dia. Hose, pressure gauge, ball valve, flange and coupling	ea	1	$4,500.00	$4,500.00
21	**a)** Supply and deliver 1.2m x 2.4m Project Information Sign	ea	1	$2,000.00	$2,000.00
	b) Installation and Maintain 1.2m x 2.4m Project Information Sign	ea	1	$750.00	$750.00
22	**a)** Supply and deliver sampling well	ea	1	$500.00	$500.00
	b) Installation of sampling well	ea	1	$750.00	$750.00

SUBTOTAL	**$1,273,745.00**
20% CONTINGENCY	**$254,749.00**
TOTAL	**$1,528,494.00**