Naujaat Sewage Lagoon Upgrade

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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 disposal facility and complete the detail planning and design for the Sewage Lagoon Upgrade, for the Hamlet of Naujaat (Hamlet), Nunavut in 2013. Currently, this project is being reviewed and updated for a design in 2020.

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 with a proper retention cell complete with liner. Nunavut Water Board has identified conditions to be addressed in Hamlet of Naujaat license number 3BM-REP1520.

This report highlights the key updates to the project-based reports issued by the Dalhousie Centre for Water Resources Studies group in Nova Scotia. In addition to the report, population projections have been updated, along with new sizing parameters being assessed.

1.1 Background

The Hamlet utilizes a sewage disposal facility located approximately 400 meters from the northeast edge of the community as shown on Figure 2-1 - Location Plan. The sewage disposal facility, which is located at the old solid waste disposal site, consists of a simple truck offload discharge area. Wastewater is directed to a natural wetland area. The wastewater proceeds downstream through the wetland along a 1,400m flow path, passing through a series of wetlands and surface water bodies, prior to entering Hudson Bay. This facility was referenced as the licensed sewage discharge location in NWB Water License No. 3BM-REP1520. The license is in effect until April 8th, 2020. This license indicates maximum effluent parameters, which included BOD5 of 80 mg/L and suspended solids of 70 mg/L. The GN position based on the research completed by Dalhousie University and ongoing discussions with Environment and Climate Change Canada (ECCC) regarding wastewater regulations in the north, is that effluent quality limits for a lagoon/wetland system discharging into a well flushed receiving environment should be 100mg/L $cBOD_5$ and 120mg/L TSS.The Naujaat sewage management system was the subject of a report prepared by Ferguson, Simek and Clark (FSC) in March 2002. This study reports that references are made to this sewage discharge point in various reports prepared by Dillon, DPW (GNWT) and UMA over the period 1984 to 1994. The study examined the treatment performance of this system and, based upon sampling by Dillon in 1998, reported the following performance.

Table 2-1: System Treatment Performance

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

FSC conducted a review of wetland performance based upon hydraulic and organic loadings and concluded that the hydraulic loading fell within the recommended range. It was noted that organic load may exceed recommended values during the spring, but that NWB effluent requirements should be met for a further 20 years. It was recommended that the wetland be monitored for indications of erosion, channeling or anaerobic conditions.

1.2 Regulatory Issues

The sewage treatment facility is subject to existing Water License Number 3BM-REP1520 dated April 9th, 2015. Under this license, the NWB has identified conditions to be addressed in the Hamlet of Naujaat include:

- Part D stipulates effluent performance parameters for the facility.
- The effluent parameters are to be measured at monitoring site REP-6, which is defined as the final discharge point of the sewage system. A precise location for this station is not provided.
- A freeboard of at least 1.0 meter, 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.
- The Sewage Disposal Facility is to be maintained and operated, to the satisfaction of an Inspector in such a manner as to prevent structural failure.

The INAC Water Use Inspection Report for 2010 provides specific comments regarding the sewage treatment system in Naujaat. It is noted that discharge quality and seepages are considered to be unacceptable. In terms of non-compliance, the comment was made that “Sewage is released directly into the environment and runs to the ocean through a valley in a melt water flow channel.” It is also noted that there is no lagoon in the community.

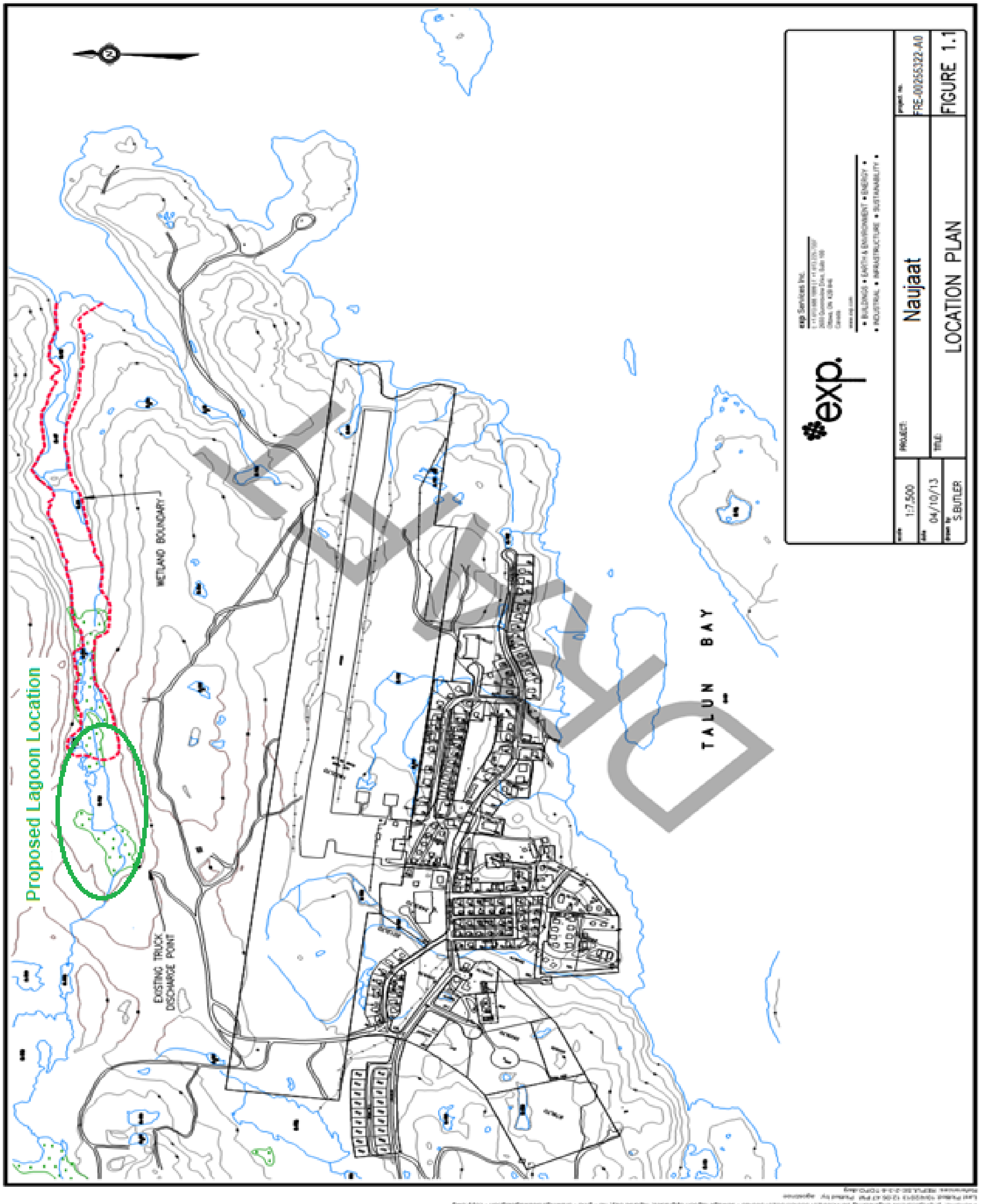

Figure 2-1: Location Plan

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. Update EXP 2013 design of the Sewage Holding Cell.
2. The design shall indicate the estimated quantity based on the specifications for different applications (embankment, Sub-base, Base, Surface and Concrete Aggregate).
3. Drawings & O&M manuals to meet NWB requirements.
4. Prepare Construction Documentation and Specifications and Class A Estimate

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 license. 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, ending in 2040.

2.2 Population

The population projections for this project were taken from the Census 2016 for Naujaat and the Nunavut Bureau of Statistics. Since these statistics do not extend to 2040, the population numbers were extrapolated using the average percent increase used.

2.3 Sewage Generation

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. For communities that make use of trucked water and sewage services, the base water consumption rate is assumed to be 90 liters per capita day (L/c/d). In addition, an allowance must be made for non-residential water uses such as commercial, institutional and industrial demands. The total community water use per capita is estimated using the following formula from the "Good Engineering Practice for Northern Water and Sewer Systems".

PCC = RWU (1.0+0.00023 x Population) Where:

PCC is per capita consumption, and

RWU is the residential water consumption (90 L/c/d)

Table 2-1: Anticipated Sewage Generation over the Project Planning Horizon

Year	Population	PPC (L/cap/day)	Daily Generation (L/day)	Annual Generation (m^3)
2019	1,160	114.0	132,227	48,263
2024	1,302	117.0	152,287	55,585
2029	1,462	120.3	175,806	64,169
2034	1,641	124.0	203,471	74,267
2040	1,886	129.0	243,370	88,830

2.4 Regulatory Requirements

The GN position based on the research completed by Dalhousie University and ongoing discussions with Environment and Climate Change Canada (ECCC) regarding wastewater regulations in the north, is that effluent quality limits for a lagoon/wetland system discharging into a well flushed receiving environment should be **100mg/L cBOD$_5$ and 120mg/L TSS**. The Naujaat lagoon and wetlands area will be designed to achieve effluent quality below these limits. The effluent quality standards are summarized in Table 2-2.

Table 2-2 Effluent Quality Standards

Parameters	Maximum Concentration
BOD5	100 mg/L
Total suspended solids (TSS)	120 mg/L
Faecal coliforms	1 x 10^6 CFU/100 mL
Oil and grease	No visible sheen
pH	Between 6 and 9

2.5 Geotechnical Investigation

The field work for the geotechnical investigation was performed in early October, 2012. The scope of this field program included the drilling of 7 boreholes to depths of 1.2 to 6 meters, and the installation of thermistors in 2 boreholes. At 6 of the 7 boreholes silt, sand and gravel where found at depths of 1.2 to 4.4 meters. Two of the boreholes terminated in this stratum. Granite bedrock was cored at 5 of the 7 boreholes. Based on the observed conditions at the boreholes it has been concluded that the proposed lagoon site is largely underlain by permeable soils. This also indicates that the materials that are available for berm construction will be permeable. Thus, some method that avoids seepage through the berms must be identified. The following alternatives were considered.

- Synthetic liner in the berms, and keyed into the permafrost.
- Maintaining a frozen core within the berms.
- Fully lining the lagoon with a synthetic liner.

Successful design of the alternative of a synthetic liner in the berms requires definition of the long-term extent of thaw below the lagoon and within the berms. This indicates the need for a geothermal analysis. The alternative of maintenance of a frozen core within the berms requires a geothermal assessment to confirm the viability and implications of this alternative. A fully lined lagoon will provide an effective barrier against seepage, but the risk of uplift due to hydrostatic pressure must be recognized. Measures that should be considered, if a full liner is selected, include an under-drain system.

Slope stability for the lagoon berms has been evaluated. The recommended berm slopes are as follows:

- For the upstream face (lagoon internal face) 3H:1V
- For the downstream face (external face of berm) 4H:1V

The geotechnical investigation indicated the potential for thaw settlement. The potential for this settlement must be incorporated into the design of any synthetic liners, as there is a risk of tear for the liner if appropriate measures are not incorporated. Thaw settlement may have ongoing operating implications, in that occasional reshaping may be required over the lagoon service life.

In summary, an assessment of local soils indicated that the matter of seepage through the permeable native materials must be considered, and measures must be designed to manage this seepage potential. The need for a geothermal analysis is indicated.

2.6 Geothermal Assessment

A geothermal assessment was conducted by Naviq Consulting Inc. The following is excerpted from the recommendations of that study.

- Berms that incorporate a frozen core approach may not be feasible. An impermeable barrier system is recommended.
- The liner or barrier should ideally be located on the upstream face of the berm. The liner should be installed to un-weathered bedrock, which is located at depths of 3 to 5 meters.

- As an alternative to installation of the liner to sound bedrock, thermosyphons can be used. These thermosyphons would be placed horizontally at a depth of 2 meters below existing grade.
- Advice is provided regarding the extent of the thermosyphon system required along the north perimeter of the lagoon to avoid leakage along the interface between the berm and the existing slopes.
- There is the potential for the placement of the liner in the downstream face of the berms. The downstream toe of the liner should be placed at a depth of 3 to 2.5 meters in undisturbed soil. Issues, such as seepage pressure must be considered, should this concept be selected.
- The selection of liners materials requires careful consideration.
- The geothermal analysis has not considered the impact of structures such as culverts and access manholes. Careful attention should be directed towards such structures, should they be incorporated into the design.

In summary, the geotechnical investigation has identified the issue of permeable soils that must be considered during the design of the lagoon berms. The geothermal assessment provides advice regarding liners, as a method of avoiding seepage of the lagoon contents, and guidance regarding actions required to render the liner resistant against leakage of the lagoon contents.

2.7 Wetlands Assessment

An assessment of the condition and performance of the existing wetland has been conducted. The assessment report also provides information gathered from a literature review and comments regarding potential performance. The assessment reported that phytoremediation is occurring in the wetland, but it is also reported that indications of overload of organic material were noted during the September 2012 site visits. The literature review indicates the potential for removal of up to 90% of suspended solids and BOD is achievable with a wetland.

In summary, the existing wetland appears to be removing contaminants despite overload of organic materials. Provision of a sewage lagoon upstream of the wetland is recommended as a method to reduce contaminants and pathogens released to the wetland. The literature review has provided some guidance regarding the level of performance that can be realized within a wetland.

2.8 Environmental Assessment

A Screening Level Environmental Assessment (SLEA) was conducted, as required under the terms of the Canadian Environmental Assessment Act. This assessment was conducted to identify and document the environmental effects of the proposed project, and to determine the need to mitigate the impacts of this proposal. In general, it was concluded that the extent of existing disturbance at the proposed site was considered moderate and that upgrade to the sewage system is not expected to significantly alter the existing environment. The SLEA determined that the project will have net positive effects for the community. No significant long-term effects are anticipated. Most effects are associated with construction, and these can be managed using appropriate mitigation techniques.

3 Sewage Treatment System

3.1 General

The proposed Naujaat Sewage Treatment Facility will be comprised of a storage lagoon followed by a wetland. It is intended that the wetland remain the primary treatment method with the sewage lagoon providing a level of pretreatment as well as retention. The purpose of the sewage lagoon is to retain the sewage until the appropriate time for release to the wetland and to remove the majority of the solids from the effluent prior to its release to the wetland. It is desirable that discharge to the wetland occur during that part of the year when warmer weather prevails to maximize the opportunity for treatment.

3.2 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. To estimate influent CBOD and TSS concentrations, per capita loadings were applied to the design population within the typical range listed in the Design Guidelines for Sewage Works 2008 published by the Ontario Ministry of Environment.

Table 3-1: Characteristics of Influent Wastewater

Parameter	Influent Concentration (mg/L)	Per Capita Loading (g/day)
BOD_5	460	80
Suspended Solids	490	90

The above values are comparable to those assumed in previous assessments, including FSC 2002.

3.3 Lagoon

3.3.1 Function

The site for the proposed lagoon is tightly constrained by rising topography and the exiting solid waste site to the south, as well as the downstream wetland. Encroachment of the lagoon into the wetland is not desirable due to the disruption of this area. Challenging geotechnical conditions are anticipated within the wetland area. The site extent that is available for construction of the proposed lagoon is depicted in Figure 2-1. The proposed sewage lagoon must meet the following requirements:

- Provide sufficient capacity to meet the sewage storage requirements
- Provide for accumulated sludge storage, and
- Maintain a 1-meter freeboard

The wetland assessment of September 2012 observed that wetland was being overloaded due to the direct discharge of sewage. It was also observed that the wetland was not providing the required removal of grease and oil. These points are also supported by the “Wetland Treatment Area Study in Naujaat, Nunavut” prepared by Dalhousie University Centre of Water Resources Studies. Thus, the primary role of the lagoon will be the reduction of the loading upon the wetland. The proposed lagoon will provide the following functions:

- Over-winter storage of sewage
- Suspended solids reduction, prior to discharge to the wetland
- Reduction of organic loading into the wetland
- Grease and oil reduction, prior to discharge to the wetland
- Storage of accumulated sludge

In addition to the sewage related functions, it must be recognized that there is a small watershed area that drains towards the proposed lagoon. Allowance must be provided for runoff arising from this area. The tributary area is 46,720 m^2 and can be seen in the following drawing, Figure 3-1.

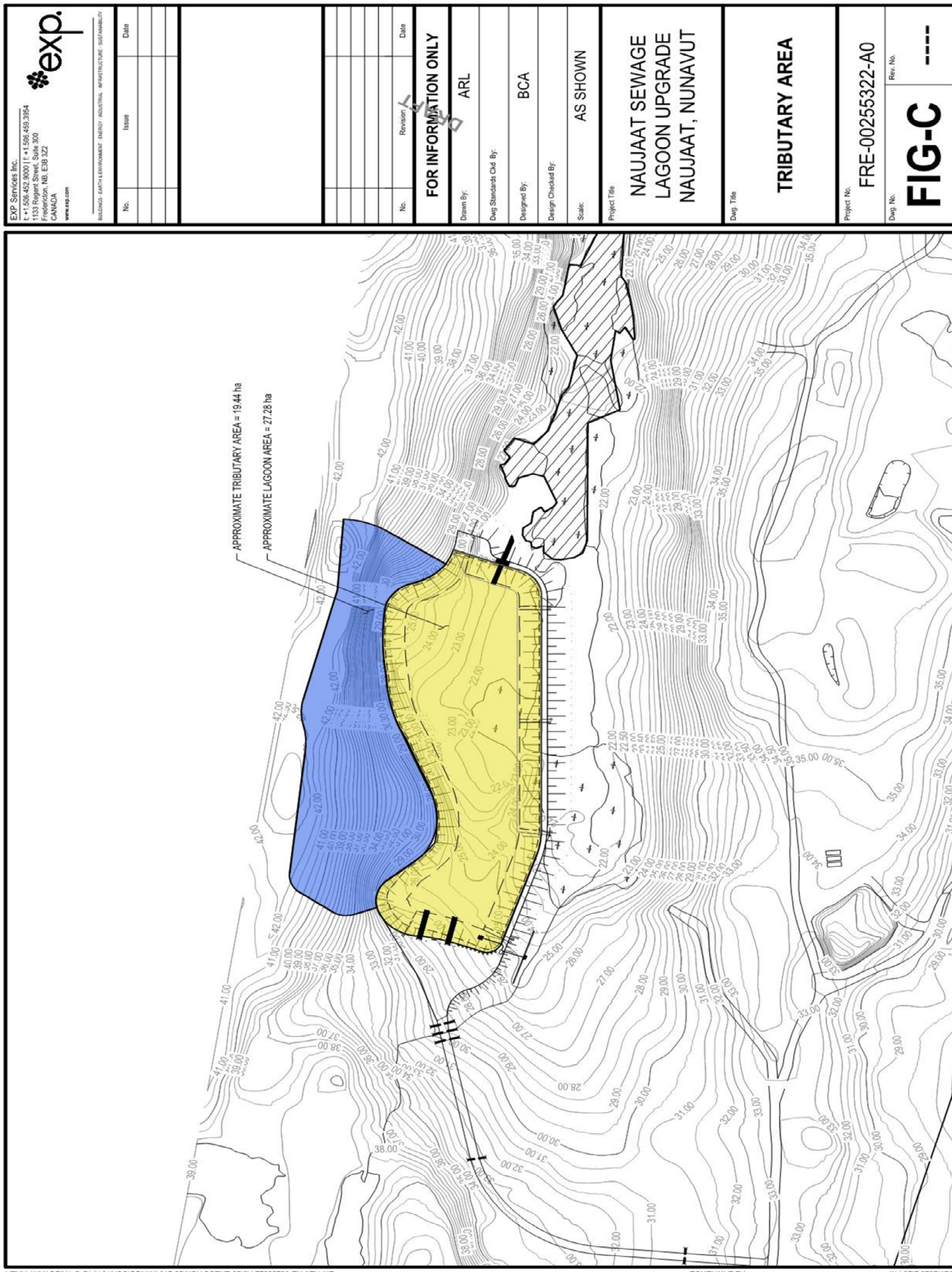

Figure 3-1: Tributary Area

3.3.2 Mode of Operation

Typically, northern sewage lagoons are designed to retain all generated sewage, and that the treated contents be discharged once annually by some decanting process. The facility proposed for Naujaat is somewhat unusual due to the constrained site, limited potential lagoon volume and presence of a substantial wetland. The following mode of operation is proposed for the lagoon.

- The lagoon refills over the winter season.
- Decanting is initiated via a spillway when the elevation of the lagoon contents rises to the spillway crest. The outflow rate to the wetland would equal the influent rate during this portion of the decanting process.
- The decanting process would be completed through active emptying of the lagoon contents over a 30-day period initiated on August 15. This would complete the annual cycle and prepare the lagoon for the pending winter.
- The lagoon is fully decanted over a 30-day period ending on September 15.

3.3.3 Sewage Generation

The estimate of the rate of sewage generation is presented above, in Section 2.3 of this report, and is summarized as follows.

Table 3-2: Estimate of the Rate of Sewage Generation

Year	Population	Daily Generation (L/day)	Annual Generation (m^3)
2019	1,160	132,227	48,263
2024	1,302	152,287	55,585
2029	1,462	175,806	64,169
2034	1,641	203,471	74,267
2040	1,886	243,370	88,830

3.3.4 Runoff Estimate

Naujaat sewage treatment area is located in a valley draining down gradient to the ocean. The lagoon watershed area, was calculated, using the Topographic Survey data, to be approximately 46,720 m^2 (3.0ha)

The volume generated from the watershed area was calculated using historic precipitation data for Rankin Inlet. This is the nearest station, for which climatic data is available, presenting an average for every month between the years 1981-2010. This data was extracted from the Government of Canada Canadian Climate Normals Station Data. This information is presented in Table 3-3.

Table 3-3: Rankin Inlet Climate Normals

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Temperature (°C)													
Daily Average	-30.8	-29.9	-25.0	-15.6	-5.8	4.2	10.5	9.7	3.8	-4.6	-17.0	-25.7	-10.5
Daily Maximum	-27.3	-26.1	-20.6	-11.1	-2.4	7.9	14.9	13.1	6.3	-1.9	-13.0	-21.9	-6.9
Daily Minimum	-34.4	-33.6	-29.2	-20.1	-9.0	-0.5	6.1	6.2	1.3	-7.3	-20.9	-29.4	-14.2
Precipitation (mm)													
Rainfall	0	0	0	1.1	7.0	22.1	41.9	57.2	39.1	12.9	0.3	0	**181.6**
Snowfall	89	85	125	192	130	46	1	2	38	255	224	133	**1319**
Precipitation	8.7	8.2	12.3	19.9	19.5	26.6	42.0	57.4	42.9	38.0	21.7	12.8	**310.1**

The proposed operating mode for the lagoon incorporates overflow into the wetland after June 15 of each year. Thus, there is no requirement to incorporate an allowance for storage of runoff that arises between June 15 and the end of lagoon decanting. Allowance must be made for the storage of runoff arising from 175.9 mm of precipitation which occurs between September 15 and June 15. Based on the watershed area of 46,720 m^2, the volume of runoff the sewage lagoon must be able to accommodate is 8,220 m^3.

A portion of the total precipitation will be lost to evapotranspiration, the sum of the evaporation and plant transpiration from the land. Given the short summer season, and limited vegetation, it has been assumed that evapotranspiration will not be considered in sizing this facility.

3.3.5 Working Volume Utilization

It is intended that the lagoon provide over-winter storage of sewage, and that overflow into the wetland be delayed until the wetland becomes active after June 15. Active decanting of the lagoon contents will take place between August 15 and September 15 of each year, in preparation for the pending winter. The required storage of 74,640 m^3, to meet this requirement for the design horizon of 2040 is determined as follows:

1. Sewage storage from the end of decanting, September 15, to the start of release, June 15, requires 273 days of storage. The projected population for the year 2040 (as per Table 2-1) is 1886 persons. The estimated per capita sewage generation rate for this population is 129.0 L/cap/day. This equals a required storage for sewage of 66,419 m^3.
2. Storage for runoff must account for the precipitation that falls between the end of decanting September 15, to the start of release, June 15. The table 5.3 above the precipitation over this period can be expected to be 175.9 mm. Given the drainage area of 46,720 m^2, the required storage capacity of 8,220 m^3 must be provided for storage of runoff.

3.3.6 Sewage Sludge Accumulation

The sewage lagoon must provide storage for solids (sludge) which accumulate in the sewage lagoon. There is very limited data regarding the operational behavior 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 the 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, and this represents a per capita volume of 0.329 m^3. The following table summarizes the rate 'of sludge accumulation anticipated in Naujaat.

Table 3-4: Sludge Accumulation Anticipated in Naujaat

Year	Population	Sludge Generated (m^3)	Sludge Accumulated (m^3)
2020	1187	391	391
2021	1215	400	791
2022	1243	409	1200
2023	1272	419	1619
2024	1302	428	2047
2025	1333	438	2485
2026	1364	449	2934
2027	1396	459	3393
2028	1428	470	3863
2029	1462	481	4344
2030	1496	492	4826
2031	1531	504	5340
2032	1567	516	5856
2033	1604	528	6384
2034	1641	540	6924
2035	1680	553	7477
2036	1719	566	8043
2037	1759	579	8622
2038	1800	592	9214
2039	1843	606	9820
2040	1886	620	10440

The sludge that is anticipated to accumulate over the 20-year design period can be accommodated within the allocated sludge storage zone located in the lowest 1.0 meters of the proposed lagoon.

3.3.7 Estimated Lagoon Performance

There are several removal mechanisms within a sewage lagoon, including sedimentation and biochemical oxidation. Sedimentation involves removal of BOD_5 and suspended solids through settling as sludge to the bottom of the lagoon. 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). Following sedimentation, BOD_5 and suspended solids concentrations are estimated as 300 mg/L and 160 mg/L, respectively.

3.3.8 General Design Characteristics

Lagoons have been constructed in the Arctic using both permeable and non-permeable berms. The use of permeable berms at this location is not considered appropriate as a controlled decanting of sewage into the wetland, both in terms of dates and location, is required to optimize performance. Thus, a method of providing non-permeable berms must be selected. The geotechnical investigation has determined that the local soils are permeable and not suitable as a water containing barrier. The geothermal assessment has discounted the use of a frozen core within the berms as a method of containing the sewage. The geothermal assessment recommends that a liner be placed on the internal face of the berms, and that this liner be keyed into un-weathered bedrock. The bedrock is found at a depth of 2 to 5 meters. As an alternative to keying into the bedrock, thermosyphons can be placed horizontally to achieve a cut-off for seepage below the berm liner.

A design that is based upon the above assumptions, including the use of thermosyphons, has been developed. Figure 3-3 illustrates this proposed lagoon layout and typical sections through the proposed lagoon cell. These sections depict the proposed liner arrangement. It is intended that 1 meter of freeboard be incorporated into the berm cross sections.

3.3.9 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

3.3.10 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 timing or rate of decanting. This method does not ensure that the lagoon will be fully decanted prior to the onset of the following winter. The use of a seepage cell has not been incorporated into the proposed design.

3.3.11 Discharge Pipe

For lagoons that are designed to be impermeable, a positive decanting method must be provided. The installation of a discharge pipe and valve through the berm is common in southern locations. In storage lagoons in northern locations, the discharge pipe is only used seasonally. This results in an arrangement where a portion of the pipe and valve arrangement are situated within a frozen berm. Frequently the pipe and valve must be thawed prior to their use, which has caused operational concerns, and in some instances has proven impossible.

As a further issue, the geothermal assessment has raised concerns relating to structures, such as control manholes, that penetrate the lagoon berms. More specifically, these penetrations provide an opportunity for additional thaw, which may result in unintended seepage in the vicinity of the control structure.

It has been determined that the use of a discharge pipe that penetrates the berm is not appropriate for this installation. This decanting mechanism has not been incorporated into the design.

3.3.12 Pumping

Pumping the effluent from the lagoon is the most operator-demanding alternative. It is also the most dependable. This method requires that the pumps be installed and removed each year. During operation the pumps 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 wetland as a secondary or additional treatment. Pumping has been selected as the preferred method of decanting the lagoon in Naujaat. A pump trailer will be located adjacent to the “Truck Turning Area” during the pumping season. The updated design includes two generator-powered pumps; one being used for redundancy.

3.3.13 Sludge Management

Effluent quality will guide when a sludge management program is implemented. Monitoring of the effluent from the lagoon will indicate deterioration in outflow quality due to re-suspension of accumulated sludge from the bottom of 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 should be covered with granular material and allowed to freeze.

3.3.14 Sewage Offloading

As the design has been updated, it was also necessary to update the “Truck Turning Area” to accommodate the updated sewage accumulation. This area was design for 2 trucks to pull up to the chute locations and have the ability to turn around. Additionally, a turning radius of 12.363 m was used with the “Rampmaster 7000 RJ Standard Tanker Truck” template in CAD.

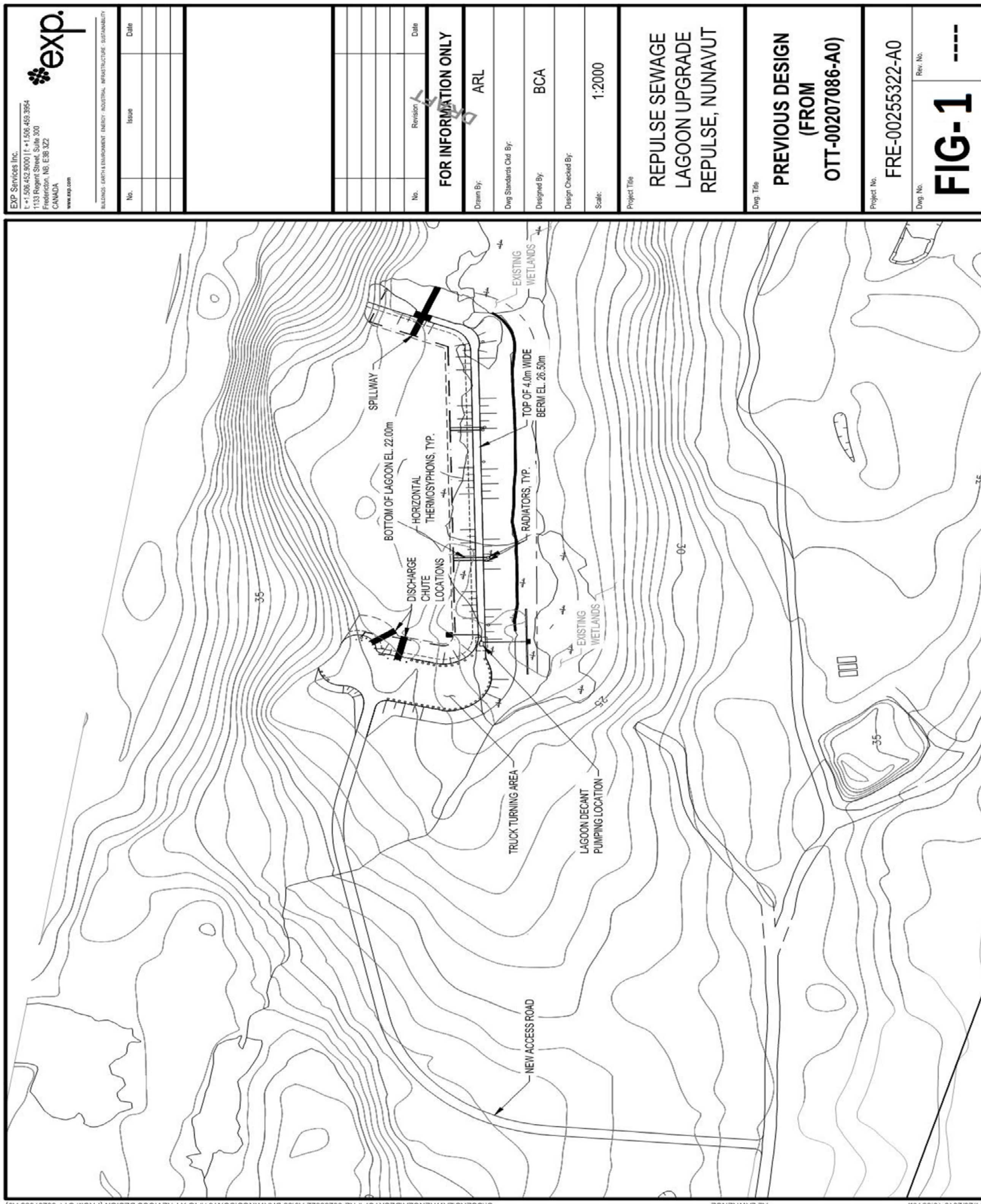

Figure 3-2: Previous Design

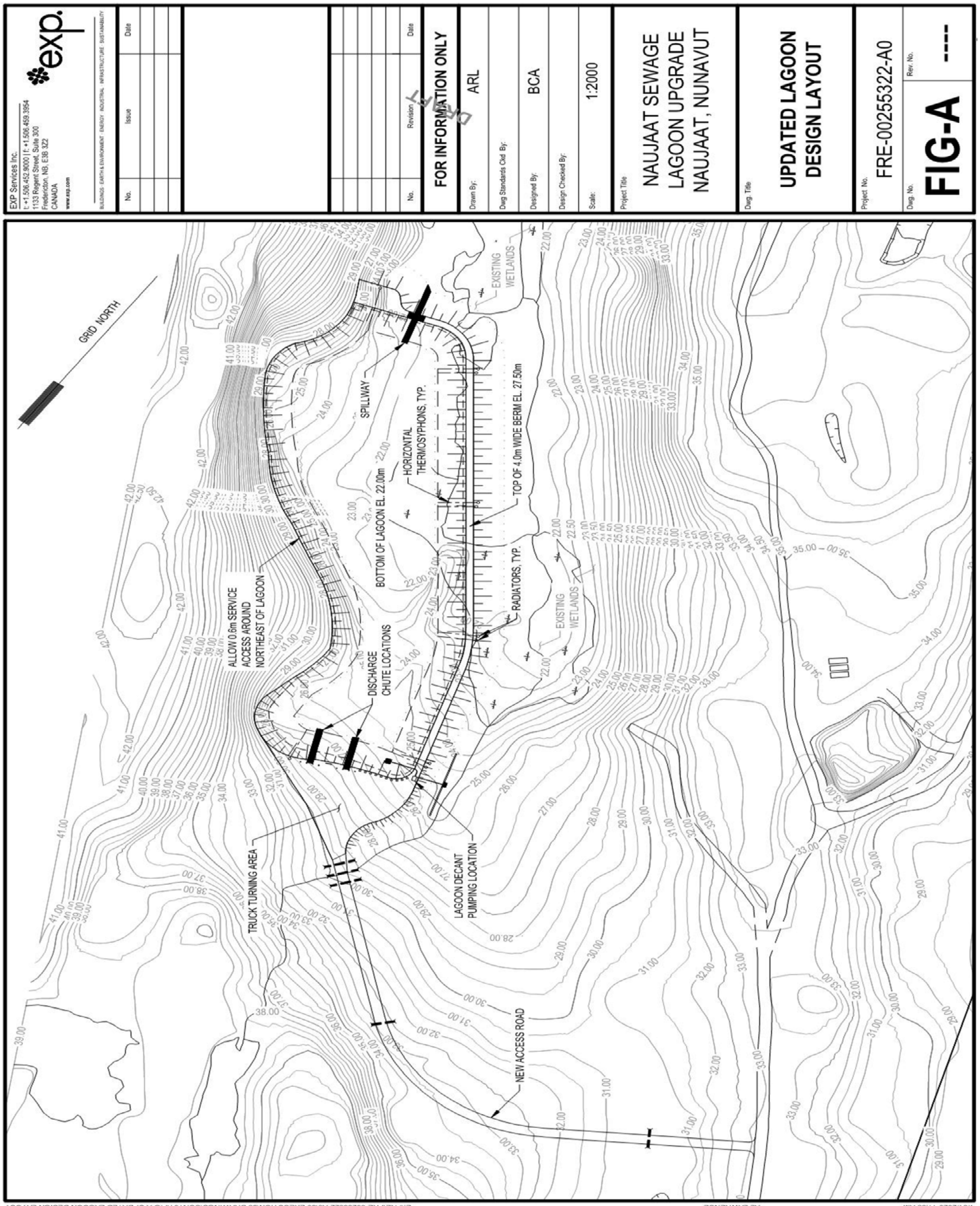

Figure 3-3: Updated Lagoon Design

3.4 Wetlands Treatment

3.4.1 General

The natural wetland downstream of the proposed lagoon site will be incorporated into the sewage system design. In order to remove contaminants effectively, treatment wetlands have to be an appropriate size. Design of constructed treatment wetlands takes contaminant loading, desired effluent concentrations and background concentrations into consideration.

The Guidelines for the Approval and Design of Natural and Constructed Treatment Wetlands for Water Quality Improvements by Alberta Environment use the following equation to calculate the required area for treatment (AE, 2000):

$$A = \frac{0.0365 \times Q}{k} \times \ln\left(\frac{C_i - C^*}{C_e - C^*}\right)$$

Q = Design Flow, m^3/d
C_i = Influent Concentration
Ce = Target Effluent Concentration
C^* = Wetland background limit (mg/L)
for TSS, $C^* = 8$
for BOD, $C^* = 5$
k = Areal rate constant @ 20 °C (m/yr)
for TSS, k = 35
for BOD, k = 98 (based on the results of the CWRS Wetland Treatment Area Study, 2016)
A = Required wetland area (ha)

The highest loading rate for the wetlands is during the 30-day decanting period. Discharge over this 30-day period of all the sewage and runoff stored in the sewage lagoon, 74,640 m^3, would give rise to a daily hydraulic loading to the wetland of 2,377 m^3/day.

The calculated BOD concentration in the influent into the wetland area from the lagoon is 300 mg/L. This influent concentration is based upon the conservative assumption that BOD reduction in the lagoon, which is limited to sedimentation, will represent 35% removal. For the purposes of these calculations an effluent BOD concentration of 40 mg/L, which is 40% of the effluent criteria has been assumed. A wetland background concentration of 5 mg/L has also been assumed. The required size of a treatment wetland for BOD removal is 1.9 ha.

Similar calculations have been conducted to develop an estimate of the area required to manage the suspended solids load. The calculated TSS concentration in the outflow from the lagoon, following 65% removal through sedimentation, is 160 mg/L and the target concentration for TSS was set at 50 mg/L.

The background concentration in the wetland was assumed to be 8 mg/L. The required size for a treatment wetland for TSS removal is 3.1 ha.

It should be noted that the above calculations are generally used for constructed treatment wetlands such as open water surface wetlands. The existing natural wetland area does not completely represent a purpose-constructed wetland. However, the area of the existing natural active wetland is 3.6 ha in size (as reported in the results of the CWRS Wetland Treatment Area Study, 2016), which indicates that there should be ample area for treatment prior to discharge to Hudson Bay.

3.4.2 Estimated System Performance

The effluent criteria assumed in this analysis are substantially more demanding that those that are typically applied to sewage treatment systems in Nunavut. Typical effluent criteria imposed in water licenses are 100-120 mg/L and 80-100 mg/L for suspended solids and BOD_5, respectively. Previous investigations, including "Vegetated Filter Strip Wetland Assessment, Arctic Bay." (Trow 2008), indicate that 80% removal of contaminants, including suspended solids and BOD_5, are possible through wetland treatment. Table 3-5 summarizes the estimated performance of the sewage treatment system.

Table 3-5: Effluent Quality from the Wetland

Parameter	Units	Influent from Lagoon	Removal	Effluent from Wetland
BOD_5	mg/L	300	80%	60
TSS	mg/L	160	80%	32

The natural wetland, which will be receiving pre-treated sewage from the newly constructed sewage lagoon, is expected to successfully remove BOD_5, TSS, pathogens, nitrogen compounds, phosphate, grease and oil before the wastewater enters the ocean. Existing native vegetation and microorganisms will be the main contributors to the reduction in contaminants and nutrients.

3.5 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 license. Table 3-6 summarizes the levels of treatment predicted from the sewage treatment system in comparison to the water license criteria.

Table 3-6: Summary of Treatment Levels

Parameter	Units	Criteria	Influent	Effluent from Lagoon	Effluent from Wetland
BOD_5	mg/L	100	460	300	60
TSS	mg/L	120	490	160	32
FC	#/100ml	1×10^6	1×10^7	1×10^6	<100,000

4 Monitoring and Compliance Points

4.1 Effluent Monitoring and Compliance

Table 4-1: Sampling Points NAD 83 Coordinates

SNP#	Description	NAD83 Coordinates	Comment
1	Truck Discharge #1	N7379019.099, E534673.6382	-
2	Truck Discharge #2	N7379011.153, 534655.5387	-
3	Lagoon Pump Discharge	N7378987.586, E534601.8897	-
4	End of Wetlands	N7377649.7580, E535390.9300	Compliance Point

Table 4-2: 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

5 Updates from 2013 Design

The updates made to the 2013 Design Brief to the 2020 Design update are summarized in the following table.

Table 5-1: Comparison Table from 2013 Design Brief and 2020 Design Update for each of the main design parameters

Parameter	2013 Design Brief	2020 Design Update	Proposed Change
Water License:	NWB3REP0409	3BM-REP1520	New License
Design Horizon (year)	2033	2040	7 Years
Projected Population	1,270	1,886	Increase of 616 People
Projected Annual Sewage Generation	53,950 m3	88,830 m3	Increase of 34,880 m3
BOD Limit	80 mg/L	100 mg/L	Change of 20 mg/L
Total suspended solids (TSS) Limit	100 mg/L	120 mg/L	Change of 20 mg/L
Required Sewage Storage Volume	40,322 m3	66,525 m3	Increase of 26,203 m3
Required Runoff Storage Volume	2,286 m3	8,220 m3	Increase of 5,934 m3
Anticipated Sludge Accumulation During Design Horizon	7,478 m3	10,460 m3	Increase of 2,982 m3
Approximate Watershed (Lagoon Surface) Area	14,000 m2	46,720 m2	Increase of 32,720 m2
Watershed into Lagoon	96ha	96ha	No Change
Total Watershed at exit of Wetland	96ha	96ha	No Change
Decanting Period Volume	42,608 m3	74,640 m3	Increase of 32,032 m3
Pump System	1 Pump	2 Pumps (1 for redundancy)	Increase of 1 Pump
Natural Wetland Area (Downstream)	No Change	No Change	No Change
Existing Swale	Alongside the Lagoon	Alongside the Lagoon	No Change
Truck Turnaround Area	2,700 m2	2,460 m2	Decrease of 240 m2
Truck Access Length	450 m	346 m	Decrease of 104 m
Truck Access Width	6 m	6 m	No Change
Access Lane Culverts	No Change	No Change	No Change
Berm Slopes	Internal Face: 3H:1V	Internal Face: 3H:1V	No Change

6 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. Sewage is currently discharged at a point near the Hamlet solid waste site. This sewage flows into a natural wetland.
2. The existing sewage disposal facilities do not meet the long-term needs of the community. Reporting by INAC in 2010 presented the opinion that the discharge quality was not acceptable.
3. A design horizon for the improvements to the sewage treatment facility has been set as 20 years. At the end of the design period the population is estimated as 1,886 and the daily sewage generation rate is projected to be 243.4 m^3.
4. The following effluent requirements have been set for this project.
    a. BOD_5 - 100 mg/L
    b. Total suspended solids - 120 mg/L
    c. Faecal coliforms – 1 $X10^4$/100mL
    d. Oil and grease – no visible sheen
    e. pH – between 6 and 9
5. The geotechnical investigation has recommended that an impermeable liner be used, based upon local soils characteristics. Installation of this liner on the inner face of the lagoon berms has been selected.
6. The geothermal assessment has determined that a frozen core within the berms is not a feasible approach for the containment of lagoon seepage. The alternatives of keying into sound rock or installation of thermosyphons are suggested. Thermosyphons, located at a depth of 2 meters below existing grade, have been selected as the preferred technique for the containment of seepage.
7. The wetland assessment has determined that phytoremediation is taking place; however, there are currently indications of overloading. This assessment recommends that a lagoon be provided to reduce contaminant loads to the wetland. Guidance is provided regarding the potential treatment that can be achieved by the wetland.
8. A sewage treatment system that includes a lagoon and the natural wetland is proposed. The lagoon will provide the following functions.
    a. Over-winter storage of sewage
    b. Reduction of solids, organic, grease and oil loadings to the wetland
    c. Storage of accumulated sludge

9. The following mode of operation is proposed for the lagoon.
    a. Over-winter storage of sewage, with delay of overflow from the lagoon until the wetland become active
    b. Active decanting of the lagoon between August 15 and September 15 of each year
10. A small area of 19.4 ha is tributary to the lagoon. Drainage from this area cannot be redirected. The lagoon must include an allowance of 8,220 m^3 for runoff from this area.
11. It is estimated that a total of 10,440 m^3 of sludge will accumulate over the 20-year planning period of this project. Lagoon effluent quality should be monitored, over the project life, as this will provide guidance regarding the need for lagoon de-sludging.
12. A total lagoon working volume of 74,640 m^3 is required.
13. The following summarizes the general arrangement of the lagoon.
    a. The lowest 1 meter of lagoon volume is reserved for sludge storage
    b. Provide 66,419 m^3 of storage for sewage generated during the over-winter period
    c. Provide 8,220 m^3 of storage for runoff
    d. A further 1 meter of freeboard is to be provided above the required working volume
14. It is recommended that the annual decanting of the lagoon be performed by pumping.
15. Estimates of the required area for a constructed wetland that would be required to manage the sewage generated in Naujaat has been prepared. The existing natural wetland is larger than these estimates.
16. It is anticipated that the proposed sewage treatment system made up of a lagoon combined with the natural wetland will provide an effluent that exceeds the discharge criteria.
17. Recommended sampling locations and frequency of sampling is provided in this report.
18. Recommend proceeding with the Design Stage.

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

9 2

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 proceas.

Primary sedimentation treatment offers low cost suspended solids and BoD 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 waetewatera exhibit BOD y and suspended solids removals of 65 and 85 per cent, reapectively. Without chemical addition for phosphorus removal, the BODg and suspended solids reductions would be 35 and 65 roer en pect ely With secondary treatment plants, the use of the secondary clarifiers for phosphorus removal has been the most oommon 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 BODY and suspended solids removals when tbe 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 showa the process to be more cost effective despite the higher chemical costa, 6-3

TABLE 6.1

SEWAGE TREATMENT PROCESSES AND TYPICAL CFFL T QLIALITY

DRAFT

PROCESS	EFFLUENT PARAMETERS (mg/L)			
	TOTAL BOD_5	SS	TAL PHOSPHORUS (as P)	FREE AMMONIA (as N)
- Without P Removal - With P Removal	110 90	70 30	5.0	20 20
CONVENTIONAL A.S.				
- -WithP M - And	15 15 10	15 15 5	3.5 1.0 0.3	17 17 17
— WitA Nitziftczftx	15	15	3.5	10
CO4TOCT ST/WfLQ/\T ION				
- Without P Removal - With P Removal	20 20	20 20	3.5 1.0	17 17
AERATION				
- Without P Removal - With P Removal - With P Removal And Filtration	15 15 5	15 15 5	3.5 1.0	 3.0 3.0
CONTINUOUS DISCHARGE LAGOON				
- Without P Removal - With P Removal	25 25	30 30	6.0	
SEASONAL RETENTION LAGOON				
- Without P Removal - With P Removal By Batch	25 15	30 20	6.0 1.0K .5	
- With P Berrxxzat By Dosage	25	30	1.0	
PE?E-iNEFtAT1O J LAGCXX4 (becibtc- Emuttz ive Type)				
- W I out P Berryaml With	60	100	6.0	

1. 7he above values are besed on typical raw sewage with Total BOD_5 = 170 mg/L, Soluble BOOK • H$, SS - 2‹ I P - 7 mgfL f4H j• 20 mg/L.