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KIMMIRUT, NUNAVUT – WASTEWATER PLANNING STUDY

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Abstract: Kimmirut is an Arctic community of 489 people at the south end of Baffin Island in Territory of Nunavut. The existing wastewater treatment system used by the community is a trench discharge that drains over a steep embankment, followed by a gradual drop through vegetation to the ocean. Some treatment is achieved through this discharge, although it may be limited to preliminary treatment only. From a regulatory perspective the existing system is unacceptable, and therefore the Government of Nunavut initiated a wastewater planning study to identify potential sites and potential processes to improve the quality of the wastewater discharge. A broad range of wastewater treatment processes were considered, including a mechanical treatment system, and these processes were applied to sites selected from an initial area analysis. This analysis culminated in the selection of 12 sites that were analyzed to develop conceptual treatment configurations; the analysis included site reconnaissance where possible. Independent fisheries, wetland, and geotechnical reviews were also completed to provide additional information for the analysis and advancement of options that could develop from any of the 12 selected sites. Based upon a decision analysis of the 12 sites, a retention lagoon system emerged as the best rated option to pursue for the community. It was recommended that this this option should be incrementally advanced to implementation. The incremental steps should include consultation with the community and the regulatory community, reconfiguration of the concept, final acceptance of the concept, consultation during the engineering process, and finally tendering and construction.

Keywords: Wastewater, Planning, Nunavut, Kimmirut, Lagoon

1 Introduction

Kimmirut is an Arctic community located on the southern end of Baffin Island at 62° 51’ N latitude and 69°53'W longitude. The hamlet occupies a triangular section of land extending from sea level to the airport, which lies at an elevation of approximately 50 metres. The current population of Kimmirut is estimated to be 489, of which 86 percent are Inuit.

The terrain in and around Kimmirut is generally “hilly” and steep. The terrain in the community slopes back from the ocean to the airport at an average grade of 10 percent; the highpoint of land near the community is at 143 metres in elevation. The geography around Kimmirut is limiting because of water bodies in addition to the limiting terrain. To the west and northwest, the Soper River and Soper Lake are limiting to the community (See Figure 1), and the Katannilik Territorial Park is also situated to the northwest, which also limits community related development. To the southwest, Fundo Lake and its catchment area limits community related development because the community water supply is located at Fundo Lake. To the east and southeast, Lake Harbour limits community related activity.

Kimmirut is situated on an uneven deposit of granular glacial soil, hemmed in by high hills of precambrian rock, with some deposits of limestone. Below the hamlet there is a stoney beach at high tide level. Bedrock is exposed extensively throughout the region and consists primarily of quartzite, schist and limestone. The area lies almost on a line separating the widespread discontinuous and continuous permafrost zones. Permafrost is present under most land areas to a depth of 60 m.

Vegetation is very limited in the terrain surrounding Kimmirut with the exception in of mosses, lichens, or grasses, areas of willows, and limited wetlands. Kimmirut experiences unusually high temperatures for the Arctic, and its sheltered location provides relatively mild winters in comparison to the rest of the region. The mean high and low temperatures for July are 12°C and 4.0°C respectively. January's mean high and low are -20°C and -27°C. Kimmirut receives 202 mm of rain and 2100 mm of snow on average annually.

2 Existing Systems and Proposed Processes

The wastewater disposal system currently used by Kimmirut has been serving the community for more than 30 years, and consists of a trench at the landfill where the trucked sewage is deposited. The sewage immediately flows onto a steep embankment with an average 1 to 4 slope, dropping a total of 40 metres (170 metres horizontally) from an elevation of 65 metres to an elevation of 25 metres. The sharp drop is followed by a gradual drop of 20 metres (200 to 300 metres horizontally) to the ocean at Lake Harbour. The gradual drop appears to have two flow directions, either northeast or south west.

The operation of the existing system is a dousing and resting process, which maximizes the potential treatment from the overland flow system through the vegetated area during the summer months. There is no available information on the effluent quality before discharge into Lake Harbour, however, there is no evidence of floatable material at the ocean, but there is evidence of the presence of nutrients with localized algae on the rocks at low tide.

The lower portion of the discharge contains significant grass and willow areas (35 by 130 metres to the southwest, and 20 by 180 metres to the northeast.) It is clearly evident that these areas provide some degree of treatment, but this may be limited to preliminary treatment. The anticipated overall performance of the existing system would be preliminary treatment because of the seasonal influences. The anticipated summer performance of the system with overland flow would be primary treatment.

A broad base of wastewater treatment processes were considered in the study, including mechanical treatment systems and lagoon (passive) systems. The mechanical systems included a Membrane Bioreactor (MBR), and a coarse screening system, and the passive systems included wastewater detention and retention, wetlands and overland flow through vegetated areas. Wastewater detention is characterized by short term holding of sewage, and wastewater retention is characterized by long term holding of sewage, which is generally a year.

Lagoon systems are generally considered to be a sustainable technology for northern communities. In particular, lagoon processes address community capacity issues associated with operational funding, and human resources, which are limited in both cases in northern communities.

3 Physical Environment, Land Use Constraints, and Potential Areas

The terrain around Kimmirut is generally “hilly” and steep, as previously discussed; the highpoint of land near the community is at an elevation 143 metres. Travel on the land is limiting in all directions because of the steep slopes.

The water bodies around Kimmirut have unique characteristics that are marine, fresh water and brackish water (estuary). The brackish water occurs in Soper Lake as a result of the “reversing falls” on the Soper River, which push salt water into the lake when the tide is high.

The immediate area around Kimmirut contains 6 distinct watersheds (see Figure 1). These watershed catchments drain into Soper Lake, Soper River (downstream of Soper Lake), Lake Harbour, Glasgow Inlet, Pleasant Inlet, and North Bay. The water supply is taken from Fundo Lake, which lies in the Pleasant Inlet watershed. Sewage from Kimmirut currently discharges in the Lake Harbour catchment area (marine environment). The community of Kimmirut itself is located in the western segment of the Lake Harbour watershed.

Definitive land use constraints for a wastewater facility in Kimmirut are associated with the Fundo Lake, which provides drinking water to Kimmirut, and an environmental setback of 450 metres from the community itself for wastewater treatment facilities. Other land use related constraints may be associated with community use along the shore of Soper Lake and along the shore of Soper River, including the Airport Zoning Plan. Any additional areas considered for sewage treatment should consider the new and somewhat isolated community development area northwest of the developed community, and a planned public area to the northeast of the community.

The planned public area to the northeast is a possible location of a future public art area , in the Lake Harbour watershed. This location is also the start of the access corridor into Katannilik Territorial Park, and the start of the access corridor for the 120 kilometre traditional trail to Iqaluit.

An initial scoping analysis identified 18 potential areas within the 6 watersheds. These potential sites were further evaluated in advance of a reconnaissance exercise to as many of the areas as possible.

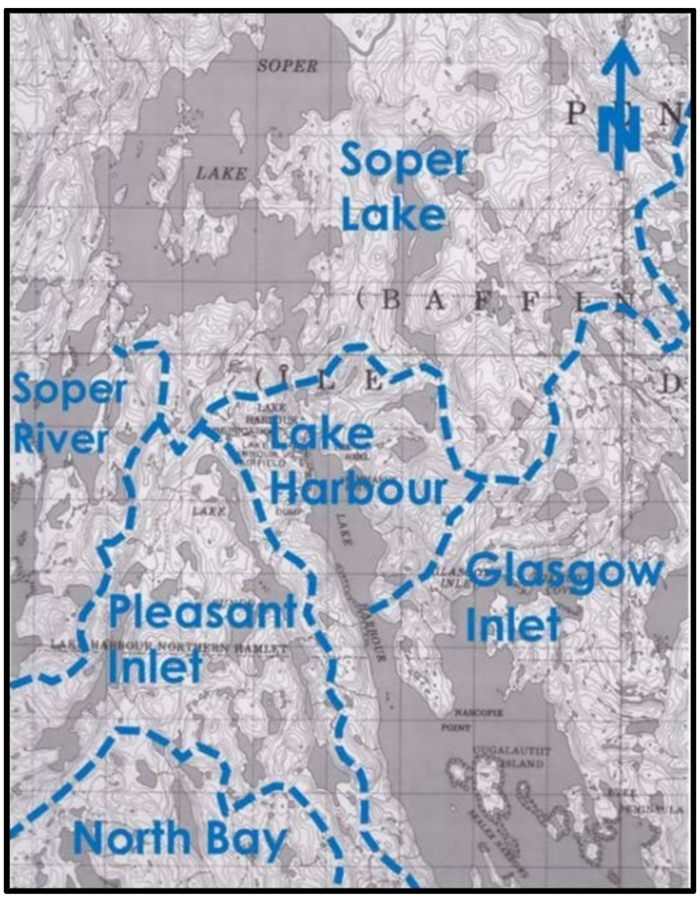

Figure 1: Watersheds around the community of Kimmirut, Nunavut

4 Wastewater Characteristics and Effluent Quality Standards

An estimate of the wastewater generation for Kimmirut for a 20 year horizon was completed using an established formula used by the Government of Nunavut, which applies a design standard of 90 l/c/day, and applied a population factor (waste generation (l/c/day) = 90 l/c/day x (1 + 0.00023 x population). For the year 2034, the estimate population is 554, and the annual sewage generation is 20,500 cubic metres.

The effluent quality standards that have been historically used by the communities of Nunavut and the Northwest Territories have been based upon the "Guidelines for the Discharge of Treated Municipal Wastewater in the Northwest Territories". These guidelines were adopted by Nunavut in 2000. The effluent quality guidelines from this document have been implemented through the community water licencing process in Nunavut.

The effluent quality standards appropriate to Kimmirut are the standards in the community water licence, and although the licence expired in January 2011, these effluent quality limits are still valid for the purposes of a planning study. These effluent quality standards are BOD^5 120 mg/L, total suspended solids of 180 mg/L,fecal coliforms of 10^6 cfu/100 mL, and pH between 6 and 9. These effluent quality standards are subject to change in the future, and could be as stringent as CBOD and total suspended solids of 25 mg/L to be compliant with the Wastewater Systems Effluent Regulations (WSER).

The Canadian Council of Ministers of the Environment (CCME) initiated a process to harmonize effluent quality standards across Canada, and this process has produced the WSER . However, the Government of Nunavut has deferred adoption of the regulation in favour of conducting Nunavut based research through Dalhousie University on the performance of lagoon systems in the north, and the receiving water conditions for effluent discharges.

5 Site Selection, Analysis and Probable Cost

Based upon the area analysis, which reduced the original 18 areas to six potential areas, and a discussion with the community Council, twelve sites were selected for consideration as wastewater treatment facility locations (see Figure 2). A systematic review was completed of the 12 selected sites applying the land use constraints, and site inspections. The site inspections consisted of treks completed on foot, and by quad over the course of 3 days in the field. A number of sites were screened from further consideration based upon land use or terrain related considerations.

A fisheries review noted that over half of the selected sites would require effluent discharges into freshwater, or an estuary associated with the Soper River, and these water bodies harbor community fishery related activities. The remainder of the sites would ultimately discharge into a marine environment, where the fishery related impacts would not be as significant.

A wetland review noted that only 1 of the selected sites would have a large enough wetland to provide significant supplemental treatment to the effluent discharge. The remainder of the potential wetland areas would provide only very limited treatment. Other land areas where effluent discharges would be directed are too steep for wetlands, and may provide only limited supplemental treatment associated with overland flow.

A geotechnical review noted that Kimmirut is deficient of any good source of granular material, and relies on periodic blasting and crushing operation to provide the building requirements. The existing terrain around Kimmirut does not afford the use of the generally configured northern lagoon system because there is no suitable level ground. The adapted configurations to meet this study included existing ponds and lakes for retention systems, and existing small valleys for detention systems.

Sites 5, 6 and 11 were screened from further consideration due to land use issues because based upon the land use information, all of these sites have potential land use conflicts. Sites 5 and 6 are within the 450 metre public health setback regulation, and therefore should not be developed. Site 11 is planned for the development of a community site, which would not be a suitable location for a nearby sewage treatment facility.

Sites 8 and 12 were screened from further consideration due to access issues. Based upon the site inspections, the terrain on route to, and around these locations is extremely steep, and would make access roads difficult to maneuver for the sewage collection truck, and expensive to construct. Site 4 was screened from further consideration because of terrain issues concerning the available slope, and the construction of a detention or retention structure.

The remaining sites 1, 2, 3, 7, 9, and 10 were the sites considered for wastewater treatment applying passive wastewater treatment process including detention, retention, and wetlands. Site 10 was selected as a potential site for a modular wastewater treatment system consisting of either a MBR, or a simple screening process.

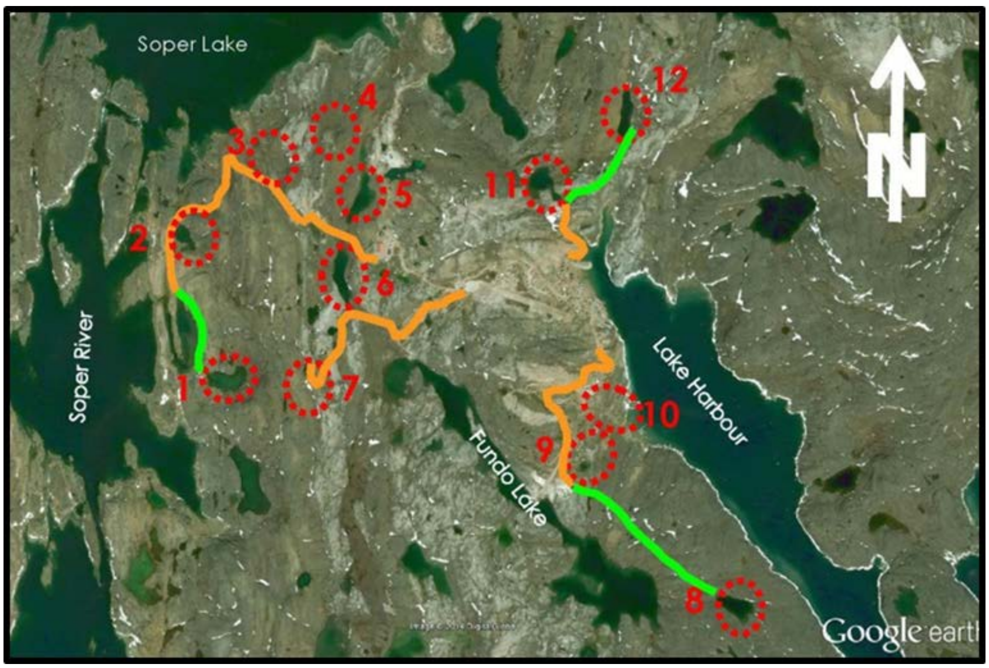

Figure 2: Sites selected for potential wastewater treatment

Site 1 is located 1.9 kilometres west from the community centre, and would be accessible with an existing road, and a length of new road. The general process technology for site 1 would be primary treatment based upon a continuous discharge from the lake, however the effluent quality could be enhanced with dilution of the influent in the lake. The system would discharge into Soper River through a pond adjacent to the river; the river has active Arctic char, cod, and mussel fisheries.

Site 2 is located 2.0 kilometres northwest of the community centre, and would be accessible with an existing road, and a length of new road. The general process technology for Site 2 would be primary treatment based upon a continuous discharge from the lake, however the effluent quality could be enhanced with a limited downstream wetland. The system would discharge into Soper Lake, which has active cod and Arctic char fisheries.

Site 3 is located 1.9 kilometres northwest of the community centre, and would be accessible with an existing road, and a length of new road. The general process technical would be secondary treatment based upon retention of the wastewater for up to a year. The effluent quality could be enhanced to some degree with the limited downstream wetland. The system would discharge into Soper Lake, which has active cod and Arctic char fisheries.

Site 7 is located 1.4 kilometres west of the community centre, and would be accessible with an existing road. The treatment processes applied would be detention, retention and wetland treatment, with an anticipated effluent quality close to, but above secondary treatment. Concerns were expressed by the regulators, the Government of Nunavut, and the community about the location of the discharge into freshwater from this location. The discharge area is a known Arctic char habitat.

Site 9 is located 1.3 kilometres south of the community centre, and would be accessible with an existing road, and a length of new road. Two processes could be established on this site. The first process (9A) would be secondary treatment based upon retention of the wastewater (impermeable berm) for up to a year. The effluent quality could be enhanced to some degree with the limited downstream overland flow. The second process (9B) would be preliminary treatment based upon a continuous discharge from the site pond, however the effluent quality could be enhanced by the limited overland flow downstream. Both systems would discharge into Lake Harbour, where there is no substantial fishery

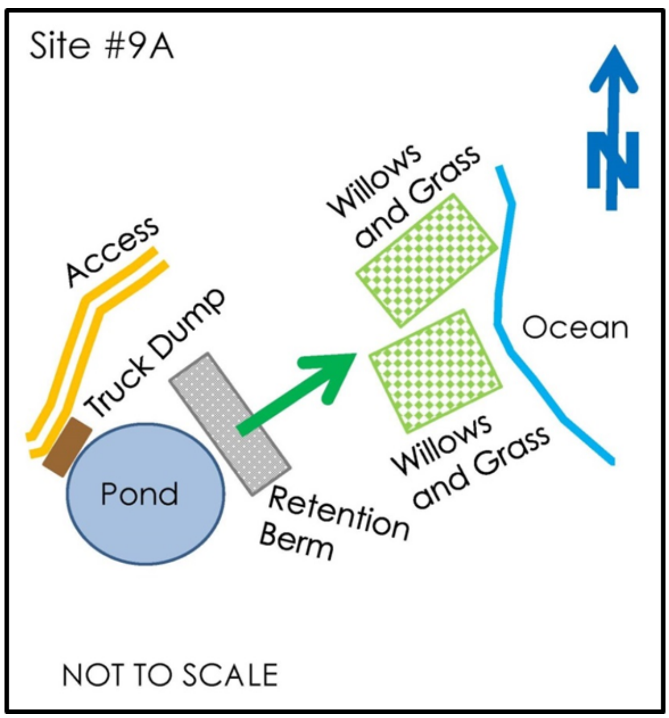

Figure 3: Unit processes for Site 9A retention lagoon system

Site 10 is located 1.0 kilometres south east of the community centre, and would be accessible with an existing road. Two processes could be established on this site. The first process would be a modular membrane bioreactor, which would provide secondary treatment based upon the standard MBR process technology with a continuous discharge from facility. The effluent quality could be enhanced by the limited overland flow downstream, and would discharge into Lake Harbour. The second process would be a modular preliminary treatment system based upon a screening system. The effluent quality could be enhanced to some degree with the limited downstream overland flow.

Site accessibility is a significant factor to the development of a sewage treatment facility in Kimmirut. The large sewage trucks must travel the access road year round and under a variety of weather conditions, some of which may be extreme. The selected sites have a variety of access road lengths, some of which are existing roadways and some of which are new roadways. Existing roadways will generally require some degree of upgrading to accommodate the sewage truck with anticipated improvements to the road width, the driving surface and possibly the road geometry. Improvements are essential to the driving safety of the road.

Site 1 is the furthest location from the community, and would require the most snow clearing to maintain a clean access road. Sites 9 and 10 are the closest sites to the community, and would consequently require the least hauling distance and least amount of snow clearing. The access for Site 7 has already been constructed, and is anticipated to require a moderate level of snow clearing in comparison to the other sites. The costs associated with road construction, snow removal and hauling distances could be further assessed to determine the relative importance of each of these factors. However, these factors will need to be balanced with other selection criteria such as total cost for each option, treatment efficiency and ease of operation to determine the optimal sewage treatment solution.

Opinions of probably cost were developed by identifying the major cost components and the quantity of each component required for each site and multiplying these components by unit cost rates from similar projects. The total component costs of the system were estimated by taking measurements from scaled preliminary drawings and multiplying these by the unit cost rate. A contingency was included to help account for differences in costs due to location, as well as account for any unknown costs which cannot be predicted at this early project phase. A sample of the cost estimates for Site 9 Option A is presented in Table 1.

The project costs are expected to be within the range of one to two million dollars for lagoon based systems, depending on which site is selected. Construction of new access roads, and improvement to existing roads are expected to have a significant impact in overall cost of a project. It was assumed existing roads connecting the community boundary to the proposed site would have to be improved to accommodate larger trucks. As a result, the more remote sites tend to have higher overall costs. Sites 1 and 3 are estimated to be approximately twice as costly as the low cost option, Site 9.

Table 1: Opinion of Probable Costs for Site 9A, with the addition of detention berms

Description	Total Capital Cost
New Access Road	$185,000
Existing Access Improvement	$130,000
Truck Turnaround	$45,000
Truck Discharge	$27,000
Detention Berm	$154,000
Retention Berm	$116,000
Pond Spillway	$38,000
Decant System	$135,000
Overland Flow Development	$50,000
Contingency Allowance (40%)	$352,000
Total	$1,232,000

The comparable opinion of probable costs for the mechanical systems at site 10 is $5.9 million for a MBR system, and $1.2 million for a screening system. The estimated operation and maintenance cost for the mechanical system would be approximately 10 percent of the capital cost, which would be $600,000 for the MBR system.

6 Decision Analysis of Options

The decision analysis was completed to provide a structured methodology for prioritizing and evaluating the information collected, included in the analysis were the screened sites and the respective process technologies. The intent was not to find a perfect solution, but rather the best possible choice, based upon achieving the outcome with minimal consequences.

The decision analysis employed a 2 stage process. The first stage evaluated the mandatory strategic requirements or “must” criteria for the options based upon discussion with the Government of Nunavut and the community. The must criteria for the sites included: land use conflicts; accessibility; discharge location; and effluent quality.

For the purposes of the decision analysis, it was mandatory that a site does not conflict with land uses as identified in the community’s land use plan, which includes potential conflicts with future residential developments or other community related development. Related with land use conflicts is the public health related setback that requires any waste management activity be setback a minimum 450 metres from residential development.

For the purposes of the decision analysis, it was mandatory that a site is reasonably easy and safe to access by a sewage pumpout truck. Reasonably easy access means an alignment that does not demand a large capital cost, as well as a large operation and maintenance cost. Safe access means an alignment that does not create a tortuous path for the sewage pumpout trucks that creates safety issues for these large vehicles.

For the purposes of the decision analysis it was mandatory that the effluent discharge does not enter waters that are used as a community fishery. Sewage effluent entering a community fishery may have an objective and subjective impact. The objective impact is the potential for directly impacting the fish and a subjective impact is a perceived impact on the fish.

Based upon the strategic requirements or “must” criteria, 10 of the 12 sites were screened from further consideration, which left only sites 9A (retention lagoon option) and 10 (MBR option) remaining for the second stage of the evaluation using the desirable criterial. At site 9 and 10 options for a detention lagoon, and a screening system were eliminated because the anticipated effluent quality would be above the water licence criteria.

The second stage of the decision analysis applied a weighting to each objective. The weighting used is also 1 through 5, with 5 being the strongest weighting for a given objective. The relative weights of the objectives are based upon an objective perspective on this project. It was anticipated that the relative weights will vary depending upon the perspective or bias of the individual.

The evaluation criteria for the decision analysis included: low capital cost; low operation and maintenance cost; low environmental risk; low performance risk; low effluent toxicity; low aesthetic impact; long service life; high effluent; space for future expansion; simple operation; ease of constructability; and ease of site accessibility.

The top ranking option of the two evaluated systems was a retention pond system near the current discharge point with enhancements of overland flow that could produce an effluent quality below the 100/120 BOD^5 / TSS limit in the water licence . The MBR system ranked second of the two options.

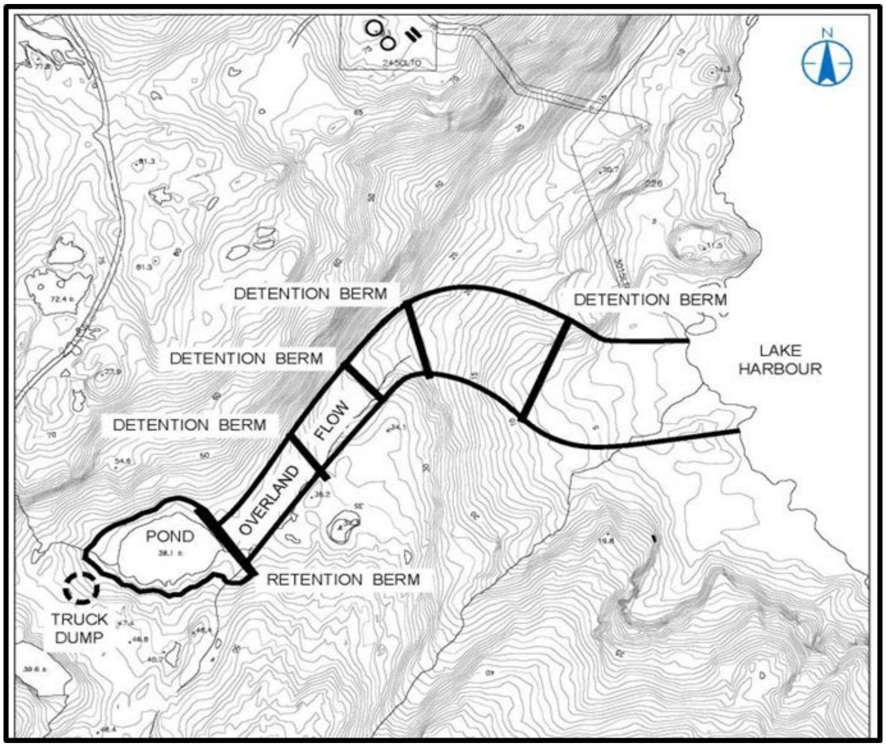

Figure 4: Conceptual design of sewage lagoon and discharge

7 Conclusions and Recommendations

The existing wastewater treatment system used by the community of Kimmirut is a trench discharge that drains to the ocean over a steep embankment, followed by a gradual drop to the ocean at Lake Harbour. Some treatment is achieved through this discharge, although it may be limited to preliminary treatment; the treatment would be enhanced during the limited summer months with overland flow treatment through the grass and willow area immediately before the ocean discharge.

A broad base of wastewater treatment processes were considered and these processes were applied to sites selected from an initial area analyses. This culminated in 12 sites that were selected and analyzed to develop conceptual treatment configurations. Independent fisheries, wetland, geotechnical and snow drift reviews were completed to provide necessary information for the analysis and advancement of options that could develop from any of the 12 selected sites.

A decision analysis was completed on the 12 sites, first applying the strategic requirements (musts) and then applying the operational requirements (wants). On the basis of the strategic requirements criteria, 10 of the 12 sites were screened from further consideration, which left sites 9 and 10 remaining for the evaluation using the desirable criteria. At sites 9 and 10, additional options for these sites were screened because the anticipated effluent quality would be above the water licence criteria.

The decision analysis applying operational requirements identified the lagoon retention system at site 9 as the better option to pursue. This lagoon option would apply an retention lagoon with seasonal overland discharge to the ocean through a series of detention berms.

This option should be incrementally advanced to implementation. The incremental steps should include consultation with the community and the regulatory community, reconfiguration of the concept (as required), final acceptance of the concept, engineering with consultation during the engineering process, and finally construction.

There will be a need for additional information collection in support of all of the steps to implementation. In particular the information will include site specific information on the local hydrology, geology, topography, fish habitat, the fishing and recreational use, vegetation, and snow accumulation. An important offsite piece of information will be the geotechnical information associated with the construction material, the updating of the community's granular needs and management plans, and the execution of the work, in advance of construction to provide the granular materials.