Government of Nunavut

Taloyoak Wastewater Treatment – Feasibility Study

Type of Document
Feasibility Study - Draft

Project Name
Taloyoak Wastewater Treatment Facility

Project Number
OTT-0000222042-A0

Prepared By:
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Canada

Date Submitted
March 2016

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1.0 Introduction

The Hamlet of Taloyoak is located on the Boothia Peninsula approximately 1,300 kilometers west of Iqaluit and 1,200 kilometers northeast of Yellowknife. Taloyoak is home to a population of approximately 1,000, and this population is expected to grow to approximately 1,340 over 20 years. Wastewater from the community is currently trucked to a small lake 2.5 Kilometers to the west of the community, which serves as a lagoon. Wastewater stored in the lagoon discharges through a natural wetland, which ultimately discharges to the sea.

Concerns have arisen with this wastewater management strategy. More specifically there is a concern that the current lagoon lacks capacity to store the annual wastewater generation from the community. Additionally there are concern relates to the nature of the discharge into the wetlands. There are currently no means to control either the timing or rate of discharge from the lagoon into the wetlands. In response to the various concerns arising from the current wastewater facilities the Department of Community and Government Services (CGS) commissioned a Wastewater Treatment Facility Feasibility Study. The following report is presented in response to the request for this assessment from CGS.

Projections of population, wastewater generation, wastewater characteristics and effluent requirements have been prepared. An initial review of candidate sites has been conducted, and from this review 2 sites were retained for further assessment. Various wastewater treatment methods have been considered, including the ability of these treatment methods to satisfy effluent requirements. Assessments of capital costs, operating costs and life cycle costs for the 2 alternative sites have been prepared. A ranking scheme has been applied to the alternatives and a preferred alternative has been selected. The following report presents a summary of these activities.

2.0 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. The design horizon for the sewage lagoon has been set at 20 years ending in 2036. This is consistent with the direction in the Term of Reference that the economic analysis be based upon a 20-year life cycle.

2.2 Population

The population projections for this project was taken from the "Nunavut: Community Population Projections" as a published by the Nunavut Bureau of Statistics, December 17, 2014. The Nunavut Bureau of Statistics provides projected populations for the Nunavut communities to the year 2036. The table 2.1, below, summarizes the population projections.

2.3 Wastewater 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. The "Water and Sewage's Facility Capital Program Standards and Criteria" as provided by the CGS, state that for the communities that make use of trucked water and sewage services, the Residential Water Usage Rate (RWU) (base water consumption rate) is to be 90 liters' per capita day (l/c/d). In addition, a series of equations based on the RWU which to take into account total water usage which includes non-residential usage such as commercial, institutional and industrial activities within the community. The non-residential activities in a community usually increases proportionately to the population of a community, therefore the MACA equations are all based on the RWU rates multiplied by a factor which is directly tied to the population of the Hamlet. The total community water use per capital is estimated using the following formula.

Total Community Population	Per Capita Water Usage
0 to 2,000	Residential Rate x (1.0 + 0.00023 x Population)
2,000 to 10,000	Residential Rate x (-1.0 + 0.323 x ln Population)
Over 10,000	Residential Rate x 2.0

Table 2.1 summarizes the anticipated sewage generation over the project planning horizon.

Table 2.1 – Population and Sewage Generation

Year	Population	Per Capita Consumption (Liters per Capita)	Daily Generation (Liters)	Annual Generation (m^3)
2016	1030	111	114,600	41,840
2021	1100	113	124,100	45,290
2026	1171	114	133,800	48,840
2031	1255	116	145,500	53,110
2036	1340	118	157,800	57,590

2.4 Wastewater Characteristics

The characteristics of sewage generated in a community are heavily dependent on the type of installation and sanitary facilities. The Hamlet of Taloyoak water and sewage systems utilize holding tanks and truck delivery and collection systems. The waste generated from this arrangement is considered to be "Moderately Diluted Wastewater", as per the Cold Climate Utility Manual. Table 2.2 - Characteristics of Basic Wastewater Categories is an excerpt from the Cold Climate Utilities Manual, summarizing the characteristics of moderately diluted wastewater.

Table 2.2 – Wastewater Characteristics

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

2.5 Regulatory Requirements

The proposed sewage treatment facility must meet the effluent quality standards as set out in the water license. The Hamlet is operating under water license 3BM-TAL1419, issued December 8, 2014 by the Nunavut Water Board, as required under the Nunavut Lands Claim Agreement and the Nunavut Waters Act. An amendment to this Water License will be required prior to the operation of new wastewater facilities in the community. This amendment will provide the effluent criteria for a new wastewater management facility.

For the purposes of this investigation effluent parameters must be assumed. The Canada-wide Strategy for the Management of Municipal Wastewater Effluent (CCME, 2007) recognizes the unique challenges associated with treated wastewater discharges in the Canadian Arctic. In recognition of these challenges, National Performance Standards have not been set for the arctic.

The best, currently available, direction available regarding effluent criteria is provided by the Guidelines for Discharge of Treated Municipal Wastewater in the Northwest Territories (Northwest Territories Water Board, 1992). This guideline is the most current information provided by the NWT Water Board. The Nunavut Water Board does not provide similar guidance. The Guidelines provide criteria based upon

discharge environment and per capita flow. It will be assumed that the criteria for a marine discharge during the summer with a flow exceeding 600 liters per capita-day are applicable, as it is anticipated that the future wastewater treatment facility will be discharge over a short period of time in late summer. The following Table 2.3 provides the effluent criteria that will be assumed for this investigation.

Table 2.3 - Effluent Quality Criteria

Parameter	Value
BOD_5	80
Total suspended solids (TSS)	70
Faecal coliforms	$1X10^4$ CFU/100mL
Oils and grease	No visible sheen
pH	Between 6 and 9

3.0 Review of Potential Sites

3.1. Initial Identification of Candidate Sites

3.1.1 Siting Criteria

For the purposes of the initial identification of potential sites for a new wastewater management facility it was assumed that a lagoon would form part or the treatment system. It was recognized that this initial assumption may require further reconsideration as the study advances. An initial estimate of the site area required to accommodate a lagoon was developed. The following Table 3.1 summarizes the assumptions used to develop the initial estimate of lagoon requirements.

Table 3.1 - Initial Lagoon Siting Criteria

Parameter	Value
Required storage volume	60,000 m^3
Freeboard	1 m
Internal berm slope	3:1 (horizontal to vertical)
External berm slope	4:1 (horizontal to vertical)
Working depth	2 m
Sludge storage zone	0.5 to 1.0m

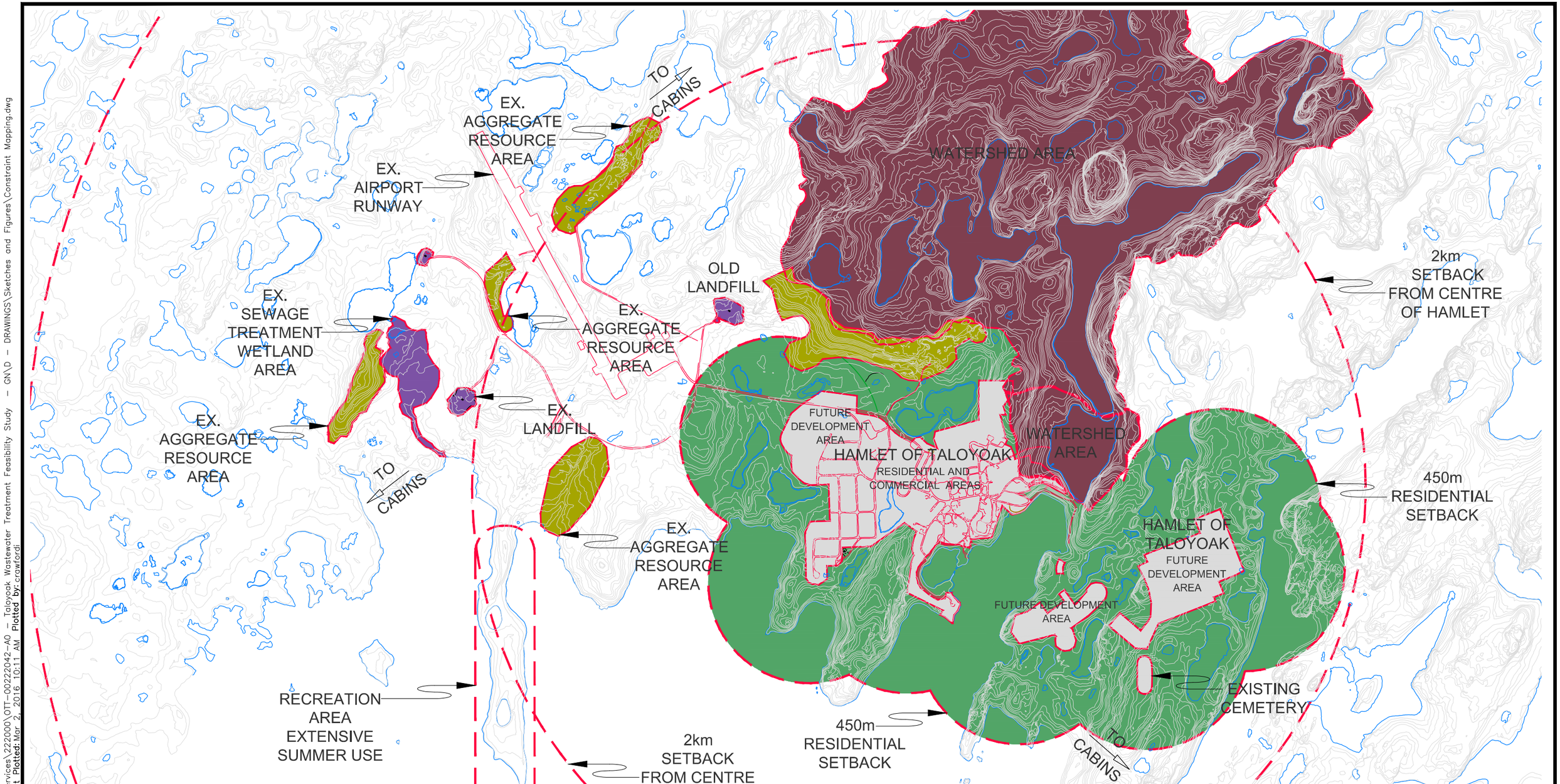
Based upon the above parameters the initial estimate of an area 200 meters' square was developed for the footprint required to accommodate a lagoon.

3.1.2 Constraints Mapping

The process of the identification of candidate sites for a wastewater treatment facility was initiated by the preparation of constraints mapping. Various sources, including the Community Development Plan, were consulted during the preparation of the Constraints Map. This mapping, which is presented as Figure 1 of this report, captures the following.

- The watershed area for Canso Lake, the community water supply.
- Locations of current and future development.
- A 450 m setback from current and future residential development.
- Existing and future granular extraction areas.
- Existing and closed landfills.
- The existing airport.

For reasons of map drawing scale, the limits of airport zoning have not been shown. The area over which airport zoning applies is a 4 km radius centered on the airfield. The airport zoning regulations that are applicable at most airports prohibit activities that attract wildlife within a 4 km radius of the airport. The



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SCALE: NTS	PROJECT: TALOYOAK WASTEWATER TREATMENT	PROJECT No.: 220042
DATE: MAR 2, 2016	TITLE: CONSTRAINT MAPPING	DRAWING No.: FIG. 1
CAD: IPC		

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current zoning regulation applicable to the airport in Taloyoak does not contain this stipulation. It is likely that this requirement will be incorporated into future airport zoning. On this basis it is felt to be prudent, as a matter of due diligence, to in assess the potential for the attraction of wildlife to the site of a new wastewater facility, if such facility falls within a radius of 4 km from the airport.

3.1.3 Initial Candidate Sites

3.1.3.1 Introduction

A total of six candidate sites, including the existing lagoon, were identified. Figure 2 depicts these sites.

3.1.3.2 Existing Lagoon

The existing lagoon is a small lake located approximately 3 km west of the community and 500 m southwest of the runway. There is a narrowing of the lake 200 meters south of the truck discharge point, but the northern and southern sections of the lake are hydraulically connected. During the summer season the contents of the lagoon flow southwards into a stream through a natural wetland. During spring melt the stored contents of the lagoon discharge, without control into the downstream wetland. This occurs during thaw and prior to the return of activity in the downstream wetland. Very limited wetland treatment is anticipated during the spring.

A truck discharge site has been developed at the north end of the existing lagoon. This discharge area includes a truck turn-around pad and three discharge chutes into the lagoon.

Samples of lagoon and wetland effluent were captured in July 2015. These samples suggest a good level of performance for both the lagoon and the wetland. This apparent performance warrants some further examination. These samples were captured following the uncontrolled discharge of the lagoon contents during spring melt. It is also noted that the sampling site downstream of the wetland is at a point where there is drainage from a substantial area beyond the lagoon discharge. It is likely that the large drainage area leads to substantial dilution at the sampling point. For these reasons it is felt that these samples do not provide a good representation of the performance of the current lagoon and wetland, especially during the initial discharge of the lagoon in the spring.

There are some further issues with the existing lagoon that must be considered. It is reported that there currently insufficient volume to contain the sewage generated over the winter. There is currently no mechanism to control the discharge or decant, therefore there is no mechanism to contain the lagoon contents until the wetland becomes active. Resolution of these matters would require berming and lining of the existing small lake and construction of an outlet structure. It is also reported that the community has limited confident in that ability of the existing lagoon to meet long term needs.

3.1.3.3 Potential Location #1

The site that is described as Potential Location #1 is located approximately 1.5 km south-east of the community and 3 km from the airport. The site may be generally characterized as bowl shaped with a small pond. Development of this site would require the provision of an engineered lagoon cell and a downstream, wetland. Access to the site would require improving approximately 1 km of existing trail from a trail to a road.

EXISTING
WETLANDS

HAMLET
OFFICE

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DENOTES LOCATION OF
PHOTOGRAPHY

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SCALE	PROJECT	PROJECT No.
NTS	TALOYOAK WASTEWATER TREATMENT	220042
DATE: MAR 2, 2016	TITLE	DRAWING No.
CAD: IPC	POTENTIAL LOCATIONS	FIG. 2

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3.1.3.4 Potential Location #2

Potential Location #2 is located to the west of the access trail to the sandy spit west of the community approximately 500 m distant from the airport runway. Development of this site would include the construction of an engineered lagoon cell and a wetland. Access to the site would be achieved through the extension of a short road from the road serving the existing lagoon. This site is approximately 300 m from the runway.

3.1.3.5 Potential Location #3

Potential Site #3 is located approximately 3 km from the community and 700 m from the runway, immediately east of the existing lagoon site. Development of this site would include the construction of an engineered lagoon cell. Vehicle access would be achieved through the construction of a short access road from the existing truck turn-around pad. Annual decanting of the lagoon contents would occur into the wetland that is currently serving the existing lagoon.

3.1.3.6 Potential Location #4

Potential Location #4 is located approximately 300 m west of the existing sewage truck turnaround on the opposite side of the existing lagoon. This site is approximately 600 m from the runway. Development of this site would require the construction of an engineered lagoon cell and an extension of the existing lagoon access road. Discharge from the lagoon could be directed into the existing lagoon, followed by the existing wetland.

3.1.3.7 Potential Location #5

Potential Location #5 is located approximately 3 km west of the community near the existing trail providing access to cabins west of the community. This site is approximately 2 km south-west of the runway and 400 m from the ocean shore. The scope of work required to develop this site includes the construction of an engineered lagoon cell, provision of a wetland and the construction of more than 2 km of access road.

3.2 Site Visit

Following the selection of candidate sites and the review of these candidates with CGS, a visit to the community was conducted in October 2014. This site program was initiated with a meeting with the Senior Administrative Officer (SAO) of the Hamlet. Each candidate site was visited and photographs were taken. The sites, together with photographs indicating typical conditions at the sites are presented on Figure 2 of this report. The initial on-site program was completed with a meeting with the mayor, the SAO, and the Assistant SAO.

During the meeting with the Mayor and Hamlet staff some community concerns and sensitivities were presented by the representatives of the community. These issues included the following.

- Locations where fishing currently takes place were identified.
- Locations and routes to cabins were identified.
- The location of the existing cemetery as confirmed.
- Long term desire to improve access to Red Fish Lake was expressed.
- Importance of the sandy spit that is immediately west of the harbour was reported.

- The desire to comply with regulatory requirements and concern for penalties arising from noncompliance was expressed.

The community concerns expressed during the meeting with the Mayor and staff were incorporated into the constraints mapping. Figure 1 of this report incorporates these additions to the constraints map.

3.3 Evaluation of Candidate Sites

The following tables summarize the merits and concerns associated with the candidate sites. Following this assessment of candidate sites, and following a review by CGS, recommendations were presented for review by the Hamlet Council.

3.4 Recommendation to Hamlet Council

The following recommendations were presented, and were subsequently approved by Hamlet Council.

- The Constraints Map, as prepared by **exp** Services, under the direction of the Department of Community and Government Services describes the major constraints that must be considered during the planning of improved wastewater facilities for the Hamlet of Taloyoak.
- Potential Location #3 and Potential Location #4 should be carried forward for further assessment. This additional assessment will include topographical survey, assessment of the wetland and a geotechnical investigation.
- Approval for the development of Potential Locations #3 and #4 should be obtained from Transport Canada.

3.5 Summary

A process which included constraints mapping, initial site reconnaissance, meetings with community officials and a review of the merits and issues of potential sites was complete. These activities led to the retention of Potential Locations 3 and 4 as viable alternatives for further assessment.

Following this initial screening and selection of alternative sites further, and more targeted investigations were undertake.

<table>
<tr><th colspan="2">Existing Lagoon</th></tr>
<tr><th>Merits</th><th>Concerns</th></tr>
<tr><td>• An access and truck discharge point has been developed at the site.
• There is a sufficient footprint within the existing lake to develop a lagoon with adequate volume to meet the needs of the community to 2036 if the existing lake is bermed.
.</td><td>• A water containing control structure must be provided at the lake outlet. The extent of existing thaw bulb and permeability of existing soils must be determined.
• A controlled method of decanting the lagoon contents into the downstream wetlands must be provided.
• Berming of most of the lagoon perimeter required to assure sufficient storage volume. These berms must be watertight.
• Polishing of lagoon contents required to meet anticipated effluent criteria.
• An alternative site is required for management of wastewater during the construction of improvements to the existing lagoon.
• The alternative wastewater management site must remain in service for the first winter following construction to permit refreeze of the permafrost to assure watertight berms.</td></tr>
<tr><td colspan="2">Site Status and Principle Reasons

Not retained for further consideration due to:

• Requirements for an alternative wastewater management site during construction and for the first year following construction.
• Challenges and risks in providing a water containing control structure at the outlet.
• Lack of community confidence in existing lagoon.</td></tr>
<tr><td colspan="2">Pending Required Action

• None at this time.</td></tr>
</table>

Potential Site #1	
Merits	**Concerns**
• An appropriate access to the site can be developed using the existing trail. • There is sufficient site area to develop a lagoon capable of meeting community needs to 2036.	• Substantial drainage area, including an upstream lake that drains through this area. Development would require control and direction of this upstream drainage. • The existing trail provides access to cabins east of the community. • Limited opportunity downstream of this potential site to develop a wetland for further effluent treatment prior to discharge to the sea. • Community cemetery overlooks site leading to strong community sentiment against development of wastewater treatment facility at this location.
Site Status and Principle Reasons Not retained for further consideration due to: • Proximity to cemetery	
Pending Required Action • None at this time	

Potential Location #2	
Merits	**Concerns**
• An appropriate access to the site can be developed with a short extension of the existing road. • There is sufficient site area to develop a lagoon capable of meeting community needs to 2038. • • The wetland effluent discharge point constructed as a purpose built structure, would provide an effluent sampling point.	• Requires the construction of a bermed watertight engineered containment. • The close proximity to the access to the sandy spit will raise significant concerns within the community. • Site is in close proximity to the airport. Approval of Transport Canada required. • Requires construction of a wetland in an area where there are community sensitivities. . • A geotechnical investigation is required to confirm the suitability and thaw stability of the site.
Site Status and Principle Reason Not retained for further consideration due to: • Impact upon sandy spit and community use of this area. • Challenges with construction of a functional wetland.	
Pending Required Action • None at this time	

Potential Site #3	
Merits	**Concerns**
• Access can be developed with a short extension of the existing road. • Sufficient site area to develop a lagoon capable of meeting community needs to 2038. • The effluent from the lagoon can be directed towards the existing wetland. • The wetland effluent discharge point will not be relocated from the current site.	• Requires the construction of a bermed watertight engineered containment. • Requires wetland treatment prior to discharge to the sea. • Site is in close proximity to the airport. Approval of Transport Canada required. • Development of site may have implications on future expansion of the solid waste management site.
Site Status and Principle Reason Retained for further consideration due to: • Potential for development of a suitable facility • Opportunity to incorporate existing wetland	
Pending Required Action • Ratification of Hamlet Council required prior to further assessment of site. • Obtain, through Nunavut Airports, approval from Transport Canada	

<table>
<tr><th colspan="2">Potential Location #4</th></tr>
<tr><th>Merits</th><th>Concerns</th></tr>
<tr><td>• Access requires short extension of the existing road.
• Extension of the access road could facilitate of development of improved access to Red Fish Lake.
• There is sufficient site area to develop a lagoon capable of meeting community needs to 2038.
• The effluent from the lagoon can be directed towards the existing wetland.
• The wetland effluent discharge point will not be relocated from the current site.</td><td>• Will require construction of a bermed and watertight engineered containment.
• Requires wetland treatment prior to discharge to the sea.
• Site is in close proximity to the airport. Approval of Transport Canada required.
• A geotechnical investigation is required to confirm the suitability and thaw stability of the site.</td></tr>
<tr><td colspan="2">Site Status and Principle Reason

Retained for further consideration due to:

• Potential for development of a suitable facility
• Opportunity to incorporate existing wetland</td></tr>
<tr><td colspan="2">Pending Required Action

• Ratification of Hamlet Council required prior to further assessment of site.
• Obtain, through Nunavut Airports, approval from Transport Canada</td></tr>
</table>

<table>
<tr><th colspan="2">Potential Location #5</th></tr>
<tr><th>Merits</th><th>Concerns</th></tr>
<tr><td>• There is sufficient site area to develop a lagoon capable of meeting community needs to 2038.
• Construction of an access road into this site could improve access to cabins west of the community.
• The wetland effluent discharge point would be constructed as a purpose built structure, including an appropriate effluent sampling point.</td><td>• Development of a lagoon at this site would require the construction of a bermed engineered containment. This containment must be watertight.
• Much of the access road would be constructed over ground that appears to be soft and muddy. Long term stability of this road will be difficult.
• The site, although more distant than the other candidate, remains within the area where airport zoning is applicable. Approval of Transport Canada is required as the site falls inside the airport zoning.
• Utilization of this site represents the creation of a new discharge point to the sea.
• Requires construction of a wetland.
• A geotechnical investigation is required to confirm the suitability and thaw stability of the site.</td></tr>
<tr><td colspan="2">Site Status and Reasons

Held in abeyance pending confirmation of status of other sites. Re-evaluate if no other suitable sites identified due to:

• Challenges of access road construction
• Need for creation of new wetland
• Creation of new discharge point</td></tr>
<tr><td colspan="2">Pending Required Action

• None at this time.</td></tr>
</table>

4.0 Site Investigations

4.1 General

Site investigations were undertaken to gather more data regarding the pair of sites that were identified during the review of candidate sites. These investigations included a site visit by a member of the **exp** technical staff, topographic surveys of the sites, a geotechnical investigation and an assessment of the wetlands.

4.2 Topographic Survey

A topographic survey of the existing facility, Alternative Site 3 and Alternative Site 4 was undertaken between July 6 and 9, 2015. 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 survey crew, in conjunction with the wetlands specialist, mapped out the alternative sites as well as the limits of the potential wetlands.

4.3 Geotechnical Survey

4.3.1 General

A geotechnical evaluation of Alternative Sites 3 and 4 was initiated by a program of test pits and bore holes conducted on July 23 and 24, 2015. The report, prepared following on-site activities, summarizes the site findings and provides advice regarding constructability of a lagoon of these sites.

For both sites advice is provided regarding slope stability of berms. Long term stability requires internal slopes of 3H:1V, and external slopes of 3.5H:1V. Additionally, drainage of the lagoon must take place over a period of 10 or more days.

It was determined that the construction of a lagoon is possible on both of the alternative sites, and advice regarding the scope of required works is provided in the report.

4.3.2 Alternative Site #3

Alternative Site 3 is overlain by tundra, with surficial boulders. Soil depths are reported between 0.8 and 3.5 meters over most of the site. A bedrock outcrop was noted in the eastern portion of the site. The drainage course, which transects the eastern portion of the site, overlies saturated soil. The soils in northern half of the site were noted as having high moisture content. Development of a lagoon on Site 3 will required the removal of ice rich soil, as a measure to avoid thaw settlement due to permafrost degradation. It is further anticipated that there will be a requirement for the redirection the drainage course followed by the removal of the underlying saturated soil.

4.3.3 Alternative Site #4

Alternative Site 4 is overlain by tundra, with surficial boulders. It is reported that the majority of the site is well drained. Soils are reported as sand to silty sand with gravel and occasional cobbles and boulders. Soil depth is reported as approximately 1 meter. Significant thaw settlement of a lagoon, or the berms, is not anticipated.

4.4. Wetlands Assessment

The status of the existing wetland was reviewed during a site visit conducted between July 6 and 9, 2015. Observations during this visit, together with data provided from testing of samples gathered during this visit raised concerns regarding the performance of the existing wetlands. More specifically, faecal coliforms exceeded the requirements of the current Water Licence, and a number of contaminants were observed at the boundary of the existing sewage treatment system at levels that may be of concern. This is interpreted as an indication that the wetland does not have the ability to appropriately reduce contaminants in the long term.

The following alternative measures are proposed as methods to improve the performance of the wetland.

- Provide an additional retention pond between the lagoon and the wetland. Lagoon contents would be decanted into this pond prior to discharge into the wetland.
- Increase the size of the wetland by damming the northern portion of the wetland.
- Redirect existing drainage away from the wetland, as a method to reduce the hydraulic loading on the wetland.

The wetland assessment also provides comments regarding Alternative Sites 3 and 4. It is noted that the measures that could potentially improve the treatment performance of the wetlands are difficult to integrate into the development of a lagoon on Site 3. This is of specific concern as long term growth in the volume of sewage requiring treatment will have an increasing impact upon the performance of the wetland. It is further noted that annual decanting of a lagoon on Site 4 into the existing lagoon would provide an additional retention pond prior to discharge into the wetland.

4.5 Wind and Snow Assessment

A wind and snow assessment has been conducted by Novus Environmental for Alternatives Sites 3 and 4. The conclusions and recommendations of this study include the following.

- Alternative Site 4 is a better option for minimizing snow drifting issues with the access road.
- Alternative Site 3 is the better alternative in terms of snow accumulation within the effluent containment area.
- For both alternatives, the preferred location for the truck discharge point is at the midpoint of the north berm face.

5.0 Evaluation of Treatment Methods

5.1 Introduction

As a first step in the development of a design for the management of wastewater in Taloyoak a review of treatment methods has been undertaken. As a general category of treatment methods, facultative lagoons have been successfully applied in many communities in Nunavut. There are several variations to the lagoon concept, with the most notable variations relating to decanting method and lagoon cell arrangement. In addition to lagoons, the alternative approach of mechanical treatment plants has been applied in a limited number of locations. The following sections of this report examine the various issues related to potentially feasible treatment methods.

5.2 Decanting Related Alternatives

The two commonly applied approaches to lagoon decanting are exfiltration through the berms, and active decanting. For the case of active decanting, this is typically associated with an impervious containment for the lagoon contents, combined with a mechanism that must be actively operated to achieve lagoon decanting.

Exfiltration lagoons are, to some degree, attractive, as this decanting method permits the discharge of the lagoon contents over an extended period of time in a simple fashion, without operator intervention. There are several important issues to consider during the evaluation of exfiltration lagoons. Recently the regulators have taken the view that a wastewater treatment system must be able to retain the lagoon contents if they are not in compliance with the Water License. There are also important technical concerns with the berms associated with exfiltration lagoons. More specifically, there are stability concerns for the berms surrounding exfiltration lagoons due to the movement of water through the berms. This movement of water leads to the displacement of fines within the fill materials and surface erosion of the berm exterior slopes, ultimately resulting in slumping of the berms. Based upon the stance of the regulators regarding control over discharge, and the issues of long term berm stability, it is concluded that an exfiltration lagoon system is not appropriate.

The remaining alternatives incorporate impermeable berms and an active decanting method. Typically, active decanting is achieved with a valve pipe through the berms or with a pump. The alternative of a pipe with a control valve is initially attractive, as the only operator action appears to involve opening the valve. This apparent simplicity ignores permafrost conditions, which lead to frozen piping beneath a portion of the lagoon berm.

Pumping, as a method of decanting lagoon contents has seen success in several communities. Selection of this approach requires the acquisition of suitable equipment, and the operation of that equipment. The use of a pump to drain the lagoon contents avoids the reliability and operation challenges arising from piping in a permafrost environment beneath the berm.

5.3 Lagoon Cell Arrangement

Improved performance, in terms of effluent quality, has been reported for lagoon systems that incorporated cells in series. With this arrangement, the initial or primary cell serves principally as a sedimentation lagoon. Further improvement in quality is the subsequent secondary cell is achieved largely through various biological processes. Transfer of liquid between the cells is the result of displacement, with the addition of

sewage into the primary cell leading to the movement of a similar volume into the secondary cell. This displacement process occurs throughout the year.

The principle challenge in implementing a series arrangement of lagoon cells in Taloyoak is the presence of permafrost. The berms separating the primary and secondary cells typically require slope of a minimum of 3:1 on each face of the berm to assure stability. With a typical lagoon depth of 4 meters, which accounts for freeboard, working volume and sludge storage, the resulting interconnecting piping would have a minimum length of 24 meters. Freeze of some portion of the interconnecting piping into the permafrost is inevitable, over the long term. Freeze of this piping would prevent displacement of liquid between the lagoon cells. As an alternative, liquid could be transferred by pump between the lagoon cells. Pumping is not viewed to be practical as a method to transfer contents between cells as this would require operation of the pump at several points during the year, including the extremes of winter.

Based upon the above comments it is concluded that a typical series arrangement that provides a primary sedimentation cell, followed by a secondary cell is not feasible in this project environment. There is the potential for a variation on this theme in Taloyoak. Candidate Site 4, to the west of the existing lagoon, provides an opportunity for decanting into the existing lagoon prior to discharge into the existing wetland. This arrangement provides an opportunity for the improvement of lagoon effluent quality prior to discharge into the downstream wetland.

The retention of the existing lagoon as a secondary cell is recommended as part of the wastewater management system for Taloyoak.

5.4 Wetland Polishing

It is unlikely that a lagoon, without additional downstream treatment, will provide an effluent that is compliant with the ultimate discharge criteria. Some subsequent treatment or polishing of lagoon effluent will be required to satisfy the anticipated regulatory requirements. Natural wetlands have proven effective in several Nunavut communities for the polishing of lagoon effluent.

An assessment was conducted in July 2015 of the existing wetland. During this assessment it was noted that the existing wetland is achieving some improvement of the quality of the existing lagoon effluent. It was further noted that rehabilitation of the existing sewage system was required. The recommend scope of rehabilitation included the existing wetland. On this basis, it is recommended that wetland polishing be incorporated into the wastewater treatment train in Taloyoak.

5.5 Alternative Treatment Methods

Alternatives to lagoon treatment have been successfully applied, especially at locations in Southern Canada. Examples of these alternative treatment methods include on-site treatment, modifications to lagoon based processes and mechanical treatment plants.

On-site wastewater treatment systems are located on the site (building lot) where the sewage is generated. An example of on-site treatment is a septic tank. On-site treatment employs sub-surface disposal of effluent into the soil. In that Taloyoak is situated in a region of permafrost, sub-surface disposal is not possible for much of the year. On this basis on-site treatment is not considered feasible.

The performance of lagoon systems has been enhanced at some sites through the use of aeration. This modification of a lagoon system improves performance through increasing dissolved oxygen within the lagoon cell and improving mixing of lagoon contents. There are several challenges associated with aerated lagoons. Capital costs are higher due to the requirement for aeration equipment, together with an electrical supply to the lagoon site. Significant operating cost is associated with the electrical energy requirements

of the aeration system. The greatest challenges with operation of aerated lagoons in an Arctic climate may relate to icing of the equipment during winter. Icing will likely render the equipment inoperable for much of the year. It is concluded that enhancements to lagoon treatment, such as aeration are not feasible.

Mechanical wastewater treatment plants have been applied, to a very limited extent, as an alternative to lagoon treatment in Nunavut. Mechanical treatment plant can reliably provide a very high quality effluent, subject to proper design and operation within the limits of that design. There are several notable issues with mechanical treatment plants. Provision of mechanical treatment has very high capital requirements. The ongoing operation is costly, in part due to the high electrical energy requirements. A very high level of operator training is required to assure successful operation of a mechanical plant.

An example of the application of mechanical wastewater treatment in Nunavut can be found in Pangnirtung. In this instance mechanical treatment was selected as there was insufficient space for the provision of a lagoon based wastewater system. In general, this facility has provided suitable effluent, but at considerable cost in terms of the provision of capital infrastructure.

In summary, a mechanical wastewater treatment can achieve the required effluent quality. For reasons of capital cost, operating cost and operating personnel requirements mechanical treatment works should be considered if no other alternative can be provided. This does not appear to be the case for the Hamlet of Taloyoak. Other alternative approaches to wastewater treatment appear to be impractical.

6.0 Compliance Feasibility

6.1 Regulatory Requirements and Guidelines

6.1.1 The Community Infrastructure Capital Standards and Criteria

The Capital Standards and Criteria direct that treatment works provide sufficient to manage the annual wastewater generation of the community and that these facilities be designed for a 20-year horizon. The Standards and Criteria stipulate regulations, codes and guidelines that must be met including the Canada-wide Strategy for the Management of Municipal Wastewater Effluent. The review and approval process of the Nunavut Water Board requires conformity with these various regulations, codes and guidelines. This evaluation will advance on the basis that conformity with Water Board requirements will satisfy the requirements of the Capital Standards and Criteria.

6.1.2 Government of the Northwest Territories Good Engineering Practices for Northern Water and Sewer Systems

Good Engineering Practices provides little direct guidance regarding wastewater treatment. These guidelines provide some very good guidance regarding general goals and principles including the following.

The goals and principles governing utilities design in the North include:

- Protecting public health and safety;
- Protecting the environment;
- Effectiveness and efficiency
- Community acceptance;
- Compliance with all relevant legislation and regulations; and
- Following accepted good engineering practices.

6.1.3 Public Health Act

The Regulations to the Public Health Act provide requirements that must be satisfied by new wastewater management works in Taloyoak.

The General Sanitation Regulations require incorporated municipalities, such as Taloyoak, to provide a system for the collection and disposal of human excreta. These regulations further prohibit the discharge of effluent under the following circumstances.

- At a location or in a manner likely injurious to heath;
- Without the approval of the Medical Officer of Health; or,
- Less than 30 meters downstream from a water intake.

The Sewage System Regulations require approval of a new lagoon. This regulation further stipulates that the final disposal of effluent not create a health hazard or aesthetically unacceptable conditions. Sewage treatment works must be designed to provide for adequate protection of receiving water. Chlorination may

be required if the Chief Medical Officer of Health considers that a public health hazard will be created by the discharge.

In view of the nature of the requirements of the Health Act, this assessment will be advanced on the basis that the process of review and approval of proposed facilities by the Nunavut Water Board will satisfy the requirements of the Health Act.

6.1.4 Nunavut Water Board

Development of a lagoon on Alternate Site #3 or Site #4 will require an amendment to the existing Water License held by the Hamlet. The Water Board has published few technical guidelines relating to effluent requirements. **exp** must draw upon recent experience with the review and design of wastewater management facilities. The following requirements are presented, based upon that experience.

- A wastewater system must be able to retain, and prevent discharge, of effluent that will lead to non-compliance. Thus, the enclosure of the lagoon contents must be impermeable.
- The design must provide for decanting at a controlled rate and at stipulated dates. Thus, a passive decanting method is not appropriate.
- The effluent criteria, as stipulated in section 2.4 of this report must be achieved prior to the final discharge point for the wastewater system. This requirement applies at the discharge point for the entire system, which may include a lagoon, followed by some form of effluent polishing.

6.2 Estimated Lagoon Performance

The removal mechanisms within a lagoon include both physical and biological processes. The physical process of sedimentation will remove BOD and suspended solids through settling. The Guidelines for the Design of Water and Sewage Treatment Works, Ontario Ministry of the Environment, state that typical removal rates of 35% and 65% of BOD and suspended solids respectively can be obtained through primary sedimentation (see Appendix A). The level of treatment based on primary treatment is summarized in Table 6.1 –Quality Post Sedimentation.

Table 6.1 –Quality Post Sedimentation

Parameter	Units	Influent Quality	% Removal	Effluent Quality
BOD_5	mg/L	460	35%	299
Susp. Solids	mg/L	490	65%	172

The International Polar Year Wetland Study (2008 – 2011) provides some guidance regarding lagoon effluent. For 3 communities served by a lagoon, followed by a wetland BOD, prior to wetland treatment, was reported as ranging from 40 to 181 mg/L. The same study reports suspended solids for the same 3 communities as ranging from 29 to 93 mg/L. The Environment Canada Wetland Study (2009-2011) also provides some guidance regarding lagoon effluent. BOD, prior to the wetland is reported in the range of 26 to113 mg/L for 7 communities. Based upon the above it is concluded that biological processes within the lagoon lead to a significant improvement in quality. It is also concluded that lagoon effluent suspended solids are similar in concentration to BOD.

A first order relation shown below can provide a prediction treatment based on temperature, influent strength and retention time.

$Ce = Cie^{-Kt}$

Where:

Ce = Effluent concentration (mg/L)

Ci = 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:

$K = K20\Theta^{T-20}$

Where:

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

K20=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 (Metcalfe and Eddy, Wastewater Engineering Treatment, Disposal and Reuse, Third Edition 1991, McGraw-Hill). The lagoon under consideration is a facultative lagoon. A value of 1.10 has been assumed for this coefficient due to the extreme conditions the lagoon will be operating, i.e. effluent near 0°C during runoff.

The BOD_5 removal rate coefficient for lagoons typically falls in the range of 0.25 to 0.50 (Metcalfe and Eddy, Wastewater Engineering Treatment, Disposal and Reuse, Third Edition 1991, McGraw-Hill). 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.

Over winter most of the lagoon contents will be frozen. In early summer no improvement in quality is anticipated during the period when the lagoon contents thaw. It is further anticipated that decanting of lagoon contents will start in early September. The period, over which biological improvements will occur, is estimated at 45 days. It is further assumed that the lagoon contents will warm to 5^0C over this period. Decanted effluent BOD is estimated at approximately 100 mg/L at the end of this 45-day period. It is also anticipated that effluent suspended solids will be similar in concentration to BOD.

The following Table 6.2 summarizes the estimated lagoon effluent quality.

Table 6.2 – Estimated Lagoon Effluent Quality

Parameter	Units	Effluent Quality
BOD_5	mg/L	100
Susp. Solids	mg/L	100

The above estimate for effluent BOD is consistent with the findings of sampling of wetland influents conducted during the International Polar Year Wetland Study (2008 – 2011) and the Environment Canada Wetland Study (2009-2011).

The assessment of the existing wetland suggested that the use of the existing lagoon as a secondary polishing pond, prior the flow of the decanted lagoon contents into the wetland. Further biological improvement of the wastewater quality will occur during the transit through the existing lagoon cell. The extent of this improvement in quality, although expected to be significant, cannot be quantified due a lack of parameters, including an estimate of the lake volume. For the purposes of the development of a design the performance of the wetland will be estimated based upon the lagoon effluent quality summarized in table 6.2 above.

The estimated lagoon effluent quality, as presented in table 6.2, exceeds the criteria presented in Section 2.5 of this report. This indicates that further effluent polishing is required prior to discharge. Good success has been reported with the use of natural wetlands for further treatment of lagoon effluent.

6.3 Estimated Wetland Performance

A copy of the Draft Guidelines for the Design and Assessment of Tundra Wetland Treatment Areas in Nunavut, as prepared by the Centre for Water Resources Studies, Dalhousie University has been provided by CGS. These Draft Guidelines provide techniques for the estimation of the performance of natural wetlands.

The wetland downstream of the existing lagoon has an area of approximately 7.5 ha. The wetland is transected by a meandering, and slow moving stream draining in the north to south direction. In that a portion of the wetland is up-slope from the watercourse, it has been assumed that 25% of the wetland will not act directly to treat lagoon effluent. The Draft Guidelines recommend a minimum retention time of 14 days. These assumptions lead to an estimated effluent BOD of 50 mg/L. Similar reductions in suspended solids are anticipated.

As is noted above, a prominent feature of the existing wetland is a shallow and slow moving stream draining towards the south. It is unlikely that the wetland currently provides 14 days of residence time, and some measures are required to achieve this. It is proposed that a series of weirs be provided along the watercourse to retard the lagoon effluent flow and extend the residence time in the wetland. In this fashion, a 14-day residence, prior to discharge to the sea, can be achieved. A specific effort should be directed towards minimizing the amount of disturbance of the existing wetland during the construction of these weirs.

6.4 Summary

In summary, it is anticipated that a lagoon will significantly improve wastewater quality, but this lagoon effluent will require further treatment to achieve the anticipated discharge criteria. Lagoon effluent is currently directed towards a natural wetland. The assessment of this wetland suggests that the performance of this wetland can be improved through the provision of a new lagoon, followed by further treatment in the existing lagoon and treatment in the existing wetland. It is anticipated that this strategy

can achieve a compliant effluent if wastewater is applied to an area of approximately 5.6 ha and if a hydraulic retention time of 7 days is achieved. It is further proposed that a series of weirs be provided to extend residence time within the wetland.

7.0 Examination of Alternative Site #3

7.1. Description

The attached Site Plan Alternative Site #3, which is located to the east of, and in close proximity to, the existing wastewater lagoon. A lagoon that is approximately 120 meters by 80 meters is required to accommodate the anticipated sewage volume generated by the Hamlet. Topographically the site rises 4 meters from southwest to northeast. A rock outcrop is located in the southeast quadrant of the site. A shallow drainage course transects the eastern portion of the site.

7.2 Scope of Work Required to Develop a Lagoon

The scope of work required to develop a lagoon on this site includes the following.

- Redirection of the existing drainage course to a location east of the proposed berm.
- Removal of the saturate and ice rich soil in proximity to the existing drainage course.
- Construction of the perimeter berms including placement of fill and provision of an impermeable liner. These berms would vary from 1 to 2.5 meters in height due to topography.
- Excavation of the rock outcrop.
- Development of a pair of wastewater discharge points. The locations of these points incorporate the comments of the Wind and Snow Assessment.
- Development of a decanting point in the southwest quadrant of the lagoon, including provisions for a decanting pump.
- Provision of detention weirs in the wetland.

Decanted lagoon contents can be discharged into the existing lagoon, prior to discharge into the natural wetland that is currently receiving effluent.

7.3 Operational Feasibility

Operation of a lagoon at Site 3 will require the provision of truck access, a discharge point and a truck turnaround for sewage trucks. There is also a requirement for the construction of a site for the pump used to decant the lagoon contents. The site for the decanting pump must be accessible by vehicle to permit fueling and maintenance. The provision of both the sewage truck access point and the site for the decanting pump can be easily accommodated on Site 3. The Site Plan depicts these required features.

In summary, no unusual impediments to the operation of a lagoon are noted for Alternative Site 3.

7.4 Economic Feasibility

7.4.1. Capital Cost Estimate

A Class C cost estimate has been prepared for the development of a wastewater treatment lagoon on Site 3. The details of this estimate are presented in Appendix B of this report. The following table summarizes this Class C cost estimate.

Table 7.1 - Capital Cost Estimate - Alternative Site 3

Description	Estimated Cost
Mobilization, site works and access	$1,048,000
Excavation, berms and liner	$3,880,000
Relocate existing drainage	$1,236,000
Influent discharge, decant point	$337,000
Sub-Total	$6,501,000
Contingency allowance (20%)	$1,300,000
Total	**$7,801,000**

7.4.2. Operating Cost Estimate

Modest ongoing operating costs are anticipated for this alternative. On an annual basis decanting, sampling of effluent and inspection of berms will be required. On a 10-year basis it is anticipated that the decanting pump will require replacement, and that there will be a need for the disposal of accumulated sludge. The estimates of operating expenses also include a modest allowance for site upkeep, such as re-grading and entrance repairs.

The following are estimates of ongoing operating expenditures.

Table 7.2 - Estimated Operational Costs- Alternative Site 3

Item	Frequency	Estimated Cost
Decanting	Annual	$10,000
Sampling and testing	Annual	$3,000
Berm visual inspection	Annual	$1,000
Site works	5 years	$10,000
Pump Replacement	10 Years	$100,000
Sludge Removal	20 Years	$200,000

7.4.3. Life Cycle Cost

An evaluation of the life cycle cost of this alternative has been undertaken. This analysis was conducted in a fashion that is consistent with the Terms of Reference for this project. Present values for capital and operating costs have been computed for a 20-year economic life. As a test of the sensitivity to discount rate, these calculations have been conducted for discount rates of 2%, 4% and 8%. The following table summarizes the present value of anticipated expenditures over the 20-year analysis period.

Table 7.3 – Life Cycle Costs- Alternative Site 3

Item	Discount Rate		
	2%	4%	8%
20 year operation and maintenance	$610,000	$610,000	$610,000
Present value of operations and maintenance	$468,100	$366,200	$236,800
Initial Capital	$7,801,000	$7,801,000	$7,801,000
Present value of costs over life cycle	**$8,269,100**	**$8,167,200**	**$8,037,800**

8.0 Examination of Alternative Site #4

8.1 Description

The attached Site Plan depicts Alternative Site #4, which is located to the west of, and in close proximity to, the existing wastewater lagoon. A lagoon that is approximately 130 metres by 80 metres is required to accommodate the anticipated sewage volume generated by the Hamlet. Topographically the site rises 3 metres from southwest to northeast.

8.2 Scope of Work Required to Develop a Lagoon

The Site Plan provides a preliminary layout of a lagoon on at Alternative Site #4. The scope of work required to develop a lagoon on this site includes the following.

- Construction of the perimeter berms including placement of fill and provision of an impermeable liner. These berms would vary from 2 to 3 metres in height due to topography.
- Development of a pair of wastewater discharge points along the north perimeter of the lagoon. A pair of discharge points is proposed to accommodate changes in wind direction.
- Development of a decanting point along the east perimeter of the lagoon.
- Extension of the existing road to provide access to the site.
- Provision of an emergency spillway on the east perimeter berm.
- Provision of detention weirs in the wetland.

Decanted lagoon contents can be discharged into the existing lagoon prior to discharge into the natural wetland that is currently receiving effluent.

8.3 Operational Feasibility

Operation of a lagoon at Site #4 will require the provision of truck access, a discharge point and a truck turnaround for sewage trucks. There is also a requirement for the construction of a site for the pump used to decant the lagoon contents. The site for the decanting pump must be accessible by vehicle to permit fueling and maintenance. The provision of both the sewage truck access point and the site for the decanting pump can be easily accommodated on Site #3. The attached Site Plan depicts these required features.

In summary, no unusual impediments to the operation of a lagoon are noted for Alternative Site #4.

8.4 Economic Feasibility

8.4.1. Capital Cost Estimate

A Class C cost estimate has been prepared for the development of a wastewater treatment lagoon on Site 4. The details of this estimate are presented in Appendix B of this report. The following table summarizes this Class C cost estimate.

Table 8.1 - Capital Cost Estimate - Alternative Site 4

Description	Estimated Cost
Mobilization, site works and access	$1,192,000
Excavation, berms and liner	$4,038,000
Influent discharge, decant point	$337,000
Sub-Total	$5,567,000
Contingency allowance (20%)	$1,113,000
Total	**$6,680,000**

8.4.2. Operating Cost Estimate

Modest ongoing operating costs, comparable to those for operation at Site Alternative 3, are anticipated for this alternative. On an annual basis decanting, sampling of effluent and inspection of berms will be required. On a 10-year basis it is anticipated that the decanting pump will require replacement, and that there will be a need for the disposal of accumulated sludge. The estimates of operating expenses also include a modest allowance for site upkeep, such as re-grading and entrance repairs.

The following are estimates of ongoing operating expenditures.

Table 8.2 – Estimated Operational Costs - Alternative Site 4

Item	Frequency	Estimated Cost
Decanting	Annual	$10,000
Sampling and testing	Annual	$3,000
Berm visual inspection	Annual	$1,000
Site works	5 years	$10,000
Pump Replacement	10 Years	$100,000
Sludge Removal	20 Years	$200,000

8.4.3 Life Cycle Cost

An evaluation of the life cycle cost of this alternative has been undertaken. This analysis was conducted in a fashion that is consistent with the Terms of Reference for this project. Present values for capital and operating costs have been computed for a 20-year economic life. As a test of the sensitivity to discount rate, these calculations have been conducted for discount rates of 2%, 4% and 8%. The following table summarizes the present value of anticipated expenditures over the 20-year analysis period.

Table 8.3 – Life Cycle Costs- Alternative Site 4

Item	Discount Rate		
	2%	4%	8%
20 year operation and maintenance	$610,000	$610,000	$610,000
Present value of operations and maintenance	$468,100	$366,200	$236,800
Initial Capital	$6,680,000	$6,680,000	$6,680,000
Present value of costs over life cycle	$7,148,100	$7,046,200	$6,946,800

9.0 Evaluation of Alternatives

9.1 General

It was first determined that the alternatives met the mandatory and minimum requirements for this project. Following confirmation that the alternatives met these minimum requirements, a ranking of the alternatives was conducted using a weighted scoring scheme.

9.2 Mandatory and Minimum Requirements

The Terms of Reference provide mandatory and minimum requirements that the alternatives must meet. These requirements are summarized in the following table.

Table 9.1 - Mandatory and Minimum Requirements

Number	Criteria	Comment
M1	Legislation, codes and guidelines	
M2	Effluent performance	
M2 a	• Criteria of section 2.5	
M2 b	• Current licence	Not achievable with lagoon technology
M3	Accommodation of annual generation for 20 years	
M4	Provision of sludge storage	

These mandatory and minimum requirements were presented to CGS for review and confirmation prior to the examination of the conformity of the alternatives to these criteria.

The issue of effluent performance merits some comment. The issue of effluent requirements is discussed in section 2.5 of this report. Currently, the National Performance Standards of the CCME do not apply in the Canadian Arctic. The current Water License contains effluent criteria that reflect these standards. Section 2.5 of this report proposes effluent criteria that are consistent with the best currently available guidance regarding effluent discharges in the Canadian North. The question of appropriate effluent criteria will be a matter of discussion during the process of a new Water License for a new wastewater facility.

Both Alternatives 3 and 4 meet the mandatory and minimum requirements, subject to the comments regarding effluent quality noted above.

9.3 Ranking of Alternatives

9.3.1 Introduction

A weighted ranking of Alternatives 3 and 4 has been conducted to assist with the identification of the most appropriate alternative. A list of criteria and a weighting scheme has been developed from the Terms of Reference. This ranking scheme, which is presented in the following table, was presented to CGS for review and comment prior to the ranking of the alternatives.

Table 9.2 - Alternative Ranking Scheme

	Criteria	Weight	Comment
W1	Capital cost	20	
W2	20 year operating costs (present value)	-	Captured in W3 below
W3	Life cycle cost (operating present value + capital)	20	
W4	Environmental impact		
W4 a	• Impact on existing water courses	10	Particularly those upstream of the wetland
W5	Optimize wetland treatment	10	
W6	Long term solution	-	Screened by mandatory requirement M3 above.
W7	Simple operation	20	
W8	Utilization of on-site materials	10	
W9	Phased construction	10	
W10	Utilize existing roads	10	
W11	Maximization of effluent quality	10	
	Total	140	

A scheme to provide a score within each of the ranking categories has been developed and this scheme is presented in the following table.

Table 9.3 - Alternative Scoring Scheme

Score	Description
5	Exceptional performance
4	Superior performance
3	Generally compliant
2	Somewhat compliant
1	Barely meets minimum requirements
0	Does not satisfy requirements

9.3.2 Examination of Alternatives

9.3.2.1 Capital Cost

Ideally, the preferred alternative can be achieved at low capital costs. Unfortunately, there are significant capital requirements for both alternatives. The estimated capital cost for the alternatives may be summarized as follows

- Alternative 3 - $7,801,000
- Alternative 4 - $6,680,000

Based on these capital costs the following scores have been assigned the alternatives

- Alternative 3 - 3
- Alternative 4 - 4

A weighted ranking of Alternatives 3 and 4 has been conducted to assist with the identification of the most appropriate alternative. A list of criteria and a weighting scheme has been developed from the Terms of Reference. This ranking scheme, which is presented in the following table, was presented to CGS for review and comment prior to the ranking of the alternatives.

9.3.2.2 Life Cycle Costs

In general, the preferred alternative should be achievable at low life cycle cost. Both alternatives are anticipated to have modest operating costs, but both alternatives require significant capital spending. The present values of the estimated life cycle expenditures for each both alternatives, for a discount rate of 4%, are as follows.

- Alternative 3 - $8,167,000
- Alternative 4 - $7,046,000

Based on these life cycle costs the following scores have been assigned the alternatives

- Alternative 3 - 3
- Alternative 4 - 4

9.3.2.3 Environmental Impacts

Of specific concern during the examination of environmental impacts, is the impact upon water courses. Development of Alternative 3 will require the redirection of an existing watercourse around the proposed lagoon. This will lead to both an impact upon the existing watercourse and a requirement to mitigate downstream impact during construction. It is also noted that both alternatives will be a downstream impact due to the discharge of effluent into the existing wetland.

On this basis the following scores have been applied to the alternatives.

- Alternative 3 - 2
- Alternative 4 - 4

9.3.2.4 Simplicity Operation

Both alternatives are considered to have relatively simple operating requirements. This does set aside the requirement for some operating activities, including sampling, operation of the decanting pump and annual berm inspection. A score of 4 has been assigned both alternatives within this category.

9.3.2.5 Utilization of On-Site Materials

The construction of both alternatives would incorporate locally available gravel. Both alternatives require the mobilization to the site of the same scope of materials. The score of 3 is assigned both alternatives.

9.3.2.5 Phased Construction

Neither alternative is amenable to phased construction. A score of 2 is assigned both alternatives.

9.3.2.6 Utilization of Existing Roads

Access to both alternatives is provided via the road to the existing lagoon. Alternative 4 will require a short extension to this road. The cost for this extension has been captured in the capital cost estimate. The following score are assigned the alternatives.

- Alternative 3 - 5
- Alternative 4 - 4

9.3.2.7 Maximization of Effluent Quality

The combination of a lagoon, followed by a natural wetland, represents a highly capable wastewater treatment system. Higher effluent quality performance can be achieved, but this would likely require the use of mechanical treatment plant, which is not an attractive alternative, for a long list of reasons. Thus, the highest potential score cannot be assigned either alternative. It is anticipated that the proposed treatment chain will provide an effluent that meets the requirements set out in section 2.5 of this report. On this basis a score of 4 has been assigned both alternatives.

9.3.2.8 Summary

The product of the score and weight within each category of the evaluation has been calculated. The weighted scores for both alternatives are summarized in the following table.

Table 9.4 - Weighted Scores for Alternatives

Criteria	Alternative 3	Alternative 4
Capital Cost	60	80
Life Cycle Cost	60	80
Environmental Impact	20	40
Simplicity of Operation	80	80
Utilization of On-Site Materials	30	30
Phased Construction	20	20
Utilization of Existing Roads	40	40
Maximization of Effluent Quality	40	40
Total	**350**	**410**

Based on the scores summarized in Table 9.4 above, Alterative 4 presents the higher ranking. Based upon this higher scoring of Alternative 4, it is proposed that this alternative be advanced into detailed design.

10.0 Summary and Recommendations

10.1 Summary

The various findings of this report may be summarized as follows.

1. The design horizon for this project has been set as 2036. At that date the served population is estimated as 1,340. Annual wastewater generation is estimated as 57,590 m^3.
2. The influent wastewater is anticipated to be moderately diluted with a concentration of BOD of 460 mg/L and Suspended Solids of 490 mg/L.
3. The following effluent characteristics are anticipated as regulatory requirements.

Parameter	Value
BOD_5	80
Total suspended solids (TSS)	70
Faecal coliforms	$1X10^4$ CFU/100mL
Oils and grease	No visible sheen
pH	Between 6 and 9

4. A minimum lagoon volume of 60,000 m^3 is required. This is inclusive of allowances for freeboard and sludge storage.
5. A constraints map has been prepared. This mapping identified locations that were inappropriate for a wastewater facility.
6. An initial list of 6 candidate sites for a wastewater facility was identified. Following an initial site review this list was reduced to Alternative 3 and Alternative 4.
7. Topographic surveys, geotechnical investigations, evaluations of snow drifting and an assessment of the existing wetlands were undertaken following the selection of Alternatives 3 and 4 for further assessment.
8. Alternative treatment methods were considered. The alternative of a lagoon with impermeable berms and active (pumped) decanting was retained.
9. In recognition of the performance limitations of lagoon treatment, it was determined that polishing of lagoon effluent through a natural wetland was appropriate.
10. Recent research indicates that a wetland should provide a minimum retention time of 14 days.
11. Provision of 14 days of retention time will require the construction of weirs to slow flow through the wetland. These weirs should be constructed with a minimum of disturbance of the existing wetland.
12. It is anticipated that a lagoon and wetland treatment system will provide an effluent that meets the requirements set out in point 3 above.
13. Estimates of capital cost were developed for Alternatives 3 and 4. They may be summarized as follows.

- Alternative 3 - $7,801,000
- Alternative 4 - $6,680,000

14. Life cycle cost, which capture the initial capital cost, plus the present value of operating costs over a 20-year period were calculated. These costs, for a discount rate of 4%, are summarized as follows.
    - Alternative 3 - $8,167,000
    - Alternative 4 - $7,046,000
15. Both alternatives were examined, in terms of compliance with the Mandatory and Minimum criteria for this project. It was determined that both alternatives satisfied these requirements.
16. Both alternatives were evaluated using a weighted scoring system. Alternative 4 scored highest using this ranking method.

10.2 Recommendations

The following recommendations are presented.

1. It is recommended that Alternative 4 be advanced into detailed design.
2. It is recommended that the effluent criteria presented in Section 2.6 of this report be discussed with the regulatory parties including Indian and Aboriginal Affairs Canada and the Nunavut Water Board.

Appendix A – Excerpt from MOE

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 Estimates

Sewage Treatment Facility
Taloyoak Alternatvie Site 3
OTT-00222042-AO

Class "C" Cost Estimate

ITEM	DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	TOTAL PRICE
1	**Mobilization / Demobilization**	L.S.	1	$900,000.00	$ 900,000.00
2	**a)** Supply and deliver silt fence, including wood stake	m	600	$ 4.00	$ 2,400.00
	b) Installation of silt fence, including wood stake and trenching	m	600	$ 4.00	$ 2,400.00
3	Deliver and place 100mm granular 'A' material to construct new discharge point	sq.m.	3,200	$ 8.00	$ 25,600.00
4	Deliver and place 200mm granular 'B' material to construct new discharge point	cu.m	640	$ 15.00	$ 9,600.00
5	Deliver and place 300mm granular 'C' material to construct new discharge point	cu.m	960	$ 20.00	$ 19,200.00
6	Rock excavation, grading and disposal off site	cu.m	1,020	$ 100.00	$ 102,000.00
7	Remove ice-rich soil soil in the existing drainage coourse	cu.m	20,000	$ 40.00	$ 800,000.00
8	Fill in existing drainage coourse	cu.m	20,000	$ 20.00	$ 400,000.00
9	Construct new Ditch and and disposal of material on site	m	240	$ 150.00	$ 36,000.00
10	Deliver and place granular material to construct new berms	cu.m	85,000	$ 22.00	$ 1,870,000.00
11	a) Supply and deliver gabion mats for erosion protection at toe of berm	m	240	$ 150.00	$ 36,000.00
	b)Installation gabion mats for erosion protection at toe of berm	m	240	$ 180.00	$ 43,200.00
12	**a**) Supply and deliver liner for proposed berm	sq.m.	39,500	$ 14.00	$ 553,000.00
	b) Installation of liner for proposed lagoon including sand bedding, sand cover and anchor trench	sq.m	39,500	$ 32.00	$ 1,264,000.00
13	**a)** Supply and deliver CMP	m	90	$ 350.00	$ 31,500.00
	b) Installation of CMP	m	90	$ 500.00	$ 45,000.00
14	**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
15	**a)** Supply and deliver truck discharge structures including erosion protection and bollards	ea.	2	$ 70,000.00	$ 140,000.00
	b) Installation of truck discharge structures including erosion protection and bollards	ea.	2	$ 25,000.00	$ 50,000.00
16	**a)** Supply and deliver piping for inlet structure including 200 dia. HDPE series 100 pipe, concrete block and pipe support	LS	1	$ 8,000.00	$ 8,000.00
	b) Installation of piping for inlet structure	LS	1	$ 5,000.00	$ 5,000.00
17	**a)** Supply and deliver piping for outlet structure including 300 dia. and 150 dia. HDPE series 100 pipe and wood support	LS	1	$ 5,000.00	$ 5,000.00
	b) Installation of piping for outlet structure	LS	1	$ 4,000.00	$ 4,000.00
18	**a)** Supply and deliver 600mm dia. nestable pipe including pressure treated wood post and lag bolt	m	44	$ 250.00	$ 11,000.00
	b) Installation of 600mm dia. nestable pipe including pressure treated wood post and lag bolt	m	44	$ 110.00	$ 4,840.00

Sewage Treatment Facility
Taloyoak Alternatvie Site 3
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Class "C" Cost Estimate

ITEM	DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	TOTAL PRICE
19	Supply, deliver and install boulder barriers	ea.	40	$ 75.00	$ 3,000.00
20	**a)** Supply and deliver thermistor casing c/w data logger	ea.	1	$ 7,000.00	$ 7,000.00
	b) Installation of thermistor c/w data logger	ea.	1	$ 3,000.00	$ 3,000.00
21	**a)** Supply and deliver seepage monitoring tubes	ea.	1	$ 500.00	$ 500.00
	b) Installation of seepage monitoring tubes	ea.	1	$ 1,500.00	$ 1,500.00
22	**a)** Supply and deliver signage	ea.	8	$ 350.00	$ 2,800.00
	b) Installation of signage	ea.	8	$ 200.00	$ 1,600.00
23	**a)** Supply and deliver pump including engine, wheel kit 150mm dia. hose, pressure gauge, ball valve, flange and coupling	ea.	1	$ 90,000.00	$ 90,000.00
	b) Installation of pump including engine, wheel kit, 150mm dia. Hose, pressure gauge, ball valve, flange and coupling	ea.	1	$ 5,000.00	$ 5,000.00
24	**a)** Supply and deliver 1.2m x 2.4m Project Information Sign	ea.	1	$ 2,500.00	$ 2,500.00
	b) Installation and Maintain 1.2m x 2.4m Project Information Sign	ea.	1	$ 750.00	$ 750.00
25	**a)** Supply and deliver sampling well	ea.	1	$ 500.00	$ 500.00
	b) Installation of sampling well	ea.	1	$ 750.00	$ 750.00

SUBTOTAL	**$**	**6,501,140.00**
20% CONTINGENCY	**$**	**1,300,228.00**
TOTAL	**$**	**7,801,368.00**

Sewage Treatment Facility
Taloyoak Alternative Site 4
OTT-00222042-AO

Class "C" Cost Estimate

ITEM	DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	TOTAL PRICE
1	**Mobilization / Demobilization**	L.S.	1	$900,000.00	$ 900,000.00
2	**a)** Supply and deliver silt fence, including wood stake	m	600	$ 4.00	$ 2,400.00
	b) Installation of silt fence, including wood stake and trenching	m	600	$ 4.00	$ 2,400.00
3	Deliver and place 100mm granular 'A' material to construct new access road	sq.m.	5,400	$ 8.00	$ 43,200.00
4	Deliver and place 200mm granular 'B' material to construct new access road	cu.m	1,800	$ 15.00	$ 27,000.00
5	Deliver and place 300mm granular 'C' material to construct new access road	cu.m	3,300	$ 20.00	$ 66,000.00
6	Deliver and place granular material to construct new berms	cu.m	100,400	$ 22.00	$ 2,208,800.00
7	**a**) Supply and deliver liner for proposed berm	sq.m.	39,500	$ 14.00	$ 553,000.00
	b) Installation of liner for proposed lagoon including sand bedding, sand cover and anchor trench	sq.m	39,500	$ 32.00	$ 1,264,000.00
8	Deliver and place 150mm of granular 'A' material to top road and turn for truck discharge point	sq.m	3,200	$ 20.00	$ 64,000.00
9	**a)** Supply and deliver CMP	m	90	$ 350.00	$ 31,500.00
	b) Installation of CMP	m	90	$ 500.00	$ 45,000.00
10	**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
11	**a)** Supply and deliver truck discharge structures including erosion protection and bollards	ea.	2	$ 70,000.00	$ 140,000.00
	b) Installation of truck discharge structures including erosion protection and bollards	ea.	2	$ 25,000.00	$ 50,000.00
12	**a)** Supply and deliver piping for inlet structure including 200 dia. HDPE series 100 pipe, concrete block and pipe support	LS	1	$ 8,000.00	$ 8,000.00
	b) Installation of piping for inlet structure	LS	1	$ 5,000.00	$ 5,000.00
13	**a)** Supply and deliver piping for outlet structure including 300 dia. and 150 dia. HDPE series 100 pipe and wood support	LS	1	$ 5,000.00	$ 5,000.00
	b) Installation of piping for outlet structure	LS	1	$ 4,000.00	$ 4,000.00
14	**a)** Supply and deliver 600mm dia. nestable pipe including pressure treated wood post and lag bolt	m	44	$ 250.00	$ 11,000.00
	b) Installation of 600mm dia. nestable pipe including pressure treated wood post and lag bolt	m	44	$ 110.00	$ 4,840.00
15	Supply, deliver and install boulder barriers	ea.	20	$ 75.00	$ 1,500.00
16	**a)** Supply and deliver thermistor casing c/w data logger	ea.	1	$ 7,000.00	$ 7,000.00
	b) Installation of thermistor c/w data logger	ea.	1	$ 3,000.00	$ 3,000.00
17	**a)** Supply and deliver seepage monitoring tubes	ea.	1	$ 500.00	$ 500.00
	b) Installation of seepage monitoring tubes	ea.	1	$ 1,500.00	$ 1,500.00
18	**a)** Supply and deliver signage	ea.	8	$ 350.00	$ 2,800.00
	b) Installation of signage	ea.	8	$ 200.00	$ 1,600.00

Sewage Treatment Facility
Taloyoak Alternative Site 4
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ITEM	DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	TOTAL PRICE
19	**a)** Supply and deliver pump including engine, wheel kit 150mm dia. hose, pressure gauge, ball valve, flange and coupling	ea.	1	$ 90,000.00	$ 90,000.00
	b) Installation of pump including engine, wheel kit, 150mm dia. Hose, pressure gauge, ball valve, flange and coupling	ea.	1	$ 5,000.00	$ 5,000.00
20	**a)** Supply and deliver 1.2m x 2.4m Project Information Sign	ea.	1	$ 2,500.00	$ 2,500.00
	b) Installation and Maintain 1.2m x 2.4m Project Information Sign	ea.	1	$ 750.00	$ 750.00
21	**a)** Supply and deliver sampling well	ea.	1	$ 500.00	$ 500.00
	b) Installation of sampling well	ea.	1	$ 750.00	$ 750.00

SUBTOTAL	**$**	**5,567,040.00**
20% CONTINGENCY	**$**	**1,113,408.00**
TOTAL	**$**	**6,680,448.00**