REPORT TO

GOVERNMENT OF NUNAVUT
DEPARTMENT OF COMMUNITY AND GOVERNMENT SERVICES

STUDY OF THE WETLAND SEWAGE TREATMENT AREA
CORAL HARBOUR, NUNAVUT

Project No. NTY71091

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1.0 INTRODUCTION

Jacques Whitford Limited (Jacques Whitford) was commissioned by the Government of Nunavut's Department of Community and Government Services (CGS) to perform a study of a tundra wetland-based sewage treatment facility for the Hamlet of Coral Harbour, Southampton Island, Nunavut (the Hamlet). The location of the community is illustrated in Drawing 1 in **Appendix A**.

The investigation described in this report (the Study) was undertaken to identify the boundaries of this natural treatment wetland system (the tundra wetland) that would constitute the Hamlet's sewage treatment system, and to provide preliminary design information to enable the tundra wetland to meet effluent requirements for a 20 year planning period. The specific objectives of the Study included:

- Project wastewater demand for 20 years and compare with the capacity of a sewage detention cell that now is upstream of the tundra wetland treatment system;
- Identify actual or potential system operating deficiencies under Water License Licence Number NWB3COR0207;
- Conduct a site visit (the Site Visit) to:
    - Identify the tundra wetland boundaries
    - Define treatment of effluent from the detention cell in the tundra wetland;
    - Identify surveillance network points;
- Assess the tundra wetland treatment system's capability for:
    - Meeting new proposed Environment Canada guidelines of 40 mg/L BOD, 40 mg/L TSS and 10 mg/L ammonia;
    - Complying with the Department of Fisheries and Oceans' (DFO) future discharge requirements;
- Complete a geotechnical evaluation of the existing sewage detention cell, and assess options to improve the performance of this detention cell;
- Identify relevant leachate discharge guidelines and applicable regulatory bodies with authority for the sewage and solid waste /tundra wetland activity; and
- Provide a cost comparison study of tundra wetland treatment versus mechanical sewage treatment options

To address the above objectives, Jacques Whitford undertook a review of available information and records, conducted the Site Visit between August 17 and 20, 2005, collected and analyzed effluent samples and analyzed data to prepare this report. Samples were collected by Jacques Whitford during the initial Site Visit, and subsequently by Sudliq Developments under the direction of Jacques Whitford. All samples were analyzed by Envirotest Laboratories of Winnipeg, Manitoba. EBA Engineering Consultants Ltd. (EBA) undertook a geotechnical investigation of detention cell berms in September 2004 and their report is appended.

1.1 Report Organization

The Study's findings are presented in twelve sections. Sections 1 and 2 present background information about the community and explains the scope of work. Section 3 presents a brief primer on treatment wetlands systems. Section 4 presents a review of information. Section 5 presents projections of future loadings to the sewage treatment system. Section 6 provides boundary definitions of the Coral Harbour Sewage Treatment System and identifies the final surveillance Network point (SNP).

Section 7 presents an assessment of the system treatment facility and capabilities of meeting projected effluent guidelines. Section 8 presents the findings of the geotechnical investigation of the sewage detention cell that was constructed in 2003. Section 9 identifies the relevant leachate discharge guidelines and applicable regulatory bodies involved in sewage and solid waste/wetland activity. Section 10 presents a cost comparison of tundra wetland treatment against a mechanical sewage treatment system. Section 11 provides conclusions and recommendations. Section 12 discusses the limitations of the assessment and its findings. Supporting information is provided in several appendices at the end of this report.

2.0 BACKGROUND

The Hamlet of Coral Harbour is located on the south shore of Southampton Island in the northern portion of Hudson Bay, Nunavut. The geographic co-ordinates of the community are 64^0 08'N, 83^0 10'W. The location of the community is illustrated on Drawing 1 in **Appendix A**.

The Hamlet in situated in the zone of continuous permafrost in the Canadian Shield. Tundra vegetation overlies bedrock, which is mainly Paleozoic marine limestone. There are gravel and fine deposits in low-lying areas, scattered boulders, muskeg and exposed rocks, often in the form of ridges a few meters to a hundred meters or more in length, usually oriented north-south. The area is characterized by low relief and many shallow surface water bodies.

The average annual precipitation in the Coral Harbour vicinity consists of 141 mm of rainfall and 1,319 mm of snowfall, resulting in an annual total of approximately 273 mm of precipitation as rain. The July mean high and low temperatures are 13.1^{o}C and 4.2^{o}C, respectively. The January mean high and low temperatures are -25.5^{o}C and -33.8^{o}C respectively.

The population of the community was estimated at 845 in 2000 rising to 1,376 by 2020 (Nunavut Bureau of Statistics, 2000). Economic activities include tourism, arts and crafts and public services. Electrical services are provided by the Nunavut Power Corporation, while the Hamlet provides trucked water, sewage and waste disposal services. The community has regularly scheduled air service. However, most supplies arrive annually by barge during the open water period.

Sewage is collected from the Hamlet's houses and other buildings by truck and discharged into the bermed sewage detention cell which is located approximately 3 km north of the community. The detention cell was constructed in 2003 and has an area of approximately 25,300 m^2. The detention cell is equipped with an outflow culvert which has a valve in it. Sewage from the detention cell is supposed to leave the cell via this discharge point but does not, instead permeating through the berms of the cell. Effluent from the detention cell flows through a tundra wetland consisting of boggy areas and a series of wetland ponds (see definitions below) which act as a further sewage treatment system, eventually reaching the ocean. During a site visit in 2004, CGS personnel observed leakage through the berms at an unconfirmed rate.

3.0 INTRODUCTION TO TREATMENT WETLANDS

3.1 Wetlands

Wetlands are defined as lands which are seasonally or permanently inundated by shallow water. There are various kinds of wetlands: **Natural Wetlands, Created Wetlands** and **Constructed Wetlands**. Created and constructed wetlands are artificial systems, designed and built for specific purposes. Created wetlands are those wetlands built for purposes other than wastewater treatment (e.g., recreation, habitat creation, mitigation). For example, Ducks Unlimited is a major constructor of created wetlands for habitat purposes.

Constructed wetlands consist of two main categories: those for water quantity control (stormwater wetlands) and those for water quality control - wastewater contaminants' removals/mitigations. The latter, to which the term constructed wetlands is more generally associated, can be used to treat municipal wastewaters (e.g., raw or partially pre-treated sewage), agricultural wastewaters (e.g., manure pile leachates) or industrial wastewaters (e.g., discharged process water and acid drainages from mining operations).

Both natural and constructed wetlands can be used for wastewater treatment (WWT) and where they do so they also are referred to as treatment wetlands.

Treatment wetlands will remove a variety of materials from any water passing through them. Surfaces under wetland water surfaces are all coated with microbial biofilms made up of complex communities of many kinds of bacteria, fungi and other microbes, and in them the bulk of WWT occurs (although some treatment also occurs in the plants directly and via planktonic microorganisms in open water areas).

Algae and aquatic plants in wetlands release oxygen as by-products of their growths. This increases the dissolved oxygen content in water and in soil/substrates in the vicinity of plant roots, thereby allowing aerobic microbial reactions to occur in an otherwise anoxic environment, supplementing the anaerobic reactions that also occur. Accordingly, wetlands can be used to treat pollutants which enter them in sewage streams, leachates, and/or surface runoff from non-point pollution sources by involving both aerobic and anaerobic removal mechanisms. Treatment wetlands therefore are kinds of natural, largely solar-powered WWT facilities.

The following are the main pollution removal processes involved in treatment wetlands:

SETTLING & FILTRATION

Suspended Solids		**Sediment**
Particulate COD	→	Sediment COD
Particulate Nitrogen	→	Sediment N
Particulate Phosphorus	→	Sediment P
Some Heavy Metals	→	Sediment

BIOACCUMULATION

Soluble Phosphorus	plants, biota →	Organic P
Soluble Nitrogen	plants, biota →	Organic N
Some Heavy Metals	plants →	Phytoextraction

CARBON OXIDATION

Organic Carbon → (bacteria, O_2) Carbon Dioxide

ANAEROBIC DIGESTION

Organic Carbon → (bacteria) CO_2, Methane

NITROGEN MINERALIZATION

Organic Nitrogen → (bacteria) Ammonia Nitrogen

NITRIFICATION

Ammonia Nitrogen → (bacteria, O_2) Nitrate Nitrogen

DENITRIFICATION

Nitrate Nitrogen → (bacteria, carbon) Nitrogen Gas

The use of wetlands for treating or polishing wastewaters has a number of advantages, including that they:

- Provide effective and reliable wastewater treatment.
- Are relatively inexpensive to adapt or even construct.
- Are relatively economical to operate and have low labour requirements.
- Are easy to maintain and have low energy requirements.
- Are able to accept varying quantities and concentrations of pollutants.
- Are quite tolerant of fluctuating hydrologic and contaminant concentration conditions.

- Provide various indirect aesthetic benefits (e.g., habitat, green space, recreation).
- Can be readily associated with other kinds of natural WWT facilities (e.g., lagoons, detention cells, sedimentation ponds, biofilters) to provide enhanced WWT.

However, using treatment wetlands for WWT is not a panacea. There are disadvantages to the use of these wetlands for WWT, including that they:

- Require large land areas.
- Are ecologically and hydrologicaly complex.
- Can lead to pest problems (e.g., mosquitoes).
- May not prove practical in some situations where local conditions (topography, drainage, soils, etc.) are not suitable.
- If constructed, may require some time before optimum efficiency is achieved.
- Do not have many years of experience to draw on so far as demonstrated technology is concerned.
- May be unfamiliar to regulatory authorities who may not have precedents.
- Be subject to erroneous negative perceptions as many early ones were mis-designed
- Operate at lower efficiencies during winter.

3.2 Natural Wetlands

Natural wetlands are those areas wherein, at least periodically, the land supports predominantly hydrophytes (water-loving plants) and whose substrate is predominantly un-drained hydric (i.e., saturated anoxic) soils, or where the substrates are non-soil and are saturated with water or covered by shallow water at some time during the growing season each year (Hammer, 1996). Flooding-intolerant vegetation is absent from them. Natural wetlands are found in surface depressions, and alongside streams, lakes and the sea; they often provide the interfaces between fully aquatic and terrestrial ecosystems. Waters in natural wetlands are generally less than two meters deep (and often very much shallower), and may stand/flow both on the surface and sub-surface in/via soils and substrates. Regular to erratic drying cycles may occur in all or part of natural wetlands. Water level fluctuations are normal in them, and morphologies usually are complex, with many flow channels, backwaters, and other heterogeneous areas.

Around the world, there are many names for different kinds of natural wetlands (e.g., tidal marshes, billabongs, carrs, mires, and mangrove swamps to name only a few) but the official designations for them in Canada are: marshes, swamps, bog, fens and shallow open water wetlands.

Marshes are areas permanently or periodically inundated and dominated by stands of emergent herbaceous vegetation such as cattails and reeds. Waters in them are neutral in pH, relatively high in dissolved oxygen and nutrients, and are generally moving. Open water areas in them may also contain floating plants (e.g., duckweed) and submergent plants (e.g., wild celery). As with other herbaceous vegetation-dominated natural wetlands, a few bushes and trees may also grow in marshes.

Swamps are wooded natural wetlands with water-logged sub-surface areas in which shrubs, bushes (e.g., willow, dogwood) and trees (e.g., white cedar) are the dominant vegetation, although some herbaceous plants are usually present among them. Waters in swamps tend to be standing or slowly moving most of the time.

Bogs are peat-covered low/no flow areas dominated by Sphagnum moss and other ombiotrophic (isolated from water sources other than precipitation) and acidophilic (thriving under acidic conditions) vegetation. Waters in bogs are low in pH, calcium, magnesium and nutrients (nitrogen and phosphorus compounds). While moss and similar herbaceous plants are the most prevalent vegetation, where conditions allow, some shrubs, low bushes and trees such as white cedar, tamarack and black spruce may grow in them too.

Fens are another kind of peatland typified by high water tables and slow internal drainage. Like bogs, herbaceous plants are the dominant vegetation in them (e.g., leather leaf), although a few shrubs (e.g., bog rosemary) and trees (e.g., willows) also may be present. Waters in fens tend to be mineral rich.

Shallow Open Water natural wetlands are ponds (potholes, sloughs, depressional basins) of standing or flowing water transitional between lakes and marshes. They often have emergent herbaceous plants growing on their peripheries and in shallower areas, and floating and submergent vegetation in the open water.

Natural wetlands are biologically extremely diverse. Seasonal and annual variations in a wetland can dramatically alter vegetation, microbial communities and wildlife in and around the wetland. Natural wetlands are ecologically important as they: provide habitat and corridors for wildlife movement; aid in flood control; protect shorelines from erosion; control and store surface water; trap sediments; immobilize contaminants and nutrients; and maintain and improve water quality.

Natural wetlands are generally used for WWT only if they already exist convenient to a wastewater source. Because of their heterogeneous natures, where they are used for WWT, very much larger areas are required for them to ensure adequate treatment. In the past, a commonly accepted hydraulic loading rate (wastewater flow rate over wetland area) for natural wetlands treating domestic sewage was 27.6 ha of wetland surface area per 1000 m^3/d of sewage flow introduced (expressed more commonly as 0.36 cm/d), but more recent studies indicate that up to 7 cm/d can be appropriate if conditions are right, some pre-treatment has occurred, and the wetland can be "engineered" to ensure maximum contact between the wastewater being treated and the vegetation/microbial biofilm matrices in the wetland (Knight et al., 1987). However, a more conservative recommendation is for 50 ha/1000 m^3/d (0.2 cm/d) for municipal wastewaters (Kadlec & Knight, 1996), especially where cold weather conditions are encountered and there is untreated ammonia nitrogen in the wastewater being treated.

It is important to note that the addition of a wastewater to a natural wetland will dramatically alter its ecology and biology. Temperature, flow regime, pH, water levels, plant growth/speciation, etc., will change. Nutrient-deficient, standing-water ones such as bogs may be converted into flowing systems and the plants in them will proliferate in the new positively stressed conditions that favour their growth.

3.3 Constructed Wetlands

Constructed wetlands (CWs) for WWT represent an environmental/biological technology (ecotechnology) that is now well developed. Unlike the situation with natural wetlands, water flow (and water level) in a CW is controlled, water is always present, and the plants used in them are often monocultures of herbaceous emergents such as cattails or reeds. Hydraulic design is for maximum wastewater/biofilm contact. Wetland plants are dormant in winter and pollutant removal from biological reactions becomes slower as the water temperature drops.

Modern CWs often consist of a number of individual, often rectilinear basins (cells) connected in series and surrounded by berms of earth, clay, rock, or concrete. Wastewater being treated in them often flows in either a single flow path (train), or in two or more parallel trains of one or more cells. These passive treatment systems (CW systems) also can include a variety of ancillaries (e.g., pumps, ditching, cascades, land treatment fields). Surge ponds and lagoon cells often complement the vegetated CW cells, (both in front and/or behind the CW cells) and are themselves regarded as cells of the CW system. There are many tens of thousands of these natural systems treating wastewaters of all sorts worldwide.

Three types of vegetated cells are used in CW systems: **pond** cells, **free water surface** (FWS) cells, and **sub-surface flow** (SSF) cells.

Pond wetlands, as the name suggests, are simple shallow pools, usually vegetated with emergent wetland vegetation (e.g., cattails) around the peripheries (10 - 30% of area) and having some portion of their surface consisting of open water in which submergent and/or floating wetland vegetation is growing. They are most commonly used in conjunction with other types of wetlands cells (e.g., as re-aeration basins between FWS cells in the common marsh (FWS) -pond-marsh kind of CW treatment system.) Pond wetlands provide quiescent areas where sediments and some of the suspended solids in a wastewater can settle out. Hence, pond wetlands are good methods for dealing with any suspended solids, and the biological oxygen demand (BOD), oil & grease, pesticides & herbicides, fertilizers, heavy metals and other organics which become associated with them in many wastewaters. (Pond wetlands differ from WWT lagoons in that they are always deliberately vegetated with wetland plants and most lagoons are not. In addition, they are usually shallower than WWT lagoons, and hence tend to be more aerobic than often-deeper, facultative lagoons [due to easier surface re-aeration]).

Free water surface (FWS) CWs are artificial marsh ecosystems in which water flows on the surface through largely emergent herbaceous wetland vegetation (e.g., cattails). In them, the submerged portions of the wetland plants, as well as the wetland soil/sediment and detritus, act as substrates for microbial biofilms. These biofilms and physical filtration are responsible for much of the removals of contaminants from wastewaters passing through them. FWS constructed wetlands are the most common type of constructed wetland in North America.

With sub-surface flow (SSF) CWs, the wastewater being treated flows just under the surface of porous materials (substrates) consisting of beds of gravel, sand or rock. SSF wetland cells may be horizontally fed (HSSF cells), or the wastewater may move vertically in the substrates (VSSF cells). With SSF CWs, wetland vegetation grows out of the substrate surfaces (usually gravel) of the wetland cells and it is possible to walk dryshod on their normally dry surfaces if one can get in among the normally dense stands of emergent vegetation. Microbial aerobic and anaerobic biological reactions in the highly porous biofilm/root system matrix in the interstices of the gravel substrate of a SSF CW are responsible for most of the pollutant removals from wastewaters passing through, not the wetland plants.

SSF CWs are smaller and more efficient than FWS CWs, but often are more costly to build because of higher design and substrates costs. Full scale, SSF wetlands treating relatively high volumes of influent (>15 L/s) are already operating treating stormwater (Higgins & MacLean, 1999), and ones treating even larger volumes of water are being designed and built.

The ultimate in constructed wetlands is the engineered wetland. Engineered wetlands (EWs) are advanced forms of CWs that involve more active manipulation of process conditions than is usual for ordinary, constructed wetlands (which are largely passive systems). For example, EW systems may involve aspects such as cell aeration, the addition of chemicals and/or energy, active phytoremediation, and/or use of specialty substrates that chemically interact with certain wastewater pollutants. Engineered wetland cells can be of the pond, FWS or SSF varieties, but are more commonly SSF ones.

As mentioned above, the removal of many pollutants such as ammonia in a treatment wetland is dependant on microbially-mediated aerobic transformations. The needed oxygen for such reactions can be supplied by wetland plants which "pump" air to microbes in their root zones but there is only a limited amount of oxygen that can be provided in this way. Various other ways are used to overcome this limitation. A simple one is to provide open water areas where surface re-aeration can restore dissolved oxygen to the wastewater being treated, and the marsh-pond-marsh design mentioned above has often been used to facilitate this. Another way is to add air to the wetland cells by placing mechanical aerators in pond cells or open water areas of FWS CWs, or by using submerged perforated or diffuser piping through which air is introduced into the water or under the substrates in SSF wetland cells. By improving aeration, ammonia nitrification rates can be increased to over 95%. With semi-passive EW systems (as compared to passive, ordinary CWs) mechanical methods such as sub-surface aeration from blowers or compressors is often used to greatly enhance performance.

3.4 Treatment Wetlands in the Arctic

Over 45% of all natural wetlands lie above 45º North Latitude, and these are largely tundra, muskeg, taiga and coastal marsh wetlands. Prior to the division of Nunavut from the Northwest Territories, the territories had the second highest total of natural wetland area in Canada, second only to Ontario.

Peatlands of various sorts (bogs, fens) dominate northern natural wetlands. An important northern kind of arctic natural wetland is the **tundra wetland**, a kind of bog/pond mixed wetland. Tundra wetlands may be viewed as almost the natural analogues of marsh-pond-marsh constructed wetlands, and consist of combinations of boggy areas and small ponds. The latter are spongy accumulations of living and dead Sphagnum moss, lichens and other vegetation; the dead plants usually only partly decomposed. Water flow through these areas is partially sub-surface and partly via surface channels. The other aspect of tundra wetlands is numerous shallow ponds that have no drainage to groundwater in the short summers due to underlying permafrost. Frost heaving during winter creates ridges and depressions with unique polygon configurations. In summer in the north, long days lead to the proliferation of algae in tundra wetland ponds, and photosynthesis leads to highly oxic conditions in them.

Three arctic natural treatment wetland systems (Baker Lake, Repulse Bay & Chesterfield Inlet) were studied by Dillon (1997). In the study, Dillon cited work by Hartland-Rowe and Wright (1974) at Hay River and Reid Crowther (1990) at Yellowknife, which, along with other studies indicated that wetlands in the north have the potential to provide efficient secondary and tertiary treatment. Dillon indicated that over the sampling period (early/late June to late August/early September), all three regions exhibited pollutant removal rates equal to or better than that expected from an annual storage lagoon.

Jacques Whitford (2003a) reviewed the sewage treatment facilities in Yellowknife, NT, which combines an initial “lagoon” (actually a series of connected natural ponds converted to WWT use) followed by a series of natural wetlands. Jacques Whitford concluded that the best available technology to achieve compliance with the most stringent effluent standards was to convert the system into an engineered wetland; one which would combine the lagoon treatment with aeration (and possibly chemical phosphorus precipitation in the lagoon), followed by natural wetland treatment in wetland areas “engineered “to enhance wastewater/wetland contact.

A Jacques Whitford review of Chesterfield Inlet’s wetland treatment system in 2003 recommended further study involving field and lab sampling and analyses. Preliminary results presented by Jacques Whitford demonstrated that the long hours of sunlight in summer in the arctic enabled algae to persist in an oxygen generating mode that resulted in water supersaturated with oxygen. This situation enhances sewage breakdown. In addition, the consumption of carbon dioxide by algae resulted in pHs often greater than 10 which, while above licence guidelines, created conditions in the wetland where ammonia stripping to very low levels occurred. Both the Chesterfield Inlet and Coral Harbour wetland treatment systems face the challenge of greater definition to enable regulatory authorities to formally recognize them as part of municipal wastewater systems.

4.0 INFORMATION REVIEW

Several investigations of the Coral Harbour Sewage Treatment system have been undertaken. This information was reviewed prior to the Site Visit and key findings are reported below.

UMA Engineering Ltd., Coral Harbour Sewage and Solid Waste Improvements (1994)

This study was summarized in the 2002 FSC Report, with the key findings including:

- Sewage discharge should be into a “lagoon” with discharge control. The main purpose of the lagoon would be to retain solids and it would not be expected to treat other contaminants.
- Existing natural wetlands downstream of the lagoon should provide adequate treatment.
- Mechanical treatment was not recommended due to extreme operating conditions re temperature, the distance and limited access for maintenance, intermittent high strength waste, and limited availability of trained personnel.

Arctic Environmental Services Review of Natural Wetlands System (1994)

Arctic Environmental Services (AES) was commissioned by the Government of the Northwest Territories to determine the effectiveness of the existing natural wetlands treatment system, and to identify any necessary changes to address public health concerns. Key findings included:

- The existing natural wetland provided good effluent treatment, with 90% removal of BOD/TSS and ammonia within 600 m from the discharge. The first two downstream ponds had a combined detention time of 94 days, and the next pond had a detention time of 236 days.

- There was no reason to enhance the flow patterns through the wetland system.
- A wastewater analysis indicated heavy metals were not present in effluent, but there was a negative impact on water quality from landfill leachate seeping from the Hamlet's landfill located alongside the sewage discharge point...
- Flow from the sewage discharge point was to the east and south.

Ferguson Simek Clark – Sewage Treatment and Solid Waste Improvements (2002)

The objective of this study was to develop a design for a new access road, dumpsite and detention cell retention pond. Key findings included:

- The total area covered by the existing natural treatment wetland system is approximately 10.5 ha, which includes approximately 7 ha of ponds and the remaining 3.5 ha covered by soils. Primary vegetation in the area was reported to be cotton grasses and sedges.
- Effluent flows predominantly to the southeast towards the ocean. Effluent flows through the toe of the expanding solid waste facility.
- The Existing natural wetland system is sufficient for treating sewage for the next 20 years.
- Flow attenuating berms should be installed to direct the effluent.

DIAND Water Licence Inspection Report (2003)

Key findings included the following non-compliance issues related to sewage treatment:

- The absence of containment for the leachate from the Hamlet's landfill.
- Insufficient treatment of the sewage effluent.
- The absence of an Operation and Maintenance Manual for the Sewage and Solid Waste Facilities.
- The absence of sampling records from Monitoring Stations COR-2 and COR-3 for the months of May-August 2003.

The existing sewage detention cell was built during the summer of 2003.

DIAND Water Licence Inspection Report (2004)

Key findings included the following non-compliance issues related to sewage treatment:

- The absence of containment of leachate at the landfill.
- Inadequate segregation of wastes at the landfill.
- Insufficient treatment of sewage effluent.
- Leakage from the berms of the new sewage detention cell.

National Testing Services Laboratory Report (2004)

CGS collected samples of soil materials similar to those which may have been used in constructing the berms of the detention cell. Laboratory results, provided in **Appendix B,** showed negligible clay and silt content in them, which indicates that a berm built from the tested material is unlikely to be watertight.

4.1 Summary

Sewage has been dumped at an open disposal area approximately 3 km north of the Hamlet since at least 1984. Effluent from this dumped sewage appears to have flowed from the dumpsite out across the surrounding tundra to the east and south, eventually reaching the ocean, a distance of between 2.5 and 3 km. Limited analyses to date suggest that existing natural wetlands through which it flows are successful in treating the effluent. In 2003, a containment detention cell was constructed at the sewage dump site to retain solids. Observations in 2004 indicated that the containment berms of the new detention cell leak.

While system analyses in 1994 and 2002 suggest that the existing natural wetlands provide adequate treatment, the wetlands are not formally included in the Hamlet's sewage treatment system permit under its Water Licence. DIAND inspectors noted that samples collected during their inspections did not comply with effluent quality guidelines for ammonia, BOD and fecal coliforms, and that effluent from the new detention cell exhibited toxicity. However, inspection samples were collected from the last point of control (e.g., discharge from the sewage truck or seepage from the detention cell) before it flowed into the wetland. As a result, the beneficial treatment provided by the downstream tundra wetland is not presently considered as part of the Hamlet's sewage treatment system.

In addition, leachate from the nearby landfill appears to be negatively affecting the quality of the sewage effluent in the wetlands system. Construction at the landfill during the summer of 2004 was intended to contain leachate and to help segregate wastes with signs to denote specific designated areas.

In summary, previous analyses suggests that the existing natural tundra wetlands provide sufficient treatment of sewage to meet effluent quality guidelines, but, several issues needed to be addressed to the satisfaction of the Hamlet and the Nunavut Water Board, including:

- Formally incorporating the tundra wetland as part of the sewage treatment facility.
- Addressing the capacity and containment status of the detention cell.
- Establishing an appropriate SNP monitoring station location for compliance monitoring.
- Continued monitoring to confirm effectiveness of the tundra wetland treatment system.
- Diverting all flows from the detention cell to the east to minimize the influence by the solid waste facility and also to prevent them from reaching the built-up area of the community.

5.0 WASTEWATER PROJECTIONS AND CAPACITY REQUIREMENTS

System analysis and design requires projection of wastewater generation rates for the next 20 years. The Nunavut Bureau of Statistics (www.stats.gov.nu.) provides population projections from 2000 - 2020. Table 1 illustrates population projections for the Hamlet of Coral Harbour to 2025, based on an annual increase of 2.45%, as projected by the Nunavut Bureau of Statistics.

Table 1: Population Projections- Coral Harbour, Nunavut

Year	Population
2005	955
2010	1,078
2015	1,219
2020	1,376
2025	1,553

* Figures from Nunavut Bureau of Statistics (www.stats.gov.nu)

Projected sewage generation rates for the period between 2005 and 2025 are illustrated in Table 2 below. Sewage volumes are anticipated to be equal to water consumption volumes. The annual sewage generation is projected, based on a per capita water consumption rate of 100 Liters per capita per day (L/c/d.). The sewage volume for a ten-month storage period each year are also included in the table.

Table 2: Sewage Generation Projections – Coral Harbour, Nunavut

Year	Population	Water Consumption (m^3)	Sewage Volume (m^3)	10 Month Sewage Volume (m^3)
2005	955	34858	34858	29048
2006	978	35697	35697	29748
2007	1,003	36610	36610	30508
2008	1,024	37376	37376	31147
2009	1,049	38289	38289	31908
2010	1,078	39347	39347	32789
2011	1,101	40187	40187	33489
2012	1,128	41172	41172	34310
2013	1,158	42267	42267	35223
2014	1,187	43326	43326	36105
2015	1,219	44494	44494	37078
2016	1,250	45625	45625	38021
2017	1,281	46757	46757	38964
2018	1,312	47888	47888	39907
2019	1,345	49094	49094	40912
2020	1,376	50224	50224	41853
2021	1,409	51429	51429	42858
2022	1,444	52706	52706	43922
2023	1,480	54020	54020	45017
2024	1,516	55334	55334	46112
2025	1,553	56685	56685	47238

Based on a desired decant of the detention cell in fall of each year, the detention cell should be sized with a storage capacity of 10 months (November to August) for the 20 year planning horizon. This would require a capacity of 47,238m^3 for the year 2025. Standard operating conditions require a minimum 1 m freeboard to be maintained throughout operation.

The dimensions of the existing detention cell are 170 m by 155 m with a planned average depth of 1.7 m. Allowing for reduced capacity due to the interior side slopes on the berms the estimated capacity of the detention cell would be approximately 41,200 m^3. Based on sewage volume projections contained in Table 2 above, the current detention cell's capacity for 10 month annual storage would be exceeded by 2020. An additional 6,000 m^3 of storage capacity is required for the detention cell to meet the annual 10 month storage requirement to 2025.

6.0 TREATMENT REQUIREMENTS

The Canadian Water Quality Guidelines for Freshwater Aquatic Life apply to the discharge of the effluent from the last control point of the Hamlet's sewage treatment facilities. A critical contaminant addressed in these guidelines is ammonia nitrogen. Its maximum allowable concentrations are 2.2 mg/L and 1.37 mg/L at pHs of 6.5 and 8.0, respectively, at 10^0C. Environment Canada is considering implementing guidelines which will include effluent pollutant concentration targets of 40 mg/L BOD, 40 mg/L TSS and 10 mg/L ammonia. It is anticipated that an ammonia level of 10 mg/L in effluent will be included in the next Water Licence for the Hamlet. Consequently, any evaluation of the wetlands treatment capacity will have to take into account the application of the more stringent Canadian Water Quality Guidelines for Freshwater Aquatic Life (CWQG[FAL]) and proposed new Environment Canada guidelines

In addition to meeting Canadian Water Quality Guidelines and potential requirements of Environment Canada and the next Water Licence, effluent from the Hamlet's WWT facilities should not be toxic to fish. Environment Canada is responsible for administering subsection 36(3) of the *Fisheries Act*, (commonly referred to as the "general prohibition"), in which it is a violation to deposit a deleterious substance into water frequented by fish, unless authorized by a regulation recognized by the *Act*.

It is reasonable to assume that if a wastewater discharge complies with the CWQG (FAL), then it will also likely comply with proposed new Environment Canada Guidelines, future Water Licence requirements, and the *Fisheries Act*. Specific toxicity testing may be required to demonstrate compliance with the *Fisheries Act*.

Based on the conservative natural wetland sizing criteria presented in Section 3.2 (50 ha/1000 m^3/d), the minimum size of a natural wetland to treat the 2005 10 month sewage generation rate (47238 m^3 or 157 m^3/d) would be 7.9 ha.

7.0 SITE VISIT AND FINDINGS

Jacques Whitford representatives Peter Hagar, P.Eng. and Dr. James Higgins, P.Eng. visited the site from August 17 to 20, 2004. Observations made during the site visit are summarized below.

7.1 Effluent Flow Directions

The sewage detention cell was observed to seep from several locations. Effluent from the leaking detention cell appeared to travel in several directions as it moved into the tundra wetland, generally initially in a southeast direction and later easterly towards the sea. Leachate from the adjacent landfill was also observed to be flowing overland into the tundra wetland, joining one of the seeps just below the landfill. The seepage flows were followed to help identify the boundaries of the tundra wetland, which, it was believed with minor engineered modifications, could define combined detention cell/tundra wetland sewage treatment facilities for the Hamlet.

Only shallow water was observed over part of the floor of the detention pond and it was clear that added sewage quickly was flowing out through its berms. (Water was collecting mostly in the southeast corner.) There was no flow or seepage from the detention cell at its intended discharge point immediately east of the center of its east berm. (A ditch running east from the intended discharge point was dry.) There was only a minor amount of seepage on the north side of the detention cell and the bulk of the seepage at the time of the Site Visit appeared to be in the southeast corner of the cell and on its south side. (The lack of a gate in the high fence on the berms around the detention cell made investigation difficult.)

Ground east of the detention cell sloped gently away to Hudson Bay, a few kilometers east. Two main seepage flows were followed from the detention cell through the tundra wetland.

One was from the southeast corner of the detention cell and flowed initially east on the surface in two streams and/then later sub-surfaced through a boggy area south of the detention cell's southeast corner, then flowed into a series of shallow ponds and then south through further boggy areas and ponds in terrain broken by north-south low rocky outcrops, each tens of meters long. The seep eventually joined flow from the second seep below a rocky ridge several hundred meters east of the landfill. There were a large amount of goose droppings on the ground around and in the seep.

The second main seep, from the south side of the detention cell, that flowed diagonally off south-southeast below (east of) the landfill quickly becoming sub-surface below the landfill then via alternate boggy areas and shallow ponds around the outcrops. Contaminated landfill leachate flowed from a pond below the landfill then through another large pond east of the recycle area of the landfill, then a boggy area and another large pond before it flowed south then north to join the second seep. Accordingly, the flow passed south-southeast through two larger ponds, then reversed and flowed almost north to join that from the first seep via several smaller ponds and alternating boggy areas. The combined flow then meandered roughly east through further bog/small ponds of the tundra wetland across a plain towards Hudson Bay. The tundra wetland ended as water flowed into several larger ponds forming part of a coastal marsh wetland near the sea.

Water in the pond below the landfill was relatively warm (~ 10 ºC) and densely colonized by algae. (In fact, the pond was acting almost as an algal scrubber and the algae's photosynthesis had led to exceptionally high dissolved oxygen levels in the water.)

The terrain south of the two larger ponds in the second seep bog/pond flow channel (one northeast of the other) of the tundra wetland showed clear indications that overflow towards the Hamlet in the distance a few kilometers to the south-southeast had occurred in the past, although there was no visible flow in that direction during the Site Visit.

A large pond on the plain close to Hudson Bay, in the area where the tundra wetland and the coastal marsh merged, was originally selected as a point where final discharge to the sea could occur. However, further investigation identified the presence of fish and shrimp in that pond. Accordingly, a more upstream water body more clearly still in the tundra wetland was defined as the final control point of the wetland treatment system. A stake was placed at this point to mark a final SNP point. The proposed final SNP point and other components of the tundra wetland are illustrated in Drawings 3 and 4.

As was mentioned, there were indications that at times some of the wastewater flowed not east to the sea but instead south-southeast towards the Hamlet. A number of structures are proposed to confine sewage effluent within the proposed tundra wetland treatment system, including diversion berms and ditches. Unlike the berms of the detention cell, these berms should consist of, or be cored with, impermeable material to stop leakage through them. A main berm is proposed south of the ponds below the landfill to prevent effluent from flowing south-southeast toward the community. As leachate will continue to be generated from the solid waste landfill, this berm will be configured to continue divert landfill leachate into the wetland treatment system and to prevent its overflow south during flood conditions. A second proposed diversion berm should be located south of the last pond before the second seep flow doubles back north to join that from the first seep. The purpose of these berms would be to prevent flow in these areas from traveling south towards the community during the freshet.

Apparently little seepage is occurring through the north berm of the detention cell, and any that did during the freshet would eventually flow east into the tundra wetland parts on the plain below where the two major seeps merge, so no action is needed in that quarter.

Ditching will enable precipitation in the watershed to be collected and diverted from treatment pond areas. This would preserve the detention time of the areas of the wetland which are providing the majority of the treatment. Due to limited opportunity and access problems during the Site Visit, a more detailed investigation to determine the need for additional diversion berms or ditches is required. The focus of this investigation can be restricted to the area identified as the proposed wetland area in Drawing 3.

The boundary of the proposed wetland treatment system encloses an area of approximately 480,000 m^2 of which 80,000 m^2 are shallow bodies of water and 400,000 m^2 are boggy areas.. With the proposed berm construction and the tundra wetland area defined as illustrated in Drawings 3 and 4, the working tundra wetland size is estimated to be at least 200,000 m^2 or 20 ha. This area is significantly larger than that envisaged in the AES report which gave an area of 11.4 ha. In either case, the tundra wetland will still be much larger than the 7.9 ha of minimum natural wetland size needed under conservative assumptions (see Section 6). The detention cell constructed in 2003 has a surface area of approximately 2.6 ha.

7.2 Effluent Treatment

The Site Visit confirmed that the effluent flow overland was providing excellent wetland treatment. During the August Site Visit, Jacques Whitford collected samples from several locations to characterize the discharge from the detention cell as it traveled through the tundra wetland. Sample collection locations are summarized in the following table and are illustrated on Drawing 3. The sampling was conducted with the assistance of Ronnie Ningeongan, of Coral Harbour who collected a second set of samples on September 16, 2004. Inclement weather prevented sample collection in October.

Table 3: Effluent Sample Locations

Sample Identifier	Sample Location
1 (Detention Cell)	Within the sewage detention cell.
2 (Seep)	Outside of detention cell where effluent has leaked out.
3 (Flow point)	A pond within the wetland treatment area in which sewage effluent was observed entering
4 (Duck/Loon Lake)	Outflow downstream of location #3 within wetland treatment area.
5 (SNP Station)	Recommended location for SNP licence monitoring.

Field analyses demonstrated that ammonia nitrogen was reduced to trace quantities within 250 m downstream of the detention cell, which implies sewage BOD and TSS removal were also high, although it should be noted that wetlands (both natural and constructed) generate organic material as part of their operations. Such material may be measured as BOD and suspended solids but has no relation to the BOD and suspended solids in the detention cell effluent (most of which was very quickly removed in the tundra wetland's initial boggy area). In addition the area east of the detention cell was frequented by geese and large amounts of goose droppings were observed everywhere. These too could contribute to pollution in the water, but any effect that they might have been having was not apparent due to the high treatment capabilities of the tundra wetland.

The presence of water fleas at sample location # 3 prevented the collection of a representative effluent sample. However, these organisms are an indicator of clean water, although from an analytical perspective, they too might be measured as suspended solids and BOD. Therefore the system in its current natural condition exhibits characteristics of a system which can meet stringent discharge criteria.

Tables 4 to 6 document the laboratory analytical results for sewage samples collected in August and September, respectively. Laboratory analytical certificates are included in **Appendix B**.

Table 4: Laboratory Results of August 20, 2004 Samples

Sample #	Ammonia	Total Phosphorus	BOD	Fecal Coliform CFU/dl	TSS	Nitrite
#1 Detention Cell	30.1	6.77	170	>110000	380	0.02
#2 Seep	16.9	4.06	25	15000	NA	NA
#4 (Duck/Loon Lake)	<0.01	3.04	80	930	NA	NA
Location	0.06	0.204	< 6	2300	17	0.02
Applicable Guidelines			120 mg/L	$1X10^6$	180 mg/L	

Notes: All units in mg/L, unless otherwise noted

Table 5: Laboratory Results of August 23, 2004 Samples

Sample #	Ammonia	Total Phosphorus	BOD	Fecal Coliform CFU/dl	TSS	Nitrate + Nitrite-N
#5 (Proposed SNP Point)	0.75	0.034	< 6	23	< 5	0.07
Applicable Guidelines			120 mg/L		180 mg/L	

Notes: All units in mg/L, unless otherwise noted

Table 6: Laboratory Results of September 17, 2004 Samples

Sample #	Ammonia	Total Phosphorus	BOD	Fecal Coliform CFU/dl	TSS	Nitrite
#1 (Seep)	35.7	3.75	41	43	51	NA
#3 (Flow)	0.19	0.041	< 6	23	< 5	NA
#4 (Duck/Loon Lake)	0.88	0.039	< 6	230	< 5	NA
#5 (SNP)	<0.01	0.003	< 6	9	< 5	NA
Applicable Guidelines			120 mg/L		180 mg/L	

Notes: All units in mg/L, unless otherwise noted

Laboratory analyses of the samples confirmed field observations; that the tundra wetland was capable of treating sewage from the Hamlet to discharge concentrations that were in compliance. The BOD, TSS and ammonia levels measured at sample locations #3 and #4 demonstrated that the anticipated Environment Canada guidelines of 40 mg/L BOD, 40 mg/L TSS and 10 mg/L ammonia could be met by the tundra wetland treatment system.

Further support for effluent compliance was demonstrated by the results of the fish toxicity and Microtox testing results. Effluent samples collected on August 20, 2004 were forwarded to Envirotest Laboratories for analysis of fish toxicity. The 96 hour LC_{50} test procedure was conducted using rainbow trout and is one of two test procedures recognized by the Department of Fisheries and Oceans (DFO). The effluent sample from sampling location #4 (the proposed SNP location) also exhibited no toxicity. The results of the fish toxicity tests are included in Appendix B. These results indicate that the tundra wetland system can comply with the DFO's requirements as well. Microtox testing was conducted as well. While the Microtox test is not recognized by DFO, it is a lower cost test which is simpler and safer to undertake. The results of the Microtox tests also confirmed that the tundra wetland treatment system can comply with the DFO requirements. The Microtox test results are provided in **Appendix B**.

Tables 7 to 9 document the analytical results for metals for the samples collected in August and September respectively. Laboratory analytical certificates are included in **Appendix B**.

Table 7: Laboratory Results of Metals Analysis – August 20, 2004

Parameter	Sample #'s				Applicable Guidelines
	Detention Cell Sample #1	Duck Pond Sample #2	Seep Sample #3	Location	
Sliver	<0.0005	<0.0005	NA	<0.0005	0.0001
Aluminum	0.05	0.05	NA	0.03	0.005-0.1
Arsenic	0.0015	0.0055	NA	<0.0005	0.005
Boron	0.408	0.722	NA	0.074	
Barium	0.0024	0.0109	NA	0.0154	
Beryllium	<0.001	<0.001	NA	<0.001	
Bismuth	<0.0001	<0.0001	NA	<0.0001	
Calcium	45.3	58.6	NA	64.7	
Cadmium	<0.0002	<0.0002	NA	<0.0002	0.000017
Cobalt	0.0009	0.0015	NA	0.0002	
Chromium	0.002	0.002	NA	0.001	0.001
Cesium	<0.0001	<0.0001	NA	<0.0001	
Copper	0.0066	0.0034	NA	0.0006	0.002-0.004
Iron	0.15	0.12	NA	0.06	0.3
Potassium	24.9	38.8	NA	3.72	
Lithium	<0.005	<0.005	NA	<0.005	
Magnesium	5.06	19.8	NA	9.00	
Manganese	0.0779	0.0114	NA	0.0337	
Molybdenum	0.0004	0.0023	NA	0.0009	0.073
Sodium	127	158	NA	42.3	
Nickel	0.0058	0.0098	NA	0.0037	0.025-0.15
Phosphorus	2.54	0.29	NA	0.06	
Lead	0.0017	0.0038	NA	0.0009	0.001-0.007
Rubidium	0.0306	0.0374	NA	0.0032	
Antimony	<0.001	0.014	NA	<0.001	
Selenium	<0.001	0.004	NA	<0.001	0.001
Silicon	6.6	3.3	NA	0.6	
Tin	0.0006	0.0002	NA	<0.0002	
Strontium	0.0596	0.320	NA	0.122	
Tellurium	<0.0005	<0.0005	NA	<0.0005	
Titanium	<0.0005	<0.0005	NA	<0.0005	
Thallium	0.0003	0.0004	NA	0.0003	0.0008
Uranium	0.0007	0.0006	NA	0.0004	
Vanadium	0.003	0.003	NA	0.002	
Tungsten	<0.0002	<0.0002	NA	<0.0002	
Zinc	0.021	<0.005	NA	<0.005	0.03
Zirconium	0.0008	<0.0004	NA	<0.0004	

Table 8: Laboratory Results of Metals Analysis – August 23, 2004

Parameter	Sample #	Applicable Guidelines
	Sample 5 Lowest Point	
Sliver	<0.001	0.0001
Aluminum	0.03	0.005-0.1
Arsenic	0.0006	0.005
Boron	0.06	
Barium	0.0179	
Beryllium	<0.001	
Bismuth	<0.0001	
Calcium	60.5	
Cadmium	<0.0002	0.000017
Cobalt	0.0003	
Chromium	<0.001	0.001
Cesium	<0.0001	
Copper	0.004	0.002-0.004
Iron	0.09	0.3
Potassium	6.5	
Lithium	<0.01	
Magnesium	6.71	
Manganese	0.0118	
Molybdenum	0.0009	0.073
Sodium	67.8	
Nickel	0.004	0.025-0.15
Lead	0.0009	0.001-0.007
Rubidium	0.0095	
Antimony	<0.001	
Selenium	<0.001	0.001
Tin	<0.0005	
Strontium	0.0923	
Tellurium	<0.001	
Titanium	0.0013	
Thallium	0.0001	0.0008
Uranium	0.0003	
Vanadium	<0.001	
Tungsten	<0.0002	
Zinc	0.01	0.03
Zirconium	0.0006	

Table 9: Laboratory Results of Metals Analysis – September 17, 2004

Parameter	Sample #'s				Applicable Guidelines
	Sample 1 (Seep)	Sample 2 (Flow)	Sample 3 (Loon Lake)	Sample 4 (SNP)	
Sliver	<0.001	<0.001	<0.001	<0.001	0.0001
Aluminum	0.12	0.02	0.09	0.08	0.005-0.1
Arsenic	0.0015	<0.0005	0.0005	<0.0005	0.005
Boron	0.34	0.05	0.04	<0.03	
Barium	0.0065	0.0154	0.0184	0.0143	
Beryllium	<0.001	<0.001	<0.001	<0.001	
Bismuth	0.0001	<0.0001	<0.0001	<0.0001	
Calcium	55.7	90.1	68.4	60.6	
Cadmium	<0.0002	<0.0002	<0.0002	<0.0002	0.000017
Cobalt	0.0012	0.0005	0.0003	<0.0002	
Chromium	0.002	0.002	0.002	0.001	0.001
Cesium	<0.0001	<0.0001	<0.0001	<0.0001	
Copper	0.021	0.003	0.002	0.002	0.002-0.004
Iron	1.36	<0.05	<0.05	0.06	0.3
Potassium	26.7	4.0	5.0	2.8	
Lithium	0.01	<0.01	<0.01	<0.01	
Magnesium	6.86	9.81	7.30	6.76	
Manganese	0.299	0.0360	0.0246	0.0011	
Molybdenum	0.0006	0.0013	0.0060	0.0005	0.073
Sodium	134	50.3	62.4	26.8	
Nickel	0.008	0.005	0.004	0.129	0.025-0.15
Lead	0.0009	<0.0005	<0.0005	<0.0005	0.001-0.007
Rubidium	0.0326	0.0048	0.0086	0.0053	
Antimony	0.001	<0.001	<0.001	<0.001	
Selenium	<0.001	<0.001	<0.001	<0.001	0.001
Tin	0.0011	<0.0005	<0.0005	<0.0005	
Strontium	0.0761	0.158	0.104	0.0990	
Tellurium	<0.001	<0.001	<0.001	<0.001	
Titanium	0.0028	0.0016	<0.0009	0.0012	
Thallium	<0.0001	<0.0001	<0.0001	<0.0001	0.0008
Uranium	0.0007	0.0005	0.0004	0.0003	
Vanadium	0.001	<0.001	<0.001	<0.001	
Tungsten	0.0002	<0.0002	<0.0002	<0.0002	
Zinc	0.03	0.02	<0.01	0.05	0.03
Zirconium	0.0010	<0.0004	<0.0004	<0.0004	

Analysis of the samples for metals indicates low to non-detectable concentrations for most parameters with the exception of the following:

- Exceedences of the CCME Guideline for chromium and copper in the detention cell in August;
- Exceedences of the CCME Guideline for aluminum, chromium, copper and iron in the seep sample in September;
- Exceedences of the CCME Guideline for chromium and selenium in sample # 2 in August;
- Exceedences of the CCME Guideline for chromium in samples #2 and #3 in the September sample; and
- Exceedences of the CCME Guideline for zinc in sample # 4 in the September sample.

7.3 Tundra Wetland Loadings

Assuming that the detention cell functions as a primary treatment unit, the hydraulic and organic loadings to the tundra wetland are provided in Tables 10 to 12. Tables 10 to12 also list the detention time of the water bodies, assuming an average depth of 0.4 m, and discharge rates calculated based on 50, 60 and 75 days of discharge, respectively.

Table 10: Discharge Loading for 50 day Detention Cell Discharge

Year	Organic Load with 50-day discharge[1]	Hydraulic Load with 50-day discharge[2]	Detention Time of 8 ha of ponds at 0.4 m deep	Detention Time during 1 inch Rain Storm	Detention Time in 1-inch Rain event if 50% of rainwater drained by ditches
2000	8	161	10.3 days	1.72 days	3.44 days
2005	9	165	10.0 days	1.70 days	3.41 days
2010	10	169	9.8 days	1.69 days	3.37 days
2015	11	174	9.5 days	1.67 days	3.34 days
2020	13	180	9.2 days	1.65 days	3.30 days
2025	15	186	8.9 days	1.63 days	3.26 days

Notes: [1] units are kg of BOD per hectare per day
[2] units are m^3 of effluent per m^2 of wetland per day

Table 11: Discharge Loading for 60 day Detention Cell Discharge

Year	Organic Load with 60-day discharge[1]	Hydraulic Load with 60-day discharge[2]	Detention Time of 8 ha of ponds at 0.4 m deep	Detention Time during 1 inch Rain Storm	Detention Time in 1-inch Rain event if 50% of rainwater drained by ditches
2000	7	135	12.3 days	1.82 days	3.66 days
2005	8	138	12.0 days	1.81 days	3.61 days
2010	9	142	11.6 days	1.79 days	3.58 days
2015	10	146	11.3 days	1.77 days	3.55 days
2020	11	151	10.3 days	1.76 days	3.51 days
2025	12	156	10.5 days	1.73 days	3.47 days

Notes: [1] units are kg of BOD per hectare per day
[2] units are m^3 of effluent per m^2 of wetland per day

Table 12: Discharge Loading for 75 day Detention Cell Discharge

Year	Organic Load with 75-day discharge[1]	Hydraulic Load with 75-day discharge[2]	Detention Time of 8 ha of ponds at 0.4 m deep	Detention Time during 1 inch Rain Storm	Detention Time in 1-inch Rain event if 50% of rainwater drained by ditches
2000	6	104	15.4 days	2.46 days	4.92 days
2005	6	107	15.0 days	2.44 days	4.88 days
2010	7	110	14.6 days	2.41 days	4.83 days
2015	8	113	14.1 days	2.39 days	4.78 days
2020	9	117	13.7 days	2.36 days	4.73 days
2025	10	122	13.2 days	2.33 days	4.67 days

Notes: [1] units are kg of BOD per hectare per day
[2] units are m^3 of effluent per m^2 of wetland per day

The tables indicate the impact of precipitation on detention time based on average loadings as well as for a 2.54 cm rain event. Ditching can be used to keep precipitation out of the effluent pathway through the tundra wetland and preserve some of the detention time, which adds assurance that even if there is a heavy rain, the effluent will undergo treatment for a reasonable period of time. Considering that the BOD test is a 5-day test, 5 days is a useful reference time.

The organic loads range from 6 kg/ha/d to 15 kg/ha/d and the hydraulic load ranges from 104 m^3/ha/d to 186 m^3/ha/d.. Both of the loads are within the wetland design rates of 0.6 -15 kg/ha/d for organic load and 18 - 400 m^3/ha/d for hydraulic loads recommended for wetland design by Dillon.

Samples submitted for analyses were collected in August and September; as such, there are no data to assess tundra wetland treatment in June or July. Meltwater would be expected to be cold, and the hydraulic load of the snowmelt in June would be expected to be high, creating conditions where treatment would might become inadequate for a period. However, freeze thaw action is effective for destroying fecal coliforms and the nearly 24 hour sunlight stimulates photosynthesis.

Dilution is a process which, while seeming to lower the concentrations of various pollutants, also has the negative impact of reducing the detention time in the tundra wetland. To reduce an influent ammonia nitrogen level of 50 mg/L to less than 2 mg/L, a 25:1 dilution ratio is needed. If the tundra wetland has a detention time of 25 days at a 1:1 dilution, a 25:1 dilution ratio would reduce the detention time to a single day. In cases where there is large dilution, diversion ditches to exclude meltwater from the tundra wetland's ponds may be beneficial for early season treatment. Alternatively, effluent can be contained until the spring surge has passed. However, reducing the discharge period would increase the hydraulic load during the discharge period.

7.4 Summary

The Study results suggest that the effluent quality from the existing tundra wetland can meet proposed Environment Canada Guidelines, even if loadings increase in the future. However, two issues require more study. First, the degree of effluent treatment early in the year requires study. Secondly, there is a natural phenomena that occurs in frozen-over shallow ponds in which ammonia may be released early in the spring after thawing as a result of decay under the ice of the biomass that grew in the summer, whether sewage is added to a pond or not. The impact of the decayed biomass in spring requires further study. Spring ammonia concentrations in ponds outside of the tundra wetland should be compared with ponds in the wetland to determine the effects of sewage loading.

More detailed engineering is required to establish precise locations of all recommended berms. However, tentative locations for two main berms that would confine all sewage to within the identified area are indicated in Drawing 4 in **Appendix A**. The detention cell should be monitored for outflow in late fall to determine when the seepage stops. Also, monitoring during the freshet is required; not only to determine when seepage starts, but also to ensure that the seepage will not compromise the integrity of the berms. Additional work in 2005 should be considered as continued investigation of addressing effluent storage, and if the monitoring at the designated SNP point complies with effluent guidelines, the repairs required to the detention cell might not need to be undertaken.

8.0 GEOTECHNICAL EVALUATION

EBA Engineering Consultants (EBA) was retained to perform a geotechnical evaluation of the berms enclosing the sewage detention cell. EBA's report is contained in **Appendix C**. EBA found that the detention cell, as constructed, is not impervious. EBA presented four options for consideration:

1. Incorporate a zone of relatively impervious fine-grained material (e.g., clay) onto the existing berms.
2. Install a liner in the detention cell.
3. Reconstruct the berms such that permafrost would agrade into the berms and present an impervious barrier.
4. Control the seepage downstream of the detention cell.

In general, Option 1 is unlikely to be successful and would be relatively expensive. Option 2 would be expensive and difficult to implement given that the detention cell is in active use and there are rocky outcrops on its bottom. Option 3, while it might be feasible, requires a large capital expenditure. Given the shortfall in the long-term storage capacity and the fact that detention cell is currently in use, Option 4 may be the most practical alternative, involving building impervious dykes to contain future effluent seepage and diversion berms downstream of the current cell to ensure effluent remains within the tundra wetland.

9.0 LEACHATE DISCHARGE GUIDELINES AND REGULATORY BODIES

Nunavut has adopted the Guidelines for Industrial Waste Discharges in the NWT as the Nunavut Guideline for Industrial Waste Discharge. The leachate seeping from the landfill should be considered to be an industrial waste discharge and monitored accordingly. The guidelines recommend the following standards for process effluents discharged to municipal sewage systems:

Table 13: Standards for Process Effluent Discharged to from Municipal Sewage Systems

Parameter	Effluent Objective (mg/L)
Aluminum	50
Arsenic	1
Barium	5
Biological Oxygen Demand	500
Cadmium	2
Chlorides	1500
Chromium	5
Copper	5
Cyanide	2
Fluoride	10
Lead	5
Iron	50
Mercury	0.1
Nickel	5
Oil & Grease	150
pH Range	6.5-10.5
Phenolic Compounds	1
Phosphorous	100
Silver	5
Sulphates	1500
Sulphides	2
Suspended Solids	600
Tin	5
Zinc	5

10.0 A COST COMPARISON STUDY OF WETLAND TREATMENT VERSUS MECHANICAL SEWAGE TREATMENT OPTIONS.

The current and proposed Coral Harbour sewage treatment facilities consist of a storage detention cell and a tundra wetland treatment system. While some improvements are necessary, it is considered that this system can effectively treat the Hamlet's sewage for a 20-year period in compliance with applicable legislation.

As part of the municipal infrastructure planning process, capital and operating and maintenance (O&M) costs for the tundra wetland system should be compared to other potential options such as those for a mechanical sewage treatment plant.

A mechanical sewage plant would be capable of meeting mandated discharge requirements. The community of Pangnirtung in the Baffin Region recently installed a mechanical sewage treatment plant. Given similarities in population and wastewater streams, the actual costs incurred at Pangnirtung are considered applicable to those that might be incurred at Coral Harbour, should a mechanical plant be built there. The capital cost of the mechanical sewage treatment plant in Pangnirtung was $4 million, with annual O&M costs of approximately $300,000 (Patricio Fuentes, CG&S, *Personal Communication*). One of the factors influencing O&M costs for a fossil-fueled mechanical sewage treatment plant is the cost of energy which is expected to continue to rise

A tundra wetland treatment system, including the modifications discussed in this report, would require capital expenditures for detailed surveying and engineering and construction of diversion berms and ditches. Estimated capital costs are as follows:

• Detailed Engineering and Surveying	$ 75,000
• Berm construction (3000m^3 @$35/m^3)	$105,000
• Ditching (lump sum 10 days @2000/day)	$ 20,000
Total	**$ 200,000**

Detailed survey and engineering would confirm the location and volumes of berms to be constructed and ditches to be excavated.

Annual operating (monitoring and maintenance) costs are estimated at $500/ha or approximately $10,000 for a 20 ha system at Coral Harbour.

The tundra wetland system has much lower capital and operating costs than those for a mechanical sewage treatment plant. Additional benefits are that it is simple to operate, requires limited expertise from outside of the community, and is not subject to external cost factors such as the rising cost of energy.

11.0 CONCLUSIONS AND RECOMMENDATIONS

Jacques Whitford was requested to investigate the treatment of sewage by tundra wetlands at Coral Harbour, Nunavut. The Hamlet of Coral Harbour's current sewage treatment system consists of a storage detention cell followed by treatment of its effluent by an adjacent natural wetland. Effluent licence limits are prescribed in the Hamlet's Water Licence issued by the Nunavut Water Board. Effluent criteria contained in the licence must be achieved at the last point of control, which is currently defined as the outflow of the detention cell.

Inspection of the sewage treatment system by Indian and Northern Affairs Canada, on behalf of the Water Board, identified the following concerns with the Hamlet's sewage treatment facilities:

- Insufficient sewage treatment (based on effluent samples from the outflow of the detention cell).
- Leakage through the detention cell's containment berms.
- Uncontained leachate discharge from the landfill adjacent to the sewage detention cell.

Jacques Whitford's investigation of the sewage treatment facilities included a review of available information; projection of wastewater treatment needs and requirements; a Site Visit to delineate the tundra wetland treatment facility and collect effluent samples at different points in the system; field and laboratory analyses of effluent samples; and the preparation of a report on the findings of the Study.

Based on a 10 month per year storage period (60 day discharge), the current detention cell's capacity will be exceeded by the year 2020. The berms were confirmed to be leaking during the August 2004 Site Visit. A geotechnical investigation confirmed that the detention cell, as constructed, cannot hold liquid without repair. However, it may be most effective to build impervious dykes downstream of the existing detention cell to divert effluent within a tundra wetland treatment facility and at a later date to provide for expanded detention cell storage. The proposed location of two diversion berms are identified on Drawing 4. However, additional topographical surveys and detailed engineering are required to establish the precise locations for the berms and for any drainage diversion ditches.

A proposed natural tundra wetland sewage treatment area was identified during the Site Visit. The proposed tundra wetland sewage treatment area comprises of an area of approximately 480,000 m^2 of which 80,000 m^2 are shallow bodies of water and 400,000 m^2 are boggy areas, although the working wetland space is estimated to be only 200,000 m^2 or 20 ha. The newly defined tundra wetland treatment area discharges into a small lake at sample point 5 (SNP) (identified on Drawing 3). It is suggested that this be the point of control where Water Licence effluent discharge criteria would be met.

Field and laboratory analyses of samples indicate that the tundra wetland system is effectively treating sewage effluent from the detention cell levels that meet Water Licence criteria and proposed Environment Canada discharge criteria. Toxicity testing of effluent collected during the Site Visit indicates that effluent at the SNP-1 is not toxic to fish. Ongoing monitoring of effluent at this location is recommended to further evaluate wetland treatment throughout the open water season. Organic and hydraulic loads to the tundra wetland resulting from a 50 to 75 day detention cell discharge are within acceptable limits proposed by Dillon in their study on sewage treatment by wetlands.

Some metals were detected in effluent samples in the wetland above the Canadian Water Quality Guidelines for the Protection of Freshwater Aquatic Life. Based on these results, it is likely that they were sourced from leachate from the solid waste landfill which is entering the tundra wetland .

Utilizing a natural wetland-based treatment facility results in considerably lower capital and O&M costs than would be experienced with a mechanical sewage treatment plant.

In conclusion, the existing tundra wetland treatment facility is considered to be sufficient to achieve compliance with current and proposed effluent criteria for the 20-year planning horizon as long as the following actions are undertaken:

- Detailed topographic survey of the proposed tundra wetland treatment area to confirm areas for the installation of diversion berms and ditches;
- Detailed design of the diversion berms and ditches;
- Establishment and recognition of location SNP as the last point of control in the Hamlet's Water Licence and the point at which compliance would be required;
- Continued monitoring of seepage from the detention cell to determine the annual period in which seepage occurs;
- Continued effluent monitoring throughout the open water season to determine treatment levels and capacity at different times and to identify the potential effects of increased ammonia release during spring; and
- Installation of a gate in the fence surrounding the lagoon to provide for easy access for inspection and sampling.

12.0 CLOSURE

This report has been prepared for the sole benefit of the Department of Community Government Services, Government of Nunavut. The report may not be relied upon by any other person or entity without the express written consent of Jacques Whitford and the Department of Community Government Services.

This report was prepared by Peter Hagar, P.Eng. and reviewed by Dr. Jim Higgins, P.Eng.

Respectfully submitted,

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13.0 REFERENCES

Arctic Environmental Services Ltd. (AES), 1994. “Review of the Natural Wetlands Sewage Disposal System at Coral Harbour, NWT”. Prepared for the Department of Municipal and Community Affairs, Government of the Northwest Territories.

Dillon Consulting Limited. 1998. “Sewage Treatment Using Tundra Wetlands.” Prepared for the Department of Municipal and Community Affairs, Government of the Northwest Territories.

EBA Engineering Consultants Ltd., 2004. “Draft Sewage Dyke Evaluation, Coral Harbour, NU. Submitted to Jacques Whitford Limited.

Ferguson Simek Clark Engineers and Architects, March 2002. “Coral Harbour Sewage Treatment and Solid Waste Site Improvements” Prepared for the Department of Community Government and Transportation, Government of Nunavut.

Hammer, 1996 “Creating Freshwater Wetlands”, Second Edition, D.A. Hammer, CRC Press, Boca Raton, FL.

Hartland-Rowe, R.C.B and P.B. Wright. 1974. “Swamplands for Sewage Effluents, Final Report.” Environmental - Social Committee, Northern Pipelines, Department of Indian and Northern Affairs. Ottawa, Ontario.

Higgins**,** and MacLean, 1999. *“*Constructed Wetland Treatment Systems for Airport Stormwater Runoff Which Do Not Attract Wildfowl,” Presentation to SAE G-12 Committee, Glycol Deicing, J**.** Higgins, and M. MacLean, Nov. 9, 1999, Washington, DC, USA.

Indian and Northern Affairs Canada, 2003 and 2004. “Water Licence Inspection Reports”. Nunavut Water Board Licence # NWB3COR0207.

Jacques Whitford Limited, 2003. “Fiddler’s Lake Sewage Lagoon Treatment Study”. Prepared for the City of Yellowknife. Yellowknife, Northwest Territories.

Jacques Whitford Limited, 2003b. “ Environmental Liability Assessment at Chesterfield Inlet, Nunavut.” Prepared for the Hamlet of Chesterfield Inlet. Nunavut.

Kadlec & Knight, 1995 “Treatment Wetlands” R. Kadlec & R. Knight, (First Edition), CRC Press, Boca Raton, FL

Knight et al., 1987 “Performance Of A Natural Wetland Treatment System For Wastewater Management”, R. Knight, T. McKim, and H. Khol, *J. Water Pollut. Control Fed*., 59:746-754.

UMA Engineering Ltd. 1994. “Coral Harbour Sewage and Solid Waste Improvements: Design and Operations Concept Report.” Prepared for the Department of Municipal and Community Affairs, Government of the Northwest Territories.

APPENDIX A

DRAWINGS

APPENDIX B

LABORATORY CERTIFICATES

APPENDIX C

EBA GEOTECHNICAL REPORT