The service life of process equipment is heavily dependent on the implementation of the maintenance program. Experience has shown that in small plants equipment maintenance is lacking and this can lead to premature failure. Dillon contacted an SBR supplier and a plant operations firm in order to identify the typical service life that can be expected assuming proper maintenance. The following summarizes these discussions:

- **IPEC Drum Screen**: 20 -25 year service
- **Pumps**: 5 – 10 years service life – heavily dependent of inspection and occasional cleaning. In remote communities it is often more economical to replace smaller pumps (<7.5 HP) than repair. Consideration should be given to providing shelf spares for all pumps in this category.
- **Blowers**: 10-15 years typical service life, with many cases of over 20 years with reasonable maintenance.
- **Diffusers**: 10 years typical service life. Equipment cost is minimal.
- **Floating Decanter**: 20 years typical service life.
- **Tanks and Pipes**: 50+ years for stainless steel or glass fused-to-steel tanks, assuming they are not frozen or otherwise abused.

The above list shows that the majority of the replacement costs will be incurred at some time during the twenty year horizon. By 20-30 years the building electrical, mechanical and structural components will also need upgrades. No cost estimates were attempted for this work as the degree of confidence would be extremely very low.

5.0 Option No 2: P-Lake Sewage Lagoon

5.1 Introduction

The terrain in the Cape Dorset area is rocky and hilly, and this makes finding a suitable lagoon site very challenging. This also explains why the existing lagoon is located in a valley with little opportunity for expansion – there was simply no other obvious location for the lagoon.

Besides the existing lagoon, three other lagoon sites have been considered in previous studies. One of these (**Site R**) was rejected due to the proximity to the airport and the increased risk of bird strikes. The second alternative was **Q Lake**, a small lake located east of the community. This option was rejected after the community water line froze and the lake was used as an emergency water supply.

The third option was **P-Lake**, which is located on Malik Mountain south of the community. This option requires an access road with steep grades and rock excavation. P-Lake was previously rejected on the basis of high development costs.

The GN requested that Dillon re-examine the P-Lake lagoon option and compare the costs to that of a mechanical treatment plant. This work was completed in May 2003 and it was concluded that the long term costs were about the same as for a mechanical plant. For this current report the cost estimates for the lagoon and the access road have been further refined. The revised total cost for this option is approximately $6.8 million, which is $650,000 higher than the previous estimate. Site information remains extremely limited for this option and therefore the degree of confidence in the cost estimates is lower than for the mechanical plant option.

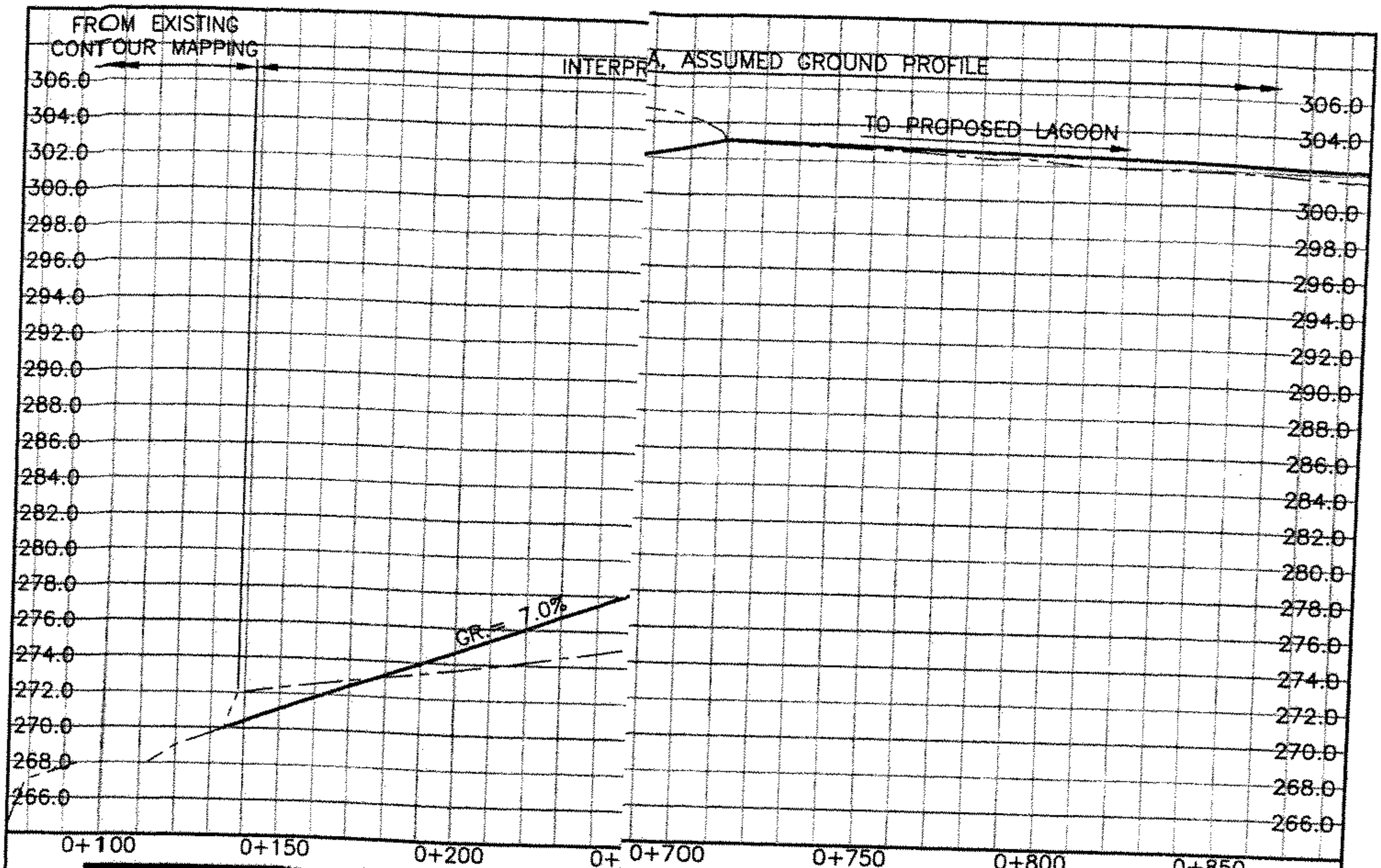
Further details are provided in the sections that follow.

5.2 Design Basis

Access Road

A site inspection and survey of the preliminary access road route was carried out in April 2003 by Dillon and GN personnel. In order to access the lagoon location a steep rock face must be traversed. The lagoon site is located on an elevated plateau south west of the Hamlet. Access would be partially provided along an existing road but a new road 850 m in length and with an elevation change of approximately 33 m would need to be constructed. The preliminary plan and profile are shown in Figure No. 6. Winter photographs of the route are in Appendix I. The profile consists of interpreted data from existing contour mapping, survey data and photographs. Before construction of this option could begin a more in depth survey, route selection, and geotechnical (surface geology) investigation would need to be performed.

The access road costs were estimated based on $100/m^3$ for rock excavation and $40/m^3$ for fill. In fill sections the road width was assumed to be 10 m in fill with 3H:1V side slopes. In cut the width was assumed to be 16 m with 0.5H:1V side slopes. Cut and fill volumes are 12,000 m^3 and



GE MANAGEMENT REVIEW SET, NUNAVUT	PROJ. NO. 031943
S ROAD CONCEPT	FIG. NO. 6

43,000 m^3 respectively. The total road cost is assumed the blasted material is suitable for fill. If this is not the case, fill material will have to be crushed on site at an additional cost of approximately $500,000.

Sewage Lagoon

The sewage lagoon was sized based on hydraulic loading criteria to provide annual storage in the year 2024 of 97,000 m^3. Lagoon storage could be provided in a 1, 2, or 3 cell configuration, depending on existing ground conditions at the site. The lagoon configuration can only be determined after a full site survey and geotechnical investigation. For the purposes of this report a 2 –cell configuration was assumed with a liquid depth of 2.0 m and on overall berm height of 3.3m. Each cell would have inside dimensions of 214 m X 110 m. The lagoon area was assumed to be fenced to prevent wildlife intrusion and for general site safety. Volumetric and cost calculations are provided in Appendix J.

5.3 Capital and Operating Costs

In May 2003 Dillon completed capital and operating cost estimates for the access road and the sewage lagoon. The total capital cost for the access road and the lagoon was $4.5 million, as shown in Table 3. For this report the previous costs estimates were revisited in order to confirm the design assumptions and refine the costs wherever possible. The most significant change since the previous estimates is the capital cost estimate for the lagoon, which has increased from $1.1 million to $1.9 million. The increase is due to the larger lagoon volume assumed for this report (97,000 m^3 vs. 88,000 m^3), and the inclusion of rough costs for site preparation and inlet and outlet controls. With these revisions the total estimated capital cost is $5.1 million (excluding engineering and contingency), as shown in Table 3. It must be emphasized that these are preliminary costs completed in the absence of any site specific data in the vicinity of the proposed lagoon.

The total estimated capital cost for this option (including engineering and contingency) is $6.9 million.

Operating costs were based on 2% of the lagoon construction cost, or $38,000 per year. This accounts for minor maintenance, fence repairs, etc. The cost does not account for sludge removal, which may be required in the long term. Sewage haulage costs are not included either.

Table 3 P-Lake Lagoon Capital and Operating Costs

Item	May 2003 Estimate	Current Estimate	Comment
Access Road	$3,400,000	$3,200,000	Earthworks volumes refined slightly
Sewage Lagoon	$1,100,000	$1,900,000	Capacity increased to 97,000 m3. Higher misc costs.
Total Capital Cost	**$4,500,000**	**$5,100,000**	
Engineering @ 10%	$450,000.00	$510,000.00	
Geotechnical @ 2%	$90,000.00	-	Geotech now assumed to be included in Engineering
Contingency @ 25%	$1,125,000.00	$1,275,000.00	
Total	**$6,165,000**	**$6,885,000**	
O + M @ 2.0% of Lagoon	$22,000	$40,000	

6.0 Analysis of Options

6.1 Life Cycle Cost Analysis

A life cycle cost analysis was undertaken for the mechanical plant and the lagoon options. Net Present Value or Life Cycle Cost considers both Capital and Operating Costs by estimating the total cost in current day dollars of a facility over a given time period. For the purposes of this study, the planning period selected is 20 years. The determination of current day dollars for future outlays is a function of inflation and future interest rates (referred to as discounted rates). Given the uncertainty in predicting future rates, often estimates are made at a variety of discount rates in order to provide a range of costs. The results of the life cycle cost analysis for the two long-term sewage management options for Cape Dorset are shown in Table 4.

The life cycle costs are shown in Table 4 below.

Table 4 Net Present Value Analysis

Option	Capital Cost	Op. & Maint.	20 Year Life Cycle Cost @ 2% Discount	20 Year Life Cycle Cost @ 4% Discount	20 Year Life Cycle Cost @ 8% Discount
Mechanical Plant	$5,600,000	$260,000	$9,700,000	$9,000,000	$8,000,000
P - Lake Lagoon	$6,900,000	$40,000	$7,500,000	$7,400,000	$7,300,000

The above table shows that the P-Lake lagoon is the more economical option.

As highlighted in Table 4, the life cycle cost analysis favours the lagoon option, however the overall margin of difference is relatively small given uncertainty in the mechanical plant operating cost and the lagoon capital cost. For example a sensitivity analysis shows that if the capital cost of the lagoon increases by 21%, the net present value (NPV) over twenty years is the same as the mechanical plant (at 4%). Given that the lagoon cost estimate is +/- 40% the sensitivity analysis highlights that the estimated life cycle costs for the two options are roughly the same when considering uncertainty.

6.2 Other Evaluation Criteria

As a decision making document, the purpose of this report is to not only provide updated cost estimates, but to introduce some of the other potentially influencing factors that GN may want to consider. Examples of these potential considerations include cost uncertainty, regulatory environment, process uncertainty, and community acceptance. The GN may determine that there are additional factors that should also be considered.

In order for the GN to make an informed decision in selecting a preferred long-term solution for sewage management specific to the situation in Cape Dorset, a weight-of-evidence approach is recommended. To assist in this regard, a matrix has been developed that allows the weighting of the various considerations based on GN priority.

The first step in the matrix analysis is to determine the criteria to be evaluated and the relative "weighting" for each. Based on our review of the previous studies, the regulatory and community history, and contacts with GN personnel over the past 1-2 years, the following seven evaluation criteria are proposed for initial consideration.

Operating and Maintenance Cost (O + M)

Operating and Maintenance Costs represent a perpetual outlay of direct dollars throughout the life expectancy of any facility or other infrastructure. O + M costs are often presented as a percentage of capital dollars that are required on an annual basis. Operating costs are estimated to range from a low of **2%** for lagoons to a high of **8%** for a pre-engineered secondary level treatment plant.

The GN has recently indicated that O + M Costs are a key concern given the limited dollars available in any given year to address a large number of priorities across the Nunavut Territory. Given this expressed concern, and the likelihood that O + M represent a greater fiscal challenge than capital expenditures, a higher weighting has been assigned to Operating Costs than for Capital Cost.

Operating Costs have been assigned a weighting of 25%.

Operating and Maintenance Cost Uncertainty

Uncertainty in the estimated Operating and Maintenance Costs are due to a lack of operating history for mechanical treatment plants in Nunavut. This is particularly true of the Sequencing Batch Reactor (SBR) process. In contrast, there are many lagoon systems installed across Nunavut and thus there exists little uncertainty in Operating Costs for these type of systems. In comparison, the Operating Costs for a lagoon are negligible to that of a mechanical sewage treatment plant. This criteria has been established to acknowledge uncertainty as a factor that may influence ultimate costs to Operate and Maintain the sewage management system.

Operation and Maintenance Cost uncertainty was assigned a value of 30% for a mechanical treatment plant and 10% for a lagoon. The mechanical plant uncertainty is subjectively assigned based on the difference between the current estimates for Operation and Maintenance Costs ($260,000) compared to the original supplier estimates. A 10% uncertainty in lagoon costs reflects the increased confidence in the estimate.

Operating and Maintenance Cost Uncertainty has been assigned a weighting of 15%.

Capital Cost

Capital cost is a quantitative criteria which can be used to compare the "up front" costs of each option. A slightly lower relative rating has been assigned to Capital Costs in comparison to the

Operating Costs. To date, the GN has not expressed concerns in the ability to secure the funding necessary for the construction of a mechanical sewage treatment plant at the existing 3-cell lagoon site. In selecting weighting criteria, an assumption has been made that funding would be also be available for the more Capital Cost intensive option of the P-Lake Lagoon. Negating uncertainties in cost estimating, the P-Lake Lagoon carries an approximately 20% higher Capital Cost than the mechanical sewage treatment plant.

Capital Cost has been assigned a weighting of 20%.

Capital Cost Uncertainty

Recent and relevant experience with the construction of a similar facility in Pangnirtung combined with detailed cost estimates obtained through a site specific pre-selection process have provided a cost estimate for a mechanical treatment plant that is considered more accurate than that for the P Lake Lagoon Option. Uncertainties that may influence the Capital Cost estimate for P-Lake Lagoon are primarily related to an absence of data related to site topography, lake bathymetry, and surficial geology information required for road and lagoon design. For planning purposes, it is reasonable to expect Capital Costs for the mechanical treatment plant to carry an accuracy of +/- 10% whereas the P Lake Lagoon may be +/- 40%.

This criteria has been established to acknowledge uncertainty as a factor that may influence ultimate costs to implement the sewage management system.

Capital Cost Uncertainty has been assigned a weighting of 10%.

Regulatory Environment

Regulatory uncertainty considers both immediate and future regulatory requirements. Immediate requirements represent the ability to, and cost implications of, obtaining the necessary approvals to implement the selected long-term sewage management option. Future needs are more obscure as they represent potential changes in the regulatory environment that may have an impact on the requirements surrounding the management of sewage. At this point in time, Dillon is unaware of imminent regulatory changes that may impact Cape Dorset.

In order to implement the long-term sewage management option in Cape Dorset, approvals are required from the Nunavut Water Board (NWB) with input from a variety of other stakeholders. Depending on the selected management option, approvals from other regulatory bodies may also be required. Interaction with the NWB and other project stakeholders commenced in the spring of 2003 with the distribution of the Concept Brief and the identification of a mechanical treatment plant as the preferred option.

The ability to obtain the necessary regulatory approvals for a mechanical treatment plant at the existing site is considered of low risk. The NWB and other stakeholders have been provided information about the treatment process and proposed discharge quality. In using the existing treatment site to implement a mechanical treatment plant, no new potential impacts on the natural environment will occur. For the P-Lake lagoon option, there is a requirement to build a new road and convert an existing water body to a sewage lagoon. It is expected that the time required to implement the sewage lagoon option will take longer than that for a mechanical treatment plant. Sufficient baseline information has not yet been collected on the natural environment to fully identify potential environmental impacts that may result from implementing this option. For example, it is not yet known if P-Lake is considered fish habitat under the definition of the Fisheries Act. With an absence of site specific information, the regulatory uncertainty for the P-Lake lagoon option is greater than that for a mechanical treatment plant.

In selecting a sewage management option, consideration should also be given to the ability to adapt to potential regulatory change. Changes most likely to impact sewage management operations would be the adoption by regulatory authorities of more stringent effluent discharge criteria. Although an annual storage facultative lagoon that discharges to a non-sensitive aquatic environment can generally meet existing regulatory expectations (as indicated by the current Water License for Cape Dorset), its' performance cannot be readily improved should more stringent criteria be adopted at some time in the future. In comparison, the discharge quality from a secondary level mechanical treatment plant is inherently superior to that of a facultative lagoon. In addition, the effluent quality from a mechanical treatment plant can generally be improved through process adjustments and if necessary through the addition of additional process units to address specific parameters of concern.

In short, should Cape Dorset be subject to changes in regulatory requirements during the course of the 20 year planning period, the cost to adapt to these changes is potentially of greater significance with a lagoon in place. There is also more uncertainty associated with the implementation of the P-Lake Lagoon option as compare to a mechanical treatment plant.

Regulatory Environment has been assigned a weighting of 10%.

Process Uncertainty

Once a new sewage management facility is commissioned, it must be operated using local personnel. The complexity of a mechanical sewage treatment plant is such that significant training is required for process operation. Local maintenance support (mechanical, electrical) as well as third party process support is also necessary and represents an added cost, especially in a remote northern setting. In contrast, a facultative lagoon requires little operator training and third party support once designed and constructed.

Consideration should be given to the local capacity required to support sewage management. Improper operation and/or management of any sewage management facility has the potential to increase liabilities for the GN. Due to the complexity of process, a lack of experience, and high training requirements, the mechanical treatment plant carries with it higher uncertainty in having the facility operational and effective 100% of the time.

Process Uncertainty has been assigned a weighting of 10%.

Community Acceptance

Formal community consultation has not been a component of this particular study. However, the community has been an active stakeholder in the sewage management planning process for Cape Dorset. Several potential lagoon sighting options were identified by the community. In response to input from the community, several potential lagoon sites were dropped for further consideration by the GN. For example, Q-Lake was dropped from further consideration due to concern from the community that the lake was a suitable and proven back-up potable water source in the event of an emergency.

Community acceptance for a given plan may be driven by a variety of issues and concerns including:

- Time required for implementation
- Familiarity with the type of facility proposed
- Complexity of the treatment process
- Proximity of the facility to Community
- Aesthetics
- Potential environmental impacts (real or perceived)

Consideration should be given to how the community may respond to the implementation of a given option in the decision making process. A sound management solution has a decreased chance of success if not embraced by the community. The suggested weighting of 10% has been assigned to this subjective consideration. The mechanical treatment plant option has been scored higher on the basis that the community was involved in the preliminary decision to move forward with that option.

Community Acceptance has been assigned a weighting of 10%.

6.3 Option and Criteria Analysis

The second step in the matrix evaluation process is to determine the extent to which each option satisfies each of the selected considerations. The purpose of this section is to present the results of the matrix table.

Quantitative and qualitative approaches were used in determining the points awarded to each of the two options depending on the consideration. Quantitative approaches to scoring could be used for cost based considerations whereas the more subjective considerations of Regulatory Environment, Process Uncertainty, and Community Acceptance were scored qualitatively.

Quantitative scoring was completed as illustrated by the example calculation for Operation and Maintenance (O&M) Cost:

Mechanical Plant O + M	=	$260,000
Lagoon O + M	=	$ 40,000
Total O + M		$300,000
Mechanical Plant Ratio	=	$260,000/ $300,000 = 87%
Mechanical Plant Points	=	(100%-87%) * Points Available
	=	(13%)*25 Points
	=	3.25 Points (say 3 Points)

Lagoon Points = Points Remaining = 25-3 = 22 Points.

The same calculation method was used for the three other cost criteria, however the Operation and Maintenance and Capital Cost Uncertainties are subjective to the extent of assigning confidence levels.

The results are summarized in Table 5.

Table 5 Option and Criteria Analysis

Criteria	Potential Points	Mechanical Plant	P Lake Lagoon	Comments
O + M Costs	25	3	22	Combined O + M cost = $300,000. Mechanical Treatment Plant represents 87% of the Combined O + M.
O + M Uncertainty	15	4	11	Combined Uncertainty is 40%. Mechanical Treatment Plant represent 75% of the Combined Uncertainty.
Capital Cost	20	11	9	Combined Capital Cost $12.5 million. Mechanical Treatment Plant represents 45% of the Combined Capital Cost.
Capital Cost Uncertainty	10	8	2	Combined Uncertainty is 50%. Mechanical Treatment Plant represents 20% of Combined Uncertainty.
Regulatory Environment	10	8	2	Subjective Assessment that regulatory issues are fewer with a mechanical plant
Process Uncertainty	10	2	8	Subjective Assessment that technology and training issues are fewer with a lagoon
Community Acceptance	10	7	3	Subjective Assessment that community will favour a mechanical plant over a sewage lagoon.
TOTAL	**100**	**43**	**57**	

<u>The option with the highest overall score is the P-Lake Lagoon.</u>

7.0 Conclusions

For the purpose of this report, Dillon has established inputs into a weight of evidence approach that is representative of our perspective and best understanding of the key issues. Input is required from the GN to refine weightings, scores, and the list of considerations/factors most reflective of current and/or anticipated government policy, priorities, perception, and understanding of the specific situation in the community of Cape Dorset.

Using this weight of evidence approach with the considerations, weights, and relative quantitative and qualitative scores, the P Lake Lagoon is shown to result in a higher total score. Operation and Maintenance Cost considerations were shown to have the greatest influence on the outcome and reflects GN concerns over long-term fiscal commitments required as part of the installation of a mechanical treatment plant. Other considerations favour the installation of a mechanical treatment plant, however, higher relative scores were outweighed by those points awarded from Operation and Maintenance costs.

As stated previously, the scope of this report is to specifically compare the options of the P Lake Lagoon to a pre-engineered sewage treatment plant located at the current lagoon site. Accordingly, analysis of these two options was completed in such a manner to assist the GN in the selection of a long-term sewage management solution. In considering its options, the GN is reminded of other alternatives that were rejected in the absence of this formal approach. For example, it would appear that lagoon Site Q was rejected primarily on the basis of community acceptance in the absence of cost considerations. Should Site Q in fact be technically feasible, integration of this option into the matrix table would likely result in a higher score than the P-Lake Lagoon option.

Should the P-Lake Lagoon remain to be the preferred option after refinement of the presented matrix based on GN input, a baseline data collection program should be completed during the summer/fall of 2003 field data to further characterize field conditions along the road right-of-way and proposed P-Lake Lagoon site. Field data needed to be collected includes, but is not limited to topography, lake bathymetry, soils/surface geology, hydrology, and fish habitat. The scope of the data collection program should be supportive of confirming technical feasibility and infrastructure design.

Should the GN conclude however that the P-Lake Lagoon or other lagoon options are not feasible and/or preferred further consideration of alternate mechanical treatment plant technologies may be warranted for the specific purpose of looking at potential reductions in Operating and Maintenance Costs. The installation of an SBR provides an opportunity for direct comparison to the Rotating Biological Contactor (RBC) based technology recently constructed in Pangnirtung. However, preliminary estimates for Cape Dorset suggest an SBR to have approximately 30% higher power consumption than that for a comparable RBC based system.

On the assumption that collected field data supports implementation of the P-Lake Lagoon option, the following schedule is proposed:

- Site Investigations by October 2003
- Regulatory Approvals by February 2004
- Design – Tender – Award by May 2004
- Road and Lagoon Construction 2004/2005

The proposed schedule reflects the reality that the access road to the P-Lake site is a major civil works undertaking for a community the size of Cape Dorset. In the interim period before the new lagoon system is commissioned, GN will need to continue to operate and maintain the existing 3-cell lagoon. Existing issues related to capacity and berm integrity will need to be managed to the extent reasonable. With 2 years required to construct a new sewage lagoon at P-Lake, regulatory issues associated with the existing system are likely to remain a challenge for the GN.

REFERENCES AND RELATED STUDIES

1. Dillon Consulting Limited, "*Sewage Facility Planning Study*", Cape Dorset, Nunavut. March 2001.

2. Cold Regions Nomograph, American Society for Civil Engineering.

3. Environmental Engineering, Peavey/Rowe/Tchobanoglous.

4. US Environmental Protection Agency Wastewater Technology Fact Sheet – Package Plants.

Appendix A
Terms of Reference