The wetland area downstream of pond "P1" is the natural receptor for surface runoff from a catchment of some 35 ha. Collection of this runoff creates the natural wetland which is approximately 16.5 ha in size, including surface water impoundments. The pond at the head of the wetland ("P1") is influenced by a catchment area of approximately 5 ha. Watershed catchment areas, and the discernable wetland area are also shown on Figure 5.1.

Because the catchment area of the wetland is mostly rock outcrop (with the exception of the wetland and pond areas), the annual runoff is generally equal to the catchment area multiplied by the annual rainfall equivalent. The runoff contribution to pond "P1" is then 50,000 m^2 x 0.249 m rainfall = 12,450 m^3/year.

The volume of spring thaw runoff can be assumed to occur very rapidly as well, due to the large percentage of rock outcrop, surrounding pond "P1". This volume is estimated as the winter rainfall equivalent multiplied by the catchment area, or 50,000 m^2 x (.249 - .146) = 5,650 m^3 m.

Any design options which utilize the upper end of the wetland area for sewage storage, or construction of a lagoon cell must incorporate the annual and spring runoff volumes into the design concept, ensuring that adequate measures are taken to prevent failure of the system.

Because the geology surrounding the proposed site consists mainly of bedrock outcrops, soil or granular material is not available in the immediate vicinity for construction of berms and dikes to control runoff. However, gravel and till deposits are located within economical transportation distance from the site, and would, therefore, make drainage control works feasible.

6.3 Sewage Storage Requirements

Chesterfield Inlet experiences approximately 67 frost-free days per year, as indicated in UMA's report ("Municipal Wastewater Treatment Technologies Capable of Achieving Compliance with the Fisheries Act in the NWT", March 1993). In general, biological treatment and nutrient removal efficiencies of sewage are proportional to temperature. Below 0°C biological processes are essentially stopped with the physical freeze/than mechanism replacing it. At low temperatures, only primary treatment processes (settling and freeze/thaw segregation) are occurring. For design purposes, the volume of sewage that must be stored for secondary treatment in the wetland can be estimated as the portion of annual sewage generated over the period of days experiencing frost, as shown below.

Total Annual Design Volume = 22,000 m^3

$$\textit{Design Winter Storage Requirement} = 22{,}000 \times \left(\frac{365-67}{365}\right) = 18{,}000 m^3$$

Alternatives for storage of this sewage will be discussed in the following sections.

6.4 Treatment System Options

As previously stated, earlier attempts at designing a full lagoon treatment system in Chesterfield Inlet were abandoned by MACA, to study the feasibility of incorporating the natural wetland into the scheme. In recent years, the use of natural wetlands to provide an engineered means of sewage treatment has been investigated and developed throughout North America. A report completed in March 1993 by UMA Engineering for Environment Canada ("Municipal Wastewater Treatment Technologies Capable of Achieving Compliance with the Fisheries Act in the Northwest Territories"), concluded that wetlands can be capable of removing nutrients, including ammonia and total kjeldahl nitrogen, to non-toxic levels, as required by the Act. Another report, completed in 1993 by Doku and Heinke for MACA ("The Potential for Use of Wetlands for Wastewater Treatment in the Northwest Territories") provides guidelines and recommendations for the use of both natural and constructed wetlands for sewage treatment. These recommendations are discussed in the following sections.

System 1: Direct Discharge to Wetland

Several northern communities located in Alaska, the Yukon Territory, the Northwest Territories, and Northern Quebec currently use wetlands treatment systems of varying complexity, with varying degrees of success. The simplest form of wetlands treatment is direct discharge of raw sewage to the upper reach of a natural wetland, year-round for treatment. This method (as currently practised in Chesterfield Inlet (Population 316) and Repulse Bay (Population 500)), provides winter storage of effluent in the form of ice mounding at the head of the wetland. No primary settling pond (other than natural impoundment features) is incorporated into this type of system, which, therefore, relies on the wetland to provide full treatment of the sewage.

This type of system is not recommended by UMA or by Doku and Heinke, due to the lack of control over the system. Performance and efficiency of the process can be variable over time, and extremely difficult to predict, and long-term performance data of such systems is not available.

It is also not possible to meet the requirements of the Fisheries Act using this system (i.e. non-acutely lethal, undiluted effluent at end of pipe, or last point of physical control) since the effluent at the end of pipe (truck discharge) is raw sewage. For practical purposes, even if the end of pipe is defined as the outlet to the open water at the Inlet, there is no control over the system in terms of sewage retention and storage beyond which the natural terrain provides.

System 2: Preliminary Treatment of Sewage Only

A recommended enhancement to the previous process is to provide preliminary wastewater treatment to at least the primary level. Hay River, NWT (Population 3,422) is an example of this type of system. Hay River's wastewater treatment facility consists of a two cell anaerobic primary lagoon system operated in series with a third smaller cell. These cells provide short hydraulic retention times for settling of suspended solids and BOD. Discharge from these cells is continuous, year-round to a natural wetland area 32 ha in size. The wetland treatment area in Hay River consists of a system of creeks and swampland passing through a forest area dominated by Black Spruce and Jackpine. Marginal areas of the creeks are dominated by poplar, alder, and willow, and the channels by cattails, sedges, and duckweed.

The wetland system provides secondary treatment of the effluent during summer months. Performance data suggests that the summertime efficiency of the system is excellent, however, no data exists for the 20 year period of operation over winter months. It is suspected that this system provides winter storage in the form of ice mounding within the wetland throughout the winter.

While the performance of this type of system has proven successful over the past 20 years, Doku and Heinke caution that its performance and operating parameters cannot be indiscriminately applied to other NWT sites. In their report, it is suggested that the Hay River system may be a special and unique case, applicable only to the particular type of wetland found in Hay River. Doku and Heinke recommend that, should this method of wastewater treatment be considered elsewhere, a thorough site-specific ecological study of the natural wetland be undertaken to evaluate the pollutional removal capabilities of the wetland and existing plant species.

System 3: Preliminary Sewage Treatment and Full Winter Storage

The method recommended by the literature of incorporating natural wetlands into a wastewater treatment system is to provide long-term storage lagoons for effluent during winter months, with summer discharge only to the wetland. An example of this type of facility is in use by the City of Yellowknife (Population 15,000). The wetland system used by the City of Yellowknife is the Fiddler's drainage area, comprised of a series of nine (9) lakes, covering a distance of approximately 20 km. The uppermost lake in the system is operated as a winter storage lagoon, with discharge bi-annually (May and October) through a man-made overflow structure.

This type of system is deemed favourable over the other methods for the following reasons:

- The end of pipe or point of final control is well defined as the lagoon discharge point. The effluent will certainly be of better quality from a long-term storage lagoon than from a pump-out truck, or from a short detention lagoon.

- Full storage of effluent throughout the winter season, with application to the wetland in warmer months, provides for the most efficient biological treatment of effluent within the wetland. While performance data is lacking, it is widely believed that the secondary treatment efficiency of the wetland, when used as a summer secondary cell, will be enhanced and have a greater sustainability over time.

6.4.1 Applicability to Chesterfield Inlet

Option 1

The head of the wetland at the proposed sewage treatment site is formed by pond "P1", with a surface area of 2,000 m^2, and an estimated volume of 3,000 m^3. Since this pond is located directly below the existing discharge point, System 1 (direct discharge to wetland) and System 2 (preliminary treatment only, using short hydraulic retention time lagoon) become essentially the same, for this specific site chosen in Chesterfield Inlet. Without control of site drainage, pond "P1" will provide approximately:

$$3{,}000\ /\ (\frac{22{,}000+12{,}450}{365} = 32 \textit{ days of hydraulic retention}$$

This value is typical of design for short-term retention lagoons.

Winter storage of effluent would be in the form of ice mounding in the upper reaches of the wetland, as the pond overflows its outlet once freezing begins. Since the pond has no natural outlet to allow draining completely prior to winter, and drainage of the pond would be impractical via pumping, the upper reaches of the wetland will be required to store the entire winter generation of 18,000 m^3. Discharge of the effluent will occur quickly in the spring during the thaw period. The estimated loading on the wetland will be:

$$(18{,}000\ m^3 + 5{,}650\ m^3)\ /16.5\ ha/67\ \textit{frost free days} = 21.4\ m^3/ha/d$$

This rate is well below the maximum hydraulic loading rate of 100 to 200 m^3/ha/d suggested as a design parameter by Doku and Heinke. The organic loading will be (assuming trucked sewage strength = 800 mg/l of BOD_5).

$$(18{,}000\ m^3\ x\ 10^3\ \frac{L}{m^3}\ x\ \frac{800\ mg/l}{10^5\ mg/kg})\ /\ 16.5\ ha\ /\ 67\ d = 13.0\ kg/ha/d$$

This rate is well above the recommended maximum of 4.0 kg/ha/d. This may lead to eventual nutrient overloading of the wetland, and problems sustaining vegetative growth.

The short term retention provided by System 2 could provide some organic load reduction. However, during spring runoff, the majority of the organic solids would be flushed through the wetland area.

Performance of this system would be difficult to predict, and would require an extensive monitoring program to determine its efficiency. The scope of this testing and monitoring program will be discussed later in this report.

Option 2

The second option for sewage treatment in Chesterfield Inlet would be to provide a winter storage cell capable of containing the 18,000 m^3 of sewage generated, with adequate berming to prevent runoff from entering the cell. This option would be similar to System 3, described earlier.

As previously described, the existing pond "P1" provides hydraulic retention for primary treatment (settling), during summer, however, would not provide any winter storage, unless the liquid contained in the cell could be emptied prior to winter. Since draining the pond would be impractical, the most feasible solution would be to provide a pond capable of storing the winter volume of 18,000 m^3, above the elevation of the natural water surface in pond "P1". At an operating depth of 2.0 m, with 0.5 m freeboard, the required cell would measure approximately 95 m square. Effluent could be discharged to the wetland following the spring thaw period through an overflow weir constructed in one of the dikes. Because of the nature of the cell construction (i.e. aboveground with diked sides), site runoff would be largely excluded from the cell. The hydraulic loading on the wetland would be:

$$18{,}000\ m^3\ /\ 16.5\ ha\ /\ 67\ d\ =\ 16.3\ m^3/ha/d$$

Assuming the primary cell would provide a 70 percent (70%) removal efficiency through settling of BOD_5 and suspended solids, the organic loading on the wetland would be:

$$18{,}000\ m^3\ x\ 10^3\ l/m^3\ x\ (0.30)\ \frac{(800\ mg/l)}{(10^6\ mg/kg)}\ /16.5\ ha/67d\ =\ 3.9\ kg/ha/d$$

Both of these values compare well with the recommended design values cited in the literature. Again, because long-term data from other sites is lacking, performance of this system would be difficult to predict. As suggested for Option 1, an extensive monitoring program should be undertaken to verify system efficiency, should this method of sewage treatment be chosen.

6.4.2 Recommended Option

To minimize capital costs, it is recommended that a pilot program be undertaken, utilizing and investigating the performance of Option 1 - direct discharge to wetland. This offers a staged approach to sewage treatment at Chesterfield Inlet, combined with an opportunity to evaluate the effective treatment capacity of the "C1" wetland area. As previously described, pond "P1" will provide approximately 32 days of hydraulic retention for primary sewage treatment during the summer months, with the wetland incorporated as the secondary treatment cell. During winter months, sewage will be stored in the upper reaches of the wetland in the form of an ice mound within and around pond "P1".

Monitoring of this system should be carried out as described in Section 7.2 throughout the monitoring period. It will become apparent if the tested parameters pass or fail the established guidelines (Table 3.1 - NWT Water Board "Guidelines for the Discharge of Treated Municipal Wastewater in the Northwest Territories"; CCME "Canadian Water Quality Guidelines for Freshwater Aquatic Life"). Two courses of action will then be available.

Pass - Continue pilot scale operation of facility over a three year period with extensive monitoring, as described in Section 7.3, to ensure continued compliance with parameter guidelines. If at any time during the pilot program, parameters fail, the test is to carry on as described next.

Fail #1 - Should parameter tests not meet the effluent quality guidelines, the system will require upgrading to provide full winter storage of sewage, as described under Option 2. Following the required upgrades, the pilot program of operation and monitoring would begin again. Passing test results of monitored parameters would indicate satisfactory performance, and continued operation would be acceptable.

Fail #2 - Failure to pass monitoring results with the system upgraded to provide full winter sewage storage would require that a two (2) cell lagoon treatment system be installed to provide full primary and secondary treatment of the effluent prior to its discharge to the wetland. With this system, the sewage would be considered fully treated prior to discharge to the wetland with the wetland providing some measure of additional polishing treatment prior to the effluent entering Finger Bay.

6.4.3 Design Ancillaries

The recommended option will require additional components to provide a complete operational facility. These components consist of a discharge flume, with a berm to remove floatable materials; a truck access route; truck discharge/turn around pad; and site access/security measures. These components are discussed below.

Truck Discharge Flume and Floatable Removal

Sewage collection trucks will discharge raw sewage into a flume to the treatment facility. The flume will be constructed of a 900 mm corrugated metal pipe (CMP). The pipe will be anchored using 15 mm steel bars (or rebar) and bedded in gravel with an insulation barrier placed below the CMP. The top end of the CMP will have a discharge pan and the bottom end will be riprapped to prevent erosion. A small bermed area will be constructed at the bottom of the discharge flume to remove floatables. These berms will consist of large rocks with no fines (rock size to be between 100 mm and 600 mm). Details of the discharge flume and floatable removal berms are illustrated in **Figures 6.1 and 6.2**.

Access and Truck Turnaround Pad

Access to the facility will be via the new road constructed for the solid waste facility. A truck turnaround pad will be constructed incorporating the following:

- A dead man structure at the discharge flume to aid the discharge operations.
- Bollards along the pad limits to delineate the area for truck safety.
- Signage to prevent inappropriate dumping.

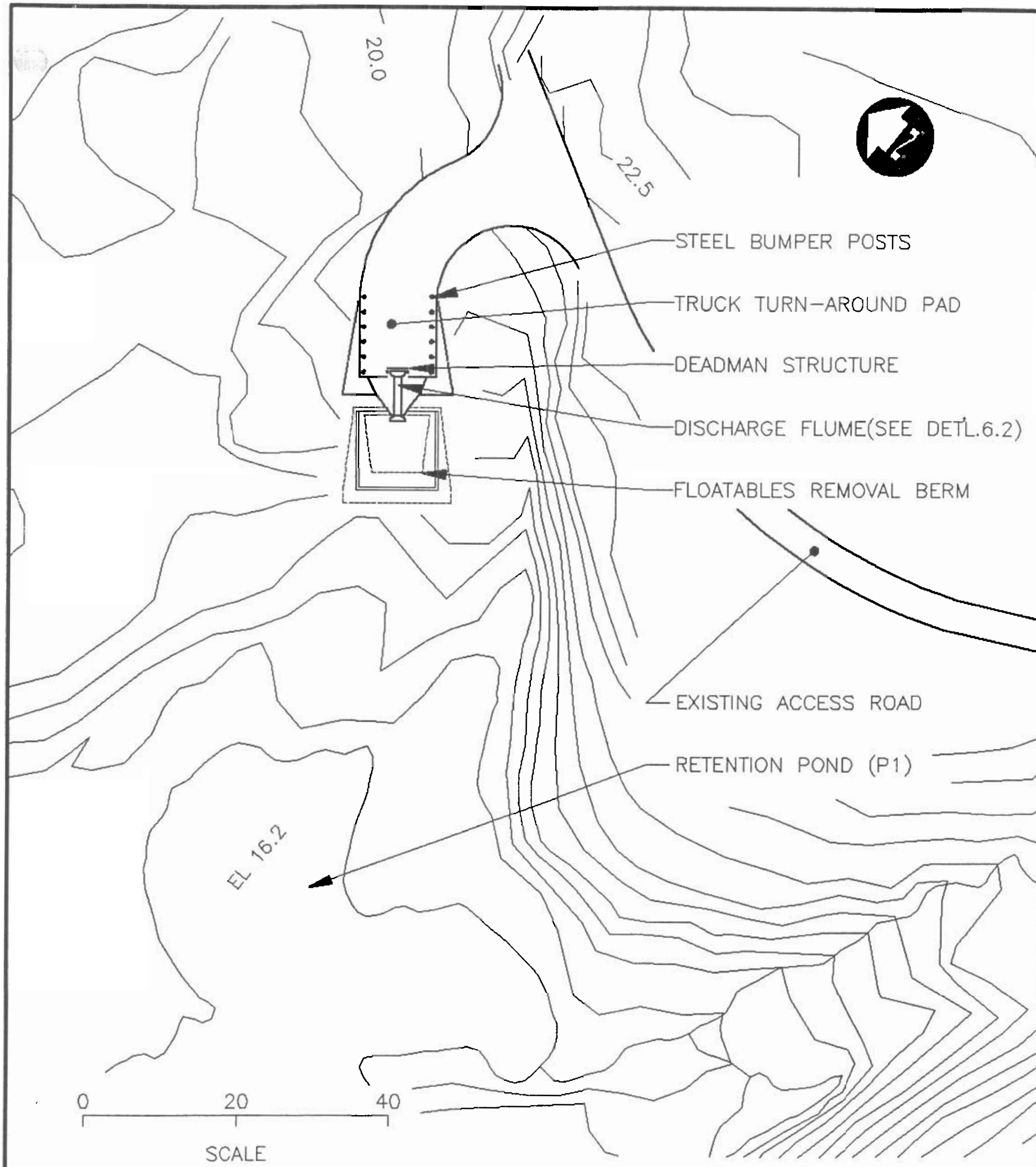
Details of the truck pad are illustrated in Figure 6.1.

Access Control

Due to the remoteness of the site from the community, and that the area has been a disposal facility for a number of years, minimal access control is required. The access road to the facility requires signs indicating the facility use. No road gate is required, and the site will be open twenty-four (24) hours per day, seven (7) days a week. It is also recommended that prominent signage be posted around the perimeter of the wetland area, indicating its use as a sewage treatment cell.

6.4.4. Further Investigation

Performance of the wetland system will be related to many factors, some of which are readily quantifiable (i.e. climate, hydrology) and others which are not, such as soil characteristics and vegetative species which the wetland supports. Due to the uncertainty of these and other characteristics of the wetland, performance efficiencies as a sewage treatment are difficult to predict.



DILLON
Consulting Engineers· Planners
Environmental Scientists

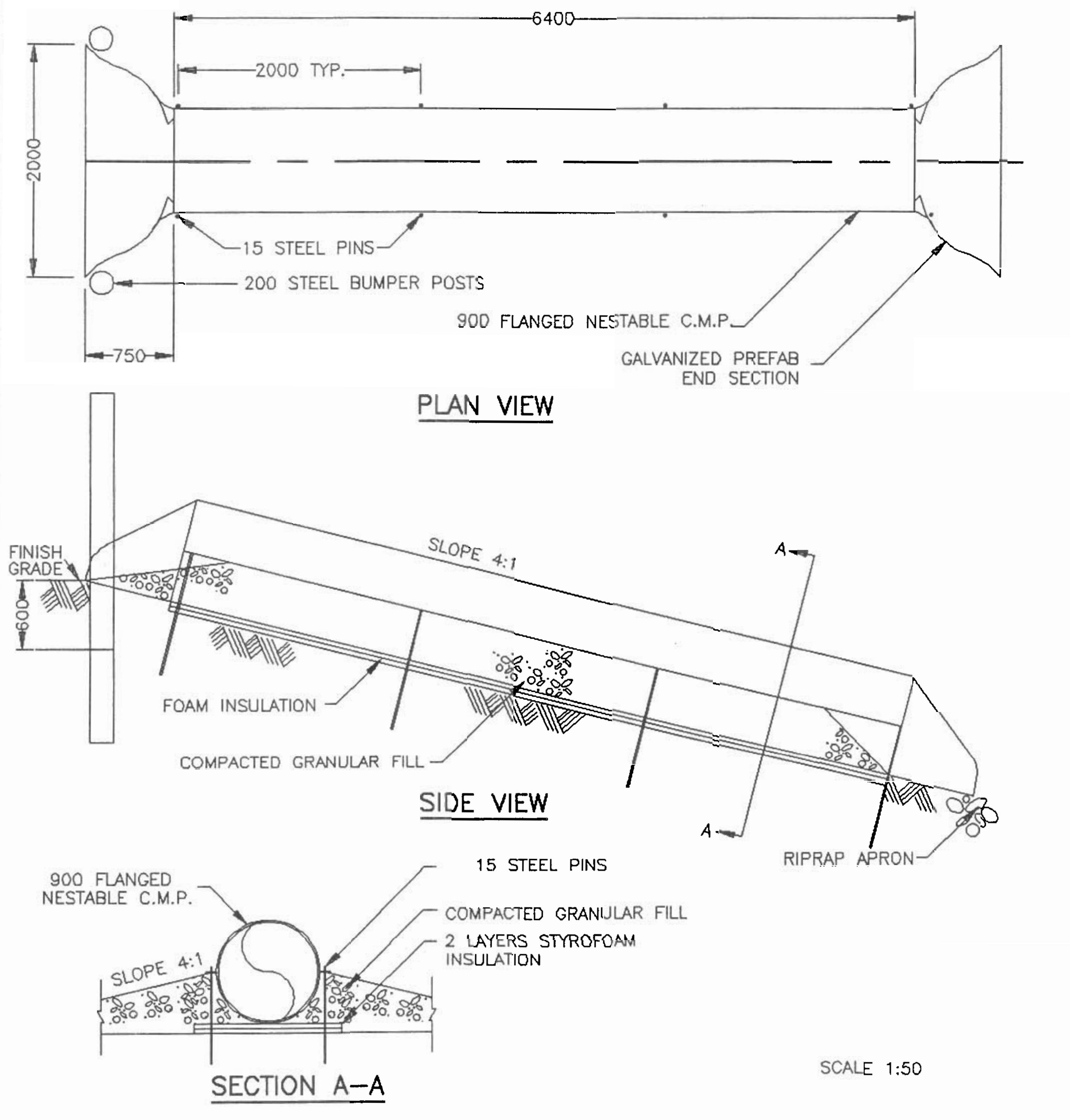
PROJECT
SEWAGE DISPOSAL IMPROVEMENTS
DESIGN AND OPERATIONS
CHESTERFIELD INLET

PROJECT NUMBER
93-1477-01

DATE
MAY 94

TITLE
SITE DEVELOPMENT
PLAN

FIGURE NUMBER
6.1



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DATE
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PROJECT
SEWAGE DISPOSAL IMPROVEMENTS
DESIGN AND OPERATIONS
CHESTERFIELD INLET

TITLE
SEWAGE LAGOON
TRUCK DISCHARGE FLUME

PROJECT NUMBER
93–1477–01

FIGURE NUMBER
6.2

Therefore, it is recommended that a program of geotechnical investigation and ecological study be undertaken. This work could be carried out prior to final design or in conjunction with the initial years of operation. This project would involve the following activities:

- Collection of soil and vegetation samples.
- Identification and mapping of soil profile throughout the wetland area.
- Identification of plant species.
- Evaluation of nutrient and pollutional removal capabilities of vegetation.
- Evaluation of soil properties with respect to drainage and ability to support plant life.

The information obtained from this phase of the investigation can then be used to validate design parameters

7.0 OPERATION, MAINTENANCE AND MONITORING

7.1 Periodic Operation and Maintenance

The operation and maintenance for the facility will be relatively simplistic due to the proposed natural treatment process. The following is a list of regular periodic tasks for the operation and maintenance of the facility.

Daily Operation

- Pump out household and commercial sewage holding tanks and haul waste to sewage facility.
- Discharge waste to flume.
- Record daily and monthly waste volumes.

Periodic Seasonal Maintenance

- Inspect ditches and drainage channels for erosion (once a month). Repair as necessary.
- Inspect discharge flume for damage or displacement (each Spring and Fall).
- Maintain roadway and truck pad with snow clearing in winter and periodic grading in the summer.
- Remove floatables from discharge pit to landfill area (to be completed in Spring and Fall).

If system has been upgraded to include storage or lagoon cells:

- Inspect storage cell or lagoon berm walls for erosion and settlement (in Spring and Fall). Repair as necessary.

The above work is to be completed by the Hamlet staff and the activities of this work is to be reported on an annual basis in compliance with the Hamlet's Water Licence.

7.2 Monitoring Program

As previously stated, Doku and Heinke recommend that any natural wetland treatment facility be operated under a pilot program, to monitor the effectiveness and performance of the system. As data are gathered and analyzed, modifications can then be made (where required) to the construction and operation of the facility. It is suggested that a monitoring and testing program be conducted following construction of the selected facility, with the following parameters monitored:

- BOD_5
- Suspended Solids (TSS)
- Volatile Suspended Solids (VSS)
- Total Coliform
- Fecal coliform
- Phosphorus
- Nitrogen
  - Ammonia Nitrogen
  - Total Kjeldahl Nitrogen

System Assessment Monitoring

The monitoring locations and frequency recommended to provide baseline data for system operation assessment, is as follows:

<u>Year 1</u>

- Monitor above parameters weekly.

- Sample Locations (total of 11 sample locations):

  - P1
  - P2
  - P3
  - Approximately every 100 m along wetland (7 samples)

- Finger Bay discharge area

- Conduct 96 hour TL_M static fish bioassay test following spring thaw and runoff period (early June).

Year 2

- Monitor above parameters monthly.

- Sample locations same as above (11 total).

- Conduct 96 hour TL_M static fish bioassay test following spring thaw and runoff period (May or June).

Year 3

- Monitor above parameters quarterly (January, April, July, and October).

- Sample locations same as above (11 total).

- Conduct 96 hour TL_M static fish bioassay test following spring thaw and runoff period (May or June).

Subsequent Years

- Monitor above parameters quarterly, skipping January quarter.

- Sample locations:

  - P1
  - P2
  - P3
  - Every 200 m along wetland (3 samples)
  - Finger Bay
  - Total of seven (7) sample locations.

Regulatory Compliance Monitoring

The monitoring program recommended for regulatory compliance and licensing is as follows:

- Sample locations (2 sites):

  - Pond P1
  - Finger Bay discharge area

- Monitored parameters:

  - BOD_5
  - TSS
  - Total Coliform
  - Fecal Coliform
  - Nitrogen, Ammonia

- Frequency:

  - Quarterly samples

8.0 ESTIMATED COSTS

8.1 Capital Costs

Total capital costs for the construction of a sewage disposal facility based on Option 1 are presented in **Table 8.1**. Costs are in 1994 dollars and are based on previous construction costs for the Community of Chesterfield Inlet. The cost for the access road is not included in this estimate as it is understood that this road will be completed through the development of the solid waste disposal facility. Capital costs for waste collection vehicles have not been included.

TABLE 8.1

20 YEAR CAPITAL COSTS

	Quantity	Unit Price	Total
1. Truck Turnaround Pad			
1) Granular Material	650	$ 60	$ 39,000
2) Dead Man Structure	1	200	200
3) Truck Bumper Posts	14	250	3,500
4) Discharge Flume	1	8,000	8,000
2. Lagoon			
1) Floatable Removal Berm	1	5,000	5,000
TOTAL CAPITAL COST			**$ 56,000**

The capital cost to implement Option 2 subsequent to installing the facilities for Option 1, is estimated to be $130,000.00

8.2 Annual Operation Costs

Based on the operational procedures described in the previous sections, the operating costs have been estimated and are as shown in **Table 8.2**. This estimate does not include the cost of waste collection.

TABLE 8.2

ANNUAL OPERATING COSTS

	Period	Cost	Annual Cost
1) Berm Maintenance	5 Years	$ 5,000	$ 1,050
2) Roadway/Turnaround Pad Snow Removal and Maintenance	Monthly	100	1,200
3) Excavation of Floatables	Annual	1,000	1,000
4) Sludge Excavation	10 Years	5,000	350
5) Water Sampling	Semi-Annual	300	600
TOTAL ANNUAL COSTS			**$ 4,200**

References

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