# EXECUTIVE SUMMARY

## THE USE OF CATTAIL MARSHES TO TREAT SEWAGE IN NORTHERN ONTARIO

### OBJECTIVE 1:

To determine if the marsh treatment technology could be applied in the more extreme climate of Northern Ontario.

### CONCLUSION 1:

It can be concluded that marsh sewage treatment technology can be transferred successfully to northern climates. The results of this study compare favourably to secondary sewage treatment standards despite the marsh being inadvertently loaded at 3 to 5 times the intended rate. Concentrations of $BOD_5$ in the marsh effluent were always below the Ministry objective of 15 mg/L, even during the oxygen-stressed winter months. Total phosphorus treatment was somewhat reduced during the winter, but effluent concentrations were only slightly elevated above the Ministry limit of 1 mg/L (set for the Great Lakes Watershed). Suspended solids levels were greater than the Ministry objective of 15 mg/L during the winter, but this may be attributable to the installation of stop logs to increase the water level.

### OBJECTIVE 2:

To determine if the construction of marshes in a mine tailings substrate would affect their performance.

### CONCLUSION 2:

The second objective of the marsh project was not met. Ironically, the conclusions that would have been made are not now crucial. In the period since the inception of the project the owner of the tailings deposit has excavated and removed the tailings for reprocessing.

### OBJECTIVE 3:

To determine the feasibility of the application of marsh treatment technology to the unique Cobalt situation.

### CONCLUSION 3:

Since it is apparent that marsh sewage treatment can produce an acceptable effluent water quality, the overall feasibility of the technology in the Cobalt situation is dependent on the capital costs, operating cost, and availability of sufficient land. In the absence of a proposed design, the capital and operating costs cannot be discussed. However, due to the absence of mechanical systems and chemical additions, it is expected that the capital and operating costs of marsh treatment will be lower than any alternative technology.

## Introduction

In July of 1980 the Ontario Ministry of the Environment started the Listowel Marsh Project in southwestern Ontario (Figure 1). The purpose of the project was to experimentally investigate the potential for using artificial cattail marshes to treat municipal sewage. The project involved five continuous flow marsh systems of varying configuration which could be loaded at different rates with different qualities of effluent. Although the work at Listowel is still on-going, interim assessments have established that properly configured cattail marshes have the capacity to significantly improve the water quality of waste-water (Black, et al. 1981). In the summer of 1984 the first full scale marsh treatment system began operating in Port Perry, Ontario.

In 1981 inquiries were made to M.O.E. from the Ontario Ministry of Northern Affairs as to the suitability of the marsh treatment technology to communities in Northern Ontario. The northern community of Cobalt (Figure 1) was suggested as one location which had sewage treatment problems that could possibly be solved by marsh treatment. In this specific case the land most ideally located for a sewage treatment facility was covered with tailings deposited from past silver mining operations (Figure 2). Since it was not known whether the Listowel treatment technology could be applied to either a northern climate or a tailings substrate the Cobalt Marsh Project was conceived.

The Cobalt Marsh Project had three objectives:

1) to determine if the marsh treatment technology could be applied in the more extreme climate of Northern Ontario.
2) to determine if the construction of marshes in a mine tailing substrate would affect their performance.
3) to determine the feasibility of the application of marsh treatment technology to the unique Cobalt situation.

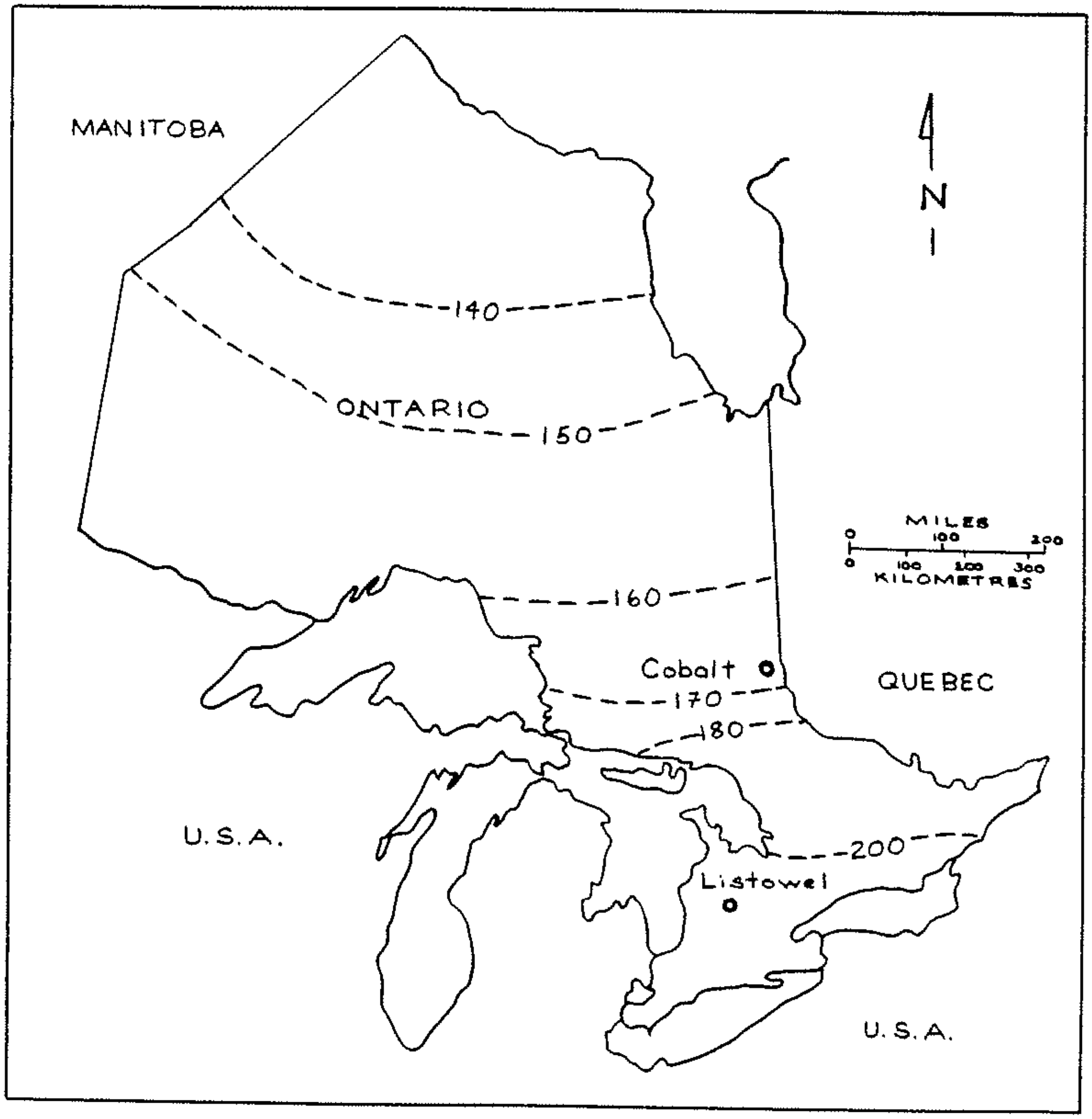



FIGURE 1: LOCATION MAP FOR THE LISTOWEL AND COBALT ARTIFICIAL CATTAIL MARSHES. THE ISOLINES SHOW THE LENGTH OF THE GROWING SEASON IN DAYS.

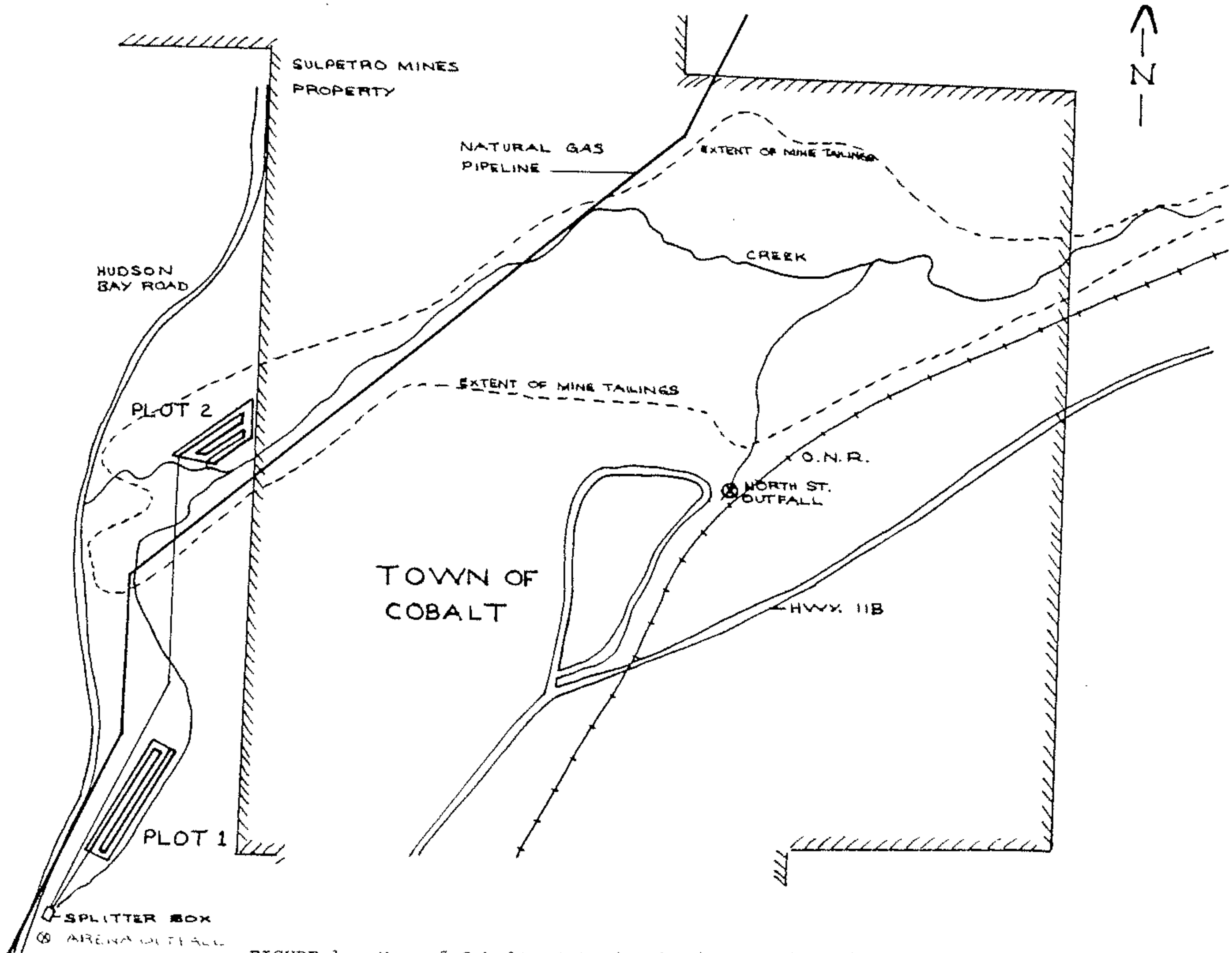



FIGURE 1: Map of Cobalt, Ontario showing the location of the marsh plots, sewage outfalls and tailings deposits.

It was intended that the first two objectives could be met through the installation and monitoring of test plots. The third objective would be satisfied when the results of these test plots were assessed with respect to the resources required and character of the total Cobalt effluent flow.

The Cobalt Marsh Project has been largely funded by the Ministry of Northern Affairs with the Ministry of the Environment providing project co-ordination and technical support. Originally the marsh plots were designed and operated by the private firm of Knox, Martin and Kretch (KMK) with consultation with Ministry of the Environment staff. Since May 13, 1983 the project has been administered by the Ministry of the Environment.

## Method

Two test plots were constructed based on the design of the best performing systems at the Listowel facility. Plot 1 was built out of insitu materials and lined with clay from off-site. Plot 2 was constructed out of the tailings deposit. Each plot was approximately 310 m in length and 3 m wide giving a length/width ratio of greater than 100:1. Each had a serpentine configuration but they were not identical. Plot 1 was rectangular with three channels (Figure 3) but property boundaries dictated that Plot 2 be trapezoidal with four channels (Figure 4).

The marshes were established by planting an individual cattail shoot with an attached piece of rhizome at one meter intervals thoughout each plot. The cattails were removed from adjacent natural stands. Plot 2 was planted in December of 1981 under the supervision of KMK but this proved to be too late in the year and the plot was replanted the subsequent June 22. Plot 1 was planted on July 14, 1982 by staff of both MOE and KMK.

The flow of sewage was controlled by a flow control structure located at the sewer outfall near the community's area. The bulk of the sewage by-passed the plots by overflowing two large

FIGURE 3: Plan view of Plot 1

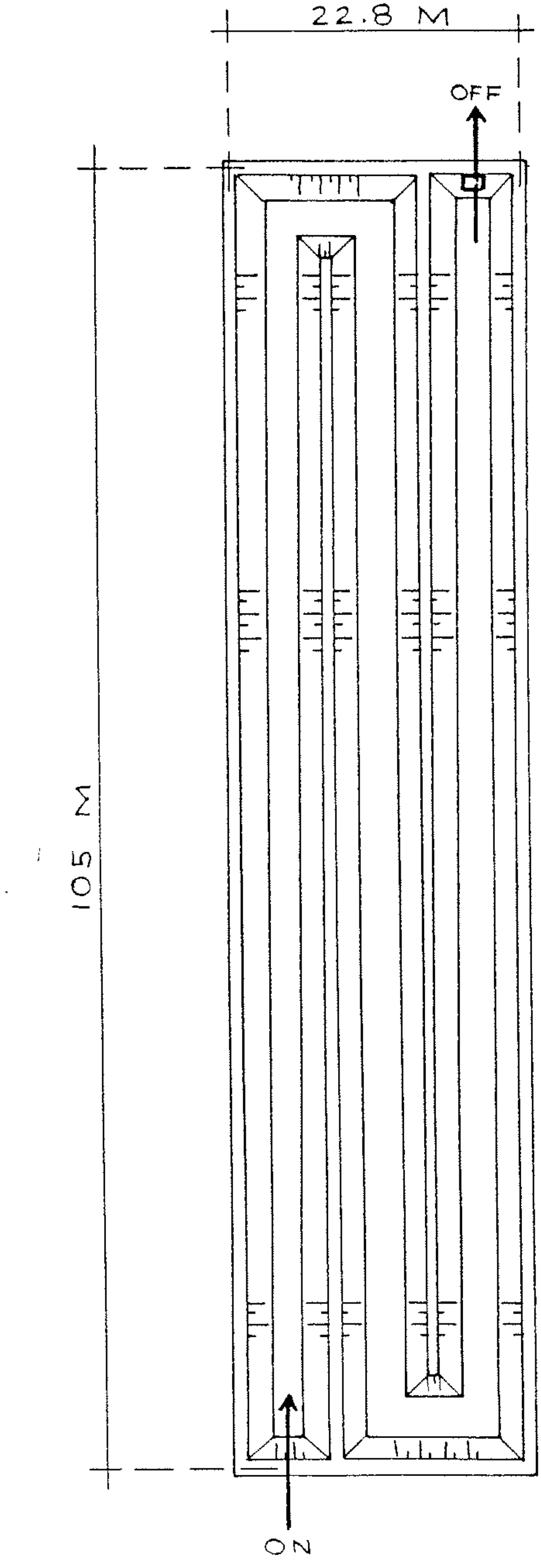
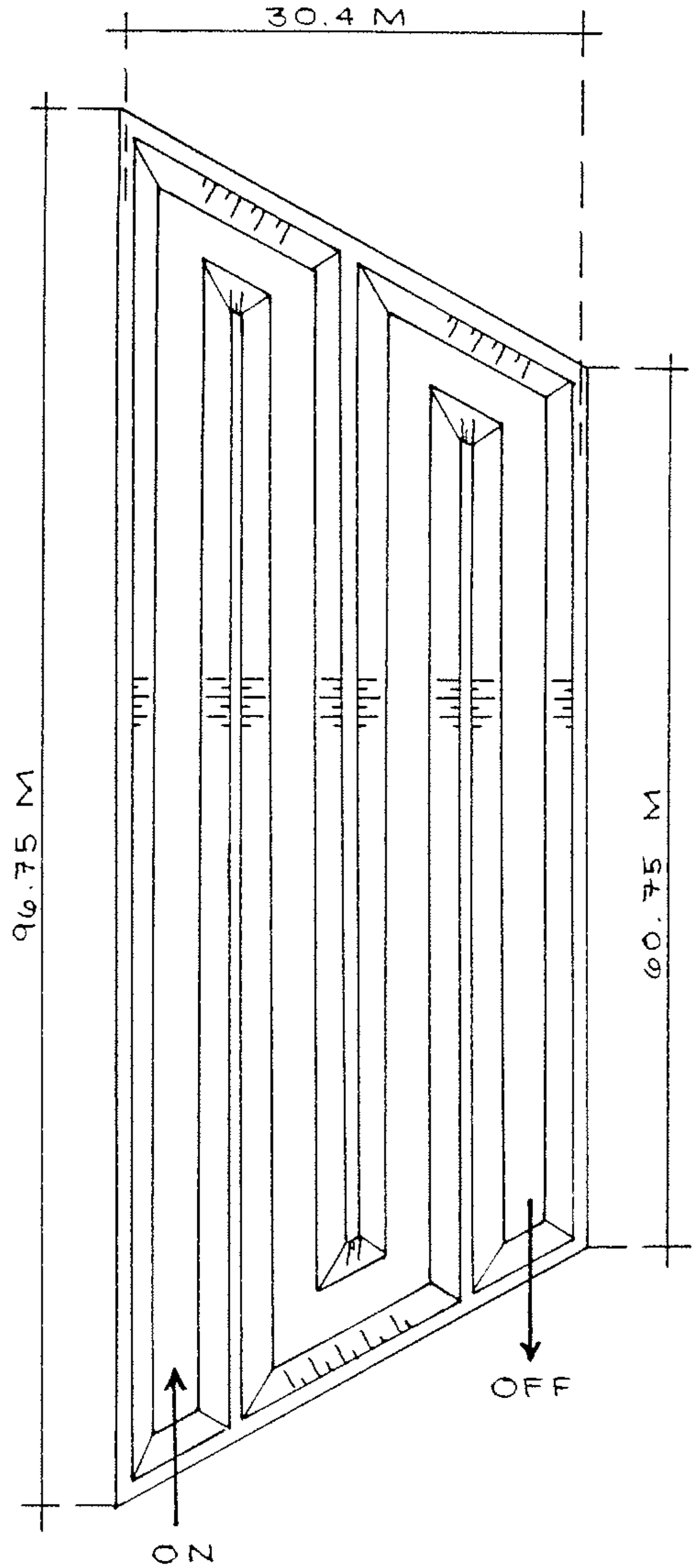


FIGURE 4: Plan view of Plot 2



rectangular weirs which acted to dampen the severe fluctuations in head which occurred in the sewer system. The flow of sewage to the plots was controlled by two 22½ degree V-notch weirs in the same structure. The head of water behind the weirs was measured by a float device and Stevens stage recorder. The calibration of stage records was maintained by the taking of timed bucket discharges during regular visits to the site. Identical weirs and stage recorders were installed in the flow control structures at the discharge from each plot.

The design called for the plots to be loaded at identical rates. Nominally this was to be approximately 0.2 L/sec. (17 $m^3$/day, 20.0 mm/day) which gave an areal loading similar to that used at Listowel. Depth was to be maintained at approximately 15 cm all year round to keep the retention time near the 7 day period used at Listowel. Depth was increased in winter time to allow 15 cm of water to be maintained under an ice layer.

The raw sewage influent to the marsh systems and the effluent from the marsh plots (if present) were sampled weekly from July 11, 1983 until the 28th of November and then alternate weeks through the winter months. The samples were analysed for $BOD_5$, suspended solids, filtered total nitrates, filtered total ammonia, total Kjeldahl nitrogen, pH, total phosphorus (TP) conductivity at 25 degrees C and sulphates.

The bacteriological quality of the water was sampled on the same dates and counts were taken of fecal streptococci, fecal coliforms and total coliforms. From July 11 to August 8, 1983 only the effluent from the plot was analysed. Subsequently, samples of both influent and effluent were monitored.

In late November the Ministry of Health Lab changed its dilution technique and method of reporting. As a result the maximum level of detection for bacterial counts was raised an order of magnitude but total coliform counts were no longer done.

The bacteriological samples were shipped on the date of sampling packed in ice packs but not always submitted to the lab the next day. Due to variation in ambient temperature and handling, samples taken on different dates may not be directly comparable.

## Results of Plot 1 - Cattail Marsh in Native Soil

### Biology of the Marsh

The growth and development of the cattails was assessed on July 5, 1983 approximately one year after their planting. As in Listowel the marsh had filled in quickly and there was evidence of both seedling establishment and continued vegetative reproduction. The cattails were approximately 1.3 m high and while there were some small voids the average density was estimated to be 20 stems/$m^2$ (Figure 5).

Also parallel to the Listowel experiment the marsh plot had already been invaded by several other species. Unidentified species of bullrush (*Scirpus*) and smartweed (*Polygonum*) were well established.

During the winter of 1982-83 muskrats tunneled through the berms of the last channel of the plot. As a result the channel dried out in the early spring and the cattails died. The holes were sealed in May and the area reflooded. Some replanting was done but it proved superfluous as new seedlings had vigorously recolonized the area by the July 5, 1983 inspection.

### Hydrology of the Marsh

Attempts to measure the incoming and outgoing flows of the experimental plot were fraught with difficulties. The stage of the water in the splitter box, behind the V-notch weirs, was subject to great fluctuations despite the dampening effect of the rectangular weirs. As well, solids accumulated in the splitter box which interfered with both the floats on the stage recorder and the V-notch weirs themselves. There were also

FIGURE 5: CATTAIL GROWTH IN PLOT 1, CONSTRUCTED FROM INSITU MATERIAL WITH A CLAY LINING.

failures in the stage recorder mechanism itself which resulted in lost data.

The recorder charts that were recovered have not been digitized at the time of this report. However, there are numerous bucket discharge measurements available which can be used to characterize flows (Table 1).

These data indicate that the marsh was loaded at a much higher rate than was originally intended. Initially the marsh received approximately three times the design volume but through time this gradually increased to five times the loading.

The outflow of the marsh always was found to be substantially less than the inflows. This was especially true during periods of the fall where stop logs had been put in place to increase the water level.

Based on the effluent flow rates, the retention time of the marsh is 6.1 days, which compares favourably with the target of 7 days retention at the Listowel marshes. However, when based on the influent flow rate, the retention time is between 2.3 and 1.5 days.

<u>Water Quality of Influent and Effluent</u>

The Town of Cobalt sewage collection system has serious infiltration problems; hence the sewage as it is discharged onto the marsh is very weakk in strength. This influent quality is similar to that from the facultative aerated 10 day retention lagoon with chemical addition for phosphorus removal used at Port Perry. Pretreatment for phosphorus and organics is generally considered as a prerequisite for marshland treatment.

The results of the water quality sampling are presented in Table 2 through 4. $BOD_5$, suspended solids and total phosphorus data are also presented graphically in Figures 6 to 8.

Table #1

Bucket Discharge Measurements

| DATE | FLOW IN L/SEC. ON | OFF |
|---|---|---|
| 1983 | | |
| Jul. 13 | 0.70 | 0.13 |
| 21 | 0.659 | 0.181 |
| 28 | 0.623 | 0.175 |
| Aug. 4 | 0.758 | 0.33 |
| 11 | 0.620 | 0.167 |
| 18 | 0.69 | - |
| 19 | - | 0.433 |
| 25 | 0.387 | 0.042 |
| Sept. 1 | 0.552 | 0.155 |
| 8 | 0.602 | 0.182 |
| 15 | 0.667 | 0.327 |
| 22 | 0.785 | 0.432 |
| 29 | 0.635 | 0.257 |
| Oct. 7 | 0.683 | 0.331 |
| 13 | 0.850 | 0.533 |
| 22 | 0.918 | 0.051 |
| 27 | 0.837 | 0.042 |
| Nov. 3 | 0.793 | 0.063 |
| 25 | 1.0 | 0.034 |
| Dec. 8 | 0.880 | 0.184 |
| 16 | 1.003 | 0.033 |
| 23 | 1.127 | 0.150 |
| 1984 | | |
| Jan. 5 | 1.03 | 0.420 |
| 13 | 1.07 | -* |
| 18 | 1.086 | 0.25 |
| 26 | 1.06 | 0.350 |
| Feb. 8 | 0.867 | 0.32 |
| 15 | 1.20 | 1.306 |

* Too Much Ice to Collect Sample

\- No Data Available

TABLE 2: Result of water chemistry sampling for $BOD_5$ SS, TP, Conductivity 25 degrees and chloride.

| DATE | BIOLOGICAL OXYGEN DEMAND mg/L | | SUSPENDED SOLIDS mg/L | | TOTAL PHOSPHOROUS mg/L | | CONDUCTIVITY µmhos/cm | | CHLORIDE mg/L | |
|---|---|---|---|---|---|---|---|---|---|---|
| | on | off | on | off | on | off | on | off | on | off |
| 1983 | | | | | | | | | | |
| July 11 | 16.6 | <2.0 | 19.7 | <3.6 | 1.40 | 1.23 | 305 | 320 | 24.0 | 23.4 |
| 18 | 27.0 | <1.7 | 42.5 | <4.5 | 1.76 | 0.40 | 465 | 280 | 96.6 | 23.6 |
| 25 | 13.2 | <2.0 | 19.5 | <0.1 | 1.35 | 0.36 | 460 | 385 | 45.4 | 48.6 |
| Aug. 2 | 33.0 | <3.4 | 38.6 | <5.8 | 1.85 | 0.44 | 423 | 278 | 38.6 | 25.6 |
| 8 | 17.6 | <4.7 | 26.1 | <5.1 | — | — | 360 | 310 | 25.6 | 24.0 |
| 15 | 35.0 | 11.0 | 30.4 | <2.8 | 2.21 | 0.49 | 335 | 295 | 21.4 | 18.6 |
| 22 | 18.4 | 6.1 | 51.2 | <3.2 | 1.93 | 0.46 | 330 | 275 | 19.8 | 18.0 |
| 29 | 9.3 | <1.4 | 20.5 | <2.7 | 1.70 | 0.23 | 320 | 265 | 18.4 | 15.0 |
| Sept.6 | 17.0 | <2.3 | 21.4 | <4.7 | 0.78 | <0.20 | 297 | 260 | 16.2 | 16.2 |
| 14 | 33.0 | 5.4 | 24.9 | 105.0 | 1.90 | 0.27 | 285 | 280 | 17.6 | 0.2 * |
| 20 | 25.0 | 1.9 | 49.5 | <2.7 | 0.72 | 0.36 | 200 | 255 | 14.4 | 18.4 |
| 26 | 27.0 | <1.4 | 52.2 | <2.3 | 1.25 | 0.44 | 315 | 313 | 22.4 | 22.6 |
| Oct. 4 | 6.4 | <2.5 | 11.5 | 8.2 | 0.60 | 0.25 | 465 | 315 | 32.2 | 19.6 |
| 11 | 27.0 | <2.9 | 37.5 | 7.9 | 1.00 | 0.43 | 475 | 360 | 36.0 | 27.4 |
| 18 | 16.4 | <1.3 | 16.6 | 7.4 | 1.70 | 0.70 | 320 | 315 | 22.8 | 24.6 |
| 24 | 21.0 | <1.4 | 17.8 | 23.7 | 2.25 | 0.70 | 310 | 310 | 18.8 | 20.4 |
| 31 | 26.0 | <2.2 | 32.3 | 24.2 | 1.80 | 0.80 | 315 | 280 | 16.8 | 17.8 |
| Nov. 7 | 48.0 | <4.7 | 38.9 | 21.0 | 2.78 | 1.03 | 365 | 300 | 29.2 | 20.6 |
| 14 | 63.0 | 6.3⇔ | 55.4 | — | 5.00 | 1.45 | 440 | 410 | 34.4 | 53.6 |
| 21 | 16.7 | 8.0 | 61.2 | 59.9 | 1.30 | 1.25 | 600 | 275 | 122.6 | 19.6 |
| 28 | 36.0 | 7.0 | 28.1 | 75.8 | 3.05 | 1.00 | 395 | 400 | 31.2 | 47.8 |
| Dec. 12 | 27.0 | 11.3 | 16.5 | 270.0 | 1.40 | 1.30 | 285 | 300 | 17.8 | 22.6 |
| 1984 | | | | | | | | | | |
| Jan. 3 | 23.0 | 9.4⇔ | 13.5 | 16.1 | 0.95 | 0.95 | 248 | 235 | 19.8 | 15.2 |
| Jan. 16 | 10.1 | 6.1 | 19.7 | 7.2 | 1.15 | 0.68 | 252 | 239 | 167.2 | 167.4 |
| Feb. 13 | 23.4 | 3.1 | 281 | 7.8 | 0.80 | 0.70 | 1100 | 387 | 288 | 61.6 |

⇔ - Approximate result

– - No data available

* - anomalous data point - inconsistent with conductivity data and other ambient chloride concentrations

continued...

Table 2: Result of water chemistry sampling for $BOD_5$ SS, TP, Conductivity 25 degrees and chloride.

| DATE | | BIOLOGICAL OXYGEN DEMAND mg/L | | SUSPENDED SOLIDS mg/L | | TOTAL PHOSPHOROUS mg/g | | CONDUCTIVITY umhos/cm | | CHLORIDE mg/L | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | on | off | on | off | on | off | on | off | on | off |
| Mar. | 13 | 27.0 | — | 23.8 | — | 0.77 | — | 255 | — | 19.8 | — |
| | 27 | 27.0 | 10.8 | 34.1 | 20.1 | 1.10 | 0.91 | 320 | 325 | 29.4 | 30.6 |
| Apr. | 9 | 14.2 | 10.7 | 14.9 | 123.0 | — | 1.88 | 450 | 490 | 62.0 | 78.4 |
| | 23 | 3.3 | 3.2 | 4.7 | 3.6 | 0.22 | 0.17 | 370 | 410 | 44.0 | 50.0 |
| May | 7 | 21.3 | 3.1 | 24.1 | 4.1 | 2.00 | 0.33 | 345 | 318 | 31.8 | 33.6 |
| | 15 | 12.1 | 0.6 | 9.5 | 3.6 | 9.5 | 3.6 | 350 | 340 | 30.2 | 31.8 |
| | 28 | 17.0 | 3.2 | 21.7 | 12.0 | 1.20 | 0.175 | 410 | 440 | 40.2 | 48.4 |
| June | 5 | 13.7 | 3.1 | 17.1 | 5.3 | 1.540 | 0.620 | 357 | 354 | 30.6 | 33.2 |
| | 12 | 22.0 | 1.8 | 23.5 | 5.3 | 1.770 | 0.360 | 377 | 298 | 33.0 | 27.4 |
| | 19 | 6.1 | 2.5 | 8.2 | 2.7 | 0.755 | 0.375 | 345 | 280 | 29.0 | 21.6 |
| | 25 | 11.3 | 2.1 | 19.1 | 4.7 | 0.620 | — | 415 | 308 | 36.8 | 24.2 |
| Jul. | 3 | 35.6 | 2.5 | 9.6 | 3.0 | 1.280 | 0.540 | 326 | 344 | 26.0 | 25.4 |
| | 9 | 19.0 | 1.6 | 13.9 | 3.4 | 1.500 | 0.350 | 324 | 294 | 22.6 | 19.0 |
| | 16 | 11.9 | 3.4 | 14.3 | 7.8 | 1.400 | 1.030 | 316 | 298 | 22.0 | 20.2 |
| | 24 | 8.6 | 3.6 | 10.3 | 7.9 | 1.700 | 0.760 | 415 | 308 | 36.8 | 24.2 |

- Approximate result

- - No data available

- anomalous data point - inconsistent with conductivity data and other ambient chloride concentrations

TABLE 3: Results of water chemistry sampling for TKN, Ammonia, Nitrates and pH.

| DATE | TOTAL KJELDAHL NITROGEN mg/L | | AMMONIA mg/L | | NITRATES mg/L | | pH | |
|---|---|---|---|---|---|---|---|---|
| | on | off | on | off | on | off | on | off |
| 1983 | | | | | | | | |
| July 11 | 7.8 | 0.9 | - | - | - | - | 6.88 | 7.44 |
| 18 | 8.2 | 1.0 | 4.3 | 0.3 | - | <0.1 | 6.83 | 8.03 |
| 25 | 5.5 | 1.5 | 3.8 | 0.3 | 0.2 | <0.1 | 7.29 | 8.14 |
| Aug. 2 | 9.3 | 1.3 | 4.3 | 0.5 | <0.1 | 0.5 | 6.86 | 7.44 |
| 8 | - | - | 5.3 | 1.7 | 0.2 | 1.5 | 6.90 | 7.28 |
| 15 | 9.3 | 1.0 | 4.0 | 0.4 | 0.2 | 0.3 | 6.71 | 7.14 |
| 22 | 6.8 | - | 4.9 | 1.4 | 0.8 | 1.6 | 6.85 | 7.01 |
| 29 | 5.8 | 0.8 | 4.7 | 0.2 | <0.1 | 0.2 | 6.72 | 7.19 |
| Sept. 6 | - | 0.5 | 3.4 | 0.4 | <0.1 | <0.1 | 6.99 | 7.10 |
| 14 | 9.0 | 1.9 U | 5.7 | 2.4 | <0.1 | 2.0 | 6.82 | 6.83 |
| 20 | 6.3 | 1.4 | 2.8 | 0.7 | 0.2 | 0.5 | 6.88 | 7.01 |
| 26 | 7.1 | 1.6 | 3.4 | 0.8 | <0.1 | 0.9 | 7.11 | 7.21 |
| Oct. 4 | 1.4 | 0.8 | <0.1 | <0.1 | 6.2 | 1.6 | 7.14 | 7.12 |
| 11 | 5.8 | 0.8 | 3.5 | 0.5 | 2.8 | 2.8 | 7.52 | 6.89 |
| 18 | 6.0 | 3.1 | 5.3 | 2.0 | 0.2 | 1.2 | 6.84 | 7.16 |
| 24 | 8.0 | 3.6 | 2.3 | 2.4 | 0.2 | 1.3 | 6.77 | 7.07 |
| 31 | 7.3 | - | 3.6 | 2.5 | 0.2 | 4.0 | 6.92 | 6.88 |
| Nov. 7 | 10.0 | 4.7 | 5.0 | 3.4 | <0.1 | 4.1 | 6.93 | 7.10 |
| 14 | 9.3 | - | 3.7 | 3.2 | <0.1 | 2.1 | 6.64 | 6.78 |
| 21 | 4.5 | - | 1.5 | 4.2 | 0.3 | 0.3 | 6.68 | 6.79 |
| 28 | 9.8 | 3.8 | 4.5 | 3.4 | 0.2 | 3.9 | 7.00 | 7.13 |
| Dec. 12 | 1.5 | 1.9 | <0.1 | <0.1 | 3.3 | 4.6 | 6.33 | 6.26 |
| 1984 | | | | | | | | |
| Jan. 3 | 3.5 | 1.0 | <0.1 | <0.1 | 3.6 | 5.2 | 6.64 | 6.26 |
| Jan. 16 | 6.0 | 4.7 | 3.3 | 0.1 | 0.1 | 0.2 | 6.78 | 6.83 |
| Feb. 13 | 4.0 | 4.5 | 1.2 | 3.2 | 0.3 | <0.1 | 6.77 | 6.67 |

U - Unreliable result
\- - No data available

continued...

Table 3: Results of water chemistry sampling for TKN, Ammonia, Nitrates and pH.

| DATE | TOTAL KJELDAHL NITROGEN mg/L | | AMMONIA mg/L | | NITRATES mg/L | | pH | |
|---|---|---|---|---|---|---|---|---|
| | on | off | on | off | on | off | on | off |
| March 13 | 5.5 | - | 3.3 | - | 0.2 | - | 6.77 | - |
| 27 | 6.0 | 5.3 | 3.3 | 3.5 | 0.2 | 0.1 | 6.99 | 6.87 |
| April 9 | - | 6.3 | 0.8 | 0.1 | 0.5 | 0.1 | 6.93 | 6.75 |
| 23 | 3.0 | 2.7 | 1.3 | 1.5 | 3.0 | 2.1 | 7.22 | 7.42 |
| May 7 | 8.5 | 1.4 | 2.5 | 0.1 | 0.1 | 0.3 | 6.67 | 8.71 |
| 15 | 10.1 | 1.1 | 0.1 | 0.1 | 1.6 | 1.2 | 7.35 | 7.90 |
| 28 | - | 0.70 | 5.0 | 0.2 | 6.20 | 0.30 | 7.22 | 7.60 |
| June 5 | 3.90 | 1.10 | 3.6 | 0.1 | 0.40 | 0.45 | 6.89 | 7.59 |
| 12 | 10.40 | 1.10 | 7.20 | 0.05 | 0.30 | 0.05 | 6.95 | 6.99 |
| 19 | 5.90 | 0.90 | 3.40 | 0.30 | 0.05 | 0.05 | 7.63 | 6.93 |
| 25 | 2.60 | - | 1.40 | 0.05 | 0.45 | 0.45 | 6.97 | 6.83 |
| July 3 | 4.30 | 1.50 | 2.35 | 0.55 | 0.75 | 0.05 | 6.87 | 6.73 |
| 9 | 4.80 | 1.40 | 5.00 | 0.90 | 0.05 | 0.50 | 7.03 | 6.86 |
| 16 | 4.00 | 3.00 | 1.45 | 2.00 | 0.30 | 0.05 | 7.02 | 7.03 |
| 24 | 4.20 | 2.90 | 2.20 | 1.90 | 0.30 | 0.15 | 6.96 | 7.20 |

U - Unreliable result

\- - No data available

TABLE 4: RESULTS OF BACTERIOLOGICAL SAMPLING PROGRAM

| DATE | FAECAL STREPTOCOCCI x 10/L | | FAECAL COLIFORMS x 10/L | | TOTAL COLIFORMS x 10/L | |
|---|---|---|---|---|---|---|
| | on | off | on | off | on | off |
| 1983 | | | | | | |
| July 11 | - | 9,000 | - | 12,000 | - | - |
| 18 | - | 8,000 | - | 280 | - | - |
| 26 | - | 9,000 | - | +++ | - | +++ |
| Aug. 2 | - | 3,840 | - | 1,200 | - | 6,400 |
| 8 | - | <40 | - | 40 | - | 2,800 |
| 15 | +++ | <100 | +++ | +++ | +++ | +++ |
| 23 | - | - - | +++ | 40 | +++ | 400 |
| 29 | +++ | 4,000 | +++ | 960 | +++ | 6,000 |
| Sept. 6 | +++ | +++ | +++ | 80 | +++ | 1,000 |
| 14 | +++ | +++ | 1,800 | +++ | 3,000 | +++ |
| 20 | +++ | 3,080 | +++ | 40 | +++ | 4,800 |
| 26 | +++ | 1,160 | +++ | 40 | +++ | 3,200 |
| Oct. 4 | 3,600 | <40 | +++ | 600 | +++ | 3,000 |
| 11 | +++ | 480 | +++ | 40 | +++ | 600 |
| 18 | +++ | 400 | +++ | 40 | +++ | 200 |
| 24 | +++ | <40 | +++ | 40 | +++ | 200 |
| 31 | +++ | <200 | +++ | 320 | +++ | 400 |
| Nov. 7 | 2,680 | 1,720 | +++ | 2,560 | +++ | 6,400 |
| 14 | +++ | 2,000 | +++ | 3,400 | +++ | 20,000 |
| 21 | +++ | +++ | +++ | +++ | +++ | +++ |
| 28* | >200,000 | 6,600 | >600,000 | 1,000 | - | - |
| Dec. 12 | 60,000 | 60,000 | 60,000 | 14,000 | - | - |
| 1984 | | | | | | |
| Jan. 3 | >200,000 | 62,000 | 290,000 | 10,000 | - | - |
| 16 | 8,000 | 2,800 | 86,000 | 16,000 | - | - |
| 30 | 16,000 | 5,400 | 44,000 | 20,000 | - | - |
| Feb. 27 | 31,000 | 2,000 | 27,000 | 2,200 | - | - |
| Mar. 13 | 22,000 | - | 220,000 | - | - | - |
| 27 | 1,800 | 3,000 | 53,000 | 20,000 | - | - |
| Apr. 9 | 18,000 | 4,000 | 150,000 | <10,000 | - | - |
| 23 | 15,000 | 800 | >200,000 | 3,000 | - | - |
| May 7 | 200,000 | 24,000 | >600,000 | <10,000 | - | - |
| 15 | 34,000 | <200 | 250,000 | <10 000 | - | - |
| 22 | 130,000 | 1,000 | 450,000 | 10,000 | - | - |
| 29 | >200,000 | 800 | >600,000 | <10,000 | - | - |
| June 12 | 130,000 | 3,200 | >600,000 | <10,000 | - | - |
| 19 | 70,000 | 24,000 | 360,000 | <10,000 | - | - |
| 25 | 40,000 | 200 | 11,000 | <10,000 | - | - |
| July 3 | 200 | 110,000 | 340,000 | <10,000 | - | - |
| 9 | 30,000 | 10,000 | 410,000 | <10,000 | - | - |
| 16 | 50,000 | 800 | 520,000 | <10,000 | - | - |
| 24 | 110,000 | 1,600 | 600,00 | <10,000 | - | - |

+++ - Denotes greater than maximum detectable number
Faecal strep. 20,000
Faecal coliform 12,000
Total coliform 80,000

* - Samples heated in transit

\- - No data available

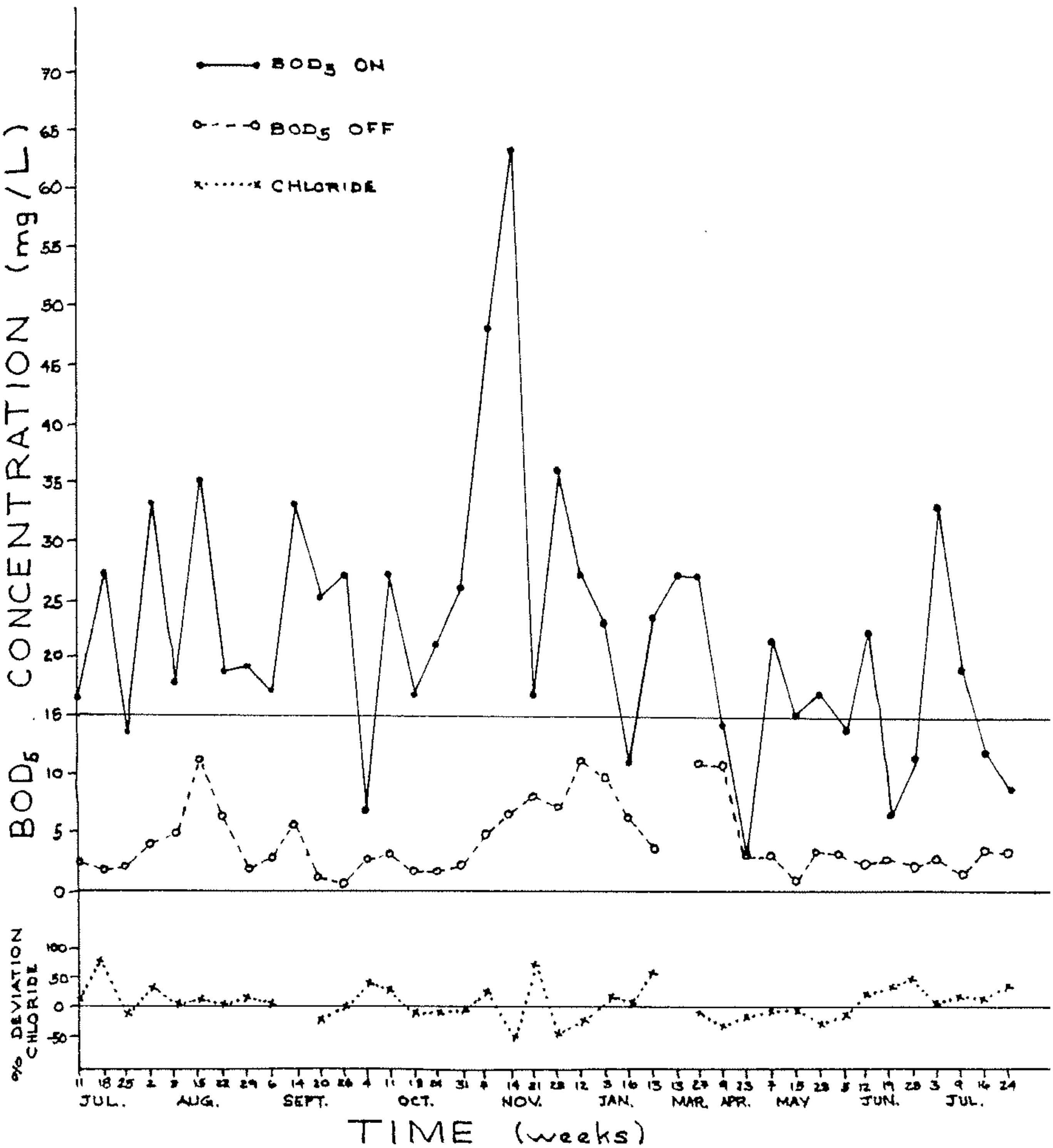



FIGURE 6: A GRAPH OF $BOD_5$ CONCENTRATIONS IN THE INFLUENT AND EFFLUENT OF THE MARSH (PLOT 1)

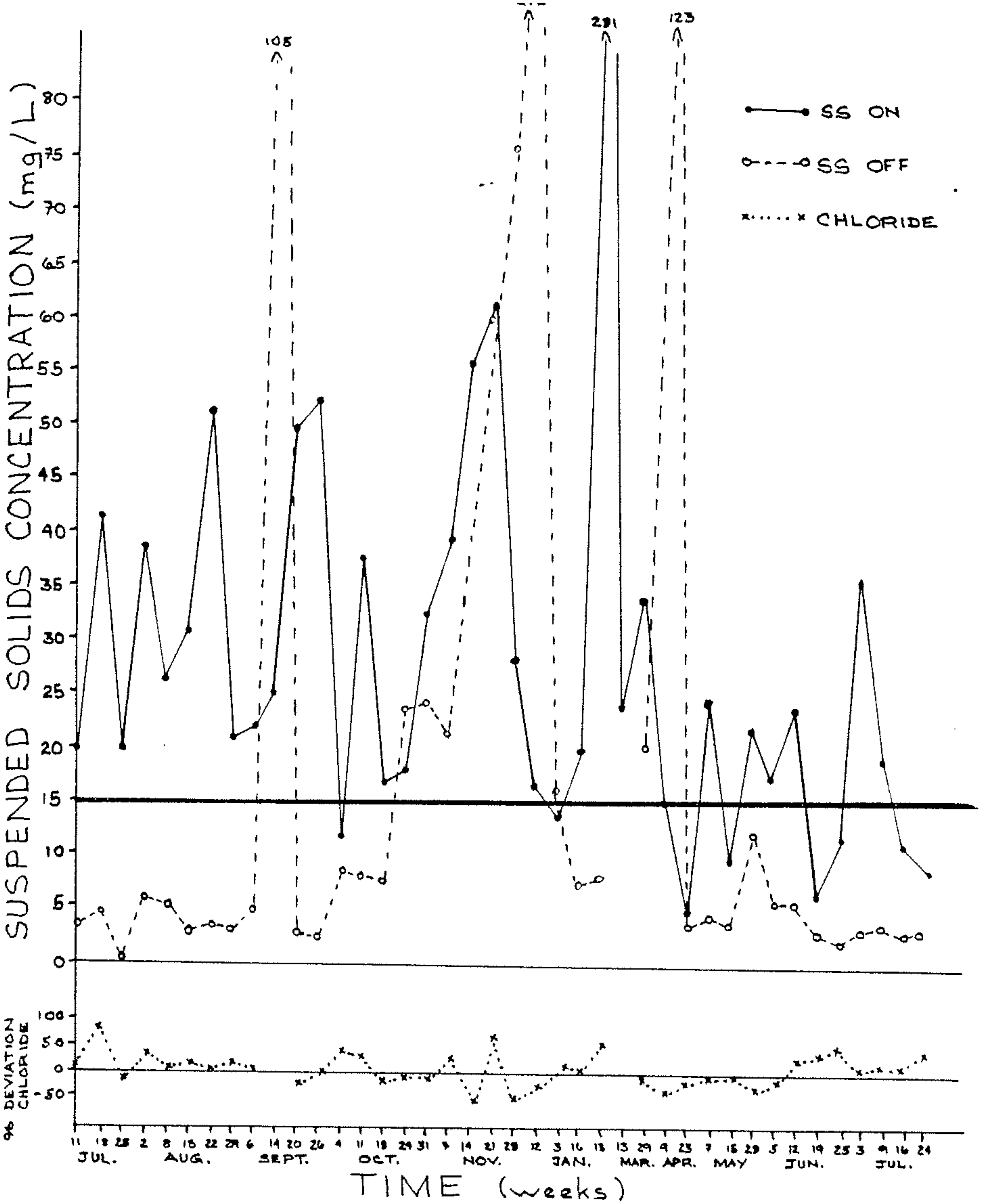



Figure 7: A graph of suspended solids concentrations in the influent and effluent of Plot 1

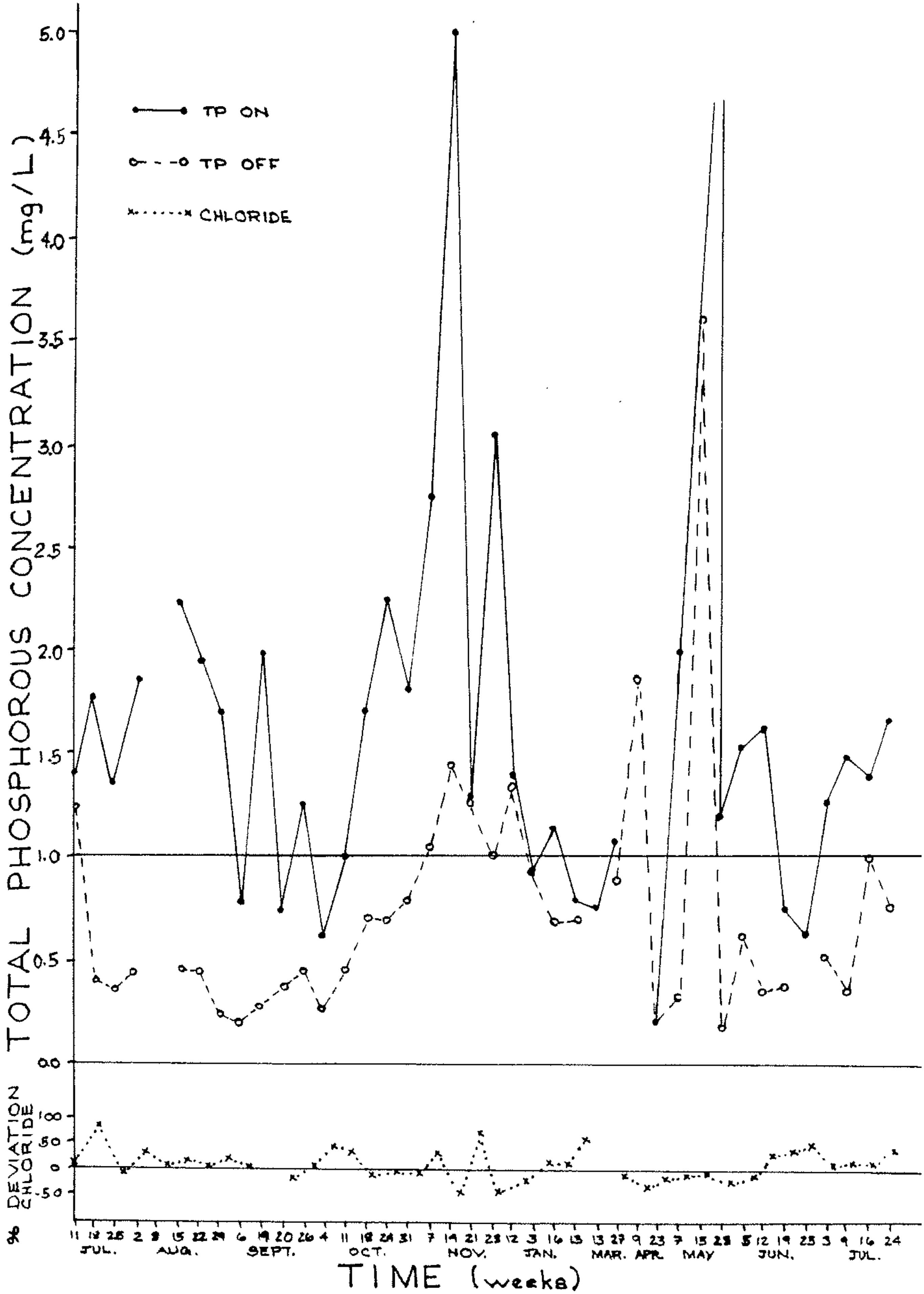



Figure 8: A graph of total phosphorus concentrations in the influent and effluent of Plot 1

The $BOD_5$ in the raw sewage averaged 21.7 mg/L, ranging from 3.3 mg/L to 63.0 mg/L (Table 2). Passage through the marsh reduced the $BOD_5$ by an average of 80.0%, producing an effluent with an average 4.1 mg/L $BOD_5$. The reduction in $BOD_5$ levels was generally less from November 1983 to April 1984 than for previous months, but the final product always contained less than 15 mg/L $BOD_5$ the objective of secondary sewage treatment.

Suspended solids in the raw sewage averaged 31.9 mg/L and ranged from 4.7 mg/L to 281 mg/L (Table 2). Thirty-two out of 38 sample pairs showed reductions in SS coming off the marsh as compared to SS loaded onto the marsh.

On September 14 and December 12, 1983, and on April 9, 1984, the effluent contained anomalously high SS. The overall average percentage reduction in SS, excluding these three anomalies, was 66.5%, resulting in an effluent with an average 10.9 mg/L SS. The objective for SS levels in a secondary effluent is 15 mg/L.

The TP in untreated sewage averaged 1.74 mg/L and ranged from 0.62 mg/L to 9.50 mg/L (Table 2). The outflow from the marsh contained an average 0.74 mg/L TP which represented a reduction of 55% from the phosphorus levels in the raw sewage. The objective for phosphorus levels in a secondary effluent in the Great Lakes Basin is 1 mg/L. The Cobalt Marsh met this objective on 27 out of 36 sampling dates.

The TKN and ammonia concentrations (Table 3) were reduced 64.9% and 72.9% respectively by passage through the marsh. In each case this reduction was less pronounced in fall and winter than in the summer.

Nitrates in the raw sewage averaged 0.89 mg/L, and were variable in the marsh effluent averaging 1.10 mg/L (Table 3). Nitrates in the effluent were generally highest in the fall and early winter.

Table 4 reports the results of the bacteria counts. On September 14, 1983 the data reported was anomalous. The values reported were the exact reverse of the values reported in both the weeks before and after. Since it is a reasonable possibility that the samples were accidentally switched on this date, these data are not considered in the analysis.

The results show that while bacterial counts are consistently high going into the plots the output counts vary. Out of 40 paired input and output samples counted for fecal streptococci, 29 showed lower bacterial populations in the outflow. Three could not be distinguished, since both input and output levels were above the maximum detectable limit of the dilution series. One sample showed a very slight increase in the fecal strep count. Similarly fecal coliforms were lower in the outflows in 32 out of 33 paired comparisons with one pair being undistinguishable.

The numerical value of the counts show that the numbers of fecal streptococci and fecal coliform discharging were usually low during cool periods. In the best of conditions the marsh is capable of discharging an effluent which meets swimming and bathing water quality objectives.

## Discussion and Conclusions

The biological growth and development of the marsh parallelled the marsh development at Listowel. The height and density of the cattails after one year were not as great as in Listowel but the vigor with which the marsh established itself was the same.

The hydraulic integrity of the marsh however was not up to the standards of the Listowel facility. The bucket discharge data (Table 1) indicates that there was a large loss of fluid from the plot due to exfiltration despite its 'clay lining'. Fortunately this loss does not interfere with the critical criteria for the assessment of the performance of the marsh since these are expressed as concentrations and not loadings. Exfiltration cannot decrease the effluent concentration, but it may increase it in the case of suspended solids and bacteria.

One consequence of the presence of an unknown level of exfiltration, however, is that one cannot be certain to what extent the improvement in the contaminant concentration seen through the marsh is a function of dilution (due to rainfall or snow melt) or concentration (due to evapotranspiration losses).

For this reason the deviation in chloride concentrations were used to calculate an index of the potential dilution/concentration by the following formula:

$$\text{Percent Deviation} = \frac{\text{Input } [Cl] - \text{Output } [Cl]}{\text{Input } [Cl]}$$

Thus, high positive values indicate an apparent period of dilution and high negative values a period of concentration. The index is presented in Figure 6 through 8 as an aid in interpretation of the data presented. It can be seen from this that during most of the study period dilution and concentration were not related to effluent improvement.

It must be noted however that the marsh is a 'plug flow' system with a relatively long residence time and that this makes the index sensitive to certain perturbations. Sudden large changes in the chloride concentration such as that which was reported on November 21, 1983 (Table 2) will result in unfair comparisons when the formula is applied. Thus, the apparent peak dilution of November 21 (Figures 6 to 8) is likely an artifact of high chloride concentration in the 'plug' entering the marsh at that time. Similarly, the apparent concentration evident the next week is likely an artifact of the tail of the same plug leaving the marsh.

As illustrated by Figure 6 the marsh maintained an effluent $BOD_5$ concentration well within the 15 mg/L standard expected of a secondary sewage treatment system during the whole study period. As was found in Listowel the effluent quality of the marsh seems to be more closely related to seasonal influences rather than influent quality. During periods of oxygen stress in August and particularly in mid winter, $BOD_5$ removal was diminished, but the final effluent concentration remained well within the Ministry objective of 15 mg/L.

The performance of the marsh with respect to the suspended solids parameter was very unusual (Figure 7). At Listowel marshes were shown to be excellent settling and filtering mechanisms. Yet in the Cobalt data high levels of SS were reported in the effluent on several occasions. One must be cautious in interpreting the significance of these observations.

The parameter of suspended solids is a useful measure for traditional sewage treatment technology since the values are quickly and easily determined and the removal of suspended solids is normally correlated to the reduction of other more directly deleterious parameters such as $BOD_5$.

However, unlike traditional sewage treatment, marshes are characterized by the autochthonous production of high cellulose, fibrous organic matter called detritus. Despite the settling capabilities of marsh systems, disturbance or erosional flow patterns can cause the resuspension of detritus with a consequent increase in suspended solids measurements. Such material, however, would differ from traditional sewage suspended solids in that it would have a very low $BOD_5$ as a consequence of its unfavourable C:N ratio. Observation of the data shows that the high suspended solids peaks in the marsh effluent did not in fact correspond to proportional increases in $BOD_5$.

The high suspended solids values are coincident with the installation of the stop logs used to increase the water level for winter operation. This disturbance would have been sufficient to resuspend detrital material from the marsh and therefore lead to unrealistically high values.

Although phosphorus removal may not be of concern in the Ottawa River watershed, Figure 8 illustrates the phosphorus reduction capabilities of the marsh. As found in Listowel phosphorus concentrations leaving the marsh during the growing season are very low although, during the cold oxygen stressed periods of winter some of the treatment is lost. The phosphorus concentration in the marsh effluent was always less than 1.5 mg/L during winter months.

The data from the nitrogen parameters again parallel the findings of the Listowel experimental marsh. There is a reduction of TKN and ammonia through the marsh in the warmer months which falls off somewhat during winter. This indicates that ammonia and organic nitrogen concentrations change mainly in response to temperature dependent biological interactions.

Whereas the nitrate concentration change through the marsh is not interpretable due to the dynamic nature of the marsh nitrogen cycles, nitrates are useful as a indication of the oxidation state of the marsh. Since the data (Table 3) indicate that surplus nitrates were present at all times it is likely that both sulphur compounds and iron largely remain in the oxidized form during the sampling period.

There are no comparable objectives for secondary sewage treatment with which to evaluate the bacteriological performance of the marsh system. The marsh effluent varies widely in quality through different seasons and conditions. It can be concluded however that the bacteriological quality of the effluent in the better operating periods far exceeds the quality to be expected for a traditional secondary treatment plant.

On the basis of this discussion it seems reasonable to conclude that plot 1 has provided sufficient information to meet the first objective of the Cobalt marsh project. It can be concluded that the marsh sewage treatment technology can be transferred successfully to northern climates. The results of this study compare favourably to secondary sewage treatment standards despite the marsh being inadvertently loaded at 3 to 5 times the intended rate.

This accidental overloading provides a bonus of information to the conclusion of the study. The original design loadings were set at Listowel arbitrarily based on conservative estimates of what the marsh could handle. There has been no attempt at Listowel to define the upper loading limit the marsh system could treat.

In this study we see that higher loadings of this particular effluent can be satisfactorily treated. We cannot strictly define what these values are due to the problems with flow regulation and exfiltration. However, it seems reasonable to conclude that areal loadings of twice to three times the Listowel rate are quite acceptable at Cobalt.

## Results and Discussion of Plot 2 - Cattail Marsh in Mine Tailings

Despite two years of effort by various parties to get plot 2 operational, no useable results were obtained from this plot. Except for a short period in the spring following construction when the frost was still in the ground, the plot lost water at such a high rate due to exfiltration that even at the maximum possible loading no flow reached the last channel.

This problem was a result of the construction of the plot at a high level above the surrounding grade out of coarse tailings material. The potential for exfiltration was recognized early on by the Ministry of the Environment. A memo was issued to the consultant in charge of the design and operation of the marsh, Knox Martin and Kretch (KMK), on November 2, 1981, warning of this problem and suggesting that a clay liner be added to control exfiltration. However, the consultant hoped that the sewage itself at high flows would plug the marsh and prevent exfiltration. It did not. In a final attempt to plug the marsh, KMK tried feeding the marsh from the outflow end, in an attempt to plug the last channel where exfiltration appeared to be most severe. This attempt was only partially successful.

On May 13, 1983, control of the Cobalt Marsh was turned over to the Minsitry of the Environment. The sewage was immediately rerouted in the original manner. Alum sludge from the water filtration plant and approximately 62 truck loads of sewage sludge were then added to the marsh channels in an attempt to plug the marsh and achieve some flow. Some plugging was observed, however, plugging adequate to give a proper discharge could not be achieved.

The above efforts continued until mid-February, 1984, when the marsh structurally failed. On or about February 15, 1984, the outside berm of the first channel of the marsh slumped due to the excessive moisture flowing through the channel wall (Figure 9). The plot was subsequently abandoned.

The growth and development of the cattails in Plot 2 was assessed on July 5, 1983, approximately one year after planting. There was sufficient moisture in the first three channels to support vigorous cattail growth, similar to Plot 1. However, the growth was not as tall and was distinctly more patchy than that in Plot 1 (Figure 5 vs 10). Therefore, it can be concluded that cattails will transplant and grow adeqately in these tailings. It remains unknown, however, how well this marsh system would have treated the sewage.

Although this second objective of the Cobalt Marsh Project was not met, the conclusions that would have been made are not now crucial. In the period since the inception of the project the owner of the tailings deposit has excavated and removed the tailings for reprocessing.

FIGURE 9: SLUMPING OF BERM IN PLOT 2.

FIGURE 10: PATCHY CATTAIL GROWTH IN PLOT 2,
CONSTRUCTED FROM MINE TAILINGS.

## THE FEASIBILITY OF MARSH TREATMENT IN COBALT

Since it is apparent that marsh sewage treatment can produce an acceptable effluent water quality the overall feasibility of the technology in the Cobalt situation is dependent on the capital costs, operating costs and availability of sufficient land. In the absence of a proposed design the capital and operating costs cannot be discussed. However, due to the absence of mechanical systems and chemical additions it is expected that the capital and operating costs of marsh treatment will be lower than any alternate technology. Therefore, this discussion of feasibility will be centered on the availabiltiy of sufficient land which might be used for the construction of a marsh.

In Cobalt untreated sewage is discharged into the surface drainage from two main sources known as the arena outfall and the North Street outfall (Figure 2). Details of the nature of these discharges and the sewer systems which feed them are described in the report entitled "The Corporation of the Town of Cobalt, Report on Municipal Services" prepared by Knox, Martin, Kretch Ltd. The marsh plots at Cobalt were fed from the arena outfall which is the more concentrated of the two effluents.

While the marsh provides acceptable treatment for the presently dilute Cobalt sewage, there may be a need for pretreatment if the sewage is substantially concentrated by improvements made to the sanitary sewer system.

Based on the total average flow from both these sources of 2900 $m^3$ per day and an areal loading rage of 50 mm per day (2.5 times the Listowel rate) there is a requirement for 5.8 ha of marsh area. To maintain this loading during peak flows of 3600 $m^3$, 7.2 ha would be required. In this case the peak flows are mainly due to storm events which represent a dilution of the effluent and not an increase in sewage load. Therefore, the design flow used to calculate the area required should be closer to the average flow than the peak flow. Perhaps a figure such as the 80th percentile of the population of hourly discharge rates could be used. Using the KMK data this value would be approximately 3200 $m^3$ per day.

Since the potential exists for upset conditions or disruptions (eg. muskrat damage) it is recommended that the necessary marsh area be operated as several small parallel systems rather than one major marsh. In addition a redundancy of approximately 20% should be designed into the system to allow for maintenance, rest periods (if the redox potential of the marsh becomes too negative) and surge capacity for peak flows. A configuration satisfying these criteria would be one of which there were 5 parallel marshes of equal size with a combined area sufficient to treat the designed flow (the 80th percentile in the example) plus a 6th redundant marsh of the same area. Such a configuration would require a total of 7.7 ha of marsh area plus sufficient land for berms, access and control structures.

The total land area available in the area of the extracted tailings deposit on Sulpetro Mines land is about 9.7 ha. Another 3 ha of unexcavated tailings and waste land owned by Sulpetro and Agnico Eagle Mines is apparently available. This area if obtained would be sufficient for a marsh treatment facility to accomodate the present needs of the Town of Cobalt. Additional land is available further downstream of the tailings area, upstream of Farr Creek that could also be utilized for a marsh treatment facility.

## References

Black, S.A., I. Wile, G. Miller. 1981. Sewage effluent treatment in an artificail marshland. Ontario Ministry of the Environment Toronto, Ontario. 23 pp.