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An Assessment of the Hydrology and Water Quality of Indian Ridge Marsh and the Potential Effects of Wetland Rehabilitation on the Diversity of Wetland Plant Communities

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Prepared for the
United States Environmental Protection Agency

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Illinois State Water Survey
Ground-Water Section
Watershed Science Section
University of Illinois
Department of Civil Engineering

A Division of the Illinois Department of Natural Resources

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ABSTRACT

Indian Ridge Marsh is a remnant of a once larger wetland complex on the southeast side of Chicago that has been severely affected by the surrounding infilling and land-use activities. This project was designed to assess the hydrology and the water quality of Indian Ridge Marsh and to begin to provide the decision-making tools necessary for recreating high-quality wetland systems. These tools have the goal of improving the water and habitat qualities of the marsh and creating a desirable distribution of wetland communities. Water quality samples were collected from the marsh during the 1997 growing season. The hydrology of the marsh was simulated using the SWAMPMOD hydrologic model, which was coupled with a rule-based vegetation model. Different scenarios were evaluated with the model to predict changes in vegetation diversity and retention times with different hydrologic modifications intended to improve the marsh, such as adding a weir, changing the topography with the addition of clean soil, or adding higher quality water from the sidestream elevated pool aeration (SEPA) station.

With the major exception of ammonia-nitrogen, the water quality characteristics of Indian Ridge Marsh generally met the Illinois Environmental Protection Agency's (IEPA) general-use standards where applicable and were comparable to values reported for other Illinois natural marshes. Ammonia-nitrogen levels in the north and south pools were greater than the general-use standard in the spring and at levels potentially toxic to many fish. The levels of dissolved and suspended solids were very high and may be having a deleterious effect on the native vegetation and the biodiversity. The concentrations of iron in five samples and lead in one sample exceeded the IEPA general-use standards. Values for aluminum, boron, lead, and zinc also were significantly greater than the maximum values reported for other Illinois natural marshes. Ground-water inflow and storm events appear to have a significant influence on the water chemistry.

The hydroperiods determined by the hydrologic modeling for many of the scenarios reflect the strong influence of Lake Michigan and the adjacent Calumet River water elevations on water levels in Indian Ridge Marsh, particularly when the lake levels are high. The modifications studied here would have some effect on the water elevations in the wetland, especially during drier times. But a comparison of predicted vegetative communities for all the scenarios suggests that the potential diversity of the system would not be increased greatly by these minor changes. Several of the scenarios resulted in a lower median retention time than the 29 days predicted for the current conditions. In the scenario that constricted flow through the culvert at 122nd Street, as often happens in the field, almost all of the water was retained for at least 29 days.

The remediation strategies modeled in this project show that the hydrology of Indian Ridge Marsh could be altered or controlled in a manner that would greatly improve the water quality of the marsh while maintaining the potential for diverse vegetative communities. The recommendation of specific strategies or combinations of strategies to use is not included in this report. That choice is left to the decision-makers for Indian Ridge Marsh who must consider other biotic elements, such as controlling invasive species or creating open water for fish foraging by birds, and other nonbiotic factors, such as the design of nature center facilities.

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INTRODUCTION

The history of Indian Ridge Marsh and the Calumet region of Chicago produced an ecological system that is quite different from the one that existed before development. The extensive wetlands that comprised the area have been reduced to smaller pockets isolated from each other by industrial, commercial, and residential areas and by transportation routes. Hydrologic flow patterns have been altered by damming and reversing the flow of the Calumet River. Development also has degraded surface and subsurface water quality. Steel mill slag and other wastes were used to fill in wetland areas, which has produced leachate that can be highly alkaline, contain little dissolved oxygen (DO), and have high concentrations of ammonia and heavy metals. Runoff on the west side of the marsh comes from a collection of disposal sites under Superfund consideration known as the Lake Calumet Cluster Site.

Although the wetlands in the region still provide a valuable habitat for many plant and wildlife species, this habitat continues to be threatened by the degraded water quality, altered flow patterns, and invasion by exotic plant species. By improving the hydrology and the water quality, the potential exists to vastly improve the quality of the habitat for birds, such as the state-endangered black-crowned night herons that nest on the site, or for fish, such as chinook salmon and yellow perch, that were previously found in neighboring Big Marsh.

The purpose of this study was to assess the hydrology and water quality of Indian Ridge Marsh, assess the consequences on wetland plant communities, and provide the decision-making tools necessary for recreating high-quality wetland systems. These tools include specific techniques for water and habitat quality improvement in the marsh and creating desirable wetland plant communities. Several scenarios have been modeled to predict changes in vegetation diversity and retention times with different hydrologic modifications to the marsh. For example, scenarios included adding a weir, changing the topography with the addition of clean soil, or adding higher quality water from the sidestream elevated pool aeration (SEPA) station. The location of the SEPA station at the south end of the marsh provides an opportunity to expand beyond the initial objective of the Metropolitan Water Reclamation District of Greater Chicago (MWRDGC) of improving the oxygen content of the Calumet River to provide further off stream habitat improvement and water quality control.

Acknowledgments

The project was funded through grants from the U.S. Environmental Protection Agency (USEPA) through the Coastal Environmental Management program and the Great Lake National Program Office. Special thanks go to Gregory Carlson, Mardi Klevs, Rosita Clark, Edward Klappenbach, and Ray Marasigan of USEPA for their technical and supportive assistance. Ken Konyha provided the latest version of the hydrologic model SWAMPMOD. Special thanks also go to several individuals at the Illinois State Water Survey: William Bogner, Ceaser Hernandez, and Kathy Brown played key roles in surveying and presenting the bathymetric data. Walton Kelly, Vernon Knapp, and Deva Borah provided a technical review of the report. Eva Kingston and Agnes Dillon provided an editorial review. Linda Hascall assisted with the graphics. The views expressed in this report are those of the authors and do not necessarily reflect those of the sponsors or the Illinois State Water Survey.

HYDROLOGY

Physical Description

The Indian Ridge Marsh consists of several wetland pools connected to the Calumet River (figures 1 and 2). The marsh sits on a rectangular site that is 1 mile long north to south and a quarter mile wide east to west. It is bounded by the SEPA station of the MWRDGC and the Calumet River to the south, Torrence Avenue to the east, 116th Street to the north, and the Norfolk Southern Railroad line to the west. East 122nd Street sits on a causeway that divides the marsh into north and south pools connected by a culvert at the west end of the causeway. Six smaller pools along Torrence Avenue are isolated from the north and south pools by undeveloped causeways.

A topographic survey of the marsh was performed to create a bathymetric map (figure 2). The topographic information also was used in hydrologic modeling. The survey was accomplished by establishing a baseline along the Norfolk Southern Railroad causeway on the west side. Eleven transects were surveyed across the marsh to Torrence Avenue using a total station instrument. Elevation benchmarks along 116th and 122nd Streets were established using a high-resolution global positioning system (GPS) based on a datum from a National Geodetic Survey benchmark near the intersection of 130th Street and Brainard Avenue. Leica System 200 GPS equipment was used. It is reported to have an accuracy of 2 centimeters (cm) in the horizontal direction and 4 cm in the vertical direction (Leica, 1993). The outlines of the pools were digitized from 1:6000 scale aerial photos provided by the Illinois Department of Transportation and verified in the field. Shallow water depths and a soft bottom prohibited access to the north end of the north pool either by canoe or on foot. The excessive height of more than 14 feet of the common reed (*Phragmites australis*) stands caused additional difficulty. This area was subsequently mapped when access by canoe was possible to the portions that are open water.

Based on survey results, the total wetland area in Indian Ridge Marsh is approximately 92 acres. Table 1 divides this area by elevation. The surface areas of the north pool, south pool, and the six combined east pools are 49, 26, and 17 acres, respectively. In addition, there are almost 4 acres of wetland and open water at the SEPA station. Excluding the half-block area in the northeast corner that contains several homes, there are 68 acres of dry upland area comprised largely of wooded causeways and a meadow in the north-central portion roughly 20 acres in size.

Most of the marsh has a bottom elevation between 580 and 582 feet. Because the present dry upland area was created by postsettlement fill, the shorelines tend to be regular with steep banks comprised of rubble. One prominent topographic feature in the marsh is a main channel that runs along the western edge of the marsh adjacent to the railroad causeway. This channel averages roughly 50 feet wide and extends the length of the marsh. The central pond in the north pool has a deep spot at which the bottom elevation is 575 feet. This area was probably the result of mining of the Dolton Sand that underlies the marsh. This central pond also has a narrow connection to the main channel that can become cluttered with debris when the water level drops below 582 feet. The bottom of one of the east pools is higher than the rest of the marsh and is

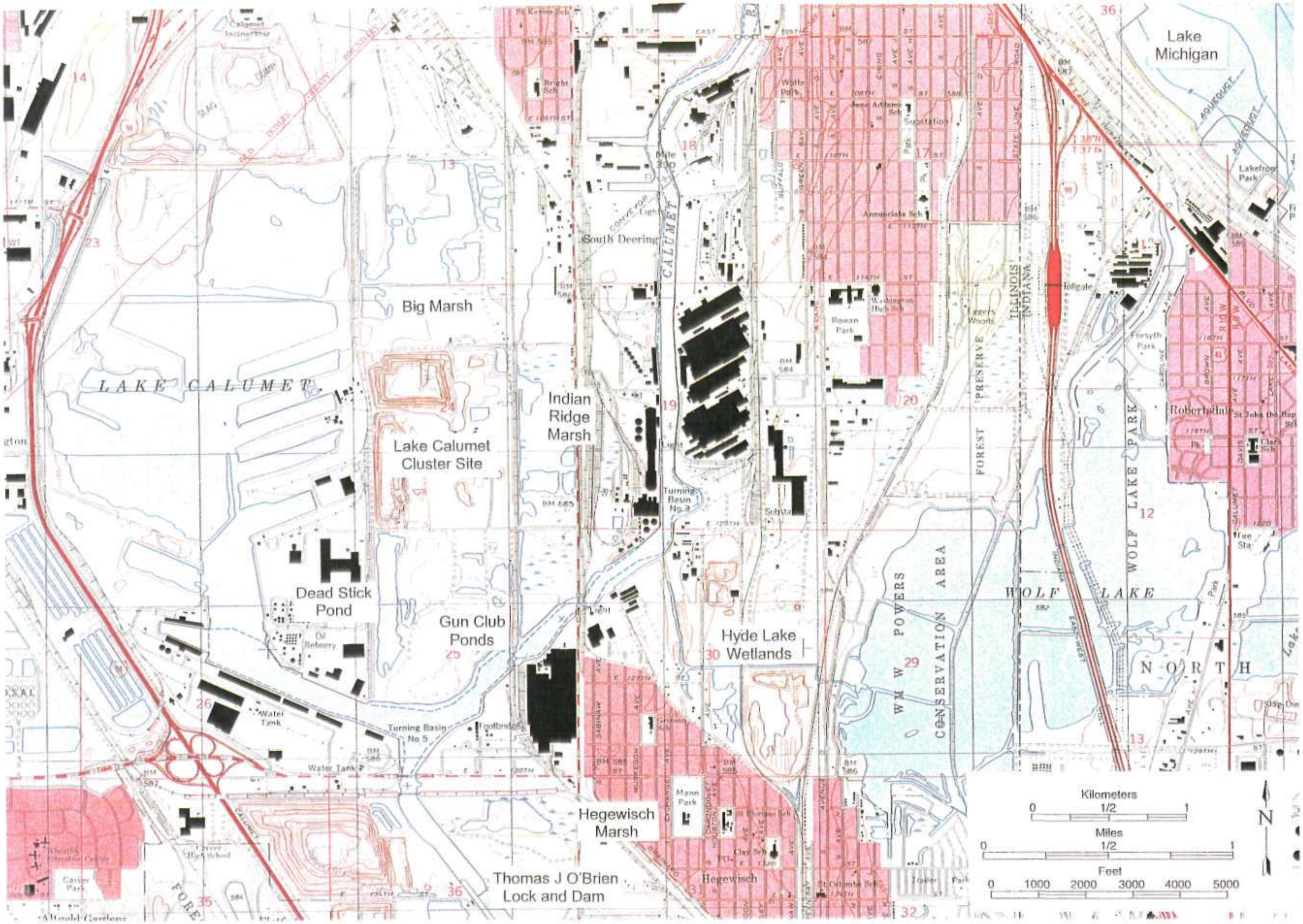

Figure 1. Location map of Indian Ridge Marsh (modified from USGS, 1997).

Figure 2. Bathymetric elevation map and sampling locations.

Table 1. Bathymetric Elevation Summary of Indian Ridge Marsh and Surrounding Wetlands

Elevation (feet)	*Indian Ridge Marsh (acres)*	*Total mapped wetlands (acres)*	*Surrounding unmapped wetlands (acres)*	*Lake Calumet and the Calumet River (acres)*
<579	1.70	23.17		993.05
579 - 580	4.73	4.90		
580-581	33.58	60.50		
581-582	41.78	87.60		
582 - 583	6.22	69.08		
583 - 584	0.66	20.21		
584-585	3.14	3.68		
585 - 586	0	12.07		
586 - 589	0	2.51		
589 - 592	0	0.89		
Total	91.81	284.61	130.65	993.05

Note: The Calumet River acreage includes the area between 107th Street and 130th Street.

likely the result of incomplete infilling and blockage of the surface drainage. The outlet at the south end of the south pool is cluttered with debris and has an elevation of 580.5 feet, but this elevation could change if the debris is removed or if more debris piles up. Active erosion may further decrease the outlet elevation with time. The areas with the three highest elevations listed in table 1 are at the SEPA station.

Surrounding Indian Ridge Marsh are a large number of other wetlands and lakes. More than 284 acres of the wetlands to the west have been mapped (table 1), including Big Marsh, Dead Stick Pond, and unnamed wetlands often referred to as the Gun Club Wetlands. Another 131 acres of unmapped wetlands are within a mile of the marsh, including ponds on the waste sites to the west, the wetlands north of Big Marsh, and Hegewisch Marsh to the south. However, there are probably an additional 40-50 acres of small wetlands in the area that are too small to be delineated for the larger scale map (figure 1). Thus there are nearly 500 acres of wetlands in and around Indian Ridge Marsh. In addition to the surrounding Lake Calumet and the Calumet River, there are 804 acres of open water and wetlands in the William Powers Conservation Area at Wolf Lake approximately 1 mile to the southeast. Lake Michigan is 2.5 miles to the northeast.

Flow Characteristics

Flow occurs generally from north to south. Water enters the wetland system at the north pool with flow from both the east and the west. Smaller flows enter from the north. Three culverts are located beneath the railroad tracks approximately one block south of 116th Street. These culverts carry runoff from a drainage area estimated to be approximately 13 acres on the Lake Calumet Cluster Site. Flow from this culvert exceeds ~ 5 cubic feet per second (cfs) during large storm events. A culvert under 116th Street conveys runoff from an estimated one-acre drainage area along the railroad tracks to the north, although no measurable discharge was observed in this culvert during storm events. There does not appear to be any overland flow from the adjacent coke plant into the north pool.

Between the north pool and Torrence Avenue there are an estimated 26 acres of upland dry area that drain into the north pool; the remaining upland dry areas drain into the east pools or onto Torrence Avenue where flow is collected by a storm drainage system. Assessing runoff patterns in the upland area was difficult due to the flat, but erratic, surface of the anthropogenic fill. The many wet spots and undulations in the topography would indicate that the site was not properly graded after the infilling. The inefficiency of the storm drains along Torrence Avenue caused constant flooding problems on the street, which made determining the amount of runoff to the drains impossible.

Water from the north pool flows through the culvert under the 122nd Street causeway and into the south pool. This connecting culvert is often blocked by sediment or debris, which can cause the water level in the north pool to rise by several feet. After flowing through the south pool, the water flows through a channel to the Calumet River. Flow through the marsh is diverted through the main channel on the west side, which may limit its interaction with the plants in the marsh and thus reduce the capacity of the marsh to treat contaminants in the water.

The smaller, isolated east pools are hydraulically connected only by ground-water flow through the causeways. In 1994, a broken water main along Torrence Avenue released a large quantity of potable water into the second east pool north of 122nd Street. This discharge continued for at least several months. During this time the water level in the second east pool was 2.26 feet higher than in the north pool. In 1997, the water level in the pools along Torrence Avenue were similar and were consistent with north pool elevations.

Ongoing alterations to the watershed may alter flow dynamics. The construction of the deep tunnel along Torrence Avenue could reduce the amount of any road runoff that can go into the eastern pools during storm events. The potential reconstruction of 122nd Street may provide an opportunity to connect some of these isolated pools to the main part of the marsh.

The water level at the outlet of the marsh is controlled by the Calumet River, which in turn is controlled by the Thomas J. O'Brien Lock and Dam and the level of Lake Michigan. Prior to settlement and construction of the Cal-Sag Channel, the Calumet River was a small, meandering stream that flowed toward Lake Michigan with combined flow from the Little Calumet River, the Grand Calumet River, and Lake Calumet. Unlike the controlled water surface elevations of today, historic water surface elevations were more variable. During this historic time, the mouth of the river possibly was blocked periodically by sandbars and spits during low flows. In addition, none of the causeways or filled-in areas surrounding the marsh existed, allowing natural hydrologic retention functions to operate in the presettlement wetlands. Historical flow dynamics probably produced water levels that were both higher and more responsive to precipitation, even though there was a good connection with Lake Michigan to remove water from this area.

Today the Calumet River is a deep navigation channel from Lake Michigan to the Thomas J. O'Brien Lock and Dam 1.5 miles south of the marsh outlet. The river has a very low discharge for its channel cross section, with flow reversals common due to the lock and dam operation and storms on Lake Michigan. A hydrograph of the Calumet River near the Indian Ridge Marsh outlet (figure 3) was developed by combining two sets of stage data. Daily stage data for the Calumet River on the lake side of the lock were available for 1986-1997 from the U.S. Army Corps of Engineers, Rock Island District Office. Missing data not exceeding three consecutive days were interpolated linearly. Lake Michigan elevation data at the Calumet Harbor were obtained from the National Oceanic and Atmospheric Administration (NOAA) for 1978-1997. Using the data from both sets, the slope between the stations was computed. The elevation adjacent to the wetland for each day was then calculated as the slope multiplied by the distance from Lake Michigan to Indian Ridge Marsh and added to or subtracted from the lake elevation.

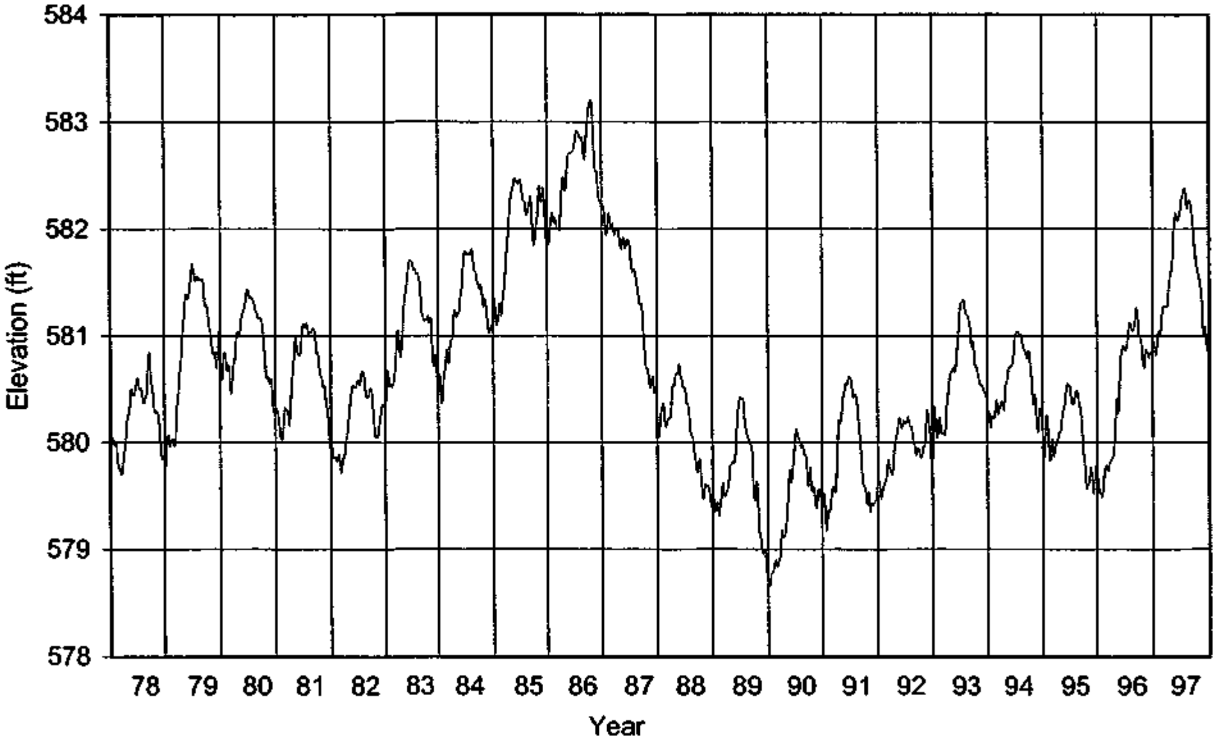

Figure 3. Hydrograph of the Calumet River at the Indian Ridge Marsh outlet.

During normal and low-stage conditions, when the water level in the river is lower than the level in the wetland, water flow was assumed to be out of the south pool into the Calumet River. However, during high Calumet River stages, the river stage/elevation is higher than the marsh, and water is expected to flow into the wetland at its normal discharge point from the Calumet River. Water from the Calumet River may pass through the south pool and enter the north pool if the stage of the river is very high. At present, there is no structure controlling flows between the river and the wetland pools.

Geology and Ground-Water Flow

The geologic deposits in the Lake Calumet region are comprised of unconsolidated lake sediments and glacial tills overlying Silurian dolomite bedrock. An additional layer of fill material covers much of the surface area of the region. The Silurian dolomite is several hundred feet thick, with a top elevation of around 500 feet at the site. This unit forms an aquifer and is used extensively for water supply in some of the outer suburbs. The deep tunnel being constructed under Torrence Avenue to collect combined sewer overflows is in this unit. Overlying the dolomite is approximately 70 feet of the Wedron Formation that is divided into a lower Lemont Drift and an upper Wadsworth Till. Both of these units are described in the region as gray silty clays with traces of sand and gravel (Roadcap and Kelly, 1994). The elevation of the upper surface of the till is around 570 feet and slopes gently to the east, reflecting an erosional surface at the bottom of Lake Michigan immediately following glaciation.

Overlying the till is the Equality Formation, which is comprised of the beach sands of the Dolton Sand Member and the lacustrine sands, silts, and clays of the Carmi Member. Strong longshore currents and waves brought in sediments from retreating glaciers and eroding shorelines to the north, forming a large sand deposit east and south of Lake Calumet (Bretz, 1955). As the water level of Lake Michigan receded, a series of low beach ridges was formed parallel to the present shoreline. Due to the lack of any topographic relief, rivers, lakes, and wetlands were formed between these ridges. Lake Calumet and its surrounding wetlands, including Indian Ridge Marsh, occupied a large backwater area formed as a result of the longshore current being deflected to the east by the Stony Island bedrock high north of the site. As a result, the sands underlying Indian Ridge Marsh tend to be silty and only 5-12 feet thick.

A large amount of fill was used to raise the low-lying areas high enough to be developed as industrial or residential property. Due to the haphazard, truckload-by-truckload way in which the fill was dumped, the lithologic and hydraulic character of the fill is extremely variable and cannot be quantified into a single description for even short horizontal and vertical distances. The main types of fill in the region are slag wastes from nearby steel mills, dredged material from the Calumet River system, demolition debris, municipal wastes, and other industrial wastes (Colton, 1985; Roadcap and Kelly, 1994; Kay et al., 1996). In Indian Ridge Marsh, demolition debris and slag are the dominant fill materials visible along the edges of the pools and at the surface of the upland areas. Most of the pool bottoms do not appear to have any fill. Reported fill thicknesses are as much as 11 feet in the north-central portion of the property (Roadcap and Kelly, 1994). From the 1928 U.S. Geological Survey (USGS) topographic map and the 1938 aerial photo, much of the filling along the causeways appears to have occurred in the 1930s.

Much of the large upland area in the north-central portion was filled in the 1960s and 1970s (Kay et al., 1996).

To the west of the marsh are several industrial and municipal waste disposal sites, collectively known as the Lake Calumet Cluster Site, that are under Superfund consideration. As outlined by Roy F. Weston, Inc. (Bosko, 1998a), the dumping and landfilling at the Cluster Site has caused numerous environmental and water-quality problems. The surface drainage area that contributes flow to the marsh was estimated to be 13 acres; however, the ground-water drainage area could be much larger because the marsh is much lower in elevation than the Cluster Site.

Detailed soil survey information is not available for the marsh. The bottoms of the wetland pools generally can be characterized as being very soft, organic-rich clays and silts. The quality and characteristics of the soil on the upland areas depends greatly on the type of fill material present, how permeable it is, how reactive it is, and how long it has been vegetated. According to the general soil map of Du Page County and part of Cook County, the Calumet region is classified as Urban Land-Selma-Oakville soil (USDA-SCS, 1979). This soil is characterized as deep; level to undulating; well-drained to poorly drained, with a loamy, silty, or sandy subsoil formed in glacial outwash and in glacial lake sediments.

The interaction between ground water and the wetlands is very complicated due to the extreme heterogeneity of the fill material. Duwal (1994) examined ground-water flow rates and the response to precipitation at an Illinois State Water Survey (ISWS) study site equipped with piezometers, wells, seepage meters, and raingages on Big Marsh The erratic nature of the fill has caused extensive macropore systems to develop that appear to have a hydraulic conductivity two orders of magnitude or more greater than that of surrounding fill and underlying deposits. These preferential pathways are manifested in the wetlands as springs regularly spaced 12-20 meters (m) apart. Flow in the springs greatly increases between 6 and 16 hours after a storm event begins, suggesting that macropore systems are acting more like drains than an aquifer. Higher and slower water-level fluctuations in wells away from the macropores indicate hydraulic behavior more typical of a ground-water system.

Ground-water inflow into Indian Ridge Marsh was directly observed on January 19, 1999, when the water in the pools was frozen. The discharge of warmer ground water kept small areas along the bank either free of ice or covered by a much thinner layer of ice than on the rest of the pool. The main area of ground-water inflow was along the middle third of the western boundary of the north pool. This area would be between 118th and 120th Streets if they existed. Large, individual springs were not observed, probably because the underlying sand and/or the ballast under the railroad tracks diffuses any macropore flow. A small spring also was observed in the northeast corner of the north pool. Although it was partially blocked, flow through the culvert under 122nd Street was roughly 5-7 gallons per minute, which kept the ice thin around the northern end of the south pool.

WATER QUALITY

Existing Water Quality Data

Surface water and ground-water samples were collected from Indian Ridge Marsh as a part of other past and existing ground-water related projects by the ISWS and the USGS (Roadcap and Kelly, 1994; Duwelius et al., 1996). Appendix A includes these data and refers to them in the discussions of the different physical and chemical characteristics in this section. The ground-water samples were collected from ISWS monitoring wells 17 and 18 in the northeast corner of the marsh and well 20 along the 122nd Street causeway. Samples also were collected from a private monitoring well (well 70) northwest of the site. The surface water samples were collected from the locations close to the sampling sites for this study as described in the following section, except where noted in appendix A. The sampling of the six sites in April 1995 was in response to a large fish kill observed in the north pool. These data represent a snapshot of the water quality in the marsh at the time of the kill and would not be indicative of the water quality throughout 1995. Water from a leaky city water main along Torrence Avenue may have contributed to the more dilute water found in the east pools.

Material and Methods

Field Measurements

In order to assess the current water quality conditions in Indian Ridge Marsh, a monitoring program was set up during the 1997 growing season. Five sites were sampled on a monthly basis from April 15 to October 15,1997. Additional samples were collected on May 19, June 16, and July 20, 1997, from each site following storm events of 0.94, 0.75, and 2.81 inches, respectively, for a total of ten samples. Appendix B includes the amount of local precipitation recorded at an ISWS raingage 1 mile east of the marsh at 12233 S. Avenue O (Westcott, 1998). The first event followed a relative dry 2½-month period that experienced less than 4 inches of rain. The August 20, 1997, sample also represents poststorm conditions in that it was preceded by 3.47 inches of rain 3-9 days earlier. Another set of samples was collected on September 2, 1997, from the north pool for analysis of organic contaminants. Follow-up grab samples were collected on May 7, 1998, and January 19, 1999, and analyzed for ammonia-N. The winter months were not sampled because they are generally less ecologically important and the water chemistry is expected to be relatively consistent during this period, as was the case in Wolf Lake (Lin et al., 1996), which is a mile to the east of Indian Ridge Marsh.

Figure 2 shows the locations of the monitoring stations, and table 2 provides site-specific information. The north pool, south pool, and outlet locations were selected because they are representative of the main water bodies and because the existing data indicated degraded water quality. The east pool site was selected as representative of water quality in the six isolated eastern pools. Samples were collected away from shore areas using a lightweight, 6-foot hard plastic raft. Because the draft of the raft was minimal, it was possible to move the raft without disturbing bottom sediments in shallow areas. The SEPA station site was chosen because of the potential use of this water as part of a remediation scheme in the marsh. The uppermost pool of

Table 2. Indian Ridge Marsh Sampling Stations

Station	*Description*
1	Second east pool north of 122nd Street and next to Torrence Avenue, near center of the pool next to a 10-inch diameter post
2	North pool, 500 feet north of 122nd Street (4th electric pole) and in center of main channel east of railroad
3	South pool, 400 feet south of 122nd Street (5th electric pole) and in center of main channel east of railroad
4	Near south pool outlet, approximately midway between Station 3 and the confluence with the Calumet River
5	Northeast corner of uppermost SEPA station pool

the SEPA station was chosen because the water has already undergone some aeration and it has the highest hydraulic head to best gravity feed water into the marsh. When the SEPA station was not operating, water samples also were collected from the Calumet River (April 15 and August 20, 1997).

In situ observations were made for water temperature, DO, and Secchi disc transparency in conjunction with each sample. A Yellow Springs Instrument model 58, with a 50-foot cable and probe, was used for DO measurements. The meter was calibrated at the site using the saturated air chamber standardization procedure. Temperature and DO profiles were measured when possible. The profile interval was 1 foot. Secchi disc transparency was determined using an 8-inch diameter Secchi disc, which was lowered until it disappeared from view, and the depth was noted. The disc was lowered further, then slowly raised until it reappeared. This depth was also noted, and the average of the two depths was recorded.

Water Chemistry

Grab samples for water chemistry analyses were taken near the surface (at a depth of 6 inches) using 1000-milliliter (mL) plastic bottles. Two samples for nutrient analyses were collected in 125-mL plastic bottles with and without filtration (0.45-micrometer or µm membrane filter) using reagent-grade sulfuric acid as a preservative. Samples for metals analyses were collected in 250-mL plastic bottles containing reagent-grade nitric acid as a preservative. Samples for organic analyses were taken in 1-gallon dark amber bottles filled without any headspace. All samples were kept on ice until transferred to the laboratory for analysis. Table 3 indicates the method and procedures involved in the analytical determinations.

For the metal analyses, sample preparations were performed in the ISWS laboratory at Peoria, Illinois. Analyses for metals and organic compounds were carried out using an inductively coupled plasma detector and a gas chromatograph/mass spectrometer, respectively, by PDC Laboratories, Inc., which is an Illinois Environmental Protection Agency (IEPA)

Table 3. Analytes, Method Detection Limits, and Analysis Methods

A) Analytical Determinations

Analyte	MDL[1]	Standard methods[2]	USEPA method[3]	USEPA method[4]
Nutrients (mg/L)				
Nitrite and Nitrate, NO_2-N+NO_3-N	0.06	4500-NO_3-F		
Ammonia + Ammonium, NH_3-N + NH_4-N	0.02	4500-NH_3-N		
Total and Dissolved Phosphate-P	0.01	4500-P-B&E		
Total Kjeldahl Nitrogen, TKN	0.15			351.1
Dissolved Cations/Metals (ug/L)			6010B	
Aluminum, Al	0.3			
Antimony, Sb	0.3			
Arsenic, As	0.2			
Barium, Ba	0.2			
Beryllium, Be	0.2			
Boron, B	5			
Cadmium, Cd	0.05			
Chromium, Cr	0.4			
Cobalt, Cb	0.05			
Copper, Cu	0.1			
Iron, Fe	10			
Lead, Pb	0.05			
Magnesium, Mg	3			
Manganese, Mn	0.04			
Molybdenum, Mo	0.1			
Nickel, Ni	0.2			
Selenium, Se	0.5			
Silver, Ag	5			
Sodium, Na	1			
Thallium, Th	1			
Vanadium, V	0.2			
Zinc, Zn	0.5			
Laboratory Measured Physical/Chemical Properties (mg/L)				
Total Alkalinity (as $CaCO_3$)	2	2320		
Total Solids	10	2540B		
Total Suspended Solids	1	2540D		
Volatile Suspended Solids	1	2540E		

B) Other Physical/Chemical Properties

Parameter	Equipment accuracy	Standard methods[2]	ASTM method[5]
Laboratory			
pH (units)	0.03	4500-H^+ B	
Turbidity (NTU)	±2	2130B	
Field			
Dissolved Oxygen, (mg/L)	±0.01		D888
Secchi Disc Transparency (inches)	±2		
Specific Conductance (µmho/cm)	±1	2510	
Temperature (°C)	±0.1		

Notes:

[1] Method Detection Limit

[2] Source: APHA et al., 1992.

[3] Source: USEPA, 1996a.

[4] Source: USEPA, 1983.

[5] Source: ASTM, 1989.

certified laboratory. Organic analyses were performed according to U.S. Environmental Protection Agency (USEPA, 1996a) method SW846 in the 8000 series, i.e., 8260 and 8270. The USEPA (1996a) methods of SW 846-6010 were used for metal analyses.

Quality Assurance and Control Summary

A quality assurance project plan or QAPP (R.A. Locke II, 1997, unpublished) was developed for this project and submitted to the USEPA - Region 5 Office. The overall quality assurance objective for this study was to develop and implement field sampling and laboratory analysis procedures that would help accomplish the following study goals:

- Determine the feasibility of restoring the Indian Ridge Marsh complex.
- Study the hydraulic and chemical behavior of the marsh complex.
- Develop and test viable low-cost methods to restore contaminated wetlands.
- Recommend restoration options at the Indian Ridge Marsh complex.

The quality assurance project plan specifically identified:

- measurements to be made in the field and lab,
- all methods of analysis to be used,
- field procedures for sampling, and
- methods to assess the quality of data from water sampling.

Methods described in the QAPP are summarized in this report when appropriate, and additional data are presented below.

A total of 66 sample sets (48 samples, 8 trip blanks, and 10 field duplicates) were collected from water matrices between April 15, 1997, and October 15, 1997. Methods described in the *Quality Assurance and Field Methods Manual* (IEPA, 1987) were used as a basis for surface water sampling procedures. Methods used for sample analysis in the laboratory are cited from either the USEPA or the American Public Health Association and are noted with the method detection limit (MDL) for each analyte in table 3. All samples were analyzed within the sample-holding times specified in the QAPP.

Several noncritical analytes (e.g., turbidity, volatile suspended solids or VSS, and total suspended solids or TSS) were added during the project. Organic compounds also were added as noncritical analytes. These additions were done in order to better characterize the surface water quality at Indian Ridge Marsh. Results from all analyses are presented in the text of this report, except for the organic compound analyses listed in appendix C.

Data Precision. Data precision was assessed by the collection and analysis of duplicate samples in the field and in the laboratory. The relative percent difference (RPD) was calculated for each sample and its duplicate according to the following equation:

$$RPD = \{(S-D)/[(S+D)/2]\} * 100$$

where:
S = original sample value.
D = duplicate sample value.

For concentrations (in the original sample) at or above ten times the MDL, an RPD of up to 20 percent between a duplicate and original sample analysis was acceptable. For concentrations between one and ten times the MDL, an RPD of up to 100 percent was allowed. When analytes were added, the preceding criteria also were used to judge their validity.

For dissolved nutrients and laboratory-measured physical and chemical properties, ten sets of field duplicates were taken in addition to the original 48 sample sets (21% duplication). Ten sets of laboratory duplicates per 48 sample sets (21 % duplication) also were analyzed. For the field duplicates, RPDs were calculated for 116 of 120 pairs of original/duplicate measurements. The RPDs for 110 (94.8%) of those pairs were acceptable; 80 pairs (69.0%) had RPDs within 10 percent of the original values. The RPDs for four pairs were not calculated because concentrations were not above the MDL. These measurements were considered valid. All unacceptable RPD values occurred in either the VSS or TSS data.

For the laboratory duplicates, RPDs were calculated for 117 of 120 pairs of original/duplicate measurements. The RPDs for 116 (99.1 %) of those pairs were acceptable; 103 pairs (88.0%) had RPDs within 10 percent of the original values. The RPDs for three pairs were not calculated because concentrations were not above the MDL. These measurements were considered valid. The only unacceptable RPD value occurred in a TSS analysis. The most problematic analyte was TSS (particularly in the field duplicate samples). However, the lowest (7 milligrams per liter or mg/L) and highest (114 mg/L) values recorded were valid measurements.

For metals, one field duplicate was taken per 14 samples (7% duplication). A duplicate sample was taken on August 20, 1997, from the east pool (Station 1). The RPDs were calculated for 18 of 22 pairs of original/duplicate measurements. The RPDs for 16 (88.9%) of those pairs were acceptable; 9 pairs (50.0%) had RPDs within 10 percent of the original values. The RPDs for four pairs were not calculated because concentrations were not above the MDL. These measurements were considered valid. Unacceptable RPD values were calculated for boron and iron.

Data Accuracy. Data accuracy was assessed by the collection and analysis of field blanks to test sampling procedures and lab matrix spikes to test laboratory procedures. For dissolved anions, nutrients, and laboratory measured physical and chemical properties, eight sets of field blanks per 48 sample sets (17% duplication) were taken to spot check for sample bottle contamination. Table 4 shows the field blank results. These show no evidence of sample bottle contamination. All reported values (except pH) were near or below the MDL.

Significant concentrations of aluminum, boron, and copper were observed in the field blank taken from the east pool on August 20, 1997. In addition, much higher concentrations of barium and zinc were observed in the August 20, 1997, sample. Because there was only one

Table 4. Water Quality Characteristics of Field Blanks

Date	*pH, units*	*Total alkalinity*	*Conductivity, μmho/cm*	*Turbidity, NTU*	*TSS*	*VSS*	*Total solids*	*Total phosphate-P*	*Dissolved phosphate-P*	*Nitrate and nitrite-N*	*Ammonia-N*	*Total Kjeldahl-N*
4/15/97	5.76	2	1.2	4	2	2	2	0	0	<0.05	<0.02	<0.15
5/13/97	5.89	2	1.8	0	0	0	0	<0.01	<0.01	<0.05	<0.02	0.38
6/16/97	5.75	2	1.2	0	1	1	1	0	0	<0.06	<0.02	<0.15
6/29/97	5.77	1.6	1.0	0	0	0	0	0.03	<0.01	<0.06	<0.02	<0.15
7/20/97	5.61	0.8	1.8	0	0	0	0	0.01	<0.01	<0.06	<0.02	<0.15
8/20/97	5.77	0	1.1	0	0	0	0	0	0	<0.06	<0.02	<0.15
9/23/97	5.60	0	1.6	0	0	0	0	0	0	<0.06	<0.02	<0.15
10/15/97	5.71	0	1.7	0	0	0	0	0	0	<0.06	<0.02	<0.15

Note: Values are in mg/L unless otherwise indicated.

field blank, limited validations of the accuracy of metals data can be made. Caution should be exercised when using data for aluminum, boron, and copper because of the expected positive bias. Possible error sources include sample bottle contamination, improperly filtered ultrapure water used for the blank, addition of analyte by reagents used in sample processing, or improper analysis.

The USEPA 6010B method describes that "a method blank is used to identify sample contamination resulting from... acids used in sample processing" (USEPA, 1996a). The results from analysis of the method blanks for the metals are included in the metals discussion. It is evident that 50 and 57 micrograms per liter (μg/L) of boron and aluminum, respectively, were added as a result of sample processing. With boron, this accounts for nearly all of the boron identified in the field blank. Boron sample values could be reduced by 50 μg/L to more accurately reflect the field concentrations. However, with aluminum and copper, the observed concentrations in the method blank were significantly lower than those in the field blank, and a similar treatment would not remove the expected bias.

Ten sets of laboratory matrix spikes per 48 samples (21%) were prepared, and 60 analyses of spiked samples were performed by the ISWS laboratory. Percent recoveries (%R) of 80-120 were acceptable as calculated by the following formula:

$$\%R = [(A - B)/C] * 100$$

where:
A = analyte concentration determined experimentally from the spiked sample.
B = background level determined by a separate analysis of the unspiked sample.
C = amount of the spike added.

Sixty (100%) of the analyses were acceptable. This indicates that laboratory procedures were sufficient to accurately reproduce sample results in the spiked samples.

Data Completeness. Data completeness is a measure of the amount of valid data obtained from a measurement system compared to the amount that was expected to be obtained under normal conditions. Data completeness of 90 percent was defined as acceptable to meet project goals. A percent completeness (%C) of 97.3 was estimated for the field and laboratory chemistry data by the following formula:

$$\%C = 100 * (V/T)$$

where:
V = number of measurements judged valid.
T = total number of measurements.

Physical Characteristics

Tables 5-9 list the results of analyses of physical parameters for the five sampling stations. Table 10 presents a summary of results and statistics. To provide a basis for comparing Indian Ridge Marsh results with other wetlands in Illinois, table 11 includes data from Simon and Cahill (1996) for various wetlands in Illinois collected at various times throughout the year. Table 11 also includes general-use water quality standards for Illinois waters. Indian Ridge Marsh does not fit any of the categories of wetlands developed by Simon and Cahill (1996). The

Table 5. Water Quality Characteristics in the East Pool (Station 1), 1997

Date	*Temp., °C*	*Dissolved oxygen*	*DO saturation, %†*	*Secchi disc, inches*	*Conductivity, µmho/cm*	*Turbidity, NTU*	*TSS*	*VSS*	*Total solids*
4/15	13.9	15.5	150	18	624	16	20	14	366
5/13	14.4	12.9	126	24	664	14	14	3	378
5/19	20.7	13.0	146	24	559	12	9	0	350
5/30	18.3	10.7	114	24	629	24	24	22	406
6/16	21.5	>20	>270	26	618	14	24	15	392
6/29	27.2	6.0	76	22	623	21	37	26	430
7/20	27.3	6.3	80	23	590	37	67	35	432
8/20	23.3	7.6	90	20	554	50	54	27	398
9/23*	18.7	9.6	103	4	624	117	138	20	498
10/15	12.5	11.8	111	4	678	97	104	28	532

Date	*pH, units*	*Total alkalinity*	*Total phosphate-P*	*Dissolved phosphate-P*	*Nitrate and nitrite-N*	*Ammonia-N*	*Un-ionized ammonia-N†*	*Total Kjeldahl-N*	*Water depth, inches*
4/15	8.66	126	0.13	0.01	<0.05	<0.02	<0.002	1.38	30
5/13	8.76	124	0.10	0.03	<0.05	<0.02	<0.003	1.30	27
5/19	9.29	98	0.11	0.03	<0.06	0.02	0.009	1.39	36
5/30	7.97	130	0.14	0.04	<0.06	0.06	0.002	0.95	30
6/16	8.82	126	0.17	0.04	<0.06	<0.02	<0.005	1.62	30
6/29	8.87	106	0.23	0.04	<0.06	0.02	0.007	2.07	29
7/20	8.62	121	0.41	0.06	<0.06	<0.02	<0.005	2.89	26
8/20	8.44	105	0.32	0.02	0.08	0.02	0.003	3.38	24
9/23*	8.11	119	0.56	0.03	<0.06	0.03	0.001	3.55	15
10/15	8.33	124	0.47	0.03	<0.06	<0.02	<0.001	4.03	14

Notes:
Values are in mg/L unless otherwise indicated.
* Duplicate samples were taken.
† Values were calculated.

unique characteristics of the marsh are produced by infilling with waste materials and by disruptions in the natural flow patterns. Although Indian Ridge Marsh is unique, it is still possible to use water-quality characteristics from a natural marsh and general-use standards to evaluate monitoring data collected in this study.

Temperature

Water temperature is one of the most important factors affecting the rate of chemical reaction and biological activities (growth) in an aquatic environment. In general, the reaction rate and/or the growth increases with increasing temperature. In a lake or reservoir, thermal stratification occurs during the summer period when the upper layer (epilimnion) is isolated from the lower layer of water (hypolimnion) by a temperature gradient (thermocline). Lakes will experience spring and fall turnovers. However, these are not significant for shallow wetland areas. In Indian Ridge Marsh the water depths in the three pools were less than 3 feet (tables 5-7), mostly between 1.5 and 2 feet in depth, which allows wind mixing to overcome any thermal

Table 6. Water Quality Characteristics in the North Pool (Station 2), 1997

Date	*Temp., °C*	*Dissolved oxygen*	*DO saturation, %†*	*Secchi disc, inches*	*Conductivity, µmho/cm*	*Turbidity, NTU*	*TSS*	*VSS*	*Total solids*
4/15*	13.9	7.9	77	17	2220	8	10	10	1524
5/13	17.1	4.0	42		2250	4	5	3	1580
5/19	19.9	12.9	143	12	806	14	14	12	514
5/30	18.3	12.9	138	18	1357	8	6	5	714
6/16	21.2	>20	>230	19	2060	5	9	6	1492
6/29	27.2	6.0	76	20	890	10	23	19	566
7/20	24.8	10.8	132	23	816	12	54	46	550
8/20	22.0	13.0	150	24	1360	33	70	70	984
9/02	23.5	8.8	104	22	1364	13	20	18	916
9/23	18.3	16.0	171	16	1377	19	36	25	940
10/15	13.3	6.1	58	13	1911	9	16	6	1276

Date	*pH, units*	*Total alkalinity*	*Total phosphate-P*	*Dissolved phosphate-P*	*Nitrate and nitrite-N*	*Ammonia-N*	*Un-ionized ammonia-N†*	*Total Kjeldahl-N*	*Water depth, inches*
4/15*	7.77	402	0.07	0.02	0.45	33.9	0.523	35.9	19
5/13	7.96	406	0.06	0.03	0.86	22.6	0.677	27.9	-
5/19	8.51	178	0.13	0.03	0.87	3.25	0.386	4.10	18
5/30	7.77	302	0.06	0.03	0.37	7.09	0.151	24.0	24
6/16	8.01	370	0.08	0.02	1.64	15.5	0.694	43.3	24
6/29	7.88	236	0.13	0.02	0.34	1.02	0.052	2.80	24
7/20	8.54	267	0.34	0.03	0.64	0.54	0.092	4.37	**24**
8/20	8.52	343	0.46	0.03	0.49	0.84	0.116	6.89	**26**
9/02	8.08	374	0.23	0.03	0.28	0.24	0.015	3.17	25
9/23	8.40	348	0.23	0.03	0.39	1.28	0.109	4.06	16
10/15	8.19	504	0.09	0.02	0.23	8.68	0.329	10.9	15

Notes:
Values are in mg/L unless otherwise indicated.
* Duplicate samples were taken.
† Values were calculated.
- Not measured.

stratification that might develop. Water temperatures from the surface to the bottom were similar at each of the five sampling locations. The median water temperatures for the five sites during the growing season were between 18.7°C and 21.2°C (table 10). The maximum temperatures were observed on June 29, 1997, at all the sampling stations except the SEPA station, which had a maximum temperature 2.2-4.3°C cooler that occurred on August 20, 1997.

Dissolved Oxygen

Dissolved oxygen concentrations in water are controlled by temperature, with higher concentrations of DO found in cooler waters. Dissolved oxygen also is modified by biological activity. Photosynthesis will produce oxygen in the water, leading to elevated, even supersaturated, DO concentrations. Respiration removes oxygen. When respiratory activity is high, for example in bottom sediments, DO may decrease, and in some cases may be completely consumed. Similar to temperature, DO concentrations in the water column for all five sites were found to be uniform with depth, except for samples collected in July and August 1997. The DO concentrations at the surface, at a 1-foot depth, and at the bottom (~2 feet) showed significant variation during this period (table 12).

Table 7. Water Quality Characteristics in the South Pool (Station 3), 1997

Date	*Temp., °C*	*Dissolved oxygen*	*DO saturation, %†*	*Secchi disc, inches*	*Conductivity, µmho/cm*	*Turbidity, NTU*	*TSS*	*VSS*	*Total solids*
4/15	14.1	7.7	75	13	2260	12	17	12	1534
5/13	15.2	5.6	56	16	1129	17	18	6	724
5/19	19.0	7.0	76	18	551	16	46	18	382
5/30*	18.4	12.2	130	21	1120	12	11	8	888
6/16	21.1	>20	>230	24	1716	5	14	9	1178
6/29	28.2	4.5	59	24	426	10	25	16	274
7/20	26.9	11.0	139	30	669	8	34	24	422
8/20*	22.3	12.0	139	24	1202	40	84	80	856
9/23	18.0	19.5	207	12	1219	32	79	68	852
10/15	12.9	16.1	153	19	1779	9	10	6	1180

Date	*pH, units*	*Total alkalinity*	*Total phosphate-P*	*Dissolved phosphate-P*	*Nitrate and nitrite-N*	*Ammonia-N*	*Un-ionized ammonia-N†*	*Total Kjeldahl-N*	*Water depth, inches*
4/15	7.78	403	0.11	0.02	0.42	31.9	0.511	33.3	16
5/13	7.91	216	0.11	0.01	1.09	9.3	0.217	9.50	16
5/19	8.09	130	0.09	0.01	0.71	0.98	0.045	2.00	24
5/30*	7.91	266	0.09	0.02	0.35	5.00	0.147	14.0	24
6/16	7.97	346	0.15	0.02	1.07	9.43	0.384	24.2	26
6/29	7.99	136	0.06	0.01	0.21	0.69	0.047	1.24	28
7/20	8.12	216	0.19	0.02	0.63	1.15	0.095	2.70	25
8/20*	8.41	325	0.45	0.02	0.46	0.69	0.078	6.57	24
9/23	8.57	309	0.60	0.03	0.50	0.74	0.088	7.21	24
10/15	8.42	453	0.09	0.02	0.51	6.80	0.414	9.52	19

Notes:
Values are in mg/L unless otherwise indicated.
* Duplicate samples were taken.
† Values were calculated.

Percent DO saturation values were determined from DO and temperature measurements using a conversion table (ASCE, 1960). The calculated values are included in tables 5-9. As shown in table 5, during the summer period from June 29-August 20, 1997, DO was undersaturated in the east pool; but for the rest of the monitoring period (70% of the time), it was supersaturated. This lower DO concentration was likely due to the influence of bottom sediment respiration, which is expected to peak during high summer temperatures. Most of the samples from the north and south pools were supersaturated. Saturation was over 200 percent at all five sites during the storm event on June 16 and at the south pool on September 23, 1997. The high and supersaturated DO concentrations in the pools were likely due to photosynthesis of observed algal populations. The Calumet River water in the SEPA pool had DO concentrations that hovered around the saturation level, except on May 30 and June 16, 1997, when the DO was considerably supersaturated. The samples at the SEPA station were collected from the water in the uppermost pool, which undergoes some aeration as it is pumped up from the river.

The observed DO levels in the three pools and near the outlet generally met the Illinois Pollution Control Board's (IPCB) general-use standards of not less than 5.0 mg/L. Only three observations, May 13 at the north pool, June 29 at the south pool, and July 20, 1997, at the outlet, had DO concentrations below 5.0 mg/L. Due to alternating algae photosynthesis and

Table 8. Water Quality Characteristics Near the Outlet (Station 4), 1997

Date	*Temp., °C*	*Dissolved oxygen*	*DO saturation, %†*	*Secchi disc, inches*	*Conductivity, µmho/cm*	*Turbidity, NTU*	*TSS*	*VSS*	*Total solids*
5/13	14.5	9.4	93	-	511	14	12	2	290
5/19*	-	-	-	-	493	9	13	3	306
6/16	21.2	>20	>230	15	1390	9	45	21	968
6/29*	26.1	5.8	72	19	352	5	7	3	248
7/20*	24.6	4.2	51	19	357	5	19	6	230
8/20	21.9	9.5	109	18	835	18	40	34	550
9/23	18.4	14.5	156	13	510	22	58	50	356
10/15	16.4	14.0	144	10	542	17	35	28	468

Date	*pH, units*	*Total alkalinity*	*Total phosphate-P*	*Dissolved phosphate-P*	*Nitrate and nitrite-N*	*Ammonia-N*	*Un-ionized ammonia-N†*	*Total Kjeldahl-N*	*Water depth, inches*
5/13	8.20	118	0.03	0.01	0.61	0.10	0.004	0.87	-
5/19*	7.80	124	0.11	0.02	0.64	0.08	-	0.82	-
6/16	8.00	296	0.20	0.03	1.11	3.44	0.151	7.25	18
6/29*	8.08	114	0.03	0.01	0.28	0.05	0.004	0.38	19
7/20*	7.93	123	0.07	0.04	0.59	0.10	0.005	0.35	15
8/20	8.00	238	0.17	0.02	0.46	0.32	0.015	2.55	20
9/23	8.48	148	0.52	0.09	0.21	<0.02	<0.002	4.61	14
10/15	8.65	156	0.26	0.02	0.47	0.48	0.060	3.44	10

Notes:
Values are in mg/L unless otherwise indicated.
* Duplicate samples were taken.
† Values were calculated.
- Not measured.

respiration, DO levels in a wetland can be on a diurnal cycle. The DO measurements were made at midday when the DO levels are highest; DO levels in the night and early morning are expected to be lower.

Secchi Disc Transparency

Secchi disc measurements are a measure of the water transparency, which can be related to the depth of light penetration into a body of water and the potential for photosynthetic activity. Even though the Secchi disc transparency is not an actual quantitative indication of light transmission, it provides an index for comparing similar bodies of water or the same body of water at different times and assists in interpreting other water quality results (e.g., DO). Transparency can be affected by suspended materials (turbidity) or by the color of the water. Turbidity can be produced by suspension of inorganic particles in the water or by the growth of algae or other planktonic aquatic life. The Secchi disc transparency is correlated with the depth at which photosynthesis can occur, the photic zone. In general, photosynthesis can occur at two to three times the Secchi disc transparency measurement (USEPA, 1980). Secchi disc readings

Table 9. Water Quality Characteristics in the SEPA Station (Station 5), 1997

Date	*Temp., °C*	*Dissolved oxygen*	*DO saturation, %†*	*Secchi disc, inches*	*Conductivity, µmho/cm*	*Turbidity, NTU*	*TSS*	*VSS*	*Total solids*
4/15‡	9.6	12.6	110	-	835	10	11	10	374
5/19	15.2	10.5	105	26	441	16	15	0	275
5/30	15.9	19.4	197	30	458	12	11	5	300
6/16*	22.0	>20	>230	31	349	7	16	4	216
6/29	22.6	8.7	102	30	339	8	14	5	250
7/20	23.3	7.9	93	34	324	7	15	4	226
8/20‡	23.9	6.7	82	-	342	15	13	5	222
9/23	20.2	9.0	100	26	334	19	22	6	224
10/15*	18.3	9.8	105	27	329	19	20	4	218

Date	*pH, units*	*Total alkalinity*	*Total phosphate-P*	*Dissolved phosphate-P*	*Nitrate and nitrite-N*	*Ammonia-N*	*Un-ionized ammonia-N†*	*Total Kjeldahl-N*	*Water depth, inches*
4/15‡	8.30	117	0.03	0.02	0.86	0.19	0.007	0.81	-
5/19	8.35	118	0.02	0.01	0.51	0.05	0.003	0.46	36
5/30	8.27	118	0.02	<0.01	0.48	0.10	0.005	0.70	30
6/16*	8.30	110	0.02	<0.01	0.34	0.06	0.005	0.28	33
6/29	8.34	111	0.02	<0.01	0.29	0.04	0.004	<0.15	35
7/20	8.22	110	0.03	0.02	0.28	0.11	0.009	<0.15	34
8/20‡	8.28	104	0.04	0.01	0.26	0.10	0.010	0.39	-
9/23	8.32	102	0.04	0.01	0.24	0.07	0.006	0.26	36
10/15*	8.35	108	0.03	0.01	0.34	0.02	0.002	<0.15	36

Notes:
Values are in mg/L unless otherwise indicated.
* Duplicate samples were taken.
† Values were calculated.
‡ Samples were taken from Calumet River.
\- Not measured

combined with other field observations may furnish information on suitable habitat for fish and other aquatic life, water quality and aesthetics, the state of the nutrient enrichment, and problems with recreational use impairment.

Median values observed for Secchi disc transparency at the five sampling sites were 22.5, 18.5, 20, 16.5, and 30 inches, respectively (table 10). In many cases, the Secchi disc was still visible when resting on the bottom. Secchi disc transparencies in the east pool on September 25 and October 15, 1997, were very low, only 4 inches (table 5). During those sampling periods, water depth was only about one-half of normal depth (14-15 inches). Field notes indicated turbid conditions were likely due to wind-/wave-induced turbulence that resuspended bottom materials.

Turbidity

Turbidity is an expression of the property of water that causes light to be scattered and absorbed and is related to particles in the water such as clay, silt, fine inorganic and organic matter, soluble colored organic compounds, and plankton and other microorganisms. Turbidity is measured by passing light through a column of water and measuring the amount of scattering

Table 10. Statistical Summary of Water Quality Characteristics of Indian Ridge Marsh, 1997

	Temperature, °C		*Dissolved oxygen*		*Secchi disc, inches*		*Conductivity, µmho/cm*		*Turbidity, NTU*	
Location	*Median*	*Range*	*Median*	*Range*	*Median*	*Range*	*Median*	*Range*	*Median*	*Range*
East pool	19.7	12.5-27.3	11.3	6.0->20	22.5	4-26	624	554-678	22.5	12-117
North pool	19.9	13.3-27.2	10.8	4.0->20	18.5	12-24	1364	806-2250	10	4-33
South pool	18.7	12.9-28.2	11.5	4.5->20	20	12-30	1166	426-2260	12	5-40
Outlet	21.2	14.5-26.1	9.5	4.2->20	16.5	10-19	511	352-1390	11.5	5-22
SEPA st.	20.2	9.6-23.9	9.8	6.7->20	30	26-34	342	324-835	12	7-19

	TSS		*VSS*		*Total solids*		*pH, units*		*Total alkalinity*		*Water depth, inches*	
Location	*Median*	*Range*	*Median*	*Range*	*Median*	*Range*	*Median*	*Range*	*Median*	*Range*	*Median*	*Range*
East pool	30.5	9-138	21	0-35	402	350-532	8.64	7.97-9.29	123	98-130	28	14-36
North pool	16	5-70	12	3-70	940	514-1580	8.08	7.77-8.54	348	178-504	24	15-26
South pool	21.5	10-84	14	6-80	854	274-1534	8.04	7.78-8.57	288	130-453	24	16-28
Outlet	27	7-58	13.5	2-50	331	230-968	8.04	7.80-8.65	136	114-296	16.5	10-20
SEPA st.	15	11-22	5	0-10	226	216-374	8.30	8.22-8.35	110	102-118	35	30-36

	Total phosphate-P		*Dissolved phosphate-P*		*Nitrate and nitrite-N*		*Ammonia-N*		*Total Kjeldahl-N*	
Location	*Median*	*Range*	*Median*	*Range*	*Median*	*Range*	*Median*	*Range*	*Median*	*Range*
East pool	0.2	0.10-0.56	0.03	0.01-0.06	<0.06	<0.05-0.08	0.02	<0.02-0.06	1.85	0.95-4.03
North pool	0.13	0.06-0.46	0.03	0.02-0.03	0.45	0.23-1.64	3.25	0.24-33.9	6.89	2.80-43.3
South pool	0.11	0.06-0.60	0.02	0.01-0.03	0.51	0.21-1.09	3.08	0.69-31.9	8.36	1.24-33.3
Outlet	0.14	0.03-0.52	0.02	0.01-0.09	0.53	0.21-1.11	0.1	<0.02-3.44	1.71	0.35-7.25
SEPA st.	0.03	0.02-0.04	0.01	<0.01-0.02	0.34	0.24-0.86	0.07	0.02-0.19	0.28	<0.15-0.81

Note: Values are in mg/L unless otherwise indicated.

Table 11. Ranges of Water Chemistry Results for Various Wetlands in Illinois

Analyte	*Natural marshes*	*Natural swamps*	*Restored or created marsh/ponds*	*Natural fens*	*Northern flatwood forests*	*General-use water quality standards**
Number of locations	8	3	6	2	1	
Number of samples	24	14	14	13	12	
Total Dissolved Carbon	37.3-265.6	27.2-60.1	39.2-156.6	73.9-130.7	75.3-164.1	
Dissolved Organic Carbon	14.9-75.2	13.4-27.1	14.2-80.5	14.2-30.7	46.4-85.7	
Total Nitrogen	0.38-9.06	0.50-3.9	0.68-5.34	0.05-8.74	0.48-2.12	
Total Kjeldahl Nitrogen	0.01-8.91	0.22-3.82	0.36-5.34	0.05-8.74	0.48-2.12	
Ammonia	0.01-3.18	0.06-0.81	0.01-0.33	0.01-2.17	0.01-0.10	15
Nitrate	0.07-7.29	0.05-0.25	0.06-0.58	0.05-0.22	0.05-0.15	
Total Phosphorus	0.02-2.20	0.05-0.55	0.01-1.29	0.02-1.55	0.01-0.20	
Sulfate	4.5-129.0	0.65-22.8	0.3-135.0	5.8-52.7	3.3-319.0	500
Fluoride	<0.01-0.13	<0.01-0.07	<0.01-0.17	<0.01-0.29	<0.01-0.12	1.4
Chloride	8-815	0.5-9.9	0.8-129.0	21.8-76.6	1.8-173.0	500
Bromide	<0.01-0.13	<0.01-0.22	<0.01-0.07	0.04-0.11	<0.01-0.10	
Total Alkalinity	8-815	20-176	38-311	232-421	46-314	
pH, units	6.0-9.5	6.2-8.7	6.8-8.7	7.5-8.6	7.0-7.8	6.5-9.0
Conductivity, µmho/cm	89-1236	43-339	85-989	629-748	164-867	
Dissolved Oxygen						5.0†
Total Dissolved Solids						1000†
Aluminum	<0.02-0.15	0.02-0.05	<0.02-0.07	<0.02-0.17	<0.02-0.10	
Arsenic	<0.1	<0.1	<0.1	<0.1	<0.1	0.36
Boron	<0.02-0.11	<0.02-0.08	<0.02-0.06	<0.02-0.10	<0.02-0.06	1.0
Barium	0.01-0.12	0.03-0.10	0.01-0.07	0.04-0.21	0.01-0.05	5.0
Calcium	9.7-179.0	5.4-45.1	9.8-108.0	56-109	12.9-130.0	
Cadmium	<0.02-0.03	<0.02	<0.02	<0.02	<0.02	0.05
Chromium	<0.01	<0.01	<0.01	<0.01	<0.01	4.0
Copper	<0.01	<0.01-0.03	<0.01-0.01	<0.01	<0.01	1.0
Iron	0.02-3.58	0.01-2.61	0.02-0.45	0.01-0.21	0.05-0.45	1.0
Potassium	<1-8	<1-2	1-8	1-3	2-6	
Magnesium	2.2-83.0	1.4-16.7	4.3-51.7	37.4-46.3	5.9-72.0	
Manganese	0.01-4.85	0.01-4.3	0.01-0.72	0.01-0.57	0.01-0.10	1.0
Sodium	1.5-67.2	0.8-11.0	0.10-40.7	11.9-29.5	1.2-99.3	
Nickel	<0.03	<0.03	<0.03	<0.03	<0.03	1.0
Lead	<0.04	<0.04-0.07	<0.04	<0.04-0.04	<0.04	0.1
Mercury						0.5t
Selenium	<0.2	<0.2	<0.2	<0.2	<0.2	1.0
Silver						5t
Silicon	0.4-27.6	1.5-5.7	0.04-5.89	5.9-10.8	1.7-7.0	
Strontium	0.03-0.69	0.03-0.07	0.02-0.16	0.08-0.30	0.02-1.21	
Zinc	<0.01-0.02	<0.01-0.06	<0.01-0.02	<0.01-0.02	<0.01	1.0

Notes:
All values in mg/L unless otherwise indicated.
All metals data are for the soluble fraction.
* IEPA,1999.
† Not analyzed or not reported by sources.
Sources: Simon and Cahill (1996) and Admiraal et al. (1997).

Table 12. Variation of Dissolved Oxygen (mg/L) with Depth in July and August 1997

	East Pool		*North Pool*		*South Pool*		*Outlet*
Depth	***7/20***	***8/20***	***7/20***	***8/20***	***7/20***	***8/20***	***7/20***
Surface	11.1	11.0	19.8	>20	13.2	19.6	4.4
1-foot	6.3	7.6	10.8	12.9	10.8	11.8	4.0
2-foot	3.0	6.2	7.0	7.7	9.1	3.5	

or absorbance. Turbidity is reported as nephelometric turbidity units (NTU). Generally, turbidity in lakes and wetlands is influenced by runoff containing high concentrations of suspended solids, resuspension of bottom sediments caused by flow or wind-induced turbulence, or blooms of algae in the water column.

The median turbidity for the five sampling sites was 22.5, 10, 12, 11.5, and 12 NTU, respectively (table 10). High turbidity values (117 and 97 NTU) were observed on September 23 and October 15, 1997, at the east pool and correspond to the very low Secchi disc transparency measurements made on the same date (table 5) and were related to sediment sources rather than algal blooms. At the north and south pools, the highest turbidity (33 and 40 NTU, respectively) occurred on August 20, 1997 (tables 6 and 7). Turbidity values on August 20, 1997, also were high at the outlet and the SEPA pool, but were only half those of the north and south pools.

According to the Illinois Lake Assessment Criteria (IEPA, 1978), a turbidity value between 7 and 14 NTU indicates a moderate amount of sediment. Turbidity > 15 NTU is indicative of substantial suspended sediment. This higher criteria frequently was exceeded, especially in the east pool. The median turbidity values at the other four sites is within the criteria and indicates a moderate amount of sediment.

Conductivity

Specific conductance is a measure of the capacity of water to convey electric current. It is used as an estimate of the quantity of dissolved minerals in water. Conductivity can be related to the total concentration of ionized substances. Conductivity measurements must be adjusted for temperature to reflect temperature effects on ionic activity. Specific conductance measurements are affected by the nature of the dissolved substances, their relative concentrations, and the ionic strength of the water sample. Because the geochemistry of the drainage basin is the major factor determining the chemical constituents in the waters, conductivity measurements provide a useful tool for identifying water sources and the influence of rainfall (rainwater has low conductivity).

The median values of specific conductance for the five sampling stations were 624, 1364, 1166, 511, and 342 mircomhos per centimeter (µmho/cm), respectively (table 10). The river water had the lowest conductivity and the north and south pools had the highest. Discussion of the temporal trends in conductivity values and implications for source water are included in the solids section. In Indian Ridge Marsh, the north and south pools have significantly higher conductivity values than found in other natural marshes in Illinois (table 11).

Chemical Characteristics

pH

The pH value, or hydrogen ion concentration, is a measure of the acidity or alkalinity of water; values below 7.0 indicate acidic water and values above 7.0 indicate alkaline water. Most Illinois lakes have a pH between 6.5 and 9.0. The pH value is greatly influenced by the dissolved carbonate species in the water. The carbonate system is affected by the photosynthetic activity of algae and other aquatic plants, which produce changes in pH. For example, during the day photosynthesis uses carbon dioxide, and pH levels will rise. Photosynthesis is not possible at night and respiration of plants and animals produce carbon dioxide, causing pH levels to drop. It is generally considered that pH values above 8.0 in natural waters are produced by photosynthesis when the plant use of carbon dioxide exceeds the production of carbon dioxide in respiration and decomposition (Mackenthun, 1969). The pH also is controlled by the presence of minerals, mainly carbonates, in the sediment that buffer changes in pH by solution and precipitation.

The pH of Indian Ridge Marsh potentially could be affected by alkaline ground-water discharge. As shown by well 70 in appendix A, pH values greater than 12 have been observed in ground-water monitoring wells in the region that are completed in fill material containing a large amount of steel slag (Roadcap and Kelly, 1994). Where the ground-water discharge is focused into a small water body, the surface water pH also can be above 12. Another phase of ISWS research is currently investigating methods of remediating these high pH discharges.

The ranges of pH at the five sampling stations were 7.97-9.29, 7.77-8.54, 7.78-8.57, 7.80-8.65, and 8.22-8.35, respectively. The IPCB (IEPA, 1999) general-use water quality standards set a pH range of between 6.5 and 9.0, except for natural causes. All pH values observed were above the minimum acceptable value, and only one sample taken from the east pool on May 19, 1997, exceeded the maximum. The observed pH ranges were within the range indicated for natural marshes. If any high pH ground-water inflow is occurring, it is being sufficiently diluted and/or offset by an abundance of natural buffering compounds in the lake water and the watershed. Likewise, acidic rainwater (pH about 4.4) is also being sufficiently buffered.

Alkalinity

Alkalinity is a measure of water's acid-neutralizing capacity, and the total alkalinity is defined as the amount of acid required to lower the pH of a water to 4.5. The alkalinity is usually controlled primarily by the concentration of bicarbonate and/or carbonate ions. Hydroxide ions can contribute significantly to the alkalinity in the high pH waters found in the region. Alkalinity is expressed in terms of an equivalent amount of calcium carbonate ($CaCO_3$) that the acid must dissociate to allow the pH to drop to 4.5. Lakes with low alkalinity are, or have the potential to be, susceptible to damage from acid precipitation. However, Midwestern lakes usually have high alkalinity and thus are well buffered from the impacts of acid precipitation. Natural waters generally have a total alkalinity between 20 and 200 mg/L (APHA et al., 1992).

The median total alkalinity of the east pool and the SEPA station were around 123 mg/L (as $CaCO_3$) and varied little throughout the growing season (table 10). The median total alkalinity of 348 mg/L at the north pool was the highest, followed by 288 mg/L at the south pool and 136 mg/L at the outlet. The ranges of total alkalinity at the north and south pools also were greater than at the other three stations. Higher values were observed during cooler periods in April and October (tables 6 and 7). The alkalinity levels in Indian Ridge Marsh were in the 8-815 mg/L range of other marshes in Illinois (table 11).

Solids

Total Solids. The total solids (TS) value is measured as the residue that remains when a well mixed sample is evaporated in a weighed dish and dried in an oven at 104°C. The increase in weight represents the TS (APHA et al., 1992). The amount of TS in a water sample is the sum of the total dissolved solids (TDS) and the total suspended solids (TSS). The TSS analysis results can correlate with both the Secchi disc transparency and the turbidity if the TS are dominated by suspended material. The TDS also can correlate with conductivity in samples in which high levels of dissolved solids are present. In the Indian Ridge Marsh samples, the mean TS values were 10-40 times greater than the TSS values, indicating that most of the solids are in the dissolved form. In natural waters, dissolved solids consist mainly of carbonates, bicarbonates, sulfates, chlorides, phosphates, nitrates, sodium, calcium, magnesium, and potassium, with traces of iron, manganese, and other substances. The TDS composition depends to a large extent on the geochemistry of the soil and aquifer material that the surface runoff and ground water pass through before reaching the marsh.

All salts in solution change the physical and chemical nature of the water and may affect aquatic biota. Many of the plant species native to the region may not be tolerant to elevated levels of total solids. Some salts have physiological as well as toxic effects. However, possible synergistic or antagonistic interactions among salts, when in solution, may produce effects different from the effects due to salts occurring separately. Greeson (1971) observed that high dissolved solids content in Oneida Lake (New York) in 1967 and 1969 accompanied high algal production, and low dissolved solids content in 1968 accompanied lower algal production. He concluded that dissolved solids concentration is an important index of potential algal productivity because no element, ion, or compound is likely to be a limiting factor when the dissolved solids content is high.

Median TS concentrations for the five sampling stations were 402, 940, 854, 331, and 226 mg/L, respectively (table 10). The SEPA station had the lowest amount of TS and the north and south pools had the highest. The TS correlated well with the conductivity measurements. At the north pool the TS values (mg/L) were 67 ± 5 percent of the conductivity value (µmho/cm) except on May 30, 1997, which was only 53 percent. Because the TSS values were not high,

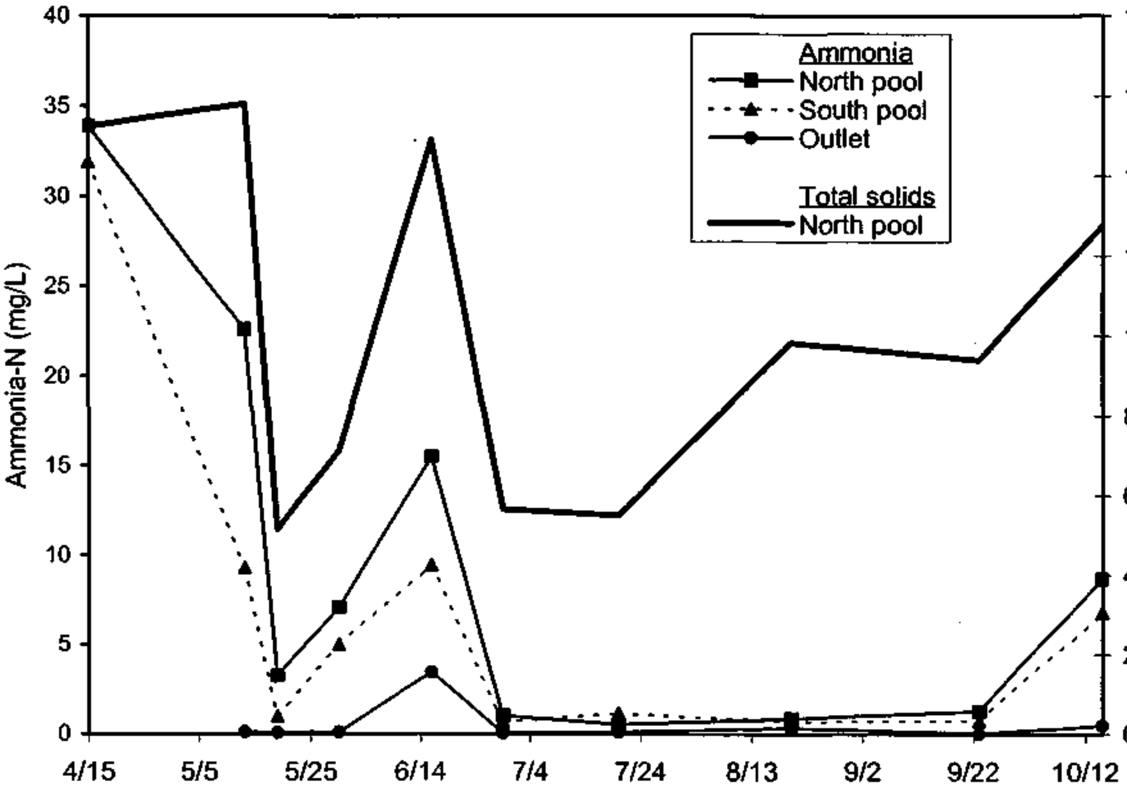

Figure 4. Trends in total solids and ammonia-N concentration, 1997.

most of the solids are in the dissolved form. Therefore, one-third of the samples collected from the north and south pools exceeded the TDS standard of 1000 mg/L (tables 6 and 7).

The trends in the amount of TS gives some insight as to the sources of water to the marsh. The north pool had the highest TS in a relatively dry April and early May (figure 4). The storm that occurred on May 18, 1997, lowered the TS values by more than half with dilute rainwater. The conductivity of the May 7, 1998, runoff from the culvert draining the Lake Calumet Cluster Site at 117th Street was 670 µmho/cm. This conductivity is equivalent to a TS value of approximately 450 mg/L, indicating the runoff may be a significant source of solids but is not likely to be the principle source. All of these results suggest that the water chemistry of the north pool is heavily influenced by ground water, which has very high TDS values in the range of 1090-3039 mg/L (appendix A).

The storm event of June 16, 1997, however, caused the opposite effect with the TS increasing to near the previous high values of early spring. Several possible factors could contribute to this increase. The month previous to the May 18, 1997, event had been fairly dry so the inflow of high TDS ground water would have caused the solids in the marsh to go back up. The 0.75-inch rainfall also may have been insufficient to generate a significant amount of runoff. In addition, the sample was collected during the storm event, and the north pool sampling site is in the main channel along the west side where any effect of runoff from the cluster site would be first felt. Mixing with more dilute waters in the central portions of the north pool (appendix A) may not occur until after the event is over. Because the cluster site is poorly graded, an unusual overflow event in the existing drainage on the site also may have occurred and flushed a considerable amount of dissolved solids off the surface or out of the many areas of standing water. As discussed in the nitrogen section, the composition of nitrogen species was more indicative of surface runoff than a large ground-water influx.

The TS concentration may have been additionally affected by a slow rise in the water level of the Calumet River in the spring and summer of 1997. This rise, which peaked in July, caused water levels to increase in the marsh (tables 5 and 6) by direct inflow from the river and/or by backing up the existing water in the marsh. The higher water levels likely caused a reduction in the amount of ground-water inflow. The inflow of low TDS river water and a decrease in the inflow of high TDS ground water likely contributed to the lower TS observed in July.

The large July 18, 1997, storm event did not affect the solids content of the north pool (figure 4). In this event there may have been sufficient rainwater to dilute any runoff that is high in TS. During the rest of the growing season, the TS increased as evaporation and light rainfall increased the influence of ground water.

Total Suspended Solids. The TSS value represents the residue left on a ≤ 2.0 μm filter and is a standard measure for inorganic and organic materials suspended in the water column. Typical inorganic components originate from the weathering and erosion of rocks and soils in a lake's watershed and resuspension of lake sediments. Organic components are derived from a variety of biological origins, but in shallow lakes and pools suspended solids are mainly composed of algae and resuspended plant and animal material from the lake bottom. The amount of suspended solids in lakes and ponds is small compared to the amount in streams because solids tend to settle in the low turbulence environment of lakes. However, in shallow lakes, wind-induced turbulence and wave action may resuspend previously settled material.

A high TSS concentration results in decreased water transparency, which can reduce photosynthetic production of oxygen and lead to dominance of respiration and the production of low DO, even anoxic conditions. Generally, the higher the TSS concentration, the lower the Secchi disc reading. The presence of low DO conditions in water may limit fish habitats and potentially cause taste and odor problems by releasing noxious substances such as hydrogen sulfide, ammonia, iron, and manganese from lake bottom sediments.

During this study, ranges of TSS for the five stations were 9-138,5-70,10-84,7-58, and 11-22, respectively (table 10). The TSS values generally increased during the growing season with the higher values composed largely of VSS. The TSS values also correlated well with the turbidity measurements. A wide variation in TSS values was found at the east pool, with high concentrations in the September and October 1997 samples (138 and 104 mg/L). The east pool is relatively shallow (table 5), allowing wind-induced turbulence to resuspend bottom sediments and increase the TSS concentration. High TSS concentration corresponded with low Secchi disc measurements at the east pool station.

On the basis of the Illinois Lake Assessment Criteria (IEPA, 1978), water with a TSS > 25 mg/L is classified as having a high-use impairment, and water with a TSS between 15 and 25 mg/L indicates moderate-use impairment. Water with TSS < 15 mg/L is considered to have minimal impairment. On the basis of the state's criteria, all three pools, including the outlet, can be classified as having high-use impairment; and the river water pumped into the SEPA station is considered as having moderate-use impairment.

Volatile Suspended Solids. Volatile suspended solids are the portion of TSS lost to ignition at 500 ± 50°C. The VSS represent the organic portion of TSS, such as phytoplankton, zooplankton, other biological organisms, and other suspended organic detritus. Ranges of VSS at the five stations were 0-35, 3-70, 6-80, 2-50, and 0-10 mg/L, respectively (table 10). The median VSS values for those stations were 21, 12, 14, 13.5, and 5 mg/L, respectively. On the basis of the median values, the organic portions of suspended solids for these five stations were 69, 75, 65, 50, and 33 percent, respectively. The organic fraction of the suspended solids in the four marsh samples is much higher than at the SEPA station.

Nitrogen

Nitrogen (N) is generally found in surface waters in the form of ammonia ($NH\ ^{\circ}$), ammonium (NH_4^+), nitrite (NO_2^-), nitrate (NO_3^-), and organic nitrogen. Organic nitrogen is determined by subtracting ammonia and ammonium from the total Kjeldahl nitrogen (TKN) measurements. Total nitrogen is the sum of nitrite, nitrate, and TKN. The IEPA (1999) stipulates that ammonia plus ammonium should not exceed 15 mg/L (as N) and nitrate plus nitrite should not exceed 10.0 mg/L (as N).

Nitrogen is an essential nutrient for plant and animal growth and is one of the principal elemental constituents of amino acids, peptides, proteins, urea, and other organic matter. The various forms of nitrogen cannot be used to the same extent by different groups of aquatic plants and algae.

Ammonia and Ammonium. Ammonia and ammonium result from the decomposition of nitrogenous organic matter. They also can result from municipal and industrial waste discharges to streams and lakes. There are no direct discharges into the marsh except for six septic discharges from the houses at the north end, five of which are into the northernmost isolated east pool. Runoff from the adjacent MWRDGC sludge-drying beds is controlled; however, a significant amount of sludge builds up along the south shoulder of 122nd Street from the tires of the passing sludge-hauling trucks. Ammonium levels are generally very low in ground water because it can be adsorbed by clay particles; however, wells completed in slag around Indian Ridge Marsh (appendix A) have very high ammonium levels. Some of this ammonium is from the anaerobic decay of organic matter in the wetland soil that was covered with fill. The breakdown of any organic matter or garbage in the fill could also generate ammonium. High levels of ammonium in ground water also have been observed at old coal gasification plants that produced coal gas and coke from coal (Davidson and Lerner, 1998). Ammonia wastes generated at the Acme Coke Plant north of Indian Ridge Marsh are treated, and the treated water is discharged into the sanitary sewer (David Holmberg, Acme Steel, 1999, personal communication). Ammonia has not been a problem in the Acme's permitted discharge into the Calumet River, which includes the storm water runoff from the plant along with significantly larger volumes of noncontact cooling water.

The amount of ammonia-N (as N) reported in tables 4-10 is the total amount of nitrogen in both the ammonium ion (NH_4^+) form and the un-ionized ammonia (NH_3^0) form. Eight often samples collected at the east pool had ammonia-N levels equal to or less than the detection limit of 0.02 mg/L (table 5). One sample collected from the SEPA station on September 23, 1997, had an ammonia-N concentration less than the detection limit. At the outlet, the maximum was 3.44 mg/L and occurred on June 16, 1997 (table 8). Very high concentrations of ammonia-N were found in the samples from the north and south pools; four samples exceeded the Illinois ammonia-N standard of 15 mg/L (tables 6 and 7). Their medians and ranges were 3.25 mg/L and 0.24-33.9 mg/L for the north pool and 3.08 mg/L and 0.69-31.9 mg/L for the south pool (table 10). The highest values occurred on April 15 and May 13, 1997, for both stations. These high ammonia-N levels are much higher than the range of 0.01-3.18 mg/L found in other Illinois natural marshes (table 11).

The temporal trend in ammonia-N for the north pool follows the same trends as the TS (figure 4). This would indicate that the source is also likely to be ground water. The ammonium concentration of the precipitation in the region is relatively much smaller at 0.48 mg/L (National Atmospheric Deposition Program, 1997). Similar to the TS, the increase in ammonia-N in early June also may be due to runoff of organic nitrogen as discussed below with the TKN measurements. By July, the amount of ammonia-N was drastically reduced because the nitrifying ($NH_4^+ \rightarrow NO_3^-$) and denitrifying ($NO^{3-} \rightarrow N_2$) capacity of the bacteria in the marsh is probably much greater than the ammonia-N influx. The ammonia-N increases in October when the water is cooler and the nitrifying bacteria may be less active.

To help determine where the ammonia-N is coming into the north pool, grab samples were collected on May 7, 1998, and January 19, 1999. Samples of the major runoffs from the Lake Calumet Cluster Site to the marsh during a 3-inch rainfall on May 7, 1998, showed ammonia-N levels of 2.3 mg/L at the U.S. Drum site at 119th Street and 0.9 mg/L from the culvert draining the Paxton I site at 117th Street. These low values indicated that surface water runoff is not a direct source of ammonia-N to the north pool. Although the amount of flow through the north culvert at 116th Street was insignificant, a sample from the standing water in the culvert did show an ammonia-N level of 9.3 mg/L.

The grab samples from January 19, 1999, were collected when the marsh was frozen over (table 13). Because of the ice cover, wind mixing was nonexistent and flow was assumed to be unidirectional to the south. With one exception, these samples were collected along the main channel on the west side of the marsh at locations approximately where the cross streets would be if they all existed. The 116th Street sample was collected in the northeast corner of the north

Table 13. Ammonia-N Concentrations in Grab Samples from January 19, 1999

Location	*Ice thickness (inches)*	*Ammonia-N (mg/L)*	*Conductivity (µmho/cm)*	*pH*
116th St.	<1	21	1831	7.46
117th St.	12	3	1764	7.50
118th St.	<1	10	1874	7.49
119th St.	<1	7	1723	7.58
119.5th St.	<1	22	1843	7.45
120th St.	<1	23	1869	7.42
121st St.	15	11	1874	7.65
122nd St. culvert	open	10	1959	7.87
123rd St.	12	15	2280	7.80

pool. Five of the samples were collected where the ice was less than an inch thick and are expected to be more representative of warmer inflowing ground water.

From these samples it appears there may be at least two sources of ammonia-N, one at 116th Street on the north side and one downstream between 118th and 120th Streets on the west side. Judging by the very small area of thin ice at the 116th Street spring, there did not appear to be enough inflow to supply the marsh with enough ammonia-N to explain the other samples. The area of thin ice was much larger along the west edge of the channel where ground water is discharging between 118th and 120th Streets. This area is next to the U.S. Drum portion of the Lake Calumet Cluster Site. Several tadpoles and small fish were observed at the 118th and 119th Street sites, but neither were observed at the 119.5th and 120th Street sites. The conductivity and pH values from these samples (table 13) are very similar and do not indicate drastically different TDS concentrations and pHs in the inflowing ground water. However, the conductivity values could be greatly skewed by the ice formation, which concentrates the dissolved solids in the liquid phase.

The calculated values for the un-ionized ammonia-N (NH_3) based on the observed temperatures and pH values also are shown in tables 5-9. The values were calculated using the formula given in the IPCB Rules and Regulations (IEPA, 1999). The general-use water quality standards stipulate that, from April through October, the un-ionized ammonia-N should not exceed an acute standard of 0.33 mg/L and a chronic standard of 0.057 mg/L. From November through March the acute and chronic standards drop to 0.14 mg/L and 0.025 mg/L, respectively.

The east pool and the SEPA station met the standards for un-ionized ammonia for all of the observations. However, the north and south pools frequently exceeded limits. Five of 11 observations in the north pool (table 6) met or exceeded the acute standard, and only one observation was significantly below the chronic standard. Three often observations in the south pool exceeded the acute standard, and only two observations were below the chronic standard.

Only one observation at the outlet exceeded the chronic limit. The chronic high levels of un-ionized ammonia-N are considered toxic to fish.

Total Kjeldahl Nitrogen. The TKN measurements represent the sum of the organic nitrogen and ammonia-N. Because the amount of ammonia-N in the east pool was very low, almost all of the nitrogen reported by the TKN measurement was in the organic form. The TKN contents at the SEPA station were low, ranging from <0.15-0.81 mg/L, with a median of 0.28 mg/L (tables 9 and 10). The ranges of TKN for the first four sampling sites were 0.95-4.03, 2.80-43.3,1.24-33.3, and 0.35-7.25 mg/L, respectively. Their median TKN concentrations were 1.85, 6.89, 8.36, and 1.71 mg/L, respectively (table 10). The TKN concentrations in the north and south pools were substantially higher than the 0.01-8.91 mg/L range for the eight other natural marshes in Illinois.

In the north pool, percentages of organic nitrogen varied widely (figure 5); they were generally lower during the cooler periods and higher during the summer period, indicating higher biological productivity during the warm period. However, the May 30 and June 16, 1997, samples proved to be a major exception with very high amounts of organic nitrogen, the likely source of which is organic nitrogen on the upland surface being carried into the marsh by surface runoff. Springtime TKN spikes have been observed in other locations such as the Sangamon River in central Illinois (Demissie and Keefer, 1996). The increase in ammonia-N on June 16, 1997, is from the bacterial breakdown of organic nitrogen, which can form ammonia-N as an intermediate step. The lack of organic nitrogen, the high DO content, and the cooler temperatures in the fall and early spring would eliminate nitrogen reduction as a cause of the high ammonia-N.

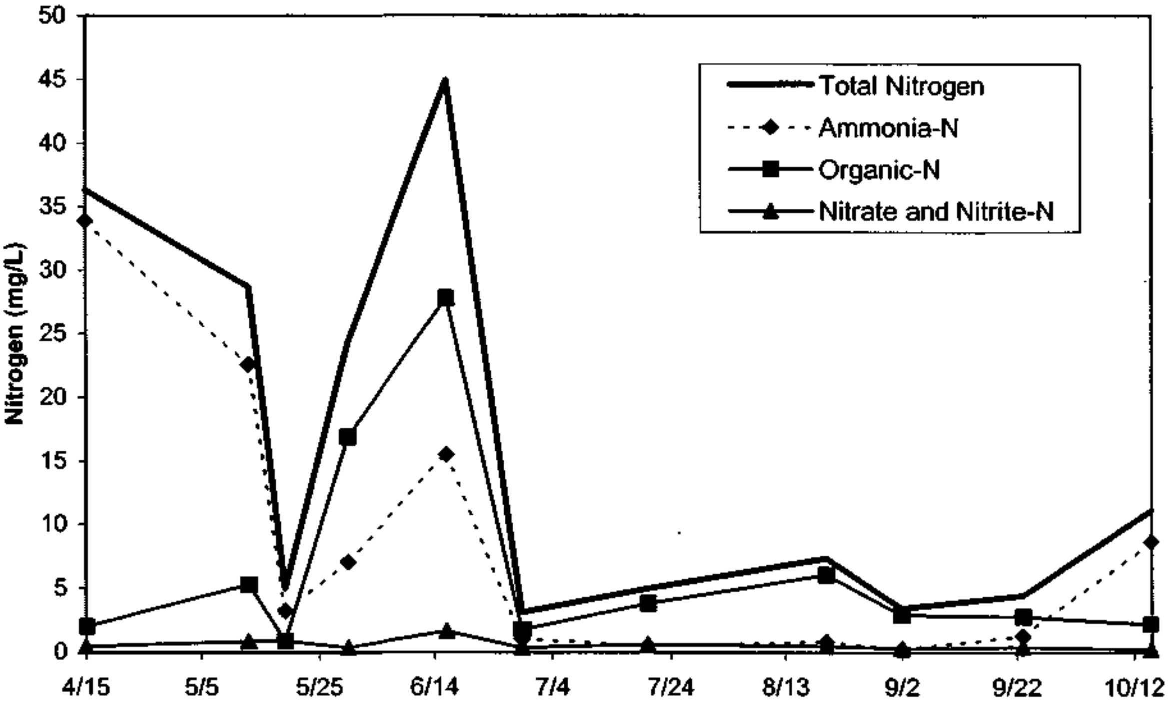

Figure 5. Total nitrogen composition of the north pool, 1997.

Nitrate and Nitrite. Nitrate is the end product of the aerobic stabilization of organic nitrogen, and as such it is found in polluted waters that have undergone self-purification or aerobic treatment processes. Nitrate also can occur in discharging ground waters but has not been found in significant concentrations in the area (Roadcap and Kelly, 1994). Nitrate is a public health concern because it has adverse physiological effects on bottle-fed infants, and the traditional water treatment processes have no effect on the removal of nitrate. The IPCB (IEPA, 1999) has stipulated that nitrate-N and nitrite-N not exceed 10 mg/L and 1 mg/L, respectively, for public water supply and food processing waters.

Nitrite/nitrate-N levels in the east pool were below the detection level of 0.05 mg/L except for one sample collected on August 20, 1997, which had a concentration of 0.08 mg/L (table 5). Median concentrations for the north pool, the south pool, and the outlet were between 0.45 and 0.53 mg/L. Their ranges were 0.23-1.64,0.21-1.09, and 0.21-1.11 mg/L, respectively. At the SEPA station, nitrite/nitrate-N values ranged from 0.24- 0.86 mg/L with a median of 0.34 mg/L. The relatively small amount of nitrate and nitrite in the marsh and the high DO content indicate that sewage effluent is probably not the source on the high ammonia-N concentrations.

Inorganic nitrogen (ammonia plus nitrite/nitrate nitrogen) concentrations in excess of 0.30 mg/L along with inorganic phosphorus concentration in excess of 0.01 mg/L are known to stimulate nuisance algal blooms (Sawyer, 1952). The nitrogen levels in the north and south pools and at the outlet exceed this critical value and, therefore, will not be a limiting factor for algal growth.

Total and Dissolved Phosphorus

The term total phosphorus (TP) represents all forms of phosphorus in water, both particulate and dissolved forms, and includes three chemical types: reactive, acid-hydrolyzed, and organic. Dissolved phosphorus (DP) is the soluble form that is filterable through a 0.45-µm filter.

Phosphorus as phosphate may occur in surface water or ground water as a result of leaching from minerals or ores, natural processes of degradation, or agricultural and urban drainage. Phosphorus is an essential nutrient for plant and animal growth and, like nitrogen, it passes through cycles of decomposition and photosynthesis. With phosphorus being singled out as probably the most limiting nutrient, various facets of phosphorus chemistry and biology have been extensively studied in the natural environment. It also has become the focus of attention in environmental management, particularly eutrophication prevention in lakes. In any ecosystem, the two aspects of interest for phosphorus dynamics are phosphorus concentration and phosphorus flux (concentration times flow rate) as functions of time and distance. The concentration alone indicates the possible limitation that this nutrient can place on vegetative growth in the water. Phosphorus flux is a measure of the phosphorus transport rate at any point in flowing water.

Phosphorus applied to the land as a fertilizer is held tightly to the soil. Most of the phosphorus carried into streams and lakes from runoff over cropland will be in the particulate form adsorbed to soil particles. However, the major portion of phosphate-phosphorus emitted from municipal sewer systems is in a dissolved form. This is also true of phosphorus generated from anaerobic degradation of organic matter in lake bottom sediments. Consequently, the form of phosphorus, namely particulate or dissolved, is indicative of its source to a certain extent. Dissolved phosphorus is readily available for algae and macrophyte growth. However, the DP concentration can vary widely over short periods of time as plants take up and release this nutrient. Therefore, TP in lake water is the more commonly used indicator of a lake's nutrient status.

To prevent biological nuisance, the IEPA (1999) stipulates that phosphorus as P shall not exceed a concentration of 0.05 mg/L in any reservoir or lake with a surface area of 8.1 hectares (20 acres) or more or in any stream at the point where it enters any reservoir or lake. Wetlands can reduce phosphorus levels in a flow system. Stover et al. (1997) studied a wetland (155 m by 155 m) used for tertiary wastewater treatment and found significant reductions in phosphate (55-87%), nitrate (95-99%), and sulfate (65-85%).

The ranges of total phosphorus concentration for the five stations were 0.10-0.56,0.06-0.46, 0.06-0.60, 0.03-0.52, and 0.02-0.04 mg/L, respectively (table 10). The TP levels in the pools were higher than the critical level of 0.05 mg/L for potential algal growth and, therefore, will not be a limiting growth factor. Total phosphorus concentrations in Indian Ridge Marsh did not exceed the range of other Illinois wetland areas (0.02-2.20 mg/L).

Dissolved phosphorus concentrations were in the range of 0.01-0.09 mg/L for all five stations (table 10), with median values between 0.01 and 0.03 mg/L. These values were similar to concentrations in Wolf Lake (Lin et al., 1996), which is a mile to the east of Indian Ridge Marsh. The low amount of DP compared to the TP would indicated that the phosphorus in the marsh is not coming from a wastewater source.

Metals

Water samples for metal analyses were collected on May 13 and 19, 1997, and again on August 20, 1997, from the three pools and the outlet. Only two samples were taken from the SEPA station. The results of metals analyses for those samples as well as for controls are presented in table 14. Analytical results of duplicate samples for the east pool taken on August 20, 1997, showed reasonable agreement between samples, except for boron and iron (table14). Thallium, silver, beryllium, and chromium were less than the detection values for all or most samples.

Five of the 14 samples exceeded the general-use standard of 1000 µg/L for iron. Samples taken on August 20, 1997, from the east pool have a mean lead concentration of 155 µg/L, which exceeded the general-use standard of 100 µg/L and was substantially higher than the maximum for the other Illinois natural marshes (<40 µg/L). Aluminum, boron, and zinc concentrations observed in Indian Ridge Marsh were significantly greater than the maximum values recorded for the other eight Illinois marshes. Sodium levels for samples collected on May 13 and August

Table 14. Observed Metal Concentrations of Indian Ridge Marsh, 1997

	Date	Aluminum	Antimony	Arsenic	Barium	Beryllium	Boron	Cadmium	Chromium	Cobalt	Copper	Iron
East Pool	5/13	960	1.8	2.3	23	<0.2	96	0.12	<0.4	0.22	3.5	930
	5/19	760	2.0	2.1	18	<0.2	130	0.08	<0.4	0.22	2.6	820
	8/20	1500	0.8	5.9	54	<0.2	110	0.09	1.1	0.50	24	2500
	8/20	1500	2.2	4.9	50	<0.2	280	0.09	3.2	0.44	26	2000
North Pool	5/13	500	0.9	1.3	77	<0.2	870	0.06	<0.4	1.3	2.3	650
	5/19	920	0.6	1.2	38	<0.2	220	<0.05	<0.4	0.31	1.6	1200
	8/20	440	2.7	2.2	84	<0.2	510	<0.05	<0.4	0.44	22	710
South Pool	5/13	680	1.0	1.5	59	<0.2	470	0.1	0.6	0.80	5.8	2100
	5/19	990	0.8	1.5	38	<0.2	180	0.1	<0.4	0.39	3.5	1800
	8/20	690	1.5	3.2	80	<0.2	550	<0.05	<0.4	0.44	17	970
Outlet	5/13	800	0.7	1.2	30	<0.2	90	<0.05	<0.4	0.28	6.8	660
	5/19	790	<0.3	1.6	29	<0.2	48	0.12	0.8	0.51	4.1	260
	8/20	830	2.1	2.5	52	<0.2	360	<0.05	<0.04	0.37	24	1400
SEPA st.	5/19	570	0.7	1.0	26	<0.02	120	<0.05	<0.4	0.23	4.5	590
	8/20	1600	0.9	1.3	25	0.3	78	<0.05	3.2	0.20	57	520
Field Blank	8/20	290	<0.3	<0.2	<0.2	<.0.2	60	<0.4	<0.4	<0.04	43	<10
Digestion Blank		57	0.4	<0.2	<0.2	0.3	50	<0.05	<0.4	<0.05	0.2	<10
Detection Limit		0.3	0.3	0.2	0.2	0.2	5	0.05	0.4	0.05	0.1	10
IL natural marshes		<20-150		<100	10-120		<20-110	<20-30	<10		<10	20-3580

	Date	Lead	Magnesium, mg/L	Manganese	Molybdenum	Nickel	Selenium	Silver	Sodium, mg/L	Thallium	Vanadium	Zinc
East Pool	5/13	9.0	14	84	20	2.5	<0.5	<5	57	<1	3.7	13
	5/19	9.8	12	83	20	2.0	0.6	<5	50	<1	3.8	7.1
	8/20	160	13	270	19	4.5	<0.5	<5	54	<1	6.5	40
	8/20	150	12	250	17	3.1	1.1	<5	49	<1	5.9	35
North Pool	5/13	1.6	70	440	9.7	12	7.4	7	150	<1	1.6	<0.5
	5/19	2.8	19	180	8.6	3.1	<0.5	<5	50	<1	2.6	2.3
	8/20	1.8	41	270	4.0	6.6	<0.5	<5	96	<1	1.6	140
South Pool	5/13	8.2	38	280	8.4	6.7	1.1	<5	87	<1	2.6	24
	5/19	7.2	14	170	7.4	2.7	0.8	<5	37	<1	2.9	24
	8/20	1.8	39	260	4.4	6.5	1.7	<5	100	<1	2.3	41
Outlet	5/13	3.8	14	64	6.3	2.7	0.7	<5	35	<1	2.4	20
	5/19	8.0	12	130	5.2	13	<0.5	<5	28	<1	2.4	33
	8/20	3.2	25	150	3.8	4.5	<0.5	<5	60	<1	2.0	69
SEPA st.	5/19	4.8	12	43	4.6	2.6	0.8	<5	27	<1	1.9	18
	8/20	4.0	10	41	4.2	2.0	<0.5	<5	16	<1	1.7	450
Field blank	8/20	0.43	0.016	0.3	0.3	1.4	<0.05	<5	0.82	<1	0.4	<0.5
Digestion blank		0.32	0.036	0.2	0.9	<0.2	2.4	<5	1.6	<1	0.2	<0.5
Detection bimit		0.05	0.03	0.04	0.1	0.2	0.5	5	0.001	1	0.2	0.5
IL natural marshes		<40	2.2-83	10-4850		<30	<20		1.5-67.2			< 10-20

Note: Values are in µg/L unless otherwise indicated.

20, 1997, from the north and south pools also were greater than the maximum concentration (67.2 mg/L) for the other marshes. Concentrations of barium, cadmium, iron, magnesium, and manganese in Indian Ridge Marsh were found to be lower than the highest values reported for the other Illinois natural marshes. Concentrations of arsenic, chromium, nickel, and selenium were detected at levels below the detection limits for the other marshes shown in table 11. Antimony, cobalt, molybdenum, and vanadium also were detected, but there is no data from the other marshes for comparisons.

The May 18, 1997, storm event caused a substantial drop in the concentrations of most of the metals, especially in the north and south pools where the concentrations of sodium and magnesium decreased by approximately 65 percent. The major exceptions were aluminum, which rose in the north and south pools, and iron, which doubled in the north pool. Most of the metal concentrations from the August 20, 1997, samples for the north and south pools and the outlet were within or near the range of the two May samples. The August 20, 1997, sample from the east pool had substantially higher levels of iron, manganese, and lead.

The concentrations of metals in the marsh is influenced by the large amount of organic material in the sediment, which can remove metals from the water by providing a lot of sites for sorption. Sediment samples collected by Roy F. Weston, Inc. (Bosko, 1998a) in the main channel show that some metals such as iron, lead, and zinc are elevated above IEPA background concentrations.

In addition to ground-water inflow and surface water runoff, atmospheric deposition also is a source of metals to the marsh. At a sampling station located at Bright School on 109th Street north of the marsh, Sweet and Vermette (1993) found elevated levels of metals in airborne particulate matter which they attributed to the steel industry. The concentrations of chromium, manganese, iron, zinc, and lead were greatest when the wind was from the southeast, the direction of several blast furnaces.

Volatile and Semivolatile Organic Compounds

Appendix C lists the results of organic analyses for water samples taken on September 2, 1997, from the north pool. The total organic carbon was 21 mg/L and the total organic halides were 0.05 mg/L. Each of 18 acid compounds, 93 base neutral organics, methoxychlor, and 43 volatile organic compounds analyzed for were below the laboratory detection limit. The grab samples of runoff from the Lake Calumet Cluster Site collected on May 7, 1998, also showed no volatile organic compounds above the laboratory detection limit. Samples taken by Bosko (1998a) also show no significant detections of volatile and semivolatile organic compounds or pesticides/PCBs in a sample taken in the south pool.

Bosko (1998a) reported numerous priority organic compounds in the sediments of the north and south pools, but only concentrations of benzo(a)pyrene and dibenz(a,h)anthracene were above IEPA Tier 1 soil cleanup objectives for commercial/industrial land uses. Because residential development is not deemed a reasonable future land use for the Lake Calumet Cluster Site, the less restrictive commercial/industrial standards were used for the risk assessment.

Bosko (1998a) reported several additional compounds above USEPA (1996b) toxicological standards for aquatic life, suggesting there may be some increased risk to the ecosystem. Due to many other factors in an ecosystem, these lower thresholds are considered benchmarks and not standards, remediation goals, or sole measures of sediment toxicity.

Potential Impact of Water Quality on Biodiversity

The quality of the water in Indian Pudge Marsh may produce adverse effects on the diversity of the vegetation and may contribute greatly to the dominance of invasive and weedy species. Recently Roy F. Weston, Inc., performed an ecological analysis of several wetlands in the Calumet region for the City of Chicago (Bosko, 1998b). They reported finding 122 plant species in the wetland and upland areas of the northern portion of Indian Ridge Marsh. Of these species, 60 are normative to this area. A previous assessment by Southern (1983) found 178 plant species, of which 71 were normative. General observation indicates that normative purple loosestrife (*Lythrum salicaria*) and native, but very weedy, common reeds (*Phragmites australis*) and cattails (*Typha* spp.) dominate the lowland areas.

A high TDS level is one water-quality component that may have a significant effect on the vegetation. At the Sterne's Woods fen complex in McHenry County, Panno et al. (1999) found that contamination plumes with high concentrations of sodium and chloride in the discharging ground water had an adverse effect on the vegetation. Within the areas of the plumes, the diverse vegetation found in the rest of the fen was replaced by more salt-tolerant narrow-leaf cattail (*Typha angustifolia*). In one case the source of the contamination was the runoff of road salt applied to an adjacent highway; in the other case the source was discharge from the septic field of an adjacent house (Panno et al., 1999). The range in TDS found by Panno et al. (1999) in the contamination plumes was 456-1297 mg/L, and the median TDS was 715 mg/L. The higher TDS contents found in the north and south pools of Indian Ridge Marsh, computed by subtracting the TSS from the TS in tables 6 and 7, had ranges of 500-1575 mg/L and 249-1517 mg/L, respectively, and medians of 904 mg/L and 772 mg/L, respectively.

The *Wetland Planting Guide for the Northeastern United States* (Thunhorst, 1993) lists many wetland plants that require salinity less than 0.5 part per thousand (approximately 500 mg/L), including several species listed by Bosko (1998b). Three examples of native plants in Indian Ridge Marsh are: the common water plantain (*Alisma subcordatum*), path rush (*Juncus tenuis*), and small duckweed (*Lemna minor*). Much of the marsh is currently dominated by common reeds (*Phragmities* sp.), which have a much higher salt tolerance of 20,000 mg/L. This gives the common reed a competitive advantage in areas with an inflow of ground water high in TDS or along the shorelines where the soil is composed of fill materials such as slag that are high in TDS. The common reed provides some cover for birds and animals but has a low food value, and purple loosestrife has a low overall wildlife value (Thunhorst, 1993). Many of the trees found by Bosko (1998b) on the upland fill areas are described by Thunhorst (1993) as resistant to high salinity, including eastern cottonwood (*Populus deltoides*), box elder (*Acer negundo*), hackberry (*Celtis occidentalis*), and green ash (*Fraxinus penn.*).

Of the 175 bird species observed by Southern (1983) in the area over a 12-month period, 77 are dependent upon wetland habitats. Fifteen of the observed species were on the Illinois threatened and endangered lists, and 11 of these depend on wetlands including the black-crown, night heron. However, the percentage of bird species nesting in the area was lower than expected, which Southern (1983) attributes to poor habitat quality caused by dense plant growth that leaves very little open water.

The quality of the habitat for fish and birds in Indian Ridge Marsh also may be degraded by the hydrology and water quality of the site. Southern (1983) considered the fish habitat to be of low quality, with only five species found in the north pool. Sixty-seven percent of the individuals found in the north pool were green sunfish, a pioneering species with wide ecological tolerances, and 14 percent were carp.

The biodiversity of the marsh may still be recovering from past activities that occurred earlier in the 20th century. The infilling that occurred on the upland areas likely sent large pulses of sediment and polluted water into the marsh. Weedy and invasive plant species were likely to have been the first species to colonize these disturbed areas. Infilling and the other waste disposal activities that occurred on the Lake Calumet Cluster Site also could have created damaging inflows of sediment and pollution. The marsh also may have been severely affected by contamination in the Calumet River. The water quality of the Calumet River has dramatically improved since the 1960s when the river received large volumes of untreated sanitary and industrial effluent. As part of a regional water-quality study, the U.S. Department of Health, Education, and Welfare (1965) found that all of the bottom organisms in the Calumet River near the marsh outlet were species considered to be pollution tolerant. The study also reports severe bacterial contamination, and DO levels periodically fell to zero.

Potential Steps To Improve the Water and Habitat Quality

Several remediation opportunities exist to improve the water and habitat quality. The effects of several remediation options are discussed in the hydrologic modeling section. Although these actions by themselves do not guarantee more diverse vegetation, the changes proposed to Indian Ridge Marsh do help level the playing field for native species to compete. The benefits of these actions on the wildlife may be more immediate.

Addition of Water from the Calumet River

The water quality in the marsh and at the outlet could be improved by diluting source waters high in TDS with higher-quality water from the SEPA station or the Calumet River. The median TDS of 226 mg/L in the SEPA station was almost four times lower than the median of 940 mg/L in the north pool. Water would be diverted from one of the elevated pools at the SEPA station after the water has undergone some aeration. Alternatively, water could be pumped directly from the river and, if necessary, aerated separately. To prevent the incoming water from immediately exiting at the outlet, a pipeline to the north end, a weir across the outlet, or a new outlet at the north end would have to be constructed. Because the station works by pumping out a large amount of water, 100-400 cfs, into a pool 12 feet above the river then discharging it over a series of waterfalls back into the river, a sufficient volume of water may be available to enhance Indian Ridge Marsh.

Reducing the Amount of Ground- Water Inflow

The water quality in the marsh could also be improved by reducing the amount of ground-water inflow. This could be accomplished by constructing trenches or drains along the edges of the marsh that would drain the intercepted water to storm drains or another basin. The area of ground-water inflow from the Lake Calumet Cluster Site between 118th and 120th Streets may be the best area for application of this interception-based remediation technique. If facilities and parking lots are developed on the upland areas of the marsh, they could be equipped with leaky storm drains that would drain ground water off to the storm sewer along Torrence Avenue. Although reducing groundwater inflow may improve some habitat conditions, any remediation using this technique should be evaluated against the effect on wetland hydroperiod, which is essential for maintenance of high quality wetland vegetation and corresponding high quality habitat.

Control of Runoff from 122nd Street

By placing curbs and storm sewers along 122nd Street, the runoff of road salt and sludge into the marsh could be reduced. Roadcap and Kelly (1994) found very little to no road salt contamination in monitoring wells along curbed roads versus significant contamination in wells along uncurbed roads. Much of the sludge falling off the trucks coming from the drying beds also would be collected by the curbs and storm sewers.

Addition of Clean Soil and Removal of Fill

Clean soil could be added to the shorelines, which currently consist of slag, demolition debris, and other fill material, to improve the water quality of the soil and promote native vegetation. Because the banks of the marsh are very steep, adding soil and regrading the shorelines would enhance the interspersion zone and promote different plant communities in a localized area. Alternatively, the fill material could be removed and thus restore the original wetland surface and expanding the marsh. The original wetland soil is likely to underlie most of the upland areas. Exposure of historical wetland soils can take advantage of seed banks in these soils, which may enhance revegetation efforts. Clean soil also can be added to locations within the marsh to produce topographic diversity, which will enhance vegetation diversity and meet specific wildlife habitat needs (e.g., nesting islands).

Placement of a Weir across the Outlet

A weir placed across the outlet of the marsh at the Calumet River would provide the means to control the water level. Water levels could be raised if more open water was desired to increase the fish population and provide more food for some of the bird species such as the black-crown night heron. The weir also could be used to create late summer drawdowns as part of any larger plan to control invasive plant species.

HYDROLOGIC MODELING

The modeling of Indian Ridge Marsh was conducted to characterize the hydrologic conditions and the effect of hydrology on retention times and on different plant communities in the wetland. The probable vegetative communities were predicted based on existing, and modified, hydrologic regimes. Possible alterations to the site that would change the hydrology and the plant communities also were examined to predict which alterations might diversify the plant community. Perhaps the most important aspect of hydrology for plant communities is the hydroperiod, which describes the water level in the wetland over the course of a year. Water levels and their change over time have a direct effect on the types of plants that colonize an area and the way in which plant community succession proceeds. For this reason, the hydroperiod is a major focus of the modeling. A generalized example of plant community succession is shown by the series of photographs in figure 6, taken of the north pool looking north from 122nd Street. Another important hydrologic parameter is retention time. With more time, more contaminants have the opportunity to settle out of the water, are taken up by plants, or are converted to less harmful products by natural degradation processes. Conversely, shorter retention times may reduce the accumulated contaminants, such as ammonia-N in the early spring, that cannot be assimilated by a wetland function.

Although hydrology is extremely important in determining vegetative development and is the focus of this report, it must be kept in mind that it is not the only factor affecting the development of different plant communities. Considering the history of use of the Indian Ridge Marsh, limits to plant diversity also may be due to poor water and soil quality, competition from invasive plants, or lack of an adequate seed source in the area to stimulate colonization.

The Modeling Process

The SWAMPMOD Model

The hydrologic model used in this research was SWAMPMOD (Konyha et al., 1995). This continuous hydrologic simulation evaluates the hydrology of a wetland system using several years of daily climate and adjacent stream elevation data. For each day of the simulation, a water-budget analysis is performed by setting the change in volume of water in the wetland over an incremental time equal to the difference of the inflows to the wetland and the outflows from the wetland. The inflows include precipitation, surface and subsurface runoff from the watershed, and seepage from ground water into the wetland. Outflows from the wetland include evaporation, transpiration, flow through a principal spillway, outflow over an emergency spillway, lateral seepage, and deep percolation leaving the wetland.

Input data required to run the model include data on the local climate and physical environment. A climate/watershed file is prepared that contains the rainfall, potential evapotranspiration, rapid runoff from the watershed such as surface runoff, moderate runoff such as subsurface runoff flow, and slow flows including lateral seepage and deep seepage for each day of the simulation. A stream elevation file is required if the wetland is located adjacent to a stream or river with variable water levels. This file contains the stream's water-level elevation for each day of the simulation as determined in the climate file. Topographic data, including watershed and wetland size and shape, are needed, as well as soil characteristics such as hydraulic conductivity, difference in volumetric water content at field capacity and wilting point, and water storage capacity of the soil. It also is necessary to know the depth to which the roots of the wetland plants extend. Management parameters can be used that define types and elevations of control structures incorporated into the wetland design. These control structures include a principal spillway that may or may not have an adjustable height, an emergency spillway, and an embankment.

Summary files generated by SWAMPMOD contain inflows, outflows, and water elevations in the wetland averaged over various time intervals. Another output file provides data that can be used to plot hydrographs of storm events when rainfall exceeds a trigger level. A retention time file contains outflow rate, water velocity, and retention time data. The retention times calculated assume complete mixing in the wetland; and, although this may not be a perfect assumption, the data are still useful when comparing different wetlands. These output files can be used with other programs or spreadsheets to provide information that is useful in deciding which modifications, if any, would enhance the wetland functions desired in the system being studied (figure 7).

The Vegetation Model

A separate vegetation model was used to predict the plant community that results from the hydroperiods produced by SWAMPMOD. The vegetation model estimates the extent of vegetation zones that develop at different elevations based on the hydrologic conditions (Wickenkamp, 1994). The vegetation model is based on work by Poiani and Johnson (1993), who developed a set of general rules that relate water levels in a wetland over time to conditions that support seedling success and plant development. Wickenkamp (1994) used these rules to develop a rule-based model compatible with SWAMPMOD.

Wickenkamp's model uses the daily water elevation data output from SWAMPMOD. For selected elevations above a datum established in the wetland, a continuous assessment of the hydrologic conditions is performed throughout the growing season, April-September. The hydrologic conditions are then related to the expected vegetation zones for each month according to the rules summarized below (Wickenkamp, 1994).

Seedlings can only dominate between May and August following a period dominated by open water with submerged and floating vegetation or no vegetation at that elevation. There must be less than 3 cm of standing water for at least 21 days in the month for seedlings to become established. If the water depth continues to be less than 3 cm during the month following the establishment of seedlings, a community of mixed species of young plants will develop. If the soil becomes inundated to a depth greater than 3 cm, the area will revert back to no vegetation as the seedlings are flooded

A community of mixed young plants will proceed to mixed species of emergent plants if the time they are saturated or inundated exceeds the time they are dry. The mixed young plants will produce a wet meadow system only during the first month of the growing season

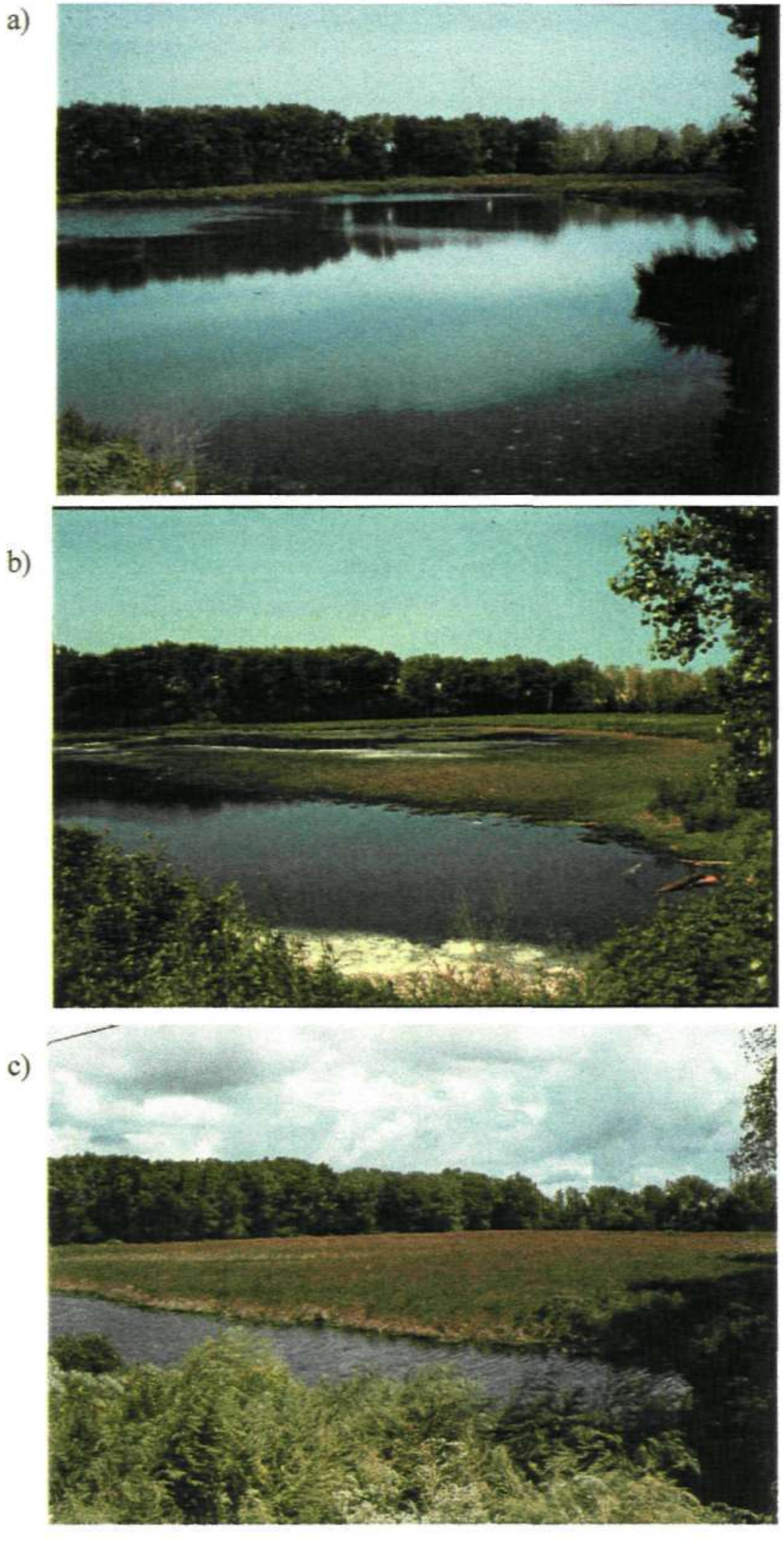

Figure 6. Example of plant community succession, north pool of Indian Ridge Marsh: a) 1993, b) 1994, c) 1998.

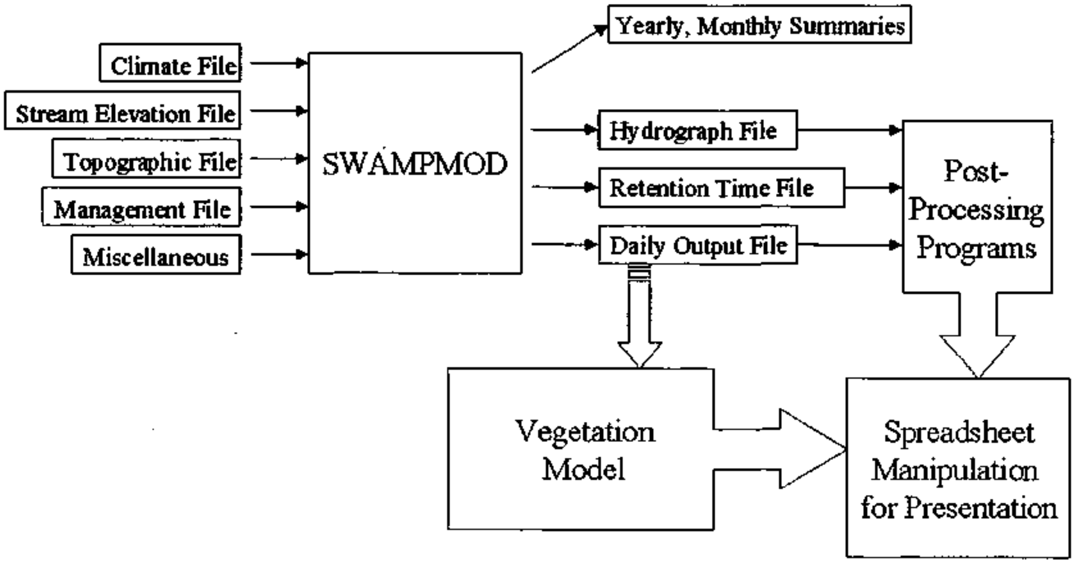

Figure 7. The modeling process.

(April) and only if the soil is dry more often than saturated. If the amount of time during the month the soil is dry exceeds the amount of time it is saturated, but the month is not April, that location will maintain its mixed system of wet and dry species.

A mixed emergent community will be succeeded by a deep marsh community if more than 4 cm of water covers the soil for six growing-season months. Mixed emergents will be joined by drier species to make a mixed-plant community if the soil remains dry (more than 10 cm above the surface of the water) for more than six months. If neither of these conditions occur, the mixed-emergent system will continue to dominate.

Deep marsh species will be joined by shallower species to make up a mixed-emergent community if, after two years of inundation, the soil becomes dry to saturated for a month during the growing season. Upland plant species and wet meadow species will die and there will be no vegetation if the soil becomes flooded to a depth of at least 4 cm for at least seven days of the month. Open water vegetation will colonize an area with no vegetation if the area is submerged for six months of the growing season. All vegetation types will yield an open-water system if flooded with at least 56 cm of water and will yield upland vegetation if dried to more than 55 cm above the water level for two years.

Further discussion and justification of these rules can be found in the Poiani and Johnson paper (1993). Though an oversimplification of the true dynamics of succession, these rules provide an ecologically sound prediction of the types of vegetation that may be expected at a site based on hydrologic history and the life history of wetland plant species.

Data Preparation

As described earlier, SWAMPMOD requires site data for calibration and operation. Some of the data used to run the model require on site data collection; other input data may be estimated. In the case of estimated data, a range of values was used in this study to determine the significance of any errors that might be introduced by estimation. The modeling exercise considered the north and south pools of the Indian Ridge Marsh that are usually hydraulically connected. The smaller east pools are excluded because they are connected to the main pools only by ground-water flow.

The watershed/climate file was prepared using actual daily rainfall and potential evapotranspiration from the NOAA weather station at O'Hare International Airport. Data for 20 years, 1978-1997, were obtained from the Midwestern Climate Center at the ISWS. Surface and subsurface runoff was combined and calculated using the Soil Conservation Service curve number method. The curve number selected was 75, a typical value for the soils and cover found in the area. To determine the significance of error introduced in assuming this value, a range of curve number values was tested in the sensitivity analysis as described in the Parameter Sensitivity and Uncertainty section.

Lateral seepage into the wetland was calculated using Dupuit's formula for steady seepage through a porous medium with a constant hydraulic head (Yen, 1993). This is the same formula used by SWAMPMOD to calculate seepage outflow from the wetland. In using the formula, it was assumed that seepage of ground water, with a head of 582.5 feet at l00 feet from the pool, flowed into the wetland at an average elevation of 580.5 feet. The seepage face was assumed to include the 5000 feet of shoreline along the west and north sides of the north pool. These values were approximated based on field observations and water elevations in monitoring wells in the surrounding area. A hydraulic conductivity of 3.3 feet/day, which represents a midrange value for soils in the area (Roadcap and Kelly, 1994), was used for this calculation as well as the SWAMPMOD calculations. The resulting flow of 18,500 feet^3/day (0.21 cfs or 0.42 acre-feet/day) was incorporated into the watershed/climate file as lateral seepage. As will be discussed in the sensitivity analysis, a range of lateral seepage inflows was analyzed for sensitivity to this parameter.

It was necessary to estimate the size of the watershed draining into the wetland because complete survey data are not available, and disturbances to the area have altered natural overland and subsurface flow. The area used for most of the model simulations was 40 acres, but a range of values from 30-50 acres also was tested in the sensitivity analysis.

The stream water elevation file was prepared by using data from two sources as described previously. Figure 3 shows the resulting hydrograph for 1978-1997. These data also were analyzed statistically to determine the median, maximum, and minimum elevations for each day of the year. This information is plotted in figure 8 for comparison to hydroperiods obtained in the various simulations.

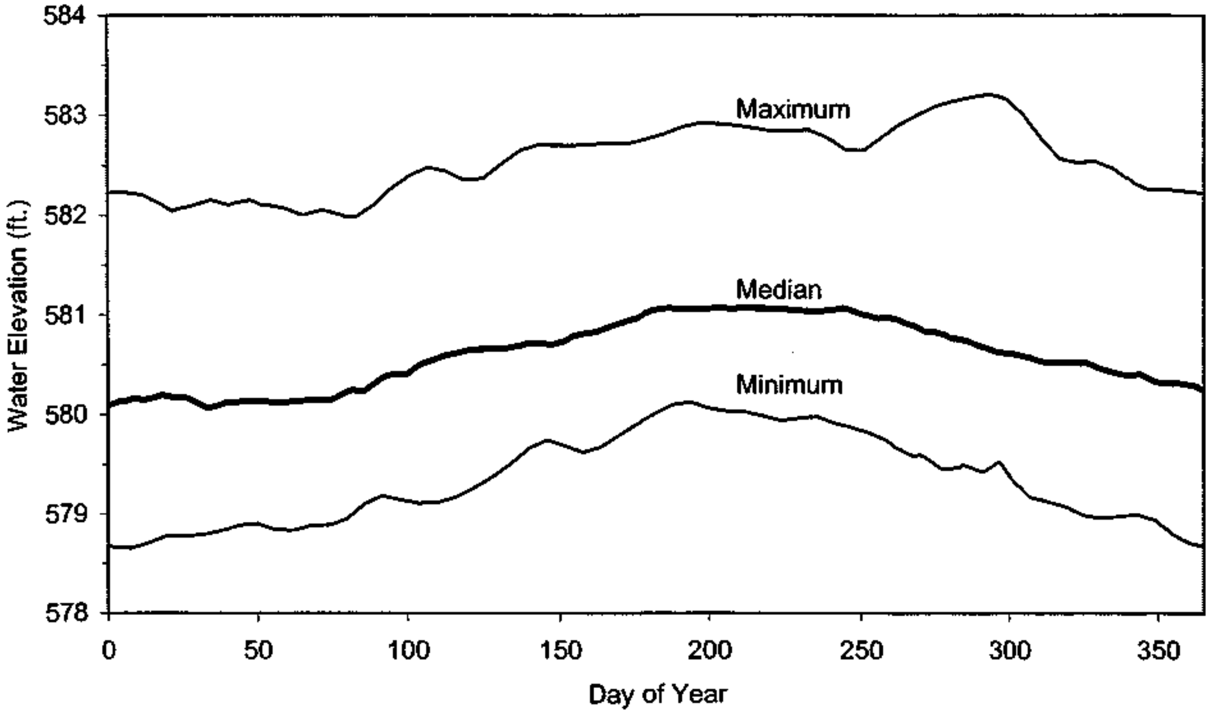

Figure 8. Statistical elevations of the Calumet River at Indian Ridge Marsh.

The topographic data for the wetland area were developed based on surveys of the area. For some parameters in this file, such as root depth and difference between water content at field capacity and water content at wilting point, typical values were assumed to be applicable. Parameters needed to determine lateral seepage from the wetland were based on the assumption that water would be seeping out at the south end to the river when the river is lower than the water level in the wetland.

The management file varied significantly based on the simulation being performed; therefore, the inputs to this file will be described with the discussion of the separate model runs. In general, the placement of control structures, especially a principal spillway and an emergency spillway, were modeled. The principal spillway was typically a weir 5-10 feet wide located at the outlet of the wetland that would discharge less water than currently flows through the outlet channel. The emergency spillway was a larger weir, about 25 feet wide, also at the outlet that would allow larger outflows as necessary when the water elevation in the wetland exceeded its height.

Model Results and Scenarios

The results of the modeling conducted in this research are provided in the appendices. Appendix D provides estimated statistical hydroperiods for each scenario. Appendix E provides representations of the vegetation model outputs. The plots show the estimated chronological progression of vegetation communities at eight different elevations for the growing seasons for the 20-year simulation period. To choose the eight elevations analyzed and indicated on the vertical axis (appendix E), the wetland was divided into eight equivalent sized areas defined by elevation. The elevation in the middle of each zone was chosen to represent the area. For example, the bar labeled with the lowest elevation (appendix E) represents the deepest eighth of the marsh; that with the highest elevation represents the shallowest eighth of the marsh, and each other bar represents an eighth in between. The horizontal axis (appendix E) is growing season time from the beginning of the simulation period to the end. Appendix F contains graphs that indicate SWAMPMOD's estimate of the retention time distribution. These estimates assume a completely mixed system. The actual distribution would differ somewhat, but differences between scenarios are still very relevant. The plots in appendix F show the percentage of water that exceeds given retention times. Table 15 provides a brief summary of all of the scenarios.

Estimate of Current Conditions at Indian Ridge Marsh

The model was run with parameters chosen to simulate the existing conditions at the marsh for the purposes of estimating the eventual diversity of the system based on the hydrologic conditions with no alterations to the system. The current conditions were modeled by setting the principal and emergency spillways in the management file at elevations of 580.5 feet, the elevation of the channel that flows into the Calumet River. The spillways were assigned a width of 30 feet in accordance with observations of the outlet channel.

Statistical hydroperiods indicate that the water levels in the wetland closely follow those of Lake Michigan and the Calumet River, as can be seen by comparing figure 8 and the first plot of appendix D. Both plots indicate clear trends of a rise in spring, continued elevation through the summer, and a drop back down in the late fall. During drier times when the river and lake levels are below the elevation of the outlet channel, the river has less effect on the water levels in the wetland. During this period, ground-water seepage into the north pool exceeded the seepage outflow at the south end of the marsh, keeping the minimum water level at 580.5 feet. The similarity in the two plots is what would be expected for a depressional wetland near a large lake, as is the case for the Indian Ridge Marsh.

The vegetation model outputs suggest that, considering only hydrology, a diverse plant community is possible in Indian Ridge Marsh without any modification of the existing hydroperiod. Approximately 1/4 of the wetland would be dominated by an open-water community of submerged and floating vegetation. Another 1/4 to 3/8 would vary between deep marsh and mixed-emergent vegetation. The rest of the wetland would include wet meadow plants, and occasional flooding would produce temporary emergent communities.

The retention time profile shows that almost half of the water has a retention time of more than 30 days. The slope of the profile from 5-30 days is fairly constant, which suggests evenly distributed retention times. The long retention time may be beneficial for the treatment of some contaminants such as suspended solids and nutrients, but it also may contribute to the accumulation of other contaminants such as dissolved chloride and ammonium.

Effect of Flooding

A second simulation was done to determine the effect of adding a spillway weir at an elevation of 583 feet and an emergency spillway at 584 feet located at the existing outlet channel. There are several reasons for interest in such a scenario. First, interest has been expressed in creating more open water in the marsh to expand the hunting ground for birds that feed on fish. Second, flooding may be included in a possible schemes to help control invasive species and allow other species the opportunity to colonize. Large die-offs of common reeds (*Phragmites australis*) were observed in Big Marsh when it became flooded in late 1998 and early 1999; however, without other measures the same infested areas may be recolonized by common reeds in late 1999 and early 2000. Third, a potential scheme to move more water through the system and improve the water quality would add water from the SEPA station and move the marsh outlet from the south end to the northwest corner. The marsh could then drain into Big Marsh, whose elevation at the point closest to Indian Ridge Marsh is approximately 583 feet. This section only addresses the effects of raising the water level; the additional effects from adding water are discussed in the SEPA station section.

As the hydroperiod graphs suggest, the effect of this alteration would be to retain the rain, runoff, and lateral seepage from the surrounding high water table and raise the overall water level in the wetland. Drier years might produce a drawdown in summer due to lack of rainfall and resulting runoff.

After turning the wetland into a large pond, the dominant vegetation community would be that found in open water, but the edge of the pond probably would still have some emergent species. The retention time distribution shows that almost 100 percent of the water would be retained for more than 30 days and, thus, may cause an accumulation of contaminants from the ground water.

Placement of an Adjustable Weir

Scenarios were modeled that added an adjustable weir. This was done to mimic a summer drawdown that would be experienced by a wetland adjacent to an uncontrolled stream or river, and to determine if such a modification would produce different plant communities. Before the Calumet River was dammed, higher flows would occur in the spring followed by lower flows in the summer. The lower flows in the summer would allow the water levels in the wetland to drop, and plants that require such a drawdown for the germination of their seeds would have a chance to become established. With the river dammed, this drawdown cannot occur, so an adjustable weir could be a way to achieve a similar hydroperiod. The management file was altered to simulate a 5-foot long weir placed at 580 feet, dropped to 579 feet on July 1, and raised back to 580 feet on August 30. The emergency spillway was placed at 583 feet.

The hydroperiod estimated for this configuration shows that the median and wet years do not have significantly altered conditions. This is probably due to the fact that the river contributes large quantities of water to the wetland either through seepage or direct flow through the simulated weir. Only the dry years were affected because the rain, runoff, and seepage into

Table 15. Summary of Scenarios Modeled for Indian Ridge Marsh

Scenario	*Modification features*	*Hydroperiod features*	*Vegetation features*	*Retention time*
Current conditions	none - 30-foot wide outlet channel at 580.5 feet	similar to river elevations; baseline ~580.6 feet; median and wet years rise May-October	~25% open water, ~35% deep marsh and mixed emergent, ~35% wet meadow	median ~30 days
Effect of flooding	5-foot wide weir at 583 feet; 30-foot wide spillway at 584 feet	~583 feet; in dry years water drops May-Ocober; more peaks	> 85% open water; some deep marsh	median >30 days
Placement of adjustable weir	5-foot wide weir at 580 feet September-June; at 579 feet July-August	dry years show drop in July and August	drier at low elevations and more variable over time than current conditions	median~21 days
	10-foot wide weir at 580 feet September-June; at 579 feet July-August	same as 5-foot weir	same as 5-foot weir	median~19 days
Altered topography	small quantity of soil added	same as current conditions	drier; less open water, and emergents, more wet meadow	median~16 days
Topographic change and weir placement	uniform addition of 0.5 foot of soil; 10-foot wide weir at 581 feet	baseline ~581.1 feet; dry years drop below	more open water than altered topography alone; much more wet meadow than other scenarios	median~17 days
Modeled as two separate pools	north pool modeled with existing 2-foot culvert between	similar to current conditions; few more peaks	similar to current conditions; little more open water, less emergents	median ~17 days
	north pool modeled with existing culvert constricted to ~8% of cross-sectional area	baseline ~580.8 feet	much wetter; ~40% open water, <25% wet meadow	median >30 days
	south pool modeled with existing 2-foot culvert between	baseline ~581 feet	similar to current conditions	median <1 day
	south pool modeled with existing culvert constricted to ~8% of cross-sectional area	baseline ~580.5 feet	similar to current conditions; little drier	median <1 day

Table 15. (Concluded)

Scenario	*Modification features*	*Hydroperiod features*	*Vegetation features*	*Retention time*
Addition of SEPA station water to existing system	existing system with additional inflow of ~2 cfs	same as without addition of water	same as without addition of water	median ~14 days
	existing system with additional inflow of ~4 cfs	same as without addition of water	same as without addition of water	median ~7 days
Addition of SEPA station water to flooded system	weir at 583 feet; additional inflow of ~2 cfs	~ 583.25 feet; never drops	100% open water	median >30 days
	weir at 583 feet; additional inflow of ~4 cfs	~583.4 feet; never drops	100% open water	median ~26 days
Addition of SEPA station water to adjustable weir	10-foot wide weir at 580 feet dropped to 579 feet in summer; additional inflow of ~2 cfs	same as without addition of water	same as without addition of water	median~13 days
	10-foot wide weir at 580 feet dropped to 579 feet in summer; additional inflow of ~4 cfs	same as without addition of water	same as without addition of water	median ~6 days
Addition of SEPA station water to south pool	south pool; additional inflow of ~2 cfs	same as without addition of water	same as without addition of water	median <1 day
	south pool; additional inflow of ~4 cfs	same as without addition of water	same as without addition of water	median <1 day
"Ideal" hydroperiod 1	10-foot wide weir at 580.5 feet raised to 582.5 feet from 4/1 to 8/15	rises almost 1 foot in late April; remains elevated until mid-August	almost 50% open water with mixed emergent and wet meadow vegetation; little deep marsh	median~13 days
"Ideal" hydroperiod 2	10-foot wide weir at 580.5 feet raised to 582.5 feet from 4/1 to 7/15; additional inflow of ~2 cfs from 5/1 to 7/31	rises almost 2 feet in early May; remains elevated until mid-July	more than 25% open water; almost 50% mixed emergent vegetation; little wet meadow; few periods of seedlings	median >29 days

the wetland that were previously held back by the higher outlet channel bottom is released through the lower weir. The only significant change to the vegetation was that deep marsh and mixed-emergent vegetation were sometimes present at lower elevations.

This scenario was altered slightly to estimate the effect of using a wider weir, which would allow more flow when water levels exceed the weir height. The results for a 10-foot adjustable weir with the same settings as the 5-foot weir show very little change to the hydroperiod (a 0.2 feet drop in water level at dry times) and the vegetation structure.

The retention times for both weir widths were on average just slightly lower than the estimate for the existing conditions, which is what would be expected with the lower outflow elevation. The median retention time for the 5-foot weir was approximately 21 days; that for the 10-foot weir was approximately 19 days.

Effects of Altered Topography

Another simulation considered the effects of changing the topography of the wetland by adding a small quantity of soil. There are several reasons for considering this. One reason is to attempt to reduce the area of open water, which is estimated to take up approximately 25 percent of the current system and to increase the area of the emergent vegetation zone. A second reason for the addition of soil is to remediate the fill soils along the banks and to reduce the steep bank slops. Another reason is to consider the effects of sedimentation of soil particles in the pools that enter the wetland in runoff from the surrounding area. To model this, the area of the wetland that is currently at 580 feet was elevated to 580.5 feet, and all points between 580.5 and 582 feet on the area versus the elevation plot were raised slightly to form a smooth, constant slope.

This modification to the site would have a negligible effect on the hydroperiod, as can be seen by comparing the resulting hydroperiod with that predicted by SWAMPMOD for the current conditions. The difference is noticeable, however, in the vegetation predicted at equally incremented areas. The amount of open water is limited to an eighth of the total area, and a corresponding increase in the amount of emergent and wet meadow vegetation is predicted.

The retention times for this scenario would be slightly lower than for the existing conditions. The decrease in retention times can be attributed to the small decrease in total volume imposed by the addition of soil. The median retention time was close to 16 days.

Topographic Change and Weir Installation

The addition of a weir at the outlet of the wetland and the uniform addition of 0.5 foot of soil were simulated together to address the concern that the addition of fill, although useful for enhancing the soil, may render the wetland too dry. As shown in the vegetation chart for the previous scenario (appendix E), 75 percent of the area experiences conditions suitable for wet meadow vegetation at least some of the time. Therefore, if additional high quality soil is desired, a weir may be necessary to maintain substantial areas of the deeper vegetation zones.

A comparison of the statistical hydroperiods for a scenario with soil addition and a weir with a simulation of current conditions shows that the wet periods would be unaffected by the weir as in the other cases in which a weir was modeled. Under drier conditions, the level of water in the wetland would be higher because ground water would still be able to seep in, and outflow would be restricted to only seepage loss. The results of this modeling indicate that, at equal elevations, the wetland would be generally wetter than the existing situation. However, comparing only conditions at equal elevations obscures the effect of raising the wetland by adding the soil. When the total area of the wetland is divided evenly by area and vegetation is compared, the modifications described seem to favor vegetation that requires drier conditions. Because more soil was added than in the previous scenario, the highest half that is above the weir elevation would remain drier. The overall effect is a less diverse system.

The retention time profile for this second scenario is very similar to the profile for the previous scenario in which only soil was added. There is a slightly greater percentage of water with lower retention time with the addition of the weir, but the median retention time was just slightly higher, around 17 days.

Modeling as Two Separate Pools

The wetland was broken down into two pools, and the model was used to simulate conditions in each pool separately. This was done because the SWAMPMOD model assumes a uniform water level over the entire surface of the wetland. Because Indian Ridge Marsh covers a large area and actually consists of two pools connected by a culvert, which at times restricts flow between the pools, modeling the marsh as one system may not be accurate. The division also allows us to consider the pools separately with respect to different restoration goals, namely water quality treatment and habitat provision. Water quality degradation, including high levels of ammonia and elevated levels of dissolved solids and metals, apparently is produced by ground water entering the wetland through seepage from the north and west. This is supported by the fact that the north pool has a higher water surface elevation than the south pool when the culvert is constricted. If treatment of this ground-water seepage is proposed as part of a larger remediation project, the north pool would be the focus of the more intensive treatment. The focus of restoration activity in the south pool then would be the establishment of higher quality wetland vegetation while accomplishing further removal of lower concentrations of various contaminants. With different priorities for each pool, the hydrology is best considered separately.

The part of the marsh north of 122nd Street was modeled using the same watershed inputs as before, but with new outputs as flow through the 2-foot diameter culvert under 122nd Street (at 580.5 feet) and seepage through the causeway. The outflows from the north pool were then used as the watershed inflows into the pool south of 122nd Street. Although no other modifications to the system have been modeled simultaneously at this time, any combination of alterations discussed in other sections can be applied to either or both of the pools separately.

Both pools are predicted to have hydroperiods and vegetation very similar to the simulation of the combined system if the culvert is open so water can flow freely between the pools. The downward spikes in the hydroperiod during drier periods are modeling artifacts that occur during iterations when water is transferred from the south pool to the north pool. Because the culvert sometimes becomes clogged with debris, the two pools also were modeled with the cross-sectional area of the culvert reduced to approximately 8 percent of its maximum area. In this case water levels in the north pool would be elevated and cause more open water and less wet meadow vegetation. The south pool water levels and vegetation, as estimated by the models, remain relatively unchanged because the water levels are controlled by ground-water seepage inflows and the adjacent river as in the current conditions. Reducing inflows from the north pool does not significantly change the water levels in the south pool.

Addition of SEPA Station Water

The addition of water from the SEPA station, which is located on the south edge of Indian Ridge Marsh on the north side of the Calumet River, was considered as part of remediation planning. If water quantity was insufficient in the wetland under natural flow conditions, then water flow into the wetland could be supplemented by water from the SEPA station. Although this flow does not appear to be needed to maintain wetland plant communities, the addition of SEPA flows could be a potential tool to improve the water quality in the marsh. High levels of dissolved solids and other pollutants in the water entering the system may inhibit the establishment of a diverse plant community, due to toxicity and the inability of many species to compete with weedy species under such conditions. Because the quality of the water in the SEPA station was generally much better than that of the marsh, the diversion of SEPA station water may provide conditions that would allow other plants, as well as other fish and wildlife, to be competitive.

Using the estimated ground-water inflow of 0.21 cfs and assuming an average TS concentration of 2000 mg/L for the ground water and 226 mg/L for the SEPA station water, approximately 2 cfs of SEPA station water would be required to lower the TS concentration in the marsh to 400 mg/L. Assuming an average ammonia-N concentration of 60 mg/L for the ground water and 0.20 mg/L for the SEPA station water, the maximum levels of ammonia-N in the marsh during the winter and spring would drop to below 6 mg/L. Adding 4 cfs would lower the TS level to around 300 mg/L and the maximum ammonia-N level to around 3 mg/L. These values are very similar to the median TS concentration of 331 mg/L and the maximum ammonia-N concentration of 3.44 mg/L found at the outlet (table 10) and suggest that the water quality of the marsh outflow would not be changed significantly.

The model was used to consider additions of approximately 2 cfs and 4 cfs to four of the scenarios: the current system, the flooded system, the system with the adjustable weir, and the south pool alone. For most of these scenarios the increased inflow had almost no effect on the water levels and, therefore, no effect on the predicted plant communities. The impact of the SEPA station water on the hydroperiod was minimized by the large volume of the marsh and large size of the outlet. For those scenarios that showed some change to the hydroperiods, the vegetation model was run as well. The results are shown in appendix E.

The most significant effect of adding the water that is apparent from SWAMPMOD would be the reduction in retention time for the water entering the wetland. For example, addition of 2 cfs to the existing wetland would reduce the median retention time from close to 30 days to between 13 and 14 days. With the addition of 4 cfs, the median retention time would be reduced to six to seven days. Although adding 2 cfs to the scenario in which a weir is placed at 583 feet produces very little change in the retention distribution for times under 30 days, addition of 4 cfs brings the median time down to approximately 27 days. The effect on the scenario for which an adjustable weir was placed at the outlet was similar to the effect on the existing system. The smooth, shallow slope of the graph representing no water added was replaced by one that drops off with a median retention time of about 13 days. Increasing the quantity of water reduced the time to close to six days. Although the retention times for the south pool alone are generally much lower than those for the other scenarios because a much smaller volume is being considered, addition of water from the SEPA station would bring the times down even further.

Although the model assumes complete mixing of the water, which is not a totally accurate assumption, the general trend toward shorter retention time with greater inflow is logical and would likely be the case. Because the SEPA station is at the downstream end of the marsh, consideration needs to be given as to how and where the water is introduced. Introduction of the water at the south end of the south pool may limit mixing, whereas a gravity-fed pipe discharging into an east pool with a second connection to the north pool may greatly enhance the mixing.

Creation of an "Ideal" Hydroperiod

A few of the techniques described above were combined in an attempt to create a hydroperiod (figure 9) similar to that determined by Busch (1990) to be "ideal" for Great Lakes

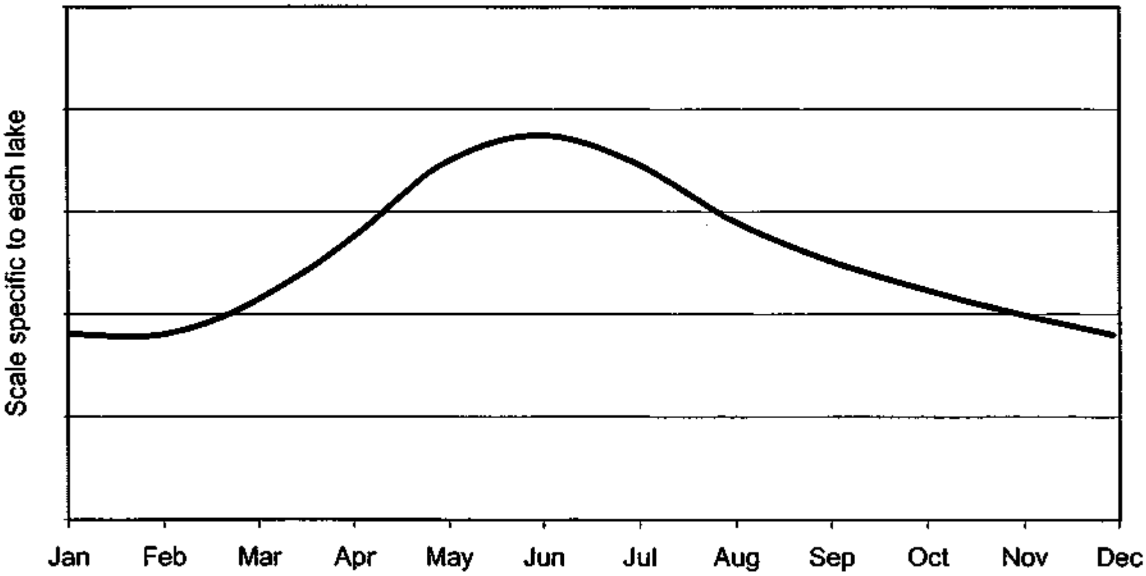

Figure 9. The "ideal" hydroperiod for Great Lakes wetlands (from Busch, 1990).

wetlands. According to his studies, the water level in a wetland along the Great Lakes should be relatively low in the winter, rise roughly 2 feet through the early spring and summer, and decrease by late summer. The SWAMPMOD estimates of the current hydroperiod do show an average rise in the spring and summer, but this rise is only on the order of half a foot. To achieve a more suitable profile, this rise should be increased significantly.

The first attempt to mimic the profile proposed by Busch (1990) was made by simply simulating the installment of an adjustable weir similar to those described previously. The 10-foot wide weir was designed to be kept at 580.5 feet, the current outlet elevation, during the fall and winter months and raised to 582.5 feet from April 1st through August 15th. The resulting hydroperiod, shown in appendix D, indicates that the weir alone would not be enough to raise the median water level by 2 feet. The water rose less than 1 foot for the median hydroperiod and even less for drier years. A comparison of the predicted vegetation during this simulation with the simulation of the current conditions shows that more open water and mixed emergent vegetation would be expected with considerably less time and space occupied by wet meadow communities.

Several additional simulations were run in an attempt to achieve Busch's (1990) ideal hydroperiod that combined the use of an adjustable weir with the addition of water from the SEPA station. One of the hydroperiods that came reasonably close to this ideal was obtained by adding 2 cfs of water from May 1st until July 31st and installing a weir at 580.5 feet raised to 582.5 feet from April 1st through July 15th. This simulation, shown as attempt 2 in the appendices D, E and F, created a narrow peak in the hydroperiod centered at early to mid-June with a sharp drop in the middle of July. The major difference between this profile and Busch's ideal profile is the sharpness of the rise and especially the fall of the water level. This simulation produced a dominance of mixed emergent plants with some deep marsh and wet meadow vegetation as well as sufficient open water within the basins modeled.

The retention time profiles indicate that holding back water by raising a weir substantially increases the retention time, as would be expected. Because the retention time profiles are based on the fraction of water with different retention times, the scenario in which SEPA water is added when the weir is elevated have an even larger fraction of water with higher retention times. For this situation the median retention time was greater than 29 days.

The attempts to establish a hydroperiod that is similar to Busch's (1990) "ideal" hydroperiod provided interesting results. The short-term disturbance of the greatly increased water level might be expected to cause more variation in the plant communities over time and perhaps more times during which there would be no vegetation due to the disturbance. However, when the water level rise was sufficiently short, the result was less variation over time, much more emergent vegetation, and smoother transitions with fewer periods of no vegetation followed by a restart from seed. There are a number of possible explanations for these results. Keddy (1990) provides examples of the effects of water fluctuation in a wetland. He refers to a general trend that the area of emergent marsh and wet meadow zones increase with the amplitude of water level fluctuations, and that without these fluctuations, these zones are minimized. Although his definitions of these community types may not be exactly the same as those used by Poiani and Johnson (1993), the concept may explain the drastic increase in the area of mixed emergent vegetation. Though the results of the vegetation modeling for the second attempt at creating an "ideal" hydroperiod did not show an increase in wet meadow vegetation for the area modeled, it is possible that, outside the modeled basins, more wet meadow vegetation would thrive. In comparing the statistical hydroperiods for wet and dry years, it is apparent that this seasonal rise and fall becomes dependable, not changing much from year to year. Perhaps this predictability in the seasonal fluctuations would produce a more stable system.

Parameter Sensitivity and Uncertainty

Obtaining useful information from the SWAMPMOD model requires having sufficient data for the location being analyzed. Detailed information was not available for some of the parameters needed to run the model, and estimations or typical values were used. To test the sensitivity of the model predictions to inaccuracies in predicting these values, several model runs were performed using a range of values to determine whether or not the uncertainties introduced significant error. The parameters examined include the curve number used in determining runoff from the surrounding watershed, seepage inflows from the water table, hydraulic conductivity of the soil, and watershed size.

The soils and other land cover comprising the portion of the watershed draining into the wetland vary considerably. The area contains roads, industrialized sites, and some open vegetated areas that are fairly compacted. The curve number of 75 that was used is typical for this type of cover, but values in the range of ±10 percent were tested. As shown by the hydrographs in appendix D, varying the curve number within this range had very little effect on the water levels in the marsh.

The lateral seepage into the marsh was calculated using uncertain, variable values for the water-table depth and hydraulic conductivity near the wetland. The formula used to calculate the seepage quantity also assumes that the water-table depth is constant at a known distance from the pool. Due to these uncertainties and assumptions, a range of inflows of from 13,900 ft^3/day to 37,000 ft^3/day was tested. Although small changes can be detected, the hydrographs show that water levels are not significantly affected by changes of this magnitude (appendix D). The median retention times changed only slightly (appendix F).

The hydraulic conductivity used by the model to calculate seepage outflows is a spatially variable parameter according to the report by Roadcap and Kelly (1994). Because the values reported vary considerably, values were tested between 0.4 and 2.9 inches/hour, which represents the value estimated ±75 percent. No noticeable change in water levels resulted.

As stated previously, determination of the exact size of the upland watershed was difficult due to the nature of the fill surface. The sensitivity of the model to inaccuracies in the 40-acre estimate was tested using a range from 30-50 acres. As in the other scenarios, the model proved to be fairly insensitive to changes in these values.

DISCUSSION

The 92-acre Indian Ridge Marsh consists of several wetland pools connected to the Calumet River. The marsh is surrounded by additional wetlands, roads, railroads, a coke plant, the Lake Calumet Cluster Site, and a SEPA station. East 122nd Street sits on a causeway that divides the marsh into north and south pools connected by a culvert. Six smaller pools along the eastern side of the site are isolated from the north and south pools by causeways. A topographic survey of the marsh determined that most of the marsh has a bottom elevation between 580 and 582 feet. One prominent topographic feature of the marsh is a main channel along the western edge.

Flow occurs generally from north to south. Water enters the wetland system at the north pool, with runoff from both the east and the west. Three culverts, located beneath the railroad tracks west of the north pool, carry runoff from a drainage area of approximately 13 acres on the Lake Calumet Cluster Site. Inflows from the west are diverted by the main channel, which reduces the interaction with the heavily vegetated area of the marsh and, thus, potentially reduces the capacity of the marsh to treat contaminants. Water from the north pool flows through the culvert under the 122nd Street causeway and into the south pool. This connecting culvert is often blocked or restricted by sediment or debris, which can cause the water level in the north pool to rise by several feet. After flowing through the south pool, the water flows through a channel to the Calumet River. The water level at the outlet of the marsh is controlled by the Calumet River, which in turn is controlled by the Thomas J. O'Brien Lock and Dam and the level of Lake Michigan. The main area of ground-water inflow appears to be along the middle third of the western boundary of the north pool. A small spring also was observed in the northeast corner of the north pool.

A large amount of fill was used to raise portions of the original marsh high enough to be potentially developed as industrial or residential property. The main types of fill used throughout the region are slag wastes from nearby steel mills, dredged material from the Calumet River system, demolition debris, municipal wastes, and other industrial wastes. In Indian Ridge Marsh, demolition debris and slag are visible along the edges of the pools and on the surface of the upland areas. Most of the pool bottoms do not appear to have any fill. Reported fill thickness is as much as 11 feet in the north-central portion of the property

A monitoring program was implemented during the growing season (April-October) of 1997 to assess the current water quality conditions in Indian Ridge Marsh Five sites were sampled on a monthly basis from April 15-October 15, 1997, and additional samples were collected after storm events. The physical water-quality characteristics were defined by in situ observations of temperature, DO, and Secchi disc transparency and laboratory measurements of turbidity and conductivity. The observed DO levels generally met the IPCB general-use standards of not less than 5.0 mg/L. Many of the samples from the pools contained high or supersaturated DO concentrations that were likely due to photosynthetic oxygen production of observed algal populations. Some oxygen stratification did occur in July and August. Many of the conductivity measurements greatly exceeded the maximum value found at other natural marshes in Illinois. The turbidity frequently exceeded 15 NTU, which is indicative of substantial suspended sediment.

The north and south pools had very high levels of TS, but the SEPA station had a median level that was only 25 percent of those pools. Most of the solids are in the dissolved form, and one-third of the samples collected from the north and south pools exceeded the TDS standard of 1000 mg/L. Ground water is the likely source of the dissolved solids because surrounding monitoring wells had very high TDS concentrations. The TSS values generally increased during the growing season, with the higher values composed largely of VSS. With the exception of the SEPA station, almost half of the samples from the marsh had TSS concentrations that exceeded 25 mg/L, which is classified as having a high general-use impairment.

Very high concentrations of ammonia-N (>30 mg/L) were found in the north and south pools in the early spring. These high ammonia-N levels are much higher than the range of 0.01-3.18 mg/L found in other Illinois natural marshes. In these two pools, 19 percent of the samples exceeded the Illinois ammonia-N standard of 15 mg/L and 62 percent exceeded the un-ionized ammonia standard of 0.1 mg/L. These high levels are considered toxic to fish and capable of stimulating nuisance algal blooms. Very little ammonia-N was detected in the east pool and at the SEPA station. By July, the amount of ammonia-N was drastically reduced, probably because the nitrifying capacity of the bacteria in the marsh is much greater than the ammonia-N influx. Ground water is the likely source of the ammonia-N because of the elevated levels found in the monitoring wells and the similarity of the temporal trends of ammonia-N to the trends in TS. There is also an insufficient amount of organic nitrogen and nitrate/nitrite to attribute the elevated ammonia to the reduction of organic matter or sewage wastes. Follow-up grab samples identified two potential locations at which ground water with high ammonia-N is entering the marsh: in the northeast corner of the north pool along 116th Street and along the west side of the north pool between where 119th and 120th Streets would be located. Because the unexpected buildup of ammonia-N during the winter, additional sampling of the ground-water inflow and the pool during the winter months would be beneficial to future research at the marsh.

The levels of organic nitrogen were relatively low, except in late May and after the June 16, 1997, storm when the concentration in the north pool increased to 28 mg/L. The maximum nitrate/nitrite concentration observed in the marsh was 1.64 mg/L in the north pool. The total phosphorous levels in the marsh were above the critical level of 0.05 mg/L necessary for potential algal growth and did not exceed the range for other natural marshes in Illinois.

The concentrations of iron in five samples and lead in one sample exceeded the IEPA general-use standards. Aluminum, boron, lead, and zinc concentrations observed in some of the Indian Ridge Marsh samples were significantly greater than the maximum values recorded for the other natural marshes in Illinois. Sodium levels in two sets of samples from the north and south pools also were greater than the maximum concentration for other marshes. Concentrations of barium, cadmium, iron, magnesium, and manganese in Indian Ridge Marsh were found to be lower than the highest values reported for the other Illinois marshes. Low concentrations of antimony, arsenic, chromium, cobalt, molybdenum, nickel, selenium, and vanadium also were detected.

The hydrologic modeling of Indian Ridge Marsh was conducted to characterize the hydrologic conditions and the effect of hydrology on retention times and on different plant communities in the wetland. The hydrologic model was constructed using SWAMPMOD (Konyha et al., 1995), which is a continuous hydrologic simulation that evaluates the hydrology of a wetland system using several years of daily climate and adjacent stream elevation data. The inflows into the model include precipitation, surface and subsurface runoff from the watershed, and seepage from ground water into the wetland. Outflows from the wetland include evaporation, transpiration, flow through a principal spillway, outflow over an emergency spillway, and lateral seepage leaving the wetland. Using the results from the hydroperiods produced by SWAMPMOD, a separate vegetation model was used to estimate the extent of the different vegetation zones that develop at different elevations based on the hydrologic conditions. The vegetation model is based on a set of general rules that relate water levels in a wetland over time to conditions that support seedling success and plant development

The probable vegetative communities and retention times were predicted based on existing and modified hydrologic regimes. Possible alterations to the site that would change the hydrology and the plant communities also were examined to predict which alterations might diversify the plant community. The modifications considered with the model include: placement of a high weir, placement of an adjustable weir, alteration of the marsh topography, constriction of flow between the north and south pools, and the addition of SEPA station water to the marsh.

The hydroperiods for many of the scenarios reflect the strong influence of Lake Michigan and the adjacent Calumet River water elevations on water levels in Indian Ridge Marsh, particularly when the lake levels are high. The model predicted that diverse vegetative communities should exist under the current conditions, unfortunately the marsh is currently dominated by weedy species that are tolerant to a wide range of conditions. The modifications studied here would have some effect on the water elevations in the wetland, especially during drier periods; but a comparison of predicted vegetative communities for all the scenarios suggests that the potential diversity of the system would not be increased greatly by many of these changes. In the scenario where a weir was added at an elevation of 583 feet, the marsh was converted almost entirely to open water. Adding soil to the marsh caused there to be less open water and more mixed emergent and wet meadow communities. Constricting the culvert under 122nd Street produced more open water in the north pool and left the south pool largely unaffected. Recreating the "ideal" hydroperiod resulted in more open water and mixed emergent communities.

The quality of the water in the SEPA station was better than the four sampled pools in the marsh, with lower levels of solids and very little ammonia-N. The metal levels also were lower. The model results show that the addition of SEPA station water should not affect the predicted vegetative communities in the marsh and should greatly reduce the retention time of the water. The TS level would be reduced below the salinity tolerance level for many native plant species and maximum ammonia-N levels would be reduced below the standard. The water quality at the marsh outflow would not change significantly. Therefore, the introduction of some SEPA station water into Indian Ridge Marsh has the potential to improve the water quality in the marsh without adversely affecting the vegetation.

CONCLUSIONS

Indian Ridge Marsh, a valuable ecological resource to the Chicago region, is currently affected by several water-quality problems. If these problems could be successfully addressed, the quality of this resource could be substantially improved. Reducing the ammonium influx could improve the habitat for fish and other aquatic life; and reducing the total solids influx could improve the chances for survival of native wetland plants. Potential steps to remediate the water quality problems include:

- adding water from the SEPA station or the Calumet River,
- reducing the amount of ground-water inflow,
- controlling the runoff from 122nd Street,
- adding clean soil and removing fill, and
- placing a weir across the outlet.

The hydrologic modeling of the marsh shows that the proper hydroperiod currently exists to support a diversity of wetland plant communities, and that the potential for these communities could be maintained with properly designed remediation schemes.

The information contained in this report builds toward a naturalization design for Indian Ridge Marsh. A final design needs to couple community visions for the site with relevant engineering elements to produce final rehabilitation designs that are robust in this highly modified environment. As the ecological objectives and designs for the site become more defined, further sampling, modeling, and designing will be required. Soil and water quality issues, as well as biotic factors such as competition for resources by invasive species, need to be addressed. Rehabilitation strategies that may alter topography and/or water flow quantities should continue to be evaluated using the SWAMPMOD and vegetation modeling tools to estimate potential diversity that would result in the wetland.

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Appendix A. Existing Water-Quality Data

	Ground water				*Indian Ridge Marsh*						
Site	*Well 17*[a]	*Well 18*[a]	*Well 20*[b]	*Well 70*	*East Pool*[c]	*East Pool*	*North Pool*	*Cental Pool*[d]	*Central Pool*[e]	*South Pool*	*Outlet*
Sample date	*5/96*	*6/96*	*91-94*	*7/91*	*4/95*	*4/95*	*4/95*	*4/94*	*4/95*	*4/95*	*4/95*
Parameter											
Temperature, °C	14.6	14.6	16	17	12	10.4	8.4		9.56	8.1	10.1
Dissolved Oxygen	2.83	2.89	0.83		10	10.4	14.4		9.43	13.7	12.4
pH, units	6.15	6.19	7.31	12.3	7.98	7.86	8.11		8.1	8.08	8.03
Redox Potential, mV	97.5	109	9	-400							
Alkalinity (as $CaCO_3$)	274	313	389	1122	136	134	356	323	195	529	481
Conductivity, µmho/cm	1965	2150	2590		300	330	1600		567	2600	2400
Turbidity, NTU								50			
Volatile Suspended Solids								46			
Total Suspended Solids			1745					70			
Total Dissolved Solids	2505	2750	3039	1090	190	206	1233		367	1532	1467
Major Cations and Anions											
Calcium	579	573	468	445	35	41	172	68	54	150	128
Magnesium	36	47	64	<0.04	10	11	61	24	27	77	67
Sodium	30	35	441	22.5	6	8.2	75	15	16	180	158
Potassium	1.5	3.3	45	18.6	3	2.4	15	5.9	6.7	39	32
Chloride	38	53	917	7.3	14.8	16.7	105	20.4	23.2	258	236
Sulfate	1380	1490	1024	14.9	11.7	26.6	544	<10	80.6	445	423
Secondary Constituents											
Dissolved Phosphorus-P	<0.08	<0.08	<0.08		0.09	0.26	0.13	0.14	0.12	0.27	0.14
Total Phosphorus-P								0.54			
Ammonia-N	3.35	7.33	2.2	33	0.05	0.02	53	0.32	0.59	61	53
Nitrate/Nitrite-N	<0.02	<0.02	<0.1	<0.1	<0.02	<0.02	0.25	0.01	0.26	0.21	0.24
Total Kjeldahl-N					1.06	1.03	25.4	3.1	1.91	24.5	21.8
Organic Carbon	10.8	8.1	18	74				29.7			
Aluminum	0.025	0.042	0.014	1.22	0.140	0.444	0.134	0.14	0.169	0.162	0.046
Boron	<0.015	<0.015	0.415	0.142	<0.15	<0.15	0.390	0.15	0.304	0.914	0.763
Fluoride	<0.1	<0.1	1.6	4.6	0.9	0.9	1.1		0.8	0.6	0.6
Iron	11.5	8.96	17.0	0.02	0.66	0.91	1.81	2.1	0.60	1.96	1.45
Manganese	0.585	0.372	1.91	<0.002	0.161	0.119	0.797	1.4	0.066	0.461	0.481
Silicon	10.1	11.9	9.54	2.26	1.03	0.94	7.13		0.47	7.11	6.15
Strontium	0.555	1.09	1.23	0.88	0.110	0.118	0.698	0.22	0.281	0.794	0.701

Appendix A. (Concluded)

	Ground Water				*Indian Ridge Marsh*						
Site	*Well 17*[a]	*Well 18*[a]	*Well 20*[b]	*Well 70*	*East Pool*[c]	*East Pool*	*North Pool*	*Cental Pool*[d]	*Central Pool*[e]	*South Pool*	*Outlet*
Sample Date	*5/96*	*6/96*	*91-94*	*7/91*	*4/95*	*4/95*	*4/95*	*4/94*	*4/95*	*4/95*	*4/95*
Trace Metals (ug/L)											
Antimony	<100	<100	<100	<150	<100	<100	<100		<100	<100	187
Arsenic	<40	<40	<40	<80	<40	<40	<40		<40	<40	<40
Barium	23	22	96	451	6	21	90	51	75	113	95
Beryllium	<1	2	<1	<1	<1	<1	<1	<1	<1	<1	<1
Cadmium	<4	<4	<4	<6	<4	<4	<4	<3	<4	<4	<4
Chromium	<4	8	<4	11	<4	<4	<4	<5	<4	<4	<4
Cobalt	6	8	<4	<6	<3	<3	<3	<5	<3	<3	4
Copper	<3	<3	<3	<1	<3	<3	<3	<5	<3	<3	<3
Lead	<12	<12	<12	<27	<12	<12	<12	<5	<12	<12	<12
Lithium	14	21	227	40	4	<4	48		24	67	57
Mercury	<20	<20	10	<30	<0.5	<0.5	<0.5	<0.05	<0.5	<0.5	<0.5
Molybdenum	<6	<6	<6	17	<6	7	<6		6	<6	<6
Nickel	<6	6	15	<18	<6	<6	<6	<15	<6	13	8
Selenium	<50	<50	<50	<110	<50	62	<50		<50	<50	<50
Silver	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3
Thallium	<50	<50	<50	<240	<50	<50	<50		58	<50	<50
Tin	<40	<40	<40	<60	<40	<40	<40		<40	<40	<40
Titanium	12	13	4	3	3	10	8		6	8	5
Vanadium	4	4	<3	<11	<3	4	3	<5	<3	<3	3
Zinc	55	91	78	<3	11	16	15	<100	19	15	7

Notes:

Values are in mg/L unless otherwise indicated.

[a] Median of 6 multi-level sampling ports.

[b] Median of 4 samples collected on 9/91, 6/92, 6/93, and 9/94.

[c] First east pool north of 122nd Street.

[d] South-central pool of the north pool.

[e] Central pool of the north pool

Appendix B. Precipitation Record (inches) at 12233 S. Avenue O, Chicago, Illinois, 1997

Day	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*June*	*July*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
1	-	-	0.08	-	0.31	-	-	-	-	-	-	-
2	-	-	-	-	0.19	-	-	-	-	-	-	-
3	-	0.05	-	-	0.05	-	-	-	-	-	0.35	-
4	0.42	0.45	-	0.03	-	-	-	-	-	0.42	0.02	-
5	-	-	-	0.19	0.09	-	-	-	-	-	0.12	-
6	-	-	-	-	-	0.87	0.06	-	-	-	0.06	-
7	-	-	-	-	0.35	0.10	-	-	-	-	-	-
8	-	-	-	-	-	-	0.35	-	0.57	-	-	-
9	0.44	-	0.22	0.19	-	-	-	-	-	0.25	-	0.10
10	0.15	-	-	-	-	-	-	-	-	-	-	0.75
11	-	0.03	-	0.76	-	0.31	-	1.06	-	-	-	-
12	-	0.07	-	0.02	-	0.05	-	0.37	-	-	-	-
13	-	-	0.38	-	$\boxed{-}$	-	0.15	-	-	0.23	0.03	-
14	-	-	0.02	-	0.13	-	-	-	-	-	0.02	-
15	0.36	0.03	-	$\boxed{0.07}$	-	-	-	-	-	$\boxed{-}$	0.34	-
16	-	0.27	-	0.13	-	$\boxed{0.75}$	-	1.28	0.56	-	-	-
17	-	-	-	-	-	-	-	0.76	0.5	-	-	-
18	-	-	-	0.06	0.94	-	2.81	-	-	-	-	-
19	-	-	-	0.14	$\boxed{-}$	-	-	-	0.46	-	-	-
20	-	1.14	-	-	-	-	$\boxed{-}$	$\boxed{-}$	-	-	-	-
21	0.26	2.66	-	-	-	0.05	0.32	-	-	-	-	-
22	-	0.03	-	-	-	-	0.09	-	0.04	-	-	0.28
23	-	-	-	0.09	-	-	0.39	-	$\boxed{0.1}$	0.03	-	-
24	0.19	-	0.19	-	0.05	-	-	0.18	-	0.14	-	0.53
25	-	-	0.05	-	0.17	0.03	-	-	-	-	-	0.03
26	0.12	0.8	-	-	-	-	0.30	-	-	1.26	-	-
27	0.10	0.31	-	-	-	-	0.22	-	-	0.13	0.29	-
28	-	0.02	0.06	-	0.08	-	-	-	-	-	0.04	-
29	-		0.07	-	-	$\boxed{-}$	-	-	-	-	0.19	-
30	-		-	0.17	$\boxed{-}$	0.57	-	-	-	-	-	-
31	-		-		-		-	-		-		-
Monthly Total	2.04	5.86	1.07	1.85	2.36	2.73	4.69	3.65	2.23	2.46	1.46	1.69

Notes:

- No precipitation.

Sampling dates appear in boxes.

Source:

Westcott(1998)

Appendix C. Volatile and Semivolatile Organic Compound Analysis

Abbreviations

ACD =Acid compounds
BN = Base neutral
TOC = Total organic carbon
TOX = Total organic halides
PST = Pesticide
VOC = Volatile organic compounds

PDC Laboratories, Inc.

ILLINOIS STATE WATER SURV
SHUNDAR UN
PO BOX 697
PEORIA IL 61602

Purchase Order No: RUJ 6395 D
Date of Report: *9/24/97*

Sample Number: 97090112
Date Collected: 9/2/97
Date Recafved 9/3/97
Description: STATION #2 INDIAN RIDGE WETLAND

Analysis	**Results**	**Unit of Measure**
Inorganics		
INO		
TOC	21	mg/l
TOX	0.05	mg/l
Organics		
ACQ		
2,3,4,6-Tetrachlorophenol	<0.10	mg/l
2,4,5-Trichlorophenol	<0.010	mg/l
2,4,6-Trichlorophenol	<0.010	mg/l
2,4-Dichlorophenol	<0.010	mg/l
2,4-Oimethylphenol	<0-010	mg/l
2,4-Din'rtrophenol	<0.050	mg/l
2,6-Dichlorophenol	<0.010	mg/l
2-Chlorophenol	<0.010	mg/l
2-Methylphenol(o-cfesol)	<0.010	mg/l
2-Nitrophenol	<0.010	mg/1
3-Methyiphenol	<0.010	mg/1
4,6-Dinitro-2-methylphenoI	<0.050	mg/l
4-Chloro-3-methylphenol	<0.010	mg/l
4-Methylphenol(m. p-cresol)	<0.010	mg/l
4-Nitrophenol	<0.050	mg/l
Benzoic Acid	<0.050	mg/l
Pentachlorophenol	<0.050	mg/l
Phenol	<0.010	mg/l

Project Manager

Analysis	Results	Unit of Measure
BN		
1,2,4,5-Tetrachlorobenzene	<0.010	mg/l
1,2,4-TrichIorobenzene	<0.010	mg/l
1,2-Dichlorobenzene	<0.010	mg/l
1,2-Diphenylh.ydrazina	<0.010	mg/l
1,3,5-Trinitrobenzene	<0.010	mg/l
1,3-Dichlorobenzene	<0.010	mg/l
1,4-Dichlorobenzene	<0.010	mg/l
1,4-Naphthoquinone	<0.010	mg/l
1-Chloronapthalene	<0.010	mg/l
1-Naphthylamine	<0.010	mg/l
2,4-Dinitratoluane	<0.010	mg/l
2,6-Dinrtrotoluene	<0.010	mg/l
2-Acstylaminofluorene	<0.010	mg/l
2-Chloronaphthalene	<0.010	mg/l
2-Methytnaphthalene	<0.010	mg/l
2-Naphthyiamine	<0.010	mg/l
2-Nitroaniline	<0.010	mg/l
2-Picoline	<0.010	mg/l
3.3-Dichlorobenzidine	<0.010	mg/l
3,3-Dimethylbenzidine	<0.010	mg/l
3-Methyicholanthrene	<0.010	mg/l
3-Nitroaniline	<0.010	mg/l
4-Aminobiphenyl	<0.010	mg/l
4-Bromophanyl-phenylether	<0.010	mg/l
4-Chloroaniline	<0.010	mg/l
4-Chlorophanyl-phenylether	<0.010	mg/1
4-Nitroaniline	<0.010	mg/l
4-NitroquinoIine-1-oxide	<0.010	mg/l
5-Nitro-o-toluidine	<0.010	mg/l
7,12-Dimethytbenz(a)anthracane	<0.010	mg/l
a,a-Oirnethylphenethylamine	<0.010	mg/l
Acenaphthens	<0.010	mg/l
Acenaphthylene	<0.010	mg/l
Acetophenone	<0.010	mg/l
Aniline	<0.010	mg/l
Anthracene	<0.010	mg/l
Aramita	<0.050	mg/l
Benzidine	<0.050	mg/l
Benzo(a)anthracene	<0.010	mg/l
Benzo(a)pyrene	<0.010	mg/l
Benzo(b)fluoranthene	<0.010	mg/l
Benzo(g.h.i)perylene	<0.010	mg/l
Benzo(k)fluoranthene	<0.010	mg/l
Benzyl Alcohol	<0.010	mg/l
Bis(2-chloroethoxy)rnethane	<0.010	mg/l
Bis(2-chloroethyl)ether	<0.010	mg/l

Analysis	**Results**	**Unit of Measure**
Bis(2-chloroisopropyl)ether	<0.010	mg/l
Bis(2-ethy1hexyl)phthalate	<0.010	mg/l
Butyl benzyl phthalate	<0.010	mg/l
Chrysene	<0.010	mg/l
Di-n-butyl phthalate	<0.010	mg/l
Di-n-octyl phthalate	<0.010	mg/l
Dibenz(a,j)acridine	<0.010	mg/l
Dibenzo(a,h)anthracene	<0.010	mg/l
Dibenzofuran	<0.010	mg/l
Diethyl phthalate	<0.010	mg/l
Dimethyl phthalate	<0.010	mg/l
Diphenylamine	<0.010	mg/l
Ethyl Methanesulfonate	<0.010	mg/l
Fluoranthene	<0.010	mg/l
Fluorene	<0.010	mg/l
Hexachlorobenzene	<0.010	mg/l
Hexachlorobutadiene	<0.010	mg/l
Hexachlorocyclopentadiene	<0.010	mg/l
Hexachloroethane	<0.010	mg/l
Hexachloropropene	<0.010	mg/l
lndeno(1,2,3-cd)pyrene	<0.010	mg/l
Isophorone	<0.010	mg/l
Isosafrole	<0.010	mg/l
Methapyrilene	<0.010	mg/l
Methyl Methanesulfonate	<0.010	mg/l
N-Nitrosodl-n-butylamine	<0.010	mg/l
N-Nitrosodi-n-propylamine	<0.010	mg/l
N-Nitrosodiethylamine	<0.010	mg/l
N-Nitrosodimethylamine	<0.010	mg/l
N-Nitrosodiphenylamine	<0.010	mg/l
N-Nitrosomethylethylamine	<0.010	mg/l
N-Nitrosomorphofine	<0.010	mg/l
N-Nitrosopiperidine	<0.010	mg/l
N-Nitrosopyrrolidine	<0.010	mg/l
Naphthalene	<0.010	mg/l
Nitrobenzene	<0.010	mg/l
0,0,0-Triethyl phosphorothioate	<0.010	mg/l
o-Tduidlne	<0.010	mg/l
p-Phenylenediamine	<0.010	mg/l
Pentachlorobenzene	<0.010	mg/l
Pentachloronitrobenzene	<0.010	mg/l
Phanacetin	<0.010	mg/l
Phenanthrene	<0.010	mg/l
Pronamide	<0.010	mg/l
Pyrene	<0.010	mg/l
Pyridine	<0.010	mg/l
Safrole	<0.010	mg/l

Analysis	Results	Unit of Measure
voc		
1,1,1,2-Tetrachloroethane	<0.010	mg/l
1,1,1-Trichloroethane	<0.005	mg/l
1,1,2,2-Tetrachloroethane	<0.005	mg/l
1,1,2-Trichloroethane	<0.005	mg/l
1,1-Dlchloroethane	<0.005	mg/l
1,1-Dichloroethene	<0.005	mg/l
1,2,3-Trichlorapropane	<0.005	mg/l
1,2,4-TrichIorobenzene	<0.005	mg/l
1,2-Dibromo-3-Chloropropane	<0.005	mg/l
1,2-Dibromoethane	<0.005	mg/l
1,2-Dichiorobenzene	<0.005	mg/l
1,2-Dichloroethane	<0.005	mg/l
1,2-Dichloropropane	<0.005	mg/l
1,3-Dichlorobenzene	<0.005	mg/l
1,4-Dichlorobenzene	<0.005	mg/l
Benzene	<0.005	mg/l
Bromochloromethane	<0.005	mg/l
Bromodichlorometriane	<0.005	mg/l
Bromoform	<0.005	mg/l
Bromomethane	<0.010	mg/l
Carbon Tetrachloride	<0.005.	mg/l
Chlorobenzene	<0.005	mg/l
Chloroethane	<0.010	mg/l
Chloroform	<0.005	mg/l
Chloromethane	<0.010	mg/l
cis-1,3-Dichloropropene	<0.005	mg/l
Dibromochloromethane	<0.005	mg/l
Dibromomethana	<0.005	mg/l
Dichlorodifluoromethane	<0.005	mg/l
Ethylbenzene	<0.005	mg/l
Hexachlorobutadiene	<0.005	mg/l
sopropylbenzane	<0.005	mg/l
Methylene Chloride	<0.005	mg/l
Naphthalene	<0.005	mg/l
o-Xylene	<0.005	mg/l
Styrene	<0.005	mg/l
Tetrachloroethene	<0.005	mg/l
Toluene	<0.005	mg/l
trans-1,2-Dichloroethene	<0.005	mg/l
trans-1,3-Dichloropropene	<0.005	mg/l
Trichloroethene	<0.005	mg/l
Trichlorofluoromethane	<0.005	mg/l
Vinyl Chloride	<0.010	mg/l
PST		
Methoxychlor	<0.100	mg/l

Appendix D. Statistical Hydroperiods

Dl Current conditions.
D2 Weir at 583 feet.
D3 5-foot adjustable weir at 580 feet dropped to 579 feet in July-August.
D4 10-foot adjustable weir at 580 feet dropped to 579 feet in July-August.
D5 Altered topography.
D6 Topographic change and weir placement at 581 feet.
D7 North pool with an open culvert.
D8 North pool with a constricted culvert.
D9 South pool with an open culvert.
D10 South pool with a constricted culvert.
Dl 1 Weir at 583 feet and ~2 cfs of SEPA station water added.
D12 Weir at 583 feet and ~4 cfs of SEPA station water added.
D13 Addition of weir and water for the "ideal" hydroperiod 1.
D14 Addition of weir and water for the "ideal" hydroperiod 2.
D15 Current conditions with a curve number of 67.5.
D16 Current conditions with a curve number of 82.5.
D17 Current conditions with seepage inflow of 37,000 ftVday.
D18 Current conditions with seepage inflow of 13,900 ftVday.
D19 Current conditions with hydraulic conductivity of 0.4 in./hr.
D20 Current conditions with hydraulic conductivity of 2.9 in./hr.
D21 Current conditions with watershed of 30 acres.
D22 Current conditions with watershed of 50 acres.

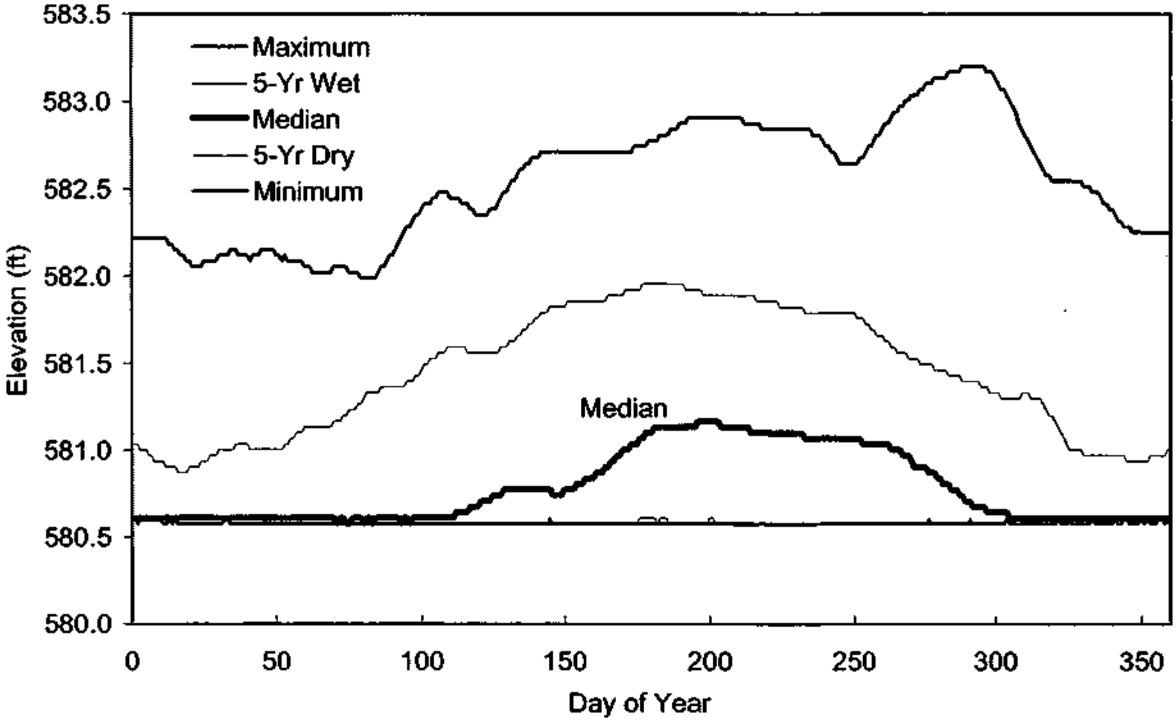

Figure D1. Current conditions.

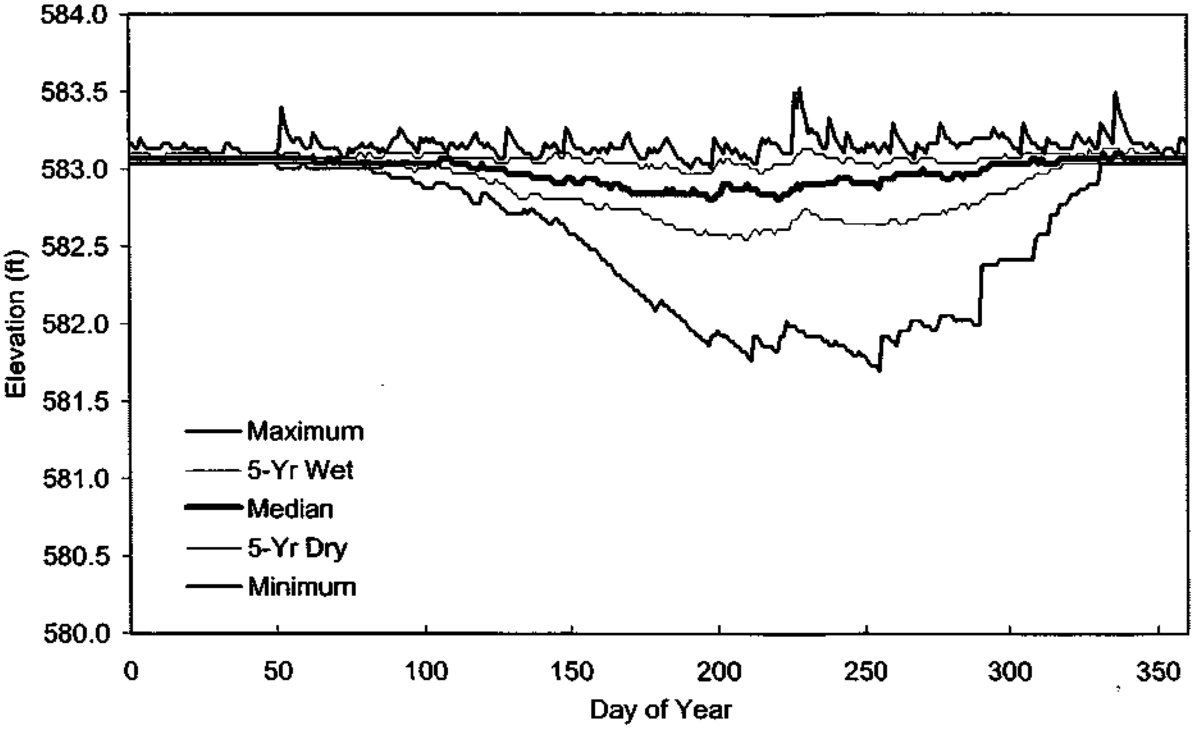

Figure D2. Weir at 583 feet.

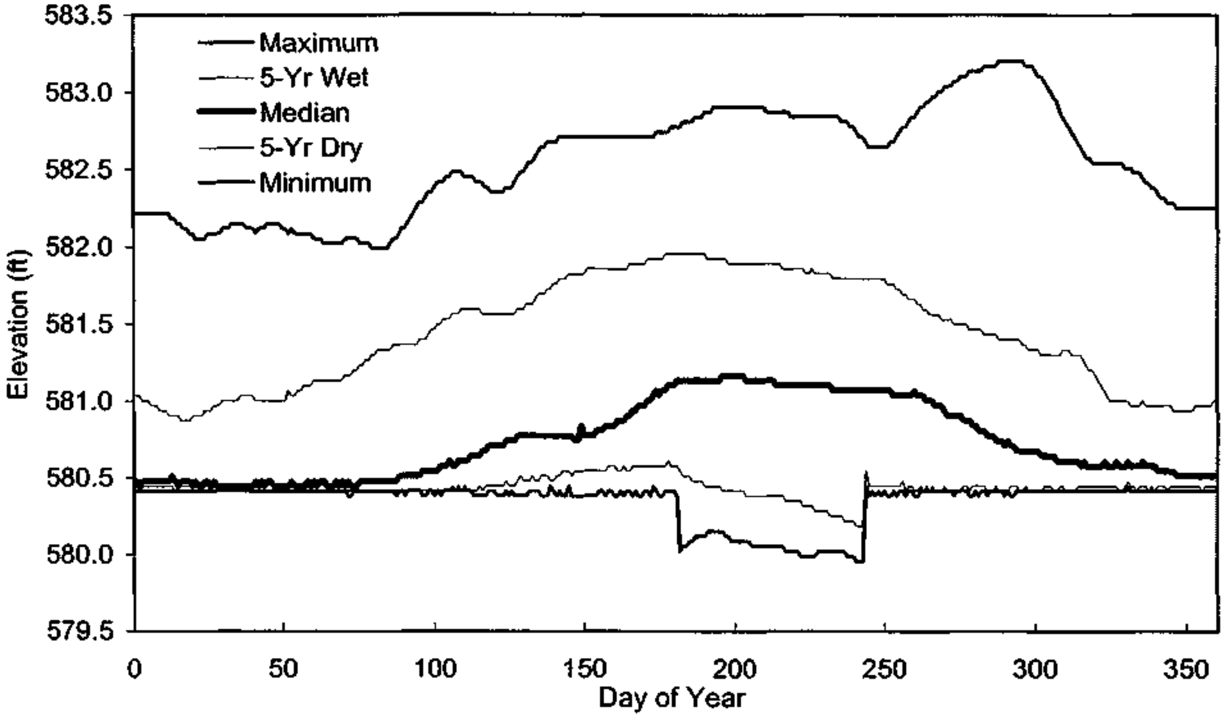

Figure D3. 5-foot adjustable wier at 580 feet dropped to 579 feet in July-August.

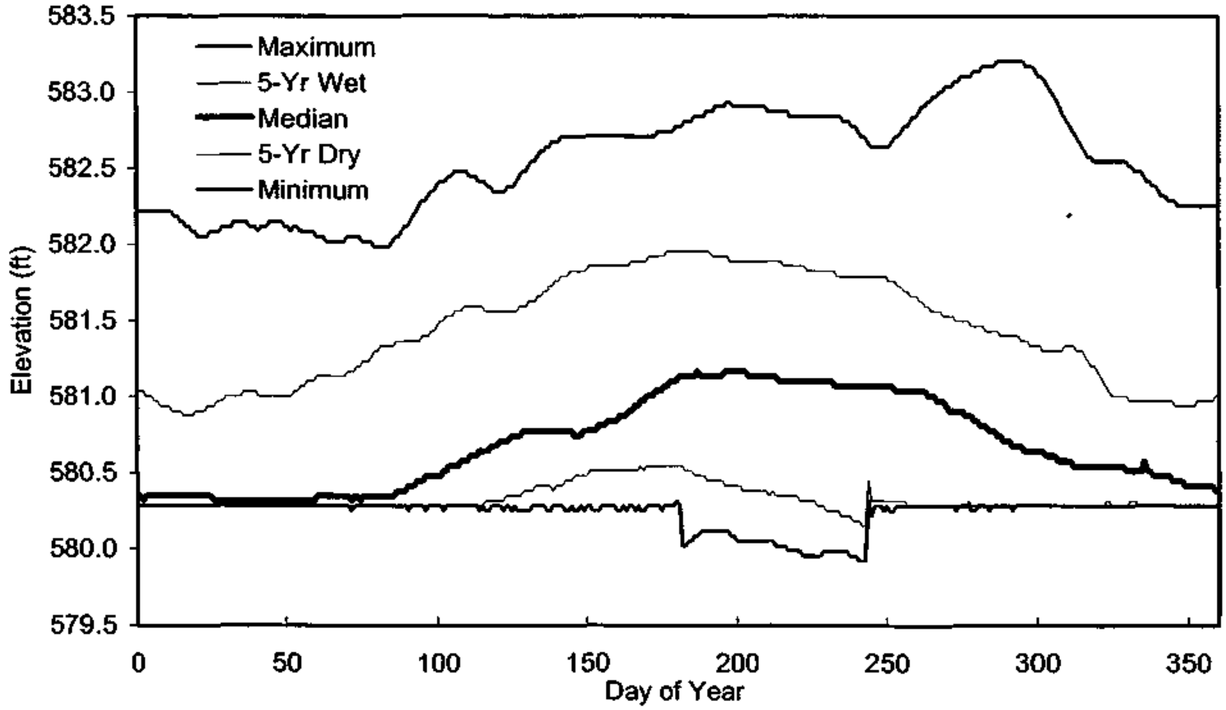

Figure D4. 10-foot adjustable wier at 580 feet dropped to 579 feet in July-August.

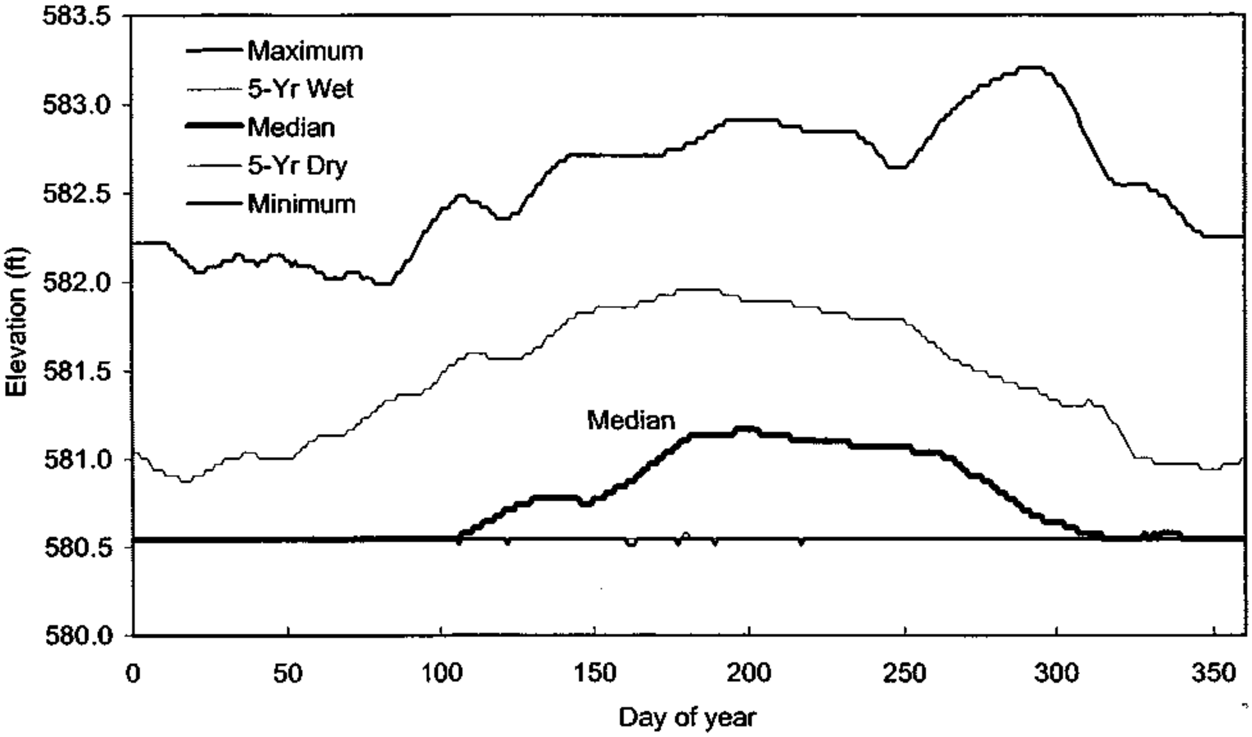

Figure D5. Altered topography.

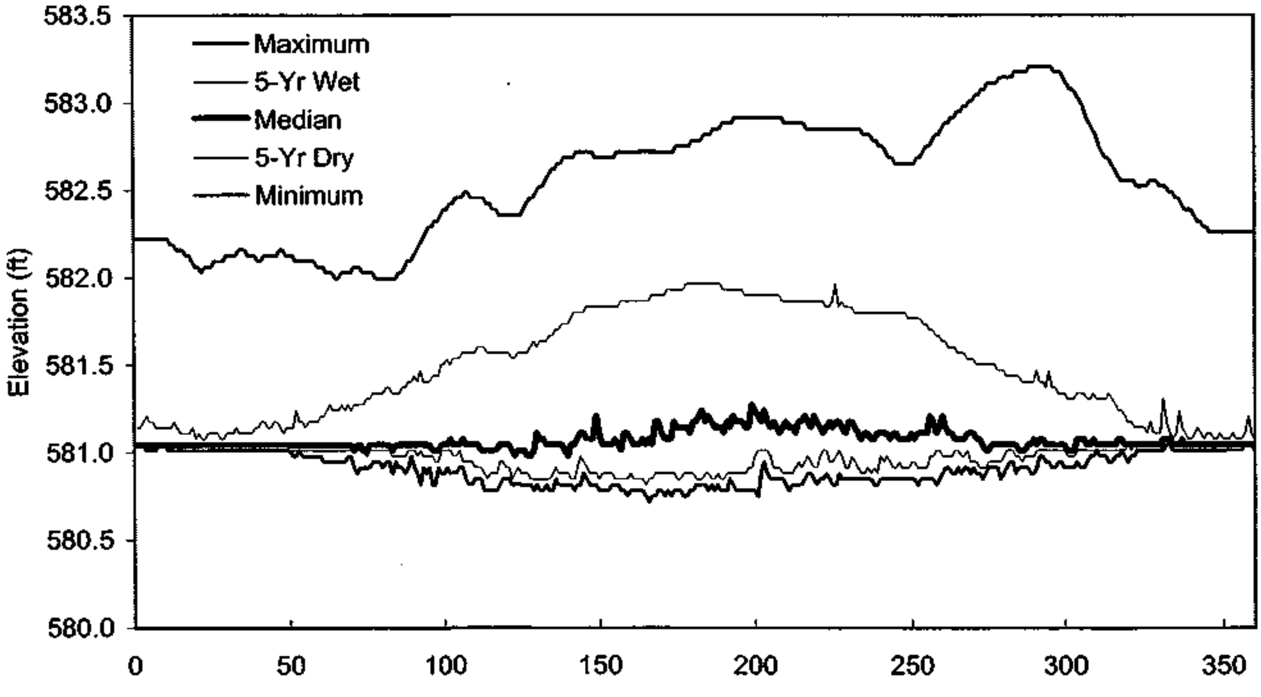

Figure D6. Topographic change and weir placement at 581 feet.

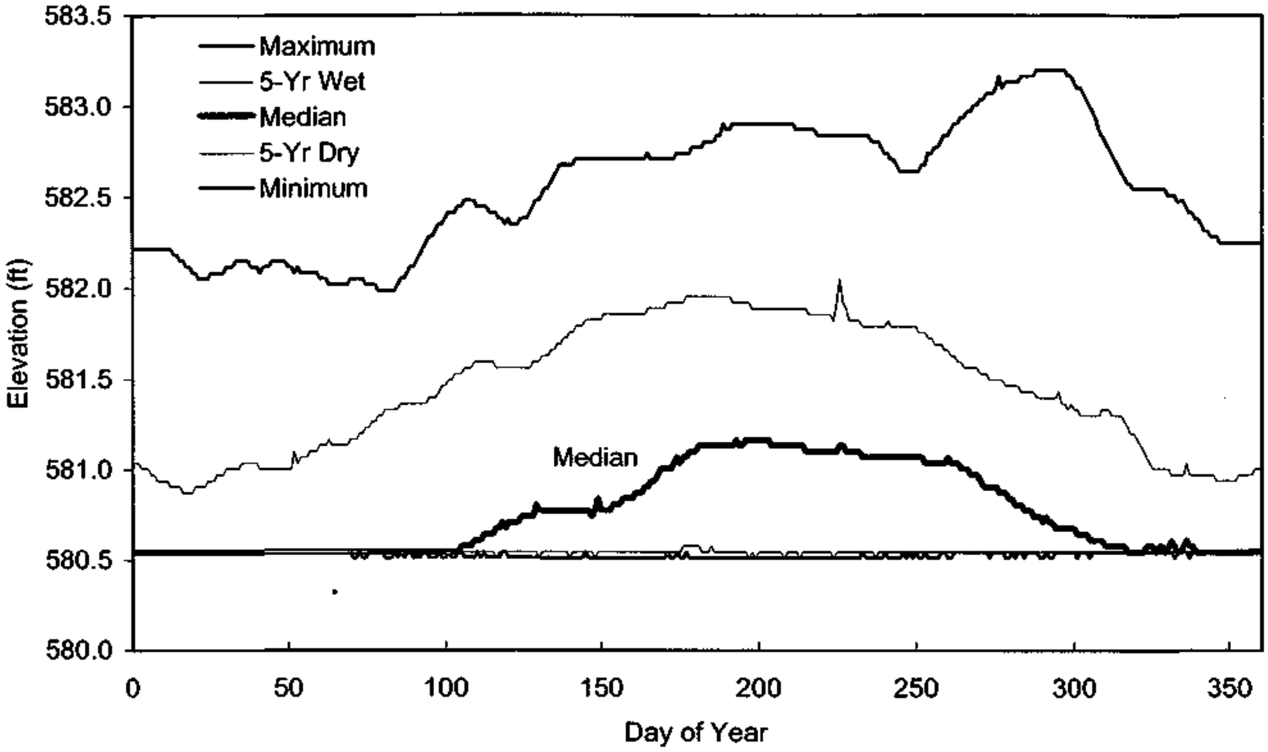

Figure D7. North pool with an open culvert.

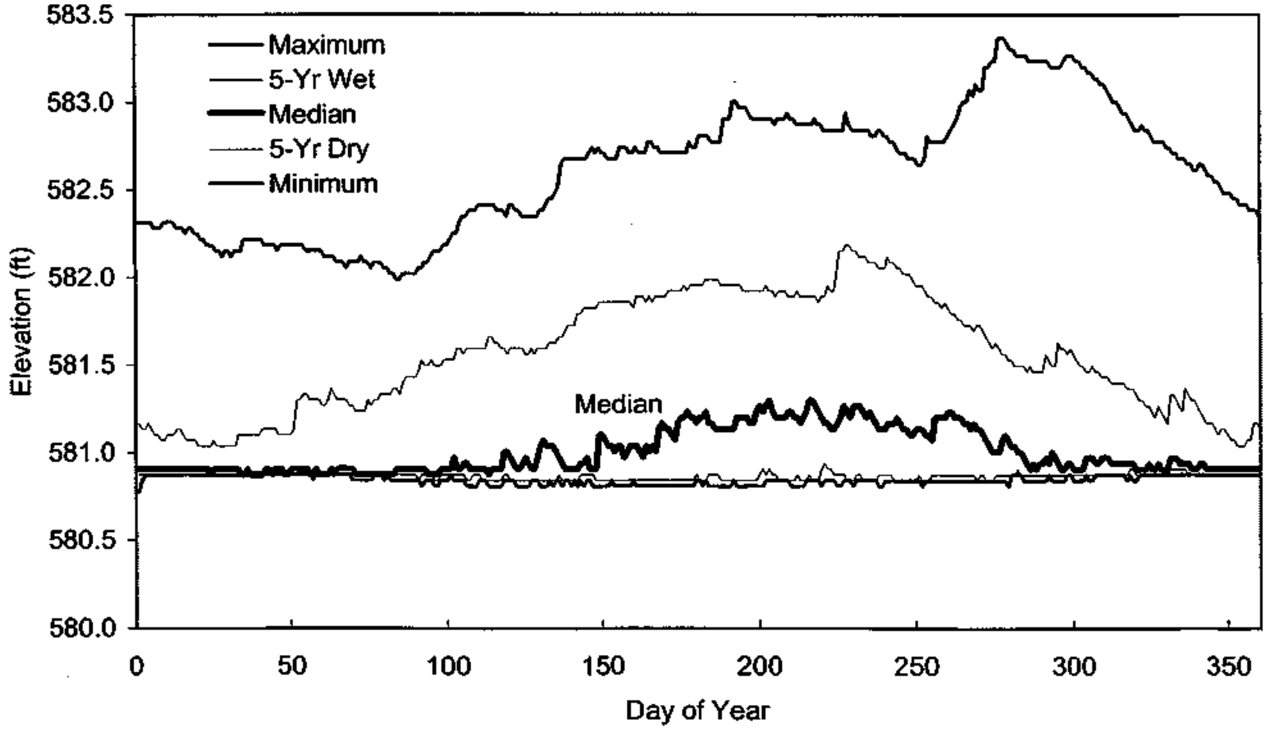

Figure D8. North pool with a constricted culvert.

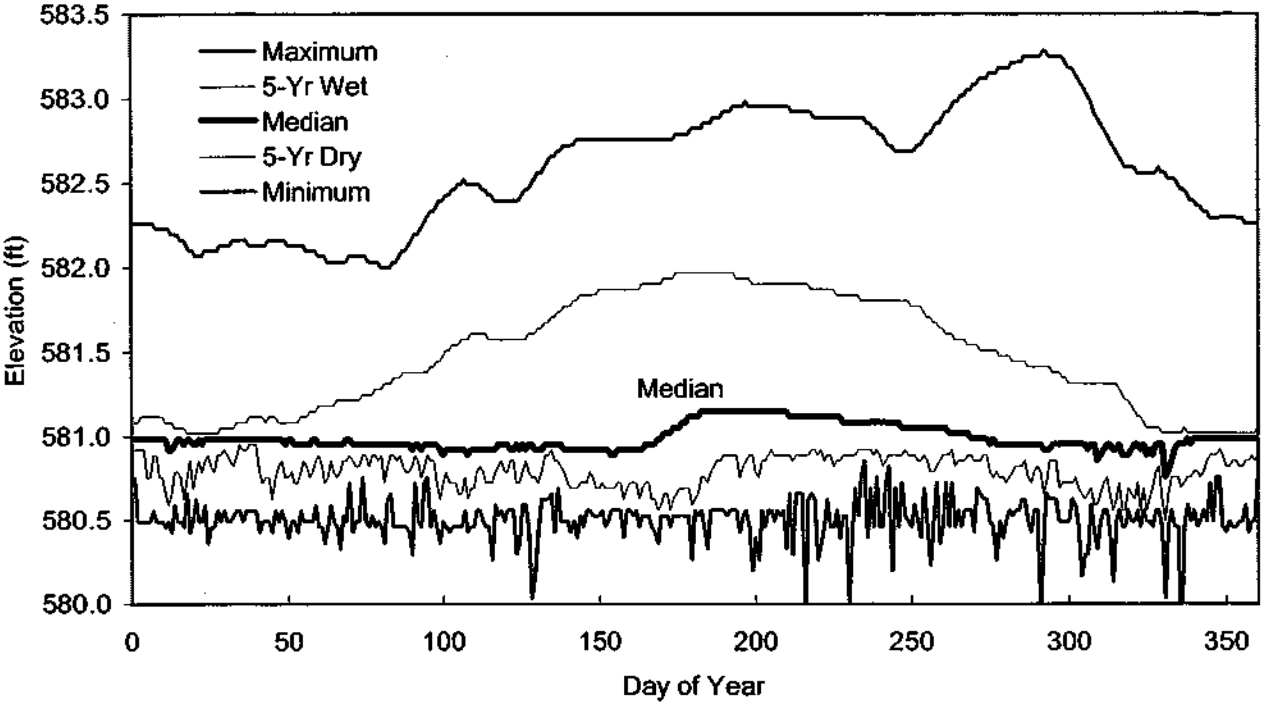

Figure D9. South pool with an open culvert.

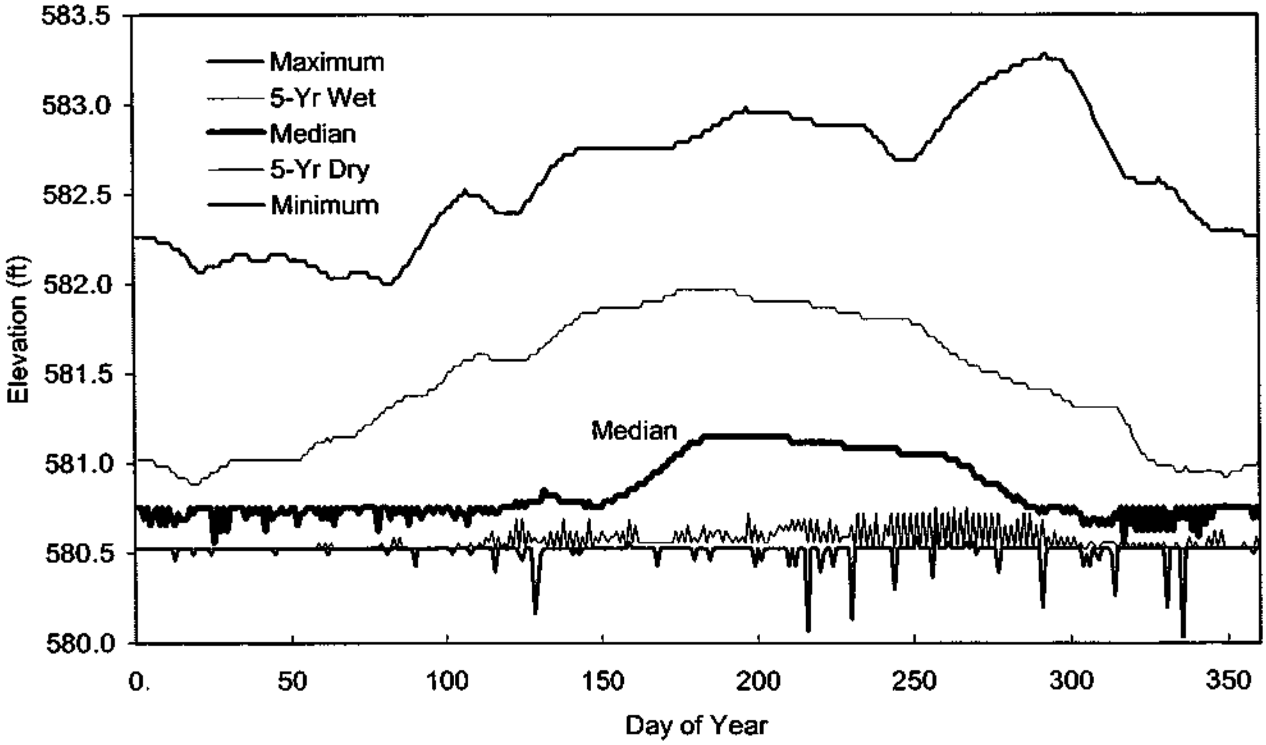

Figure D10. South pool with a constricted culvert.

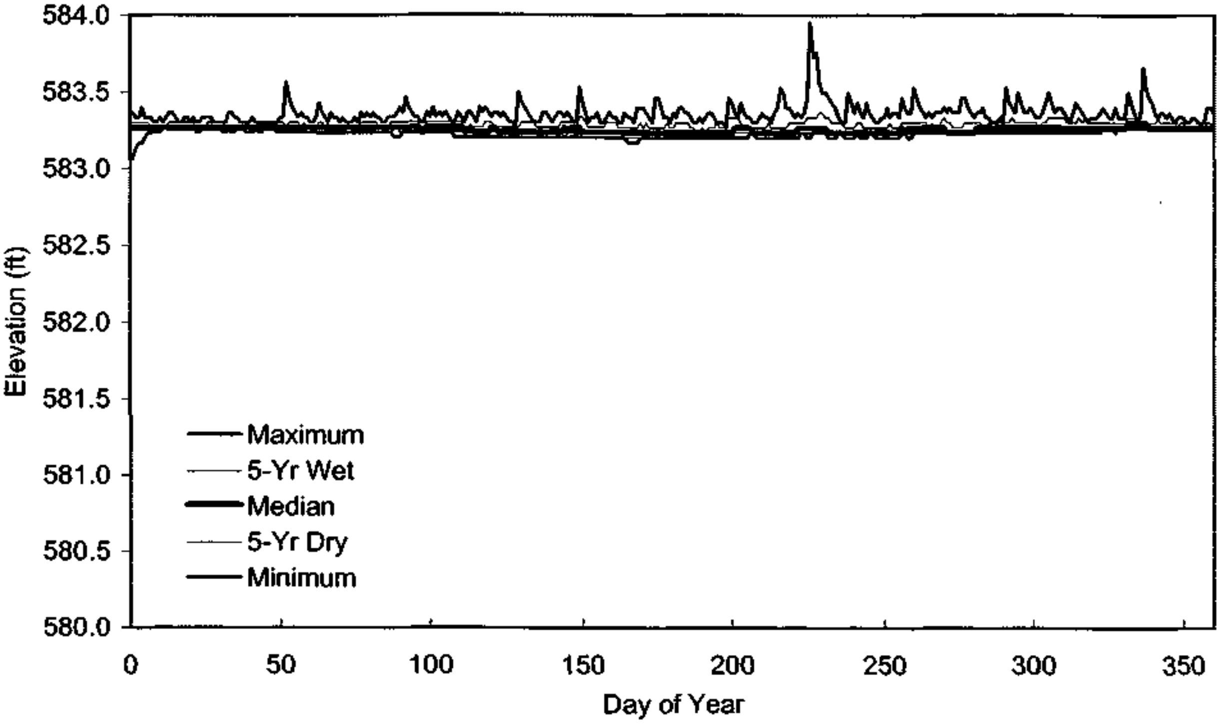

Figure Dl 1. Weir at 583 feet and ~2 cfs SEPA station water added.

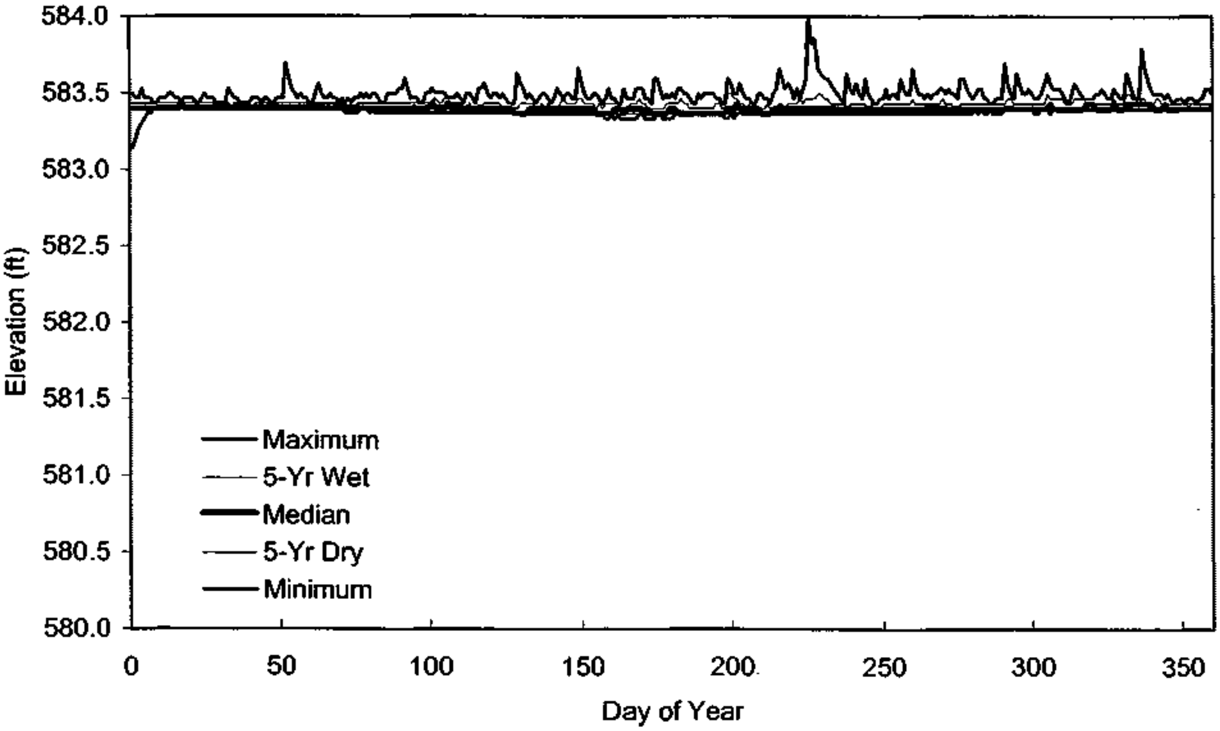

Figure D12. Weir at 583 feet and ~4 cfs SEPA station water added.

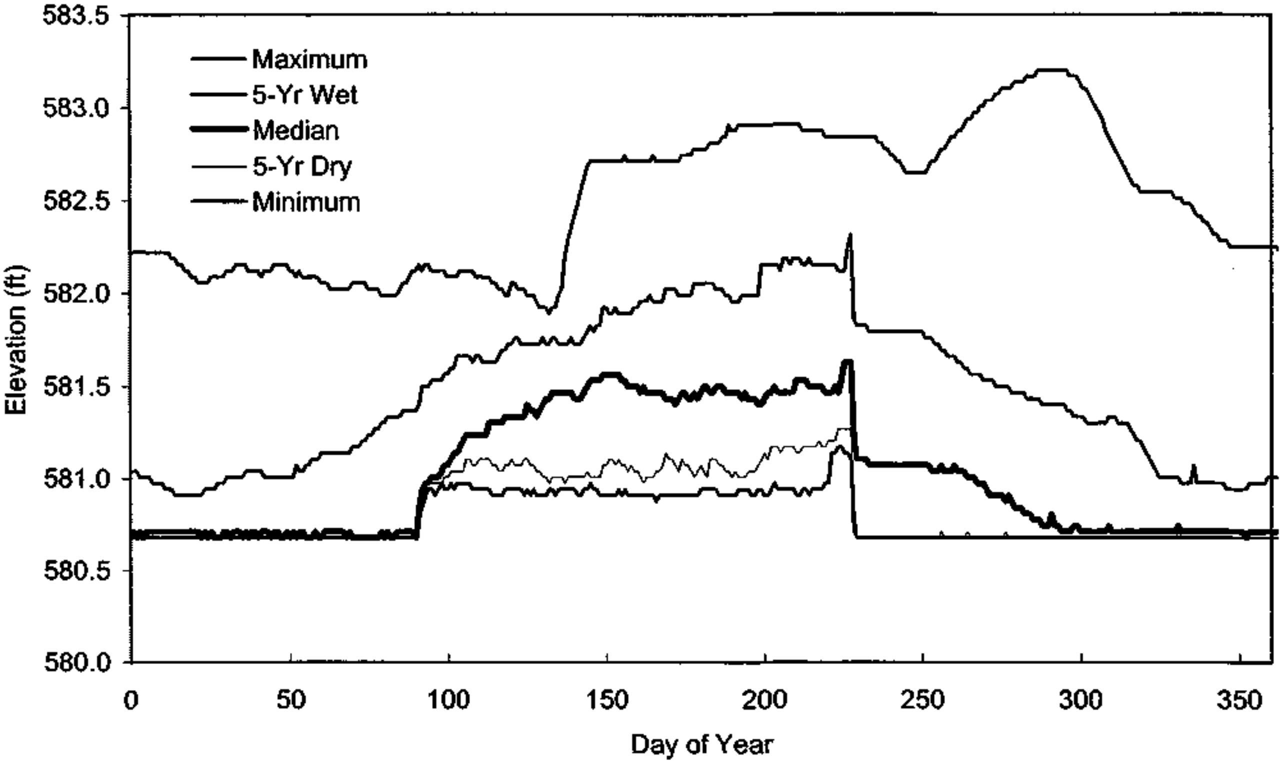

Figure D13. Addition of weir and water for the "ideal" hydroperiod 1.

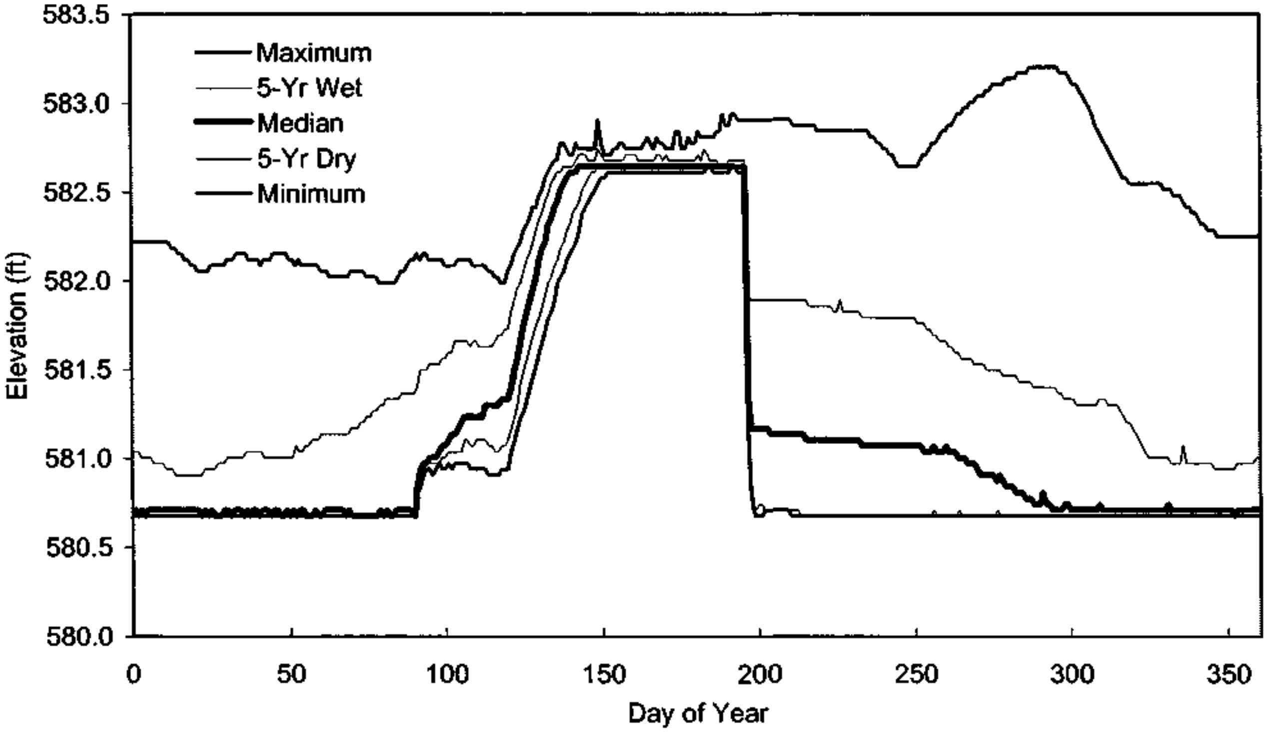

Figure D14. Addition of weir and water for the "ideal" hydroperiod 2.

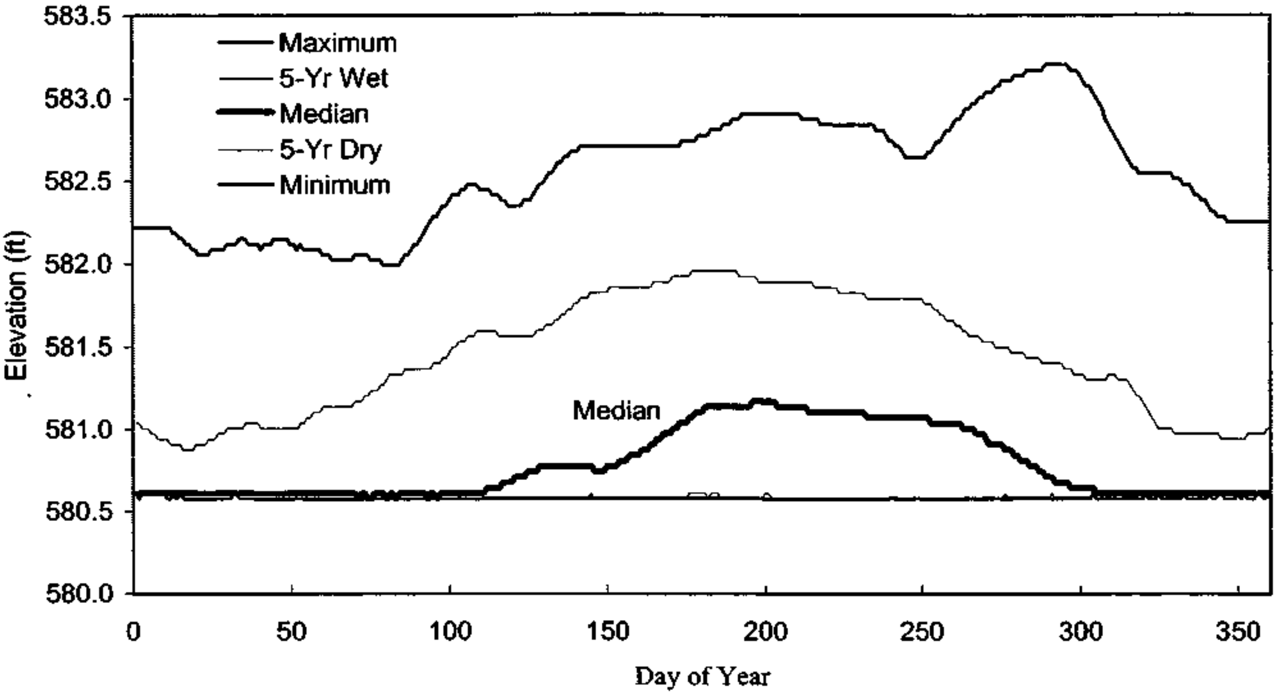

Figure D15. Current conditions with a curve number of 67.5.

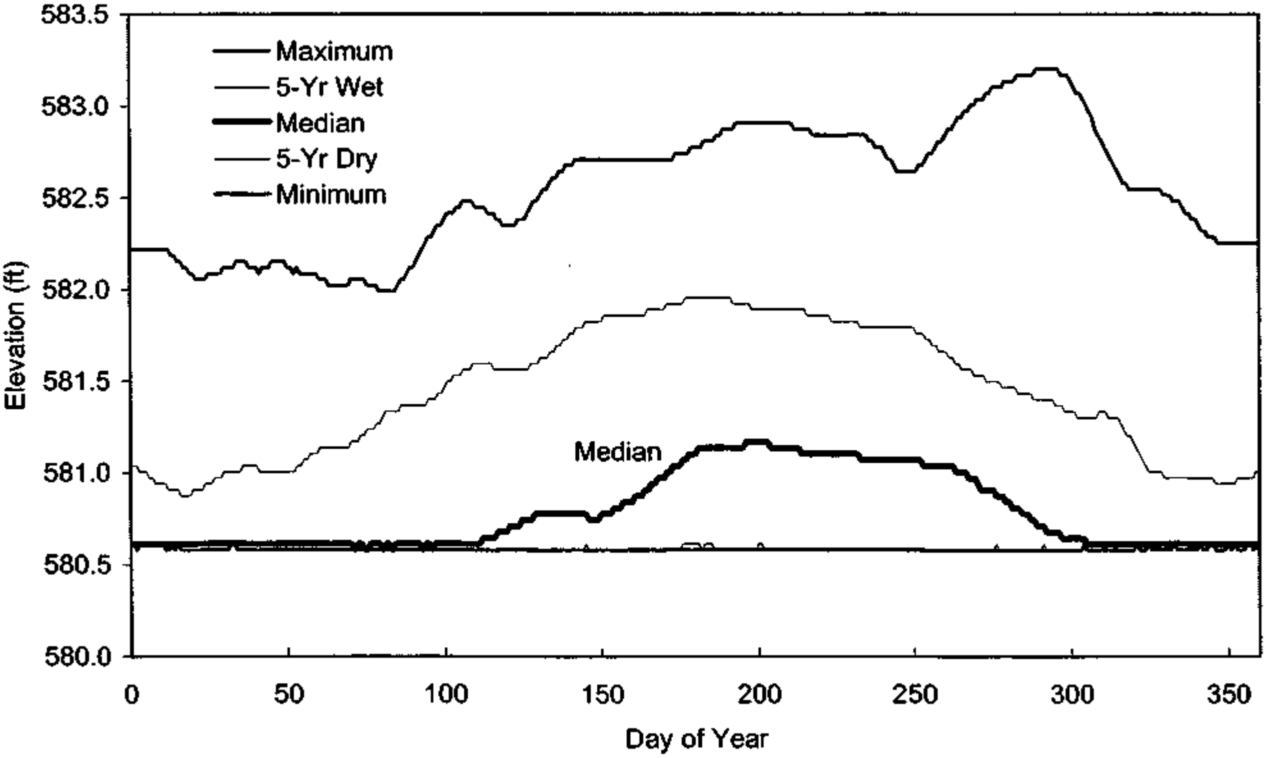

Figure D16. Current conditions with a curve number of 82.5.

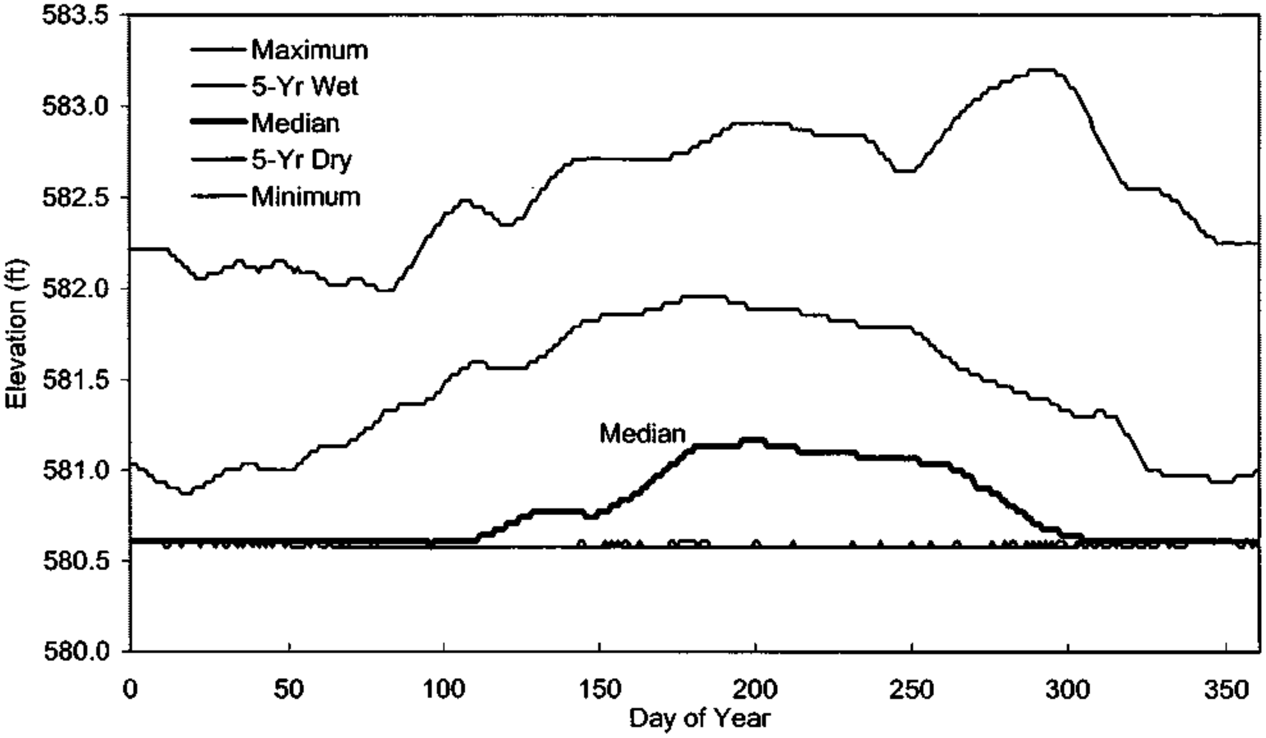

Figure D17. Current conditions with seepage inflow of 37,000 ft^3/day.

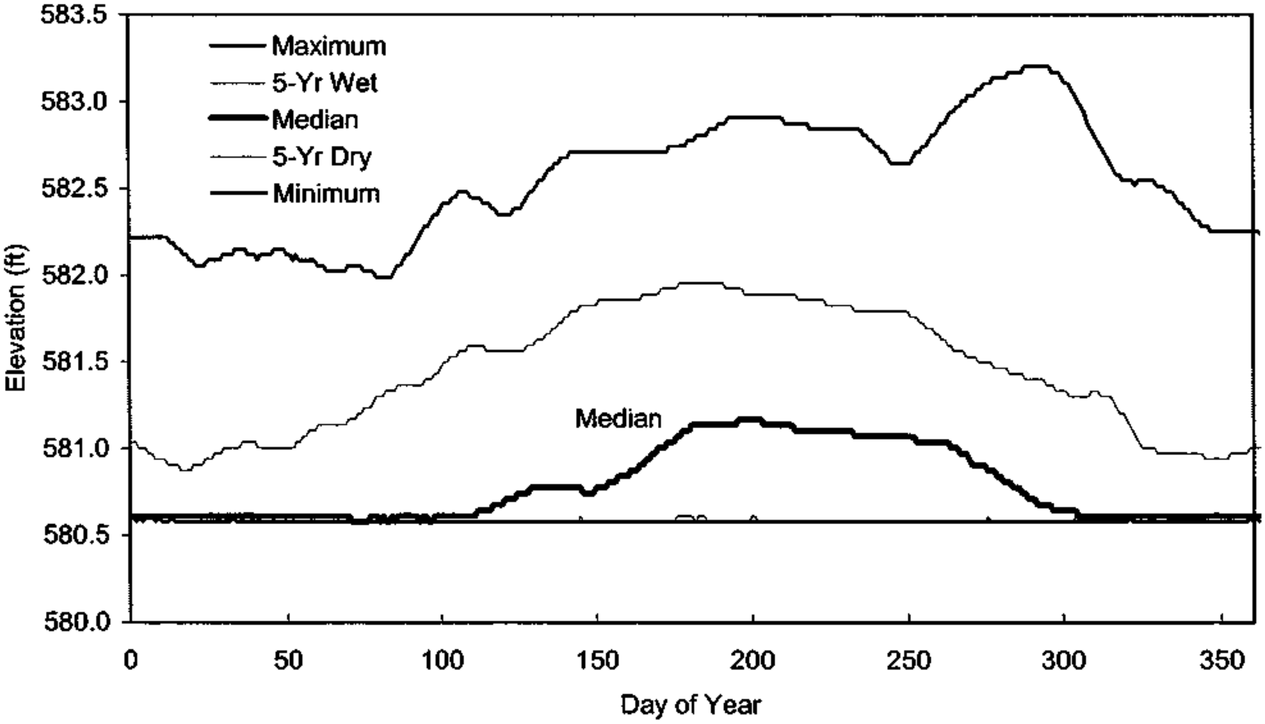

Figure D18. Current conditions with seepage inflow of 13,900 ft^3/day.

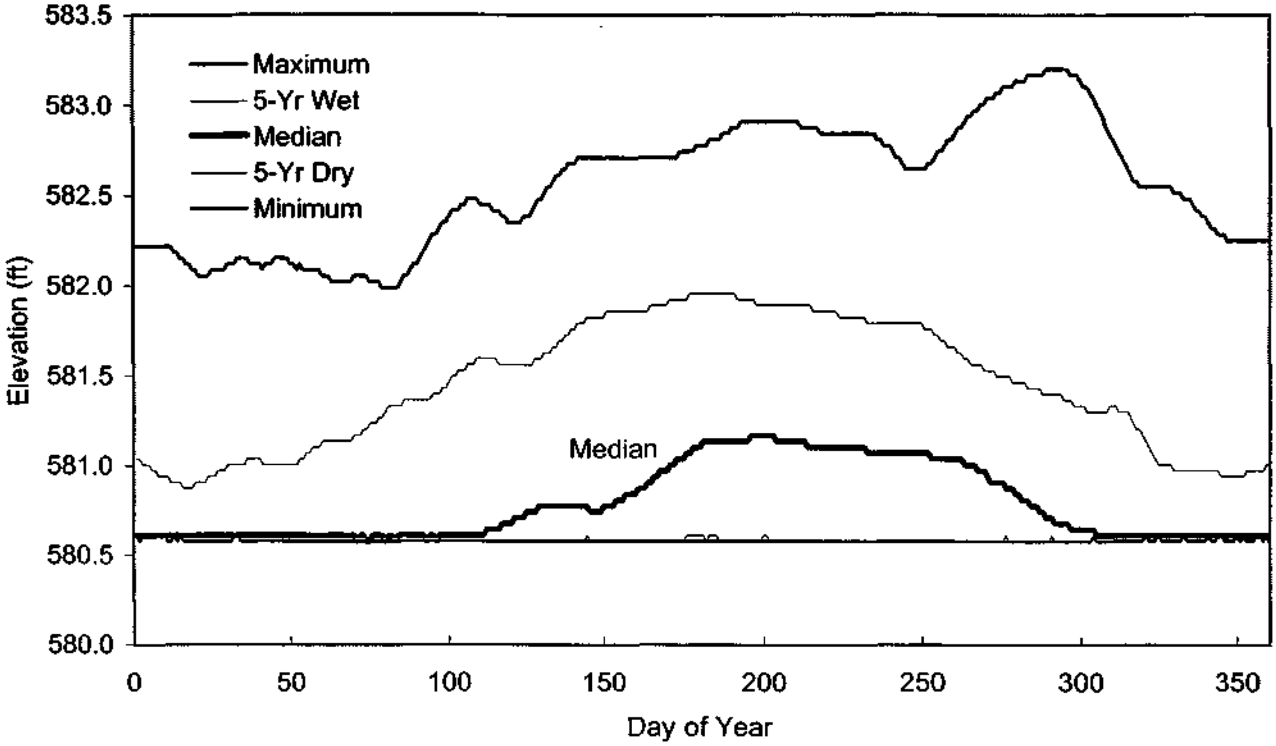

Figure D19. Current conditions with hydraulic conductivity of 0.4 in./hr.

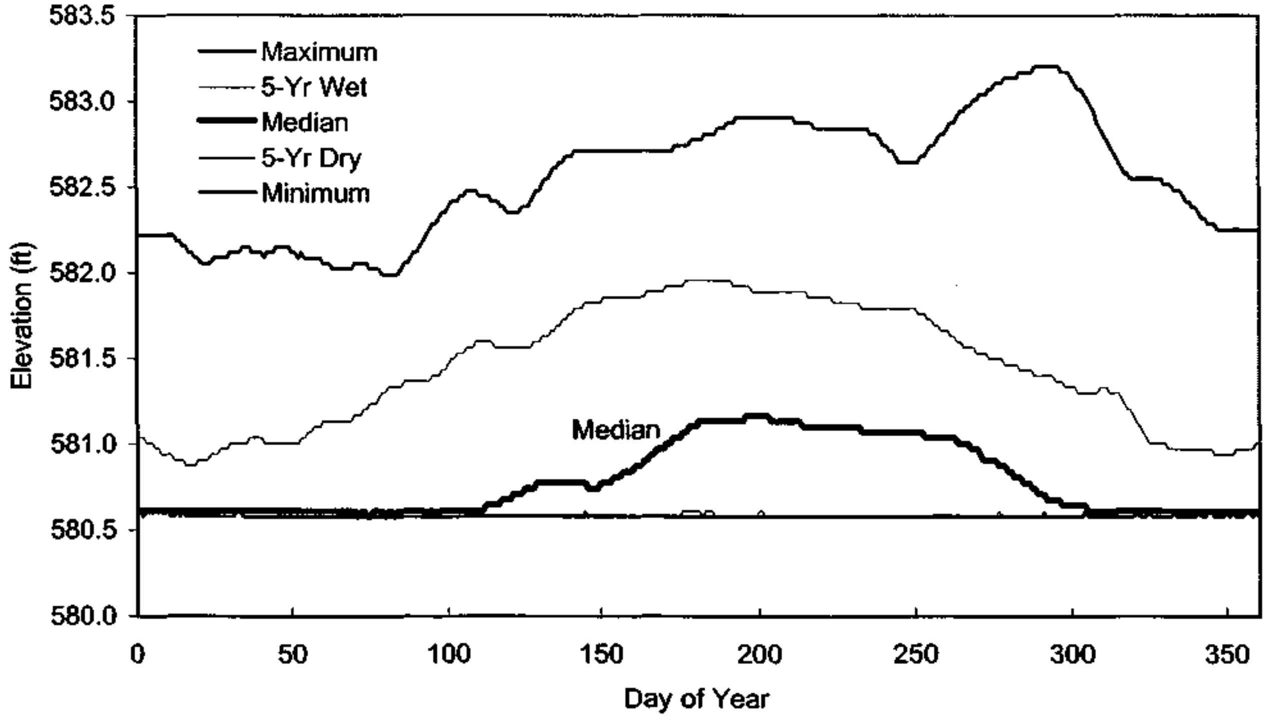

Figure D20. Current conditions with hydraulic conductivity of 2.9 in./hr.

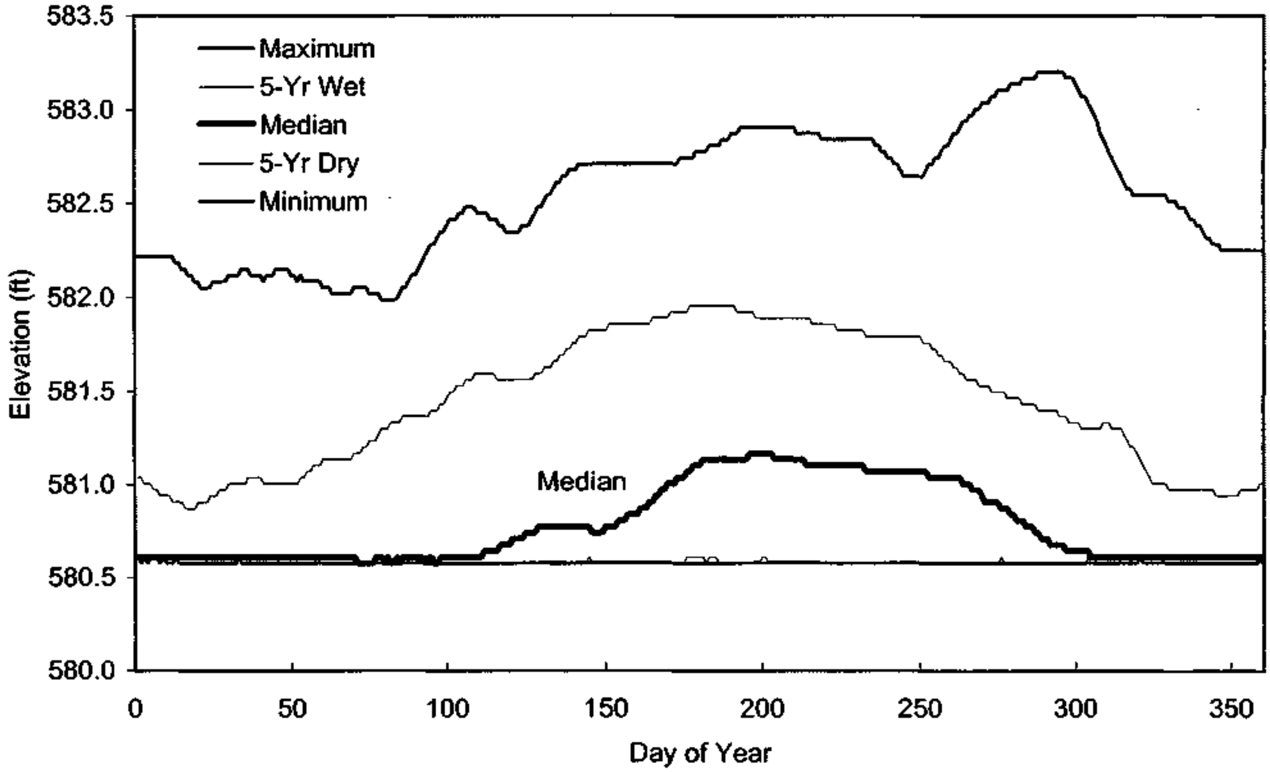

Figure D21. Current conditions with watershed of 30 acres.

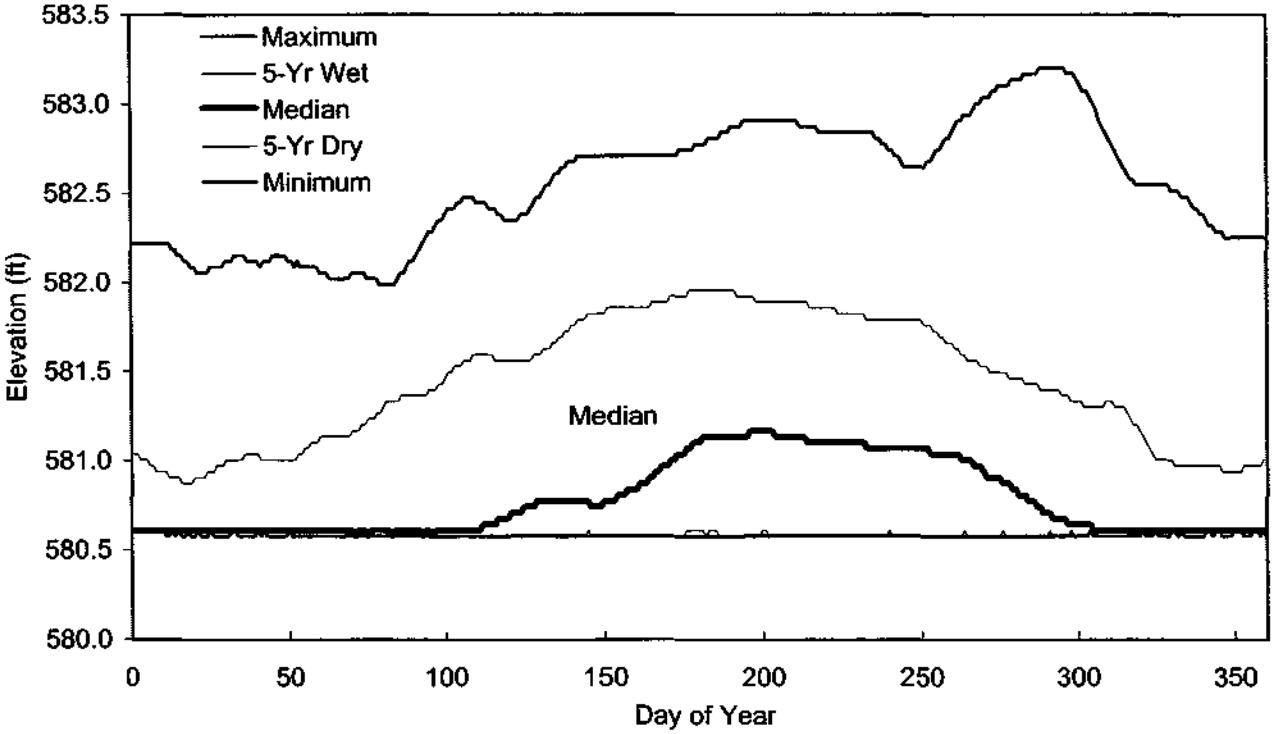

Figure D22. Current conditions with watershed of 50 acres.

Appendix E. Predicted Vegetation at Incremental Areas

El Current conditions.
E2 Weir at 583 feet.
E3 Weir at 583 feet and ~2 cfs of SEPA station water added.
E4 5-foot adjustable weir at 580 feet dropped to 579 feet in July-August.
E5 10-foot adjustable weir at 580 feet dropped to 579 feet in July-August.
E6 Altered topography.
E7 Topographic change and weir placement at 581 feet.
E8 North pool with an open culvert.
E9 North pool with a constricted culvert.
E10 South pool with an open culvert.
E11 South pool with a constricted culvert.
El 2 Addition of weir and water for the "ideal" hydroperiod 1.
El 3 Addition of weir and water for the "ideal" hydroperiod 2.

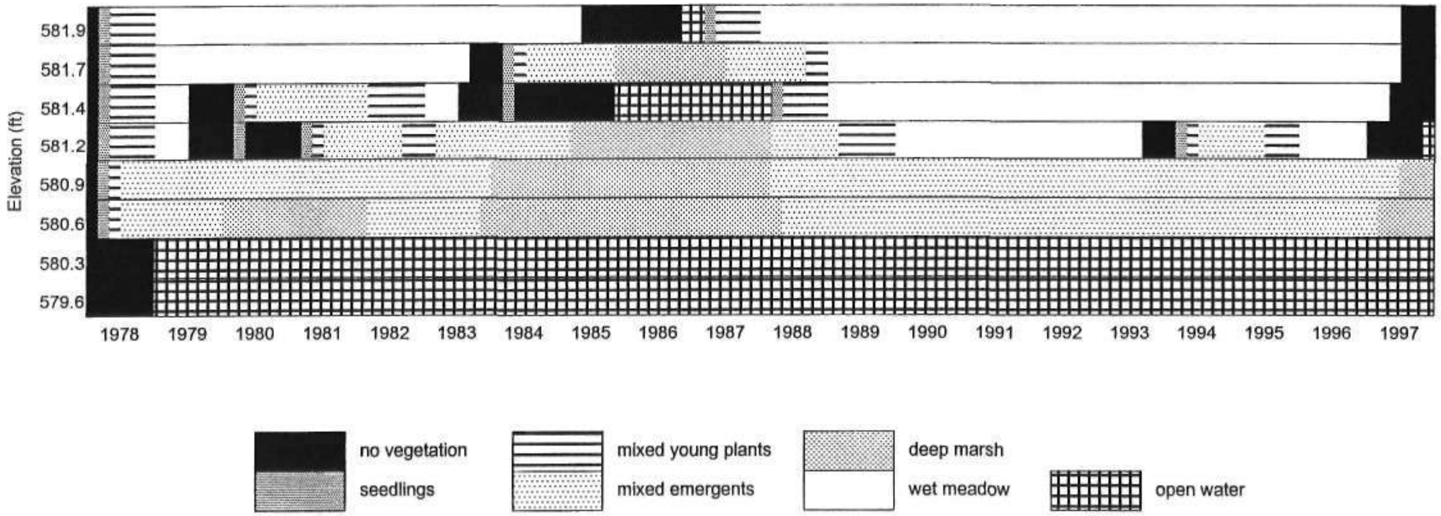

Figure E1. Current conditions.

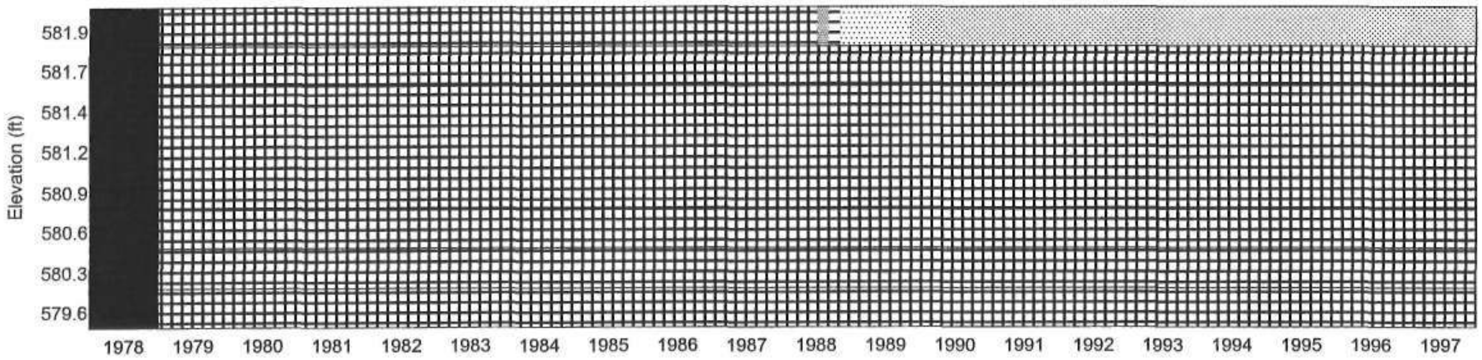

Figure E2. Weir at 583 feet.

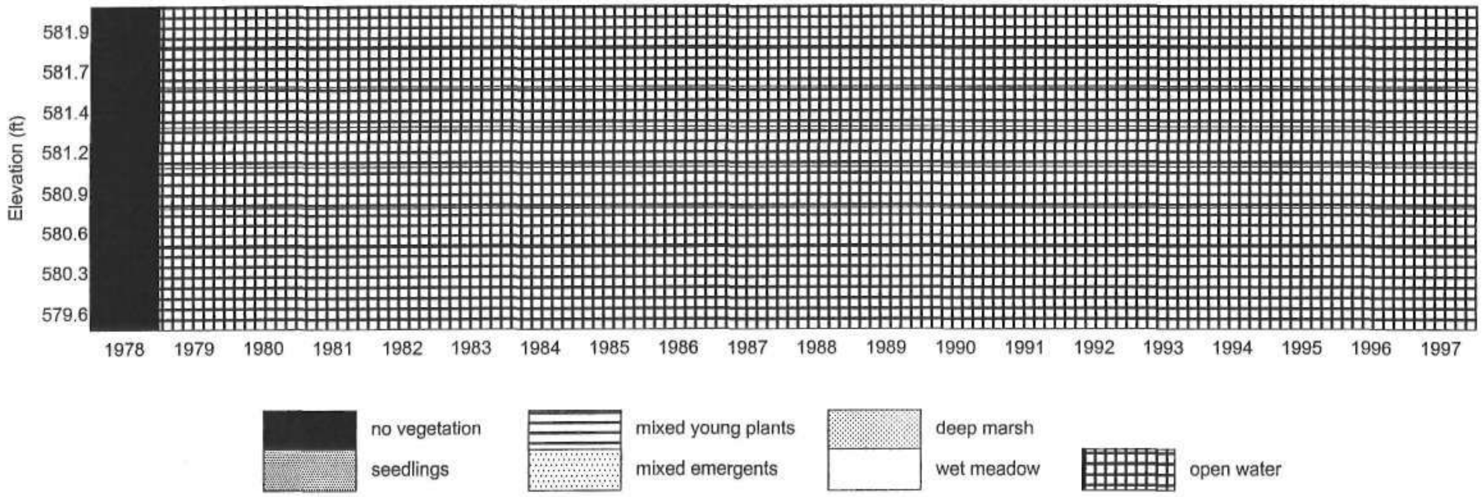

Figure E3. Weir at 583 feet and ~2 cfs of SEPA station water added.

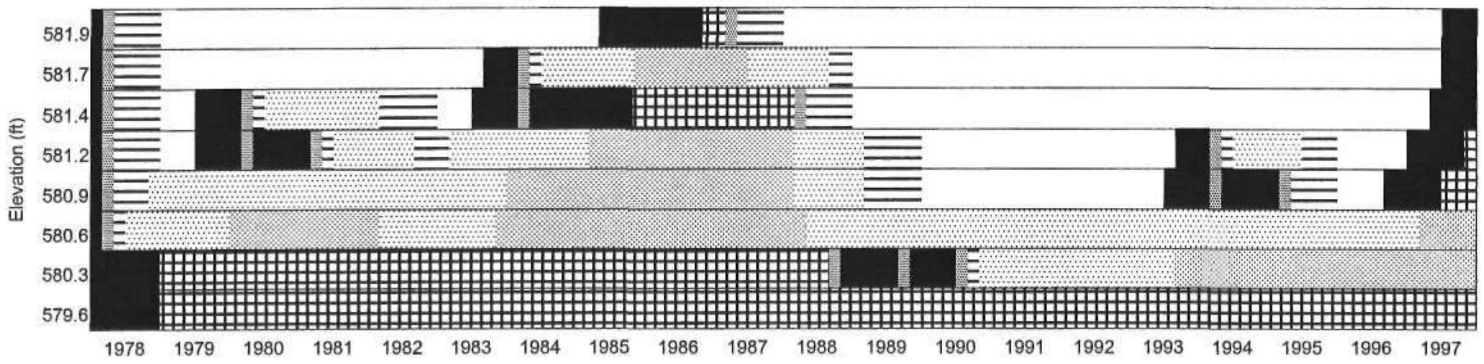

Figure E4. 5-foot adjustable weir at 580 feet dropped to 579 feet in July-August.

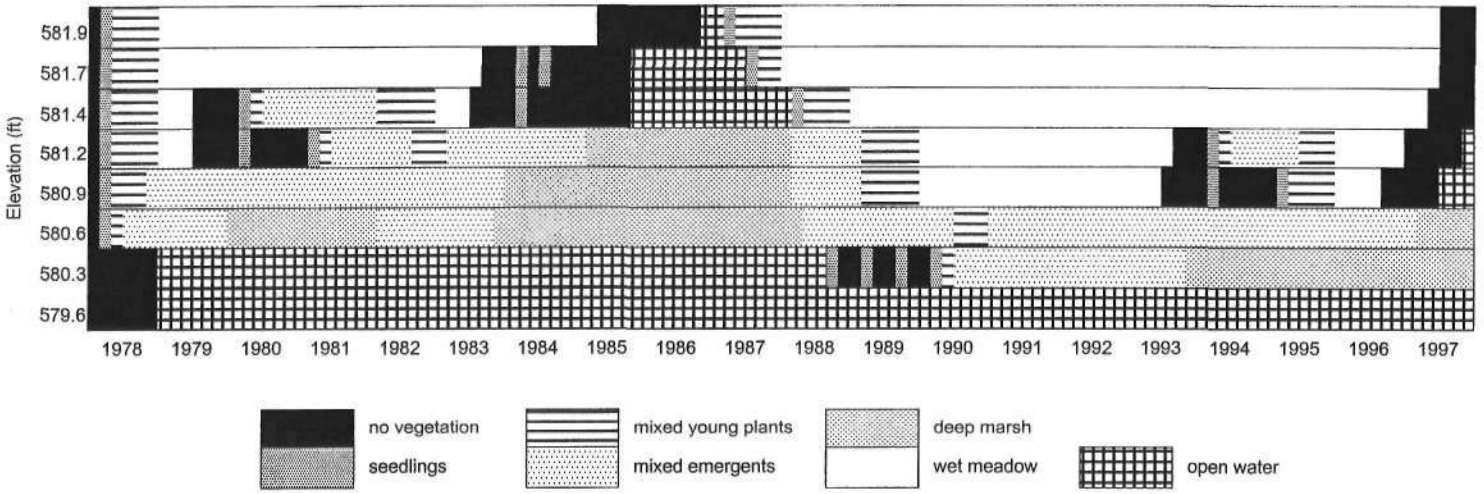

Figure E5. 10-foot adjustable weir at 580 feet dropped to 579 feet in July-August.

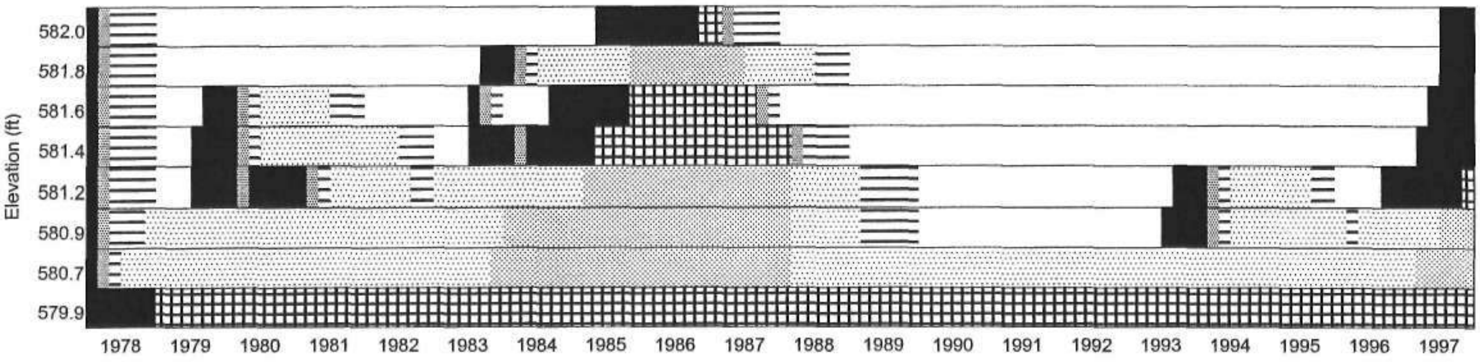

Figure E6. Altered topography.

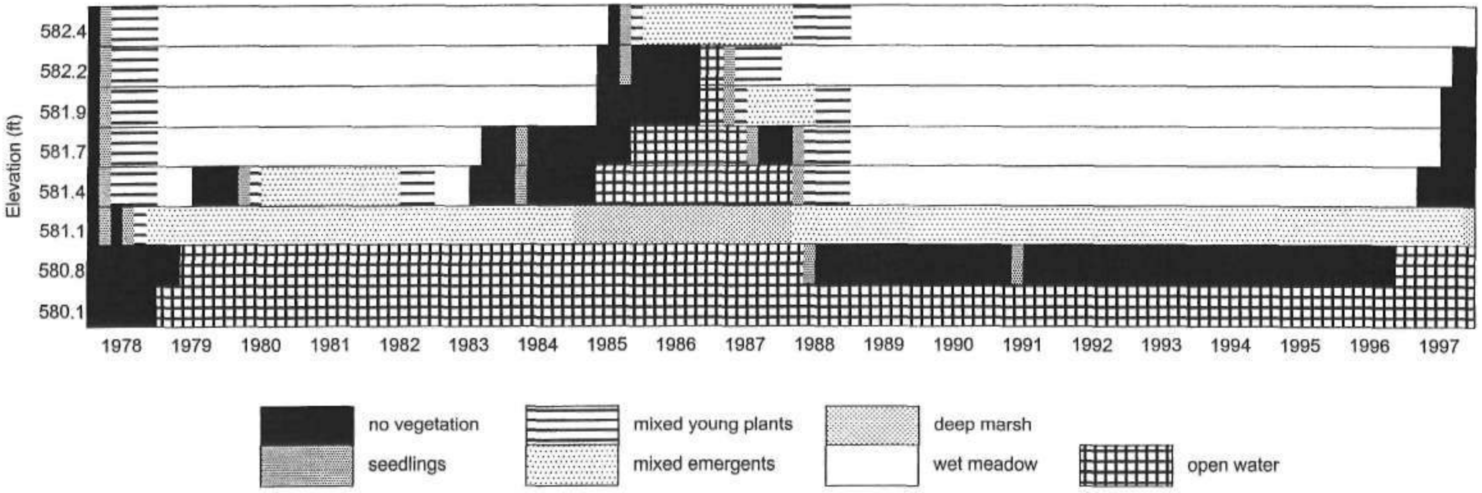

Figure E7. Topographic change and weir placement at 581 feet.

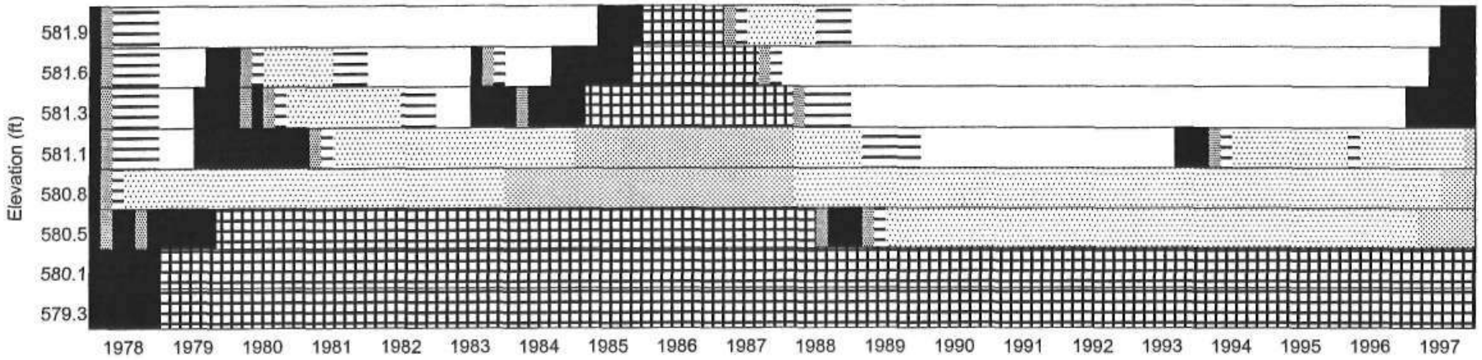

Figure E8. North pool with an open culvert.

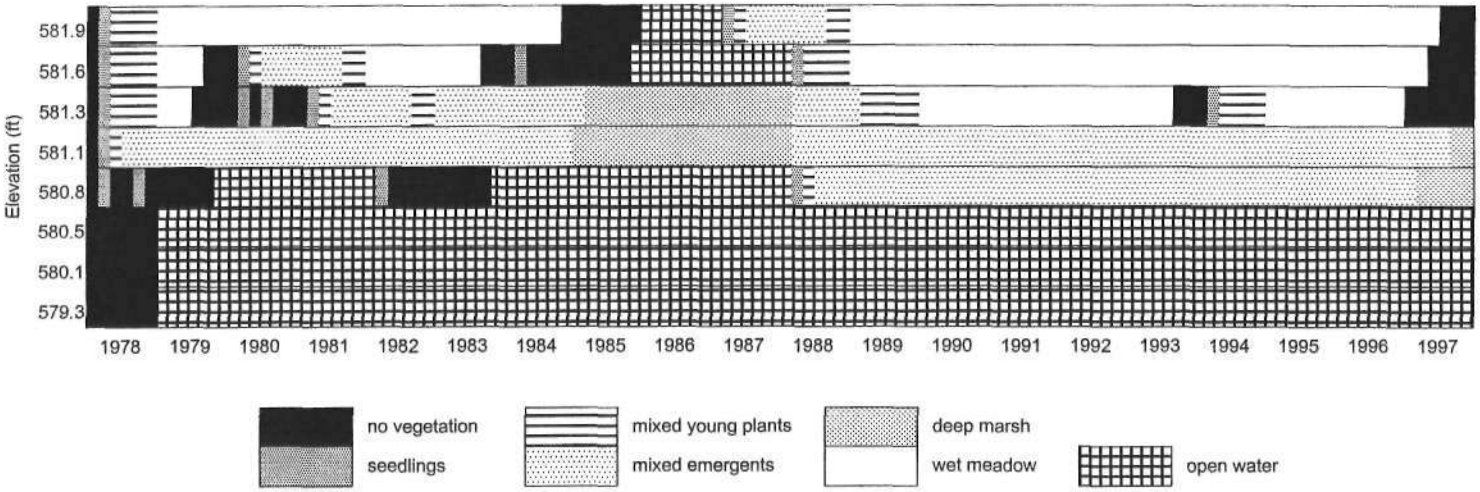

Figure E9. North pool with a constricted culvert.

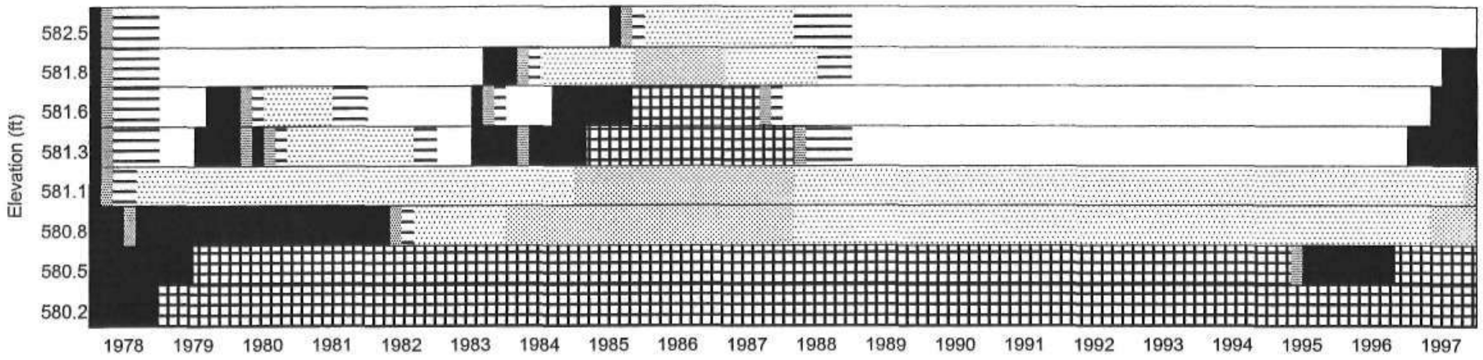

Figure E10. South pool with an open culvert.

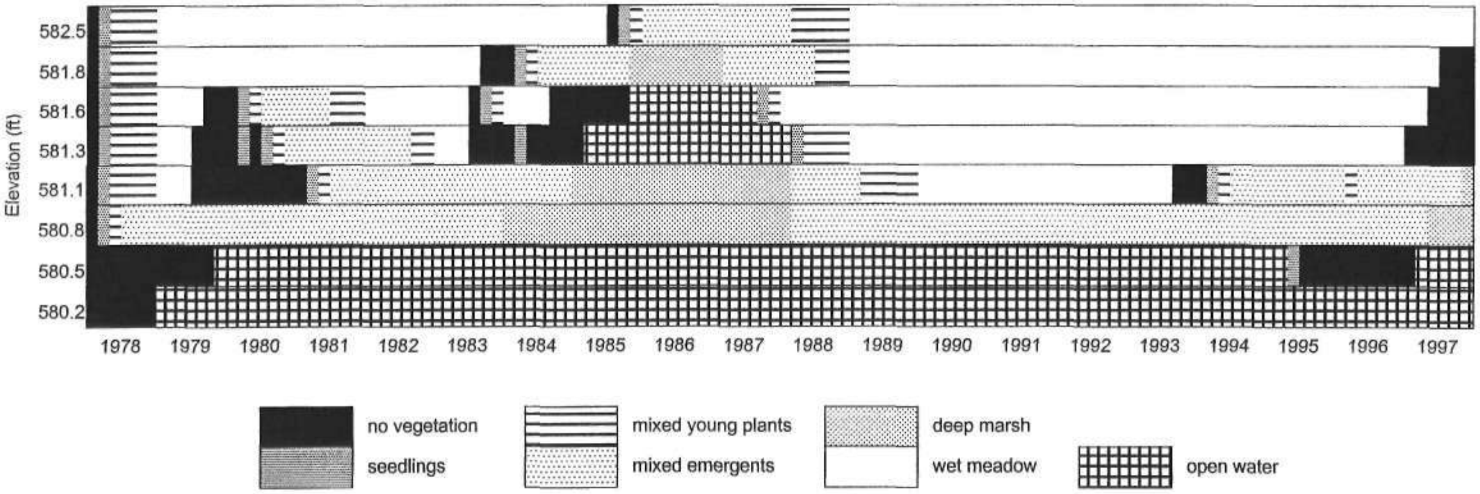

Figure E11. South pool with a constricted culvert.

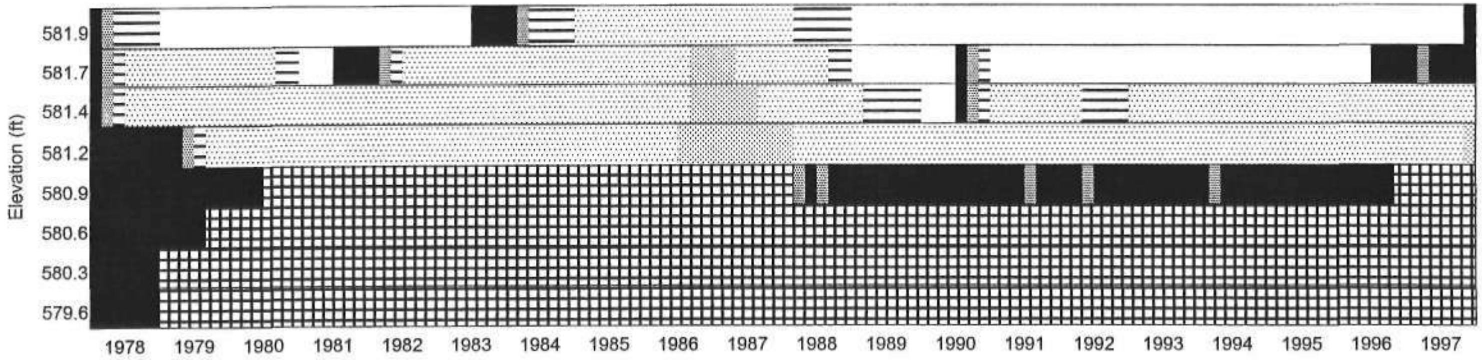

Figure E12. Addition of weir and water for the "ideal" hydroperiod 1.

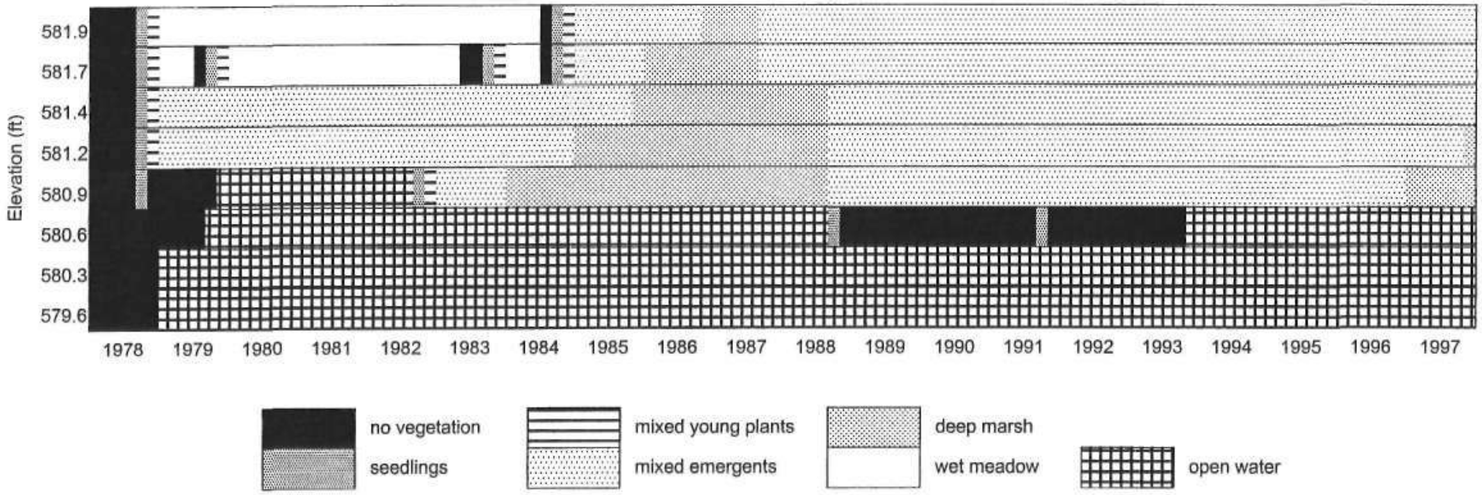

Figure E13. Addition of weir and water for the "ideal" hydroperiod 2.

Appendix F. Retention Time Distributions

Fl Current conditions.
F2 Current conditions with ~2 cfs SEPA station water added.
F3 Current conditions with ~4 cfs SEPA water added.
F4 Weir at 583 feet.
F5 Weir at 583 feet with ~2 cfs SEPA station water added.
F6 Weir at 583 feet with ~4 cfs SEPA station water added.
F7 5-foot adjustable weir at 580 feet dropped to 579 feet in July-August.
F8 10-foot adjustable weir at 580 feet dropped to 579 feet in July-August.
F9 10-foot adjustable weir at 580 feet dropped to 579 feet in July-August with ~2 cfs SEPA station water added.
F10 10-foot adjustable weir at 580 feet dropped to 579 feet in July-August with ~4 cfs SEPA station water added.
F11 Altered topography.
F12 Topographic change and weir placement at 581 feet.
F13 North pool with an open culvert.
F14 North pool with a constricted culvert.
F15 South pool with an open culvert.
F16 South pool with a constricted culvert.
F17 Addition of weir and water for the "ideal" hydroperiod 1.
F18 Addition of weir and water for the "ideal" hydroperiod 2.

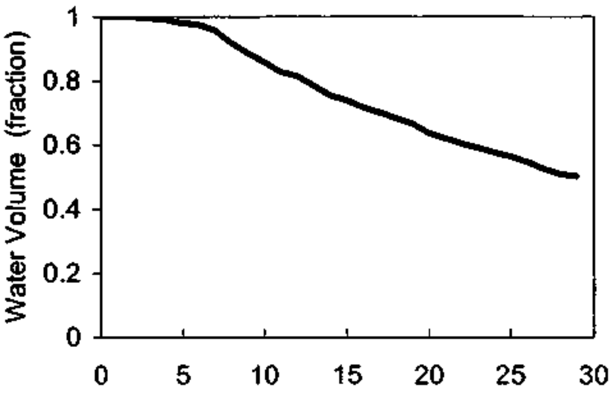

Figure F1. Current conditions.

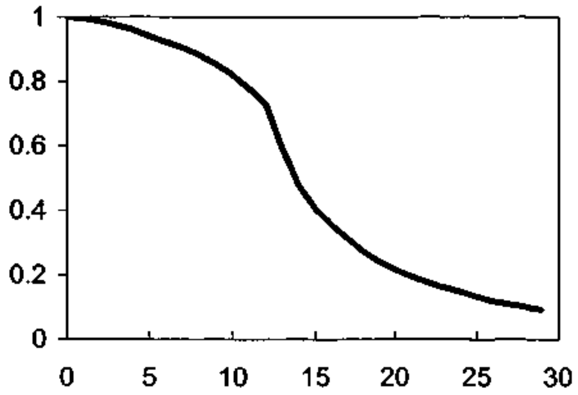

Figure F2. Current conditions with ~2 cfs SEPA station water added.

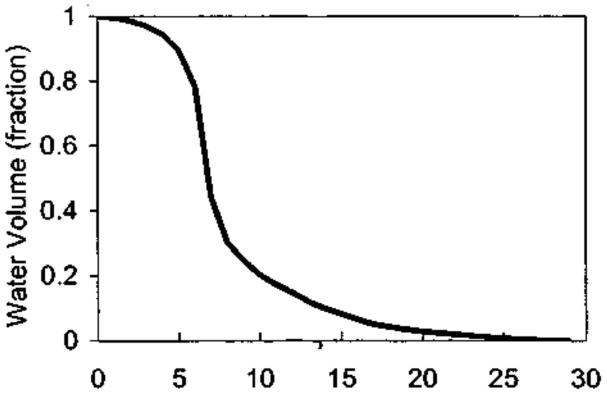

Figure F3. Current conditions with ~4 cfs SEPA station water added.

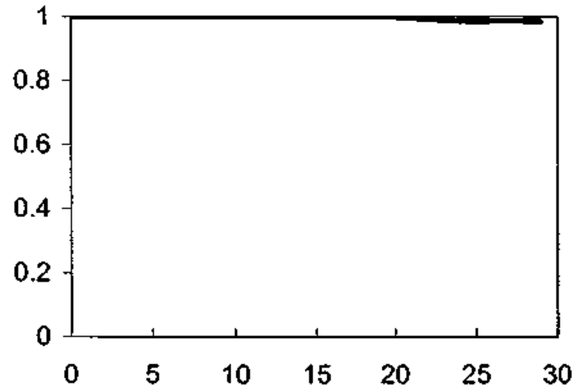

Figure F4. Weir at 583 feet.

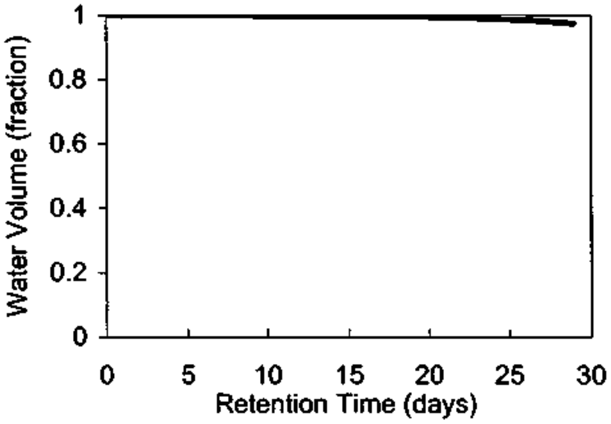

Figure F5. Weir at 583 feet with ~2 cfs SEPA station water added.

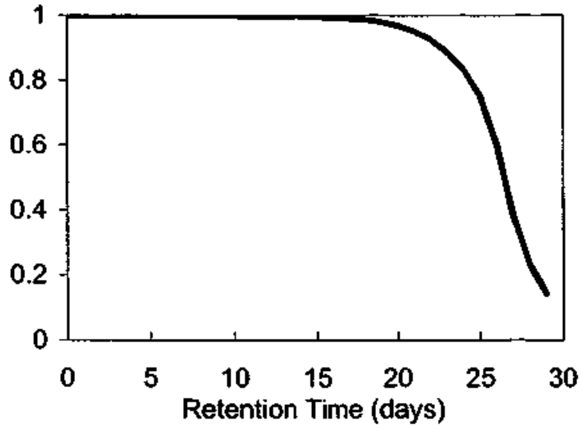

Figure F6. Weir at 583 feet with ~4 cfs SEPA station water added.

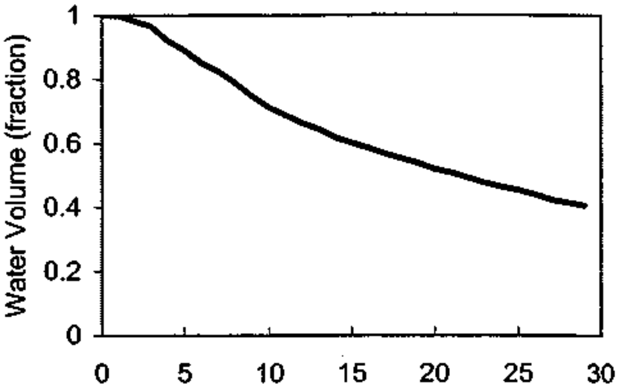

Figure F7. 5-foot adjustable weir at 580 feet dropped to 579 feet in July-August.

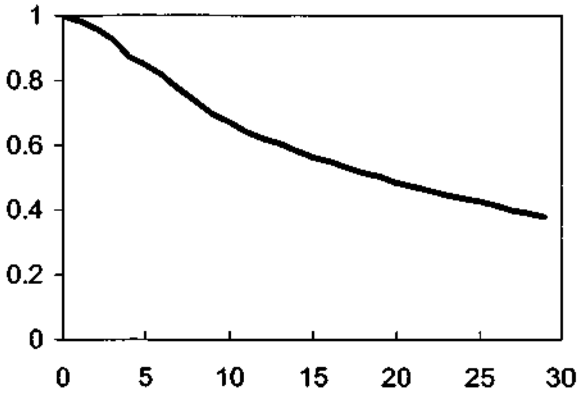

Figure F8. 10-foot adjustable weir at 580 feet dropped to 579 feet in July-August.

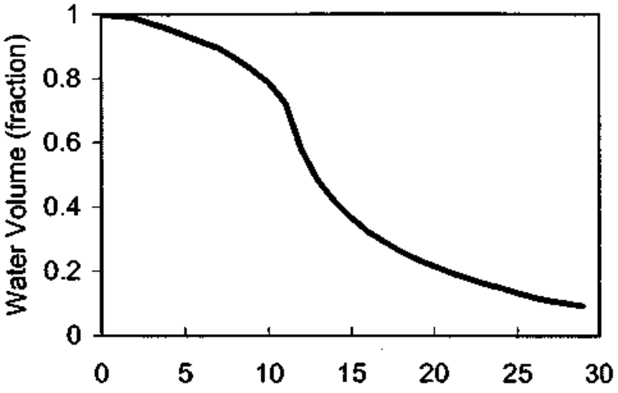

Figure F9. 10-foot adjustable weir at 580 feet dropped to 579 feet in July-August with ~2 cfs SEPA station water added.

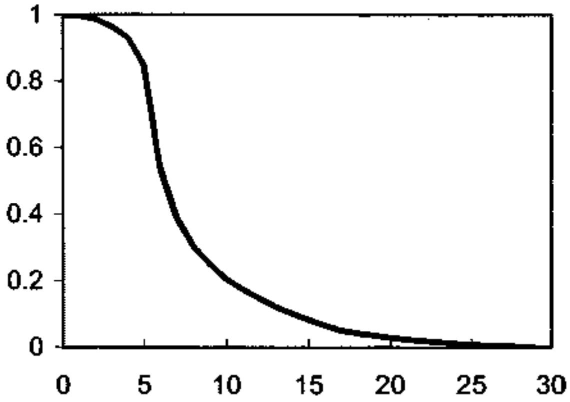

Figure F10. 10-foot adjustable weir at 580 feet dropped to 579 feet in July-Aug with ~4 cfs SEPA station water added.

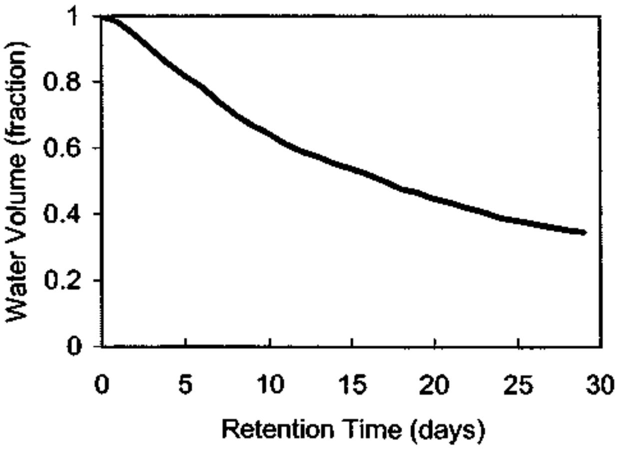

Figure F11. Altered topography.

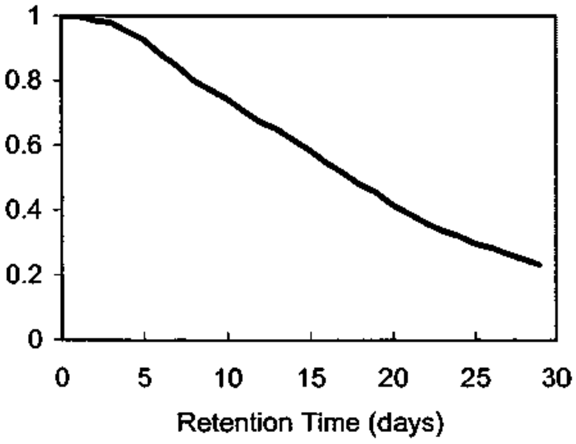

Figure F12. Topographic change and weir placement at 581feet.

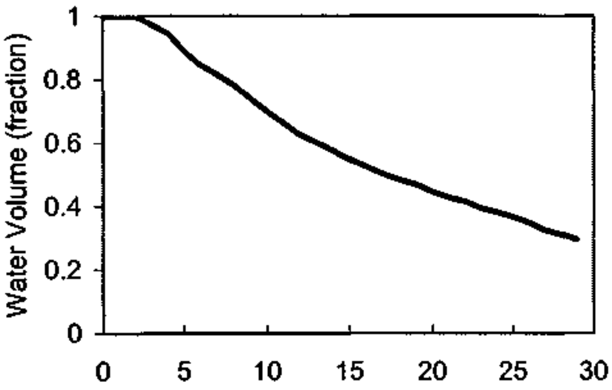

Figure F13. North pool with an open culvert.

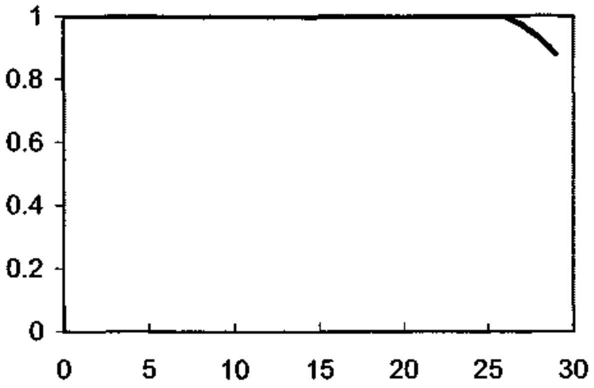

Figure F14. North pool with a constricted culvert.

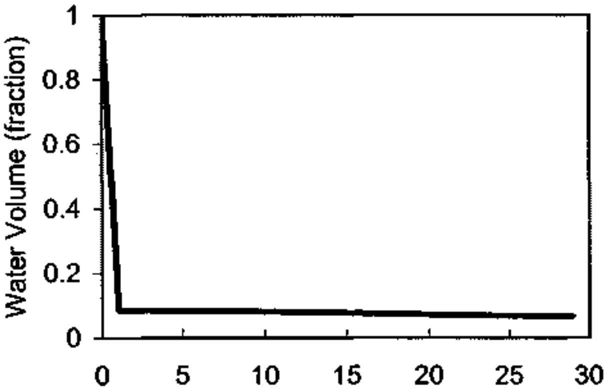

Figure F15. South pool with an open culvert.

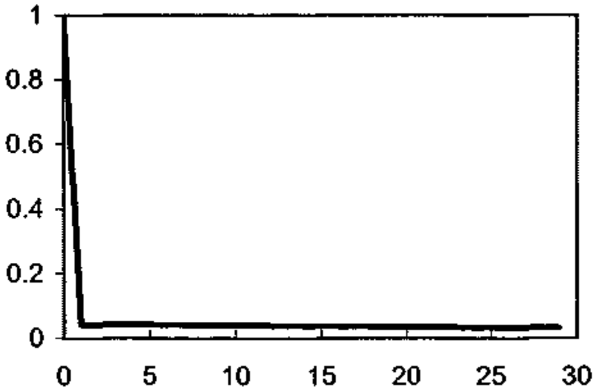

Figure F16. South pool with a constricted culvert.

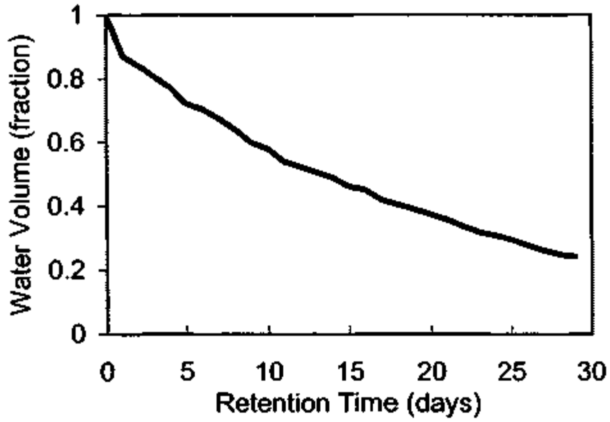

Figure F17. Addition of weir and water for the "ideal" hydroperiod 1.

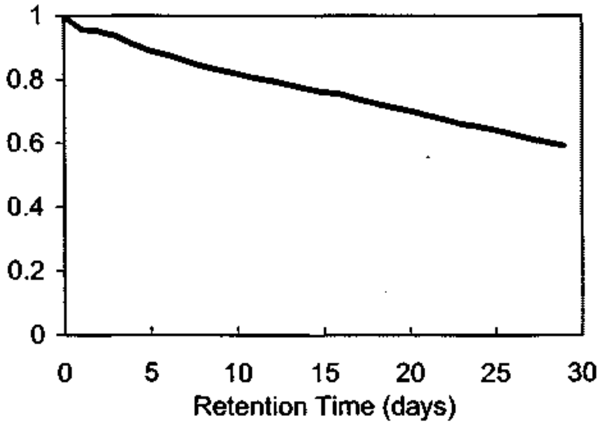

Figure F18. Addition of weir and water for the "ideal" hydroperiod 2.

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