Hydraulic relations between Little Sand, Oak, Duck, Skunk, and Deep Hole Lakes and the main ground water aquifer Crandon Project. 1985

[s.l.]: [s.n.], 1985

https://digital.library.wisc.edu/1711.dl/IMU5XEDDWA5D583

HYDRAULIC RELATIONS BETWEEN LITTLE SAND, OAK, DUCK, SKUNK, AND DEEP HOLE LAKES AND THE MAIN GROUND WATER AQUIFER CRANDON PROJECT

Prepared For

Exxon Minerals Company

Dames & Moore

HYDRAULIC RELATIONS BETWEEN LITTLE SAND, OAK, DUCK, SKUNK, AND DEEP HOLE LAKES AND THE MAIN GROUND WATER AQUIFER CRANDON PROJECT

Prepared For

Exxon Minerals Company

Dames & Moore

April 4, 1985

Table of Contents

LIST OF APPENDICES

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

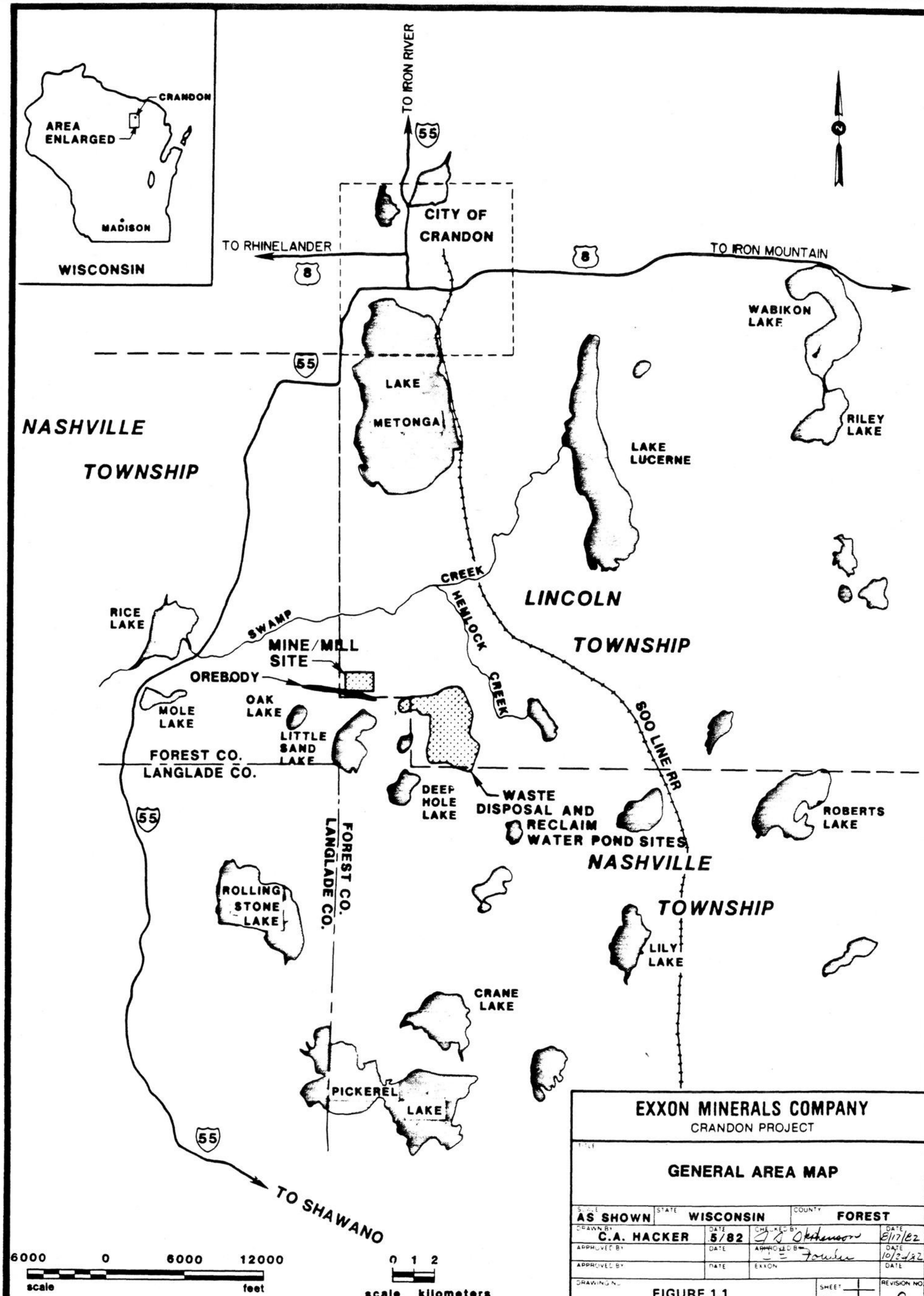
Exxon Minerals Company is currently working to obtain permits to construct and operate an underground zinc, copper, and lead mine and mill complex near Crandon, Wisconsin (Figure 1.1). Ground water drainage into the mine and subsequent dewatering of the main aquifer will cause lowered ground water levels in the Project Site Area. Ground water drawdown is expected to extend under five lakes near the mine: Little Sand, Oak, Duck, Skunk, and Deep Hole lakes.

As part of environmental studies for the Crandon Project, Dames & Moore has examined the relations between these lakes and the main ground water aquifer. The objectives of this study were to:

1. Determine baseline water balances for the lakes;

2. Determine the seepage component of the water balance on the basis of field data collected specifically for this purpose; and

3. Examine the relationship between water balance components, especially seepage, and the hydrogeological setting of the lakes.



EXXON MINERALS COMPANY
CRANDON PROJECT

GENERAL AREA MAP

SCALE	STATE	COUNTY
AS SHOWN	WISCONSIN	FOREST

DRAWN BY	DATE	CHECKED BY	DATE
C.A. HACKER	5/82	[signature]	8/17/82
APPROVED BY	DATE	APPROVED BY [signature]	10/2/82
APPROVED BY	DATE	EXXON	DATE

DRAWING NO. FIGURE 1.1 SHEET OF — REVISION NO. 0

This report presents the methods and results of studies on the relationship between each of the lakes and the main ground water aquifer. It supercedes the previous Dames & Moore report entitled "Hydraulic Relationship Between Site Area Lakes and the Main Ground Water Aquifer, Crandon Project, Forest County, Wisconsin" dated September 20, 1984.

Hydraulic relations between lakes and ground water were defined by using geological and hydrological information on the lakes and their surroundings obtained during earlier phases of the Crandon Project environmental studies. Boring logs and ground water level information were available from the Project area, and from borings conducted in the lakes.

Water balances were computed to quantify the rate of seepage under baseline conditions, and to allow comparison with other water balance components. Water balances are of two different types:

1. Short-term water balances for Little Sand, Oak, Duck, and Skunk lakes were determined during a 3-week period in January, 1985. These water balances summarize the results of a field program designed specifically to obtain water balance information. This program was conducted to provide improved measurements of precipitation, evaporation, and stream inflow and outflow, thus allowing seepage to be calculated as a

water balance residual. A short-term water balance was not determined for Deep Hole Lake because of the difficulty in obtaining reliable measurements of stream outflow.

2. Annual water balances for all five lakes were calculated. Water balances are presented separately for wet, dry, and average years. The annual water balance for Deep Hole Lake was calculated by analogy with Little Sand Lake.

2.0 METHODS OF INVESTIGATION

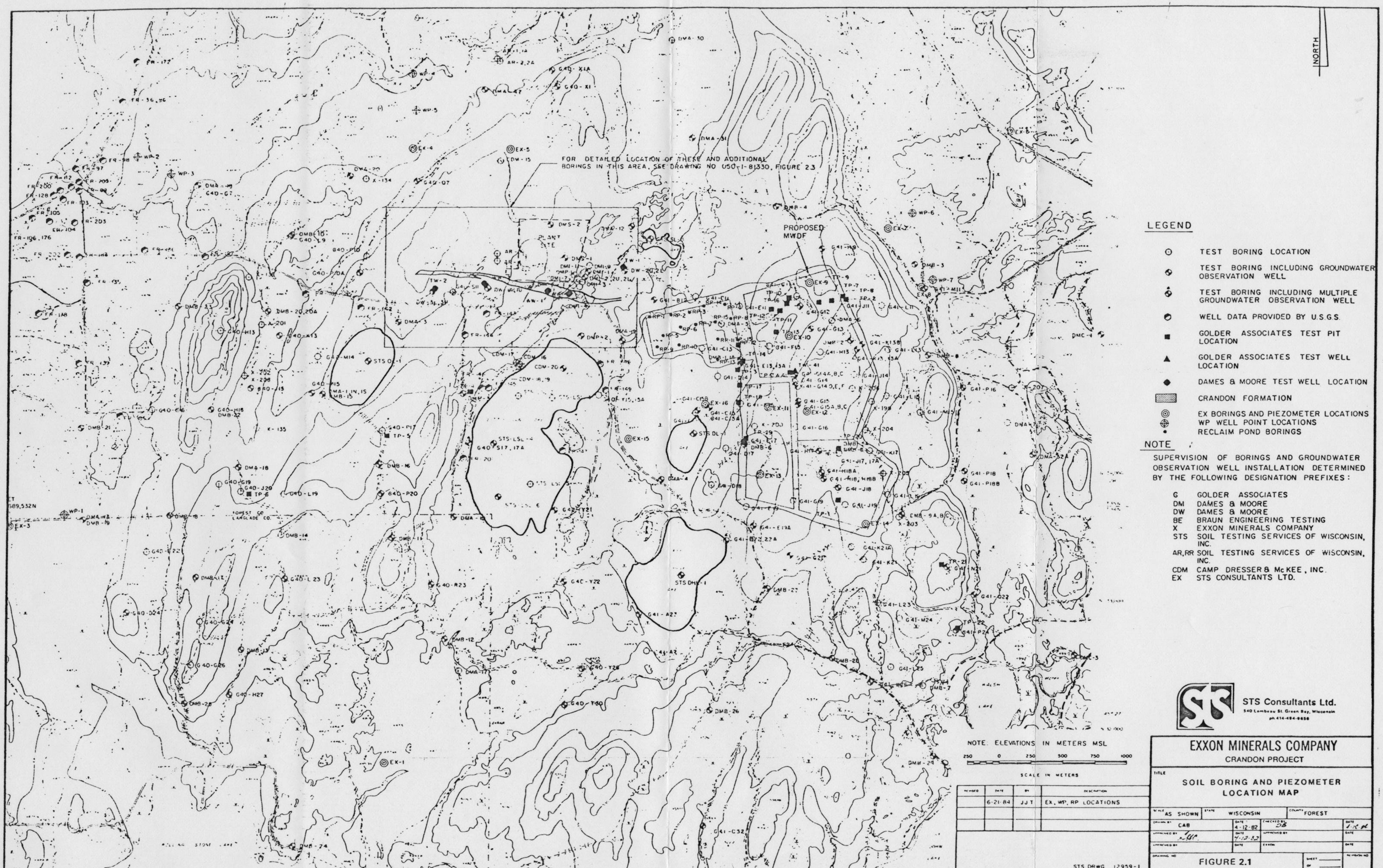
2.1 Hydrogeological Data from Other Investigations

2.1.1 General Hydrogeological Investigations

Extensive ground water and surface water investigations were conducted from 1977 through 1980 (Exxon Minerals Company, 1982). Additional field data were obtained from 1981 through 1984 (STS Consultants, 1982, 1984a,b). All of these data have been evaluated and utilized in the preparation of this report.

The initial ground water investigations included extensive drilling and the installation of monitoring wells and piezometers by various contractors. More than 100 borings were drilled and over 150 piezometers were installed to facilitate monitoring of ground water potentiometric levels and water quality. The locations of these borings and piezometers are presented in Figure 2.1.

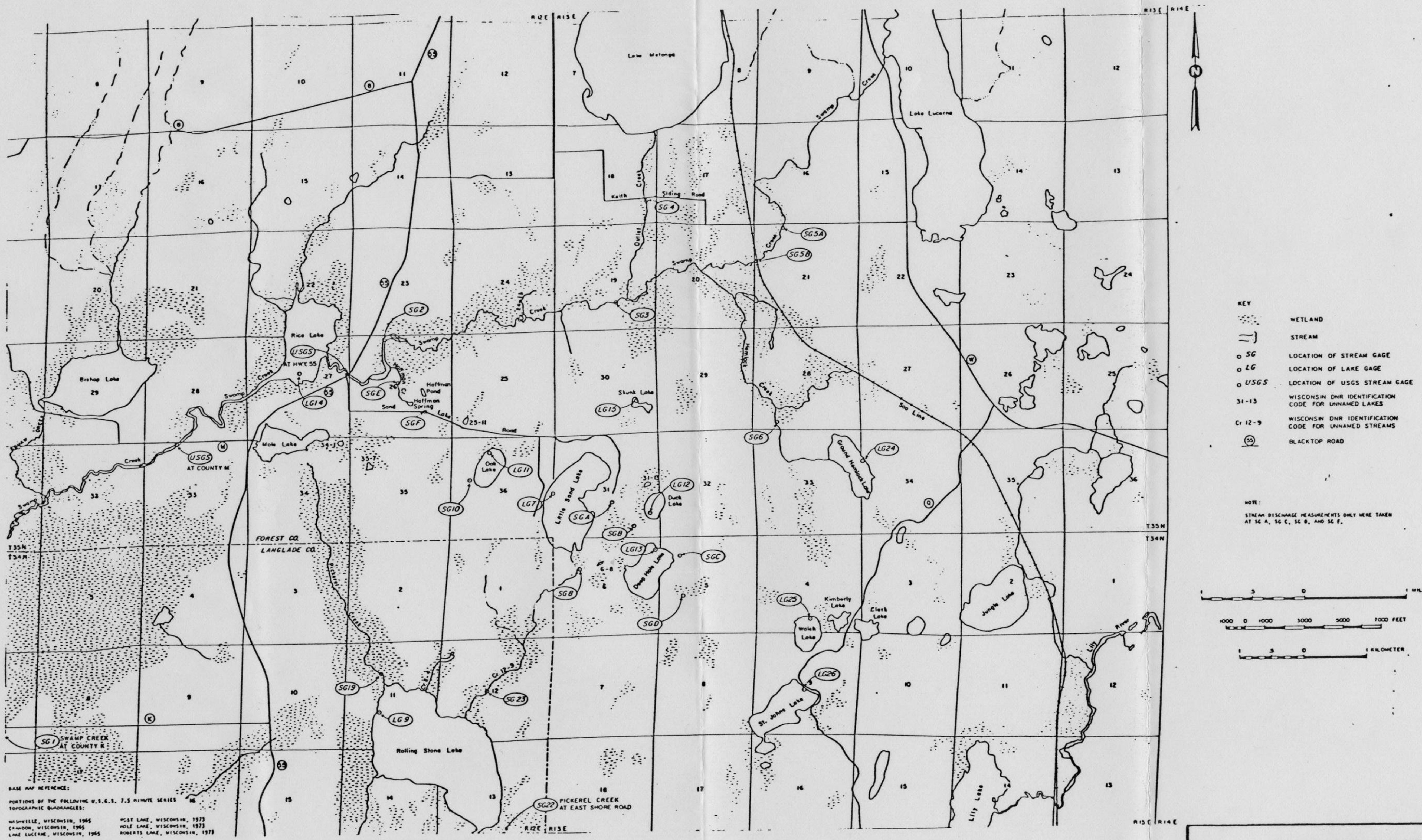
During February and March, 1984, STS Consultants Ltd. completed additional hydrogeological work which included sixteen soil boring locations (EX-1 through EX-16) with multiple boring and piezometer installations (Figure 2.1), giving a total of approximately 65 additional piezometers. Fifteen shallow soil


NORTH
FOR DETAILED LOCATION OF THESE AND ADDITIONAL BORINGS IN THIS AREA, SEE DRAWING NO U50-1-81330, FIGURE 2.3
PLANT SITE
PROPOSED MWDF
LEGEND
TEST BORING LOCATION
TEST BORING INCLUDING GROUNDWATER OBSERVATION WELL
TEST BORING INCLUDING MULTIPLE GROUNDWATER OBSERVATION WELL
WELL DATA PROVIDED BY U.S.G.S.
GOLDER ASSOCIATES TEST PIT LOCATION
GOLDER ASSOCIATES TEST WELL LOCATION
DAMES & MOORE TEST WELL LOCATION
CRANDON FORMATION
EX BORINGS AND PIEZOMETER LOCATIONS
WP WELL POINT LOCATIONS
RECLAIM POND BORINGS
NOTE
SUPERVISION OF BORINGS AND GROUNDWATER OBSERVATION WELL INSTALLATION DETERMINED BY THE FOLLOWING DESIGNATION PREFIXES:
G GOLDER ASSOCIATES
DM DAMES & MOORE
DW DAMES & MOORE
BE BRAUN ENGINEERING TESTING
X EXXON MINERALS COMPANY
STS SOIL TESTING SERVICES OF WISCONSIN, INC.
AR,RR SOIL TESTING SERVICES OF WISCONSIN, INC.
CDM CAMP DRESSER & McKEE, INC.
EX STS CONSULTANTS LTD.
STS Consultants Ltd.
NOTE: ELEVATIONS IN METERS MSL
250 0 250 500 750 1000
SCALE IN METERS
6-21-84 JJT EX, WP, RP LOCATIONS
EXXON MINERALS COMPANY
CRANDON PROJECT
SOIL BORING AND PIEZOMETER LOCATION MAP
AS SHOWN
WISCONSIN
FOREST
CAB
4-12-82
4-12-82
FIGURE 2.1
STS DRWG 12959-1

borings were also completed in the proposed reclaim pond area (Borings RP-1 through RP-15, Figure 2.1). No wells were installed in the RP borings. Seven shallow well locations were established adjacent to ground water discharge areas (WP-1 through WP-7, Figure 2.1). Well points were installed at two different depths at each location (STS Consultants, Ltd., 1984b).

Surface water investigations were conducted intermittently from 1977 through 1980. These studies documented and described the chemical and hydrological characteristics of the existing lakes, streams, and wetlands near the Project site on a seasonal basis. These characteristics included lake levels, stream discharge rates, and water and bottom sediment chemistry of both lakes and streams. The locations of the stream and lake gaging stations are presented in Figure 2.2 (Exxon Minerals Company, 1982).

Areas of lakes and adjacent wetlands used in this study were determined by IEP, Inc. as part of their studies of wetlands in the study area. These areas are summarized in a letter presented as Appendix A. Wetland areas adjacent to lakes were added to lake areas when it was believed that they represented an extension of the lake. Therefore, for calculating the amount that lake level would be affected by a given addition of water, the wetlands would act as though they were part of the lake.



EXXON MINERALS COMPANY
CRANDON PROJECT

LOCATION OF
SURFACE WATER GAGING STATIONS
IN THE ENVIRONMENTAL STUDY AREA

DAMES & MOORE

FIGURE 2.2

For Oak, Skunk, and Deep Hole lakes, the area used in the annual water balances was the total of open water and wetland, but only open water area was used for the short-term water balances. This was done because these wetlands were largely frozen during the short-term study, and did not contribute to seepage from the lake. For Duck Lake, surrounded by a floating bog, the sum of open water and wetland area was used for both annual and short-term water balances. Little Sand Lake has no lakeside wetlands.

Effective areas of watersheds were also determined by IEP, Inc. and are summarized in Appendix A. Effective areas are the total topographical watershed areas minus non-contributing areas, such as areas of closed drainage and certain wetlands.

2.1.2 Drilling in Lakes

Lake drilling studies were conducted on Little Sand Lake in February, 1982, and in Oak, Duck, Skunk, and Deep Hole lakes in February, 1984. These involved boring through the ice, generally near the centers of the lakes, and through the fine-grained lake bottom sediments into the underlying glacial material. Locations of the lake borings are presented in Figure 2.1.

Field and laboratory procedures are presented in reports by STS Consultants, Ltd. (1982, 1984a,b). The laboratory testing program identified the index properties of representative samples from each of the lake soil borings. Constant-head permeability tests were performed in the laboratory.

Piezometers were installed in the lake bottom bore holes, and water levels were measured during the study periods (STS Consultants, Ltd., 1982, 1984a). Field permeability tests were performed in the piezometers installed at Oak, Duck, Skunk, and Deep Hole lakes a few days after their installation.

2.1.3 Bathymetric Mapping

Bathymetric mapping was conducted in Little Sand, Duck, Skunk, and Deep Hole lakes during January, 1985. The purpose of the mapping was to produce contour maps of lake depth, using a 1-foot contour interval to a depth of 5 feet, and larger intervals at greater depths. Inman-Foltz Associates, Registered Surveyors, performed the mapping and also developed outlet profiles for each of the lakes. During the mapping, the surveyor determined lake-bottom materials by probing and a description was included on the maps. The maps are presented as Figure 2.3 (in pocket at end of report).

2.2 Short-Term Water Balances

An intensive field program to measure water balance components was conducted from January 11 to 30, 1985.

Measurements were obtained of precipitation, evaporation from the snow on the lake surface, stream inflow to and outflow from the lakes, and changes in lake level. Locations where measurements were obtained are shown in Figure 2.4. The following sections describe the field methods.

2.2.1 Precipitation

Precipitation consisted entirely of snow. It was measured by a gage similar in construction to a National Weather Service standard gage, consisting of a sheet metal cylinder, 8 inches in diameter and 16 inches high. This gage was placed on the surface of Little Sand Lake, about 200 feet from the northwestern shore, inside a 5-foot diameter, snow fence wind shield. The gage was not read on a fixed schedule, but it was retrieved after snowfalls, the snow melted, and the water measured in a graduated cylinder. These measurements are summarized in Appendix B, and their cumulative total plotted in Figure 2.5.

The lakes were ice-covered and the ice was observed to be floating; therefore, it was assumed that loading from snowfall was transferred directly to the lake water, appearing as an increase in lake level. Lake levels respond in this manner because lake ice is very thin compared to the lake width, and so is flexible under loading.

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
LOCATION OF LAKE WATER
BALANCE SAMPLING STATIONS

SCALE	STATE	COUNTY	
DRAWN BY	DATE	CHECKED BY	DATE
APPROVED BY	DATE	APPROVED BY	DATE
APPROVED BY	DATE	EXXON	DATE
DRAWING NO FIGURE 2.4		SHEET ___ OF ___	REVISION NO

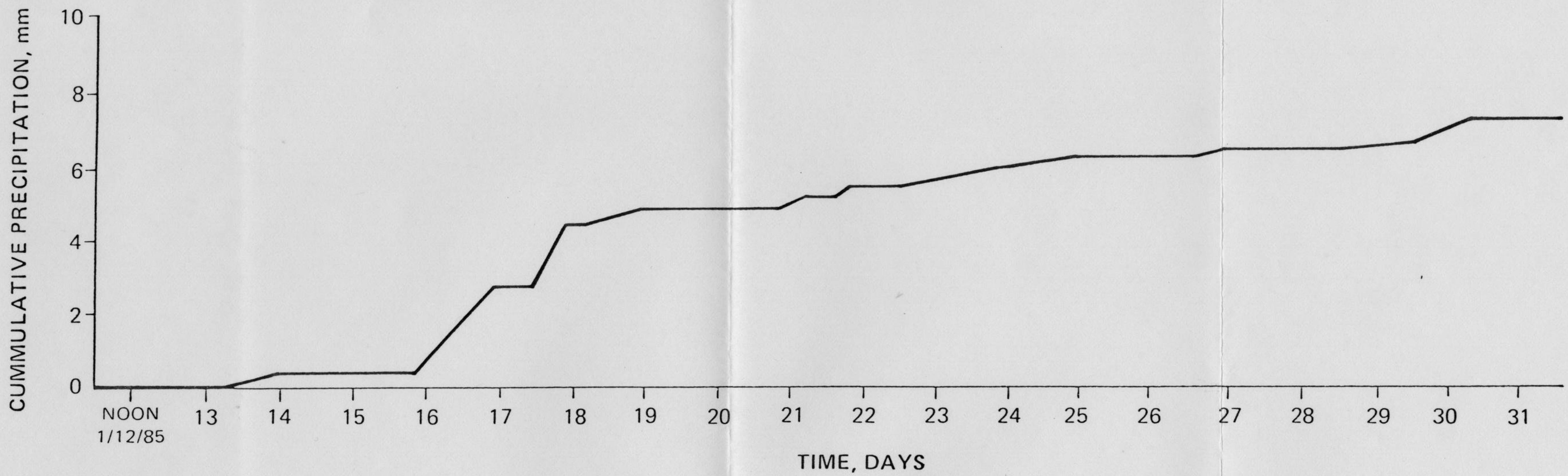


FIGURE 2.5
CUMULATIVE PRECIPITATION

Dames & Moore

2.2.2 Evaporation from Snow Surface

Evaporation from the snow was measured by an evaporation pan, a method widely used for similar studies (Slaughter, 1970). This device consisted of a wooden box, 3.3 feet (1 meter) square and 8 inches (0.2 meter) high, and fitted with hoisting eyes at the corners. The pan was placed on the surface of Little Sand Lake about 300 feet from the northwestern shore, filled with snow, and the snow surface smoothed to approximate the condition of snow on the lake. Snow was mounded around it to provide a smooth transition from the lake surface.

The box was weighed approximately every 2 days by suspending it from a tripod and weighing with a steelyard balance. The balance's smallest graduations were 8 ounces, and weighings were interpolated to the nearest 2 ounces. Because weighings were not precisely reproducible, ten independent weighings were made each time (after the first) that the box was weighed, and their average taken. Every effort was made not to disturb the snow surface and to clean adhering snow from the outside of the box.

To compute sublimation, weight changes were corrected for the additional weight of snow falling on the box. Raw weights, their averages, and corrected weights are summarized in Appendix C. The weight loss with time is shown in Figure 2.6. The best-fit line shows a weight loss of 0.45 lb/day. One mm of

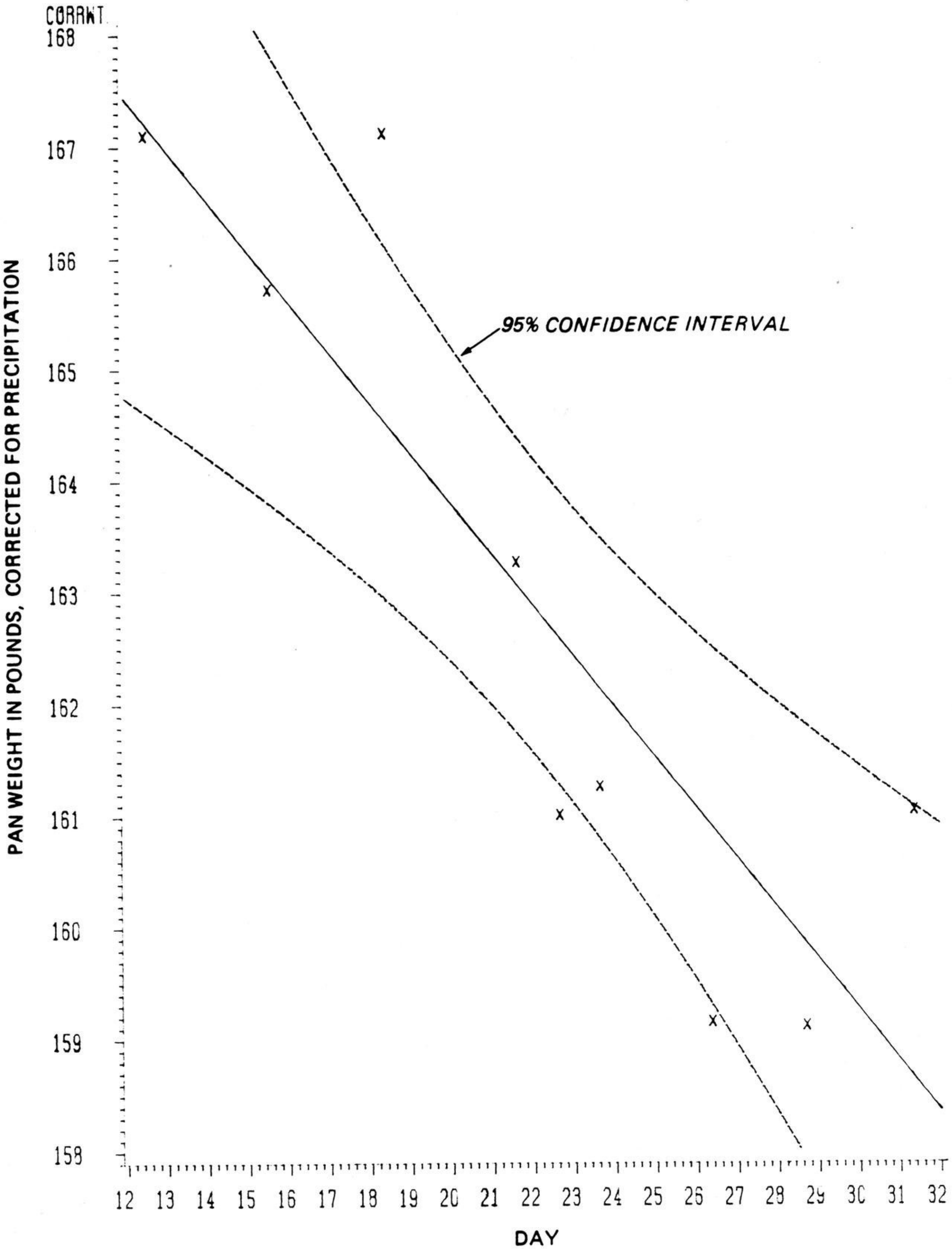


FIGURE 2.6

WEIGHT OF EVAPORATION PAN

sublimation from a 1 square meter area corresponds to a weight loss of 1 kg or 2.2 lb; thus a loss of 0.45 lb/day implies an evaporation rate of 0.20 mm/day of water.

The measured evaporation rate appears to be reasonable for the weather conditions during the study. Farnsworth and Thompson (1982, p.81) show mean total January pan evaporation of between 0.62 and 0.85 inches for four stations in Wisconsin, the equivalent of 0.5 to 0.7 mm/day. Don Baker, Professor of Soil Science at the University of Minnesota, reports that his experiments with a considerably larger, more sensitive weighing lysimeter show typical midwinter evaporation rates in the range of 0.01 to 0.1 inch/day (0.3 to 2.5 mm/day)(Baker, 1985). Temperatures during the lake water balance study were below freezing at all times, and frequently subzero. Therefore, it seems reasonable that the evaporation rate during the lake water balance study was somewhat smaller than the ranges of values reported, which may have included periods of thawing.

2.2.3 Stream Inflow and Outflow

Stream flow into and out of the lakes was measured at three locations:

1. Inflow to Little Sand Lake at a culvert under the first road upstream from the lake on the east side of the lake;

2. Outflow from Little Sand Lake at the staff gage location a few hundred feet downstream from the lake; and

3. Outflow from Duck Lake at the culvert under Sand Lake Road.

At all three locations flow was measured by a 90 degree V-notch weir. Weirs were constructed by attaching a steel carpenter's square to a notched sheet of plywood. At the culvert sites, the plywood sheet was cut to fit over the upstream side of the culvert and was sealed by a combination of plastic sheeting, stream-bottom soil, sand, and cement. At the Little Sand Lake outflow, the plywood sheet was driven into the soft bottom sediments, and other sheets similarly placed at both ends to form an improvised dam. The dam was sealed with plastic sheeting, muck, and sand placed along the upstream side.

Flow was measured by determining the head over the weir, that is, the height of water above the bottom of the notch measured at a distance at least four times the head upstream. At that position, the water level is unaffected by flow over the weir.

Head was measured by a rectangular metal gage, approximately 0.5 x 1.3 feet, with a scale in hundredths of feet along a short edge. This was placed in the notch, parallel to the flow, with minimal disturbance. The long edge could be leveled with considerable accuracy, using the water surface as a reference, and the head read from the scale. A staff gage was also installed upstream from each weir. Flow rate was computed by the formula (Olson, 1967, p.361):

$$Q=2.5h^{2.5}$$

where Q = discharge, in cubic feet per second
h = head in feet

Measurements from the weirs are summarized in Appendix D. In spite of practical difficulties caused by the freezing weather, data from the weirs are believed to be reliable.

2.2.4 Lake Level Changes

Because of the relatively short duration of this study, it was necessary to measure lake levels more precisely than is usual in lake investigations. This was done by a hook gage specially constructed for the study. Hook gage locations are shown in Figure 2.4.

A hook gage consists of a metal hook which dips below the water surface and approaches it from beneath. When the hook reaches the water surface, it produces a very obvious inflection in the surface. The surface elevation can thus be detected more precisely than by a point approaching from above or by a scale partly submerged.

Lake level measurements were taken from a steel post driven into the lake bed. The attachment for the hook gage was a steel plate, about 0.3 feet wide and 1.3 feet high, bolted securely to the post. A smooth, straight steel lip welded to its bottom was the vertical reference for the gage. In use, a magnet held the gage on the plate, the gage was pushed down against the lip, and its left side was aligned with a vertical line marked on the plate.

Between measurements, the post was covered by a steel trash can or by a portable ice-fishing shelter. A Coleman or kerosene lantern, or a Coleman camping heater, was kept burning inside to keep the hole in the ice from freezing. This was done to prevent shifting ice from raising or lowering the post and to facilitate measurements. This method kept ice from forming overnight and kept the holes open throughout the entire study.

Lake level fluctuated through a range of a few millimeters, primarily as a result of wind action on the ice. Because anticipated lake level changes were in the same order of magnitude as the wind-induced fluctuations, a measuring procedure was adopted to compensate for wind effects. On every visit to a hook gage location, a minimum of 20 measurements were made over a period of at least 10 minutes. In most instances about 25 measurements were taken. The vernier scale was read to 0.1 mm. The mean, standard deviation, minimum, and maximum of each set of measurements were computed. These values are tabulated in Appendix E, and presented in Figures 2.7 through 2.12.

Post elevations are believed to have remained stable during the study. Posts at Little Sand, Oak, and Duck lakes were driven into firm sand, generally a stable bearing material. The post at Skunk Lake was placed in finer-grained lake bottom soils. Graphs of lake levels measured relative to the posts (Figures 2.7 to 2.12) show generally smooth changes in lake level except where affected by snowfall; there are no sharp inflections that would result from a sudden blow hard enough to move the post up or down. The best evidence for post stability is the close agreement between the water level records from the posts on the east and west sides of Little Sand Lake (Figure 2.9). Although some differences occur because of wind effects, over the duration of the study they follow each other closely, and the differences appear to be random.

In an attempt to verify the stability of the posts, the elevation of the lip on each plate was surveyed against reference marks on shore either two or three times during the study. The surveys showed apparent elevation changes of from +3 mm to -32 mm, depending on location. The surveyors' report and an interpretive letter giving their opinion on the causes of the apparent change are included as Appendix F. These changes are believed to result from frost heaving of onshore reference marks, which consisted of spikes in trees. Actual post movements appear

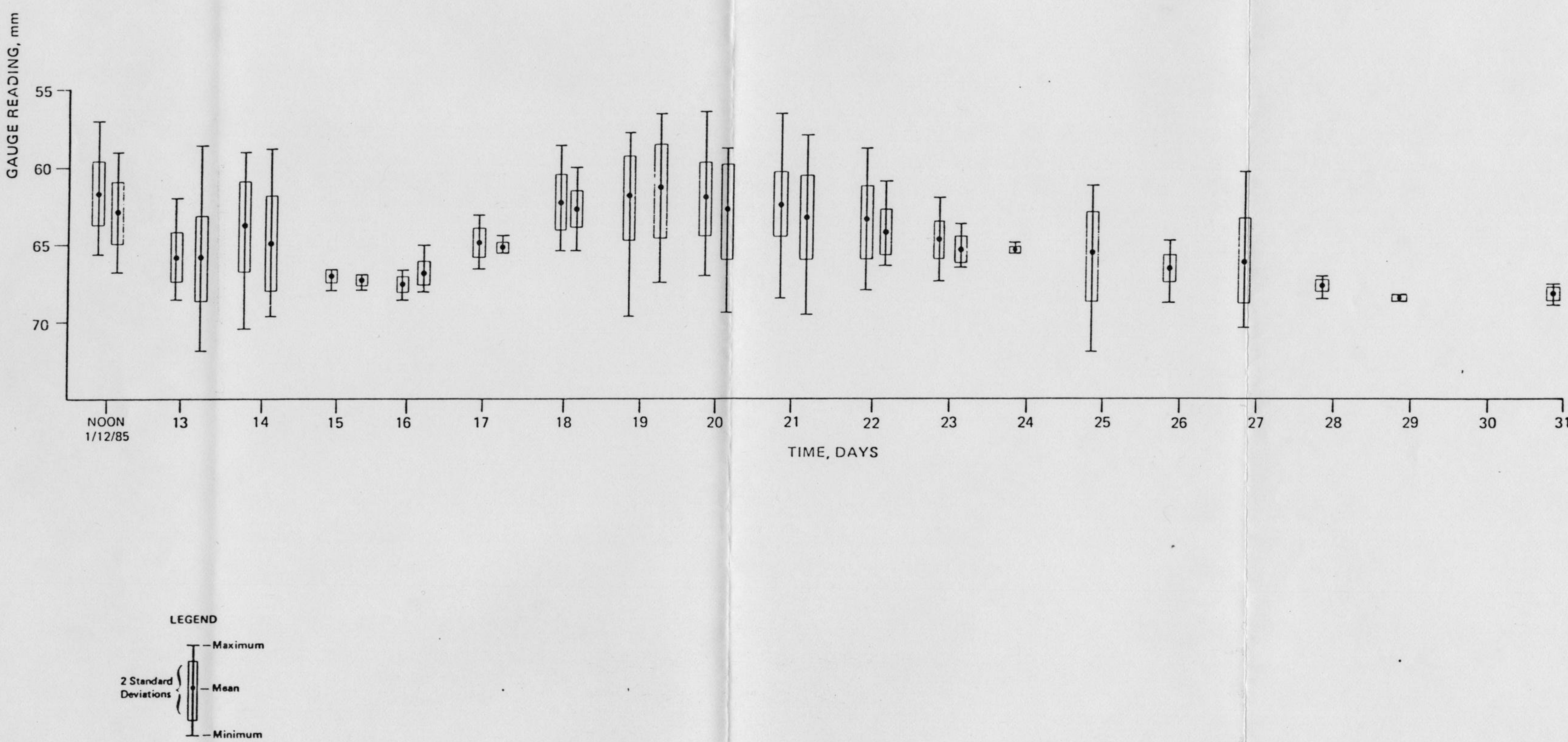


FIGURE 2.7

LEVEL OF LITTLE SAND LAKE – WEST SIDE GAUGE

Dames & Moore

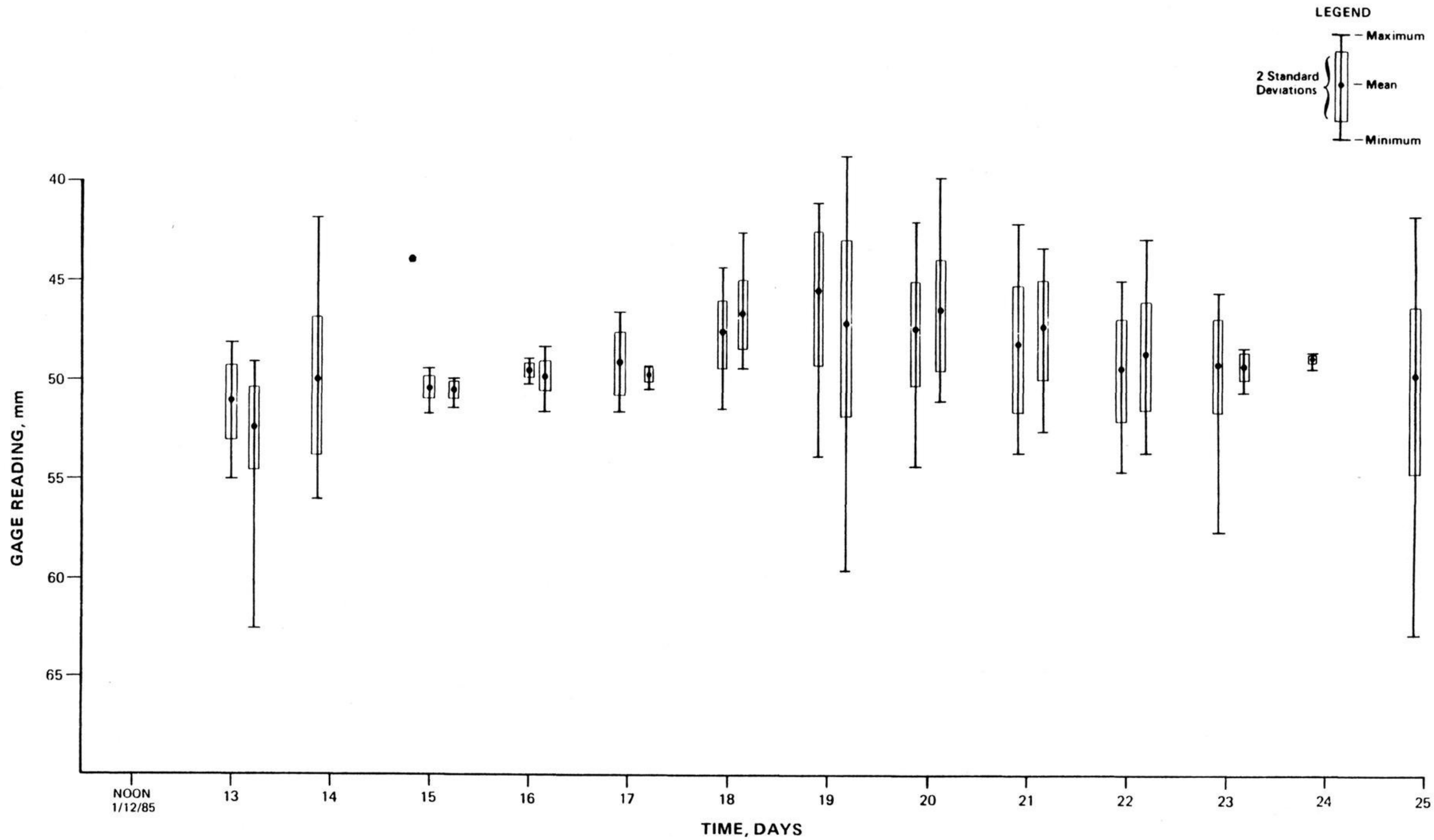


FIGURE 2.8

LEVEL OF LITTLE SAND LAKE – EAST SIDE GAUGE

Dames & Moore

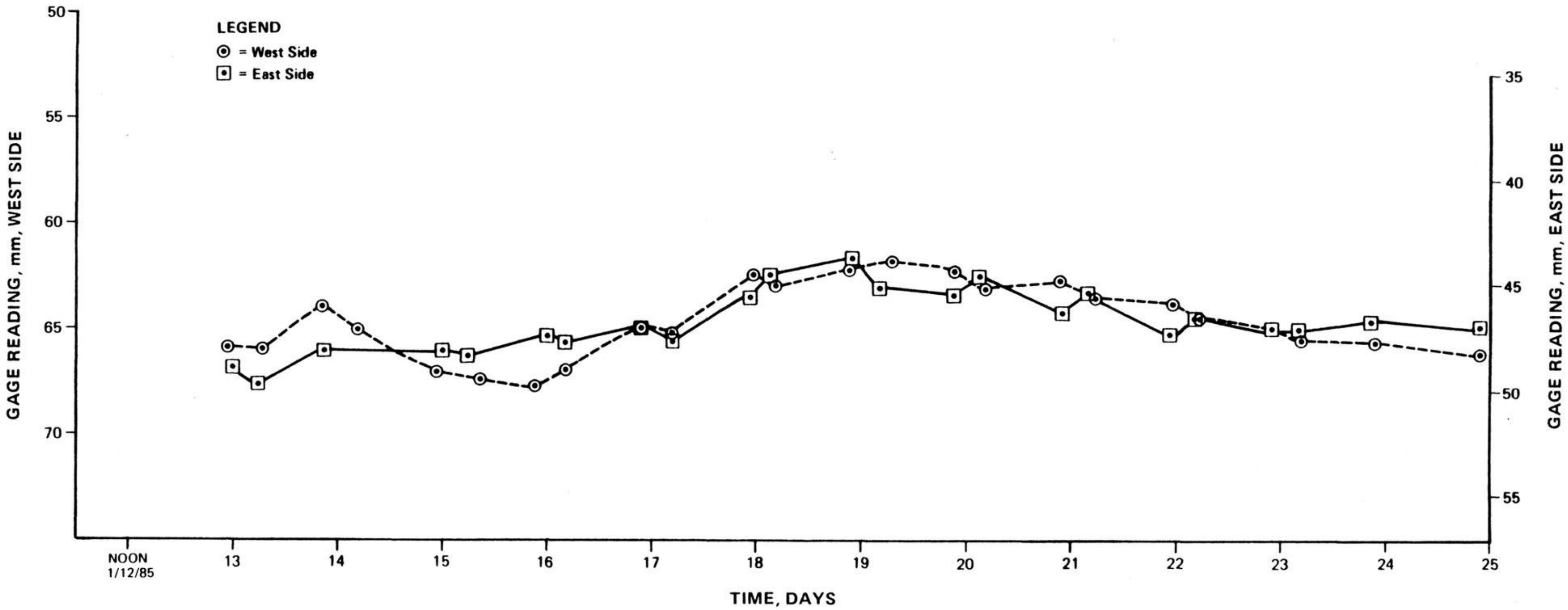


FIGURE 2.9
LEVEL OF LITTLE SAND LAKE– BOTH GAUGES COMBINED

Dames & Moore

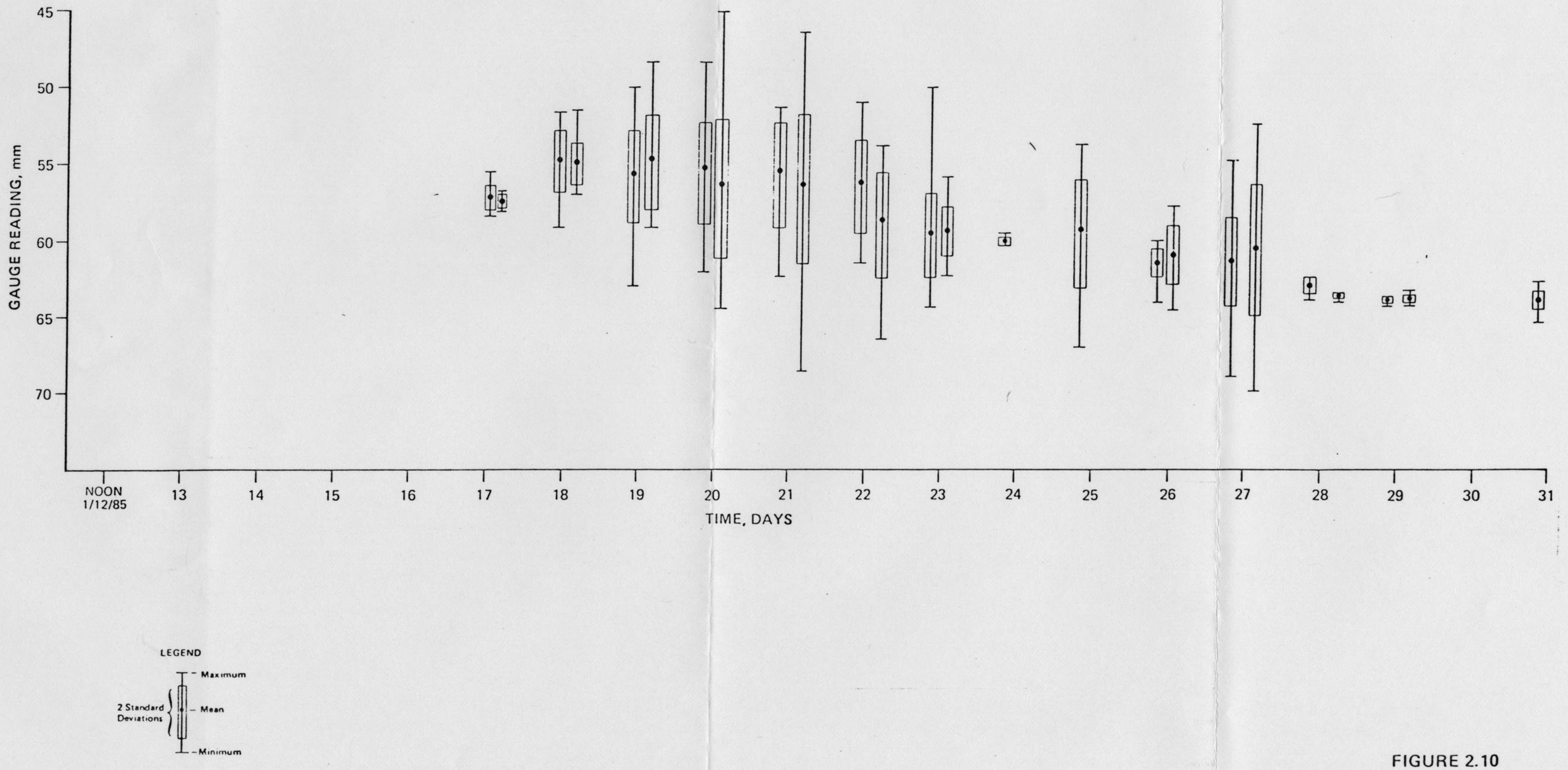


FIGURE 2.10
LEVEL OF OAK LAKE

Dames & Moore

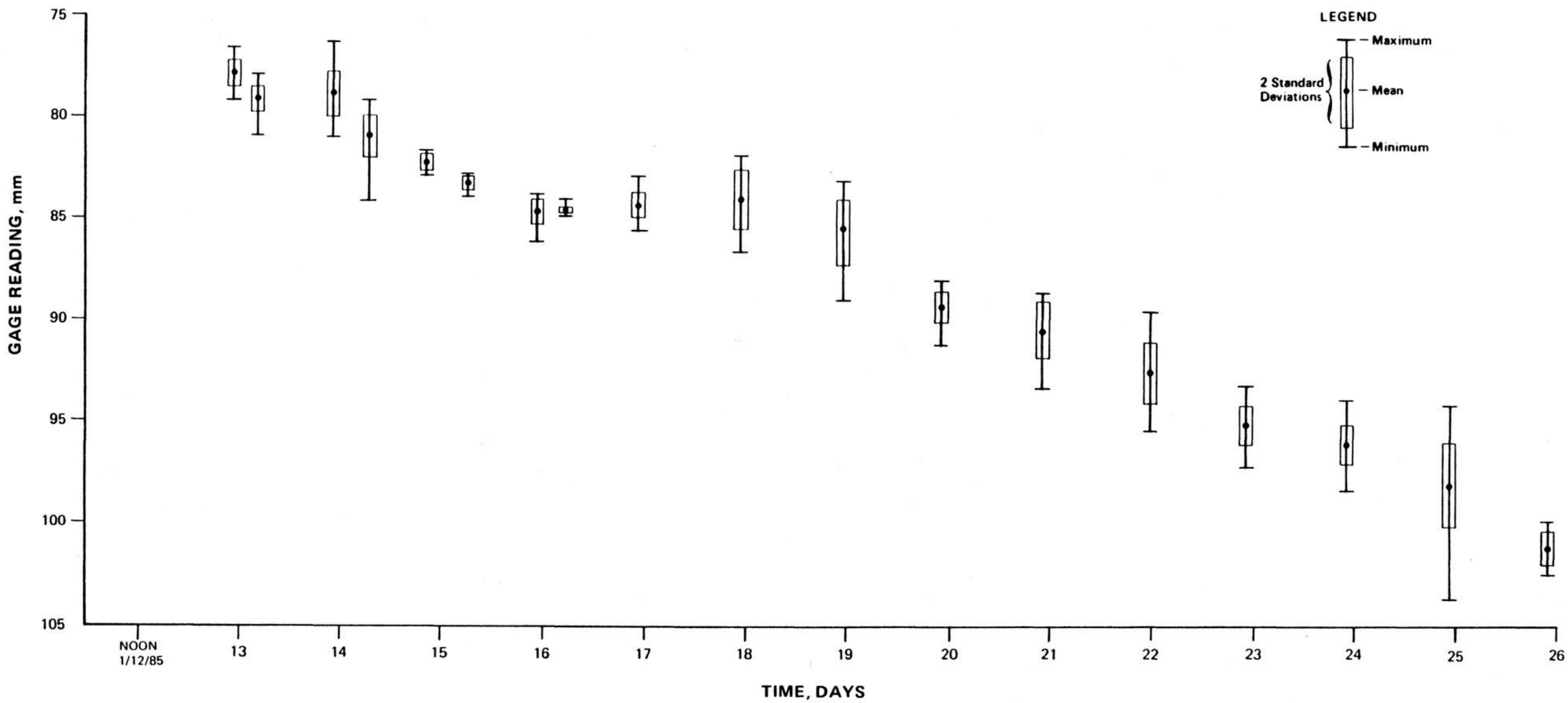


FIGURE 2.11
LEVEL OF DUCK LAKE

Dames & Moore

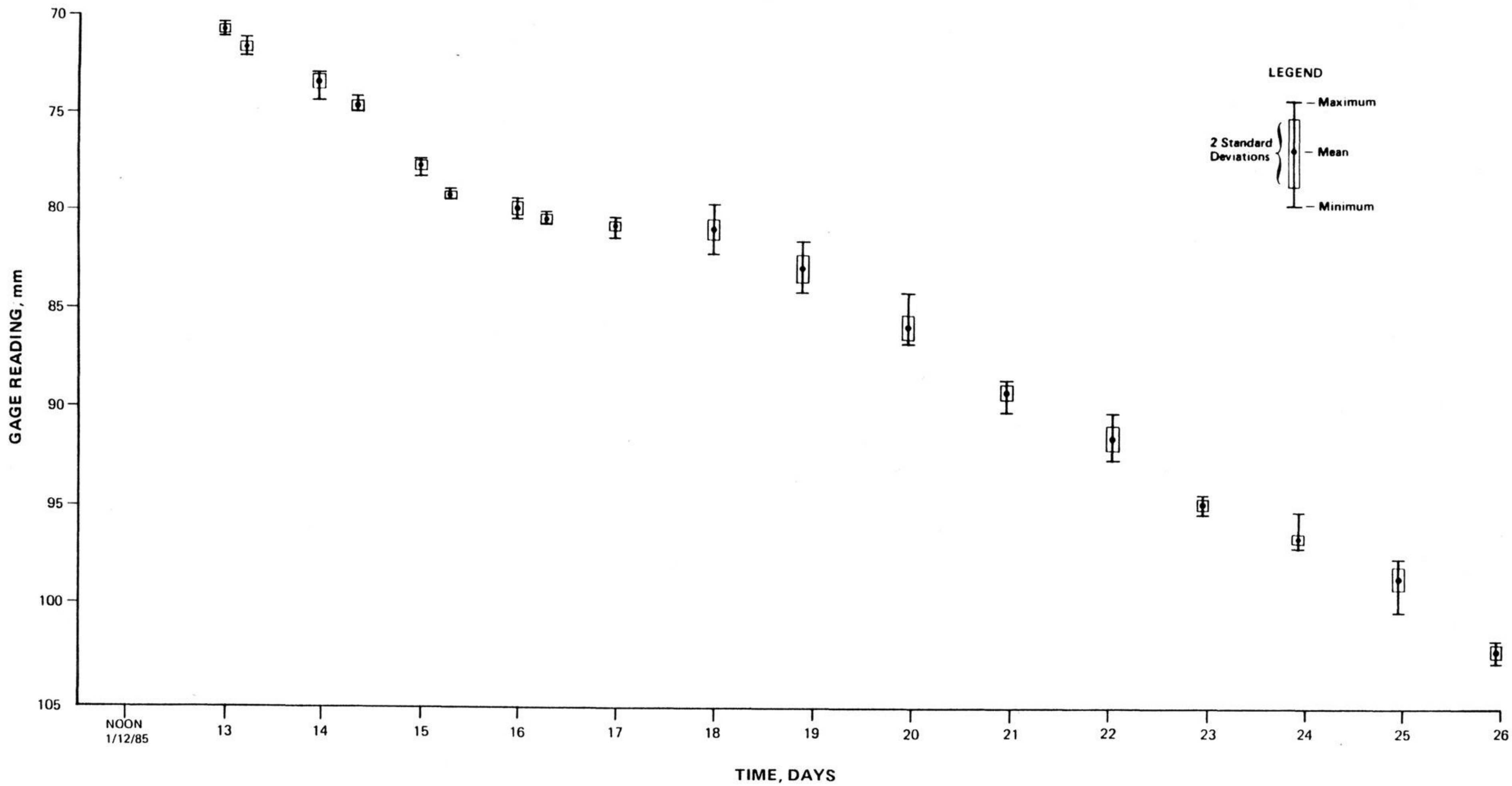


FIGURE 2.12

LEVEL OF SKUNK LAKE

Dames & Moore

improbable because of the lack of any evidence in the lake hydrographs for sudden elevation changes of this size, and in view of the consistency of the two Little Sand Lake records. Frost heaving of 0.1 to 0.2 ft (30 to 60 mm) during a winter is common, however, in areas with high water tables, according to George Carlson of the U.S. Geological Survey (Carlson, 1985). Because the posts were in unfrozen lake bottom soils, they would not be affected by frost heaving.

2.2.5 Seepage

In the short-term water balance study, seepage was computed as a residual. All gains of water to the lake were added, all losses subtracted from their total, and the difference between that number and the measured lake level change presented as seepage. Note that the residual value also includes the net error, which cannot be distinguished from seepage by computation from other water balance components alone. The resulting seepage rates are discussed along with other water balance components in Section 4.1.

2.3 Annual Water Balances

Three annual water balances were computed for each of the five lakes: one each for a wet, a dry, and an average year. Water balances were developed by month. Previously existing data from other sources were used to compute precipitation, evaporation, and runoff (stream and overland) into the lakes. For Little Sand, Oak, Duck, and Skunk lakes, seepage values were obtained from the short-term water balances, and stream outflow values were based on relations between lake level and outflow rate derived from previously existing data. Similar seepage and outflow data were not available for Deep Hole Lake; instead, the seepage rate and lake level/outflow relation were assumed to be the same as at Little Sand Lake. The following sections describe how these data were obtained and integrated into the water balances.

2.3.1 Precipitation

National Weather Service records from Nicolet College, Rhinelander, Wisconsin, 28 miles west of the site, were used to define precipitation during wet, dry, and average years. These data, and statistical computations to determine precipitation for wet, dry, and average years, are included in Appendix G.

Monthly precipitation during a typical wet year was taken as the monthly mean of the five wettest water years (October-September) over the period 1942-1981 (1942, 1951, 1968, 1973, and 1978). Similarly, the typical dry year was defined as the monthly mean of the five dryest water years during that period (1948, 1957, 1963, 1969, and 1976). The average year was the monthly mean for that period. Precipitation totals for calendar and water years 1942-1981 are tabulated in Appendix G, both in chronological order and in order of total precipitation for the year. The programs used for these tabulations and statistical calculations are also presented in Appendix G.

2.3.2 Evaporation From Lake Surface

Weather Service evaporation pan data from Rainbow Reservoir, 42 miles northwest of the Project site, were used to compute lake evaporation during the open-water season (May-October). These data, and statistical computations to determine evaporation for wet, dry, and average years, are included in Appendix G. A coefficient of 0.81 was multiplied by the pan data to obtain lake evaporation. This coefficient, which represents the ratio of lake evaporation to pan evaporation, was obtained from maps in Farnsworth, Thompson, and Peck (1982).

Monthly lake evaporation derived in this way should be regarded as an approximation, which can differ from more accurate values by a factor of 2 or more because of the greater heat storage in a lake than in an evaporation pan. The pan coefficient was derived specifically for annual totals, however, so that annual lake evaporation values obtained from pan evaporation are considerably more accurate than some of the monthly values.

No systematic evaporation measurements are available for the remainder of the year. Evaporation for November through

April was computed from coefficients in Table 3 of Farnsworth, Thompson, and Peck (1982). The coefficients represent the fraction of total annual evaporation occurring during these months. On the basis of the two nearest stations for which these coefficients are available (Trempleau Dam, Wisconsin and East Lansing Horticultural Farm, Michigan), the coefficient for the site is interpolated as 23 percent. The coefficients vary little over the upper Midwest, and the variation from station to station is smooth. The interpolated coefficient is believed to be accurate in spite of the distance between the Trempleau Dam and East Lansing stations. Using the 23 percent coefficient, the May-October evaporation is 77 percent of the annual evaporation. Total annual evaporation was computed by dividing measured May-October evaporation at Rainbow Reservoir by 0.77. Monthly evaporation rates for November through April are computed as one-sixth the total for this period.

Evaporation used for a wet year was the monthly means of evaporation for the five years having lowest evaporation. Evaporation for a dry year used the monthly means of the five years having highest evaporation, and evaporation for an average year used monthly means of all years.

2.3.3 Surface Water Runoff

Direct measurements of all surface inflows into the study lakes are not available. To compute the total surface water runoff entering the lakes, monthly and seasonal runoff coefficients were defined to indicate the proportion of monthly or seasonal precipitation that is likely to enter the lakes via tributary stream channels or by overland runoff. Once the coefficients were defined, surface flows into the lakes were determined from observed or assumed values of precipitation.

Runoff coefficients vary both temporally and spatially. The coefficients change seasonally in response to increases in evaporation and transpiration during the warmer periods. In addition, the coefficients may differ from year to year in response to climatic variations. For example, the coefficients may be different if a certain magnitude of precipitation in one year occurs from storms with short duration and high intensity, while in another year the same amount is produced by storms with long duration and less intensity.

Spatially, the coefficients may vary from site to site in response to hydrologic conditions. Smaller coefficients may be expected from drainage areas with flat and pervious surfaces rather than from basins with steep, impervious surfaces. Also, basins having channels that intercept ground water may have larger coefficients than basins where the channels lie above ground water level. Although no unique value of the coefficients may be established for any site, it is possible to define an average value for use in water balance studies.

Stream gaging and precipitation records were analyzed to evaluate the runoff coefficients applicable to the Crandon Project area. Stream flow records for three complete record gages operated by the U.S. Geological Survey and for nine partial record gages operated as part of the Crandon Project site baseline study were used. Precipitation records for Rhinelander were considered directly applicable for the Project area.

Analysis began by computing the ratio of total surface water runoff (in inches) to the observed precipitation (in inches) for each available flow record in the period 1977 through 1982. To avoid anticipated complications of the snow accumulation and melt process, an average seasonal coefficient also was defined for the period November through April. Computed results are presented in Table 2.1.

Additional analysis defined runoff coefficients for direct runoff, that is, for stream flow that occurs only in response to recent precipitation or snow melt. Direct surface water runoff omits the portion of observed surface water runoff that derives from ground water or lake storage in the drainage basin. Direct surface water runoff, therefore, suggests a

Table 2.1
SUMMARY OF TOTAL RUNOFF COEFFICIENTS

Swamp Creek Above Rice Lake (USGS Gage No. 04074538)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Nov-Apr	Annual
1978	.36	.19	.37	.96	1.03	3.07	.45	.21	.19	.16	.11	.15	.42	.22
1979	.44	.31	.33	.30	.32	.35	2.35	.45	.42	.28	.15	.67	.49	.39
1980	.11	.41	1.02	.31	1.91	1.32	.77	.40	.20	.13	.08	.18	.63	.23
1981	.38	.70	.44	1.12	.29	1.26	.35	.26	.14	.59	.43	.14	.48	.30
1982	.23	1.30	.31	.26	1.52	.58	.35	.32	.25	.12	.13	.12	.42	.24
5-Yr. Avg.	.30	.58	.49	.59	1.01	1.32	.85	.33	.24	.26	.18	.24	.49	.28

Swamp Creek Below Rice Lake (USGS Gage No. 04074548)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Nov-Apr	Annual
1978	.38	.23	.46	1.31	.137	4.00	.52	.23	.19	.18	.13	.16	.52	.26
1979	.61	.42	.45	.41	.41	.43	2.88	.55	.52	.31	.20	1.02	.62	.50
2-Yr. Avg.	.50	.33	.46	.86	.89	2.22	1.70	.39	.36	.24	.17	.47	.57	.38

Wolf River At Langlade (USGS Gage No. 04074950)

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Nov-Apr	Annual
1977	1.14	1.75	1.27	.83	1.16	0.45	0.49	0.30	0.15	0.22	0.08	0.20	0.61	0.30
1978	.51	.26	.52	1.40	1.53	4.93	0.61	0.27	0.25	0.19	0.14	0.23	0.59	0.31
1979	.78	.28	.28	.47	0.48	0.54	3.61	0.72	0.55	0.30	0.20	0.96	0.73	0.57
1981	.65	1.18	.71	1.47	0.45	1.79	0.49	0.35	0.16	0.75	0.77	0.26	0.70	0.43
1982	.41	2.44	.53	.36	2.09	0.67	0.50	0.46	0.29	0.17	0.21	0.17	0.61	0.35
5-Yr. Avg.	.70	1.24	.66	.91	1.14	1.68	1.14	0.42	0.28	0.33	0.28	0.36	0.65	0.39

GENERAL NOTES
(1) Nov-Apr runoff coefficient is total Nov-Apr runoff divided by total Nov-Apr precipitation.

Table 2.1 (cont'd)

SG-1 - Swamp Creek At County Road K

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Nov-Apr	Annual
1978	.53	.14	.37	1.25	1.55	4.40	.83	.36	.28	.22	.17	.24	.56	.33

SG-2 - Swamp Creek Above Highway 55

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Nov-Apr	Annual
1978	.46	.24	.42	1.04	1.16	3.40	.31	.17	.11	.14	.12	.19	.42	.22

SG-5B - Swamp Creek At Railroad Bridge

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Nov-Apr	Annual
1978	.15	.08	.15	.42	.45	1.33	.17	.08	.09	.12	.07	.08	.26	.11
1980							.27	.18	.10	.08	.05	.08		

SG-6 - Hemlock Creek

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Nov-Apr	Annual
1977										.25	.84	.26		
1978	.41	.29	.55	1.31	1.42	4.80	.73	.28	.47	.13	.09	.31	.61	.32

SG-8 - Little Sand Lake Outflow

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Nov-Apr	Annual
1978	.08	.044	.047	.22	2.37	7.33	.124	.075	.040	.034	.028	.040	.10	.057

GENERAL NOTES
(1) Nov-Apr runoff coefficient is total Nov-Apr runoff divided by total Nov-Apr precipitation.
(2) "SG- " indicates a staff gage; source is Exxon Minerals Company (1982).

Table 2.1 (cont'd)

SG-19 - Pickerel Creek Northwest

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Nov-Apr	Annual
1978	.49	.36	.70	1.84	1.97	6.06	.79	.23	.19	.28	.76	.35	.78	.37
1979														
1980							1.01	.38	.24	.59	.30	.45		

SG-22 - Pickerel Creek At East Shore Drive

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Nov-Apr	Annual
1978	.43	.23	.58	1.49	1.73	4.60	.72	.29	.18	.20	.11	.26	.63	.31
1980							1.16	.45	.19	.12	.09	.13		

SG-B - Duck Lake Outflow

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Nov-Apr	Annual
1978										.15	.05	.11		

SG-23 - Northwest of Rolling Stone Lake

Water Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Nov-Apr	Annual
1978							.31	.17	.11	.09	.11	.11		
1980							.74	.54	.17	.15	.10			

SUMMARY STATISTICS

	Oct	May	June	July	Aug	Sept	Nov-Apr	Annual
N	19	24	24	26	26	25	19	19
MEAN	0.45	.3218	.2275	.2255	.1890	.2748	.5358	.3062
ST. DEV.	0.2444	.1542	.1357	.1725	.1999	.2527	.1634	.1211

GENERAL NOTES
(1) Nov-Apr runoff coefficient is total Nov-Apr runoff divided by total Nov-Apr precipitation.
(2) "SG- " indicates a staff gage; source is Exxon Minerals Company (1982).

minimal or lower limit of runoff coefficients that should show less site to site variability than total runoff coefficients. Direct surface water runoff was evaluated from total runoff hydrographs by hydrograph separation (Riggs, 1963; Linsley, Kohler, and Paulhus, 1975, p.230). As with the total flow coefficients, direct runoff coefficients were computed as a proportion of observed monthly and/or seasonal precipitation. Computed coefficients are presented in Table 2.2.

Determination of the expected values of runoff coefficients for use in the water balance study of Crandon Project lakes, presented in Table 2.3, was based primarily on an assessment of the areal variability of runoff coefficients presented in the tables. The assessment was performed by comparing the hydrological characteristics of the watershed areas by means of topographic and ground water potentiometric surface maps. The expected value of runoff coefficient was therefore established on the basis of the following engineering judgements:

1. Drainage channels above staff gage SG-5B (Swamp Creek at Railroad Bridge) and above staff gage SG-8 (Little Sand Lake Outlet) are believed to be primarily above the water table elevation, as are tributary channels to the study lakes. Runoff coefficients for staff gage SG-5B and staff gage SG-8, therefore, should be more representative of the lake study drainage area than are the regional runoff coefficients.

Table 2.2
SUMMARY OF DIRECT RUNOFF COEFFICIENTS

Swamp Creek Above Rice Lake (USGS Gage No. 04074538)

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Nov-Apr	Annual
1977											0.023	0.061		
1978	0.060	0.051	0.070	0.072	0.079	0.733	0.189	0.055	0.036	0.081	0.044	0.042	0.106	0.066
1979	0.077	0.064	0.069	0.085	0.057	0.122	0.963	0.123	0.144	0.080	0.040	0.202	0.158	0.119
1980	0.042	0.153	0.186	0.055	0.348	0.324	0.242	0.093	0.066	0.026	0.033	0.074	0.166	0.069
Average	0.060							0.090	0.082	0.062	0.035	0.095	0.143	0.085

SG-6 Hemlock Creek

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Nov-Apr	Annual
1977										0.130	0.030	0.090		
1978	0.10	0.080	0.090	0.110	0.050	1.270	0.520	0.090	0.080	0.070	0.040	0.130	0.230	0.110

SG-8 Little Sand Lake Outflow

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Nov-Apr	Annual
1978	0.010	0.010	0.030	0.000	0.030	0.130	0.040	0.020	0.004	0.010	0.007	0.005	0.024	0.013

SG-19 Pickerel Creek Northwest of Rolling Stone Lake

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Nov-Apr	Annual
1978	0.140	0.140	0.080	0.070	0.110	1.470	0.430	0.090	0.080	0.210	0.090	0.160	0.220	0.150
1979														
1980							0.520	0.150	0.110	0.210	0.140	0.240		

GENERAL NOTES
(1) Nov-Apr runoff coefficient is total Nov-Apr runoff divided by total Nov-Apr precipitation.
It cannot be computed directly from runoff coefficients shown for these months.
(2) "SG- " indicates a staff gage; source is Exxon Minerals Company (1982).

Table 2.2 (cont'd)

SG-22 Pickerel Creek at East Shore Drive

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Nov-Apr	Annual
1978	0.150	0.070	0.050	0.070	0.210	1.060	0.380	0.080	0.040	0.090	0.020	0.060	0.180	0.090
1979														
1980							0.420	0.150	0.080	0.030	0.030	0.040		

SG-23 Northeast of Rolling Stone Lake

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Nov-Apr	Annual
1978							0.310	0.040	0.010	0.020	0.050	0.050		
1979														
1980							0.230	0.100	0.050	0.020				

SG-5B Swamp Creek at Railroad Bridge

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Nov-Apr	Annual
1978	0.028	0.017	0.011	0.036	0.026	0.200	0.058	0.019	0.022	0.064	0.025	0.030	0.042	0.033
1980							0.094	0.041	0.033	0.017	0.017	0.026		

SUMMARY STATISTICS

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Nov-Apr	Annual
N	8.000							13.000	13.000	14.000	14.000	14.000	8.000	8.000
MEAN	0.076							0.080	0.059	0.076	0.042	0.086	0.141	0.081
ST. DEV.	0.0510							0.044	0.040	0.067	0.034	0.071	0.077	0.045

GENERAL NOTES

(1) Nov-Apr runoff coefficient is total Nov-Apr runoff divided by total Nov-Apr precipitation. It cannot be computed directly from runoff coefficients shown for these months.

(2) "SG- " indicates a staff gage; source is Exxon Minerals Company (1982).

Table 2.3
RUNOFF COEFFICIENTS FOR LAKE WATER-BALANCES

ITEM	Oct	Nov-Apr	May	June	July	Aug	Sept	Annual
Regional Average	0.45	0.54	0.32	0.23	0.23	0.19	0.28	0.31
Expected Values	0.15	0.24	0.16	0.12	0.13	0.09	0.12	0.14

2. Since coefficients for staff gage SG-8 are greatly affected by the large storage effect of the upstream lakes, the values for staff gage SG-5B are probably more representative of the lake study tributary areas.

3. Runoff coefficients for staff gage SG-5B are about 50 percent of the coefficients for concurrent 1978 and 1980 water years at Swamp Creek above Rice Lake. Because the 5-year average coefficient is considered more representative of average conditions than the lower-than-average coefficients for 1978 and 1980 water years, the expected runoff coefficients for the lake study tributary areas are judged to be 50 percent of the 5-year average coefficients for Swamp Creek above Rice Lake.

Expected runoff coefficients were used in preparing lake water balances for existing baseline conditions.

The expected runoff coefficients were applied by determining surface inflow to each of the study lakes as the product of the runoff coefficient for the month or season, the precipitation during the period, and the ratio of the effective watershed drainage area to the area of the lake. This computation was expressed by the following equation:

$$R = cP(DA/LA)$$

where R = Surface water runoff to lake, in inches
c = Runoff coefficient (dimensionless)
P = Precipitation, in inches
DA = Effective drainage area, in acres
LA = Effective lake area, in acres

Not all of each lake's watershed area contributes runoff. The areas used in water balance calculations are effective watershed areas, derived by subtracting the areas of major wetlands believed not to contribute runoff from the total area of each watershed. The effective areas are tabulated, and the basis for deriving them is described, in Appendix A.

In a similar way, the areas of some of the lakes were increased for purposes of water balance calculations by adding the areas of lakeside wetlands in which water levels follow the lake. This was done because these wetlands store water in much the same way as the lake basin. The added wetland areas are also tabulated in Appendix A.

2.3.4 Stream Outflow

Stream outflow for each month was computed from the lake level at the end of the previous month. To provide a starting point for these calculations, it was assumed that spring rain and snowmelt will fill the lake at the end of May. The level at the end of May is thus assumed to be known. This elevation is presented on the water balance tables.

Rating equations describing the relations between lake level and outflow rate at the outlets of Little Sand and Oak lakes were determined previously (Exxon Minerals Company, 1982, Appendix 2.4K). At Duck Lake, the staff gage measuring outflow rate is too far downstream from the outlet to reflect lake level. Therefore, a relation was derived on the basis of three discharge measurements for which simultaneous lake level measurements are available. At Deep Hole Lake, no outflow measurements are available; it was assumed that the relation is the same as at Little Sand Lake. No outflow occurs from Skunk Lake.

All relations are in the form used previously to describe stream flow and lake level relations (Exxon Minerals Company, 1982):

$$Q = (a(h-b))^c$$

where Q = Stream outflow rate, in cfs
a = An empirical constant
h = Lake surface elevation, in feet MSL
b = A constant, representing an elevation (in feet)
c = An empirical constant

Constants a, b, and c for each of the lakes, and information on their derivation, are provided in Appendix H.

Given the May lake level as a starting point, the June lake outflow rate for a lake (in cfs) was computed by substituting the May lake level into the level-outflow relation for that lake. The corresponding June outflow rate in inches was then computed as Q. The June lake level was then computed as described in the following section, and the process repeated from month to month to obtain outflow rates and lake levels for the remaining months. Comparison of computed outflows with available outflow measurements shows them to be within a reasonable range.

The May starting water level was determined for Little Sand, Oak, Duck, and Deep Hole lakes by adjusting the starting level until the total water level change for the average year was zero. The same starting level was then used for wet and dry year water balances for the same lake. This water level thus represents the long-term average lake level that is consistent with the other data in the water balance.

2.3.5 Lake Level Changes

The lake level change that occurred during a month was computed as the residual, or difference between all other water gains and losses during the same month. Lake level change was calculated for each month after calculation of the discharge for that month. In equation form (modified from Hutchinson, 1957), this-calculation is:

$$L = P + R - E - SO + S$$

where L = Lake level change, in inches (positive for rising lake level)
P = Precipitation, in inches
R = Surface water runoff, in inches on lake
E = Evaporation, in inches
SO = Stream outflow, in inches on lake
S = Seepage, in inches (negative if outward)

The actual lake level (in feet above MSL) was computed for the end of each month by adding the water level change computed for the current month to the lake water level at the end of the previous month. As with outflow calculations, this process began with the known May water level and proceeded from month to month to calculate water levels for the remainder of the year.

2.3.6 Seepage

The seepage rates used in computing annual water balances were the seepage rates computed as residuals in the short-term water balance studies. For Deep Hole Lake, where a short-term study was not possible, the rate was assumed to be the same as in Little Sand Lake. No corrections were made for changes in viscosity associated with water temperature changes, or for differences in lake and ground water level.

2.4 Seepage Meter Tests

Seepage meter tests were conducted at two locations in Little Sand Lake to verify that the technique was applicable to this lake, and to provide confirmatory information on seepage rates.

Many forms of seepage meters have been devised. Most are described in a review by Carr and Winter (1980). The type used at Little Sand Lake is shown in Figure 2.13. It is based on the design used extensively by Lee (1977) and Lee and Cherry (1978). It consists of a steel pan, made by cutting off the end of a 30-gallon steel drum (15.75 inches in diameter). A steel tube is installed through the pan's flat end. The tube has a valve on the top and a smaller copper tube installed through its side just below the valve.

In use, the valve is first opened to relieve water pressure that builds up inside the pan during installation. The pan is placed under water and completely filled. It is then inverted, so the pan opening is downward, and pushed a few inches into the lake bottom sediments. After the pan is installed, a thin plastic bag containing a measured volume of water is attached to the small tube. The bag is left attached for a period that typically ranges from 2 to 24 hours, depending on the seepage rates expected to be measured. If there is outward

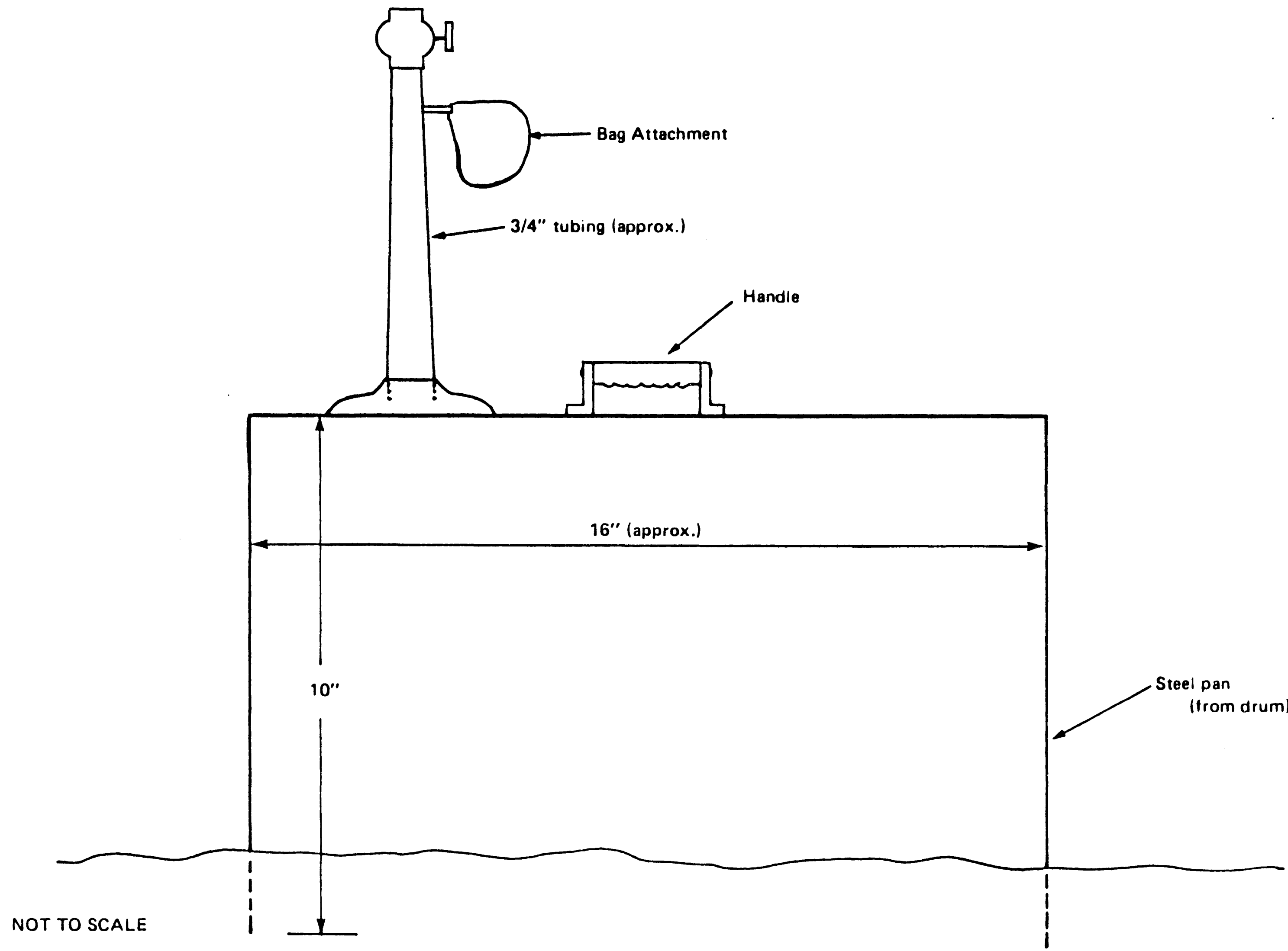


FIGURE 2.13
SEEPAGE METER SKETCH

Dames & Moore

seepage, the volume of water in the bag will decrease as water flows out of the bag to replace water lost from beneath the pan. Similarly, inward seepage will cause the bag volume to increase. The seepage rate can be calculated from the volume change in the bag, the time for which the bag was attached, and the pan area.

2.5 Minipiezometer Tests

Minipiezometer tests were made at a number of locations on Little Sand and Deep Hole lakes to verify that the method is workable in these lakes and to confirm that outward seepage measured by the seepage meters is outward everywhere in the lakes.

Minipiezometers are smaller versions of conventional wells or piezometers. They are designed to be installed by hand at shallow soil depths. A number of different forms are described by Carr and Winter (1980).

Data from two types of minipiezometers were used in this study. The type used by Dames & Moore consists of a 3-foot length of 3/8 inch stainless steel tubing. Five holes, 3/16 inch in diameter, are drilled near the bottom of the tube and a 60-mesh stainless steel screen is installed inside the tube to keep out sediment. The opening at the end is sealed with the head of a round-headed steel screw that is epoxied in place and ground to conform to the outside of the tube. The minipiezometer is installed by pushing it into the sediments.

The type used by the Wisconsin Department of Natural Resources (DNR) consists of a semi-rigid plastic tube about 3/8 inch in diameter with holes at its lower end covered by a fine-mesh nylon cloth. To install, a steel pipe whose end is capped with a short, loose-fitting steel bolt is pounded into the sediments. The piezometer tube is inserted into the pipe and the pipe is then withdrawn, leaving the bolt and the minipiezometer in place.

After installation, the water level is allowed to stabilize in the minipiezometers before measurement. The most important information from the minipiezometers is whether the stabilized water level is above or below lake level. A level below lake level implies outward seepage, and a level above lake level implies inward seepage.

Practical difficulties resulted from the fine texture of lake-bed sediments at some of the test locations. Soils a few inches below the lake bed were often a mixture of fine sand and silt, and had permeabilities so low that minipiezometer water levels would not stabilize within a reasonable time. It was thus practical to obtain measurements at only some of the locations.

3.0 RELATIONS BETWEEN LAKES AND GROUND WATER

3.1 Comparison of Lake and Ground Water Levels

The potentiometric contour map shown as Figure 3.1 (STS Consultants, 1984b) and the potentiometric levels from lake piezometers presented in Table 3.1 (Exxon Minerals Company, 1982) show all lake elevations to be measurably above the level of nearby ground water. This elevation difference indicates clearly that seepage is outward from lakes to ground water, and that a layer of low permeability lies between them. The actual rate of seepage will depend on the permeability of soils between lakes and ground water as well as on the head difference. The nature of subsurface soils near the lakes is shown in the cross sections presented as Figures 3.2 through 3.6.

This conclusion is based on comparison of numerous measurements of lake and ground water levels. Levels of Little Sand, Oak, Duck, Skunk, and Deep Hole lakes were measured discontinuously from April, 1977 to November, 1980 (Exxon Minerals Company, 1982). Ground water levels were measured discontinuously from May, 1977 to January, 1985 and the data were tabulated by Exxon Minerals Company. Ground water levels measured in all accessible wells during April and May, 1984, were used to develop a potentiometric surface map of the site area, presented

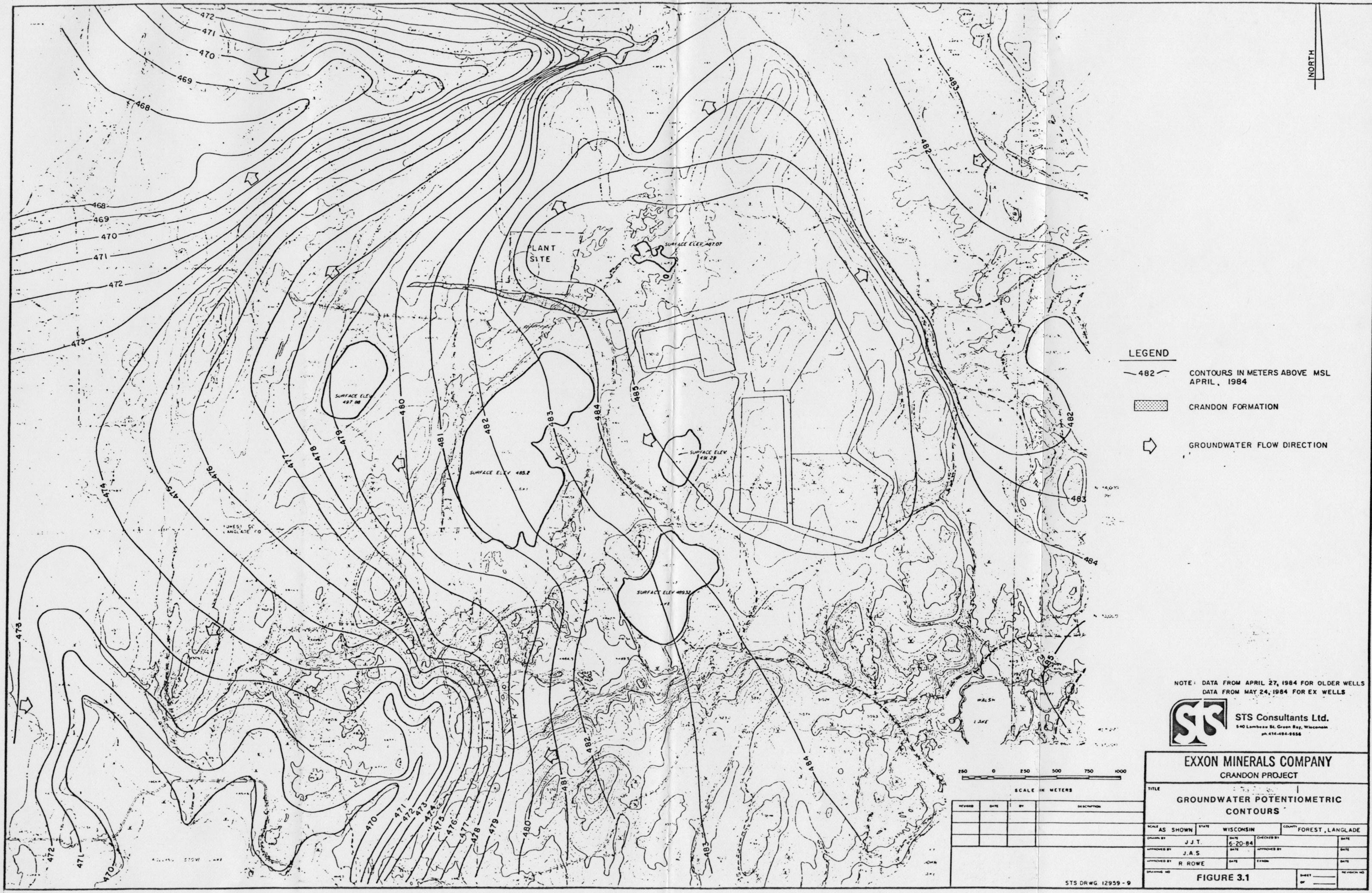

NORTH
PLANT SITE
SURFACE ELEV 497.07
SURFACE ELEV 497.98
SURFACE ELEV 483.2
SURFACE ELEV 491.29
SURFACE ELEV 489.32
WALSH LAKE
LEGEND
482 CONTOURS IN METERS ABOVE MSL APRIL, 1984
CRANDON FORMATION
GROUNDWATER FLOW DIRECTION
NOTE: DATA FROM APRIL 27, 1984 FOR OLDER WELLS
DATA FROM MAY 24, 1984 FOR EX WELLS
STS Consultants Ltd.
SCALE IN METERS
250 0 250 500 750 1000
EXXON MINERALS COMPANY
CRANDON PROJECT
GROUNDWATER POTENTIOMETRIC CONTOURS
AS SHOWN
WISCONSIN
FOREST, LANGLADE
J.J.T.
6-20-84
J.A.S
R ROWE
FIGURE 3.1
STS DRWG 12959-9

Table 3.1

SELECTED WATER SURFACE ELEVATIONS (msl)

Lake	Lake Surface (feet) Lowest (date)	Highest (date)	Level Change	September 1980	Underlying Potentiometric Elevation (feet) September 1980	Lake/Water Table Difference (feet)
Little Sand	1590.82 (7-30-77)	1592.96 (4-20-79)	2.14	1591.80 (9-10-80)	1587	5
Oak	1632.11 (8-03-77)	1634.21 (4-21-79)	2.20	1632.69 (9-11-80)	1574	59
Duck	1610.23 (7-29-77)	1612.32 (7-20-80)	2.09	1611.56 (9-11-80)	1590	22
Deep Hole	1604.96 (7-30-77)	1607.10 (4-21-79)	2.14	1605.79 (9-10-80)	1588	18
Skunk	1596.48 (10-30-77)	1598.26 (5-16-80)	1.78	1597.49 (9-11-80)	1594	3

SOURCE: Exxon Minerals Company (1982).

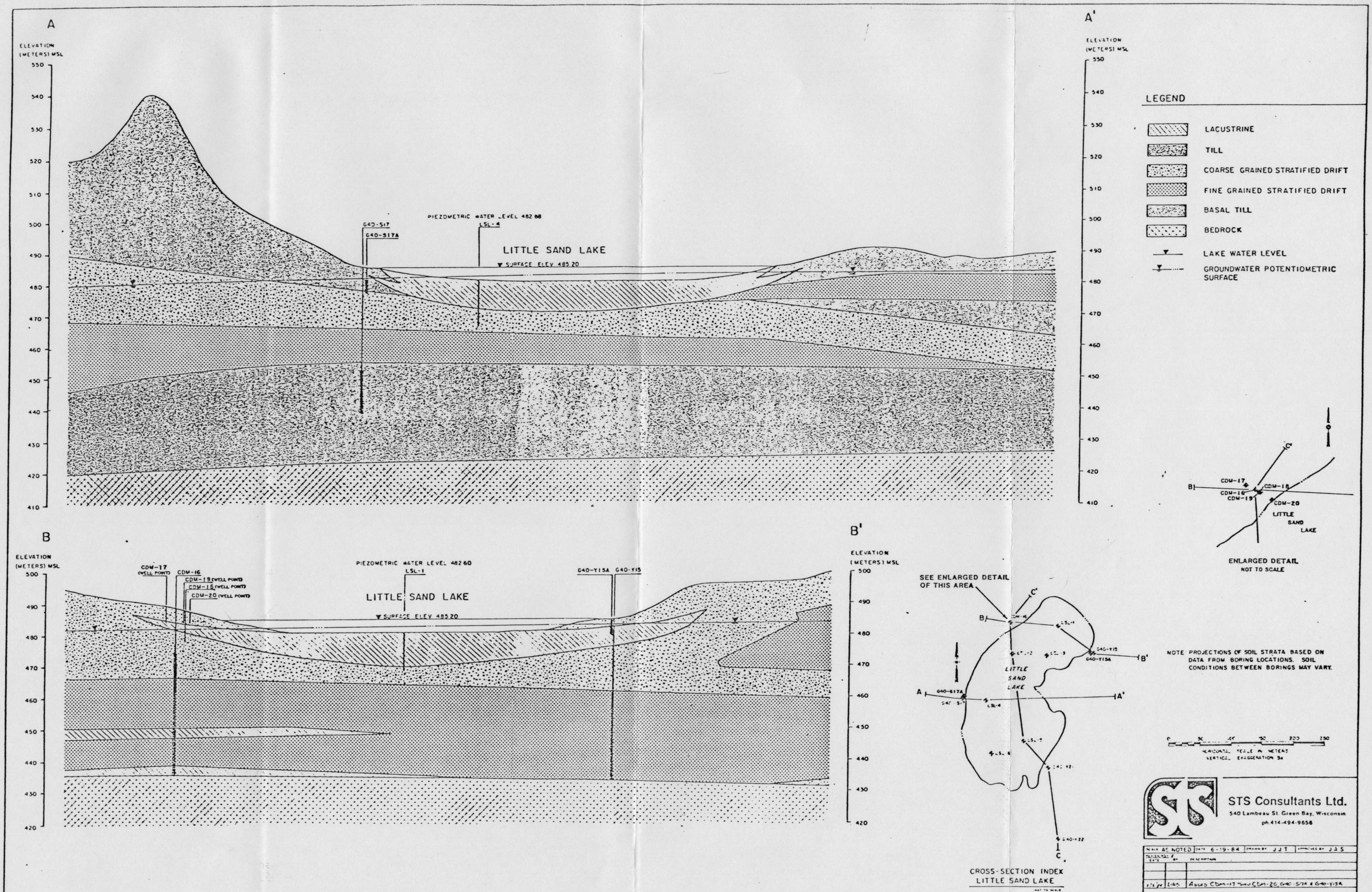


FIGURE 3.2

EXPANDED GEOLOGIC CROSS-SECTIONS OF LITTLE SAND LAKE

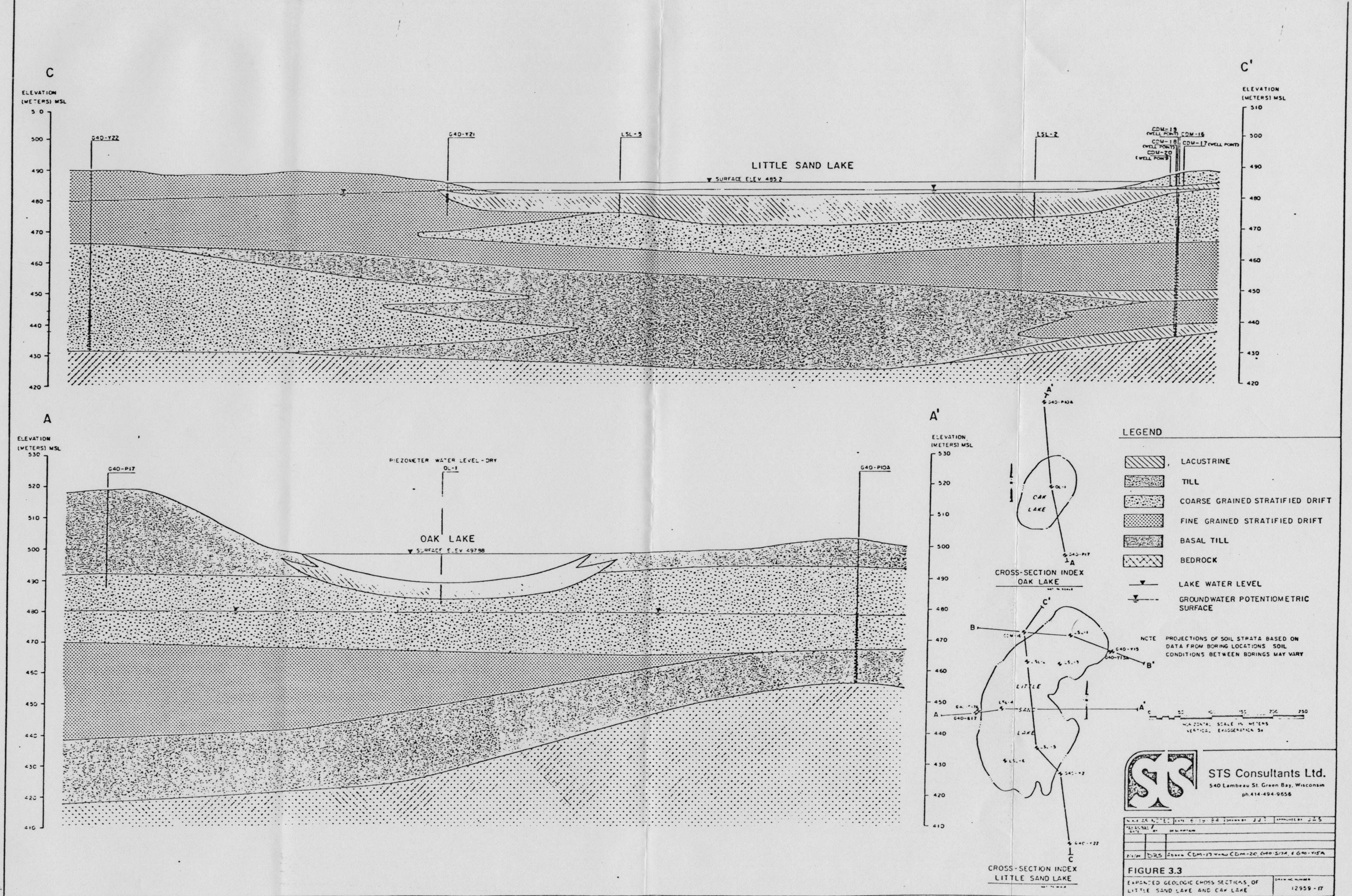
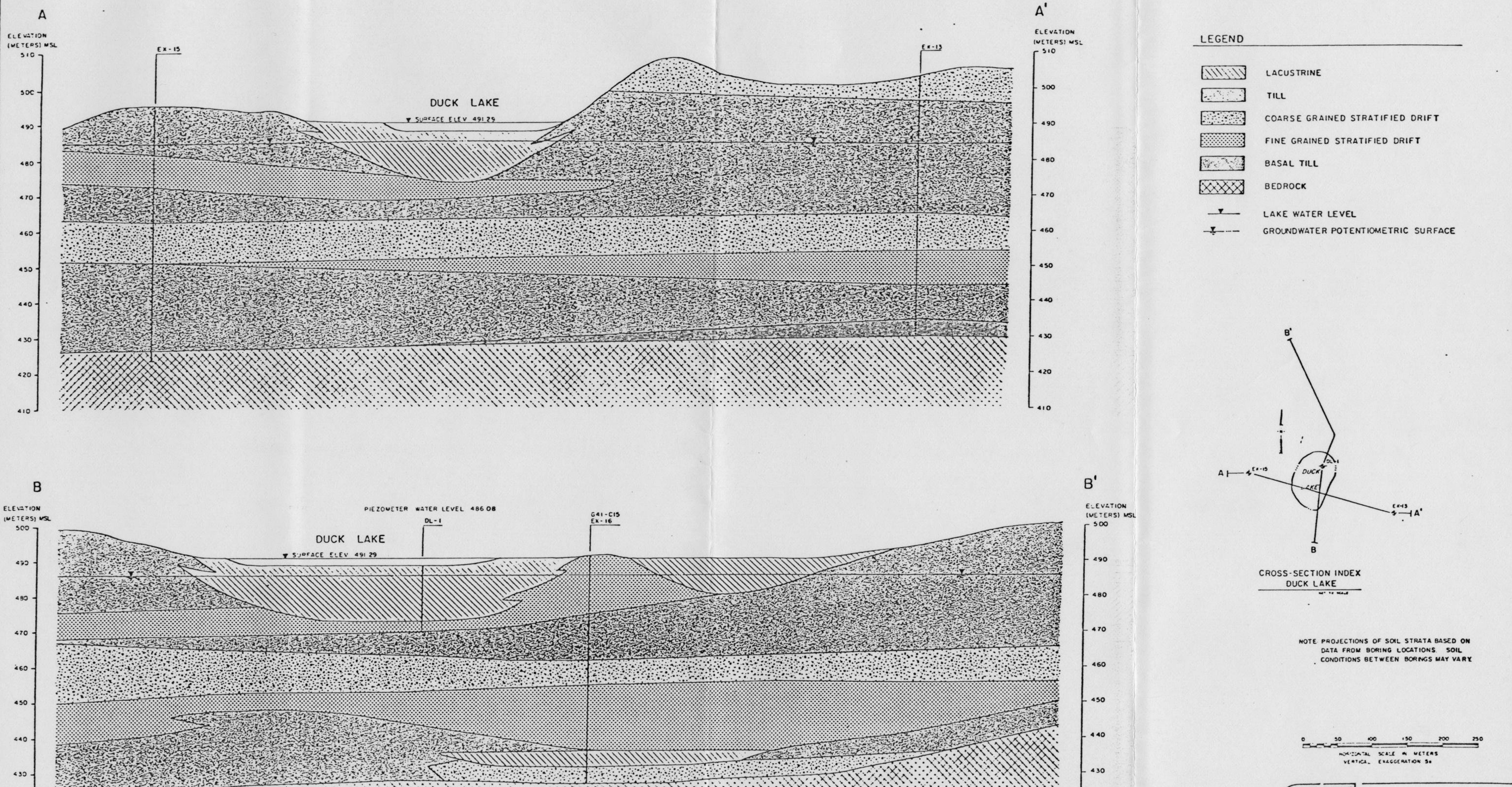


FIGURE 3.3

EXPANDED GEOLOGIC CROSS SECTIONS OF LITTLE SAND LAKE AND OAK LAKE



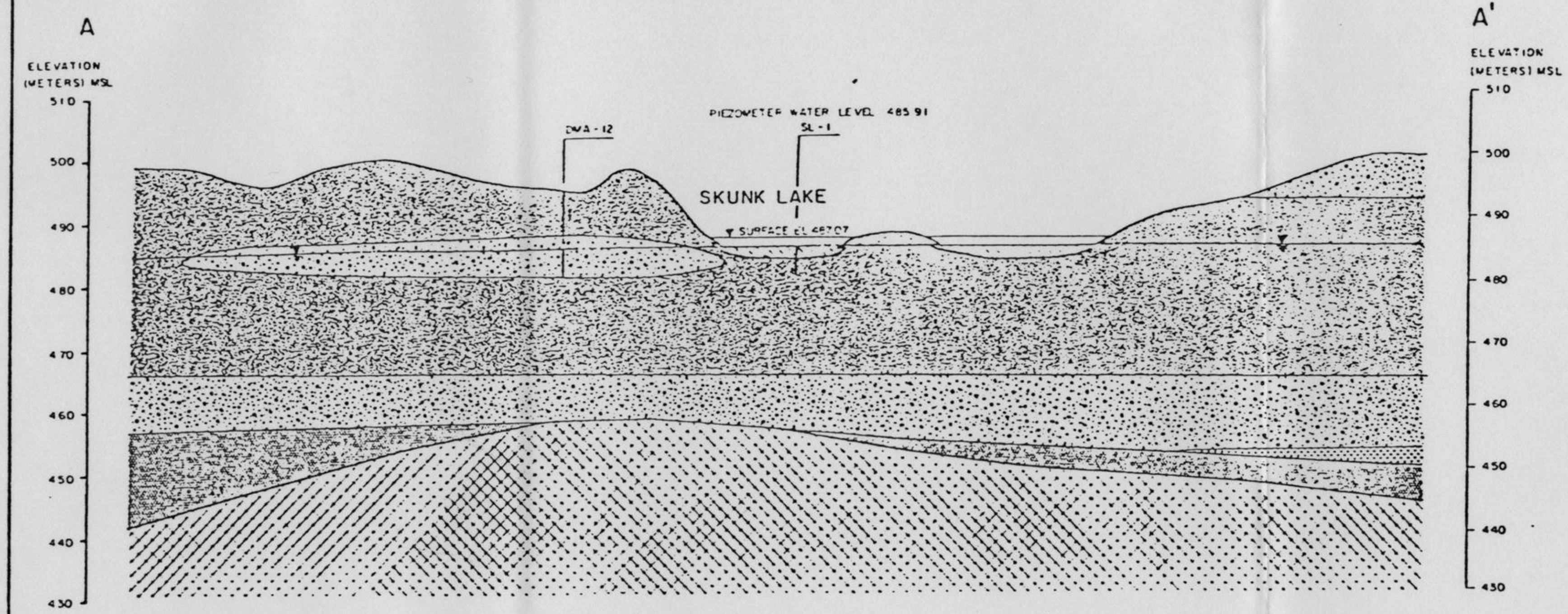
STS Consultants Ltd.
540 Lambeau St. Green Bay, Wisconsin
ph.414-494-9656

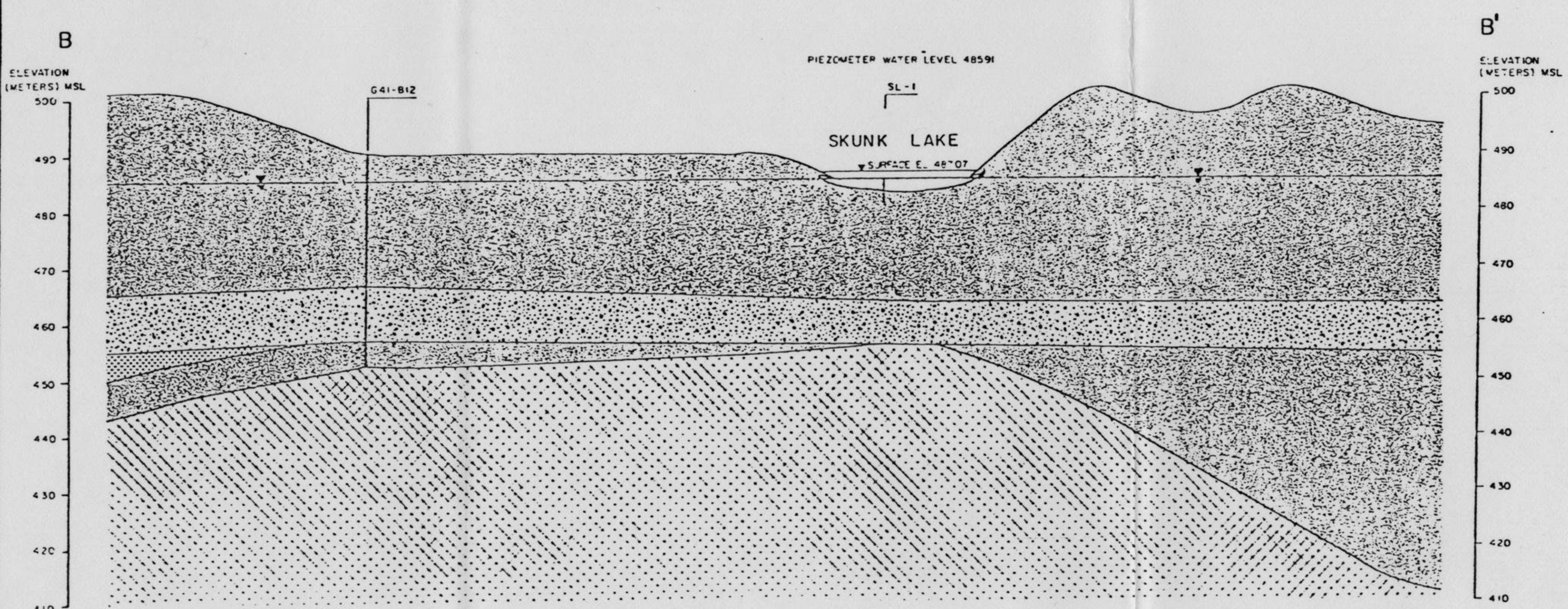
DATE 6-15-84 | DRAWN BY JJT | APPROVED BY JAS

FIGURE 3.4

EXPANDED GEOLOGIC CROSS-SECTIONS OF DUCK LAKE

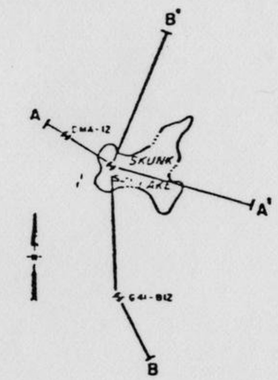
DRAWING NUMBER 12959-15





LEGEND

- LACUSTRINE
- TILL
- COARSE GRAINED STRATIFIED DRIFT
- FINE GRAINED STRATIFIED DRIFT
- BASAL TILL
- BEDROCK
- LAKE WATER LEVEL
- GROUNDWATER POTENTIOMETRIC SURFACE



CROSS-SECTION INDEX
SKUNK LAKE

NOT TO SCALE

NOTE: PROJECTIONS OF SOIL STRATA BASED ON DATA FROM BORING LOCATIONS. SOIL CONDITIONS BETWEEN BORING MAY VARY

0 50 100 150 200 250

HORIZONTAL SCALE IN METERS
VERTICAL EXAGGERATION 5x

STS Consultants Ltd.
540 Lambeau St. Green Bay, Wisconsin
ph.414-494-9656

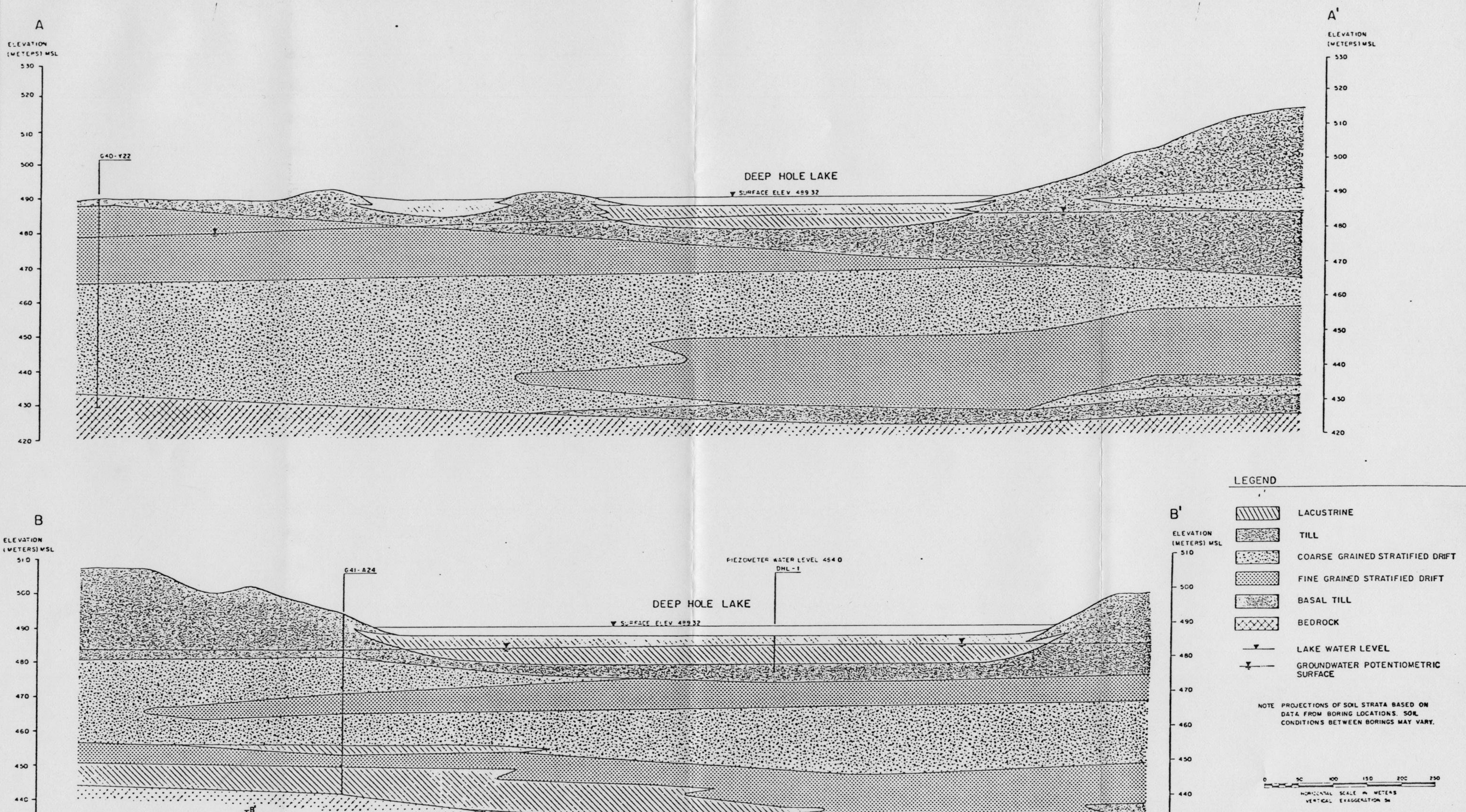
SCALE AS NOTED	DATE 6-18-84	DRAWN BY JJT	APPROVED BY JAS

REVISIONS: DATE | BY | DESCRIPTION

FIGURE 3.5

EXPANDED GEOLOGIC CROSS-SECTIONS OF SKUNK LAKE

DRAWING NUMBER 12955-13



STS Consultants Ltd.
540 Lambeau St. Green Bay, Wisconsin
ph.414-494-9656

DATE 6-19-94 | DRAWN BY JJT | APPROVED BY JAS

FIGURE 3.6

EXPANDED GEOLOGIC CROSS-SECTIONS OF DEEP HOLE LAKE

DRAWING NUMBER 12959-14

here as Figure 3.1 (STS Consultants, 1984b). Selected lake and ground water elevations from September, 1980, together with 1977-80 extremes of lake levels, are shown in Table 3.1 in order to allow comparisons for a specific date.

The possibility that unusually high short-term lake levels together with low ground water levels might lead to erroneous conclusions was considered. Lowest observed lake levels were above the maximum recorded nearby ground water levels at all lakes. Specific information supporting this conclusion for each lake is as follows:

1. Little Sand Lake had a recorded low surface elevation of 1590.82 feet. Monitoring well DMP-2, about 80 m (260 ft) from the north lake shore (Figure 2.1), had a recorded high water elevation of 1587.99 feet, or 0.86 m (2.83 feet) lower. In terms of the general piezometric surface shown in Figure 3.1, this well is located upgradient from the lake; this is the position where seepage into the lake would be most likely if, in fact, it ever occurs. Measurements of this well from September, 1980 to October, 1984 show a total fluctuation of 1.06 m (3.48 feet). Figure 3.1 shows the highest piezometric surface elevation beneath the lake of 484 m (1588 feet) near the northeastern lake shore; this is about 1 m (3 feet) below the lowest lake level. Inward seepage thus appears unlikely, considering the fact that low ground water and lake levels are likely to occur within the same

general dry periods. Outward gradients are confirmed by four wells (LSL-1, 2, 4, and 6) installed through the lake bottom sediments. Their levels ranged from 7.21 to 11.05 feet below lake level (STS Consultants, 1982).

2. Oak Lake had a recorded low surface elevation of 1632.11 feet, approximately 18 m (59 feet) above the nearby ground water level shown in Figure 3.1. A monitoring well (DMA-3), about 140 m (460 feet) upgradient of the lake was dry to its screened elevation of 1603 feet, which is approximately at the level of the lake bottom as shown in the cross section, Figure 3.3. A well (OL-1) installed through the lake bottom sediments into underlying sandy drift was dry, indicating that the lake is underlain by unsaturated materials, and that the difference between lake and ground water levels was greater than 44.1 feet directly beneath the lake (STS Consultants, 1984a). Another nearby well (DMB-15) has a recorded water level fluctuation of 0.37 m (1.2 feet). These data indicate that Oak Lake is far above the normal position of the main ground water aquifer piezometric surface, and that piezometric surface fluctuations are much too small to raise the piezometric surface above lake level. Therefore, Oak Lake never receives inward seepage from the main aquifer.

3. The same situation occurs at Duck Lake, where the lowest recorded lake elevation of 1610.23 feet is approximately 5.8

m (19 feet) above the aquifer potentiometric surface elevation of 485 m (1591 feet) shown in Figure 3.1. The nearest upgradient well (G41-C15B) is about 50 m (164 feet) away and had a recorded water elevation of 1592.4 feet, or 17.8 feet below lake level. A well (DL-1) installed through the lake sediments had a water level 17.1 feet below lake level (STS Consultants, 1984a). The greatest level fluctuation recorded in nearby wells is 0.37 m (1.2 feet) for DMA-4 (approximately 140 m (460 feet) southwest).

4. At Skunk Lake, the lowest recorded lake elevation is 1596.48 feet. Figure 3.1 shows potentiometric surface elevation of about 486 m (1594 feet), or about 0.8 m (2.6 feet) lower. More direct information is from the well (STS-SL-1) installed through lake bottom sediments (STS Consultants, 1984a). Its level was 1.16 m (3.8 feet) below that of the lake. The closest onshore well, DMA-12, is downgradient; it had maximum water elevation of 1595.21 feet from September, 1980 to October, 1984, or 0.39 m (1.27 feet) below the lowest recorded lake elevation of 1596.48 feet.

5. Deep Hole Lake had a minimum recorded surface elevation of 1604.96 feet. The highest point on the potentiometric surface shown in Figure 3.1 beneath the lake was about 1589 feet, or 16 feet lower. Monitoring well DMB-27, about 400 m (1300 feet) east of the lake had a recorded high water elevation of 1588.1 feet, which is 5.15 m (16.9 feet) below

the lowest recorded lake elevation. A well (DHL-1) installed through the bottom sediments had a water level 18.6 feet below lake level (STS Consultants, 1984a).

In Little Sand and Deep Hole lakes, additional evidence of downward gradients was provided by minipiezometer tests. In all locations where tests gave meaningful results, they indicated downward hydraulic gradients. Similar tests by State of Wisconsin personnel, described in two letters included as Appendix J, show downward gradients at seven locations along the west shore of Little Sand Lake, and no measurable gradient either in or out at one location. This may have been due to very fine sediments which would have required a longer time than was available for water level stabilization in the minipiezometer, rather than to an actual lack of gradient.

Nests of piezometers completed at different depths were installed at several locations near lake shores (Exxon Minerals Company, 1982). An example is the group of piezometers CDM-16, 17, 18, 19, and 20, slightly north of Little Sand Lake. These nests show downward gradients, that is, higher water levels in the shallower piezometers. This observation supports the conclusion that seepage is outward from the lakes; the observed head gradients are associated with water moving downward from the lakes to the main piezometric surface.

3.2 Lake-Bottom Soils

During March, 1982, STS Consultants installed six wells and sampled lake sediments in Little Sand Lake (STS Consultants, Ltd., 1982). Similar borings and well installations were carried out in Oak, Duck, Skunk, and Deep Hole lakes in February, 1984 (STS Consultants, Ltd., 1984a). Table 3.2 presents laboratory testing results from all lakes. Thickness of lake sediments and the differences between lake levels and ground water levels in the glacial materials beneath the lake sediments are summarized in Table 3.3.

Lake sediment permeabilities are in the range from 4.3E-8 to 2.3E-6 cm/s, with a median of 2.6E-7 cm/s (Table 3.2). Most values are in the range of 1.0E-7 cm/s to 7.3E-7 cm/s. These permeabilities are very low, much less than those of materials that form the area aquifer.

Figures 3.2 through 3.6 show geologic cross sections through the lakes and their underlying soils, including both lake basin sediments and the glacial soils beneath them. Data for these cross sections were derived from the lake boring program and from borings previously conducted on the shore.

These sections show that the lakes lie in basins in the glacial soils, the basins being partly filled with very fine lacustrine sediments. These were formed in part by deposition of

Table 3.2

SUMMARY OF LABORATORY TEST RESULTS FROM LAKE DRILLING PROGRAMS IN DUCK, SKUNK, OAK, DEEP HOLE, AND LITTLE SAND LAKES

BORING NUMBER	SAMPLE NUMBER	DEPTH (feet)	WATER CONTENT (%)	DRY UNIT WEIGHT (pcf)	ORGANIC CONTENT (%)	PERCENT P-200	PERCENT CLAY[a]	ATTERBERG LIMITS (%) LL	PL	PI	USCS CLASSIFICATION	PERMEABILITY COEFFICIENT (cm/s)
DL-1	10	25.5 - 28.0	19.9	104.	--	78.	--	--	--	--	(CL)	1.3×10^{-6}
DL-1	15	38.0 - 40.0	28.7	99.	1.4	93.	--	30.4	21.3	9.1	(CL)	1.0×10^{-7}
SL-2	1A	9.1 - 10.0	20.6	108.	1.8	93.	--	31.9	19.5	12.4	(CL)	4.3×10^{-8}
OL-1	4	37.5 - 39.5	27.2	103.	--	88.	--	--	--	--	(CL)	2.3×10^{-6}
OL-1	6	42.5 - 44.5	32.4	101.	0.7	93.	--	29.2	21.1	8.1	(CL)	3.5×10^{-7}
DHL-1	6	21.0 - 23.0	43.6	95.	1.7	95.	--	28.8	25.0	3.8	(ML)	6.8×10^{-7}
DHL-1	11	33.5 - 35.2	35.2	92.	--	88.	--	--	--	--	(ML)	6.8×10^{-8}
LSL-1	9[b]	30.0 - 32.0	51.5	73.1	--	99.2	14.0	37.1	11.8	25.3	--	1.4×10^{-7}
LSL-1	15	44.5 - 47.0	33.6	88.6	--	94.4	19.0	--	--	--	--	1.7×10^{-7}
LSL-2	5	24.5 - 26.5	36.6	80.0	--	97.7	11.5	--	--	--	--	7.3×10^{-7}
LSL-2	12	39.0 - 40.5	--	--	--	4.6	0.0	--	--	--	--	--
LSL-3	8	28.0 - 30.0	56.3	67.1	--	99.0	19.0	--	--	--	--	3.7×10^{-7}
LSL-3	12	37.0 - 39.0	35.9	87.8	--	99.5	15.0	--	--	--	--	1.5×10^{-7}
LSL-3	15	43.5 - 45.0	--	--	--	4.2	0.0	--	--	--	--	--
LSL-4	9	30.5 - 32.5	43.3	81.0	0.8	96.8	15.0	32.0	15.8	16.2	--	1.1×10^{-7}
LSL-4	16	45.5 - 47.0	--	--	--	18.7	--	--	--	--	--	--
LSL-5	5	20.0 - 22.0	45.7	78.5	--	98.4	17.0	--	--	--	--	1.6×10^{-4} [c]
LSL-5	9	28.0 - 30.0	37.3	84.5	--	96.8	19.0	--	--	--	--	1.5×10^{-7}
LSL-6	4	16.0 - 18.0	107.4	41.8	5.4	93.3	8.0	115.3	62.6	52.7	--	3.7×10^{-7}
LSL-6	10	28.0 - 30.0	34.8	86.8	--	98.3	19.0	--	--	--	--	1.6×10^{-6}

[a] Percent clay based on 0.005 mm size.

[b] Specific gravity = 2.66.

[c] Erroneous permeability coefficient due to side channeling.

Table 3.3

LAKE BORING DATA

Lake	Well No. (date)*	Depth to Ground Water From Lake Surface (feet)	Measured Lake Sediment Thickness (feet)	Source
Little Sand	LSL-1 (3-18-82)	8.58 (3-22-82)	37.5	STS, 1982
	LSL-2 (3-22-82)	7.21 (3-23-82)	27.5	STS, 1982
	LSL-3 (3-19-82)		30.5	STS, 1982
	LSL-4 (3-21-82)	8.27 (3-23-82)	30.6	STS, 1982
	LSL-5 (3-20-82)		19.0	STS, 1982
	LSL-6 (3-20-82)	11.05 (3-22-82)	22.0	STS, 1982
Duck	DL-1 (2-08-84)	17.1 (2-28-84)	47.5	STS, 1984a
Skunk	SL-1 (2-09-84)	3.8 (2-27-84)	6.3	STS, 1984a
	SL-2 (2-27-84)		6.0	STS, 1984a
Oak	OL-1 (2-10-84)	Over 44.1 (dry on 2-23-84)	16.9	STS, 1984a
Deep Hole	DHL-1 (2-13-84)	18.6 (2-23-84)	26.8	STS, 1984a

* Installation date.

fine materials during and after glaciation (STS Consultants, 1984b).

4.0 WATER BALANCES

4.1 Short-Term Water Balances

The results of the short-term water balance study are presented in Table 4.1 for Little Sand, Oak, Duck, and Skunk lakes.

A water balance is an accounting of a lake's total gains and losses of water. The relations among the water balance components are most easily explained in the form of an equation. Because seepage was computed as a residual in the short-term study, the water balance equation was used in this form, modified from Hutchinson (1957):

$$P + SI - E - SO - L = -S$$

where P = Precipitation
SI = Stream inflow
E = Evaporation
SO = Stream outflow
L = Lake level change
S = Seepage

In this equation, the quantities that were measured in the field are shown on the left side of the equation. Losses of water (E and SO) are subtracted from the gains (P and SI). Lake level may rise or fall. The convention is used in this equation that a

Table 4.1
SHORT-TERM LAKE WATER BALANCES
FROM
JANUARY 1985 FIELD MEASUREMENTS

	LITTLE SAND	OAK LAKE	DUCK LAKE	SKUNK LAKE
Area (acres)	244.1	52.3	78.7	8.8
Start Date	12-Jan-85	17-Jan-85	13-Jan-85	13-Jan-85
Start Time	938	1245	1045	1128
End Date	31-Jan-85	31-Jan-85	26-Jan-85	23-Jan-85
End Time	851	826	954	1051
Days	18.90	13.55	12.90	9.91
Evap. Rate (mm/day)	0.20	0.20	0.20	0.20
GAINS				
Precipitation (mm)	7.2	4.5	6.2	5.6
Stream (mean, cfs)	0.086	0.000	0.000	0.000
Stream (mm)	4.0	0.0	0.0	0.0
TOTAL (mm)	11.2	4.5	6.2	5.6
LOSSES				
Evaporation (mm)	3.8	2.7	2.6	2.0
Stream (mean, cfs)	0.085	0.000	0.077	0.000
Stream (mm)	4.0	0.0	7.6	0.0
TOTAL (mm)	7.8	2.7	10.2	2.0
LAKE STORAGE				
Hook Gage Start (mm)	61.7	57.3	77.8	70.8
Hook Gage End (mm)	68.7	64.1	100.9	94.6
NET LEVEL CHANGE (mm)	-7	-6.8	-23.1	-23.8
SEEPAGE (Residual) (mm)	-10.5	-8.6	-19.1	-27.4
Seepage rate (mm/day)	-0.6	-0.6	-1.5	-2.8
Annual seepage (mm)	-202.2	-231.5	-540.4	-1010.3
Annual seepage (in.)	-8.0	-9.1	-21.3	-39.8

GENERAL NOTES--
(1) Gage readings from Little Sand Lake are from west side of lake.
Readings from east side gage were used for confirmation but are not shown.
(2) Annual seepage is simple extrapolation from test period
(3) No corrections were made for viscosity or head changes during year.

rising lake level corresponds to positive values of lake level change, and a falling level to negative values. This requires that the lake level be subtracted. Seepage, on the right side of the equation, is obtained as the sum of gains, losses, and lake level change. Seepage has a minus sign in the equation because of the convention that inward seepage is positive and outward seepage negative.

The possible range of uncertainty in the short-term water balances was examined. Results are presented in Appendix I. This appendix contains four tables, each of which includes three separate water balances for each lake. The first water balance in each table uses the field values of water balance components that were presented in Table 4.1. In the other two, values are adjusted to estimate the maximum and minimum seepage that are consistent with the available data. Maximum and minimum estimates were obtained by estimating the maximum probable uncertainty in each measured water balance component, either as a percentage or a value, then adjusting individual components upward or downward by these amounts to produce the maximum or minimum calculated residual seepage.

4.2 Annual Water Balances

Annual water balances were computed for all five lakes for wet, dry, and average years. The data used in preparing them were described previously.

Annual water balances for Little Sand, Oak, Duck, Skunk, and Deep Hole lakes are presented as Tables 4.2 to 4.17. Table 4.2 is a summary table showing the principal facts from the other tables. Tables 4.3 through 4.17 present annual water balances for wet, dry, and average years, broken down by month.

The relations between the water balance components are most easily explained by the equation (modified from Hutchinson, 1957):

$$P + R - E - SO + S = L$$

where P = Precipitation
R = Surface water runoff, including stream inflow and overland runoff
E = Evaporation
SO = Stream outflow
S = Seepage
L = Lake level change

This equation differs slightly from that used to represent the short-term water balances. Here, R (surface water runoff) takes the place of SI (stream inflow) because of the need to include overland runoff; this did not occur during the short-term study because of freezing temperatures. Lake level change is shown as the residual, on the right side of the equation, because it is computed from the other components for each month.

The procedure for interpreting annual water balances was described earlier in terms of the individual components

TABLE 4.2

SUMMARY OF ANNUAL WATER BALANCES

	LITTLE SAND LAKE			OAK LAKE			DUCK LAKE		
	Wet	Dry	Average	Wet	Dry	Average	Wet	Dry	Ave
GAINS									
Precipitation	41.23	22.80	30.71	41.23	22.80	30.71	41.23	22.80	30.71
Runoff	49.39	28.95	37.28	32.57	19.08	24.58	25.11	14.71	18.95
TOTAL	90.62	51.75	67.99	73.80	41.88	55.29	66.34	37.51	49.66
LOSSES									
Evaporation	22.77	29.06	25.69	22.77	29.06	25.69	22.77	29.06	25.69
Outflow	55.10	18.37	34.30	37.80	5.41	20.49	15.90	0.26	2.67
TOTAL	77.86	47.44	59.99	60.57	34.47	46.17	38.67	29.33	28.36
LAKE STORAGE	4.76	-3.69	.00	4.11	-1.69	.00	6.37	-13.11	.00
SEEPAGE	-8.00	-8.00	-8.00	-9.10	-9.10	-9.10	-21.30	-21.30	-21.30
LAKE LEVEL									
Start (May) (ft)	1591.7820	1591.7820	1591.7820	1633.1930	1633.1930	1633.1930	1611.0580	1611.0580	1611.0580
Maximum	1592.2	1591.8	1591.8	1633.6	1633.2	1633.4	1611.7	1611.1	1611.2
Minimum	1591.4	1591.3	1591.5	1632.8	1632.8	1633.1	1611.0	1610.1	1610.9
Range (ft)	0.8	0.5	0.3	0.8	0.4	0.3	0.7	1.0	0.3

	SKUNK LAKE			DEEP HOLE LAKE		
	Wet	Dry	Average	Wet	Dry	Average
GAINS						
Precipitation	41.23	22.80	30.71	41.23	22.80	30.71
Runoff	46.08	27.00	34.78	44.37	26.01	33.49
TOTAL	87.31	49.80	65.49	85.60	48.81	64.20
LOSSES						
Evaporation	22.77	29.06	25.69	22.77	29.06	25.69
Outflow	0.00	0.00	0.00	50.49	15.11	30.51
TOTAL	22.77	29.06	25.69	73.25	44.18	56.20
LAKE STORAGE	24.74	-19.06	.00	4.35	-3.37	.00
SEEPAGE	-39.80	-39.80	-39.80	-8.00	-8.00	-8.00
LAKE LEVEL						
Start (May) (ft)	1598.0900	1598.0900	1598.0900	1606.5145	1606.5145	1606.5145
Maximum (ft)	1599.7	1598.1	1598.3	1606.9	1606.5	1606.6
Minimum (ft)	1598.1	1596.7	1598.1	1606.2	1606.0	1606.2
Range (ft)	1.6	1.4	0.2	0.7	0.5	0.4

GENERAL NOTES
(1) Units are inches of lake level except as indicated.
(2) Negative lake storage values indicate fall in water level.
(3) Negative seepage values indicate outward seepage.
(4) Derivation of values is explained in notes to Tables 4.3 through 4.17 and in text.

Table 4.3

ANNUAL WATER BALANCE, LITTLE SAND LAKE

WET YEAR (MEAN OF FIVE WETTEST WATER YEARS)

Lake area (ac)=	244.1
Watershed area (ac)=	2519
Effective area (ac) =	1866.5

ESTIMATED WATER BALANCE COMPONENTS==========

GAINS	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	YEAR
Precipitation	3.37	2.08	1.54	0.77	0.77	2.85	2.69	5.52	4.65	6.02	5.14	5.83	41.23
Runoff coeff.	0.15	0.24	0.24	0.24	0.24	0.24	0.24	0.16	0.12	0.13	0.09	0.12	
Runoff	3.87	3.82	2.83	1.41	1.41	5.23	4.94	6.75	4.27	5.98	3.54	5.35	49.39
TOTAL	7.24	5.90	4.37	2.18	2.18	8.08	7.63	12.27	8.92	12.00	8.68	11.18	90.62
LOSSES													
Evaporation	1.36	0.87	0.87	0.87	0.87	0.87	0.87	3.42	3.93	3.96	2.96	1.90	22.77
Outflow (cfs)	3.37	1.32	1.45	1.05	0.58	0.43	1.53	2.10	1.17	1.41	2.67	1.51	
Outflow (in.)	9.98	3.91	4.31	3.11	1.71	1.29	4.53	6.22	3.47	4.18	7.92	4.48	55.10
TOTAL	11.34	4.78	5.18	3.98	2.58	2.16	5.40	9.64	7.40	8.14	10.88	6.38	77.86
LAKE STORAGE	-4.77	0.45	-1.48	-2.47	-1.07	5.25	1.56	1.97	0.85	3.20	-2.87	4.13	4.76
LAKE LEVEL (ft)	1591.8	1591.9	1591.7	1591.5	1591.4	1591.9	1592.0	1591.8	1591.9	1592.1	1591.9	1592.2	
SEEPAGE	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-8.00

GENERAL NOTES

(1) Units are inches of lake level unless otherwise specified
(2) Runoff=Precip (in.) * Runoff Coeff. * Effective watershed area (ac.) / Lake area (ac.)
(3) Evaporation Nov-Apr estimated from measured evaporation during remainder of year.
(4) Negative lake storage values indicate fall in water level.
(5) Negative seepage values indicate outward seepage.
(6) Seepage is value from short-term study.
(7) Ordinary High Water Mark = 1591.96 feet.
(8) May level= 1591.7820 feet at start of lake level calculations
(9) Outflow (cfs) = $[0.58(L-1590)]^{4.76}$ where L = Lake level in feet.

Table 4.4

ANNUAL WATER BALANCE, LITTLE SAND LAKE
DRY YEAR (MEAN OF FIVE DRIEST WATER YEARS)

Lake area (ac)=	244.1
Watershed area (ac)=	2519
Effective area (ac) =	1866.5

ESTIMATED WATER BALANCE COMPONENTS==========

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	YEAR
GAINS													
Precipitation	1.44	2.22	1.18	1.11	0.72	1.23	1.65	2.35	3.03	2.52	2.87	2.48	22.80
Runoff coeff.	0.15	0.24	0.24	0.24	0.24	0.24	0.24	0.16	0.12	0.13	0.09	0.12	
Runoff	1.65	4.07	2.17	2.04	1.32	2.26	3.03	2.88	2.78	2.50	1.98	2.28	28.95
TOTAL	3.09	6.29	3.35	3.15	2.04	3.49	4.68	5.23	5.81	5.02	4.85	4.76	51.75
LOSSES													
Evaporation	1.94	1.11	1.11	1.11	1.11	1.11	1.11	3.91	4.77	5.21	4.02	2.53	29.06
Outflow (cfs)	0.30	0.26	0.73	0.63	0.55	0.38	0.45	0.67	1.17	0.56	0.28	0.23	
Outflow (in.)	0.88	0.78	2.16	1.86	1.64	1.13	1.32	2.00	3.47	1.65	0.82	0.67	18.37
TOTAL	2.82	1.89	3.28	2.98	2.75	2.24	2.44	5.91	8.24	6.86	4.84	3.20	47.44
LAKE STORAGE	-0.39	3.73	-0.60	-0.50	-1.38	0.58	1.57	-1.35	-3.09	-2.50	-0.66	0.89	-3.69
LAKE LEVEL (ft)	1591.3	1591.6	1591.6	1591.5	1591.4	1591.5	1591.6	1591.8	1591.5	1591.3	1591.3	1591.3	
SEEPAGE	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-8.00

GENERAL NOTES

(1) Units are inches of lake level unless otherwise specified.
(2) Runoff=Precip (in.) * Runoff Coeff. * Effective watershed area (ac.) / Lake area (ac.).
(3) Evaporation Nov-Apr estimated from measured evaporation during remainder of year.
(4) Negative lake storage values indicate fall in water level.
(5) Negative seepage values indicate outward seepage.
(6) Seepage is value from short-term study.
(7) Ordinary High Water Mark = 1591.96 feet.
(8) May level= 1591.7820 feet at start of lake level calculations
(9) Outflow= $[0.58 (L - 1590)]^{4.76}$ where L = Lake level in feet.

Table 4.5

ANNUAL WATER BALANCE, LITTLE SAND LAKE
AVERAGE YEAR (MEAN OF WATER YEARS 1942-1981)

Lake area (ac)=	244.1
Watershed area (ac)=	2519
Effective area (ac) =	1866.5

ESTIMATED WATER BALANCE COMPONENTS==========

GAINS	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	YEAR
Precipitation	2.27	1.92	1.19	1.07	0.86	1.59	2.33	3.49	4.42	3.57	4.27	3.73	30.71
Runoff coeff.	0.15	0.24	0.24	0.24	0.24	0.24	0.24	0.16	0.12	0.13	0.09	0.12	
Runoff	2.60	3.52	2.18	1.96	1.58	2.92	4.28	4.27	4.06	3.55	2.94	3.42	37.28
TOTAL	4.87	5.44	3.37	3.03	2.44	4.51	6.61	7.76	8.48	7.12	7.21	7.15	67.99
LOSSES													
Evaporation	1.67	0.98	0.98	0.98	0.98	0.98	0.98	3.74	4.21	4.41	3.52	2.23	25.69
Outflow (cfs)	1.32	0.97	1.19	0.78	0.62	0.47	0.69	1.35	1.17	1.20	0.85	0.96	
Outflow (in.)	3.90	2.87	3.54	2.32	1.84	1.40	2.04	4.01	3.47	3.57	2.51	2.83	34.30
TOTAL	5.57	3.86	4.52	3.31	2.82	2.38	3.02	7.75	7.68	7.98	6.03	5.06	59.99
LAKE STORAGE	-1.36	0.92	-1.82	-0.94	-1.05	1.46	2.92	-0.65	0.13	-1.53	0.51	1.42	.00
LAKE LEVEL (ft)	1591.7	1591.8	1591.6	1591.6	1591.5	1591.6	1591.8	1591.8	1591.8	1591.7	1591.7	1591.8	
SEEPAGE	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-8.00

GENERAL NOTES

(1) Units are inches of lake level unless otherwise specified.
(2) Runoff=Precip (in.) * Runoff Coeff. * Effective watershed area (ac.) / Lake area (ac.).
(3) Evaporation Nov-Apr estimated from measured evaporation during remainder of year.
(4) Negative lake storage values indicate fall in water level.
(5) Negative seepage values indicate outward seepage.
(6) Seepage is value from short-term study.
(7) Ordinary High Water Mark = 1591.96 feet.
(8) May level= 1591.7820 feet at start of lake level calculations
(9) Outflow (cfs)= $[0.58(L-1590)]^{4.76}$ where L = Lake level in feet.

Table 4.6

ANNUAL WATER BALANCE, OAK LAKE

WET YEAR (MEAN OF FIVE WETTEST WATER YEARS)

Lake area (ac)= 69.9
Watershed area (ac) = 375
Effective area (ac) = 352.4

ESTIMATED WATER BALANCE COMPONENTS==========

GAINS	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	YEAR
Precipitation	3.37	2.08	1.54	0.77	0.77	2.85	2.69	5.52	4.65	6.02	5.14	5.83	41.23
Runoff coeff.	0.15	0.24	0.24	0.24	0.24	0.24	0.24	0.16	0.12	0.13	0.09	0.12	
Runoff	2.55	2.52	1.86	0.93	0.93	3.45	3.25	4.45	2.81	3.95	2.33	3.53	32.57
TOTAL	5.92	4.60	3.40	1.70	1.70	6.30	5.94	9.97	7.46	9.97	7.47	9.36	73.80
LOSSES													
Evaporation	1.36	0.87	0.87	0.87	0.87	0.87	0.87	3.42	3.93	3.96	2.96	1.90	22.77
Outflow (cfs)	1.25	.00	0.04	0.10	0.05	0.04	0.46	0.36	0.12	0.28	0.90	0.04	
Outflow (in.)	12.90	0.05	0.45	1.04	0.57	0.41	4.81	3.74	1.20	2.90	9.31	0.43	37.80
TOTAL	14.26	0.92	1.33	1.92	1.44	1.28	5.68	7.16	5.13	6.86	12.27	2.33	60.57
LAKE STORAGE	-9.10	2.91	1.32	-0.97	-0.50	4.26	-0.49	2.06	1.57	2.34	-5.55	6.27	4.11
LAKE LEVEL (ft)	1632.8	1633.1	1633.2	1633.1	1633.1	1633.4	1633.4	1633.2	1633.3	1633.5	1633.1	1633.6	
SEEPAGE	-0.76	-0.76	-0.76	-0.76	-0.76	-0.76	-0.76	-0.76	-0.76	-0.76	-0.76	-0.76	-9.10

GENERAL NOTES

(1) Units are inches of lake level unless otherwise specified.
(2) Runoff=Precip (in.) * Runoff Coeff. * Effective watershed area (ac.) / Lake area (ac.).
(3) Evaporation Nov-Apr estimated from measured evaporation during remainder of year.
(4) Negative lake storage values indicate fall in water level.
(5) Negative seepage values indicate outward seepage.
(6) Seepage is value from short-term study.
(7) Ordinary High Water Mark = 1633.17 feet.
(8) May level= 1633.1930 feet at start of lake level calculations
(9) Outflow (cfs)= $[0.65\ (L-1632)]^{8.47}$ where L = Lake level in feet.

Table 4.7

ANNUAL WATER BALANCE, OAK LAKE
DRY YEAR (MEAN OF FIVE DRIEST WATER YEARS)

Lake area (ac)= 69.9
Watershed area (ac) = 375
Effective area (ac) = 352.4

ESTIMATED WATER BALANCE COMPONENTS==========

GAINS	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	YEAR
Precipitation	1.44	2.22	1.18	1.11	0.72	1.23	1.65	2.35	3.03	2.52	2.87	2.48	22.80
Runoff coeff.	0.15	0.24	0.24	0.24	0.24	0.24	0.24	0.16	0.12	0.13	0.09	0.12	
Runoff	1.09	2.69	1.43	1.34	0.87	1.49	2.00	1.90	1.83	1.65	1.30	1.50	19.08
TOTAL	2.53	4.91	2.61	2.45	1.59	2.72	3.65	4.25	4.86	4.17	4.17	3.98	41.88
LOSSES													
Evaporation	1.94	1.11	1.11	1.11	1.11	1.11	1.11	3.91	4.77	5.21	4.02	2.53	29.06
Outflow (cfs)	0.01	0.01	0.05	0.06	0.06	0.03	0.05	0.10	0.12	0.04	0.01	.00	
Outflow (in.)	0.07	0.06	0.53	0.60	0.59	0.33	0.47	1.07	1.20	0.37	0.07	0.04	5.41
TOTAL	2.01	1.17	1.64	1.72	1.71	1.45	1.58	4.98	5.97	5.58	4.09	2.57	34.47
LAKE STORAGE	-0.24	2.98	0.21	-0.02	-0.88	0.51	1.30	-1.49	-1.87	-2.16	-0.68	0.65	-1.69
LAKE LEVEL (ft)	1632.8	1633.1	1633.1	1633.1	1633.0	1633.1	1633.2	1633.2	1633.0	1632.9	1632.8	1632.9	
SEEPAGE	-0.76	-0.76	-0.76	-0.76	-0.76	-0.76	-0.76	-0.76	-0.76	-0.76	-0.76	-0.76	-9.10

GENERAL NOTES

(1) Units are inches of lake level unless otherwise specified.
(2) Runoff=Precip (in.) * Runoff Coeff. * Effective watershed area (ac.) / Lake area (ac.).
(3) Evaporation Nov-Apr estimated from measured evaporation during remainder of year.
(4) Negative lake storage values indicate fall in water level.
(5) Negative seepage values indicate outward seepage.
(6) Seepage is value from short-term study.
(7) Ordinary High Water Mark = 1633.17 feet.
(8) May level= 1633.1930 feet at start of lake level calculations
(9) Outflow (cfs)= $[0.65 (L-1632)]^{8.47}$ where L = Lake level in feet.

Table 4.8

ANNUAL WATER BALANCE, OAK LAKE
AVERAGE YEAR (MEAN OF WATER YEARS 1942-1981)

Lake area (ac)=	69.9
Watershed area (ac) =	375
Effective area (ac) =	352.4

ESTIMATED WATER BALANCE COMPONENTS==========

GAINS	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	YEAR
Precipitation	2.27	1.92	1.19	1.07	0.86	1.59	2.33	3.49	4.42	3.57	4.27	3.73	30.71
Runoff coeff.	0.15	0.24	0.24	0.24	0.24	0.24	0.24	0.16	0.12	0.13	0.09	0.12	
Runoff	1.72	2.32	1.44	1.29	1.04	1.92	2.82	2.82	2.67	2.34	1.94	2.26	24.58
TOTAL	3.99	4.24	2.63	2.36	1.90	3.51	5.15	6.31	7.09	5.91	6.21	5.99	55.29
LOSSES													
Evaporation	1.67	0.98	0.98	0.98	0.98	0.98	0.98	3.74	4.21	4.41	3.52	2.23	25.69
Outflow (cfs)	0.33	0.12	0.24	0.10	0.08	0.05	0.11	0.38	0.12	0.20	0.09	0.16	
Outflow (in.)	3.45	1.21	2.51	0.99	0.79	0.53	1.14	3.99	1.20	2.04	0.96	1.69	20.49
TOTAL	5.12	2.19	3.49	1.98	1.77	1.51	2.13	7.73	5.41	6.45	4.48	3.92	46.17
LAKE STORAGE	-1.89	1.29	-1.62	-0.37	-0.63	1.24	2.26	-2.18	0.92	-1.30	0.97	1.30	.00
LAKE LEVEL (ft)	1633.2	1633.3	1633.2	1633.1	1633.1	1633.2	1633.4	1633.2	1633.3	1633.2	1633.2	1633.4	
SEEPAGE	-0.76	-0.76	-0.76	-0.76	-0.76	-0.76	-0.76	-0.76	-0.76	-0.76	-0.76	-0.76	-9.10

GENERAL NOTES

(1) Units are inches on lake unless otherwise specified.
(2) Runoff=Precip (in.) * Runoff Coeff. * Effective watershed area (ac.) / Lake area (ac.).
(3) Evaporation Nov-Apr estimated from measured evaporation during remainder of year.
(4) Negative lake storage values indicate fall in water level.
(5) Negative seepage values indicate outward seepage.
(6) Seepage is value from short-term study.
(7) Ordinary High Water Mark = 1633.17 feet.
(8) May level= 1633.1930 feet at start of lake level calculations
(9) Outflow (cfs)= $[0.65\ (L-1632)]^{8.47}$ where L = Lake level in feet.

Table 4.9

ANNUAL WATER BALANCE, DUCK LAKE
WET YEAR (MEAN OF FIVE WETTEST WATER YEARS)

Lake area (ac)= 78.7
Watershed area (ac)= 330
Effective area (ac) = 305.9

ESTIMATED WATER BALANCE COMPONENTS==========

GAINS	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	YEAR
Precipitation	3.37	2.08	1.54	0.77	0.77	2.85	2.69	5.52	4.65	6.02	5.14	5.83	41.23
Runoff coeff.	0.15	0.24	0.24	0.24	0.24	0.24	0.24	0.16	0.12	0.13	0.09	0.12	
Runoff	1.96	1.94	1.44	0.72	0.72	2.66	2.51	3.43	2.17	3.04	1.80	2.72	25.11
TOTAL	5.33	4.02	2.98	1.49	1.49	5.51	5.20	8.95	6.82	9.06	6.94	8.55	66.34
LOSSES													
Evaporation	1.36	0.87	0.87	0.87	0.87	0.87	0.87	3.42	3.93	3.96	2.96	1.90	22.77
Outflow (cfs)	0.73	0.10	0.13	0.08	0.03	0.01	0.06	0.17	0.02	0.03	0.15	0.22	
Outflow (in.)	6.67	0.94	1.16	0.77	0.27	0.11	0.56	1.52	0.22	0.28	1.39	2.03	15.90
TOTAL	8.03	1.81	2.03	1.64	1.14	0.98	1.43	4.94	4.15	4.24	4.35	3.93	38.67
LAKE STORAGE	-4.47	0.44	-0.83	-1.93	-1.43	2.75	1.99	2.24	0.90	3.05	0.81	2.85	6.37
LAKE LEVEL (ft)	1611.3	1611.3	1611.2	1611.1	1611.0	1611.2	1611.4	1611.1	1611.1	1611.3	1611.4	1611.7	
SEEPAGE	-1.78	-1.78	-1.78	-1.78	-1.78	-1.78	-1.78	-1.78	-1.78	-1.78	-1.78	-1.78	-21.30

GENERAL NOTES

(1) Units are inches of lake level unless otherwise specified.
(2) Runoff=Precip (in.) * Runoff Coeff. * Effective watershed area (ac.) / Lake area (ac.).
(3) Evaporation Nov-Apr estimated from measured evaporation during remainder of year.
(4) Negative lake storage values indicate fall in water level.
(5) Negative seepage values indicate outward seepage.
(6) Seepage is value from short-term study.
(7) Ordinary High Water Mark = 1611.09 feet.
(8) May level= 1611.0580 feet at start of lake level calculations
(9) Outflow (cfs)= $[0.579\ (L-1610)]^{7.69}$ where L = Lake level in feet.

Table 4.10

ANNUAL WATER BALANCE, DUCK LAKE
DRY YEAR (MEAN OF FIVE DRIEST WATER YEARS)

Lake area (ac)= 78.7
Watershed area (ac)= 330
Effective area (ac) = 305.9

ESTIMATED WATER BALANCE COMPONENTS==========

GAINS	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	YEAR
Precipitation	1.44	2.22	1.18	1.11	0.72	1.23	1.65	2.35	3.03	2.52	2.87	2.48	22.80
Runoff coeff.	0.15	0.24	0.24	0.24	0.24	0.24	0.24	0.16	0.12	0.13	0.09	0.12	
Runoff	0.84	2.07	1.10	1.04	0.67	1.15	1.54	1.46	1.41	1.27	1.00	1.16	14.71'
TOTAL	2.28	4.29	2.28	2.15	1.39	2.38	3.19	3.81	4.44	3.79	3.87	3.64	37.51
LOSSES													
Evaporation	1.94	1.11	1.11	1.11	1.11	1.11	1.11	3.91	4.77	5.21	4.02	2.53	29.06
Outflow (cfs)	.00	.00	.00	.00	.00	.00	.00	.00	0.02	.00	.00	.00	
Outflow (in.)	.00	.00	.00	.00	.00	.00	.00	.00	0.22	0.05	.00	.00	0.26
TOTAL	1.94	1.11	1.11	1.11	1.11	1.11	1.11	3.91	4.99	5.26	4.02	2.53	29.33
LAKE STORAGE	-1.44	1.40	-0.61	-0.74	-1.50	-0.51	0.30	-1.87	-2.32	-3.24	-1.92	-0.67	-13.11
LAKE LEVEL (ft)	1610.3	1610.4	1610.3	1610.3	1610.1	1610.1	1610.1	1611.1	1610.9	1610.6	1610.4	1610.4	
SEEPAGE	-1.78	-1.78	-1.78	-1.78	-1.78	-1.78	-1.78	-1.78	-1.78	-1.78	-1.78	-1.78	-21.30

GENERAL NOTES

(1) Units are inches of lake level unless otherwise specified.
(2) Runoff=Precip (in.) * Runoff Coeff. * Effective watershed area (ac.) / Lake area (ac.).
(3) Evaporation Nov-Apr estimated from measured evaporation during remainder of year.
(4) Negative lake storage values indicate fall in water level.
(5) Negative seepage values indicate outward seepage.
(6) Seepage is value from short-term study.
(7) Ordinary High Water Mark = 1611.09 feet.
(8) May level= 1611.0580 feet at start of lake level calculations
(9) Outflow (cfs)= $[0.579\ (L-1610)]^{7.69}$ where L = Lake level in feet.

Table 4.11

ANNUAL WATER BALANCE, DUCK LAKE
AVERAGE YEAR (MEAN OF WATER YEARS 1942-1981)

Lake area (ac)=	78.7
Watershed area (ac)=	330
Effective area (ac) =	305.9

ESTIMATED WATER BALANCE COMPONENTS==========

GAINS	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	YEAR
Precipitation	2.27	1.92	1.19	1.07	0.86	1.59	2.33	3.49	4.42	3.57	4.27	3.73	30.71
Runoff coeff.	0.15	0.24	0.24	0.24	0.24	0.24	0.24	0.16	0.12	0.13	0.09	0.12	
Runoff	1.32	1.79	1.11	1.00	0.80	1.48	2.17	2.17	2.06	1.80	1.49	1.74	18.95
TOTAL	3.59	3.71	2.30	2.07	1.66	3.07	4.50	5.66	6.48	5.37	5.76	5.47	49.66
LOSSES													
Evaporation	1.67	0.98	0.98	0.98	0.98	0.98	0.98	3.74	4.21	4.41	3.52	2.23	25.69
Outflow (cfs)	0.04	0.03	0.05	0.03	0.02	0.01	0.01	0.02	0.02	0.03	0.01	0.02	
Outflow (in.)	0.35	0.32	0.45	0.27	0.15	0.06	0.08	0.23	0.22	0.25	0.13	0.16	2.67
TOTAL	2.02	1.30	1.44	1.25	1.13	1.05	1.06	3.97	4.43	4.66	3.65	2.39	28.36
LAKE STORAGE	-0.21	0.64	-0.91	-0.96	-1.25	0.25	1.67	-0.08	0.28	-1.07	0.34	1.30	.00
LAKE LEVEL (ft)	1611.1	1611.2	1611.1	1611.0	1610.9	1610.9	1611.1	1611.1	1611.1	1611.0	1611.0	1611.1	
SEEPAGE	-1.78	-1.78	-1.78	-1.78	-1.78	-1.78	-1.78	-1.78	-1.78	-1.78	-1.78	-1.78	-21.30

GENERAL NOTES

(1) Units are inches of lake level unless otherwise specified.
(2) Runoff=Precip (in.) * Runoff Coeff. * Effective watershed area (ac.) / Lake area (ac.).
(3) Evaporation Nov-Apr estimated from measured evaporation during remainder of year.
(4) Negative lake storage values indicate fall in water level.
(5) Negative seepage values indicate outward seepage.
(6) Seepage is value from short-term study.
(7) Ordinary High Water Mark = 1611.09 feet.
(8) May level= 1611.0580 feet at start of lake level calculations
7.69
(9) Outflow (cfs)= [0.579 (L-1610)] where L = Lake level in feet.

Table 4.12

ANNUAL WATER BALANCE, SKUNK LAKE
WET YEAR (MEAN OF FIVE WETTEST WATER YEARS)

Lake area (ac) = 15.7
Watershed area (ac) = 375
Effective area (ac) = 112.0

ESTIMATED WATER BALANCE COMPONENTS==========

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	YEAR
GAINS													
Precipitation	3.37	2.08	1.54	0.77	0.77	2.85	2.69	5.52	4.65	6.02	5.14	5.83	41.23
Runoff coeff.	0.15	0.24	0.24	0.24	0.24	0.24	0.24	0.16	0.12	0.13	0.09	0.12	
Runoff	3.61	3.56	2.64	1.32	1.32	4.88	4.61	6.30	3.98	5.58	3.30	4.99	46.08
TOTAL	6.98	5.64	4.18	2.09	2.09	7.73	7.30	11.82	8.63	11.60	8.44	10.82	87.31
LOSSES													
Evaporation	1.36	0.87	0.87	0.87	0.87	0.87	0.87	3.42	3.93	3.96	2.96	1.90	22.77
Outflow (cfs)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Outflow (in)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	1.36	0.87	0.87	0.87	0.87	0.87	0.87	3.42	3.93	3.96	2.96	1.90	22.77
LAKE STORAGE	2.30	1.45	-0.01	-2.10	-2.10	3.54	3.11	5.08	1.38	4.33	2.16	5.60	24.74
LAKE LEVEL (ft)	1599.4	1599.5	1599.5	1599.3	1599.2	1599.5	1599.7	1598.1	1598.2	1598.6	1598.7	1599.2	
SEEPAGE	-3.32	-3.32	-3.32	-3.32	-3.32	-3.32	-3.32	-3.32	-3.32	-3.32	-3.32	-3.32	-39.80

GENERAL NOTES

(1) Units are inches of lake level unless otherwise specified.
(2) Runoff=Precip (in.) * Runoff Coeff. * Effective watershed area (ac.) / Lake area (ac.).
(3) Evaporation Nov-Apr estimated from measured evaporation during remainder of year.
(4) Negative lake storage values indicate fall in water level.
(5) Negative seepage values indicate outward seepage.
(6) Seepage is value from short-term study.
(7) Ordinary High Water Mark = 1598.09 feet.
(8) May level= 1598.0900 feet at start of lake level calculations
(9) Outflow (cfs)= 0 at all times.

Table 4.13

ANNUAL WATER BALANCE, SKUNK LAKE
DRY YEAR (MEAN OF FIVE DRIEST WATER YEARS)

Lake area (ac) = 15.7
Watershed area (ac) = 375
Effective area (ac) = 112.0

ESTIMATED WATER BALANCE COMPONENTS==========

GAINS	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	YEAR
Precipitation	1.44	2.22	1.18	1.11	0.72	1.23	1.65	2.35	3.03	2.52	2.87	2.48	22.80
Runoff coeff.	0.15	0.24	0.24	0.24	0.24	0.24	0.24	0.16	0.12	0.13	0.09	0.12	
Runoff	1.54	3.80	2.02	1.90	1.23	2.11	2.82	2.68	2.59	2.34	1.84	2.12	27.00
TOTAL	2.98	6.02	3.20	3.01	1.95	3.34	4.47	5.03	5.62	4.86	4.71	4.60	49.80
LOSSES													
Evaporation	1.94	1.11	1.11	1.11	1.11	1.11	1.11	3.91	4.77	5.21	4.02	2.53	29.06
Outflow (cfs)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Outflow (in)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	1.94	1.11	1.11	1.11	1.11	1.11	1.11	3.91	4.77	5.21	4.02	2.53	29.06
LAKE STORAGE	-2.28	1.59	-1.23	-1.42	-2.48	-1.09	0.04	-2.19	-2.46	-3.67	-2.62	-1.24	-19.06
LAKE LEVEL (ft)	1597.1	1597.2	1597.1	1597.0	1596.8	1596.7	1596.7	1598.1	1597.9	1597.6	1597.4	1597.3	
SEEPAGE	-3.32	-3.32	-3.32	-3.32	-3.32	-3.32	-3.32	-3.32	-3.32	-3.32	-3.32	-3.32	-39.80

GENERAL NOTES

(1) Units are inches of lake level unless otherwise specified.
(2) Runoff=Precip (in.) * Runoff Coeff. * Effective watershed area (ac.) / Lake area (ac.).
(3) Evaporation Nov-Apr estimated from measured evaporation during remainder of year.
(4) Negative lake storage values indicate fall in water level.
(5) Negative seepage values indicate outward seepage.
(6) Seepage is value from short-term study.
(7) Ordinary High Water Mark =1598.09 feet.
(8) May level= 1598.0900 feet at start of lake level calculations
(9) Outflow (cfs)= 0 at all times.

Table 4.14

ANNUAL WATER BALANCE, SKUNK LAKE
AVERAGE YEAR (MEAN OF WATER YEARS 1942-1981)

Lake area (ac) = 15.7
Watershed area (ac) = 375
Effective area (ac) = 112.0

ESTIMATED WATER BALANCE COMPONENTS==========

GAINS	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	YEAR
Precipitation	2.27	1.92	1.19	1.07	0.86	1.59	2.33	3.49	4.42	3.57	4.27	3.73	30.71
Runoff coeff.	0.15	0.24	0.24	0.24	0.24	0.24	0.24	0.16	0.12	0.13	0.09	0.12	
Runoff	2.43	3.29	2.04	1.83	1.47	2.72	3.99	3.98	3.78	3.31	2.74	3.19	34.78
TOTAL	4.70	5.21	3.23	2.90	2.33	4.31	6.32	7.47	8.20	6.88	7.01	6.92	65.49
LOSSES													
Evaporation	1.67	0.98	0.98	0.98	0.98	0.98	0.98	3.74	4.21	4.41	3.52	2.23	25.69
Outflow (cfs)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Outflow (in)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	1.67	0.98	0.98	0.98	0.98	0.98	0.98	3.74	4.21	4.41	3.52	2.23	25.69
LAKE STORAGE	-0.29	0.91	-1.07	-1.40	-1.97	0.01	2.02	0.42	0.68	-0.85	0.17	1.38	.00
LAKE LEVEL (ft)	1598.2	1598.3	1598.2	1598.1	1597.9	1597.9	1598.1	1598.1	1598.1	1598.1	1598.1	1598.2	
SEEPAGE	-3.32	-3.32	-3.32	-3.32	-3.32	-3.32	-3.32	-3.32	-3.32	-3.32	-3.32	-3.32	-39.80

GENERAL NOTES

(1) Units are inches of lake level unless otherwise specified.
(2) Runoff=Precip (in.) * Runoff Coeff. * Effective watershed area (ac.) / Lake area (ac.).
(3) Evaporation Nov-Apr estimated from measured evaporation during remainder of year.
(4) Negative lake storage values indicate fall in water level.
(5) Negative seepage values indicate outward seepage.
(6) Seepage is value from short-term study.
(7) Ordinary High Water Mark = 1598.09 feet.
(8) May level= 1598.0900 feet at start of lake level calculations
(9) Outflow (cfs)= 0 at all times.

Table 4.15

ANNUAL WATER BALANCE, DEEP HOLE LAKE
WET YEAR (MEAN OF FIVE WETTEST WATER YEARS)

Lake area (ac)= 128.9
Watershed area (ac)= 885.5
Effective area (ac) = 885.5

ESTIMATED WATER BALANCE COMPONENTS==========

GAINS	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	YEAR
Precipitation	3.37	2.08	1.54	0.77	0.77	2.85	2.69	5.52	4.65	6.02	5.14	5.83	41.23
Runoff coeff.	0.15	0.24	0.24	0.24	0.24	0.24	0.24	0.16	0.12	0.13	0.09	0.12	
Runoff	3.47	3.43	2.54	1.27	1.27	4.70	4.44	6.07	3.83	5.38	3.18	4.81	44.37
TOTAL	6.84	5.51	4.08	2.04	2.04	7.55	7.13	11.59	8.48	11.40	8.32	10.64	85.60
LOSSES													
Evaporation	1.36	0.87	0.87	0.87	0.87	0.87	0.87	3.42	3.93	3.96	2.96	1.90	22.77
Outflow (cfs)	1.77	0.54	0.69	0.49	0.26	0.19	0.76	1.04	0.54	0.67	1.35	0.69	
Outflow (in.)	9.95	3.05	3.86	2.75	1.45	1.07	4.29	5.82	3.03	3.77	7.57	3.89	50.49
TOTAL	11.31	3.92	4.73	3.62	2.32	1.95	5.16	9.24	6.96	7.73	10.53	5.79	73.25
LAKE STORAGE	-5.14	0.92	-1.32	-2.25	-0.95	4.94	1.30	1.68	0.86	3.00	-2.88	4.18	4.35
LAKE LEVEL (ft)	1606.5	1606.6	1606.5	1606.3	1606.2	1606.6	1606.7	1606.5	1606.6	1606.8	1606.6	1606.9	
SEEPAGE	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-8.00

GENERAL NOTES

(1) Units are inches of lake level unless otherwise specified.
(2) Runoff=Precip (in.) * Runoff Coeff. * Effective watershed area (ac.) / Lake area (ac.).
(3) Evaporation Nov-Apr estimated from measured evaporation during remainder of year.
(4) Negative lake storage values indicate fall in water level.
(5) Negative seepage values indicate outward seepage.
(6) Seepage is value from short-term study.
(7) Ordinary High Water Mark = 1605.83 feet.
(8) May level= 1606.5145 feet at start of lake level calculations
(9) Outflow (cfs)= $[0.58\,(L-1605)]^{4.76}$ where L = Lake level in feet.

Table 4.16

ANNUAL WATER BALANCE, DEEP HOLE LAKE
DRY YEAR (MEAN OF FIVE DRIEST WATER YEARS)

Lake area (ac)= 128.9
Watershed area (ac)= 885.5
Effective area (ac) = 885.5

ESTIMATED WATER BALANCE COMPONENTS==========

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	YEAR
GAINS													
Precipitation	1.44	2.22	1.18	1.11	0.72	1.23	1.65	2.35	3.03	2.52	2.87	2.48	22.80
Runoff coeff.	0.15	0.24	0.24	0.24	0.24	0.24	0.24	0.16	0.12	0.13	0.09	0.12	
Runoff	1.48	3.66	1.95	1.83	1.19	2.03	2.72	2.58	2.50	2.25	1.77	2.04	26.01
TOTAL	2.92	5.88	3.13	2.94	1.91	3.26	4.37	4.93	5.53	4.77	4.64	4.52	48.81
LOSSES													
Evaporation	1.94	1.11	1.11	1.11	1.11	1.11	1.11	3.91	4.77	5.21	4.02	2.53	29.06
Outflow (cfs)	0.11	0.10	0.32	0.28	0.25	0.16	0.20	0.31	0.54	0.23	0.10	0.08	
Outflow (in.)	0.63	0.56	1.80	1.57	1.39	0.92	1.11	1.75	3.03	1.31	0.58	0.46	15.11
TOTAL	2.57	1.68	2.92	2.69	2.50	2.04	2.22	5.66	7.80	6.52	4.60	2.99	44.18
LAKE STORAGE	-0.31	3.54	-0.46	-0.41	-1.26	0.55	1.48	-1.39	-2.94	-2.41	-0.62	0.87	-3.37
LAKE LEVEL (ft)	1606.1	1606.4	1606.3	1606.3	1606.2	1606.2	1606.3	1606.5	1606.3	1606.1	1606.0	1606.1	
SEEPAGE	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-8.00

GENERAL NOTES

(1) Units are inches of lake level unless otherwise specified.
(2) Runoff=Precip (in.) * Runoff Coeff. * Effective watershed area (ac.) / Lake area (ac.).
(3) Evaporation Nov-Apr estimated from measured evaporation during remainder of year.
(4) Negative lake storage values indicate fall in water level.
(5) Negative seepage values indicate outward seepage.
(6) Seepage is value from short-term study.
(7) Ordinary High Water Mark = 1605.83 feet.
(8) May level= 1606.5145 feet at start of lake level calculations
(9) Outflow (cfs)= $[0.58 (L-1605)]^{4.76}$ where L = Lake level in feet.

Table 4.17

ANNUAL WATER BALANCE, DEEP HOLE LAKE

AVERAGE YEAR (MEAN OF WATER YEARS 1942-1981)

Lake area (ac)= 128.9
Watershed area (ac)= 885.5
Effective area (ac) = 885.5

ESTIMATED WATER BALANCE COMPONENTS==========

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	YEAR
GAINS													
Precipitation	2.27	1.92	1.19	1.07	0.86	1.59	2.33	3.49	4.42	3.57	4.27	3.73	30.71
Runoff coeff.	0.15	0.24	0.24	0.24	0.24	0.24	0.24	0.16	0.12	0.13	0.09	0.12	
Runoff	2.34	3.17	1.96	1.76	1.42	2.62	3.84	3.84	3.64	3.19	2.64	3.07	33.49
TOTAL	4.61	5.09	3.15	2.83	2.28	4.21	6.17	7.33	8.06	6.76	6.91	6.80	64.20
LOSSES													
Evaporation	1.67	0.98	0.98	0.98	0.98	0.98	0.98	3.74	4.21	4.41	3.52	2.23	25.69
Outflow (cfs)	0.64	0.45	0.57	0.36	0.28	0.21	0.32	0.67	0.54	0.56	0.38	0.45	
Outflow (in.)	3.62	2.54	3.22	2.02	1.58	1.18	1.80	3.75	3.03	3.16	2.12	2.50	30.51
TOTAL	5.29	3.53	4.21	3.00	2.57	2.16	2.78	7.49	7.24	7.57	5.64	4.73	56.20
LAKE STORAGE	-1.35	0.89	-1.72	-0.84	-0.95	1.38	2.72	-0.83	0.16	-1.47	0.61	1.40	.00
LAKE LEVEL (ft)	1606.5	1606.5	1606.4	1606.3	1606.2	1606.4	1606.6	1606.5	1606.5	1606.4	1606.5	1606.6	
SEEPAGE	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-0.67	-8.00

GENERAL NOTES

(1) Units are inches of lake level unless otherwise specified.
(2) Runoff=Precip (in.) * Runoff Coeff. * Effective watershed area (ac.) / Lake area (ac.).
(3) Evaporation Nov-Apr estimated from measured evaporation during remainder of year.
(4) Negative lake storage values indicate fall in water level.
(5) Negative seepage values indicate outward seepage.
(6) Seepage is value from short-term study.
(7) Ordinary High Water Mark = 1605.83 feet.
(8) May level= 1606.5145 feet at start of lake level calculations
(9) Outflow (cfs)= $[0.58\ (L-1605)]^{4.76}$ where L = Lake level in feet.

discussed in Section 2.3. It can be summarized as the following steps:

1. For each month, precipitation is obtained from National Weather Service records.

2. Surface water runoff is computed from precipitation, a runoff coefficient, and lake and effective watershed areas.

3. Evaporation is computed from National Weather Service pan evaporation records by multiplying monthly totals by a conversion factor (for the open-water season) or by assuming a constant relation to the total for the open-water season (for the remainder of the year).

4. The monthly seepage rate is computed as 1/12 of the annual rate from the short-term water balance studies.

5. The lake is assumed to be "full" at the end of May. To determine the exact level used for May, the remainder of the water balance table for the average year is completed, and a range of May water levels is tested, using the procedure in the following steps, to determine the level that makes the net annual water level change zero for the average year. This same level is then used for May of the wet and dry years.

6. Beginning with June, the stream outflow for the current month is computed from the lake level at the end of the preceding

month. The computation uses an equation representing the relation between lake level and outflow rate. This rate, in cfs, is converted to inches on the lake.

7. Lake level change for the current month is computed from the other components for the month by use of the water balance equation given above.

8. The lake level at the end of the current month is computed by adding the change in water level for the current month to the lake level at the end of the preceding month. Steps 6 through 8 are repeated until all months have level changes and lake levels.

This procedure works, in that it produces water balances that are reasonable for the data base used. The following particular points should be noted, however, in interpreting the water balances:

1. The data used to construct the annual water balances are composites of five years (for the wet and dry years) or forty years (for the average year). Furthermore, the practices of combining maximum precipitation with minimum evaporation, and minimum precipitation with maximum evaporation, are intended to produce conservative water balances. The water balances should not be expected to exactly match any particular year.

2. Because of the way that the water balances are computed, the balance is achieved by adjustment in the stream outflow and lake level components.

3. May water levels for Little Sand, Oak, Duck, and Deep Hole lakes are relatively close to the Ordinary High Water Mark, given on each annual water balance table as a note. This is because computed lake levels are to a large extent controlled by the lake level/discharge relationship used to compute outflow, and because May levels are chosen that will produce a zero lake level change for an average year.

4. Seepage has been assumed constant.

5. No correction has been made for change in lake area with change in level. The range of fluctuation is small enough that this was considered negligible.

6. Although annual totals of evaporation are considered fairly reliable for Little Sand, Oak, Duck, and Deep Hole lakes, monthly values should be interpreted with caution. Actual evaporation rates in most lakes rise more slowly in the spring, and decline more slowly in the fall, than the values in the tables indicate.

4.3 Interpretation and Confirmation of Seepage Rates

4.3.1 Relation of Seepage Rates to Hydrogeological Settings

The rate of lake seepage is a function of the hydraulic properties of the underlying sediments and the hydraulic head acting upon those sediments. The cross sections in Figures 3.2 through 3.6 provide the information used in these analyses.

Drilling indicates that the area lakes are underlain by relatively thick accumulations of lacustrine sediments of very low permeability. Several piezometer wells in the glacial deposits near the margins of the Little Sand Lake indicate that the lacustrine sediments often extend beyond the edge of the lake. Even though drill hole density associated with other area lakes is sparse, conditions are expected to be similar to Little Sand Lake because the lakes are of similar geologic origin.

Figures 3.2 through 3.6 are interpretative cross sections prepared by STS Consultants through each of the area lakes. The lakes contribute seepage to ground water through two routes: 1) by seepage through the lake bottom lacustrine sediments, and 2) by seepage into the glacial deposits near lake margins. The lake bottom lacustrine sediments are dominantly clay, are of extremely low permeability, and are homogenous in consistency and areal distribution. Seepage will be very low, uniform, and will vary directly with thickness and hydraulic head. By contrast, seepage rates into the glacial deposits near lake margins will be high. Glacial deposits are commonly two to four orders of magnitude higher in permeability than lacustrine sediments. Seepage rates near lake margins will be variable because different types of glacial deposits vary in permeability and because the distribution of lacustrine sediments which underly the glacial deposits near lake margins may be irregular.

Small lakes have a higher shore-length-to-area ratio than large lakes. Since seepage rates into the glacial deposits near lake margins are higher than seepage rates in the lake bottom lacustrine sediments, it follows that larger lakes should have lower seepage rates (averaged over the entire lake) than smaller ones, since larger lakes have a smaller ratio of shore length to area. This is consistent with the observed seepage rates, which were smallest in Little Sand Lake, the largest, and greatest in Skunk Lake, the smallest.

Skunk Lake has thin lake bottom lacustrine sediments (6.0 feet) compared to all the other area lakes. In addition, much of the lacustrine sediments are either organic or contain thin sand lenses that would substantially increase average permeability. Such conditions, coupled with the high shore-length-to-area ratio, explain the higher seepage rates for Skunk Lake.

4.3.2 Results of Seepage Meter Tests

Seepage meter tests were made at two locations on Little Sand Lake, along the south and west shores (Figure 2.4). On the south shore one set of six tests was conducted, and on the west shore two sets of six tests each. In each set of tests, six seepage meters were placed a few feet apart at each of three distances from shore in a line extending into the lake. The seepage meters were left in the same locations for the two sets of tests on the south shore. The three sets of measurements are summarized in Table 4.18.

Nine of the eighteen Dames & Moore tests showed zero seepage rates. Some of these are known to be due to problems with installation of the seepage collectors, in particular, with sediments blown out by water pressure during installation, thus creating a gap at the bottom of the collector. In these cases disturbed sediments were observed and the cause of the zero seepage measurement verified. In other instances no disturbance was apparent. These may represent areas where seepage rates are too small to measure with the methods used.

Four other tests were made in October, 1984, by personnel from the State of Wisconsin. These are described in letters included as Appendix J. Their results were mixed. In two cases they indicated inward seepage and in two, outward. The

TABLE 4.18
SEEPAGE METER TEST RESULTS

Test 1 - South Shore Little Sand Lake

METER NO.	BAG NO.	DISTANCE FROM SHORE (Ft.)	DEPTH (Ft.)	TIME Start	TIME Finish	TIME Elapsed	VOLUME (ml) Start	VOLUME (ml) Finish	VOLUME (ml) Change	RATE (ml/hr)	RATE (in/yr)
1	13	33	1.4	1452	1044	1192	230	230	0	0	0
2	1	33	1.4	1455	1047*	1192	211	198	-13	-0.011	-1.8
8	8	63	1.8	1458	1049*	1192	156	72	-84	-0.07	-11.5
9	11	63	1.8	1502	1054*	1192	124	124	0	0	0
13	9	216	3.0	1506	1058*	1192	192	195	-3	0	0
14	5	216	3.0	1509	1101*	1192	133	94	-39	-0.033	-5.4

Test 2 - West Shore Little Sand Lake
(First Set of Tests)

METER NO.	BAG NO.	DISTANCE FROM SHORE (Ft.)	DEPTH (Ft.)	TIME Start	TIME Finish	TIME Elapsed	VOLUME (ml) Start	VOLUME (ml) Finish	VOLUME (ml) Change	RATE (ml/hr)	RATE (in/yr)
1	9	22	1.4	1350	940	1190	194	195	+1	0	0
2	4	22	1.4	1354	943	1189	168	170	+2	0	0
8	2	44	1.8	1359	947	1188	145	146	+1	0	0
9	7	44	1.8	1401	950	1189	235	183	-52	-0.044	-7.3
13	1	81	2.9	1404	952	1188	200	197	-3	0	0
14	6	81	2.9	1408	955	1187	242	237	-7	-0.006	-1

Test 3 - West Shore Little Sand Lake
(Second Set of Tests)

METER NO.	BAG NO.	DISTANCE FROM SHORE (Ft.)	DEPTH (Ft.)	TIME Start	TIME Finish	TIME Elapsed	VOLUME (ml) Start	VOLUME (ml) Finish	VOLUME (ml) Change	RATE (ml/hr)	RATE (in/yr)
1	9	22	1.4	940	1404	264	195	195	0	0	0
2	4	22	1.4	943	1406	263	170	167	-3	0	0
8	2	44	1.8	947	1409	262	146	138	-8	-0.031	-5.1
9	7	44	1.8	950	1411	261	183	175	-8	-0.031	-5.1
13	1	81	2.9	952	1413	261	197	189	-8	-0.031	-5.1
14	6	81	2.9	955	1415	260	237	209	-28	-0.108	-17.8

* = Estimated Time. Time of first bag installation (1044) recorded in field notes, remainder estimated from time needed to install subsequent bags during other sets of tests.

inward seepage is inconsistent with all other evidence, and these measurements are considered erroneous.

The similarity between seepage rates measured by seepage meters and by water balances tends to confirm the finding that most of Little Sand Lake, including its shoreline areas, is underlain by fine-grained lake basin sediments. If these sediments had been absent in the areas where the seepage meter tests were conducted, measured seepage rates would be expected to be considerably greater than the average seepage rate for the entire lake that was measured by the water balance studies.

4.3.3 Average Hydraulic Conductivity of Lake Bed

Average hydraulic conductivities were calculated for the beds of Little Sand, Duck, and Skunk lakes by Darcy's Law, as expressed in the form:

$$V = k(dH/dL)$$

where V = Seepage velocity (cm/s)
k = Hydraulic conductivity (cm/s)
dH = Head difference across sediments (ft)
dL = Thickness of lake-basin sediments (ft)

The calculation used seepage rates measured by short-term water balances, and sediment thicknesses and head gradients across the lake basin sediments measured in the lake drilling program. The data and results are shown in Table 4.19.

Table 4.19
COMPUTED AVERAGE LAKE SEDIMENT PERMEABILITIES

LAKE	HEAD DIFFERENCE (ft)	SEDIMENT THICKNESS (ft)	SEEPAGE RATE (in/yr)	SEEPAGE RATE (cm/s)	PERMEABILITY (cm/s)
Little Sand	8.8	27.9	-8.0	6.4E-07	2.0E-06
Duck	17.1	47.5	-21.3	1.7E-06	4.8E-06
Skunk	3.8	6.2	-39.8	3.2E-06	5.2E-06

Note: Sediment thickness and head difference are averages

The average hydraulic conductivities in the three lakes were in the range of 2.0E-6 to 5.2E-6 cm/s. This is approximately one order of magnitude greater than most laboratory hydraulic conductivity measurements from the lake drilling program.

5.0 SUMMARY

This study had the following primary objectives: 1) Determining baseline water balances for Little Sand, Oak, Duck, Skunk, and Deep Hole lakes, 2) Obtaining measurements of seepage rates from the lakes on the basis of field observations, and 3) Examining the relationships between seepage rates and the hydrogeological settings of the lakes. The principal activities and findings of this study are summarized as follows:

1. Little Sand, Oak, Duck, Skunk, and Deep Hole lakes lie above the water table that occurs in the surrounding soils. Seepage moves outward from all of the lakes to ground water.

2. The lakes are underlain by fine-grained sediments filling the basins that they occupy in the glacial deposits. The lake basin sediments considerably impede outward seepage from Little Sand, Oak, and probably Deep Hole lakes. Their effect is less at Duck and Skunk lakes. The impeding effect depends both on the hydraulic conductivity and the subsurface extent of these sediments.

3. Short-term water balances were obtained during a 3-week period in January, 1985 for Little Sand, Oak, Duck, and Skunk

lakes. It was not possible to determine the water balance of Deep Hole Lake during this period.

4. Best estimates of outward seepage rates during the short-term study were: Little Sand Lake, 8.0 in/yr; Oak Lake, 9.1 in/yr; Duck Lake, 21.3 in/yr; and Skunk Lake, 39.8 in/yr. Differences among seepage rates seem to be reasonably explainable on the basis of differing lake areas and relations among lakes, soils, and ground water.

5. Annual water balances were computed for all five lakes on the basis of the short-term water balance and of information that was available on precipitation, evaporation, and stream flow. Three water balances were computed for each lake, representing conditions in wet, dry, and average years.

6. The source of water to all lakes includes precipitation and surface water runoff; neither component is strongly dominant in any lake. Stream outflow is the dominant water loss component in Little Sand and Deep Hole lakes, and in Oak Lake as well during wet years. Evaporation and seepage produce similar losses in Duck Lake, together considerably exceeding losses by stream outflow. Skunk Lake has no outflowing stream, and loses water by evaporation and seepage, with seepage dominant over evaporation.

7. The seepage component is a relatively small part of the water balances of Little Sand, Oak, and probably Deep Hole lakes.

Variations in seepage from these lakes tend to be eompensated, within a certain range of lake levels, by increases or decreases in stream outflow. Seepage is a greater proportion of the water balance of Duck Lake; however, seepage variations may be partly compensated by changes in stream outflow. Seepage is the major loss from Skunk Lake.

8. Starting from the May levels selected to produce no net level change during an average year, the net water level increases predicted for a wet year are: Little Sand Lake, 4.76 inches; Oak Lake, 4.11 inches; Duck Lake, 6.37 inches; Skunk Lake, 24.74 inches; and Deep Hole Lake, 4.35 inches. The maximum water level in the wettest months exceeds these values.

9. Starting from the May levels selected to produce no net level change during an average year, the net water level decreases predicted for a dry year are: Little Sand Lake, 3.69 inches; Oak Lake, 1.69 inches; Duck Lake, 13.11 inches; Skunk Lake, 19.06 inches; and Deep Hole Lake, 3.37 inches. The minimum water level in the dryest months is less than these values.

6.0 REFERENCES CITED

Baker, Don, 1985, Personal communication. (Professor of Soil Science, Dept. of Soil Science, College of Agriculture, University of Minnesota, Minneapolis).

Carlson, George, 1985, Personal communication. (Hydrologist, U.S. Geological Survey, Water Resources Division, St. Paul, Minnesota.)

Carr, M.R., and Winter, T.C., 1980, An annotated bibliography of devices developed for direct measurement of seepage: U.S. Geological Survey Open-File Report 80-344, 38p.

Exxon Minerals Company, 1982, Environmental impact report, Volumes II and VII: Exxon Minerals Company, Rhinelander, Wisconsin.

Farnsworth, R.K., and Thompson, E.S., 1982, Mean monthly, seasonal, amd annual pan evaporation for the United States: NOAA Technical Report NWS 34, 81p.

_____, _____, and Peck, E.L., 1982, Evaporation atlas for the contiguous 48 states: NOAA Technical Report NWS 33, 26p.

Fellows, C.R., and Brezonik, P.L., 1980, Seepage flow into Florida lakes: Water Resources Bulletin, vol. 16, no. 4, p.635-641.

Hutchinson, G.E., 1957, A treatise on limnology, Vol. 1: New York, John Wiley, 1015 p.

John, P.H., and Lock, M.A., 1977, The spacial distribution of groundwater discharge into the littoral zone of a New Zealand lake: Journal of Hydrology, vol. 33, p.391-395.

Lee, D.R., 1977, A device for measuring seepage flux in lakes and estuaries: Limnology and Oceanography, vol. 22, no. 1, p. 140-147.

_____, and Cherry, J.A., 1978, A field exercise on groundwater flow using seepage meters and mini-piezometers: Journal of Earth Science Education, vol. 27, p. 6-10.

_____, _____, and Pickens, J.F., 1980, Groundwater transport of a salt tracer through a sandy lake bed: Limnology and Oceanography, vol. 25, no. 1, p.45-61.

Linsley, R.K., Kohler, M.A., and Paulhus, J.L.H., 1975, Hydrology for engineers (Second Edition): McGraw-Hill Series in Water Resources and Environmental Engineering: McGraw-Hill Book Company.

McBride, M.S., and Pfannkuch, H.O., 1975, The distribution of seepage within lakebeds: Journal of Research of the U.S. Geological Survey, vol. 3, no. 5, p. 502-512.

Olson, R.M., 1967, Essentials of engineering fluid mechanics (Second edition): International Textbook Company, Scranton, Pennsylvania, 448p.

Riggs, H.C., 1963, The base-flow recession curve as on indicator of ground water: in Publication No. 63, Berkeley, 1963; International Association of Scientific Hydrology.

Slaughter, C.G, 1970, Evaporation from snow and evaporation retardation by monomolecular films, a review of literature: U.S. Army Corps of Engineers, Cold Regions Research and Engineering Laboratory, Hanover, NH, Special Report 130, 31p.

STS Consultants, Ltd., 1982, Soil boring and laboratory test results of Little Sand Lake drilling project for the Exxon Crandon Project mine development: Green Bay, Wisconsin.

________, 1984a, Lake sediment sampling, Duck, Skunk, Oak, and Deep Hole lakes, Crandon Mine Project: Green Bay, Wisconsin.

________, 1984b, Hydrogeologic study update for the Crandon Project, Exxon Minerals Company: Green Bay, Wisconsin.

APPENDIX A

LAKE WATERSHED AND WETLAND AREAS

IEP inc.

CONSULTING ENVIRONMENTAL SCIENTISTS
6 MAPLE ST. · P.O. BOX 780, NORTHBOROUGH, MA 01532
(617) 393-8558 / 890-2130

March 12, 1985

Dr. Joseph DeMarte
Exxon Minerals Company
P.O. Box 813
Rhinelander, WI 54501

RE: Lake Watershed Area Measurements

Dear Dr. DeMarte:

Per your request, IEP, Inc. has prepared the following area measurements for your use.

Lake	Open Water	Lakeside Wetland	Effective Topographic Watershed
Oak	52.3a	17.6a	352.4a
Little Sand	244.1a	0.0a	1866.5a
Skunk	8.8a	6.9a	106.0a
Duck	26.2a	52.5a	305.9a
Deep Hole	100.5a	28.4a	885.5a

All measurements were made from the 1"=400' orthophoto maps, Plates 5, 6, 8 and 9 showing wetlands and watersheds from Normandeau Associates and IEP, 1982, Wetland Assessment Report. Open water was that area mapped as open water. Lakeside wetlands were those areas mapped as lakeside vegetated wetland to include all or portions of R3, F12, F19, F28, F22, F23 and F37. These are wetlands which have a water table elevation equal to that of the adjacent lake and are portions of the lake which have become filled with organic soil and vegetation. They are also believed to be ombrotrophic wetlands per the definition found in Boelter and Verry 1977, Peatland and Water in the Northern Lake States: USDA Forest Service, General Technical Report NC-31. Ombrotrophic wetlands are those which have a water balance dominated by precipitation and surface water, with little or no groundwater inflow.

Effective Topographic Watershed is that area tributary to a given lake. It does not include areas which are tributary to a closed basin such as the watersheds of F15, F34, F35, F36, F86, F87, F90, F116, F119, F121, F122, F125 and F126.

BRANCH OFFICES
MARION, MASSACHUSETTS WAUKESHA, WISCONSIN SUNDERLAND, MASSACHUSETTS

All measurements were made using a digital planimeter. A minimum of three measurements per acre were made to insure accuracy. The areas measured are shown on the enclosed map.

Please call me if you have any questions.

Very truly yours,

IEP, Inc.

Garrett G. Hollands
Vice President
Senior Geologist

GGH/mgw

Enclosure

APPENDIX B

PRECIPITATION RECORDS

PRECIPITATION OBSERVATIONS

DATE	TIME	EVENT	WEATHER	PRECIP (mm.) OBSERVED	PRECIP (mm.) CUMULATIVE	REMARKS
13-Jan	1300	Install	Clear, lt wind	0.0	0.0	
14-Jan	1600	Measure	Clear	0.4	0.4	
17-Jan	1600	Measure	Lt snow	2.3	2.7	
18-Jan	900	Measure	Clear, calm	1.7	4.4	
18-Jan	1555	Replace	Thin cloud, bright		4.4	No snow since gage removed from lake
19-Jan	1150	Measure	Thin clouds	0.4	4.8	
20-Jan	1515	Inspect	Overcast	0.0	4.8	Light snow just beginning
21-Jan	1705	Measure	Overcast	0.3	5.1	Clearing
21-Jan	1735	Replace	Overcast		5.1	Clearing
22-Jan	1715	Inspect	Broken overcast		5.1	Estimated 0.3 mm in gage--not measured
24-Jan	850	Measure	Snow	0.8	5.9	
24-Jan	936	Replace	Overcast, lt snow		5.9	
25-Jan	843	Inspect	Clear		5.9	Estimated 0.2 mm in gage--not measured
27-Jan	854	Measure	Lt snow	0.5	6.4	
28-Jan	841	Replace	Broken overcast		6.4	No snow since gage removed from lake
30-Jan	1700	Measure	Snow	0.8	7.2	
30-Jan	2045	Replace			7.2	
31-Jan	1420	Inspect	Clear	0.0	7.2	

NOTE: Measure=Remove precipitation gage, melt and measure snow.
Gage replaced on lake within about 1 hour unless otherwise noted.
Replace=Replace emptied gage on lake for further measurements
Inspect=Inspect gage, leaving it on lake.

APPENDIX C

WEIGHTS OF EVAPORATION PAN

EVAPORATION MEASUREMENTS

Date/time	lb	oz	Dec. lb
12-Jan-85 1135	167	2	167.1

MEAN 167.1
CUMULATIVE PRECIPITATION 0
MEAN CORRECTED FOR PRECIP. 167.1

Date/time	lb	oz	Dec. lb
15-Jan-85 1245	167	8	167.5
	166	10	166.6
	167	10	167.6
	167	8	167.5
	167	2	167.1
	166	14	166.9
	165	12	165.8
	165	6	165.4
	166	2	166.1
	165	10	165.6

MEAN 166.6
STD DEV 0.8
CUMULATIVE PRECIPITATION 0.4
MEAN CORRECTED FOR PRECIP. 165.7

Date/time	lb	oz	Dec. lb
18-Jan-85 905	177	2	177.1
	177	14	177.9
	177	12	177.8
	177	4	177.3
	176	12	176.8
	177	6	177.4
	175	10	175.6
	176	2	176.1
	176	4	176.3
	175	6	175.4

MEAN 176.8
STD DEV 0.8
CUMULATIVE PRECIPITATION 4.4
MEAN CORRECTED FOR PRECIP. 167.1

Date/time	lb	oz	Dec. lb
21-Jan-85 1450	174	14	174.9
	175	0	175.0
	175	0	175.0
	174	8	174.5
	174	10	174.6
	174	6	174.4
	174	10	174.6
	173	8	173.5
	173	14	173.9
	174	14	174.9

MEAN 174.5
STD DEV 0.5
CUMULATIVE PRECIPITATION 5.1
MEAN CORRECTED FOR PRECIP. 163.3

22-Jan-85	173	6	173.4
1530	172	12	172.8
	172	12	172.8
	173	4	173.3
	172	0	172.0
	174	4	174.3
	172	10	172.6
	172	10	172.6
	172	10	172.6
	172	6	172.4

MEAN	172.9
STD DEV	0.6
CUMULATIVE PRECIPITATION	5.4
MEAN CORRECTED FOR PRECIP.	161.0

23-Jan-85	173	2	173.1
1515	174	2	174.1
	173	8	173.5
	173	12	173.8
	173	2	173.1
	174	0	174.0
	173	4	173.3
	173	8	173.5
	173	8	173.5
	174	2	174.1

MEAN	173.6
STD DEV	0.4
CUMULATIVE PRECIPITATION	5.6
MEAN CORRECTED FOR PRECIP.	161.3

26-Jan-85	173	8	173.5
850	172	12	172.8
	173	4	173.3
	172	6	172.4
	172	10	172.6
	172	12	172.8
	172	8	172.5
	173	4	173.3
	173	0	173.0
	172	6	172.4

MEAN	172.8
STD DEV	0.4
CUMULATIVE PRECIPITATION	6.2
MEAN CORRECTED FOR PRECIP.	159.2

28-Jan-85	173	0	173.0
1653	174	10	174.6
	173	8	173.5
	172	12	172.8
	172	12	172.8
	174	0	174.0
	172	12	172.8

	173	6	173.4
	172	12	172.8
	172	12	172.8

MEAN 173.2
STD DEV 0.6
CUMULATIVE PRECIPITATION 6.4
MEAN CORRECTED FOR PRECIP. 159.1

31-Jan-85	176	10	176.6
915	177	0	177.0
	176	2	176.1
	176	10	176.6
	177	6	177.4
	176	8	176.5
	177	14	177.9
	177	0	177.0
	177	2	177.1
	177	2	177.1

MEAN 176.9
STD DEV 0.5
CUMULATIVE PRECIPITATION 7.2
MEAN CORRECTED FOR PRECIP. 161.1

APPENDIX D

WEIR MEASUREMENTS

LITTLE SAND LAKE--STREAM INFLOW

Date	Time	Gage (ft)	Head (ft)	Discharge (cfs)	Comments
15-Jan	1710	1.36	0.17	0.030	(b)
16-Jan	1520	1.44	0.25	0.078	
17-Jan	1153	1.42	0.26	0.086	
17-Jan	1637	1.46	0.26	0.086	(a)
18-Jan	1158	1.45	0.27	0.095	
19-Jan	924	1.35	0.16	0.026	(a) (b)
20-Jan	940				Ice in culvert
21-Jan	1522	1.37	0.17	0.030	(b)
22-Jan	1624	1.46	0.26	0.086	
23-Jan	943	1.45	0.25	0.078	
24-Jan	920	1.43	0.25	0.078	
25-Jan	926	1.41	0.22	0.057	Leak--est. 30% (b)
26-Jan	1352	1.49	0.29	0.113	Leak stopped
27-Jan	1525	1.46	0.27	0.095	
28-Jan	930				Large leak
29-Jan	1340	1.45	0.26	0.086	Very small leak--est. <5%
31-Jan	1450	1.44	0.24	0.071	
			MEAN	0.086	

(a) = Head computed from staff gage
(b) = Excluded from mean

LITTLE SAND LAKE--STREAM OUTFLOW

Date	Time	Gage (ft)	Head (ft)	Discharge (cfs)	Comments
14-Jan	830	0.54	0.26	0.086	(a)
14-Jan	1530	0.54	0.26	0.086	(a)
15-Jan	1638	0.54	0.26	0.086	
16-Jan	835				Washout under weir
17-Jan	1210	0.55	0.27	0.095	
18-Jan	1210	0.56	0.27	0.095	Small leaks
19-Jan	930	0.55	0.29	0.113	
20-Jan	1105	0.55	0.24	0.071	
21-Jan	1100	0.55	0.27	0.095	
22-Jan	1230	0.56	0.26	0.086	
23-Jan	1134	0.55	0.27	0.095	
24-Jan	938	0.55	0.27	0.095	
25-Jan	910	0.54	0.25	0.078	
26-Jan	1335	0.54	0.25	0.078	
27-Jan	1605	0.53	0.25	0.078	
28-Jan	908	0.53	0.25	0.078	
29-Jan	1355	0.54	0.23	0.063	
31-Jan	1435	0.55	0.24	0.071	
			MEAN	0.085	

(a) = Head computed from staff gage

DUCK LAKE--STREAM OUTFLOW

Date	Time	Gage (ft)	Head (ft)	Discharge (cfs)	Comments
16-Jan	1200	1.15	0.31	0.134	
17-Jan	1137	1.14	0.26	0.086	
18-Jan	1150	1.13	0.24	0.071	
19-Jan	1620	1.12	0.25	0.078	Ice on weir notch
20-Jan	945				Ice in culvert--no reading
21-Jan	1550				Weir clogged with ice
22-Jan	1127	1.15	0.23	0.063	
23-Jan	1114	1.14	0.20	0.045	
24-Jan	926				Ice in culvert--no reading
25-Jan	921				Ice in culvert--no reading
26-Jan	1342	1.17	0.23	0.063	
27-Jan					Weir removed
			MEAN	0.077	

(a) = Head computed from staff gage

APPENDIX E

LAKE LEVEL MEASUREMENTS

LITTLE SAND LAKE, WEST SIDE

Date	12-Jan-85	12-Jan-85	13-Jan-85	13-Jan-85	14-Jan-85	14-Jan-85	15-Jan-85	15-Jan-85	16-Jan-85	16-Jan-85	17-Jan-85
Time	938	1522	945	1759	755	1602	950	1955	912	1610	840
Dec. Day	12.40	12.64	13.41	13.75	14.33	14.67	15.41	15.83	16.38	16.67	17.36
Gage	61.9	61.7	67.0	68.3	65.3	65.3	67.3	67.3	67.7	66.5	63.2
	63.4	60.1	67.5	64.2	63.1	63.4	66.6	67.6	66.8	66.5	65.4
	59.3	63.4	66.2	64.7	65.0	69.5	66.6	67.6	68.0	66.5	64.3
	64.0	65.0	66.7	64.3	64.4	66.8	67.4	67.8	67.5	66.5	64.9
	64.3	65.0	63.7	68.5	60.1	68.7	68.0	67.9	67.5	67.2	64.4
	61.8	62.2	64.2	64.5	64.7	63.1	67.4	67.5	67.6	67.0	65.0
	65.6	63.3	65.1	64.4	60.5	68.6	67.0	67.0	68.1	66.5	65.0
	62.9	64.7	61.9	64.1	60.0	67.7	66.6	67.1	67.1	67.4	66.5
	62.6	59.0	66.0	63.6	70.4	63.5	66.7	67.1	67.1	67.4	66.7
	62.5	60.7	66.9	67.0	69.5	65.5	66.8	67.2	67.7	66.7	65.8
	60.5	62.5	68.0	68.0	59.1	69.6	66.8	67.6	68.5	66.6	64.8
	61.5	63.4	66.7	60.2	61.6	64.3	67.1	67.3	67.5	67.7	65.0
	61.5	63.6	65.4	66.1	64.2	64.5	67.5	67.4	67.4	67.1	63.6
	63.1	66.8	68.6	65.3	64.3	59.0	67.4	67.0	68.1	66.2	66.5
	59.0	64.6	64.7	71.8	65.8	58.7	67.1	67.1	68.6	66.5	64.8
	62.3	61.8	67.5	58.6	63.2	61.2	66.7	67.5	67.4	67.7	65.4
	59.6	59.8	64.7	67.9	63.2	66.3	66.6	67.1	67.7	67.6	63.8
	60.1	63.5	67.0	67.9	65.7	63.6	66.6	67.4	66.6	66.8	64.3
	57.9	63.2	65.5	67.3	63.5	66.1	66.7	67.2	68.0	65.1	64.4
	60.6	63.6	66.5	66.3	63.2	65.7	66.8	66.9	67.1	67.8	64.3
	57.0		63.5	65.5		63.2		67.3		68.1	
	63.5		64.4	67.7				67.5		67.1	
	64.9		67.4	66.2						67.4	
	62.4		66.6							66.8	
	62.1		64.8							66.5	
	62.2									65.6	
	58.8										
Count	27	20	25	23	20	21	20	22	20	26	20
Mean	61.7	62.9	65.9	65.8	63.8	65.0	67.0	67.3	67.6	66.9	64.9
St Dev	2.1	1.9	1.6	2.7	2.8	3.0	0.4	0.3	0.5	0.7	0.9
Max	65.6	66.8	68.6	71.8	70.4	69.6	68.0	67.9	68.6	68.1	66.7
Min	57.0	59.0	61.9	58.6	59.1	58.7	66.6	66.9	66.6	65.1	63.2

LITTLE SAND LAKE, WEST SIDE

Date	17-Jan-85	18-Jan-85	18-Jan-85	19-Jan-85	19-Jan-85	20-Jan-85	20-Jan-85	21-Jan-85	21-Jan-85	22-Jan-85	22-Jan-85
Time	1551	817	1600	843	1658	858	1520	905	1649	1042	1604
Dec. Day	17.66	18.35	18.67	19.36	19.71	20.37	20.64	21.38	21.70	22.45	22.67
Gage	64.4	63.5	64.6	62.5	61.6	60.0	58.9	60.0	61.0	63.2	62.0
	64.7	62.9	63.5	64.0	65.6	62.3	64.2	63.1	61.1	62.5	63.2
	65.0	63.6	62.4	62.3	56.6	60.0	69.4	63.6	61.2	61.8	64.6
	65.5	61.1	63.5	64.0	59.2	61.1	62.1	59.3	65.4	62.1	62.5
	65.2	62.5	62.1	63.5	62.4	62.4	61.9	61.8	62.2	65.4	62.5
	65.5	65.4	62.2	62.3	61.0	63.3	63.5	62.2	65.4	62.5	63.8
	65.5	60.5	63.3	64.4	64.1	67.1	66.0	62.7	62.2	65.1	64.3
	65.6	62.7	63.1	62.7	61.1	62.1	64.9	63.1	66.6	63.3	66.5
	65.6	60.0	61.3	61.2	57.5	61.7	59.1	62.9	66.7	61.1	61.0
	65.5	62.5	63.4	65.7	59.0	58.0	65.2	62.4	61.1	62.8	66.2
	65.4	65.4	62.4	61.1	67.5	65.3	68.8	63.2	63.3	65.8	63.8
	65.4	62.0	62.3	62.4	60.0	61.3	65.6	62.2	58.0	63.2	65.3
	65.6	62.0	63.4	63.6	63.8	61.5	59.3	64.2	62.7	59.0	64.5
	64.7	62.5	61.4	65.3	57.8	61.8	63.4	65.2	62.3	66.2	66.4
	65.0	60.9	60.1	62.3	62.0	62.2	60.5	62.9	61.5	68.0	63.9
	64.7	63.4	62.7	59.8	57.9	61.9	62.4	61.0	67.7	64.8	64.2
	64.5	60.2	62.5	69.6	67.1	61.6	65.5	63.8	63.3	64.3	63.8
	64.6	64.3	64.4	58.4	58.9	59.0	60.2	61.9	69.6	62.2	65.4
	65.0	63.1	61.1	60.0	64.0	62.7	58.8	64.0	63.0	67.7	66.3
	65.1	58.7	63.3	63.4	65.1	66.4	60.1	68.5	63.6	65.6	64.2
	65.4	64.7	65.5	60.2	61.1	64.3		64.2		59.3	65.4
	65.5	61.3	62.3	60.9	62.3	60.9		59.3		63.5	65.3
	65.5	64.1	62.8	58.0	63.1	62.2		63.6		62.5	62.4
	65.5		63.3	61.4		63.1		60.5		61.2	65.5
	65.4		63.4	61.0		66.4		56.6		62.1	66.5
	64.6		62.3	58.0		58.6				65.6	64.6
	65.4			59.5		61.1				66.5	
	65.4			65.2		56.5				66.7	
	65.3			63.3		62.6					
				57.8		64.4					
Count	29	23	26	30	23	30	20	25	20	28	26
Mean	65.2	62.5	62.8	62.1	61.7	62.1	63.0	62.5	63.4	63.7	64.4
St Dev	0.4	1.7	1.1	2.6	3.0	2.4	3.1	2.2	2.7	2.3	1.5
Max	65.6	65.4	65.5	69.6	67.5	67.1	69.4	68.5	69.6	68.0	66.5
Min	64.4	58.7	60.1	57.8	56.6	56.5	58.8	56.6	58.0	59.0	61.0

LITTLE SAND LAKE, WEST SIDE

Date	23-Jan-85	23-Jan-85	24-Jan-85	25-Jan-85	26-Jan-85	27-Jan-85	28-Jan-85	29-Jan-85	31-Jan-85
Time	917	1533	838	848	923	838	844	858	851
Dec. Day	23.39	23.65	24.36	25.37	26.39	27.36	28.36	29.37	31.37
Gage	63.3	66.4	65.6	64.5	66.6	69.0	67.9	68.9	68.3
	65.8	65.4	65.4	67.4	68.1	65.3	67.8	69.0	69.3
	64.8	65.5	65.6	62.8	69.0	68.6	67.9	68.9	68.6
	65.4	65.7	65.5	67.3	66.4	66.9	68.0	69.1	69.1
	65.6	64.6	65.5	70.7	66.4	69.1	67.8	69.0	68.6
	66.6	64.3	65.4	66.2	66.5	60.6	68.0	69.0	69.3
	63.4	65.5	65.4	65.3	66.5	64.3	68.0	68.9	68.5
	65.4	66.7	65.2	64.5	66.5	65.5	68.4	68.8	69.0
	63.5	65.6	65.3	63.2	66.6	65.4	68.0	69.0	68.4
	63.6	66.6	65.6	63.3	68.6	66.4	67.7	68.9	69.3
	65.5	66.4	65.5	64.3	67.5	65.8	67.9	69.0	68.3
	64.4	64.8	65.6	69.5	66.5	65.8	67.9	68.9	68.1
	65.4	64.6	65.5	63.2	66.5	69.6	68.0	68.8	68.2
	65.7	65.8	65.7	63.1	66.4	64.7	68.1	68.9	68.1
	65.5	64.5	65.5	61.4	67.5	65.3	68.8	68.9	68.9
	64.6	65.4	65.5	68.1	65.0	66.4	68.1	69.0	68.6
	64.4	64.5	65.5	67.5	66.4	64.4	67.9	68.9	69.0
	67.5	63.9	65.4	72.2	65.8	70.7	67.8	68.8	68.6
	63.9	64.7	65.1	69.5	68.9	65.7	67.9	68.9	69.2
	64.4	65.9	65.4	69.4	68.4	68.5	67.9	68.9	68.6
	65.9	66.7	65.4	68.6	66.5	65.5	67.6	69.0	68.7
	62.2	65.7	65.3	65.3	66.8	67.8	67.4	69.0	68.3
	66.9	66.4	65.5	64.6	65.9	65.9	68.1	69.0	68.6
	65.3	64.9		63.6	67.5	64.8	68.8		68.9
	64.3	65.8		63.4	66.5	67.3	67.5		69.0
		65.4		63.4	67.7	66.8	68.0		
				71.3	67.0		68.8		
				66.5	68.0		67.8		
					65.8				
					66.4				
					66.2				
					67.0				
					65.3				
					65.5				
					66.5				
					66.7				
					66.8				
Count	25	26	23	28	37	26	28	23	25
Mean	64.9	65.5	65.5	66.1	66.8	66.4	68.0	68.9	68.7
St Dev	1.2	0.8	0.1	2.9	0.9	2.0	0.3	0.1	0.4
Max	67.5	66.7	65.7	72.2	69.0	70.7	68.8	69.1	69.3
Min	62.2	63.9	65.1	61.4	65.0	60.6	67.4	68.8	68.1

LITTLE SAND LAKE, EAST SIDE

Date	13-Jan-85	13-Jan-85	14-Jan-85	15-Jan-85	15-Jan-85	16-Jan-85	16-Jan-85	17-Jan-85	17-Jan-85	18-Jan-85	18-Jan-85	19-Jan-85	19-Jan-85	20-Jan-85
Time	1220	1730	905	1153	1723	1142	1530	940	1646	1012	1528	931	1628	924
Dec. Day	13.51	13.73	14.38	15.50	15.72	16.49	16.65	17.40	17.70	18.43	18.64	19.40	19.69	20.39
Gage	50.6	53.4	52.6	50.7	50.4	49.4	51.6	49.0	50.0	48.5	44.7	45.6	47.0	47.5
	50.5	50.9	53.5	50.7	50.6	49.8	50.1	46.6	50.1	48.0	42.7	41.4	47.0	47.3
	49.3	51.6	47.8	50.8	50.5	49.8	48.4	49.4	50.3	48.6	48.5	46.2	46.4	50.5
	50.3	50.8	47.4	50.5	50.6	50.0	49.5	48.6	50.5	50.5	45.2	41.9	49.6	48.2
	50.0	52.3	48.9	50.7	50.5	49.7	48.9	49.6	50.2	48.5	49.0	41.5	49.3	46.0
	49.3	54.1	45.1	50.5	50.3	49.0	49.6	47.3	50.5	47.4	48.2	45.9	51.8	48.5
	48.2	50.5	46.3	50.2	50.3	49.7	50.5	49.6	50.5	48.2	46.5	53.8	59.6	46.2
	50.2	49.2	41.8	50.0	50.3	49.5	50.8	50.6	50.3	46.4	48.4	46.4	42.4	49.1
	49.1	51.8	52.9	49.6	50.6	49.9	50.4	47.2	50.2	48.5	48.2	47.4	44.3	46.4
	52.1	49.4	52.8	49.4	50.8	50.5	50.5	48.1	50.1	50.1	49.4	43.1	48.3	48.5
	54.1	50.0	50.3	49.5	50.8	50.0	49.5	47.6	49.8	45.2	46.2	47.3	46.3	48.4
	55.0	50.9	51.7	49.5	51.3	50.5	48.6	49.4	50.0	47.5	47.3	43.6	46.4	44.1
	51.6	51.9	50.5	49.6	51.2	50.1	49.5	47.4	49.9	49.6	47.2	41.1	45.4	52.5
	51.9	50.6	53.6	49.7	51.3	50.0	50.0	50.7	49.8	47.5	46.6	50.1	46.1	47.5
	52.0	50.5	43.2	49.7	51.4	49.5	50.6	47.5	49.6	47.2	47.3	49.3	55.7	48.3
	52.4	50.7	48.2	49.9	50.0	49.8	51.6	51.7	49.5	48.7	48.5	44.2	38.8	43.5
	51.0	53.0	54.6	50.0	50.5	49.2	50.8	51.4	49.5	44.4	46.4	44.5	48.4	47.6
	51.7	53.7	51.4	50.2	50.6	48.7	50.5	51.6	49.5	45.4	47.8	48.3	46.8	45.3
	55.1	51.7	54.6	50.4	50.4	48.7	49.7	51.5	49.5	51.5	47.5	48.7	46.4	52.6
	54.0	52.7	50.5	50.6	50.6	49.5	48.7	49.4	49.6	46.3	45.4	51.1	46.3	46.2
	48.4	51.6	56.0	50.8	50.5	49.8	50.1		49.5	46.6	48.4	43.8	48.4	48.4
	49.6	51.9	51.4	51.0	50.5	50.3	49.6		49.4	47.5	45.5		40.1	44.7
	48.5	62.5	48.1	51.2	50.7	49.0	49.7		49.5		44.4		52.6	48.2
	49.4	53.4	51.7	51.5		49.3	49.5		49.4		44.8		43.9	48.1
	49.7		50.3	51.4			50.0		49.5		45.3			48.4
	51.7		54.4	51.4			50.2		49.5		46.3			54.3
	51.3		51.4	51.6			50.0		49.9					42.1
	49.7			51.6			50.5		49.6					44.1
	52.8			51.2			50.5							48.3
	55.0			51.0			49.2							49.5
	50.6			50.8			48.8							46.3
	51.6			50.5										48.2
	52.6			50.5										48.3
	52.9			50.5										44.3
				50.4										51.4
				50.3										
				49.8										
				49.8										
				50.1										
				50.1										
				50.1										
				50.1										
				50.0										
Count	34	24	27	43	23	24	31	20	28	22	26	21	24	35
Mean	51.2	52.0	50.4	50.4	50.6	49.7	49.9	49.2	49.8	47.8	46.8	46.0	47.4	47.7
St Dev	1.9	2.5	3.5	0.6	0.3	0.5	0.8	1.6	0.4	1.7	1.6	3.4	4.4	2.6
Max	55.1	62.5	56.0	51.6	51.4	50.5	51.6	51.7	50.5	51.5	49.4	53.8	59.6	54.3
Min	48.2	49.2	41.8	49.4	50.0	48.7	48.4	46.6	49.4	44.4	42.7	41.1	38.8	42.1

LITTLE SAND LAKE, EAST SIDE

Date	20-Jan-85	21-Jan-85	21-Jan-85	22-Jan-85	22-Jan-85	23-Jan-85	23-Jan-85	24-Jan-85	25-Jan-85
Time	1447	929	1531	1107	1632	956	1620	904	937
Dec. Day	20.62	21.40	21.65	22.46	22.69	23.41	23.68	24.38	25.40
Gage	49.4	47.7	50.4	49.5	42.9	50.5	48.6	48.7	47.6
	39.9	48.1	50.7	50.7	46.3	50.7	49.2	49.1	41.7
	43.2	48.3	44.3	49.7	50.4	47.6	49.5	48.8	45.4
	48.5	49.4	44.5	46.7	48.2	52.7	49.4	48.8	52.6
	47.1	50.9	49.4	51.5	50.6	47.8	50.2	49.1	48.6
	42.4	48.3	46.5	51.4	51.7	51.6	49.5	49.0	43.8
	47.0	47.7	48.6	53.8	48.9	50.0	49.5	48.7	47.1
	49.5	45.0	50.5	48.5	50.6	49.5	49.4	48.7	47.5
	44.4	42.2	49.3	49.3	52.6	46.4	48.4	49.1	48.2
	46.5	44.6	47.3	45.0	47.8	46.4	49.3	49.0	53.8
	46.6	53.7	48.7	45.3	50.6	49.5	48.6	48.7	50.0
	47.5	49.8	45.9	51.6	43.2	46.6	49.3	48.6	50.0
	49.4	49.2	47.8	46.2	53.6	48.8	49.1	48.8	45.3
	48.6	51.6	52.6	49.6	51.5	49.5	50.6	48.6	51.6
	43.2	53.4	44.2	46.3	50.0	47.4	50.3	49.1	50.6
	51.1	47.3	43.3	51.2	46.3	48.4	48.5	48.7	47.3
	49.4	44.1	52.0	54.6	46.7	45.7	48.4	49.0	53.0
	47.3	50.6	47.4	54.7	47.5	49.7	50.6	49.0	48.6
	46.4	52.4	48.4	49.3	49.3	57.6	48.5	49.0	45.0
	47.6	51.3	46.5	49.3	45.2	46.3	49.7	48.6	46.4
		50.5	48.3	51.5	48.5	49.5	49.4	48.8	52.3
		44.2	44.2	49.4	49.4	50.5	48.4	49.1	62.0
		46.1	47.7	49.6	48.3	50.6	48.6	48.6	47.4
		48.3	46.2	45.1	48.4	48.1	48.5	49.0	52.5
		53.6	44.2	49.5	53.6	50.9	49.8	49.2	48.7
		43.6		48.5	46.7	52.5		49.1	48.7
				49.2		49.6		49.3	
				47.8		47.2		49.3	
						47.5		49.4	

										MEANS
Count	20	26	25	28	26	29	25	29	26	26
Mean	46.8	48.5	47.6	49.5	48.8	49.3	49.3	48.9	49.1	46.9
St Dev	2.8	3.2	2.5	2.6	2.7	2.4	0.7	0.2	3.9	
Max	51.1	53.7	52.6	54.7	53.6	57.6	50.6	49.4	62.0	
Min	39.9	42.2	43.3	45.0	42.9	45.7	48.4	48.6	41.7	

OAK LAKE

Date	17-Jan-85	17-Jan-85	18-Jan-85	18-Jan-85	19-Jan-85	19-Jan-85	20-Jan-85	20-Jan-85	21-Jan-85	21-Jan-85	22-Jan-85
Time	1245	1615	944	1621	1005	1557	835.00	1422	842	1600	1020
Dec. Day	17.53	17.68	18.41	18.68	19.42	19.66	20.36	20.60	21.36	21.67	22.43
Gage	56.0	56.8	54.9	57.0	50.1	56.1	52.9	58.9	56.4	51.7	56.8
	57.2	57.6	55.5	53.6	58.0	57.3	48.5	56.2	58.2	60.0	56.0
	57.2	58.0	52.1	52.6	55.0	57.3	57.5	54.0	52.6	62.3	56.8
	57.7	57.8	58.0	56.1	54.9	58.9	53.2	55.8	54.3	57.0	61.4
	58.4	56.8	51.7	57.0	55.8	58.8	56.1	57.0	62.1	68.5	54.3
	56.8	57.4	51.6	51.5	61.1	56.7	55.7	62.1	62.3	54.7	54.8
	56.3	57.9	56.0	53.6	57.8	48.4	54.8	62.3	54.8	59.3	54.9
	57.0	57.7	54.9	56.0	56.5	49.1	56.8	53.1	51.5	54.8	55.8
	58.0	57.1	54.0	53.5	56.9	52.9	58.9	53.2	54.0	52.3	53.8
	56.4	57.0	56.4	55.8	57.9	54.6	56.3	54.5	56.0	46.5	58.0
	56.2	57.2	58.2	55.4	55.8	55.0	56.8	64.9	56.8	59.2	51.9
	58.1	57.6	56.8	54.9	53.1	56.9	61.9	55.8	59.1	58.0	51.1
	58.0	57.8	54.9	56.0	56.2	49.7	61.9	62.0	53.0	60.2	60.5
	57.1	57.7	53.0	54.9	52.7	57.7	51.7	55.4	51.5	55.2	60.8
	56.1	57.6	51.8	55.2	53.6	54.6	54.3	60.0	53.5	59.9	52.7
	58.0	57.1	59.2	55.9	58.0	54.9	55.7	63.2	61.5	60.6	53.8
	57.8	56.9	56.8	56.9	62.8	55.0	59.2	58.1	58.2	52.6	60.2
	58.2	57.3	55.7	55.0	51.5	59.2	55.2	49.2	51.3	58.0	54.5
	57.2	58.0	55.1	54.2	58.3	51.6	52.6	52.4	55.9	54.9	58.0
	56.9	57.5	54.3	55.9	53.5	52.7	59.1	54.7	55.0	49.4	58.0
	57.3	57.4	52.8	54.7	54.9	57.0	52.9	45.2	51.3	52.0	60.0
	58.0	56.9	54.6	56.8		52.8	50.5		57.9	61.2	61.2
	58.1	57.4	54.5	54.0			53.7				54.9
	57.1		53.9	56.2			55.1				58.0
	57.1		53.6	55.1			62.0				51.7
	58.3		55.9				55.2				60.1
	57.9										57.5
	58.0										
	55.5										
	57.3										
Count	30	23	26	25	21	22	26	21	22	22	27
Mean	57.3	57.4	54.9	55.1	55.9	54.9	55.7	56.6	55.8	56.7	56.6
St Dev	0.8	0.4	2.0	1.4	3.0	3.1	3.3	4.7	3.4	4.8	3.0
Max	58.4	58.0	59.2	57.0	62.8	59.2	62.0	64.9	62.3	68.5	61.4
Min	55.5	56.8	51.6	51.5	50.1	48.4	48.5	45.2	51.3	46.5	51.1

OAK LAKE

Date	22-Jan-85	23-Jan-85	23-Jan-85	24-Jan-85	25-Jan-85	26-Jan-85	26-Jan-85	27-Jan-85	27-Jan-85	28-Jan-85	28-Jan-85
Time	1658	856	1559	818	825	833	1306	817	1541	822	1741
Dec. Day	22.71	23.37	23.67	24.35	25.35	26.36	26.55	27.35	27.65	28.35	28.74
Gage	57.0	60.1	58.1	60.2	55.9	61.2	63.3	62.6	59.6	63.5	68.6
	58.2	60.8	56.0	60.1	59.3	61.2	60.1	61.1	63.8	62.6	68.5
	58.0	62.5	60.4	60.1	57.6	61.2	59.2	61.4	66.6	62.9	68.4
	63.4	56.3	59.5	60.3	65.1	61.3	61.6	64.0	57.8	63.6	68.7
	55.0	57.0	58.3	60.2	66.5	61.7	59.2	62.2	57.3	62.4	68.4
	59.2	62.2	59.4	59.9	63.5	63.0	61.1	59.9	53.1	62.9	68.3
	61.2	60.3	61.5	60.3	62.2	61.5	61.9	61.1	64.0	63.8	68.7
	58.3	57.9	60.6	59.8	58.3	60.1	57.1	60.4	63.2	63.5	68.2
	57.2	59.7	57.8	60.1	55.8	60.1	59.1	68.8	63.2	62.6	68.5
	66.5	61.2	59.1	60.3	56.0	61.5	63.4	64.5	56.2	62.5	68.2
	53.8	56.9	61.6	59.8	62.5	63.2	58.7	62.1	62.0	63.3	68.4
	58.0	59.4	62.3	60.1	63.4	62.5	59.4	61.9	65.5	63.4	68.3
	64.1	59.3	58.9	59.9	60.6	61.3	63.4	61.3	59.5	63.5	68.7
	54.5	61.1	59.1	60.0	57.1	61.6	62.3	56.8	60.1	62.8	68.4
	59.0	59.4	59.4	60.2	56.8	61.2	60.1	65.4	64.4	63.4	68.5
	61.2	61.1	59.4	60.1	55.2	61.7	61.0	61.1	69.9	63.2	68.4
	54.0	60.3	59.4	60.0	59.1	61.3	64.4	60.4	66.4	63.9	68.4
	62.2	61.6	59.3	60.0	61.3	61.1	64.6	60.2	57.9	62.8	68.4
	60.1	59.7	61.1	59.9	61.1	61.0	62.4	58.8	54.1	62.8	68.4
	58.2	60.0	61.1	60.1	54.8	60.9	62.2	65.6	53.7	63.3	68.3
		62.2	57.1	59.7	56.7	61.6	58.7	57.6	64.3	63.3	
		50.2	59.0	60.0	62.5	62.5	61.2	60.4	52.5		
		64.4	60.0	60.0	67.0	64.1	59.1	60.5	61.5		
		60.8	62.3	60.1	61.9	62.6	62.7	63.5	60.3		
			57.4		53.8	61.7	61.4	54.9	63.8		
					58.0	60.6	62.4		61.5		
					61.1	60.4	61.0		61.1		
					57.4	61.0	61.2		59.4		
						61.4	61.3				
						62.5	63.2				
						62.7	61.2				
						61.3	58.8				
						62.5	57.0				
							62.5				
							63.2				
Count	20	24	25	24	28	33	35	25	28	21	20
Mean	59.0	59.8	59.5	60.1	59.7	61.6	61.1	61.5	60.8	63.1	68.4
St Dev	3.3	2.7	1.6	0.2	3.5	0.9	1.9	2.9	4.3	0.4	0.1
Max	66.5	64.4	62.3	60.3	67.0	64.1	64.6	68.8	69.9	63.9	68.7
Min	53.8	50.2	56.0	59.7	53.8	60.1	57.0	54.9	52.5	62.4	68.2

OAK LAKE

Date	29-Jan-85	29-Jan-85	31-Jan-85
Time	836	1623	826
Dec. Day	29.36	29.68	31.35
Gage	64.1	63.7	64.7
	64.1	63.6	63.8
	64.1	64.3	63.8
	63.8	64.3	63.6
	63.9	63.6	64.5
	64.0	64.4	64.0
	64.1	64.2	64.6
	64.1	63.7	63.6
	64.0	63.8	64.9
	64.1	63.6	65.5
	63.9	64.0	64.9
	64.0	64.1	63.6
	64.0	63.7	63.4
	64.0	64.3	64.6
	64.3	64.1	63.8
	64.0	63.4	63.1
	64.1	64.1	64.5
	63.9	64.4	63.8
	63.9	63.5	62.8
	64.0	63.5	64.3
	63.9	63.8	64.1
	64.0	64.0	64.1
	63.8	63.9	
		63.5	
Count	23	24	22
Mean	64.0	63.9	64.1
St Dev	0.1	0.3	0.6
Max	64.3	64.4	65.5
Min	63.8	63.4	62.8

DUCK LAKE

Date	13-Jan-85	13-Jan-85	14-Jan-85	14-Jan-85	15-Jan-85	15-Jan-85	16-Jan-85
Time	1045	1600	951	1907	858	1827	1028
Dec. Day	13.45	13.67	14.41	14.80	15.37	15.77	16.44
Gage	77.6	79.2	80.1	80.4	82.5	83.0	86.1
	79.2	78.2	78.1	80.8	82.3	83.1	83.9
	78.6	78.5	78.9	79.2	82.4	83.4	84.9
	77.7	79.3	78.3	80.4	82.7	83.5	84.6
	77.2	78.6	77.1	82.3	82.8	83.1	83.9
	78.1	79.3	77.1	80.4	82.5	83.6	85.3
	77.5	79.6	78.6	80.2	82.1	83.3	84.0
	78.1	79.5	78.0	80.3	81.9	83.0	84.9
	79.2	78.9	79.2	80.3	81.8	83.3	85.5
	78.1	77.9	79.3	81.5	82.3	82.9	84.9
	77.3	78.1	80.4	81.4	82.7	83.1	84.6
	77.2	79.5	80.2	81.2	82.8	83.9	83.9
	77.2	80.9	78.2	80.6	82.7	82.9	84.6
	77.5	79.7	78.3	79.8	82.1	82.8	85.0
	77.5	79.3	77.1	80.4	81.7	82.9	85.6
	77.3	79.5	78.4	81.8	81.8	83.4	84.4
	78.6	80.9	80.3	81.1	82.5	83.2	84.5
	78.0	79.6	81.0	84.1	82.5	83.5	85.0
	76.6	78.4	80.2	80.5	82.4	83.3	84.5
	78.1	78.5	80.3	80.4	82.0	82.8	83.8
	77.5	78.1	79.1	80.7		83.7	84.9
		79.3	79.2	81.9		83.3	84.5
		78.6	76.3	80.3		83.1	84.4
		79.5	77.4	81.5			
		78.7	79.3				
		79.1	79.7				
		80.3	78.5				
		79.4	80.3				
		79.4					
		78.4					
		79.3					
		79.6					
		80.2					
		78.8					
		79.5					
		80.2					
		78.3					
		78.6					
Count	21	38	28	24	20	23	23
Mean	77.8	79.2	78.9	80.9	82.3	83.2	84.7
St Dev	0.7	0.7	1.2	1.0	0.3	0.3	0.6
Max	79.2	80.9	81.0	84.1	82.8	83.9	86.1
Min	76.6	77.9	76.3	79.2	81.7	82.8	83.8

Date	16-Jan-85	17-Jan-85	18-Jan-85	19-Jan-85	20-Jan-85	21-Jan-85	22-Jan-85
Time	1028	1040	1048	1042	1010	1003	1147
Dec. Day	16.44	17.44	18.45	19.45	20.42	21.42	22.49
Gage	86.1	84.6	86.7	87.0	89.8	90.9	92.5
	83.9	84.8	82.5	83.3	89.1	88.6	95.1
	84.9	84.6	84.5	89.0	89.6	90.5	94.0
	84.6	84.7	83.0	84.1	89.3	91.9	92.9
	83.9	83.5	82.0	86.9	88.8	89.8	93.0
	85.3	83.7	83.5	85.7	88.0	89.3	90.8
	84.0	85.0	85.6	87.2	88.1	88.8	93.1
	84.9	84.5	85.6	83.4	88.5	90.0	92.0
	85.5	84.6	83.5	85.8	88.5	91.8	91.8
	84.9	84.7	84.0	88.1	90.1	88.7	91.1
	84.6	85.7	85.0	83.1	89.0	92.0	93.7
	83.9	84.6	83.1	87.1	89.7	89.8	93.3
	84.6	84.5	82.8	86.6	90.0	88.9	92.5
	85.0	85.5	81.7	85.1	91.1	91.9	91.9
	85.6	84.0	85.5	85.0	88.0	91.4	93.2
	84.4	84.2	85.9	84.4	90.1	89.9	93.0
	84.5	83.4	86.0	86.3	89.0	91.0	92.7
	85.0	84.8	83.5	86.6	88.1	90.8	92.1
	84.5	83.6	81.8	87.2	90.6	88.6	93.0
	83.8	84.7	83.6	85.5	90.1	93.4	94.5
	84.9	84.1	83.8	84.5	89.0	88.6	89.8
	84.5	85.0	85.0	84.7	89.0	89.7	92.9
	84.4	85.5	85.6	85.9	90.8	91.2	95.0
		84.0		83.4	89.8	92.3	92.3
		82.9		83.7	88.7		89.7
		84.0			88.7		91.9
		84.9			88.9		90.4
		84.0			90.2		95.4
		84.2					93.3
		84.7					89.6
Count	23	30	23	25	28	24	30
Mean	84.7	84.4	84.1	85.6	89.3	90.4	92.6
St Dev	0.6	0.6	1.4	1.6	0.8	1.4	1.5
Max	86.1	85.7	86.7	89.0	91.1	93.4	95.4
Min	83.8	82.9	81.7	83.1	88.0	88.6	89.6

DUCK LAKE

Date	23-Jan-85	24-Jan-85	25-Jan-85	26-Jan-85
Time	1035	1005	1028	954.00
Dec. Day	23.44	24.42	25.44	26.41
Gage	95.2	96.2	100.5	101.8
	95.3	96.7	97.3	100.8
	97.2	96.4	99.6	101.5
	94.0	96.5	94.2	101.1
	93.9	95.5	98.1	101.8
	96.0	95.4	95.8	100.6
	94.8	96.3	96.0	100.5
	95.7	94.8	97.5	101.9
	94.4	97.2	99.6	100.9
	95.1	96.9	97.9	99.8
	96.1	95.4	95.1	100.4
	96.1	98.3	99.3	100.5
	94.9	96.1	98.7	101.5
	94.0	96.0	95.8	101.6
	94.5	96.3	99.2	100.5
	94.4	98.2	98.6	102.5
	96.1	93.8	99.8	100.7
	96.2	95.0	97.5	100.5
	95.4	96.4	96.8	99.8
	94.0	95.5	96.8	100.4
	96.5	96.6	96.5	100.7
	95.4	97.2	98.4	100.7
	96.0	97.1	98.3	101.5
	93.2	95.4	97.1	101.7
	96.4	94.8	102.9	101.6
		95.2	103.7	100.9
		95.4		100.3
				100.4
				99.8
				100.3
				100.5
				101.8
				100.8
Count	25	27	26	33
Mean	95.2	96.1	98.1	100.9
St Dev	1.0	1.0	2.1	0.7
Max	97.2	98.3	103.7	102.5
Min	93.2	93.8	94.2	99.8

SKUNK LAKE

Date	13-Jan-85	13-Jan-85	14-Jan-85	14-Jan-85	15-Jan-85	15-Jan-85	16-Jan-85	16-Jan-85	17-Jan-85	18-Jan-85	19-Jan-85	20-Jan-85
Time	1128	1639	1028	1943	1110	1900	1101	1805	1111	1117	843	1038
Dec. Day	13.48	13.69	14.44	14.82	15.47	15.79	16.46	16.75	17.47	18.47	19.36	20.44
Gage	70.5	71.1	73.1	74.8	78.2	79.0	79.3	80.2	80.6	81.6	83.2	84.0
	70.8	71.6	73.2	75.0	77.5	79.1	79.3	80.5	80.6	81.4	83.8	86.0
	71.0	71.7	72.9	74.3	78.1	78.8	79.4	80.6	80.4	79.6	82.8	86.3
	70.7	72.1	74.1	75.0	77.5	79.0	79.8	80.4	80.7	81.3	83.0	84.9
	71.0	71.7	73.1	74.2	77.5	79.1	79.5	80.3	80.7	80.4	84.0	86.5
	70.8	71.7	73.1	74.8	77.8	79.0	79.8	80.6	80.5	80.5	83.4	86.2
	71.0	72.0	73.1	74.2	77.8	79.0	80.0	80.5	80.3	81.4	83.5	86.3
	70.8	71.7	73.2	74.8	77.5	79.3	80.0	80.5	80.5	81.3	81.4	86.0
	71.0	71.5	74.0	74.8	78.0	79.2	80.0	80.5	80.7	81.2	82.3	85.7
	70.9	71.8	74.1	74.7	77.6	79.1	79.9	80.6	80.6	81.5	82.4	85.3
	71.0	71.8	74.4	74.3	77.7	79.1	80.0	80.5	80.7	80.5	82.7	86.6
	70.7	71.9	74.1	74.6	77.6	79.0	79.5	80.5	80.8	81.4	82.4	85.4
	70.8	71.7	73.1	74.9	78.2	78.9	79.7	80.3	80.8	80.5	82.4	85.4
	71.1	71.6	73.7	74.5	77.7	79.0	79.9	80.5	80.6	80.4	82.8	86.1
	71.0	71.7	73.2	74.8	77.6	79.1	79.9	80.4	80.7	80.9	81.9	86.0
	70.9	71.8	73.3	74.3	77.6	79.1	79.9	80.4	80.7	80.3	83.2	85.4
	70.7	71.8	73.4	74.5	78.0	79.2	80.0	80.6	81.3	81.4	81.8	86.3
	70.6	71.7	73.1	74.6	77.7	79.2	79.8	80.3	80.7	80.5	82.8	86.0
	70.8	72.0	73.0	74.5	77.4	79.1	79.8	80.3	80.7	80.6	82.3	86.0
	70.7	71.8	73.0	74.3	77.7	79.2	79.8	80.2	80.7	80.8	83.8	85.7
	70.4	71.4	73.3	74.5	78.0	79.1	79.7	80.4	80.7	80.7	82.8	84.9
	70.6	71.9	74.0	74.8	77.7		80.4	80.4	80.8	82.1	82.8	85.6
	71.0	71.5	73.1	74.3	77.9		79.5	80.4	80.7	80.9	82.6	85.8
	71.0	71.4	73.6	74.6	77.6			80.4	80.9	80.5	83.8	85.5
	71.0	71.2	73.1		77.7			80.0	80.8	80.9	83.0	85.5
	71.0	71.6	73.3					80.5		81.4	82.9	84.8
	70.6	71.2	73.8					80.0			81.5	86.2
		71.8	73.2					80.3				86.6
		71.9	73.7					80.4				86.0
		71.3	73.9					80.1				
		71.4	73.8					80.1				
		71.8	74.1					80.2				
		71.7	73.1					80.2				
			73.0					80.2				
			73.1					80.2				
								80.2				
								80.3				
Count	27	33	35	24	25	21	23	37	25	26	27	29
Mean	70.8	71.7	73.4	74.6	77.7	79.1	79.8	80.4	80.7	80.9	82.8	85.8
St Dev	0.2	0.2	0.4	0.2	0.2	0.1	0.3	0.2	0.2	0.5	0.7	0.6
Max	71.1	72.1	74.4	75.0	78.2	79.3	80.4	80.6	81.3	82.1	84.0	86.6
Min	70.4	71.1	72.9	74.2	77.4	78.8	79.3	80.0	80.3	79.6	81.4	84.0

SKUNK LAKE

Date	21-Jan-85	22-Jan-85	23-Jan-85
Time	1029	1212	1051
Dec. Day	21.44	22.51	23.45
Gage	89.0	91.1	94.9
	88.8	91.2	95.2
	88.9	90.0	94.6
	89.2	91.9	94.7
	89.2	92.2	94.6
	89.2	91.5	94.6
	88.8	91.1	94.3
	89.3	91.3	94.8
	89.2	90.2	94.6
	89.2	90.8	94.6
	88.9	91.2	94.5
	89.2	90.9	94.5
	89.0	91.2	94.2
	88.4	92.0	94.6
	89.3	90.9	94.5
	89.2	90.9	94.7
	90.0	91.9	95.1
	88.3	91.2	94.4
	89.3	90.6	94.5
	89.2	91.0	94.5
	89.3	91.1	95.1
	88.8	92.1	94.7
	89.1	92.0	94.5
	88.8	92.3	95.1
	89.2	92.3	94.6
	88.4	91.2	94.5
		91.3	94.6
		92.0	
Count	26	28	27
Mean	89.0	91.3	94.6
St Dev	0.3	0.6	0.2
Max	90.0	92.3	95.2
Min	88.3	90.0	94.2

APPENDIX F

SURVEYOR'S REPORT ON POST ELEVATION

Inman · Foltz and Associates, Inc.
architects engineers surveyors
8612 highway 51 north p.o. box u
minocqua, wisconsin 54548 (715) 356-9485

RECEIVED
FEB - 1 1985
EXXON MINERALS
CRANDON PROJECT

January 31, 1985

Carlton Schroeder
Exxon Minerals Company
P.O. Box 813
Rhinelander, WI 54501

Re: Hook Gauge and V-Notch Weir Elevations

Dear Carlton:

Enclosed is the final elevation data for the hook gauges and V-notch weirs on Skunk, Duck, Oak and Little Sand Lakes. Please discard all previous data we have provided to you.

We checked the bench mark we have been using for the Duck Lake hook gauge elevations yesterday, and found it to be within 0.014 feet of the elevation we measured for it when we set it on March 13th, 1984. This discrepancy is within the limits of our normal tolerances for the bench marks we have been setting for the Crandon Project.

We also ran a new closed elevation loop yesterday from the bench mark on the west shore of Little Sand Lake (BM G40-S17A), which we had been using to measure the elevation of the west hook gauge on Little Sand, to the bench mark on the southeast shore (BM G40-Y21), which we used to measure the elevation of the east hook gauge. We found the difference in elevations between these bench marks to be 0.046' larger than the difference between the previously printed elevations, and we have therefore now recomputed all elevations for the east and west hook gauges by referencing them to only one bench mark, BM G40-Y21. This will eliminate any discrepancy the 0.046' elevation difference might have caused between the two bench marks.

I believe this completes the hook gauge and V-notch weir elevation work you have authorized, and I will bill it out as soon as I receive the work order for the last recheck done yesterday.

Thank you.

Sincerely,

Stu

Stuart L. Foltz
Professional Engineer
Registered Land Surveyor

SLF/tm
Enclosure

ELEVATIONS OF HOOK GAUGES AND V-NOTCH WEIRS

EXXON MINERALS COMPANY - CRANDON PROJECT

JANUARY, 1985

OBJECT	ELEVATION - 1/19/85		ELEVATION - 1/25/85		ELEVATION - 1/30/85	
Hook Gauge - Skunk Lake	1598.43 ft.	487.202 m.	1598.44 ft.	487.205 m.	-----------	-----------
Hook Gauge - Duck Lake	1612.47 ft.	491.482 m.	1612.41 ft.	491.464 m.	1612.366 ft.	491.450 m.
Hook Gauge - Oak Lake	1634.04 ft.	498.056 m.	1634.04 ft.	498.056 m.	1634.028 ft.	498.053 m.
Hook Gauge - Little Sand Lake (West)	1593.17 ft.	485.599 m.	1593.15 ft.	485.593 m.	1593.128 ft.	485.586 m.
Hook Gauge - Little Sand Lake (East)	1593.15 ft.	485.593 m.	1593.14 ft.	485.590 m.	-----------	-----------
V-Notch Weir Lt. Sand Inlet	1596.98 ft.	486.760 m.	1596.99 ft.	486.764 m.	-----------	-----------
V-Notch Weir Lt. Sand Outlet	1591.97 ft.	485.233 m.	1591.98 ft.	485.236 m.	-----------	-----------
V-Notch Weir Duck Lake Outlet	1608.07 ft.	490.141 m.	1608.11 ft.	490.153 m.	-----------	-----------

Datum - Mean Sea Level (1929)

Inman • Foltz and Associates, Inc.
architects engineers surveyors
8612 highway 51 north p.o. box u
minocqua, wisconsin 54548 (715) 356-9405

Inman · Foltz and Associates, Inc.
architects engineers surveyors
8612 highway 51 north p.o. box u
minocqua, wisconsin 54548 (715) 356-9485

February 25, 1985

Carlton Schroeder
Exxon Minerals Company
P.O. Box 813
Rhinelander, WI 54501

Re: Hook Gauge Levels

Dear Carlton:

Our firm was recently engaged to check the elevations of the hook gauge support posts in Little Sand, Oak, Duck and Skunk Lakes at regular intervals while the hook gauge readings were being taken. Unfortunately, we did not realize at the time that the hook gauges were being read to millimeter accuracy, and that extremely precise leveling would be required to verify any possible movements of the hook gauge support posts during the observation period. Our elevation readings on the support posts taken on January 19, 25 and 30, 1984, were observed to an estimated accuracy of ±0.01 feet, which has been our standard tolerance for most of the leveling work we have done on the Crandon Project over the past 10 years. This tolerance is obviously not sufficient when the hook gauges are being read to the nearest millimeter.

Our leveling work did, however, result in some information that might be useful to you. The support posts were checked for elevation in each case against bench marks we had previously set near the lake shores for other purposes. These bench marks are railroad spikes set in the bases of very substantial trees. For several of the hook gauge support posts, we were unable to detect any movement of the post with relation to the bench mark during the observation period, within the tolerances of the leveling we were doing. For a couple of the posts, however, most notably the one on Duck Lake, substantial movement was detected. During the observation period, this post appeared to be sinking further into the lake bottom at the rate of approximately 0.01' per day. Upon further checking of the bench mark approximately 3 weeks after the hook gauge readings were taken, however, we found that the tree in which this bench mark was set had risen 0.15' since the last hook gauge reading was taken, which was a rate of rise of approximately 0.01' per day. This accounts for what we initially thought was a lowering of the hook gauge support post, as we have proven that the bench mark was rising instead.

It is our conclusion that our system of bench marks is not sufficiently stable to detect any minuscule movements that might have occurred during the observation period, since at least one of our bench marks was moving during the observation period. Since several of the hook gauge posts showed no movement in relation to our bench marks, and it appears that bench mark movement was responsible for the apparent hook gauge support post movement in the remaining cases, we think you can be quite certain that essentially no movement of the hook gauge support posts occurred during the observation period. This conclusion is intuitively acceptable as well, as the posts were set into the lake bottoms and thus were not subject to the movements which might result from freezing and thawing of the surrounding soils.

Please request further information from us if the above is not sufficient for your needs.

Thank you.

Sincerely,

Gerald B. Inman
Professional Engineer
Registered Land Surveyor

Stuart L. Foltz
Professional Engineer
Registered Land Surveyor

SLF/tm

APPENDIX G

PRECIPITATION AND EVAPORATION STATISTICS

```
Copyright (c) 1983, 1984 SAS Institute Inc., Cary, N. C. 27511, U. S. A.
NOTE: VMS Version of SAS Release 4.07 at DAMES & MOORE (07096001).
NOTE: LICENSED CPUID MODEL = 11/780, SERIAL = 01300765.
      1 Data calyear;  Infile rhprecip;
      2 Input year m1 m2 m3 m4 m5 m6 m7 m8 m9 m10 m11 m12 caltotal;
      3 Calcsum=sum(of m1-m12);
      4 If (caltotal ne calcsum) then flag='*';  Else flag=' ';
      5
NOTE: INFILE RHPRECIP IS FILE DISK$USERS:[WA26]RHPRECIP.DAT
NOTE: 41 LINES WERE READ FROM INFILE RHPRECIP.
      THE MINIMUM LINE LENGTH IS           72.
      THE MAXIMUM LINE LENGTH IS           73.
NOTE: THE DATA SET WORK.CALYEAR HAS 41 OBSERVATIONS AND 16 VARIABLES.
NOTE: THE DATA STEP USED THE FOLLOWING COMPUTER RESOURCES -
          BUFFERED I/O            14          ELAPSED TIME      00:00:07.87
          DIRECT I/O              16          CPU TIME          00:00:04.73
          PAGE FAULTS            465
      6 Proc print;  Id year;
      7 Title1 "Precipitation, Rhinelander, WI";
      8 Title2 "by calendar year";
      9
NOTE: THE PROCEDURE PRINT USED THE FOLLOWING COMPUTER RESOURCES -
          BUFFERED I/O             6          ELAPSED TIME      00:00:04.50
          DIRECT I/O              20          CPU TIME          00:00:03.13
          PAGE FAULTS            231
     10 Data watryear;  Set calyear;
     11 Oct=lag(m10);   Nov=lag(m11);   Dec=lag(m12);
     12 If (_N_ ne 1) then do;
     13   Jan=m1;  Feb=m2;  Mar=m3;  Apr=m4;  May=m5;  Jun=m6;
     14   Jul=m7;  Aug=m8;  Sep=m9;
     15   WYTotal=sum(of Oct--Sep);
     16   Partotal=sum(of Nov--Apr);
     17   End;
     18 If (_N_ eq 1) then Delete;
     19 Keep Year Oct--Sep WYTotal Partotal;
     20
NOTE: THE DATA SET WORK.WATRYEAR HAS 40 OBSERVATIONS AND 15 VARIABLES.
     21 Proc sort;  By WYTotal;
     22
NOTE: THE DATA SET WORK.WATRYEAR HAS 40 OBSERVATIONS AND 15 VARIABLES.
NOTE: THE PROCEDURE SORT USED THE FOLLOWING COMPUTER RESOURCES -
          BUFFERED I/O            15          ELAPSED TIME      00:00:02.87
          DIRECT I/O              34          CPU TIME          00:00:01.04
          PAGE FAULTS            136
     23 Proc print;  Id year;
     24 Title1 "Precipitation, Rhinelander, WI";
     25 Title2 "by water year";
     26
NOTE: THE PROCEDURE PRINT USED THE FOLLOWING COMPUTER RESOURCES -
          BUFFERED I/O             2          ELAPSED TIME      00:00:03.14
          DIRECT I/O              21          CPU TIME          00:00:02.79
          PAGE FAULTS             40
     27 Proc means  n mean std min max;
     28 Var Oct--Partotal;
NOTE: THE PROCEDURE MEANS USED THE FOLLOWING COMPUTER RESOURCES -
          BUFFERED I/O             2          ELAPSED TIME      00:00:01.15
          DIRECT I/O              20          CPU TIME          00:00:00.86
          PAGE FAULTS             12
```

Precipitation, Rhinelander, WI
by calendar year

11:23 SUNDAY, FEBRUARY 17, 1985 1

YEAR	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	CALTOTAL	CALCSUM	FLAG
1941	0.77	0.45	0.58	1.89	3.22	2.18	4.36	6.99	6.12	5.94	1.23	0.91	34.64	34.64	*
1942	0.89	0.45	5.75	2.11	6.57	2.67	4.68	2.37	8.54	2.26	1.88	1.62	39.79	39.79	!
1943	1.06	0.30	1.95	1.37	3.96	8.56	1.11	6.16	1.74	2.04	2.34	0.03	30.62	30.62	
1944	1.06	0.59	2.13	1.33	3.96	6.49	1.82	1.88	3.46	0.70	2.00	0.46	25.88	25.88	
1945	0.61	2.78	2.06	4.37	4.00	3.22	4.33	4.24	2.19	1.54	3.30	1.86	34.50	34.50	*
1946	2.18	0.69	0.65	0.33	2.59	11.72	2.49	2.48	4.14	2.98	2.48	1.34	34.07	34.07	
1947	0.41	0.46	0.75	3.50	2.83	4.00	2.29	4.15	1.81	1.47	2.37	0.93	24.97	24.97	*
1948	0.46	1.32	0.94	1.61	0.73	3.00	4.38	2.00	2.91	0.97	3.60	0.53	22.45	22.45	
1949	1.35	0.65	1.35	0.87	3.90	5.28	6.36	1.58	4.52	2.67	1.33	1.07	30.03	30.93	*
1950	3.54	0.69	2.45	2.62	3.60	2.32	4.69	3.07	1.52	2.48	1.59	1.95	30.52	30.52	
1951	0.52	2.10	3.03	2.85	4.39	3.92	8.62	4.83	4.26	3.45	1.28	1.11	40.36	40.36	*
1952	1.64	0.49	1.58	1.95	3.28	3.87	5.75	4.88	0.70	0.23	1.47	1.33	27.17	27.17	*
1953	0.69	2.09	1.83	2.42	3.17	8.87	3.80	2.10	1.45	0.29	1.10	1.69	29.50	29.50	*
1954	0.67	0.65	1.24	4.79	3.09	4.04	2.79	1.56	6.02	3.66	0.90	0.42	29.83	29.83	
1955	0.58	0.72	1.72	2.35	3.50	2.61	4.09	4.89	2.35	3.58	1.40	1.14	28.93	28.93	*
1956	0.58	0.21	1.00	1.31	2.47	6.05	3.88	5.55	1.61	0.58	3.25	0.45	26.94	26.94	*
1957	0.31	0.70	0.99	1.33	3.04	3.19	2.13	4.66	2.88	0.93	2.26	0.41	22.83	22.83	*
1958	0.49	0.03	0.68	1.30	5.52	3.11	4.81	4.56	3.62	2.34	1.89	0.33	28.68	28.68	*
1959	0.42	0.43	0.80	1.99	3.37	2.99	4.83	8.89	7.32	3.71	0.58	2.40	37.73	37.73	
1960	1.05	0.33	0.18	3.06	5.62	4.91	2.24	5.80	3.22	2.67	1.33	0.40	30.81	30.81	*
1961	0.21	1.27	2.07	1.70	2.67	3.54	4.47	3.50	4.34	3.17	2.66	0.95	30.55	30.55	*
1962	0.67	1.69	0.40	2.12	4.59	2.93	2.71	4.52	3.20	1.55	0.74	0.66	25.78	25.78	*
1963	0.30	0.46	1.09	1.36	2.86	2.49	2.10	3.43	3.81	0.74	0.72	0.82	20.18	20.18	
1964	0.72	0.22	0.83	3.58	3.29	2.60	3.36	5.87	3.62	0.44	3.02	1.65	29.20	29.20	
1965	0.44	0.82	1.64	2.91	4.50	3.25	2.99	2.82	4.73	1.68	3.55	1.40	30.73	30.73	
1966	0.87	0.43	3.14	1.24	0.77	2.47	1.50	6.86	2.63	3.29	1.28	1.13	25.61	25.61	
1967	2.68	0.60	1.39	5.30	1.67	5.70	2.68	3.48	3.13	3.27	0.72	0.39	31.01	31.01	*
1968	0.99	0.19	1.25	2.49	5.10	9.89	4.67	1.94	7.47	2.34	0.52	2.74	39.59	39.59	
1969	2.79	0.12	0.60	1.30	3.58	4.76	2.44	0.82	2.40	4.27	1.56	2.00	26.64	26.64	
1970	0.92	0.35	0.87	1.04	4.90	2.05	3.63	0.69	8.38	3.44	2.95	1.90	31.12	31.12	
1971	2.50	2.82	1.04	0.65	4.05	5.27	3.32	3.36	5.71	3.14	2.05	2.27	36.18	36.18	*
1972	1.13	1.12	2.39	3.11	2.13	2.86	3.22	6.69	4.96	2.69	2.76	2.62	35.68	35.68	*
1973	0.92	0.72	4.09	3.25	6.86	2.29	4.41	7.42	3.20	2.05	1.29	1.55	38.05	38.05	
1974	0.50	0.83	0.61	3.41	2.59	3.03	2.97	6.33	3.21	1.18	2.72	0.79	28.17	28.17	*
1975	1.90	1.35	1.21	3.33	2.22	4.33	1.05	4.06	4.44	1.25	4.21	1.12	30.47	30.47	
1976	1.70	0.98	2.54	2.63	1.55	1.71	1.53	3.43	0.40	0.43	0.28	0.45	17.63	17.63	
1977	0.58	0.44	3.28	3.81	2.87	4.21	2.97	7.01	5.41	2.49	4.09	1.85	39.01	39.01	
1978	0.55	0.38	0.15	2.75	4.66	4.48	7.70	9.15	5.70	1.42	1.54	1.44	39.92	39.92	
1979	1.65	1.57	3.11	0.82	3.25	3.19	3.98	4.54	0.84	5.90	1.90	0.59	31.34	31.34	
1980	1.81	0.23	0.37	1.49	1.93	4.58	4.65	8.58	5.03	1.62	0.74	1.03	32.06	32.06	*
1981	0.43	1.95	0.62	3.49	4.01	10.22	1.18	0.82	2.24	2.19	0.27	1.16	28.58	28.58	*

Precipitation, Rhinelander, WI
by water year

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	WYTOTAL	PARTOTAL
1963	1.55	0.74	0.66	0.30	0.46	1.09	1.36	2.86	2.49	2.10	3.43	3.81	20.85	4.61
1948	1.47	2.37	0.93	0.46	1.32	0.94	1.61	0.73	3.00	4.38	2.00	2.91	22.12	7.63
1976	1.25	4.21	1.12	1.70	0.98	2.54	2.63	1.55	1.71	1.53	3.43	0.40	23.05	13.18
1957	0.58	3.25	0.45	0.31	0.70	0.99	1.33	3.04	3.19	2.13	4.66	2.88	23.51	7.03
1969	2.34	0.52	2.74	2.79	0.12	0.60	1.30	3.58	4.76	2.44	0.82	2.40	24.41	8.07
1964	0.74	0.72	0.82	0.72	0.22	0.83	3.58	3.29	2.60	3.36	5.87	3.62	26.37	6.89
1966	1.68	3.55	1.40	0.87	0.43	3.14	1.24	0.77	2.47	1.50	6.86	2.63	26.54	10.63
1947	2.98	2.48	1.34	0.41	0.46	0.75	3.50	2.83	4.00	2.29	4.15	1.81	27.00	8.94
1944	2.04	2.34	0.03	1.06	0.59	2.13	1.33	3.96	6.49	1.82	1.88	3.46	27.13	7.48
1979	1.42	1.54	1.44	1.65	1.57	3.11	0.82	3.25	3.19	3.98	4.54	0.84	27.35	10.13
1958	0.93	2.26	0.41	0.49	0.03	0.68	1.30	5.52	3.11	4.81	4.56	3.62	27.72	5.17
1955	3.66	0.90	0.42	0.58	0.72	1.72	2.35	3.50	2.61	4.09	4.89	2.35	27.79	6.69
1954	0.29	1.10	1.69	0.67	0.65	1.24	4.79	3.09	4.04	2.79	1.56	6.02	27.93	10.14
1961	2.67	1.33	0.40	0.21	1.27	2.07	1.70	2.67	3.54	4.47	3.50	4.34	28.17	6.98
1981	1.62	0.74	1.03	0.43	1.95	0.62	3.49	4.01	10.22	1.18	0.82	2.24	28.35	8.26
1974	2.05	1.29	1.55	0.50	0.83	0.61	3.41	2.59	3.03	2.97	6.33	3.21	28.37	8.19
1975	1.18	2.72	0.79	1.90	1.35	1.21	3.33	2.22	4.33	1.05	4.06	4.44	28.58	11.30
1956	3.58	1.40	1.14	0.58	0.21	1.00	1.31	2.47	6.05	3.88	5.55	1.61	28.78	5.64
1965	0.44	3.02	1.65	0.44	0.82	1.64	2.91	4.50	3.25	2.99	2.82	4.73	29.21	10.48
1953	0.23	1.47	1.33	0.69	2.09	1.83	2.42	3.17	8.87	3.80	2.10	1.45	29.45	9.83
1950	2.67	1.33	1.07	3.54	0.69	2.45	2.62	3.60	2.32	4.69	3.07	1.52	29.57	11.70
1962	3.17	2.66	0.95	0.67	1.69	0.40	2.12	4.59	2.93	2.71	4.52	3.20	29.61	8.49
1952	3.45	1.28	1.11	1.64	0.49	1.58	1.95	3.28	3.87	5.75	4.88	0.70	29.98	8.05
1970	4.27	1.56	2.00	0.92	0.35	0.87	1.04	4.90	2.05	3.63	0.69	8.38	30.66	6.74
1949	0.97	3.60	0.53	1.35	0.65	1.35	0.87	3.90	5.28	6.36	1.58	4.52	30.96	8.35
1945	0.70	2.00	0.46	0.61	2.78	2.06	4.37	4.00	3.22	4.33	4.24	2.19	30.96	12.28
1977	0.43	0.28	0.45	0.58	0.44	3.28	3.81	2.87	4.21	2.97	7.01	5.41	31.74	8.84
1943	2.26	1.88	1.62	1.06	0.30	1.95	1.37	3.96	8.56	1.11	6.16	1.74	31.97	8.18
1967	3.29	1.28	1.13	2.68	0.60	1.39	5.30	1.67	5.70	2.68	3.48	3.13	32.33	12.38
1960	3.71	0.58	2.40	1.05	0.33	0.18	3.06	5.62	4.91	2.24	5.80	3.22	33.10	7.60
1946	1.54	3.30	1.86	2.18	0.69	0.65	0.33	2.59	11.72	2.49	2.48	4.14	33.97	9.01
1972	3.14	2.05	2.27	1.13	1.12	2.39	3.11	2.13	2.86	3.22	6.69	4.96	35.07	12.07
1959	2.34	1.89	0.33	0.42	0.43	0.80	1.99	3.37	2.99	4.83	8.89	7.32	35.60	5.86
1971	3.44	2.95	1.90	2.50	2.82	1.04	0.65	4.05	5.27	3.32	3.36	5.71	37.01	11.86
1980	5.90	1.90	0.59	1.81	0.23	0.37	1.49	1.93	4.58	4.65	8.58	5.03	37.06	6.39
1968	3.27	0.72	0.39	0.99	0.19	1.25	2.49	5.10	9.89	4.67	1.94	7.47	38.37	6.03
1951	2.48	1.59	1.95	0.52	2.10	3.03	2.85	4.39	3.92	8.62	4.83	4.26	40.54	12.04
1973	2.69	2.76	2.62	0.92	0.72	4.09	3.25	6.86	2.29	4.41	7.42	3.20	41.23	14.36
1942	5.94	1.23	0.91	0.89	0.45	5.75	2.11	6.57	2.67	4.68	2.37	8.54	42.11	11.34
1978	2.49	4.09	1.85	0.55	0.38	0.15	2.75	4.66	4.48	7.70	9.15	5.70	43.95	9.77

Precipitation, Rhinelander, WI
by water year

11:23 SUNDAY, FEBRUARY 17, 1985 3

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
OCT	40	2.27125000	1.38968026	0.23000000	5.94000000
NOV	40	1.92200000	1.02745441	0.28000000	4.21000000
DEC	40	1.19325000	0.68757615	0.03000000	2.74000000
JAN	40	1.06925000	0.78657449	0.21000000	3.54000000
FEB	40	0.85550000	0.70137210	0.03000000	2.82000000
MAR	40	1.59425000	1.16109340	0.15000000	5.75000000
APR	40	2.33100000	1.17376624	0.33000000	5.30000000
MAY	40	3.49100000	1.36929104	0.73000000	6.86000000
JUN	40	4.41675000	2.39231610	1.71000000	11.72000000
JUL	40	3.56550000	1.67605604	1.05000000	8.62000000
AUG	40	4.27425000	2.23951791	0.69000000	9.15000000
SEP	40	3.72775000	2.00592135	0.40000000	8.54000000
WYTOTAL	40	30.71175000	5.47499720	20.85000000	43.95000000
PARTOTAL	40	8.96525000	2.40739671	4.61000000	14.36000000

```
Copyright (c) 1983, 1984 SAS Institute Inc., Cary, N. C. 27511, U. S. A.
NOTE: VMS Version of SAS Release 4.07 at DAMES & MOORE (07096001).
NOTE: LICENSED CPUID MODEL = 11/780, SERIAL = 01300765.
      1 Data calyear;  Infile rhevap;
      2 Input year m1 m2 m3 m4 m5 m6 m7 m8 m9 m10 m11 m12;
      3 Calcsum=sum(of m1-m12);
      4
NOTE: INFILE RHEVAP IS FILE DISK$USERS:[WA26]RHEVAP.DAT
NOTE: 36 LINES WERE READ FROM INFILE RHEVAP .
      THE MINIMUM LINE LENGTH IS            75.
      THE MAXIMUM LINE LENGTH IS            75.
NOTE: THE DATA SET WORK.CALYEAR HAS 36 OBSERVATIONS AND 14 VARIABLES.
NOTE: THE DATA STEP USED THE FOLLOWING COMPUTER RESOURCES -
          BUFFERED I/O           14           ELAPSED TIME     00:00:13.04
          DIRECT I/O             14           CPU TIME         00:00:03.91
          PAGE FAULTS           447
      5 Proc print;  Id year;
      6 Title1 "Evaporation, Rainbow Reservoir, WI";
      7 Title2 "by calendar year";
      8
NOTE: THE PROCEDURE PRINT USED THE FOLLOWING COMPUTER RESOURCES -
          BUFFERED I/O            6           ELAPSED TIME     00:00:05.14
          DIRECT I/O             20           CPU TIME         00:00:02.29
          PAGE FAULTS           170
      9 Data watryear;  Set calyear;
     10 Oct=lag(m10);  Nov=lag(m11);  Dec=lag(m12);
     11 If (_N_ ne 1) then do;
     12   Jan=m1;  Feb=m2;  Mar=m3;  Apr=m4;  May=m5;  Jun=m6;
     13   Jul=m7;  Aug=m8;  Sep=m9;
     14   WYTotal=sum(of Oct--Sep);
     15   Partotal=sum(of Jun--Sep);
     16   End;
     17 If (_N_ eq 1) then Delete;
     18 Keep Year Oct--Sep WYTotal Partotal;
     19
NOTE: THE DATA SET WORK.WATRYEAR HAS 35 OBSERVATIONS AND 15 VARIABLES.
     20 Proc sort;  By Partotal;
     21
NOTE: THE DATA SET WORK.WATRYEAR HAS 35 OBSERVATIONS AND 15 VARIABLES.
NOTE: THE PROCEDURE SORT USED THE FOLLOWING COMPUTER RESOURCES -
          BUFFERED I/O           15           ELAPSED TIME     00:00:04.08
          DIRECT I/O             33           CPU TIME         00:00:01.09
          PAGE FAULTS           145
     22 Proc print;  Id year;
     23 Title1 "Evaporation, Rainbow Reservoir, WI";
     24 Title2 "by water year";
     25
NOTE: THE PROCEDURE PRINT USED THE FOLLOWING COMPUTER RESOURCES -
          BUFFERED I/O            2           ELAPSED TIME     00:00:06.49
          DIRECT I/O             21           CPU TIME         00:00:02.13
          PAGE FAULTS            96
     26 Proc means n mean std min max;
     27 Var Oct--Partotal;
NOTE: THE PROCEDURE MEANS USED THE FOLLOWING COMPUTER RESOURCES -
          BUFFERED I/O            2           ELAPSED TIME     00:00:02.88
          DIRECT I/O             20           CPU TIME         00:00:00.77
          PAGE FAULTS            41
NOTE: SAS INSTITUTE INC., SAS CIRCLE, BOX 8000, CARY, N. C., 27511-8000
```

Evaporation, Rainbow Reservoir, WI
by calendar year

YEAR	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	CALCSUM
1948	.	.	.	.	.	5.193	6.069	5.33	4.171	2.28700	.	.	23.05
1949	.	.	.	.	5.18000	6.420	5.810	4.55	2.330	.	.	.	24.29
1950	.	.	.	.	.	6.450	4.700	4.28	2.830	.	.	.	18.26
1951	.	.	.	.	.	5.500	6.180	2.83	2.400	.	.	.	16.71
1952	.	.	.	.	4.67000	5.210	5.210	4.02	3.220	.	.	.	22.33
1953	.	.	.	.	5.10000	5.270	5.110	5.12	3.310	2.91000	.	.	26.82
1954	.	.	.	.	.	5.460	6.520	4.89	2.330	.	.	.	19.20
1955	.	.	.	.	5.57000	6.000	6.390	4.69	3.530	1.84000	.	.	28.02
1956	.	.	.	.	.	5.190	4.350	4.04	2.630	2.86000	.	.	19.07
1957	.	.	.	.	5.19000	5.170	4.930	4.61	3.060	.	.	.	22.96
1958	.	.	.	.	5.08000	5.360	5.270	5.16	2.880	1.88000	.	.	25.63
1959	.	.	.	.	4.91000	6.020	5.850	4.28	2.970	.	.	.	24.03
1960	.	.	.	.	.	4.830	5.540	4.75	3.130	.	.	.	18.25
1961	.	.	.	.	4.84000	5.620	4.980	4.71	2.970	.	.	.	23.12
1962	.	.	.	.	4.52000	4.860	4.970	4.07	2.140	.	.	.	20.56
1963	.	.	.	.	4.12000	5.460	6.020	4.31	2.690	2.35000	.	.	24.95
1964	.	.	.	.	4.95000	5.820	6.050	4.13	2.900	.	.	.	23.85
1965	.	.	.	.	.	5.250	5.390	3.86	1.710	1.73000	.	.	17.94
1966	.	.	.	.	4.07000	5.140	5.920	4.24	2.950	.	.	.	22.32
1967	.	.	.	.	.	4.040	5.180	4.56	2.870	1.90000	.	.	18.55
1968	.	.	.	.	3.51000	5.200	5.760	4.38	2.710	1.43000	.	.	22.99
1969	.	.	.	.	4.91000	3.130	5.130	5.07	2.920	.	.	.	21.16
1970	.	.	.	.	3.73000	5.340	5.810	4.47	2.770	1.75000	.	.	23.87
1971	.	.	.	.	4.39000	5.110	4.960	3.93	2.590	1.68000	.	.	22.66
1972	.	.	.	.	.	5.160	3.740	3.41	2.630	.	.	.	14.94
1973	.	.	.	.	2.76000	4.240	5.410	3.61	2.560	.	.	.	18.58
1974	.	.	.	.	3.78000	4.850	5.980	4.50	2.330	.	.	.	21.44
1975	.	.	.	.	4.73000	4.170	5.350	5.20	2.310	.	.	.	21.76
1976	.	.	.	.	5.20000	6.420	6.960	6.02	3.910	.	.	.	28.51
1977	.	.	.	.	6.23000	4.890	5.700	3.83	2.050	.	.	.	22.70
1978	.	.	.	.	.	4.750	4.380	4.83	3.430	.	.	.	17.39
1979	.	.	.	.	.	5.060	5.580	4.22	3.160	.	.	.	18.02
1980	.	.	.	.	5.02000	4.870	4.890	3.73	2.470	.	.	.	20.98
1981	.	.	.	.	4.87000	5.070	4.990	3.69	2.710	.	.	.	21.33
1982	.	.	.	.	4.60000	5.140	5.450	3.47	1.950	.	.	.	20.61
1983	.	.	.	.	3.65000	5.530	6.420	4.95	2.880	.	.	.	23.43

by water year

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	WYTOTAL	PARTOTAL
1972	1.68000	.	.	.	.	.	.	.	5.16	3.74	3.41	2.63	16.620	14.94
1973	.	.	.	.	.	.	.	2.76000	4.24	5.41	3.61	2.56	18.580	15.82
1980	.	.	.	.	.	.	.	5.02000	4.87	4.89	3.73	2.47	20.780	15.96
1982	.	.	.	.	.	.	.	4.60000	5.14	5.45	3.47	1.95	20.610	16.01
1962	.	.	.	.	.	.	.	4.52000	4.86	4.97	4.07	2.14	20.560	16.04
1956	1.84000	.	.	.	.	.	.	.	5.19	4.35	4.04	2.63	18.050	16.21
1965	.	.	.	.	.	.	.	.	5.25	5.39	3.86	1.71	16.210	16.21
1969	1.43000	.	.	.	.	.	.	4.91000	3.13	5.13	5.07	2.92	22.590	16.25
1981	.	.	.	.	.	.	.	4.87000	5.07	4.99	3.69	2.71	21.330	16.46
1977	.	.	.	.	.	.	.	6.23000	4.89	5.70	3.83	2.05	22.700	16.47
1971	1.75000	.	.	.	.	.	.	4.39000	5.11	4.96	3.93	2.59	22.730	16.59
1967	.	.	.	.	.	.	.	.	4.04	5.18	4.56	2.87	16.650	16.65
1951	.	.	.	.	.	.	.	.	5.50	6.18	2.83	2.40	16.910	16.91
1975	.	.	.	.	.	.	.	4.73000	4.17	5.35	5.20	2.31	21.760	17.03
1978	.	.	.	.	.	.	.	.	4.75	4.38	4.83	3.43	17.390	17.39
1952	.	.	.	.	.	.	.	4.67000	5.21	5.21	4.02	3.22	22.330	17.66
1974	.	.	.	.	.	.	.	3.78000	4.85	5.98	4.50	2.33	21.440	17.66
1957	2.86000	.	.	.	.	.	.	5.19000	5.17	4.93	4.61	3.06	25.820	17.77
1979	.	.	.	.	.	.	.	.	5.06	5.58	4.22	3.16	18.020	18.02
1968	1.90000	.	.	.	.	.	.	3.51000	5.20	5.76	4.38	2.71	23.460	18.05
1960	.	.	.	.	.	.	.	.	4.83	5.54	4.75	3.13	18.250	18.25
1966	1.73000	.	.	.	.	.	.	4.07000	5.14	5.92	4.24	2.95	24.050	18.25
1950	.	.	.	.	.	.	.	.	6.45	4.70	4.28	2.83	18.260	18.26
1961	.	.	.	.	.	.	.	4.84000	5.62	4.98	4.71	2.97	23.120	18.28
1970	.	.	.	.	.	.	.	3.73000	5.34	5.81	4.47	2.77	22.120	18.39
1963	.	.	.	.	.	.	.	4.12000	5.46	6.02	4.31	2.69	22.600	18.48
1958	.	.	.	.	.	.	.	5.08000	5.36	5.27	5.16	2.88	23.750	18.67
1953	.	.	.	.	.	.	.	5.10000	5.27	5.11	5.12	3.31	23.910	18.81
1964	2.35000	.	.	.	.	.	.	4.95000	5.82	6.05	4.13	2.90	26.200	18.90
1949	2.28700	.	.	.	.	.	.	5.18000	6.42	5.81	4.55	2.33	26.577	19.11
1959	1.88000	.	.	.	.	.	.	4.91000	6.02	5.85	4.28	2.97	25.910	19.12
1954	2.91000	.	.	.	.	.	.	.	5.46	6.52	4.89	2.33	22.110	19.20
1983	.	.	.	.	.	.	.	3.65000	5.53	6.42	4.95	2.88	23.430	19.78
1955	.	.	.	.	.	.	.	5.57000	6.00	6.39	4.69	3.53	26.180	20.61
1976	.	.	.	.	.	.	.	5.20000	6.42	6.96	6.02	3.91	28.510	23.31

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE
OCT	11	2.05609091	0.48483615	1.43000000	2.91000000
NOV	0	.	.	.	.
DEC	0	.	.	.	.
JAN	0	.	.	.	.
FEB	0	.	.	.	.
MAR	0	.	.	.	.
APR	0	.	.	.	.
MAY	25	4.62320000	0.74217990	2.76000000	6.23000000
JUN	35	5.20000000	0.66970582	3.13000000	6.45000000
JUL	35	5.45371429	0.67073307	3.74000000	6.96000000
AUG	35	4.35457143	0.62190099	2.83000000	6.02000000
SEP	35	2.74942857	0.46041505	1.71000000	3.91000000
WYTOTAL	35	21.70620000	3.24861049	16.21000000	28.51000000
PARTOTAL	35	17.75771429	1.62225530	14.94000000	23.31000000

EVAPORATION, RAINBOW RESERVOIR, WI--DRY, WET, AND AVERAGE YEARS

Pan coefficient= 0.81
% in Nov-Apr= 23

WET YEARS---------------------

	YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL	
	1972	1.68								5.16	3.74	3.41	2.63	16.62	
	1973								2.76	4.24	5.41	3.61	2.56	18.58	
	1980								5.02	4.87	4.89	3.73	2.47	20.98	
	1982								4.6	5.14	5.45	3.47	1.95	20.61	
	1962								4.52	4.86	4.97	4.07	2.14	20.56	
MEAN		1.68							4.23	4.85	4.89	3.66	2.35	21.66	=sum of monthly means
ADJ. BY PAN COEFF.		1.36							3.42	3.93	3.96	2.96	1.90	17.54	
														22.78	=annual lake evap. total
														5.24	=Nov to Apr evaporation

DRY YEARS---------------------

	YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL	
	1959	1.88							4.91	6.02	5.85	4.28	2.97	25.91	
	1954	2.91								5.46	6.52	4.89	2.33	22.11	
	1983								3.65	5.53	6.42	4.95	2.88	23.43	
	1955								5.57	6	6.39	4.69	3.53	26.18	
	1976								5.2	6.42	6.96	6.02	3.91	28.51	
MEAN		2.40							4.83	5.89	6.43	4.97	3.12	27.63	=sum of monthly means
ADJ. BY PAN COEFF.		1.94							3.91	4.77	5.21	4.02	2.53	22.38	
														29.06	=annual lake evap. total
														6.69	=Nov to Apr evaporation

AVERAGE YEAR------------------

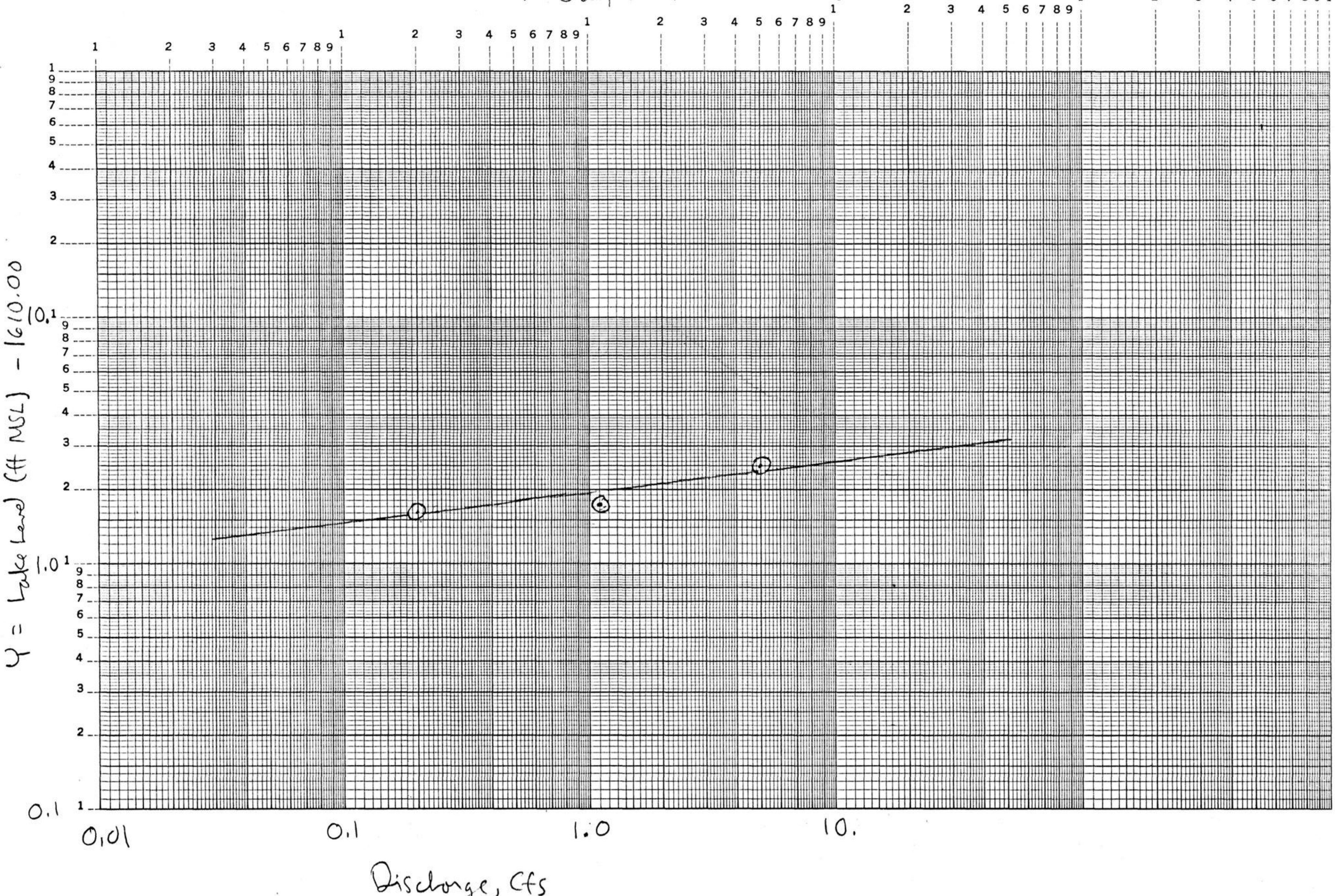
OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL	
2.06							4.62	5.2	5.45	4.35	2.75	24.43	
1.67							3.74	4.21	4.41	3.52	2.23	19.78	
												25.69	=annual lake evap. total
												5.91	=Nov to Apr evaporation

APPENDIX H

RELATIONS BETWEEN LAKE LEVEL AND STREAM OUTFLOW RATE

Duck Lake

Lake Level / Outflow Rate Relation



FILE EMC Crandon
SUBJECT Duck Lake – Lake Level/Outflow Relation
SHEET 1 OF 1

Data used to construct graph:

Date	Lake Level, ft MSL (1)	Q, cfs (2)
7/25/78	1611.75	1.1
8/30/78	1611.62	0.2
4/21/79	1612.50	5.0

(1) Data from Exxon Minerals Company, 1982, Appendix 2.4A
(2) Data from Exxon Minerals Company, 1982, Appendix 2.4B

$\log Y = \log a + b \log Q$

$b = \text{slope} = \frac{6}{47} = 0.13$
↑ from graph

Let $\log Y = \log(1.75) = 0.243$
$\log Q = \log(1.1) = 0.041$

Then $0.243 = \log a + (0.13)(0.041)$
$\log a = 0.238$
$a = 1.73$

$(\log Y - \log a)\frac{1}{b} = \log Q$

$\log Q = \frac{1}{b}\log Y - \frac{1}{b}\log a$

$= \log(Y^{1/b}) - \log(a^{1/b})$

$= \log\left(\frac{Y^{1/b}}{a^{1/b}}\right) =$

$\log Q = \log\left[\left(\frac{Y}{a}\right)^{1/b}\right]$

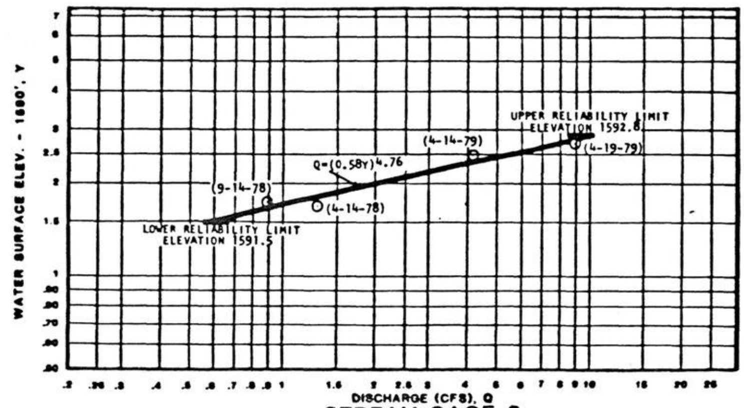
$Q = \left(\frac{1}{a}Y\right)^{1/b}$

$Q = (0.579\ Y)^{7.69}$

REVISIONS BY ____ DATE ____ TO EO ____ BY ____ DATE ____ TO EO ____

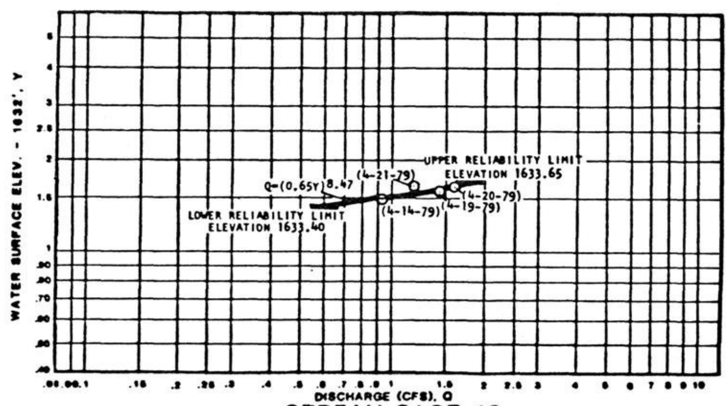
BY MSM DATE 3/11/85 CHECKED BY ____ COPY TO EO ____

Dames & Moore



STREAM GAGE 8

LITTLE SAND LAKE OUTLET



STREAM GAGE 10

OAK LAKE OUTLET

Source: Exxon Minerals Company, 1982, Appendix 2.4A

Note: Outflow relation for Deep Hole Lake is the same as for Little Sand Lake, but with a base elevation (Y) of 1605 feet.

APPENDIX I

RANGE OF POTENTIAL SEEPAGE FROM
LITTLE SAND, OAK, DUCK, AND SKUNK LAKES

LITTLE SAND LAKE
SHORT-TERM LAKE WATER BALANCE

	FIELD VALUES	MAXIMUM SEEPAGE	MINIMUM SEEPAGE	UNCERTAINTY RANGE
Area (acres)	244.1	244.1	244.1	
Start Date	12-Jan-85	12-Jan-85	12-Jan-85	
Start Time	938	938	938	
End Date	31-Jan-85	31-Jan-85	31-Jan-85	
End Time	851	851	851	
Days	18.90	18.90	18.90	
Evap. Rate (mm/day)	0.20	0.10	0.30	50%
GAINS				
Precipitation (mm)	7.2	9.4	5.0	30%
Stream (mean, cfs)	0.086	0.095	0.077	10%
Stream (mm)	4.0	4.4	3.6	
TOTAL (mm)	11.2	13.8	8.6	
LOSSES				
Evaporation (mm)	3.8	1.9	5.7	
Stream (mean, cfs)	0.085	0.077	0.094	10%
Stream (mm)	4.0	3.6	4.4	
TOTAL (mm)	7.8	5.5	10.1	
LAKE STORAGE				
Hook Gage Start (mm)	61.7	61.2	62.2	0.5 mm
Hook Gage End (mm)	68.7	69.2	68.2	0.5 mm
NET LEVEL CHANGE (mm)	-7	-8	-6	
SEEPAGE (Residual) (mm)	-10.5	-16.4	-4.5	
Seepage rate (mm/day)	-0.6	-0.9	-0.2	
Annual seepage (mm)	-202.2	-315.8	-87.6	
Annual seepage (in.)	-8.0	-12.4	-3.4	

GENERAL NOTES--
(1) Gage readings are from west side of lake. Readings from east side gage were used for confirmation but are not shown.
(2) Annual seepage is simple extrapolation from test period
(3) No corrections were made for viscosity or head changes during year

OAK LAKE
SHORT-TERM LAKE WATER BALANCE

	FIELD VALUES	MAXIMUM SEEPAGE	MINIMUM SEEPAGE	UNCERTAINTY RANGE
Area (acres)	52.3	52.3	52.3	
Start Date	17-Jan-85	17-Jan-85	17-Jan-85	
Start Time	1245	1245	1245	
End Date	31-Jan-85	31-Jan-85	31-Jan-85	
End Time	826	826	826	
Days	13.55	13.55	13.55	
Evap. Rate (mm/day)	0.20	0.10	0.30	50%
GAINS				
Precipitation (mm)	4.5	5.9	3.2	30%
Stream (mean, cfs)	0.000	0.000	0.000	10%
Stream (mm)	0.0	0.0	0.0	
TOTAL (mm)	4.5	5.9	3.2	
LOSSES				
Evaporation (mm)	2.7	1.4	4.1	
Stream (mean, cfs)	0.000	0.000	0.000	10%
Stream (mm)	0.0	0.0	0.0	
TOTAL (mm)	2.7	1.4	4.1	
LAKE STORAGE				
Hook Gage Start (mm)	57.3	56.8	57.8	0.5 mm
Hook Gage End (mm)	64.1	64.6	63.6	0.5 mm
NET LEVEL CHANGE (mm)	-6.8	-7.8	-5.8	
SEEPAGE (Residual) (mm)	-8.6	-12.3	-4.9	
Seepage rate (mm/day)	-0.6	-0.9	-0.4	
Annual seepage (mm)	-231.5	-332.7	-133.0	
Annual seepage (in.)	-9.1	-13.1	-5.2	

GENERAL NOTES--
(1) Annual seepage is simple extrapolation from test period
(2) No corrections were made for viscosity or head changes during year

DUCK LAKE
SHORT-TERM LAKE WATER BALANCE

	FIELD VALUES	MAXIMUM SEEPAGE	MINIMUM SEEPAGE	UNCERTAINTY RANGE
Area (acres)	78.7	78.7	78.7	
Start Date	13-Jan-85	13-Jan-85	13-Jan-85	
Start Time	1045	1045	1045	
End Date	26-Jan-85	26-Jan-85	26-Jan-85	
End Time	954	954	954	
Days	12.90	12.90	12.90	
Evap. Rate (mm/day)	0.20	0.10	0.30	50%
GAINS				
Precipitation (mm)	6.2	8.1	4.3	30%
Stream (mean, cfs)	0.000	0.000	0.000	10%
Stream (mm)	0.0	0.0	0.0	
TOTAL (mm)	6.2	8.1	4.3	
LOSSES				
Evaporation (mm)	2.6	1.3	3.9	
Stream (mean, cfs)	0.077	0.069	0.085	10%
Stream (mm)	7.6	6.8	8.4	
TOTAL (mm)	10.2	8.1	12.3	
LAKE STORAGE				
Hook Gage Start (mm)	77.8	77.3	78.3	0.5 mm
Hook Gage End (mm)	100.9	101.4	100.4	0.5 mm
NET LEVEL CHANGE (mm)	-23.1	-24.1	-22.1	
SEEPAGE (Residual) (mm)	-19.1	-24.1	-14.1	
Seepage rate (mm/day)	-1.5	-1.9	-1.1	
Annual seepage (mm)	-540.4	-681.4	-399.4	
Annual seepage (in.)	-21.3	-26.8	-15.7	

GENERAL NOTES--
(1) Annual seepage is simple extrapolation from test period
(2) No corrections were made for viscosity or head changes during year

SKUNK LAKE
SHORT-TERM LAKE WATER BALANCE

	FIELD VALUES	MAXIMUM SEEPAGE	MINIMUM SEEPAGE	UNCERTAINTY RANGE
Area (acres)	8.8	8.8	8.8	
Start Date	13-Jan-85	13-Jan-85	13-Jan-85	
Start Time	1128	1128	1128	
End Date	23-Jan-85	23-Jan-85	23-Jan-85	
End Time	1051	1051	1051	
Days	9.91	9.91	9.91	
Evap. Rate (mm/day)	0.20	0.10	0.30	50%
GAINS				
Precipitation (mm)	5.6	7.3	3.9	30%
Stream (mean, cfs)	0.000	0.000	0.000	10%
Stream (mm)	0.0	0.0	0.0	
TOTAL (mm)	5.6	7.3	3.9	
LOSSES				
Evaporation (mm)	2.0	1.0	3.0	
Stream (mean, cfs)	0.000	0.000	0.000	10%
Stream (mm)	0.0	0.0	0.0	
TOTAL (mm)	2.0	1.0	3.0	
LAKE STORAGE				
Hook Gage Start (mm)	70.8	70.3	71.3	0.5 mm
Hook Gage End (mm)	94.6	95.1	94.1	0.5 mm
NET LEVEL CHANGE (mm)	-23.8	-24.8	-22.8	
SEEPAGE (Residual) (mm)	-27.4	-31.1	-23.7	
Seepage rate (mm/day)	-2.8	-3.1	-2.4	
Annual seepage (mm)	-1010.3	-1146.3	-874.3	
Annual seepage (in.)	-39.8	-45.1	-34.4	

GENERAL NOTES--
(1) Annual seepage is simple extrapolation from test period
(2) No corrections were made for viscosity or head changes during year

APPENDIX J

MEMORANDA FROM WISCONSIN GEOLOGICAL
AND
NATURAL HISTORY SURVEY

GEOLOGICAL AND NATURAL HISTORY SURVEY
1815 University Avenue, Madison, Wisconsin 53706 608-262-1705

MEMO

to: Ken Wade, Jim Krohelski, Roger Gerhardt, Mary Anderson

date: Oct. 22, 1984

from: Ken Bradbury KRB

Re: Summary of field observations at Little Sand Lake, October 1984

On October 9-10, 1984 Ken Wade, Jim Krohelski, and myself conducted a reconnaissance field study of Little Sand Lake. Our objectives were to attempt to locate lake-bottom springs reported by local residents and to determine hydraulic gradients through the lake bed in near-shore areas.

This memorandum is a summary of the observations we made, with some interpretive calculations.

I. Spring Su vey

We attempted to confirm reports that springs are present in the bottom of Little Sand Lake. I had received one detailed telephone description of a spring from Mr. Richard Webb who owns a summer cottage on the lake but resides elsewhere. Mr. Webb gave us permission to visit his property, and suggested that springs occurred in a small grassy lake-bottom depression about 40 feet offshore of his property.

We located Mr. Webb's cottage, and did observe two grassy depressions in the sandy lake bed about 40 feet offshore from his property (see attached map). These depressions were circular, about 3 feet in diameter, and in about 2 feet of water. The depressions were about 6 inches deep.

We tested the water in and around these depressions for temperature and electrical conductivity. We were not able to detect any thermal or chemical changes in or near these areas, nor did we see any visual evidence of groundwater discharge (sand boils, for example). We also installed seepage meters and mini-piezometers in the depression area (see below). Data from these devices did not suggest that groundwater discharge was occurring.

We also met Mr. Tom Volmar at the lake. He pointed out an area in the northwest corner of the lake where he remembered encountering very cold water while swimming. Once again we were unable to locate or observe any active springs in this area. Several other residents who we talked to at the lakeshore also said they had often encountered cold areas while swimming, wading, or fishing in the lake, and that they believed these areas were spring discharge points. However, none of these people could direct us to an exact spot, other than again mentioning the general vicinity of Mr. Webb's cabin. In addition, these people stated that they had not observed any physical evidence for groundwater discharge, such as sand boils, in colder areas.

<u>SUMMARY</u>: Although we visited locations where several residents had reported springs in Little Sand Lake, we were unable to locate any active springs in the lake bottom.

II. Seepage Meter Results

We installed four seepage meters in the vicinity of Mr. Webb's cabin to attempt to measure groundwater flow into or out of the lake bottom. The seepage meters were located in 2 to 3 feet of water in the vicinity of the grassy depressions about 40' from shore (see sketch). After installation, each seepage meter bag was filled with 500 ml of lake water and the meters were left overnight, with the following results:

Elapsed Time: 15.25 hours

Meter	Gain or Loss (ml)	Rate ml/hr.
#1 (30 feet from shore)	-140	- 9
#2 (40 feet from shore)	+145	+10
#3 (40 feet from shore)	- 35	- 2
#4 (50 feet from shore)	+100	+ 7
Average	+ 70	+ 5

The seepage meter data are obviously somewhat contradictory. From my personal experience using seepage meters, I conclude that the observed variations are mainly due to errors in measurement and to variations in seepage meter performance, and that the net bottom seepage in the tested area is essentially zero.

III. Vertical Permeability Test

We measured the vertical permeability of the lake bed using a thin-walled metal casing (0.4 feet diameter) driven vertically 1.5 feet into the bottom sediments in about 1 foot of water. Inside the casing we installed a small piezometer with a very short screened opening at the level of the bottom of the outer casing. We filled the casing with water and observed the water level fall for over one hour. This falling-head test gave a vertical permeability of 1.6×10^{-4} cm/sec.. The material tested was a poorly sorted silty till, which occurred about 1 foot beneath the lake bed.

IV. Lake Bed Hydraulic Gradients

We measured hydraulic gradients through the lake bottom using mini-piezometers installed at 6 sites (see map). Each mini-piezometer was allowed to stabilize overnight prior to measurement. Results are as follows:

Mini-piezometer No.	Head (relative to lake) (ft)	Penetration (ft)	Gradient
1 (Northwest Shore)	0.00	1.4	0.00
2 Beach (Outer)	-0.01	3.0	-0.003
3 Beach (inner)	-0.09	0.9	-0.10
4 Webb (outer)	-0.16	2.0	-0.08
5 Webb (inner)	-0.73	2.6	-0.28
6 (South Shore)	-0.23	1.9	-0.12
Average			-0.10

Measured gradients range from 0.00 in the northwest corner of the lake to -0.28 (downward) at the Webb property. The average gradient was -0.10 (downward). The mini-piezometers provide very convincing evidence that Little Sand Lake loses water by downward seepage along its western shore.

V. Nearshore Lake Bed Materials

In order to observe geologic materials present in the lake bed, we bored several shallow holes near the Webb property using a hand auger. The logs at two of these holes are as follows:

Hole #1
Location: 40 feet offshore of Webb cottage, in 3 feet of water

Depth	Material
0 - 3 ft	Sand, fine to medium, well sorted
3 - 3.5 ft	Silt, grey, organic

Hole #2
Location: Onshore, 10 feet from shoreline

Depth	Material
0 - 5 ft	Sand, silty, with pebbles (till)

Hole 2 encountered the water table at 2.2 feet below the land surface and 0.11 feet below the lake water surface, giving a horizontal hydraulic gradient of 0.11/10 = 0.01 westward.

VI. Other Observations

We also measured depth to water in several Exxon wells, with the following results:

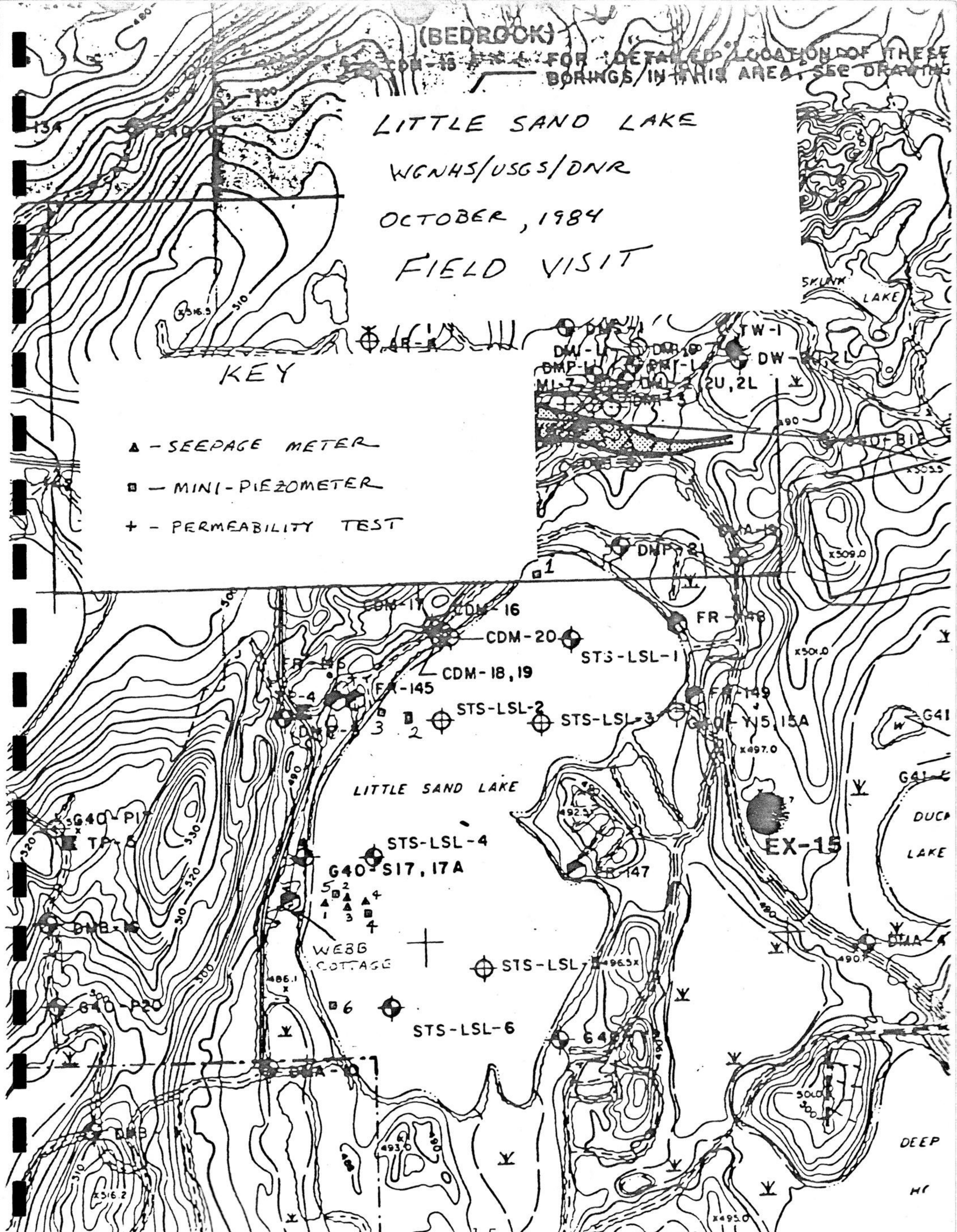
Well	Depth to water
G40-S17	20.98 feet
G46-S17A	19.03 feet
CDM 16	25.54 feet
CDM 18	Dry
CDM 19	15.15 feet
CDM 20	4.00 feet
CDM 17	Dry

In addition, we located the surface water outlet to the lake in a weedy area in the southwest corner of the lake, and followed a well-defined channel several hundred feet back into the woods. We were not able to locate any berm, dam, or obstruction which might be the main surface water level control. We did not detect any flow in the outlet channel.

VII. Summary

On October 9 and 10, 1984 we undertook a rather qualitative survey of groundwater-surface water relationships along the western shore of Little Sand Lake. We found no springs. We measured consistently downward vertical hydraulic gradients through the lake bottom, which indicates that the lake currently loses water through groundwater seepage. Along the western shore, the water table apparently slopes westward, away from the lake.

KRB:kz


(BEDROCK)
LITTLE SAND LAKE
WGNHS/USGS/DNR
OCTOBER, 1984
FIELD VISIT
KEY
▲ - SEEPAGE METER
■ - MINI-PIEZOMETER
+ - PERMEABILITY TEST
SKUNK
LAKE
TW-1
2U, 2L
DNP-2
FR-148
CDM-16
CDM-20
STS-LSL-1
CDM-18, 19
FR-145
STS-LSL-2
STS-LSL-3
LITTLE SAND LAKE
STS-LSL-4
G40-S17, 17A
WEBB
COTTAGE
STS-LSL-6
EX-15
LAKE
DEEP

UWEX GEOLOGICAL AND NATURAL HISTORY SURVEY
1815 University Avenue, Madison, Wisconsin 53706 608-262-1705

MEMO

to: Ken Wade, Dept. of Natural Resources, GEF II
date: January 31, 1985

from: Ken Bradbury KB

Re: Minipiezometer Results from Little Sand Lake

During our visit to Little Sand Lake on 1/30/85 we conducted gradient measurements and slug tests using two minipiezometers installed near Exxon seepage meters 14 and 15. Both piezometers were inserted 2.0 feet into the bottom, just below the upper sand layer.

Results are as follows:

Outer Minipiezometer:
$K = 1.6 \times 10^{-3}$ cm/sec
Grad = -0.025 (downward)

Inner Minipiezometer

$K = 1.9 \times 10^{-3}$ cm/sec
Grad = 0.07 (downward

KB:ss

FIGURE 2.3
EXXON MINERALS COMPANY
Lake Contour Mapping
Forest and Langlade Counties, Wisconsin