GLEN LAKE, SHADY OAK LAKE, AND BIRCH ISLAND LAKE WATER LEVEL INVESTIGATION

Prepared for the City of Eden Prairie, City of Minnetonka and the Nine Mile Creek Watershed District

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WATER LEVEL INVESTIGATION

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GLEN LAKE, SHADY OAK LAKE, AND BIRCH ISLAND LAKE
WATER LEVEL INVESTIGATION

The water surface elevations of Glen Lake, Shady Oak Lake and Birch Island Lake have experienced a decline in recent years which has diminishing the value of these water resources. The cities of Eden Prairie, Minnetonka, and Hopkins have requested the Nine Mile Creek Watershed District investigate the cause of the decline in the current elevation of these lakes. The Nine Mile Creek Watershed District prepared a work plan dated September 27, 1991, for a Phase One investigation in response to this request. This report summarizes this investigation and its conclusions.

The three lakes investigated are located near the common borders of the three municipalities listed above and are shown on Figure 1. The lakes have several similarities which can result in significant fluctuations in levels. The two most significant similarities are the small watershed drainage area tributary to the lakes, in relation to the surface area of the lake, and the fact that the lakes do not have low level outlets establishing a normal elevation for the lake. Lakes of this type, that do not have low level outlets, are referred to as landlocked basins. Figure 2 shows the lakes and their watershed boundaries. The figure also shows upstream areas that are currently landlocked or do not overflow except on rare occasions. The analysis to determine the hydrologic system for lakes with these characteristics is referred to as a water balance. A water balance will show the relationship between precipitation, surface water runoff, groundwater flow, evaporation, and transpiration for each of the lakes. This analysis will determine if the elevations are a result of climatic conditions or a change in the hydrologic system to the lake. The following will summarize the analysis of the hydrologic system completed for each of the lakes.

DATA COLLECTION

The initial stage of the investigation was to collect information relating to the lakes and activities that have occurred within the tributary drainage area of the lake. This information included air photographs, construction plans for development and utilities in the general area of the lakes, precipitation data, soils information for the area, and lake and groundwater data for the area. The data collected and its relationship to the analysis completed is discussed in the following paragraphs.

Lake Levels

The Nine Mile Creek Watershed District has obtained lake elevations for lakes within the District from 1964 to the present. These levels are obtained on a monthly basis, with additional measurements taken after intense rainfall events. The lake level information from the District was obtained for the three study lakes and also for comparative purposes for Lone Lake; a lake directly south of Shady Oak Lake that is also a landlocked lake and has similar characteristics to the lakes being analyzed. The range of recorded lake levels are listed in Table 1.

Weather Records

Rainfall records have been obtained by the Nine Mile Creek Watershed District since 1964 at two locations in the general area of the lakes. These continuous recording gages are currently located at the Hennepin County Maintenance facility in Hopkins and in Eden Prairie at the Minnesota Department of Transportation Maintenance facility. Yearly precipitation totals range from 39.1 inches in 1965 to 14.5 inches in 1976. The average precipitation over the watershed during this time period is 26.9 inches.

Additional precipitation records were obtained from the Minneapolis-St. Paul Airport Weather Bureau. The Weather Bureau records included monthly rainfall and the average monthly temperature, relative humidity, and wind speed. These factors are used in the estimate of the relation of the water levels to historical meteorologic conditions.

Impacts of Urbanization

As an area urbanizes, several factors can influence the total volume of surface water runoff generated within a watershed thereby affecting the level of a landlocked lake. The affects of urbanization can either increase or decrease the amount of water reaching a water body.

Sanitary Sewer

When an area first develops, on-site septic systems are often used for sanitary sewer treatment. As the discharge of water from these system infiltrates through the subsoil, a source of water is provided for the surficial (drift) groundwater. As municipal improvements are made within these areas, the installation of sanitary sewer systems replaces these on-site septic systems thereby removing a source of the water to the lakes. The installation of sanitary sewer can result in a general lowering of the groundwater level.

Water Supply

The installation of domestic supply wells in a shallow aquifer removes water from the groundwater system resulting in a general lowering of the groundwater elevation. In this instance, as municipal improvements are made and private supply wells are abandoned, a general increase can result in the level of the groundwater aquifer.

Storm Sewer

The development of an area increases the percentage of hard surface area resulting in an increase in the rate and volume of surface water runoff. However, the total area available for groundwater recharge and transpiration (the transmission of infiltrated water to the atmosphere by vegetation) is reduced as an area urbanizes. Storm sewer systems installed to convey runoff from urbanizing areas will expedite the time taken for surface water runoff to reach a receiving water body. The levels of lakes where the watersheds are served by storm sewer will generally respond (rise) much quicker than areas not served by storm sewer.

Construction Activities

An additional item which may have an affect on the level of a lake is the construction and installation of utilities in an area below the groundwater table. If proper construction techniques are not employed, the potential exists to intercept groundwater from reaching a water body by providing an underground conduit for the water to flow. Examples of this would include: (1) a storm sewer with joints that do not seal completely. The open joints allow water to leak into the pipe and the storm sewer would provide an outlet; and (2) a sanitary sewer or other utility installed without impermeable cutoffs constructed perpendicular to the pipe alignment. This condition would also provide a conduit for the conveyance of groundwater along the pipe system.

Construction activities can result in increased or decreased upstream storage areas. These, in turn, affect the groundwater recharge as well as the potential for evaporation. The watershed characteristics will determine the net effect that construction activities will have on the level of the lakes in the area.

ANALYSIS

Several approaches were pursued in the investigation of the levels of the study lakes. These included: (1) a comparison of the lake levels with each other, a comparison with other lakes within the general area (Lake Minnetonka, Lake Minnetoga, Lone Lake, and Lake Pulaski); (2) the computation of a water balance for each lake; and (3) the potential impacts that urbanization and construction activities would have on the lake levels.

Lake Level Comparison

The comparison of the levels of the study lakes with other nearby lakes was intended to determine if the lakes are behaving in a similar manner. The lakes previously listed were used for comparative purposes, however, Lone Lake, a landlocked lake in the vicinity of the study area, was used for direct comparison. Figure 3 is a graphical plotting of the levels of the study lakes. The lakes should be expected to respond in a similar manner based on the characteristics of the watersheds. The figure shows that the lakes generally exhibit similar behavior for the available lake level record, however, the significant exception is the abrupt drop of Birch Island Lake in the late 1980s to the present.

Development Records

In an attempt to further identify any aberrations in the lake levels, aerial photographs taken at approximately 5-year intervals from 1965 to the present were reviewed to determine the timing of significant development in the watersheds. The Shady Oak Lake watershed experienced a significant amount of residential development in the early 1970s. The watersheds of the other lakes did not appear to have any significant development for the period investigated.

Utility Installation

The municipal utility information indicates that the installation of the trunk utility systems within this area, sanitary sewer, water, and storm sewer were generally installed in the early 1970s. A comparison of the historic levels and with the predicted levels using the water balance computations indicated no significant impact attributable to these installations.

Water Balance

In an attempt to determine any changes in the hydrologic systems of the study lakes, a computer model was created to compute the predicted lake levels based on the weather records from 1965 to 1992. The computer model used was the Meyer Model and is discussed in detail in Appendix A. This model computes the long term watershed yield based on hydrologic and watershed factors.

The results of the water balance for Glen Lake and Shady Oak Lake is shown on Figures 4 and 5, respectively. The historic levels and the computed levels show a good comparison for the period of record. This indicates that the lake hydrology has not been significantly altered in the recent past resulting in levels lower than expected.

The results of the water balance for Birch Island Lake, however, gave different results. Figure 6 shows comparison of the historic levels and the computed levels. The computed and recorded levels compared fairly well until the late 1980s. The historic levels have dropped significantly below the predicted levels and have remained well below the predicted levels to the present time. This is an indication that a change has occurred in the watershed altering the hydrologic system of the lake.

Review of Construction Activities

The development records of the Nine Mile Creek Watershed District in the area of Birch Island Lake were reviewed to determine the potential impact of construction activities on the lake level. The areas where utilities have been installed, sanitary sewer and storm sewer, the utilities have been installed at an elevation above lake level. Therefore, there are little if any impacts expected due to the utility installation.

In 1985, Hennepin County began filling the wetland north of the Birch Island Lake for the future extension of C.S.A.H. 62. Because of poor foundation material in the area, granular fill was placed along the proposed roadway alignment to surcharge (compact) the existing organic material. Surcharging would provide a stable subbase for the roadway. The construction information indicates that approximately 35 feet of granular surcharge was placed in this area. The soils information obtained from Hennepin County indicates that the existing organic material is underlain by a sand layer. It is possible that with the placement of the granular material a connection was made with this sand layer which could prevent (intercept) surface and groundwater from reaching the lake and/or provide a seepage outlet for the lake. However, the groundwater elevation on both sides of the roadbed appears to be significantly higher, approximately 9 feet, than the lake level. This would indicate the foundation material for the roadway does not connect with the sand stratum and effect the lake level.

CONCLUSIONS

Glen Lake and Shady Oak Lake

The levels on these lakes appear to be the result of long-term climatic trends. There is the potential for adding additional drainage area to these lakes as storm sewers are installed in the upstream watersheds. For Shady Oak Lake, the potential exists for adding additional watershed to the lake by rerouting the pumped outlet from Goose Pond in Hopkins. Further review would be required to assess the potential benefits of such a project.

Birch Island Lake

The current level of Birch Island Lake ranges from 6 to 8 feet below the levels computed, water balance, with the recent climatic conditions. The construction of C.S.A.H. 62 in the area north of the lake has the potential to be the problem with the lowering of the lake level. However, because of conflicting data, a conclusion and recommendation cannot be made without further study and analysis. This would include a detailed assessment of groundwater and surface water conditions in relationship to the construction activities that have been completed and are on going in the general area of Birch Island Lake.

Water Quality

In addition to the decline in the water surface elevation of Glen Lake, the area residents indicated that there is an apparent decline in the water quality of the lake. As the Glen Lake water level has declined, an increase in aquatic weed growth infringing within the open water area of the lake has occurred. A preliminary investigation of this increase in aquatic vegetation in relationship to a possible decline in the water quality of the lake was requested to be made as part of this report.

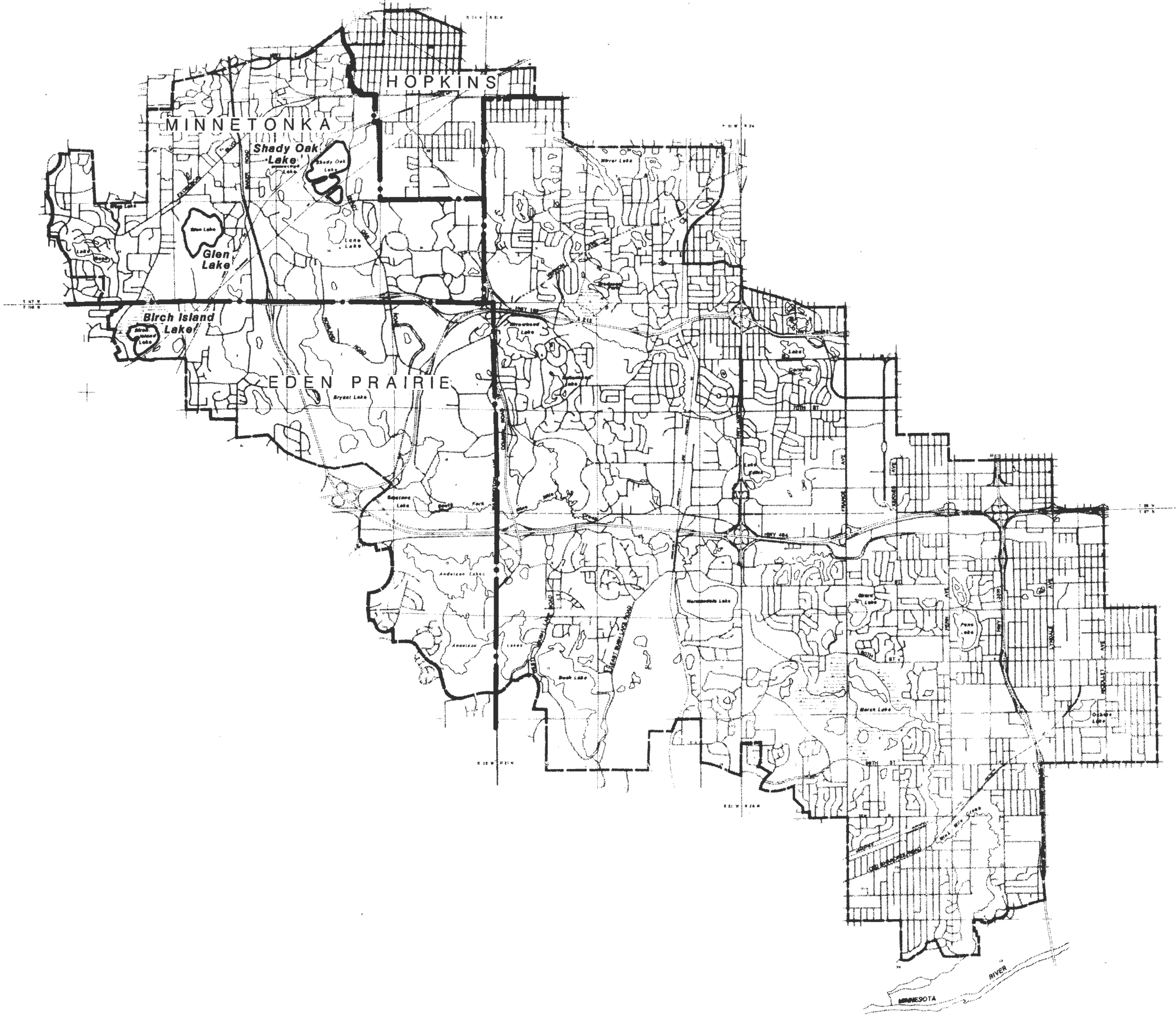
Three core samples of the bottom sediments of Glen Lake were taken to determine in lake nutrient loading, phosphorus, available for weed/algae growth within the lake. The core samples were taken to a depth of approximately 1 foot and analyzed at the surface, approximately the mid-point and at the bottom of the sample. An average of the phosphorus content ranged from 1,007 mg/kg at the surface to 690 mg/kg at a depth of 1 foot. These numbers appear to be typical of a lake receiving inflow from an urbanizing watershed. Generally, in eutrophic lakes, sediment accumulates at a rate of approximately 1 inch per 10 years. Therefore, a 12-inch core represents approximately the last 120 years of accumulated sediments, corresponding with the time period that settlement/ urbanization has occurred. The bottom sediments at the surface are fairly fertile, however, the increase in the fringe vegetation is the result of the decline in the elevation of the lake. The root structure of aquatic vegetation has been able to establish itself in areas that now have water depths less than 4 feet but were previously much deeper.

Appendix

TABLE 1

LAKE DATA

Lake	Local Tributary Drainage Area Acres	Landlocked Upstream Drainage Area Acres	Recorded High Water Elevation M.S.L.	Recorded Low Water Elevation M.S.L.
Shady Oak Lake	502	-----	904.4	897.8
Birch Island Lake	442	451	892.0	877.3
Glen Lake	693	414	905.0	898.6



NINE MILE CREEK
WATERSHED DISTRICT

NORTH

0 2000 4000 6000 8000 10,000
Scale in Feet

Figure 1
PROJECT LOCATION

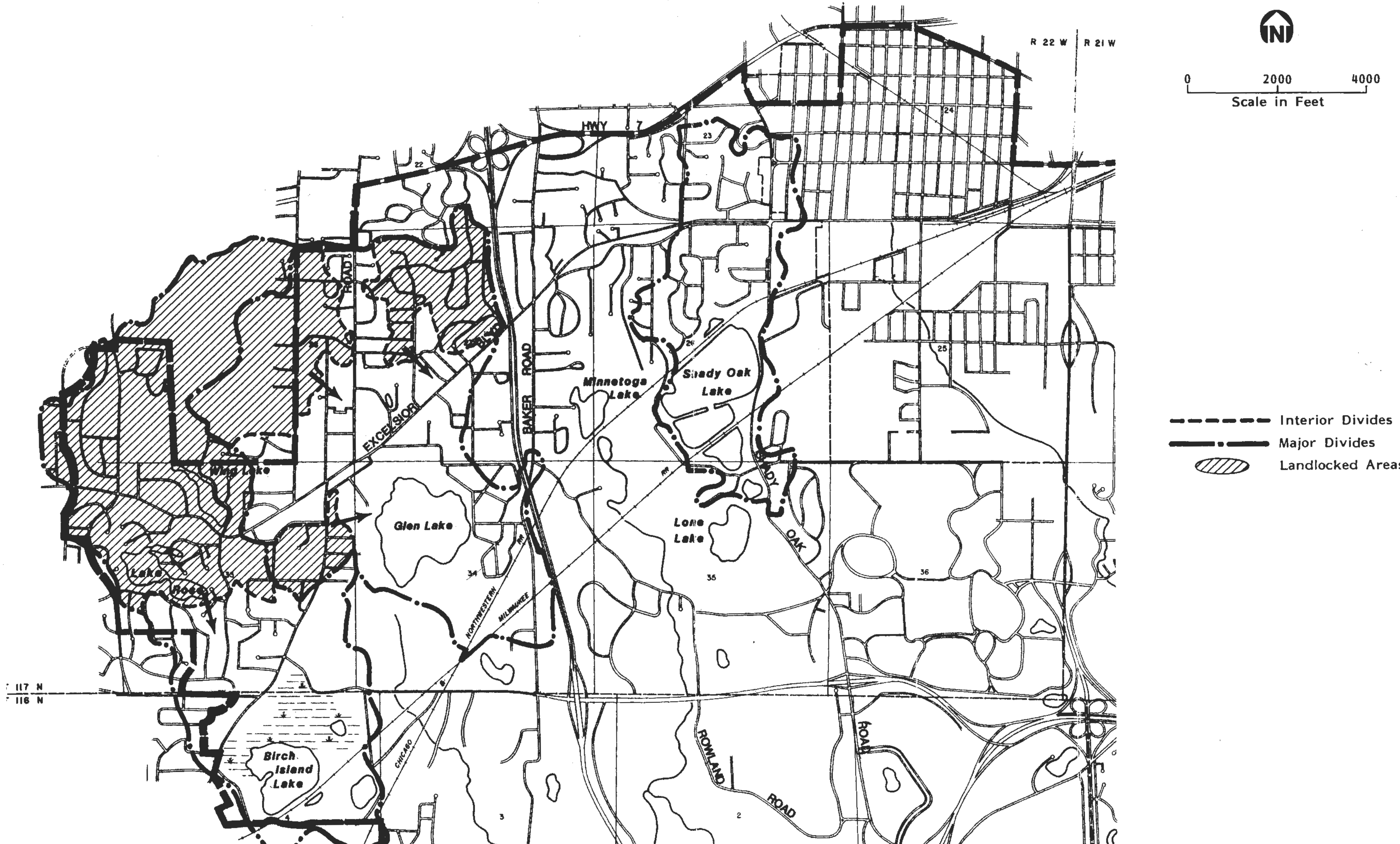


Figure 2
WATERSHED DIVIDES

Figure 3
LAKE ELEVATIONS

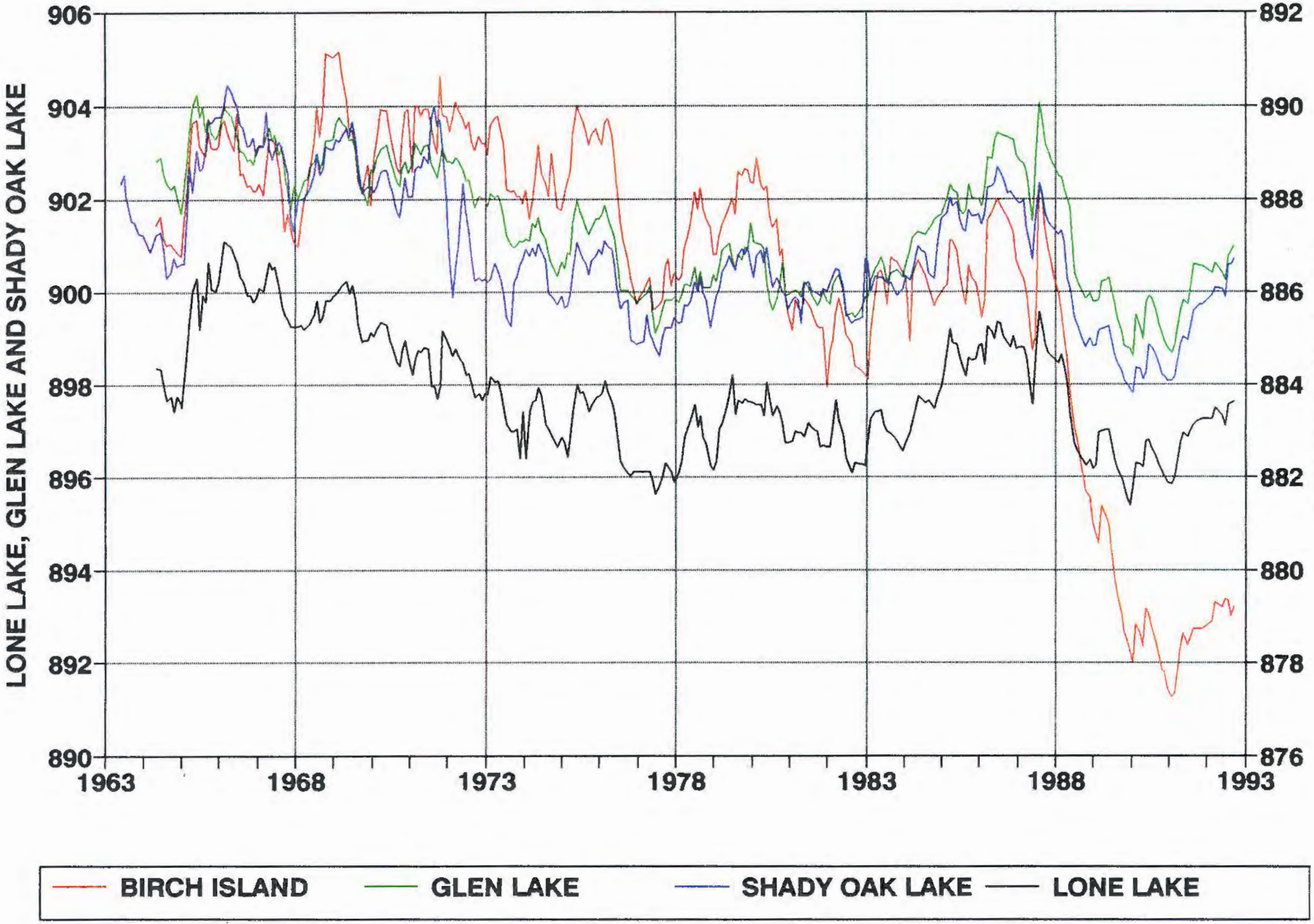


Figure 4
GLEN LAKE CALIBRATION

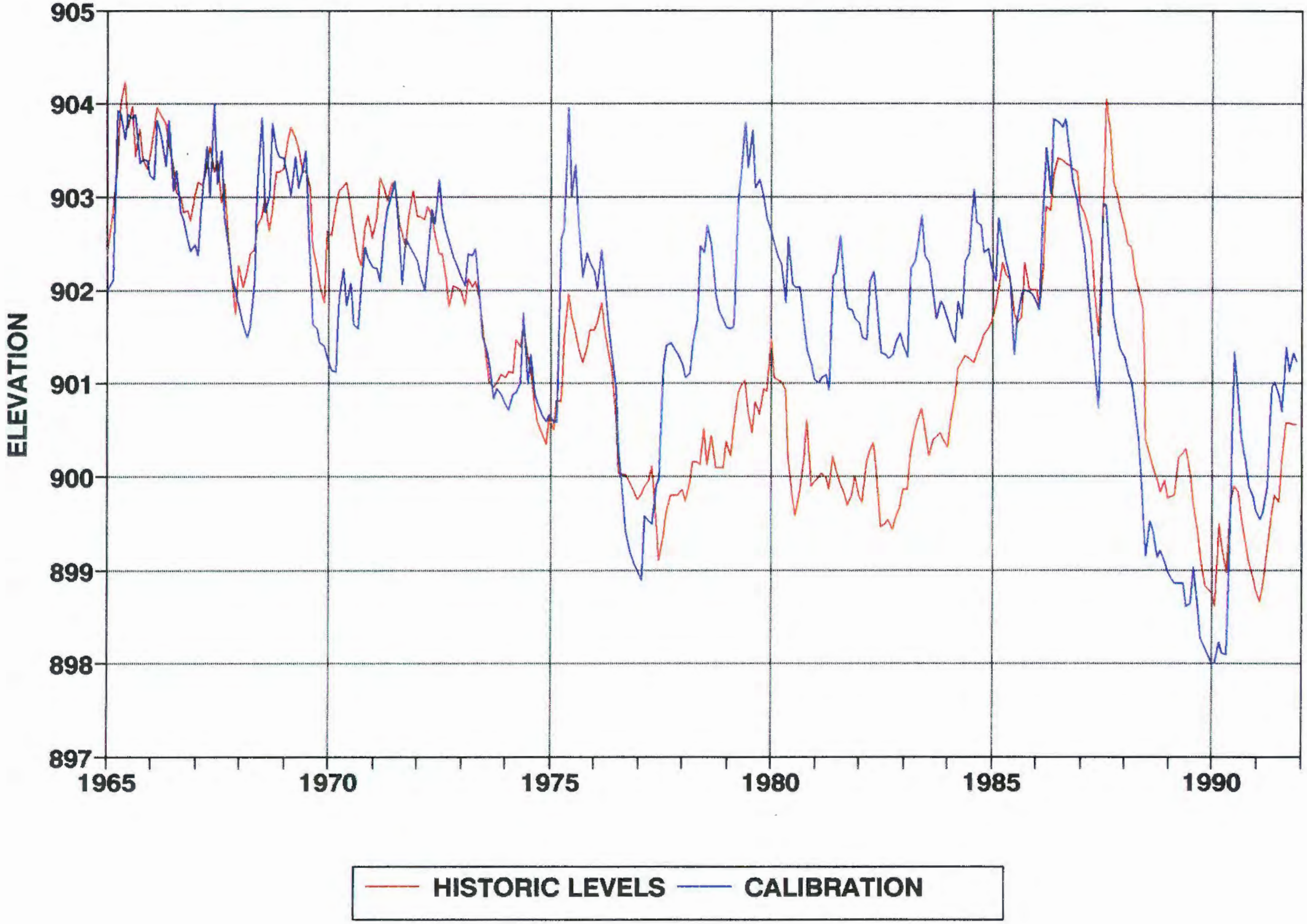


Figure 5
SHADY OAK LAKE

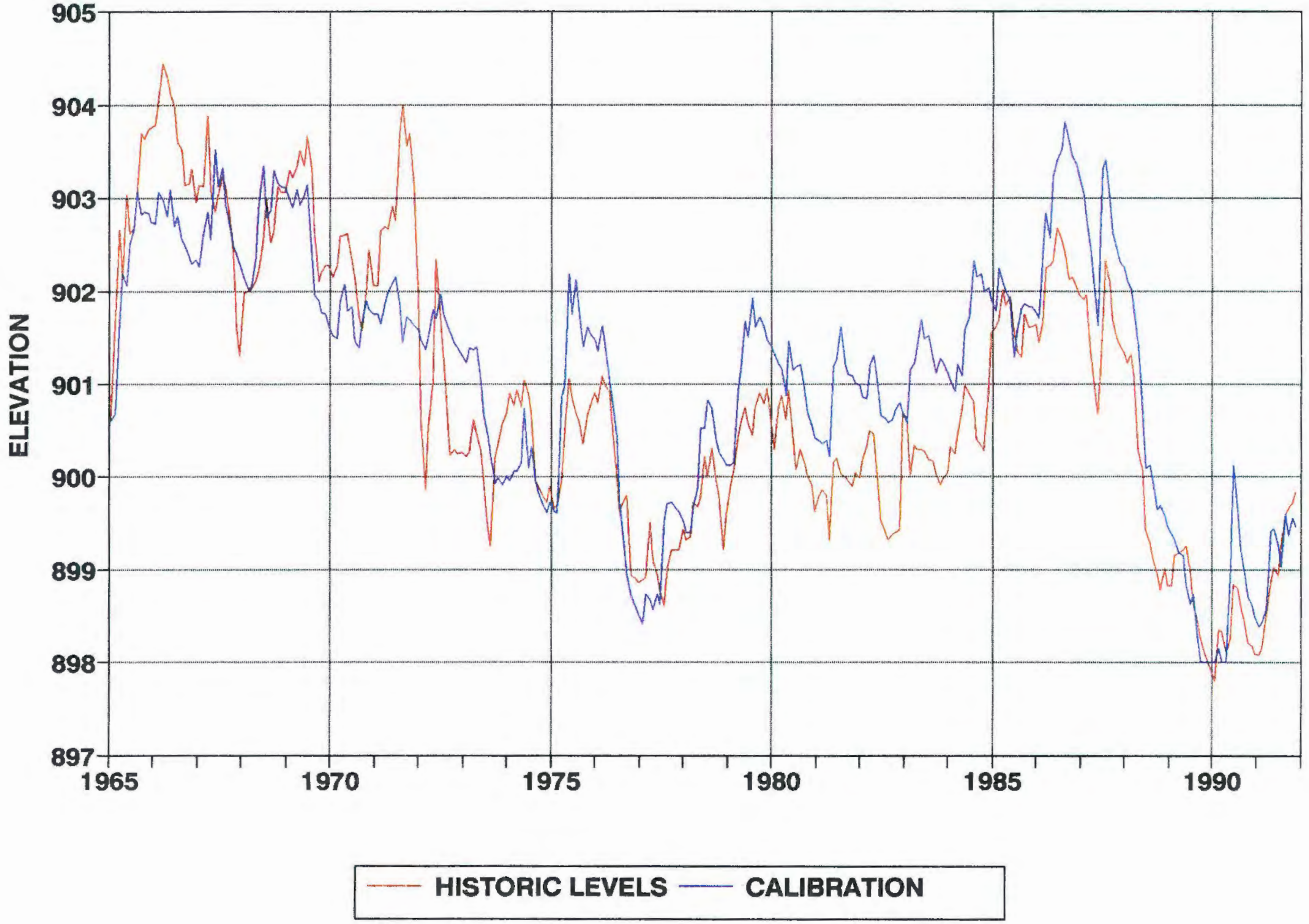
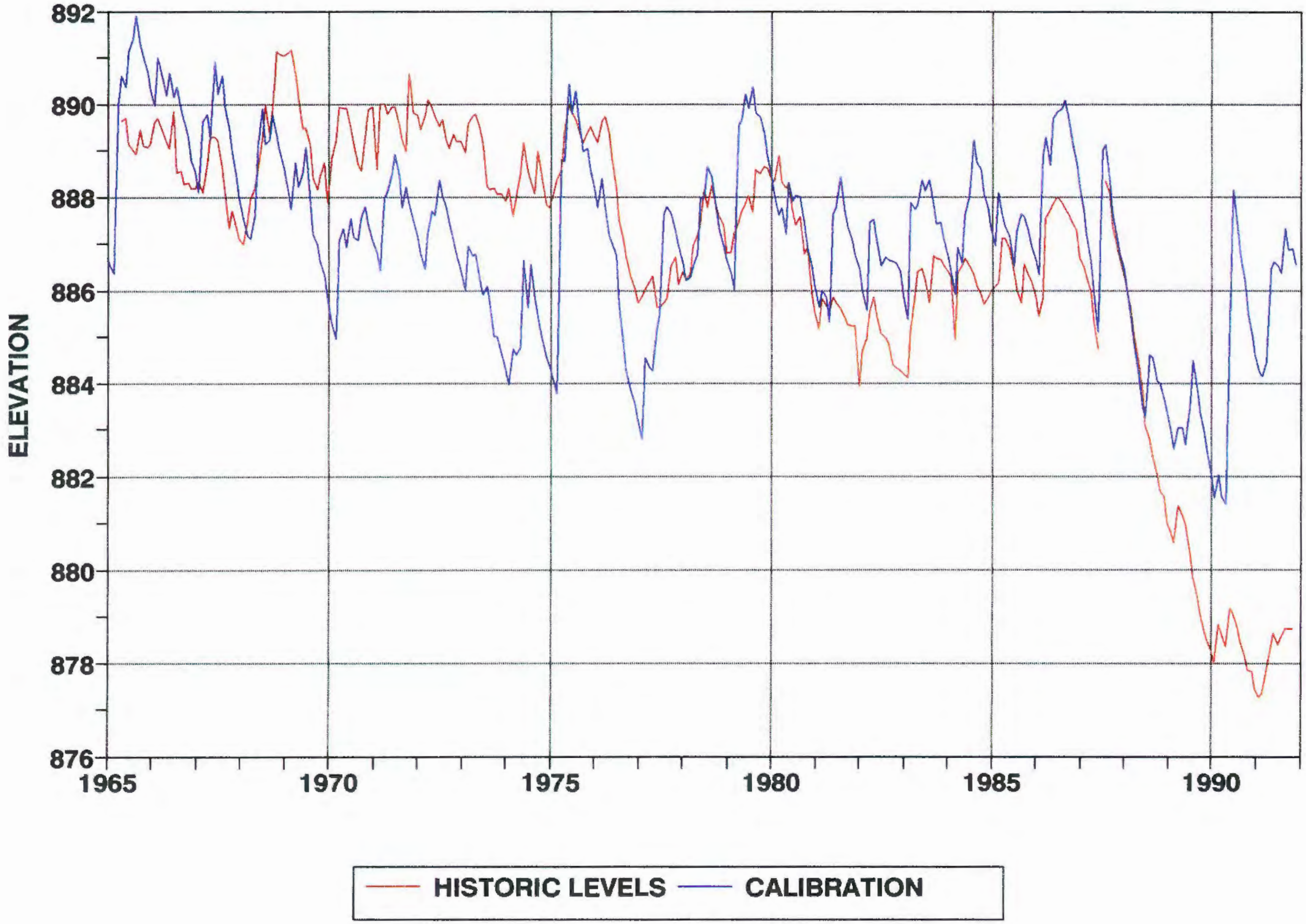


Figure 6
BIRCH ISLAND LAKE



Meyer Model Description

MEYER MODEL DESCRIPTION

The surface water inflow from the watershed was modeled by means of the Meyer Model (Molsather, et al., 1977). The Meyer Model provides an estimate of the hydrologic budget for the lake on a long-term average basis. The model estimates long-term watershed water yield based on the hydrologic and watershed factors illustrated in Figure A-1. The model can be applied to any watershed to synthesize yields based on meteorological and watershed parameters. Meteorological input includes temperature, relative humidity, precipitation and wind velocity. Watershed parameters such as groundwater characteristics, storage relationships, area, soil types, well pumping and intra-watershed diversions can also be input to the model.

The model handles the input data in two basic steps: (1) calculation of total yield and (2) routing of the yield through groundwater and surface storage. However, the groundwater storage application was not used in this study. The model concept is shown in Figure A-1. The model has the capability to consider several types of water surface and upland to account for various types of terrain, vegetative cover, and land use including marshes, shallow lakes and deep lakes. Watershed losses are calculated and subtracted from precipitation. Incremental yields from each type of upland or water surface are added to determine the total watershed yield. In the routing portion of the program, the model simulates the storage and routing features of the watershed to provide an accounting system for water remaining after the losses have been removed. Water entering the ground is added to soil moisture and routed to groundwater storage after land evaporation and transpiration demand are satisfied.

The model output is in the form of calculated runoff or yield which simulates the actual quantity and time sequence of water released from the watershed to a stream, a lake or groundwater. Where records of runoff, lake levels or other watershed data are available, the output data are compared to verify the accuracy or the simulation. Necessary adjustments are made to various functions to fine tune the model, enabling a refinement in predicted yield results. Where such verification is not possible due to a lack of hydrologic information, the model may still be used because the simulation depends only upon the input of climatological and watershed data. Figure A-2 is a generalized model schematic to illustrate the manner in which hydrologic factors and land use parameters are handled. Calculations of yield within the model are based upon methods derived by Adolph P. Meyer in his book Elements of Hydrology. The Meyer Evaporation Formula and methods for determining land evaporation and transpiration are basically empirical methods which are found to give good results when used in water balance calculations.

Water yield from open water surfaces is determined by deducting the losses to evaporation from the precipitation. By varying the coefficients for evaporation, different water surface types can be represented, i.e. deep lakes, shallow lakes and marshes with varying types of cover. Upland yield is the sum of upland runoff and percolation to the water table. Percolation is water that infiltrates into the soil less evapotranspiration losses and soil moisture storage. The evapotranspiration losses are a function of the soil moisture which is available to support those losses; thus, the model includes an accounting system for soil moisture. When soil moisture is limited, evapotranspiration is reduced, but full evapotranspiration loss is realized when adequate soil moisture is available. The remaining water becomes yield as percolation to the groundwater table. The sum of open water yield and upland yield becomes the total yield for the watershed. Use of the model permits the objective consideration of climatologic and land use factors which affect yield without confusing their effect with the effect of watershed parameters.

Figure A-1 illustrates that the upland yield and the open water yield are routed to account for surface storage, groundwater storage, and the effect of landlocked areas, well pumping and losses to seepage beyond the watershed boundaries. The final output is in the form of a daily or monthly hydrograph of runoff or volume over the period of record. As in the case of the yield calculations, the runoff can be compared with observed hydrologic data, where available, and the routing program logically modified to reflect the influence of identified watershed parameters.

The routing portion of the Meyer Model provides a summary of the average monthly surface water inflows, direct precipitation, evaporation, groundwater seepage, surface water outflow from the lake, and the resulting average lake level for the period of available meteorological data.

REFERENCES

Meyer, Adolf F. 1947. Elements of Hydrology. John Wiley and Sons, Inc.

Molsather, L.R., L.J. Kremer, and D.E. Palmer. 1977. Hydrologic Impacts of Land Use Decisions. Paper presented at American Society of Civil Engineers Convention. Preprint #2999, p. 27.

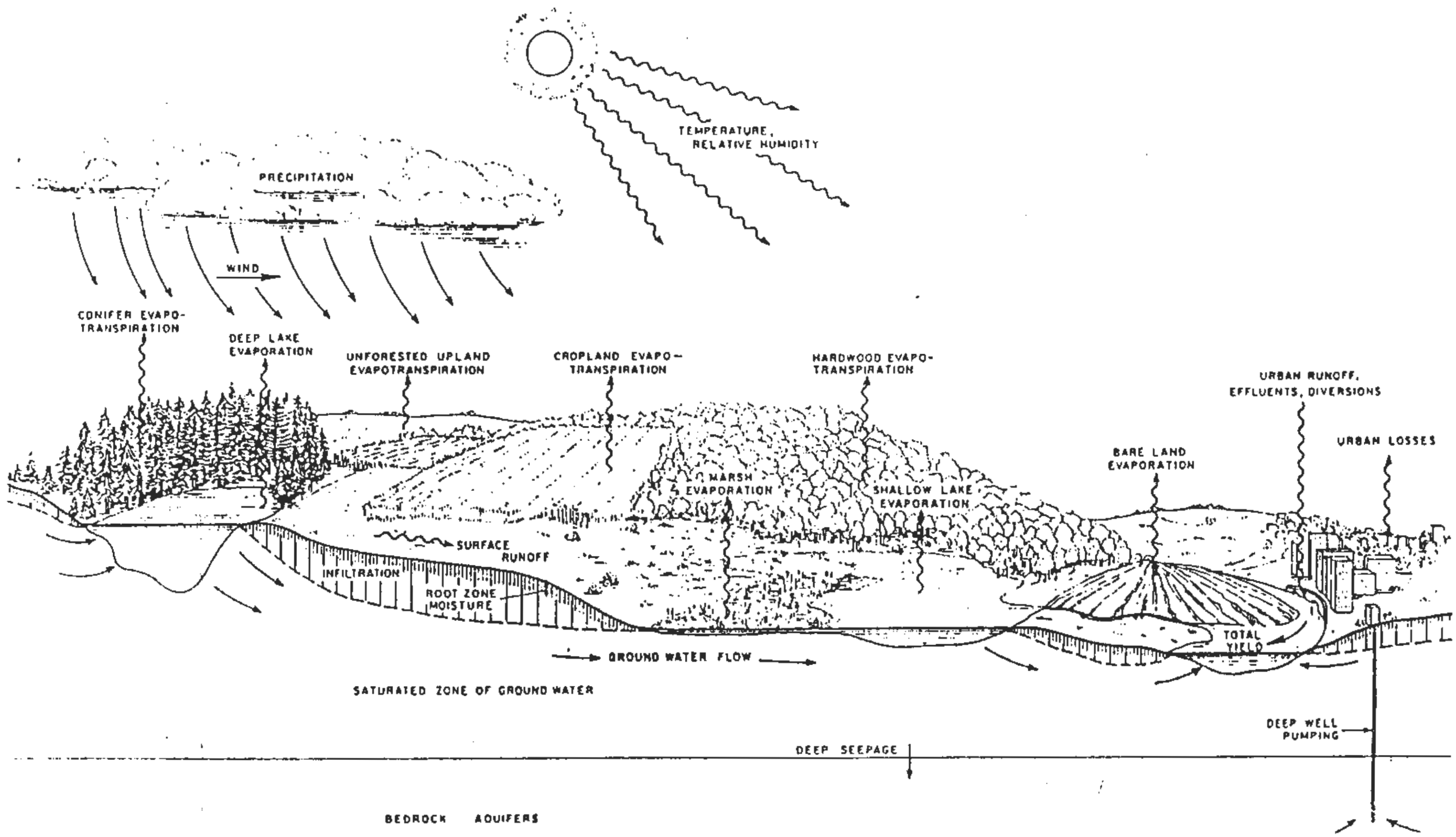


Figure 1

HYDROLOGIC FACTORS CONSIDERED BY THE MEYER MODEL

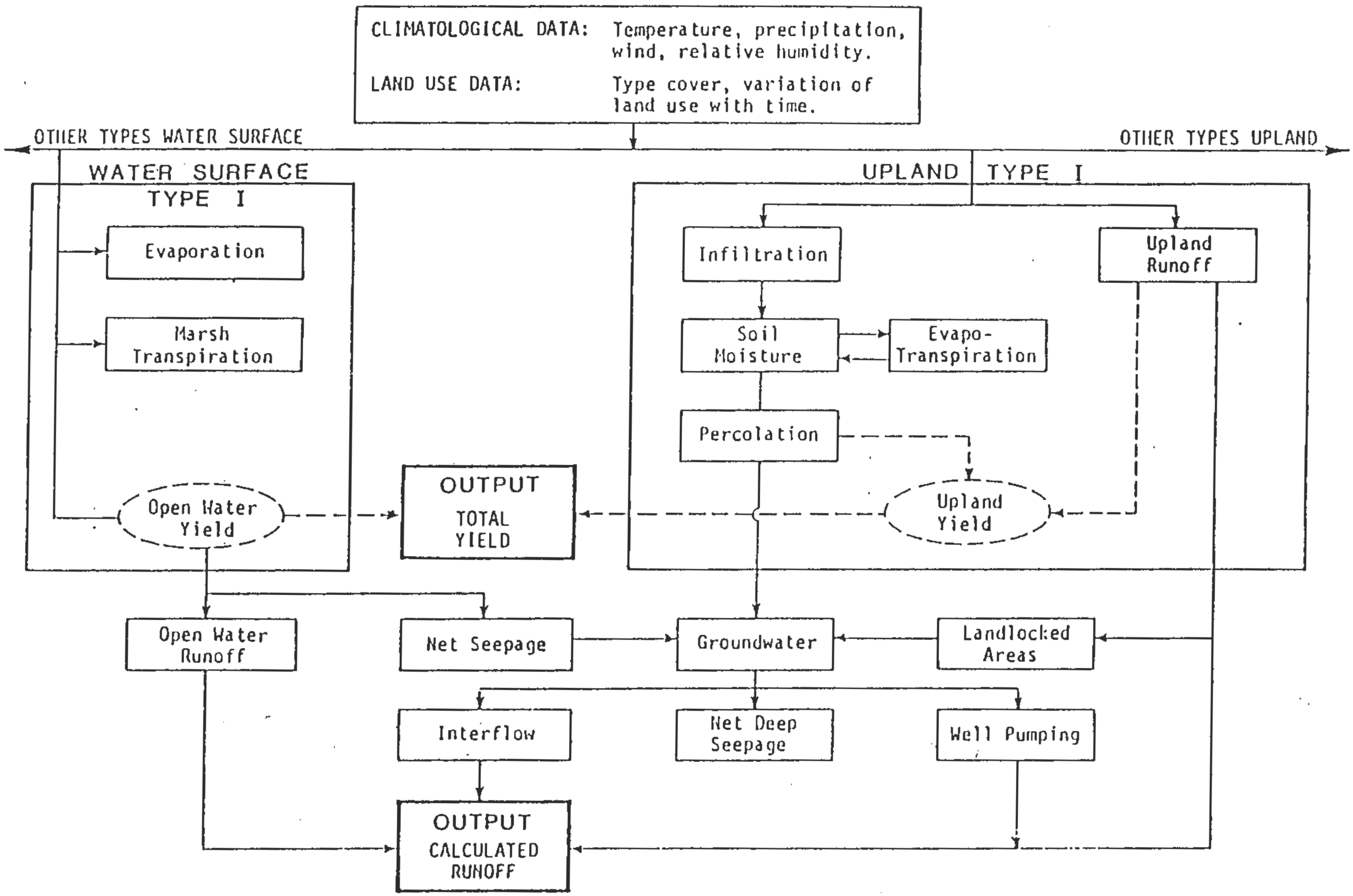


Figure 2

GENERALIZED MEYER MODEL SCHEMATIC