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Title: Hydrogeology of Maine Lakes

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Lakes are inland basins filled or partially filled with water. Many of their characteristics are related to a combination of hydrologic and geologic conditions. This booklet discusses the origin of lake basins, the modes of filling them with water, and the effects of geologic environment on sedimentation and water quality.

In the course of geologic time, lakes are transitory features of the Earth's surface. They are rapidly created, destroyed or altered by geologic processes and climatic events. The most recent period of glaciation created most of the present lakes while obliterating all pre-glacial lakes. Glacial ice left the State about 13,000 years before the present, only a moment ago in terms of geologic time.

Glaciation produced lake basins in two basic ways: erosion of solid bedrock (ledge), and deposition of sediments that were transported by ice or by streams derived from the melting of ice. Moving ice sometimes scoured out basins in the bedrock that later filled with water and became lakes. Scoured basins may follow pre-glacial stream channels or faults and less resistant strata in the bedrock. Depressions in the overburden (loose material overlying bedrock) often resulted directly from variations in the thickness of materials deposited by glaciers or glacial streams. Numerous basins in Maine resulted from a combination of rock scouring and sediment deposition. There are many varieties of lake basins in Maine, but glaciation is the agent most responsible for their present form.

All water movement above, on, and below the Earth's surface is part of the hydrologic cycle (Fig. 1). In this cycle, lakes are reservoirs of surface water that exist because the long-term rate of water inflow is equal to the rate of water outflow. Water may enter a lake from surface and ground water sources, and by precipitation falling directly on its surface. The volume of a lake's inflow depends in part upon the physical size and geomorphic characteristics of its watershed, which is the land area that contributes runoff to the lake (Fig. 2). Assuming precipitation per acre over two different watersheds is equal, the lake with a large watershed receives more inflow that the lake with a small watershed. For example, Sebago Lake obviously has a larger watershed than Long Lake, which is a tributary to it (Fig. 2).

Geographic location also affects the volume of inflow, as evidenced by mountainous areas in Maine that receive more precipitation in an average year than do adjacent coastal areas. More importantly, the topography of a lake watershed affects the rate and timing of inflow. A mountainous watershed yields runoff rapidly during storms, leaving little to flow into the lake during dry periods. In contrast, a flat and swampy watershed yields water at a more constant rate, retarding peak inflow during storms and slowly releasing runoff during periods between storms. Thus, both the volume and rate of runoff to a lake are controlled by its watershed.

Ground water enters a lake directly through seeps and springs in its banks and bottom, or indirectly as ground water runoff carried in by tributary streams. The area that contributes ground water to a lake, both directly and indirectly, is called a ground watershed, and in Maine is often defined by the same topographic divides that delineate the surface watershed (Fig. 3).

Type and thickness of surficial deposits (overburden) in a lake's watershed greatly influence the volume of ground water inflow. Regions covered by thick deposits of sand and gravel tend to yield more ground water to lakes than do areas covered by thin clayey overburden because the former have a greater ability to store and transmit ground water. When characterizing the inflow to a lake, both the surficial geology and hydraulic aspects of the watershed must be considered.

Outflow from most lakes occurs by surface outflow and evaporation (Fig. 3). Hydraulic configuration of the outlet channel controls the rate of surface water outflow, but evaporation depends mostly upon climatic factors, which are discussed later. During periods of sustained and heavy rainfall, a lake will rise rapidly if its outlet is narrow and constricts the outflow. Following the rapid rise, the lake will slowly decline to normal.

An outlet channel's geology may cause more permanent declines in lake level over a period of several decades or centuries if it is formed of glacial or other easily erodable materials. As erosion lowers the elevation of the outlet, the lake level will fall. The hydraulics and geology of the lake outlet channel can determine both short and long term changes in lake level.

In addition to the geologic and hydraulic factors discussed in the preceding paragraphs, lake levels are affected by seasonal and long-term variations in the prevailing climatic conditions. Climate influences streamflow, ground water level, and evaporation rate--all of which have a direct bearing on lake levels. The interrelationships during a typical year of several important hydrologic factors are illustrated in Figure 4 and described below.

Evaporation rate is closely related to air temperature. In mid-summer when the atmosphere is warm, the rate of evaporation is high. Lakes can lose a significant volume of water during the hot summer months, in part depending upon wind speed and direction, humidity, and the area and depth of the lake.

Precipitation is greatest in the winter and spring, and gradually declines throughout the summer and fall. Peak streamflow does not occur at the time of the annual peak precipitation because much of the water is in the form of ice and snow and cannot run off. Although spring and early summer rainfall is often heavy, streamflow declines rapidly because of the sharp increase in rate of evaporation (and use of water by plants--called transpiration).

Ground water level is highest slightly later in time than streamflow because of the time required for movement of water from the Earth's surface to the water table, a process known as recharge. Whereas streamfow is greatly affected by evaporation and transpiration, and decreases rapidly in summer, ground water level is much less affected and tends to decline at a more gradual rate. As ground water level declines, the discharge of ground water to streams decreases. During rainless periods of the summer and fall, the water in streams is largely ground water runoff. Lakes in watersheds mantled with thick sand and gravel deposits tend to continue receiving some inflow from streams even during dry summer months.

In the average year when precipitation, air temperature, and other climatic factors are about as expected, lake levels are highest in the spring and lowest in late summer. Ground water levels, which may affect the operation of septic sewage systems adjacent to a lake, are also highest in the spring.

All depressions, including lakes and their very shallow counterparts, swamps, catch and hold surface runoff in temporary storage. This storage of water decreases the intensity of downstream flooding during stormy periods. Later, when storms have passed, the water is released slowly, thereby maintaining downstream flows. Natural storage is one of the most important hydraulic functions of lakes and swamps. River basins with lakes have more constant flow, with only moderate change in river stage (water height) following storms. Those without lake storage have more irregular flow that tends to rise rapidly immediately following or during a storm (Fig. 5). The peak flow subsides quickly and little water remains to maintain streamflow during ensuing dry periods between storms. The importance of lake storage to man's activities is aptly demonstrated by the numerous dams built in Maine. The West Branch of the Penobscot River, for example, is essentially a series of man-made lakes.

Bedrock and surficial geology not only affect the form, size, depth, and hydraulics of a lake, but are also in part responsible for the quality of its water. Lakes in areas of thin overburden, or in areas of sand and gravel overburden, tend to be clearer than lakes in areas of thick clayey overburden. Clay and silt particles that are carried into a lake by streams or by wave action, remain in suspension for some time, diminishing the clarity of the water and increasing the supply of available nutrients, which are more concentrated in clayey sediments than in gravelly sediments. The erodibility of the adjacent bedrock and overburden affect the rate at which sediments fill lake basins. Where lakes receive large volumes of sediments, shallows form and support aquatic vegetation, which eventually can alter the water quality.

Surface and ground water entering a lake carry dissolved substances that affect the chemical composition of the water. The concentration of trace elements, such as metals, and the pH (degree of acidity) vary in Maine lakes according to the kinds of geologic materials present in the watershed.* In addition to these natural or background materials, lakes may contain undesirable contaminants derived from populated areas of the watershed. The severity of such contamination is often controlled by the thickness, texture and composition of the watershed's overburden, as well as by surface inflow and ground water level, which can show large seasonal variations. Because lake water is not exchanged or flushed rapidly, as compared to river water, a lake once polluted takes considerably more time to cleanse itself. The time required is related to a number of factors including the inflow and outflow characteristics discussed previously, and the ratio of lake volume (water in storage) to volume of long-term inflow. A small lake with a large watershed should have a more rapid water exchange than a large lake with a small watershed. Bedrock and overburden are not simply the shaping elements of a lake basin, but in many ways affect the chemistry and quality of water contained in the basin.

In summary, lake morphology, level, water quality, and inflow and outflow characteristics are affected by certain hydrogeologic conditions. Knowledge of these natural constraints is important to the maintenance of desirable lake qualities.

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*Kleinkoph, M. D., 1955, Trace Element Exploration of Maine Lake Water: Ph.D. Dissertation, University of Michigan

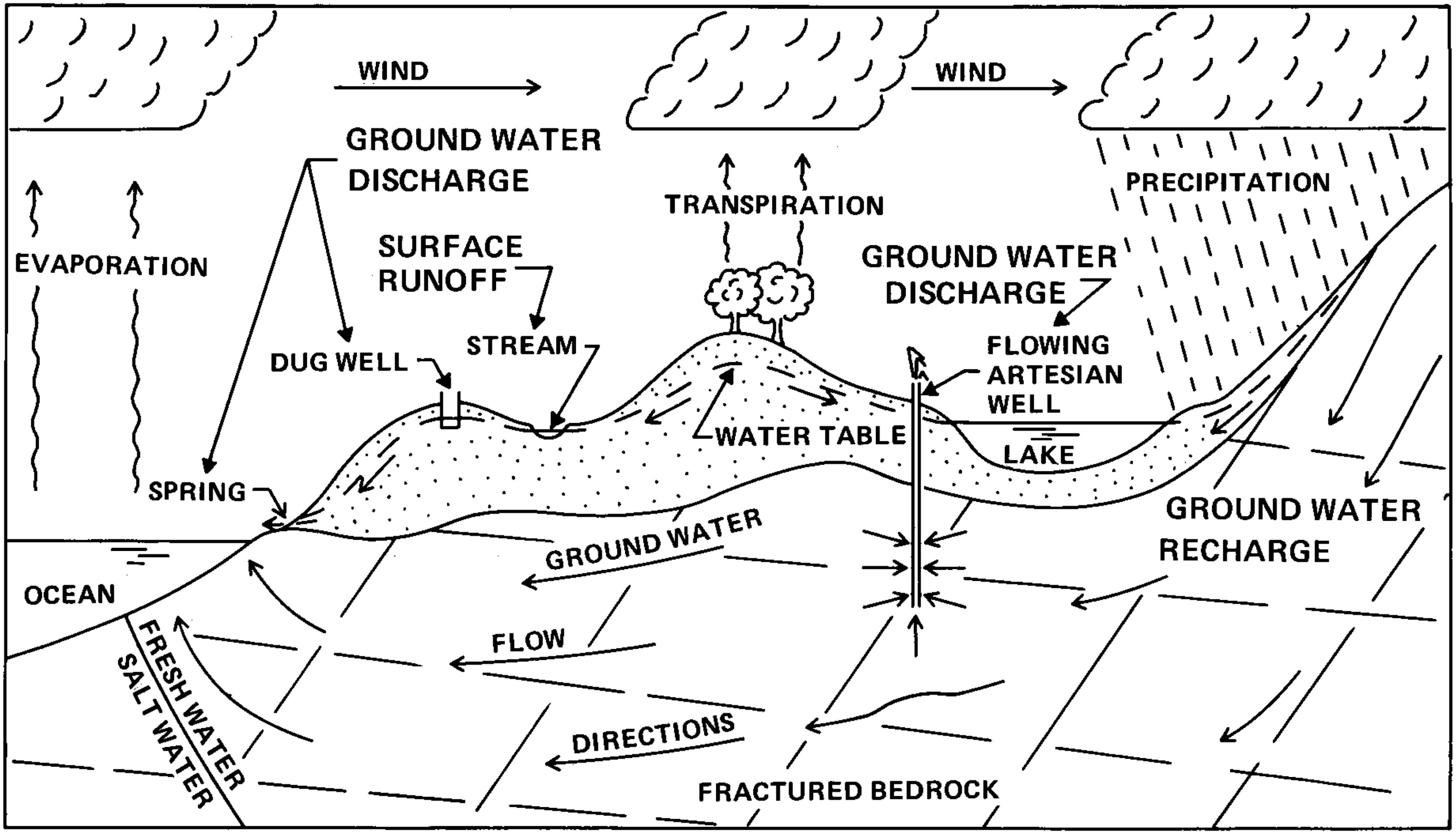

FIGURE 1
HYDROLOGIC CYCLE IN MAINE

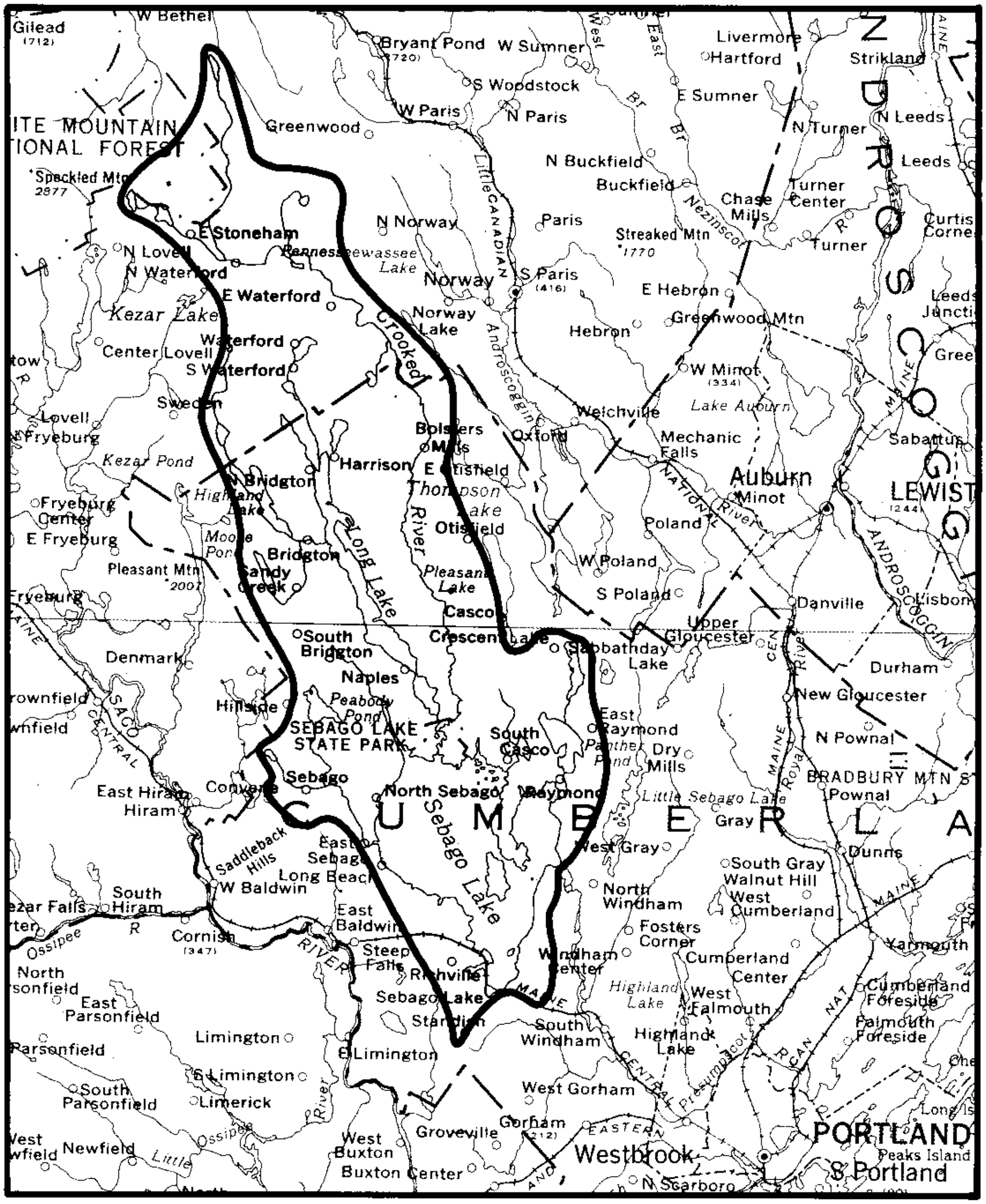

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FIGURE 2
MAP OF THE SEBAGO LAKE WATERSHED

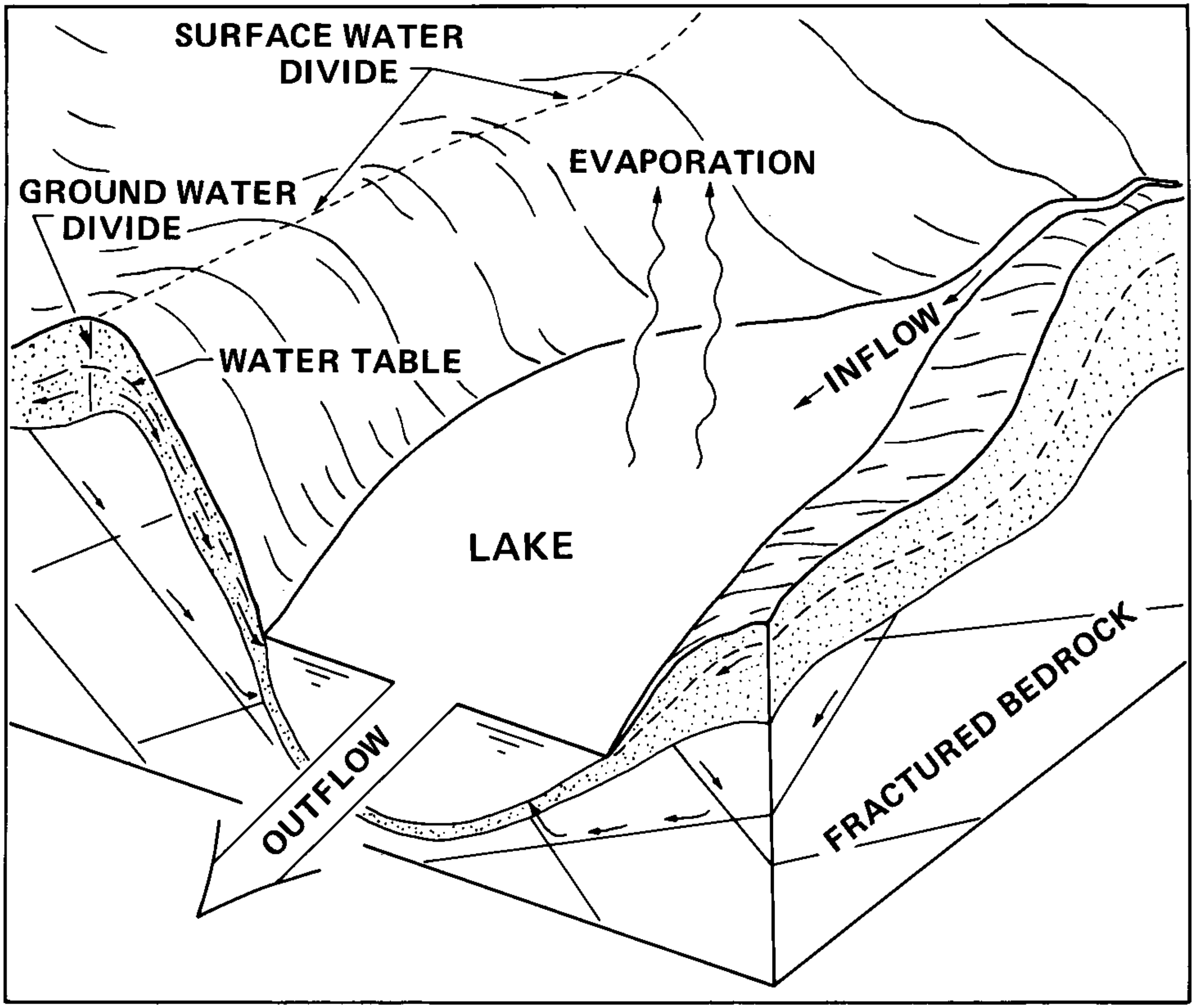

FIGURE 3

BLOCK DIAGRAM OF LAKE IN ROCK BASIN SHOWING INFLOW AND OUTFLOW OF WATER

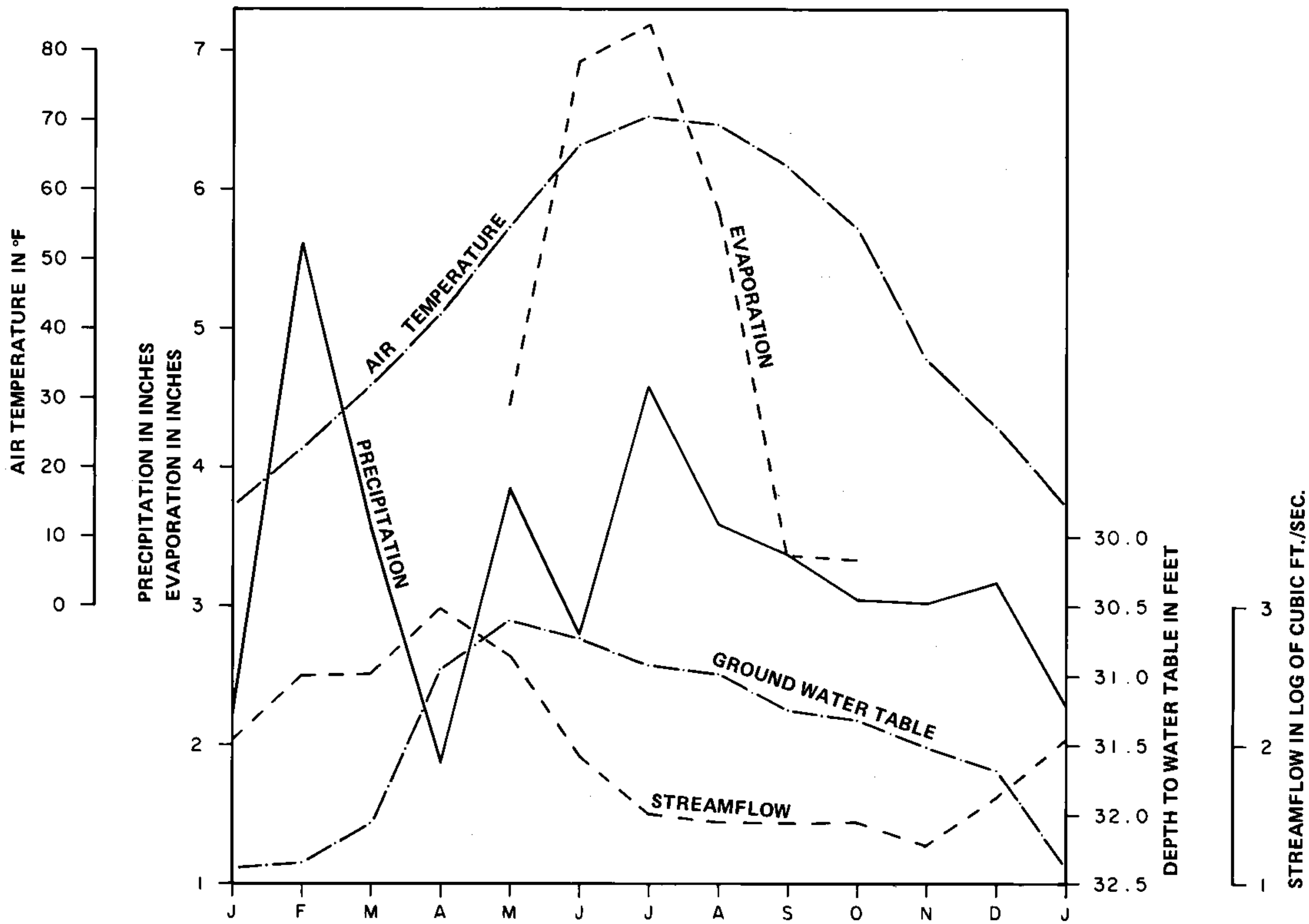

FIGURE 4

COMPARISON OF MEAN MONTHLY AIR TEMPERATURE, PERCIPITATION, EVAPORATION, STREAMFLOW, AND GROUNDWATER LEVEL

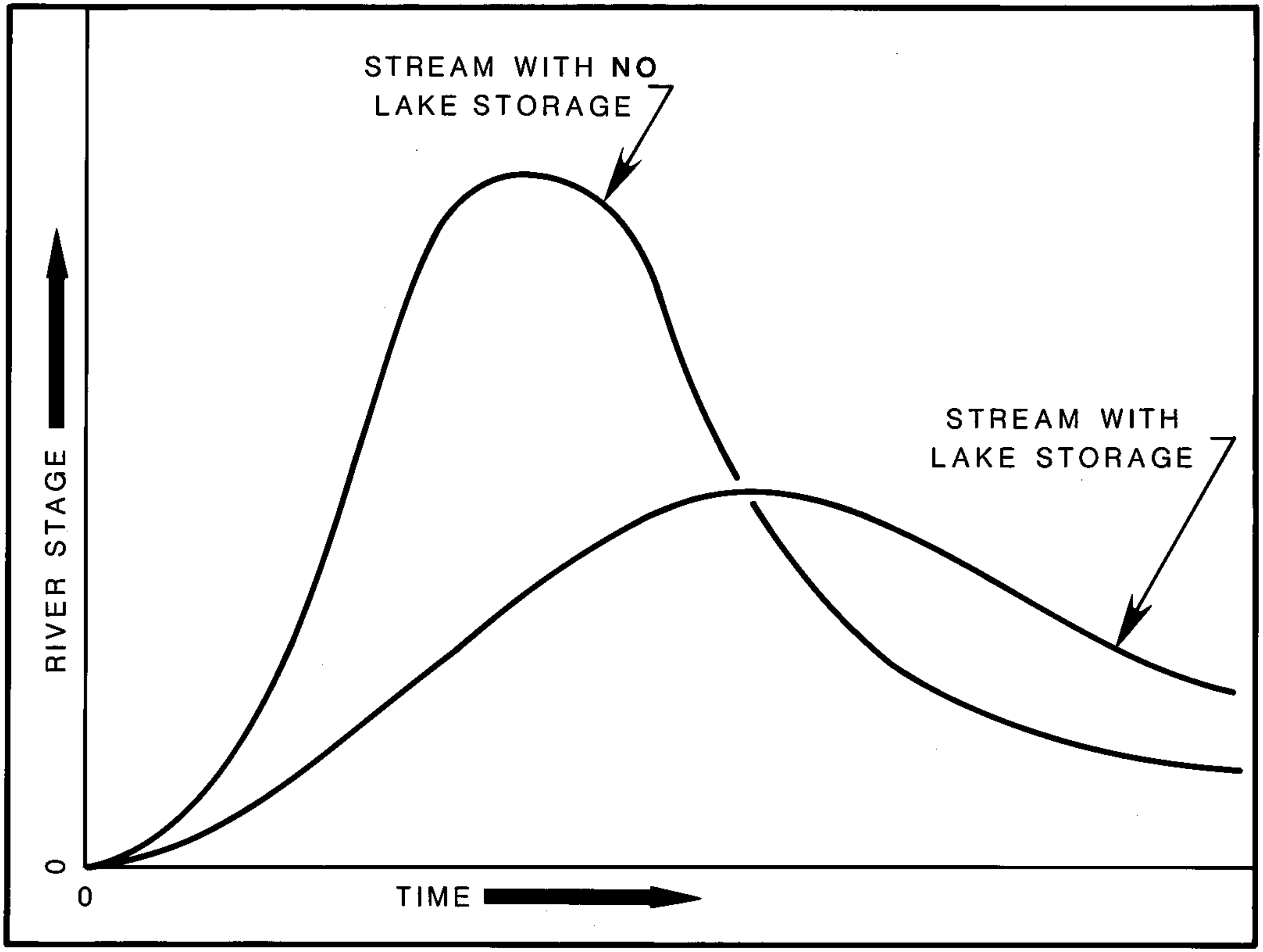

FIGURE 5

STREAM HYDROGRAPHS SHOWING TYPICAL DOWNSTREAM EFFECTS OF TEMPORARY STORAGE OF WATER IN LAKES.