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A reconnaissance of lakes and proposed lake sites
in the White Mountains, Fort Apache
Indian Reservation, Arizona

By

R. H. Musgrove and M. E. Cooley

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Introduction

During the past several years 12 lakes were built for recreational purposes on headwater streams of the Salt River on the Fort Apache Indian Reservation in the White Mountains (fig. 1). At least nine additional lakes are proposed; most of these are scheduled to be built within the next 3 years.

The Geological Survey made a reconnaissance of the lakes and proposed sites during August 9-21, 1965, at the request of the Salt River Valley Water Users' Association and the Bureau of Indian Affairs. The purpose of the reconnaissance was to determine the feasibility of measuring the amount of surface water that flows through the lakes as a means of calculating the effects of the lakes on the water resources of the area. The lakes and proposed lake sites shown below were visited during this reconnaissance (fig. 1).

Existing lakes	Proposed lake sites
Hawley Lake	Sun and Moon
Earl Lake	Bog Creek
Hurricane Lake	Upper Reservation
Pacheta Lake	Sand Creek
Tonto Lake	Lower Cooley
Reservation Lake	Upper Earl
Wilson Lake	Odart Cienaga
Little Bog Tank	Haystack Cienaga
Horseshoe Cienaga	Diamond Creek
Cooley Lake	
Snake Creek Tank	
Drift Fence Lake	

Regional Hydrogeology

Most of the lakes are impounded or proposed at altitudes between 7,500 and 8,500 feet on the western and southern slopes of the White Mountains, which drain to the Salt River. The White Mountains are astride the drainage divide between the Little Colorado and Salt Rivers along the southern border of the Colorado Plateaus physiographic province. The mountains rise to an altitude of more than 11,000 feet and are drained by streams that flow in deep canyons that generally radiate from Baldy Peak—the largest and highest peak in the White Mountains—to the Salt River by way of the White and Black Rivers. The northern and northeastern parts of the mountains are drained by northward- to northwestward-flowing tributaries of the Little Colorado River.

Sedimentary and Volcanic Rocks

The central part of the White Mountains forms a large mesalike platform (fig. 2) that extends from Springerville to Whiteriver to the north of the Black River. The lower part of the platform is cut on the sedimentary rocks of Tertiary age, which generally are tilted slightly southwestward and are more than 1,000 feet thick. Overlying the sedimentary rocks are volcanic rocks that consist principally of flows, tuffs, and cinders of Tertiary and Quaternary age. The volcanic rocks are several hundred feet thick and have been eroded into the many ridges, valleys, and peaks that comprise the bulk of the White Mountains (fig. 2). Escarpments have been eroded in the sedimentary and volcanic rocks along the North and East Forks of the White River and parts of the Black River, although the Black River is entrenched mainly in the volcanic rocks.

The sedimentary rocks consist of beds of claystone to conglomerate; mudstone, siltstone, and sandy siltstone are predominant. The

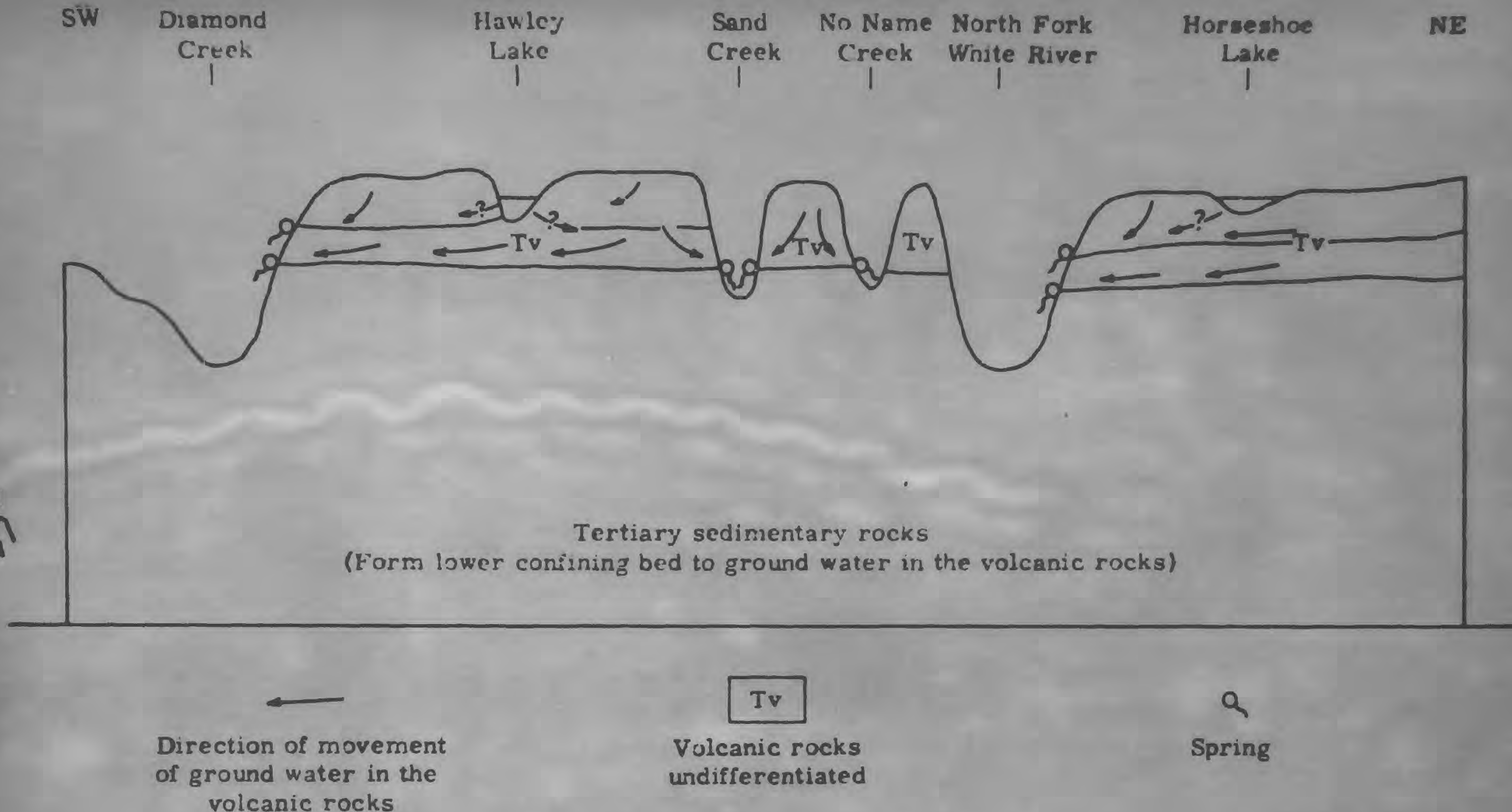

Figure 2. --Hydrologic conditions in the Hawley Lake area in the White Mountains.

conglomerate is mainly at the base, but some lenses and stringers are distributed throughout the formation. The rocks tend to be slightly tuffaceous throughout, and tuffaceous beds are common in the upper part. The sedimentary rocks are generally weakly cemented, although some of the conglomerate beds are firmly cemented. The formation is thin to very thick bedded. The coarse units generally are lenticular and in places are crossbedded and display small- to large-scale crossbeds deposited mainly at medium to low angles. The fine-grained units consist of parallel beds, which, in clear exposures, range in thickness from a few inches to several feet.

The abundance of silt, clay, and tuffaceous material and the tight cementation hinder the movement of ground water in the sedimentary rocks. A few seeps issue along bedding planes and along the base of some conglomerate and coarse tuffaceous beds, but generally the sedimentary rocks do not yield or transmit much water. They form a thick confining unit and retard the downward movement of water from the overlying volcanic rocks.

Volcanic rocks composed chiefly of andesite and basaltic(?) andesite flows interbedded with tuffaceous deposits, including cinders, are the main rocks exposed in the White Mountains. These rocks form a volcanic pile that, in places, may be more than 2,000 feet thick. The flow rocks are usually fine grained and are not strongly porphyritic.

The volcanic rocks are fractured extensively; in places the fractures are spaced a few feet apart, and in others 25 to 100 feet may separate larger fractures. Some of the fractures are "open" and appear as large cracks, but others are not readily visible except on close inspection. Many of the fractures are filled with alluvium and soil from nearby sources.

The extensive fracturing permits the rapid movement of water through the volcanic rocks. A relatively large amount of direct precipitation is intercepted by the fractures and moves downward into the rocks. After entering the rocks the water moves laterally and downward along the fractures. The interbedded tuffaceous units interrupt the downward movement of the ground water and cause the water to move laterally. Some of the water moves downward through the tuffaceous units along large fractures, through relatively permeable zones in the detrital or cinder beds, and eventually percolates into another volcanic flow beneath. Much of the water moves laterally along the top of the tuffaceous units and is discharged at the land surface. In places springs and seeps occur near the upper contact of the thick tuffaceous units.

Younger basaltic flows and cinder cones border the central part of the White Mountains and in places overlie the andesitic volcanic rocks. Although the basalt flows were not subjected to as much fracturing as the older andesitic rocks, they contain abundant fractures and, in general, have hydrologic characteristics similar to those of the andesitic rocks. Most of the associated cinder cones and deposits are very weakly cemented and have a high permeability. The basaltic rocks flowed down the valleys or canyons of streams that are tributaries of the White, Black, and Little Colorado Rivers. A thick sequence of basaltic flows and cinder cones occurs north and northeast of the White River east of McNary. These flows occupy old valleys that were tributary to the Little Colorado River. These valleys generally trend northwestward near McNary and northwest and north in the area north of Horseshoe Lake and Snake Creek Tank. Ground-water movement through the volcanic rocks generally is outward from Baldy Peak to the points of discharge along the streams. Thus, the regional movement of ground water generally is westward in the Hawley Lake area, southwestward near Diamond Creek, southward to southeastward in the Maverick-Upper Reservation Lake area, and eastward and northward between Baldy Peak and the North Fork of the White River. North and northeast of the North Fork of the White River, ground-water movement in the basaltic volcanic rocks generally is northward and northwestward to the tributaries of the Little Colorado River. In the White Mountains the ground-water discharge maintains the perennial flow in many of the streams.

Surficial Deposits and Stream Channels

Surficial deposits—such as alluvial, terrace, colluvial, and glaciofluvial deposits—and soil form a thin mantle in the valleys and on some of the ridges. In general, these deposits are thin and are exposed only in small outcrops on the sides of stream channels and in roadcuts. For the most part, these deposits are mixtures of silt and clay, sand, and gravel. Sorting is generally poor, and the distribution of the gravel is dependent on the available source and on the amount of streamflow to transport the coarse material. Thus, coarse-grained deposits occur along the large streams and in the narrow canyons along reaches of small streams. Silt and clay predominate in the broad valleys where cienagas and swampy areas have developed. A grayish-brown alluvial deposit is exposed locally in streamcuts across the wide valleys. This deposit is more tightly cemented and, thus, is less permeable than the modern and Recent deposits, and it forms a fairly effective seal to the downward movement of water, which may explain the presence of cienagas, small lakes, and shallow perched ground water in the valleys (fig. 3). The large boulders, 4 to 6 feet in diameter, may have a glacial(?) and glaciofluvial origin in the valley of the proposed Upper Reservation Lake. The low ridge at the damsite, which is composed of boulders and is probably breached by the present stream, may be the remains of a terminal moraine(?).

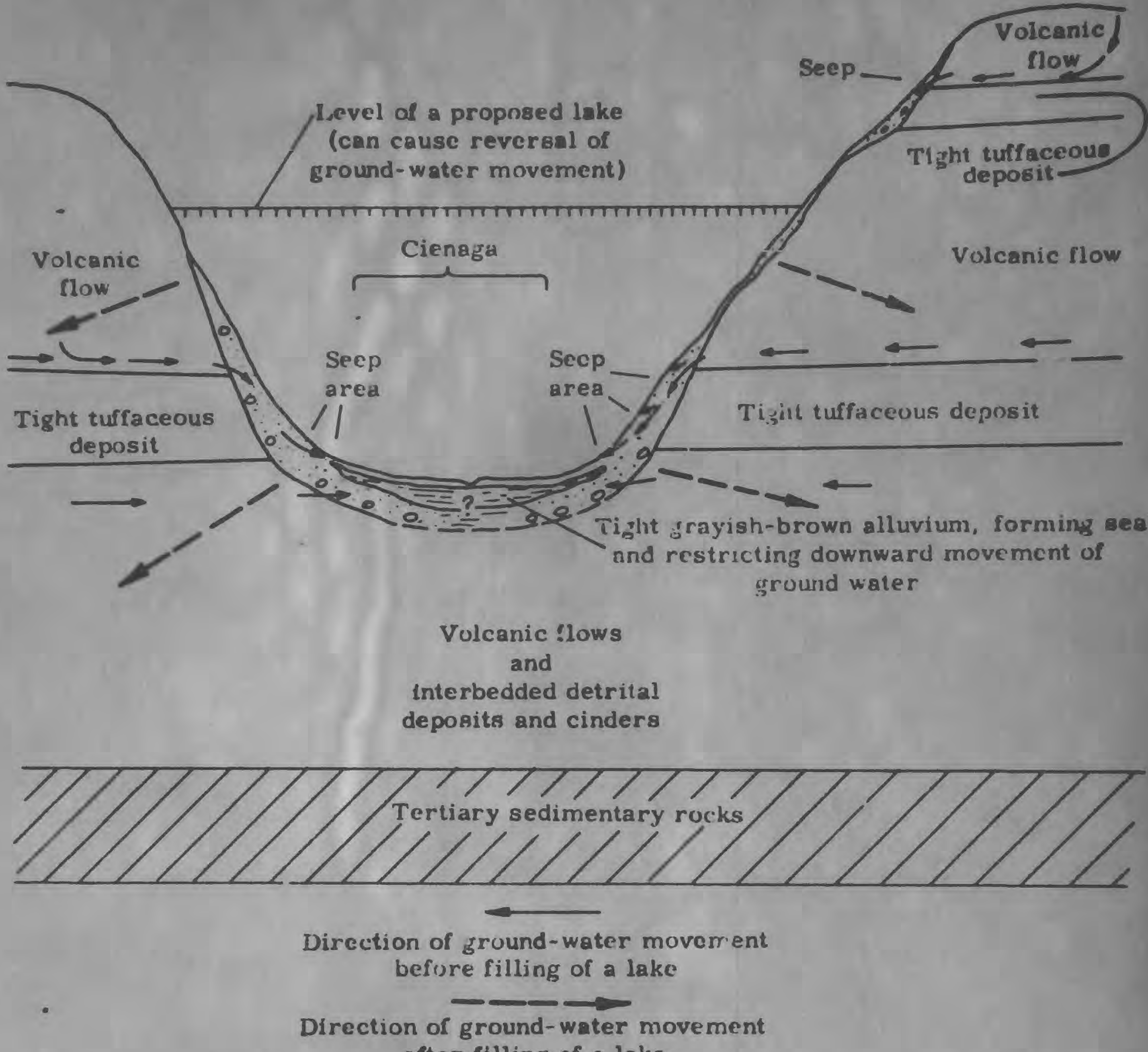

Figure 3. --Diagrammatic section of a valley, showing direction of ground-water movement, in the White Mountains.

All the surficial deposits in the valleys readily absorb water from precipitation, and the part that is not lost to evaporation is held in temporary storage. The water in the surficial deposits is discharged slowly and maintains the shallow water table in the valleys and the perennial and intermittent flow of the streams. Much of the water that enters the stream channels is below stream level and is not visible. In places, however, broad seepage areas adjoin the channels, and seepage occurs in the channel sides above stream level.

Stream channels in the White Mountains are shallow, usually less than 3 feet deep, except along the White River and the lower reaches of the main tributaries—such as Sand, Trout, Little Diamond, Diamond, and Tonto Creeks—where the channels may be from 5 to 7 feet deep. In the area of the present lakes and proposed lake sites, most channels range from 1 to 3 feet deep and are from 3 to more than 10 feet wide. Scours and bars, chiefly of gravel, cause the differences in the channel depth and width, but, in most places, the relief along the channel caused by the bars and scours is usually less than 1 foot and rarely more than 2 feet. The channels in the wide valleys are very sinuous, and S-shaped meanders form a belt 5 to 25(?) times the average width of the channel. In the canyons the channels are relatively straight because there is little room for meandering.

The meanders and bars in the stream channel affect a control on the amount of surface flow that passes through a given reach of a stream. The alluvial deposits are sufficiently permeable to allow part of the streamflow in the meandering stream channels to move directly through the alluvium; the streamflow leaves the stream in a tight bend of a meander and reenters the stream channel at another meander bend farther downstream. The gravel bars make small dams in the stream channel and aid in the subsurface movement of water from one meander to another. In addition, part of the streamflow moves as underflow through the bars, reemerging along the downstream edge of the bar.

Hydrology of the Lakes and Proposed Lake Sites

The lakes are formed by earth-filled dams as much as 50 feet high, which are placed downstream from cienagas or swampy areas. The swampy areas are underlain by relatively impermeable deposits that retard the downward movement of water (fig. 3). The lakes are maintained by direct surface runoff or sheetflow and by ground water that originates in the surrounding hills and ridges.

Based on visual observations of surface flow made during the reconnaissance, some lakes had more inflow than outflow, some had about the same inflow as outflow, and others had less inflow than outflow. The inflow to Pacheta Lake, for example, exceeded the outflow by an amount far greater than the probable rate of evaporation, which indicates that water is diverted to ground-water flow. Some lakes, such as Cooley Lake, had no surface inflow but because of ground-water inflow had outflow over the dams. Most of the dams showed evidence of leakage through the fill, either around the ends or under the bottoms of the dam. Where the earthen dams are on fractured bedrock, leakage was observed along the fractures.

Conclusions

The lakes and small streams in the White Mountains are on volcanic rocks, which are characterized by extensive fractures through which the water moves. The movement of water through the fractured rock is generally downward and laterally in a zigzag pattern until it reaches the tighter underlying Tertiary sedimentary rocks or an open stream channel. The water that moves laterally along the surface of the sedimentary rocks is discharged eventually into the open channels. In general, the perennial flow of the streams is maintained by ground water that is discharged from the volcanic rocks and from bank-storage seepage from the surficial deposits.

Generally, water that seeps from the ground will remain in open stream channels as long as the resistance to flow does not become great enough to force it back into the ground. Significant resistance to streamflow is caused by natural or manmade controls. Natural controls, such as meanders and sandbars, create only small heads and cause the water to pass through the permeable materials of the streambanks and to enter the channel a short distance downstream. The new dams and their associated lakes create relatively large heads that may cause a change or, in places, a reversal in the ground-water gradient, which will thereby modify or alter significantly the direction of ground-water movement (fig. 2). The effects that the change in head would have on the ground-water conditions cannot be determined easily or accurately, perhaps even with intensive field investigation and instrumentation.

Surface inflow into the lakes and proposed lake sites takes place in at least two open channels and at some sites may take place in as many as five or six channels. In addition, the inflow into some of the small tributary valleys is only evident in the broad seepage areas. The large number of open channels and the seepage areas would present extreme difficulties in the accurate gaging of the inflow.

Outflow from the lakes, other than through spillways, is from (1) along the contact of the dam with the underlying rocks, (2) along fractures in the rocks underlying the dam and the lake, and (3) permeable material that underlies the fill that forms the dam. Part of the outflow may enter the channel below the dam and part enters fractures and is discharged elsewhere; however, there is no way to determine accurately these amounts.

In summary, the fracturing, large number of open channels, and water in the broad seepage areas that cannot be gaged preclude calculating the effects of the lakes on the water resources of the area by means of streamflow measurements.

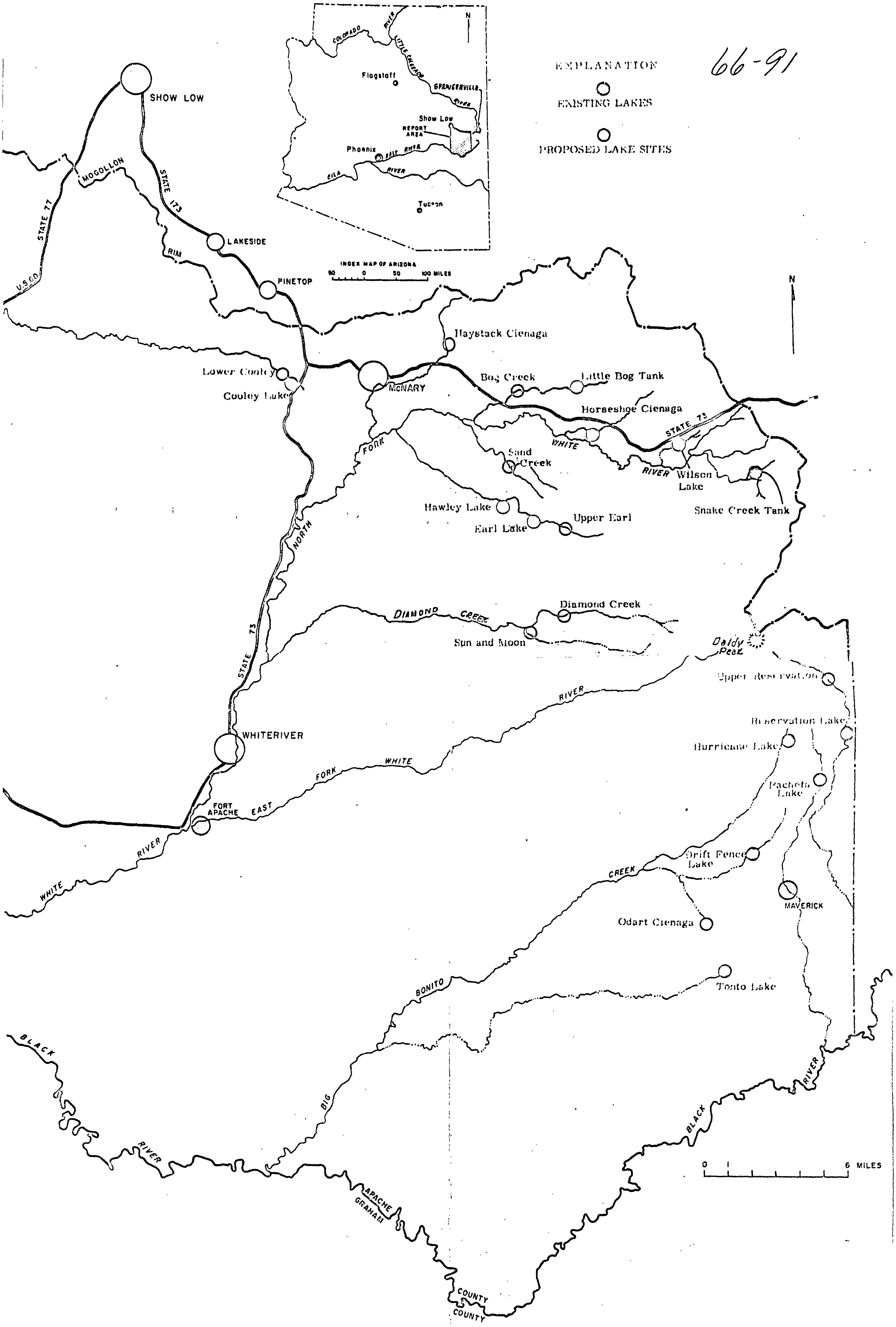

Figure 1.--Existing lakes and proposed lake sites in the White Mountains, Fort Apache Indian Reservation.