GROUND WATER IN THE LONG MEADOW AREA AND ITS RELATION WITH THAT IN THE GENERAL SHERMAN TREE AREA, SEQUOIA NATIONAL PARK, CALIFORNIA

By J.P. Akers

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CONVERSION FACTORS

For readers who prefer to use the International System of units (SI) rather than inch-pound units, the conversion factors for the terms used in this report are listed below:

Multiply	By	To obtain
acres	4,047	square meters
acre-feet (acre-ft)	1,233	cubic meters
acre-feet per year (acre-ft/yr)	1,233	cubic meters per year
feet	0.3048	meters
feet per mile (ft/mi)	0.1894	meters per kilometer
cubic feet per second (ft^3/s)	0.02832	cubic meters per second
gallons	3.785	liters
gallons per minute (gal/min)	0.06308	liters per second
gallons per minute per foot [(gal/min)/ft]	0.2070	liters per second per meter
gallons per day (gal/d)	0.003785	cubic meters per day
inches	2.540	centimeters
miles	1.609	kilometers
square miles (mi^2)	2.590	square kilometers

Degrees Fahrenheit is converted to degrees Celsius by using the formula:

$$\text{Temp } ^\circ C = (\text{temp } ^\circ F - 32)/1.8$$

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ABSTRACT

Westward movement of ground water from the Long Meadow area of Sequoia National Park, California, to the General Sherman Tree area is prevented by an eastward hydraulic gradient and low fracture permeability of a granodiorite ridge separating the two areas. Clay beds present in the alluvium in the Long Meadow area would hinder, but not preclude, recharge to the ground-water system beneath Long Meadow from streams.

A dependable ground-water supply of about 50 gallons per minute (72,000 gallons per day) can be developed from the Long Meadow area. The withdrawal of this quantity of ground water from the Long Meadow area should not affect ground or surface water in the General Sherman Tree area.

INTRODUCTION

The National Park Service is planning to move the present public accommodations and facilities from the Giant Forest area of Sequoia National Park (fig. 1) to the western part of the Clover Creek drainage basin, just north of the study area, because of heavy traffic and congestion. It plans to pipe ground water from the Long Meadow area to supply the new facilities. The Long Meadow area as used in this report, known locally as the Wolverton Valley area, includes both Wolverton Valley and Long Meadow and the surrounding ridges (pl. 1). This report covers the area indicated in figure 1.

At the present time (1984) surface water is diverted from Wolverton Creek at the northeast end of the Long Meadow area and piped into the areas of use. The National Park Service estimated that peak demand for water for all facilities during the Labor Day weekend of 1984 was about 60 gal/min or about 86,000 gal/d. The average continuous demand is expected to be no more than 50 gal/min, which is about 72,000 gal/d or 81 acre-ft/yr. Previous studies (G.L. Bertoldi and G.A. Miller, U.S. Geological Survey, written commun., 1969) indicated that the ground-water system in the area would sustain a demand of about 30 gal/min (about 43,000 gal/d) per summer-use season.

There is concern that pumping from the ground-water system in the Long Meadow area could divert water that otherwise might move southwestward to sustain trees in the General Sherman Tree area. To reach the General Sherman Tree area, ground water would have to move about 1 mile through an intervening ridge composed of granodiorite. The Long Meadow area has altitudes ranging from 7,200 to 7,280 feet; the General Sherman Tree area has altitudes ranging from 6,800 to 6,900 feet--a maximum difference of about 480 feet.

Decription of Area and Background Information

The Long Meadow area (pl. 1) is floored by a marshy or meadowy, parklike area of about 50 acres that is drained by Wolverton Creek, which flows westward, and by its tributary, Long Meadow Creek, which flows northward. Most of the marshy meadow is underlain by alluvium of Holocene age, which in turn is underlain partly by glacial till of Pleistocene age. The till forms the northern boundary of the meadow area. Granodiorite of pre-Tertiary age forms the remaining boundaries and underlies the alluvium and till.

Studies by M.G. Croft (U.S. Geological Survey, written commun., 1968), and G.L. Bertoldi and G.A. Miller (U.S. Geological Survey, written commun., 1969) indicated that the average saturated thickness of unconsolidated material, which includes both the alluvium and glacial till, is about 70 feet in the Long Meadow area. The maximum thickness is about 150 feet as determined by a seismic survey (G.L. Bertoldi and G.A. Miller, U.S. Geological Survey, written commun., 1969). A subsequent seismic survey by J.C. Tinsley (Wahrhaftig, 1984) corroborated the previously estimated maximum thickness at a point near the junction of Wolverton Creek and its tributary from the south.

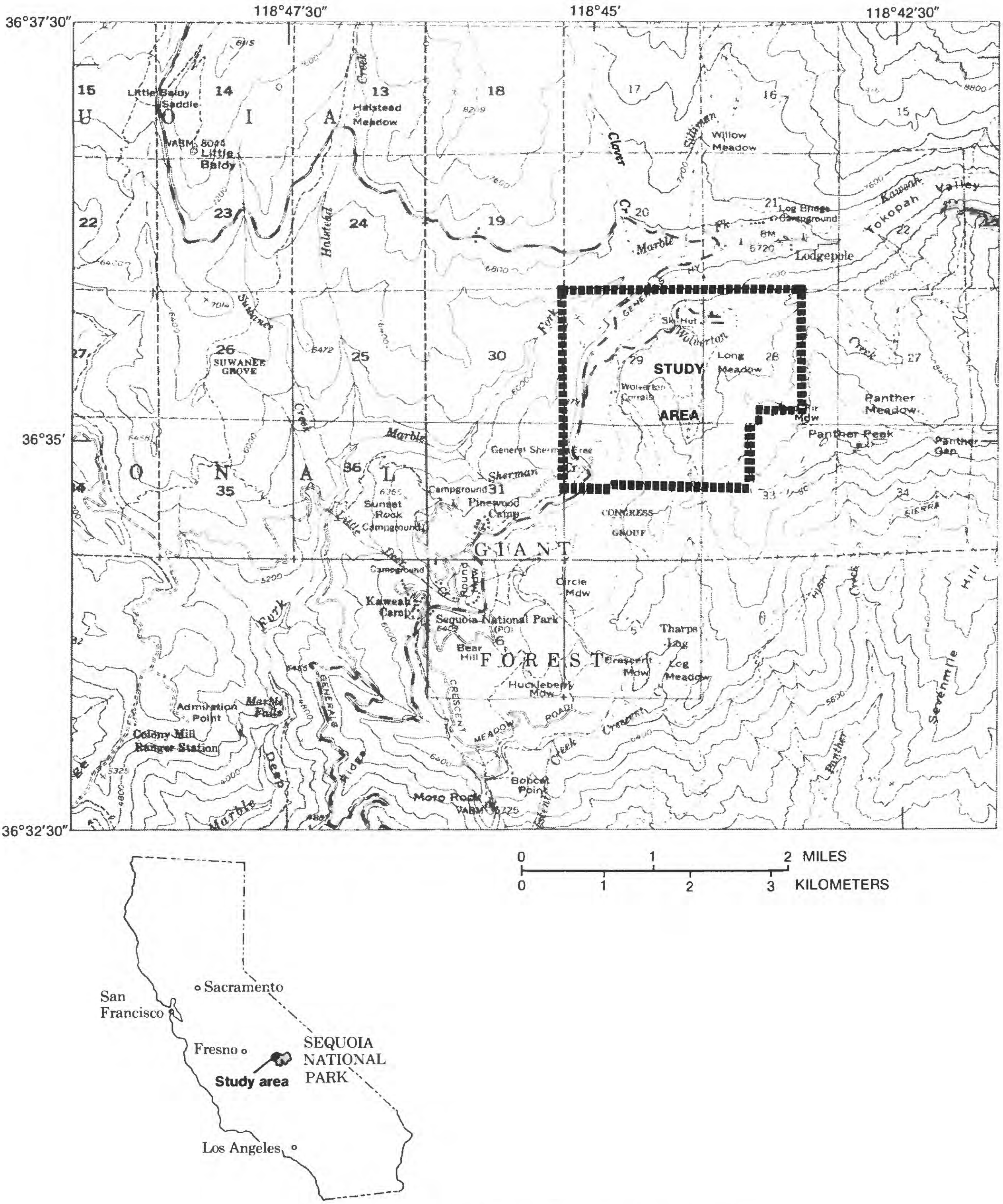

FIGURE 1. -- Location of study area.

In 1967, a well drilled to a depth of 115 feet near this area of maximum thickness had a specific capacity of 2.5 at a pumping rate of 60 gal/min; but in 1968, probably because of poor well construction, the specific capacity at that pumping rate had dropped to 1.2. The quality of water from the well is excellent for domestic use. The log of this well indicates that clay is present at a depth between 6 and 38 feet (M.G. Croft, U.S. Geological Survey, written commun., 1968).

Purpose and Scope

The purpose of this study, done in cooperation with the National Park Service, was to (1) determine if any ground water from the Long Meadow area reaches the General Sherman Tree area, and if so, (2) determine if the quantity of water reaching the General Sherman Tree area would be diminished significantly by pumping ground water from the Long Meadow area, and (3) determine if a ground-water supply of about 72,000 gal/d can be developed from the Long Meadow area. These items first required determining if the glacial materials and granodiorite transmit substantial quantities of water, and then secondly, if the clay described in the previous section is distributed extensively enough to significantly limit recharge from streams.

HYDROLOGIC CHARACTERISTICS OF THE GEOLOGIC UNITS

Granodiorite

Three 4.5-inch-diameter holes (test holes W9-W11) were drilled by air hammer to investigate the hydrologic character of the grandiorite that forms the ridge at the west boundary of the meadow area (pl. 1). The logs of these test holes are included in table 1 at the back of this report.

Test hole W9 was drilled about 200 feet east of the ridge crest. Less than 1 foot of soil covered the granodiorite at this site. In this test hole about five fractures in the first 20 feet were indicated by a sudden dropping of the bit about 2 to 3 inches and by a temporary halt in the operation of the air hammer. No other fractures were detected as the drilling progressed to the total depth of 157 feet. A small seep of water, which occurred at a depth of 39 feet, did not affect the quantity of drilling dust emitted from the test hole. The water level in this test hole was not detected immediately on completion; however, about 3.5 hours later the water level was measured at 106 feet below land surface. After 17.5 hours, on October 14, 1983, the water level had risen to 47.1 feet below land surface. The 51-foot rise, from 157 to 106 feet below land surface in the first 3.5 hours of completion of the test hole--which is most indicative of the actual yield of the hole--indicates that about 0.20 gal/min was entering the test hole during that time. However, this still may not be representative of the continuous yield of the test hole because the water might have come from a local fracture or fractures that would soon drain.

Test hole W10, 200 feet west of test hole W9, was drilled to a depth of 160 feet. Test hole W10 penetrated about 8 feet of overburden and weathered granodiorite and several other zones of weathered granodiorite between depths of 8 and 30 feet. The weathered granodiorite is brown in contrast to the gray unweathered material. No weathered zones or fractures were identified below a depth of 30 feet.

A small quantity of water--barely enough to moisten the dust from drilling--occurred at a depth of about 30 feet in test hole W10. Because of the wet borehole walls and the small quantity of water entering the test hole, a water level was not obtainable immediately after the test hole was completed. However, after a wait of about 15 hours at 8:00 a.m. on October 14, 1983, the water level stood at a depth of 29.5 feet below land surface. The minimum yield of this test hole, assuming that it took 15 hours for the water level to rise to the level of 29.5 feet, would be about 0.12 gal/min. The yield may be somewhat more than this, but probably is less than 0.20 gal/min as in test hole W9.

To test the hydraulic connection between test holes W9 and W10, test hole W10 was filled to the land surface with water, and the water level in test hole W9 was observed. The land-surface altitude at test hole W10 (determined with a hand level) is 13.5 feet higher than at test hole W9, and the water level in test hole W9 is 17.6 feet lower than that in test hole W10. Thus, the head at test hole W10 is 31.1 feet higher than at test hole W9. When test hole W10 was filled with water, the head difference was about 61 feet. The water level in test hole W9 was observed for 1 hour after introducing the water into test hole W10, but no rise was observed; in fact, during the next 4 hours the water level in test hole W9 declined about 1 foot. The cause for the decline is unknown. During the same period, the water level in test hole W10 dropped from land surface to a depth of about 17 feet. After 6 hours, the water level in test hole W10 was still about 10 feet above the original level of 29.5 feet below the land surface.

The results of this test suggest that there is no hydraulic connection between the two test holes, and that individual fractures and weathered zones in the near surface are not extensive. Mapping of joint systems in the granodiorite by Sisson and Moore (1984) corroborated the absence of obvious fracture systems other than those resulting from exfoliation in the ridge. The slow water-level decline in test hole W10, after it was filled with water, also indicates that the granodiorite has a low permeability even with the fractures and weathered zones.

Test hole W11 was drilled at the eastern foot of the ridge (pl. 1) and at the western margin of Long Meadow. This site is about 10 feet east of the granodiorite-alluvium contact. This test hole penetrated about 8 feet of soil, or slope wash, and granodiorite from about 8 feet to the bottom at 20 feet. Water was first detected at a depth of about 8 feet, but upon completion of the test hole at 6:30 p.m. on October 13, 1983, the water level was 6 feet below land surface. At 10:00 a.m. on October 14, 1983, the water level was measured at 5.18 feet below land surface; at 3:00 p.m. the same day, the water level was 5.35 feet below land surface. The change in the water levels from morning to afternoon might reflect differences in evapotranspiration and barometric pressure.

Hand-level measurements indicated that the surface water standing in the meadow (about 100 feet east of test hole W11) was approximately 10 feet lower than the water level in test hole W11. A profile of water levels (fig. 2) in all three of the test holes in the granodiorite indicates that potential ground-water gradient in the granodiorite east of the ridge crest is eastward toward the meadow. This eastward potential gradient, along with the drilling and testing, suggests that the granodiorite is virtually impermeable below the top 40 feet. This low permeability precludes the possibility that a significant quantity of ground water moves westward from Long Meadow through the granodiorite ridge to the General Sherman Tree area. Ground water moves in a direction generally parallel to the streams in the meadow area (G.L. Bertoldi and G.A. Miller, U.S. Geological Survey, written commun., 1969).

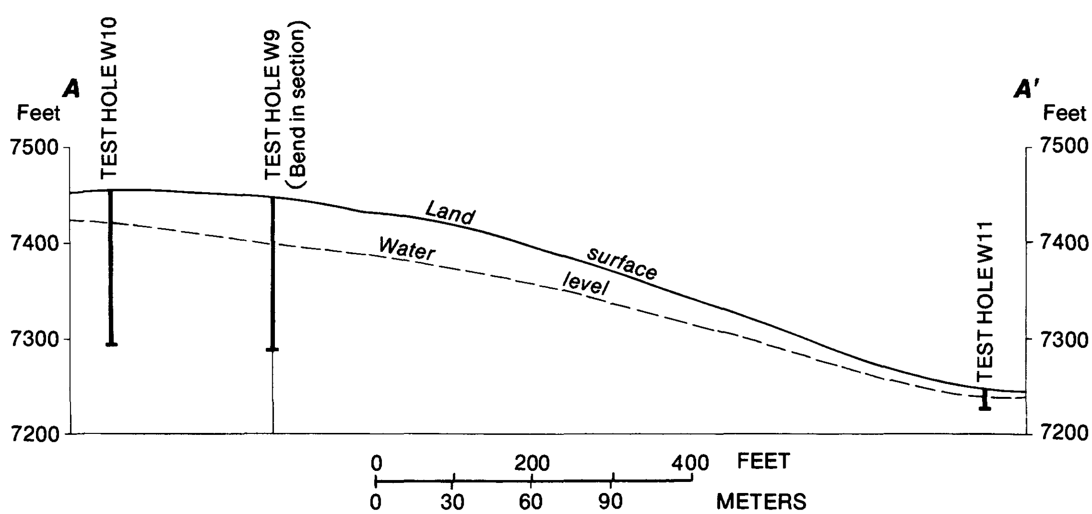

FIGURE 2. -- Water-level profile in granodiorite ridge, October 1983. (See Plate 1 for location; profile diagrammatic between holes W9 and W11.)

Glacial Till

Test hole W12, 6 inches in diameter and 70 feet deep, was drilled in the till along the northern boundary of the meadow area about 100 feet north of the west end of the parking lot (pl. 1). This test hole penetrated loose soil and slope wash from 0 to about 6 feet and till from 6 feet to the total depth of 70 feet. The till is uniformly saturated and consists of a loose, caving mixture of very coarse- to clay-sized particles. The cuttings blown from the hole during drilling closely resembled, and had the consistency of, wet light brown plaster.

An attempt was made to insert 4-inch plastic casing in the test hole to test the yield of the till, but caving prevented getting more than 57 feet of casing in the hole. The bottom 20 feet of the casing was slotted. Virtually no water was obtained during 20 to 30 minutes of attempted air lifting. After this test, the casing was pulled and the test hole filled.

Although the till will not yield enough water to sustain a well, it is saturated. The till probably underlies about half of the alluviated area, and most likely would, over a long period of time, contribute a small quantity of water to the alluvium should the alluvium be pumped by wells. The quantity cannot be estimated with available data.

Distribution of Clay Beds in the Alluvium

In an attempt to determine the areal distribution of clay in the Long Meadow area, test holes 2.75 inches in diameter were augered at eight sites (W1-W8) on the meadow floor during the week of August 22, 1983 (pl. 1). None of these holes penetrated the till beneath the alluvium. The logs of these test holes are in table 1.

Test hole W1, in the northeastern corner of the meadow adjacent to Wolverton Creek, was augered to a depth of 22 feet. The only clays intercepted were in thin beds at a depth of 3 to 5 feet at a level above that of the creek bottom. The rest of the material intercepted was saturated sand and gravel. Granodiorite was intercepted at a depth of 22 feet. Three test holes were attempted at site W2; but, in all attempts, impenetrable boulders (or perhaps the granodiorite bedrock) were struck at a depth of 5 to 6 feet. Test hole W3, 50 feet deep, had no identifiable clay; below the soil zone (0 to 6 feet) the materials penetrated were sand and gravel. Clayey material interbedded with sandy silt was encountered in test hole W4 at a depth of 30 to 35 feet. Three test holes were attempted at test-hole site W5; but, as with test-hole site W2, in all the attempts, boulders at a depth of about 6 feet made augering impossible. Two test holes were drilled at test-hole site W6. The first test hole bottomed at a boulder layer at a depth of 8 feet. The second test hole at site W6 hit a layer of small cobbles at a depth of 8 to 11 feet, silty sand from 11 to 33 feet, a somewhat sticky clay layer from 33 to 35 feet, and sandy silt from 35 feet to the bottom of the hole at 40 feet. Test hole W7 intercepted sticky clay beds at a depth of 19 to 21 feet and at 27 to 37 feet. Boulders were hit at depths of 8 to 9 feet on two attempts at test-hole site W8. At this point, the auger broke down and no further drilling was attempted.

The test-hole data indicate that the clayey beds under the valley floor are lenticular and are distributed irregularly both horizontally and vertically. These erratically distributed clay beds may somewhat limit the percolation of water from the streams, but will not prevent it. Some of the clayey beds are fairly continuous as evidenced by the water that was seeping out of the top of two existing cased wells at a point about 2 feet above the land surface in July 1983; this may indicate a degree of confinement. On August 25, 1983, the water level in one of these wells was slightly below land surface but still about 2 feet above the water surface in nearby Wolverton Creek.

STREAM-AQUIFER RELATIONS

Discharge measurements were taken September 28, 1983, at four locations along a 3,000-foot reach of Wolverton Creek (table 2 and pl. 1). No significant tributaries enter Wolverton Creek along this reach. The discharge measurements indicate that along this reach the creek was receiving about 0.40 ft^3/s (about 260,000 gal/d or about 180 gal/min) from the ground-water system; however, assuming a random distribution value of error at 5 percent, the total range of measurement error is from 0.28 to 0.56 ft^3/s or about 180,000 to 360,000 gal/d. This gain in streamflow represents ground-water outflow after evapotranspiration demands were met in the dry season of the year. This ground-water outflow may be high because precipitation in the preceding winter was well above normal; the outflow in a normal year would be less, but probably still more than the needed 50 gal/min (about 72,000 gal/d).

Ground-water outflow into the creek demonstrates that the creek and the ground-water system are directly connected and that long-term pumping from the ground-water system probably would reduce the flow in Wolverton Creek. If head conditions were reversed by ground-water withdrawal, the creek would act as a source of recharge to the ground-water system. Kenneth Bachmeyer (U.S. National Park Service, oral commun., 1984) of the Sequoia National Park, states that even during the severe drought of 1976-77, Wolverton Creek continued to flow. It seems reasonable to assume that at least one-fourth of the quantity of the 1983 dry-season discharge, or about 50 gal/min, would be available for recharge in most years.

Because the clay beds in the alluvium are discontinuous, a potential exists for contaminated water to get into the alluvial aquifer. Thus, if any ground water is pumped from the Long Meadow area it would be prudent to monitor the ground-water quality at sites downgradient from the comfort station. Suggested sites for monitoring wells are shown on plate 1. In addition, the observation well drilled in 1967 (pl. 1) should be sampled annually. The monitoring wells could be installed with an auger and cased with perforated plastic tubing. The wells should be about 50 feet deep and the annular space should be sealed in the upper 10 feet.

USE OF STABLE ISOTOPES TO DETERMINE SOURCES OF WATER IN THE STUDY AREA

The stable isotope technique was used to determine if the water in the General Sherman Tree area has its source in the ground water of the Long Meadow area. According to Muir and Coplen (1981):

> "The stable isotope technique involves measurement of the isotopic species oxygen-16 ($H_2{}^{16}O$), oxygen-18 ($H_2{}^{18}O$), and deuterium ($HD^{16}O$) in a water sample. The hydrogen isotopic ratio, D/H, is determined from $HD^{16}O$ and $H_2{}^{16}O$, and the oxygen isotopic ratio, $^{18}O/^{16}O$, is determined from $H_2{}^{18}O$ and $H_2{}^{16}O$. Variability in $^{18}O/^{16}O$ of natural waters is only a few parts per hundred, so it is convenient to determine the difference between $^{18}O/^{16}O$ abundance of a sample and that of a standard, in parts per thousand (o/oo), defined as delta ^{18}O ($\delta^{18}O$). Thus:

$$\delta^{18}O(\text{in o/oo}) = \left[\frac{(^{18}O/^{16}O)\text{ Sample}}{(^{18}O/^{16}O)\text{ Standard}} - 1\right] 1000$$

The standard used for this water-resources study is SMOW (Standard Mean Ocean Water) as defined in Craig (1961). A sample that is +10 o/oo is said to contain 10 parts per thousand or 1 percent more ^{18}O than does SMOW. In a like manner we define delta D (δD):

$$\delta D(\text{in o/oo}) = \left[\frac{\text{D/H Sample}}{\text{D/H SMOW}} - 1\right] 1000$$

The importance of the stable isotope technique in water-resources investigations is that, in general, δD and $\delta^{18}O$ are different for waters of different origin. The ratios D/H and $^{18}O/^{16}O$ of precipitation are chiefly a function of the place of precipitation. Precipitation in inland areas and higher latitudes is more depleted in ^{18}O and D than precipitation near the coast and in more temperate areas."

The plot of values of δD and $\delta^{18}O$ (fig. 3) reflects the differences in water from the General Sherman Tree and Long Meadow areas. The greatest difference is between the values for ground water in Long Meadow and the water from the General Sherman Tree area, which suggests that little, if any, of the ground water from the Long Meadow area moves to the General Sherman Tree area.

POTENTIAL FOR DEVELOPING A GROUND-WATER SUPPLY

G.L. Bertoldi and G.A. Miller (U.S. Geological Survey, written commun., 1969) computed a storage capacity in the aquifer of 450 acre-ft, which they considered to be all the saturated material in the meadow overlying the granodiorite. This included both alluvium and till, and assumed a specific yield of 15 percent.

Test drilling during this study indicated that the specific yield of the till is most likely considerably less than 15 percent. The specific yield of till from crystalline-rock terraines in New England, based on pumping tests, revealed a range from 3.9 to 31 percent (Allen Randall, U.S. Geological Survey, oral commun., 1984). However, the New England tills tested contained materials as large as pebbles and small cobbles; the till drilled in the Long Meadow area had hardly any material larger than granule size. Furthermore, the till in the Long Meadow area yielded virtually no water to the test well. This suggests that the specific yield of the till in the Wolverton area is considerably less than the lowest figure given for the coarser material in New England tills.

Wahrhaftig (1984) in his study of the Wolverton area excluded the till and the clay units in the alluvium in computing a storage capacity. The remaining more permeable alluvial material used in his estimates is mostly fine- to coarse-grained sand having a specific yield estimated at 15 percent.

Recent detailed geologic mapping (Sisson and Moore, 1984) and the test drilling done for this study indicate that the alluvium is less extensive in the Long Meadow area than was formerly assumed. The total saturated volume of both the till and the alluvium, as computed by Wahrhaftig (1984), is about 2,300 acre-ft. The test drilling suggests that about half of this is till or clay, and, in the short term (1 or 2 years), would yield little water. About 1,200 acre-ft of material remains for a specific yield of about 15 percent and a storage capacity of about 170 acre-ft.

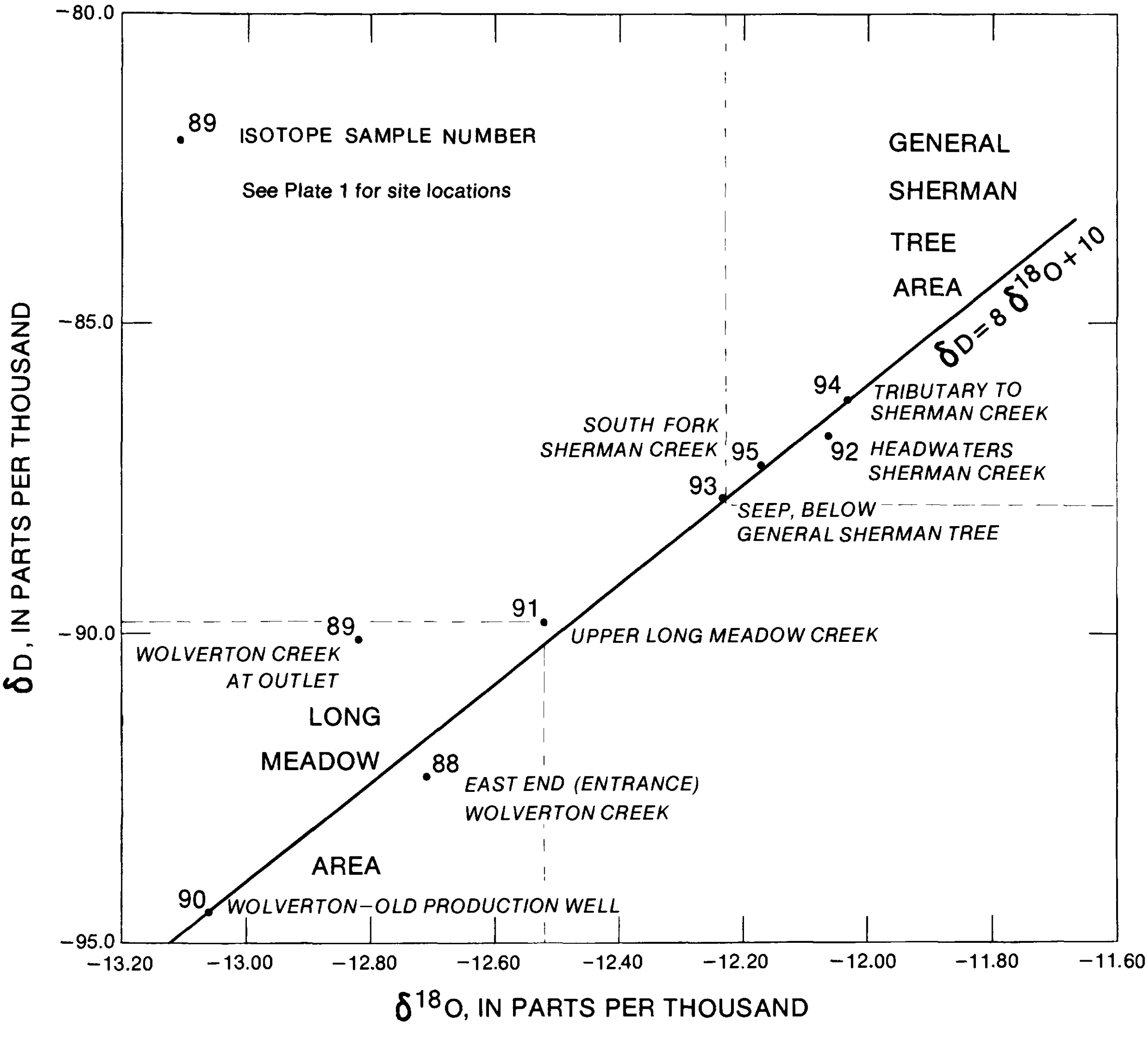

FIGURE 3. -- Plot of δD versus δ^{18}O in Long Meadow and General Sherman Tree areas.

Over a long period of time, the till and the clayey units would yield a substantial quantity of water to pumped wells. Also, as ground-water levels were lowered by pumping, some water would be induced to move from the streams into the ground-water system. The expected maximum demand of 81 acre-ft/yr (about 50 gal/min), is about one-half of the estimated storage capacity of 170 acre-ft. A 2-year drought, such as occurred in 1976-77, could significantly deplete the ground-water system and result in lowered ground-water levels and a temporary water shortage. However, in most years a withdrawal of no more than 81 acre-ft could be extracted without undue effect.

SUMMARY AND CONCLUSIONS

The granodiorite in the ridge west of Long Meadow, as determined by two deep test holes, W9 and W10, is fractured by exfoliation, or "unloading," to a depth of 30 to 40 feet. It apparently is virtually unfractured in these holes below a depth of 40 feet. The test holes, about 160 feet deep, would most likely continuously yield less than 0.20 gal/min each. The ground-water gradient in the eastern flank of the ridge west of Long Meadow is toward the east. This eastward gradient and the lack of fractures in the granodiorite below a depth of 40 feet suggest that ground water does not move from the Long Meadow area into the General Sherman Tree area. Also, stable isotope studies suggest that the Long Meadow area is not the source of water in the General Sherman Tree area.

The glacial till will not yield enough water to sustain even a small well. However, over the area that the till abuts and underlies the meadow, it is saturated and may, over the long term, furnish a small but useful quantity of water to the ground-water system.

Eight shallow test holes, W1-W8, indicate that clayey layers in the alluvium are fairly extensive but not continuous above a depth of 40 feet. These clayey layers over the short term would yield little water and would hinder but not preclude recharge from the streams to the ground-water system. The ground-water system in September 1983 contributed about 260,000 gal/d (about 180 gal/min) to a 3,000-foot reach of Wolverton Creek, indicating a hydraulic connection between the creek and the ground-water system.

The estimated storage capacity of the aquifer in the Long Meadow area is only about 170 acre-ft. A 2-year drought, coupled with an extraction of 81 acre-ft of water per year for 2 years, could temporarily, but significantly, lower ground-water levels. However, two successive dry years are not very likely; recharge from precipitation, recharge from streams, and slow drainage from the till should contribute an average of at least 50 gal/min to the ground-water system in normal years.

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TABLE 1.--Logs of test holes drilled in the Long Meadow area in 1983

[Holes W1-W8 augered, 2.75-inch diameter. See plate 1 for locations]

Depth (feet) From	To	Description
TEST HOLE W1: Augered 8-24-83, south parking lot about 350 feet east of buildings.		
0	2	Soil, dark brown.
2	3	Sand and gravel (rounded).
3	5	Clay, water.
5	8	Sand and gravel.
8	11	Gravel and small cobbles.
11	22	Clayey sand.
TEST HOLE W2: Augered 8-24-83, south of parking lot about 200 feet east of building; attempted three holes.		
0	5	Soil.
5	6	Granodiorite boulders.
TEST HOLE W3: Augered 8-24-83, south of parking lot about 150 feet east of buildings.		
0	6	Soil.
6	8	Gravel.
8	36	Fine to coarse sand.
36	38	Gravel (clayey?).
38	50	Fine to coarse sand.
TEST HOLE W4: Augered 8-24-83, in meadow about 100 feet west of ski lodge, 100 feet north-northeast of old production well.		
0	5	Soil.
5	7	Unable to determine.
7	30	Sand, fine gravel, water at 7 feet.
30	35	Sandy silt, clay.
35	40	Sand, no detectable clay.
TEST HOLE W5: Augered 8-24-83, about 15 feet north of old production well; attempted three holes.		
0	6	Soil.
6		Heavy boulders, could not auger further.
TEST HOLE W6: Augered 8-25-83, 100 feet south of garage, 20 feet north of Wolverton Creek.		
0	8	Soil.
8	11	Small cobbles and sand.
11	33	Fine to coarse sand.
33	35	Sandy clay, sticky.
35	40	Sandy silt, easy drilling.

TABLE 1.--Logs of test holes drilled in Long Meadow area in 1983--Continued

Depth (feet) From	To	Description
TEST HOLE W7: Augered 8-26-83, about 300 feet southeast of dam, 20 feet east of Culvert on tributary to Wolverton Creek.		
0	7	Soil.
7	11	Gravel and clay lenses.
11	19	Sand, medium to coarse.
19	21	Clay, sticky.
21	22	Sand, loose, running.
22	27	Sand and clay lenses.
27	37	Clay, sticky (clay sticks to auger flight).
TEST HOLE W8: Augered 8-26-83, about 1,100 feet south-southeast of dam at edge of meadow.		
0	8	Soil, water at about 5 feet.
8	9	Gravel cobbles (auger ceased to function).
TEST HOLE W9: Drilled 10-13-83, on ridge about 1,200 feet south of dam. Drilled by air hammer, 4.5-inch diameter.		
0	20	Granodiorite fractured, bit drops 2-3 inches on occasion through fractured and weathered zones.
20	40	Granodiorite, no detectable fractures, small seep of water at 39 feet.
40	157	Granodiorite, no detectable fractures; drilling is very dusty, not enough water entering hole to allay dust. Water level not detectable immediately after completion; water level at 106 feet 3.5 hours after completion, and 47.1 feet 17.5 hours after completion.
TEST HOLE W10: Drilled 10-13-83 on ridge about 1,200 feet south-southeast of dam, about 200 feet west of test hole W9. Drilled by air hammer, 4.5-inch diameter.		
0	8	Overburden and weathered, brown granodiorite.
8	10	Granodiorite, weathered, brown.
10	20	Alternating layers of gray firm granodiorite and brown weathered granodiorite.
20	30	Granodiorite, few weathered zones; moisture at 30 feet.
30	160	Granodiorite, gray, firm; no detectable fractures or weathered zones. Water level not detectable immediately after completion of hole; water level 29.5 feet 15 hours after completion.

TABLE 1.--Logs of test holes drilled in Long Meadow area in 1983--Continued

Depth (feet) From	To	Description
TEST HOLE W11: Drilled 10-13-83, foot of ridge and west edge of meadow, about 350 feet south-southeast of dam. Drilled by air hammer, 4.5-inch diameter.		
0	8	Soil and slope wash.
8	20	Granodiorite, firm; water level 5.18 feet (10-14-83).
TEST HOLE W12: Drilled 10-14-83, about 100 feet north of west end of parking lot. Drilled by air hammer, 6-inch diameter.		
0	6	Soil and slope wash.
6	70	Till, cream color, caving, saturated; has appearance and consistency of wet plaster. Installed 57 feet plastic casing (bottom 20 feet slotted) and attempted air lift. Hole yielded virtually no water.

TABLE 2.--Instantaneous discharge of streams at selected stream-measuring sites in the Long Meadow area

[See plate 1 for locations]

Stream-discharge measurement site	Date	Discharge, in cubic feet per second	Value of error at 5 percent	Range of measurement, in cubic feet per second
1--------	9-28-83	1.17	±0.06	1.11 -1.23
	11-9-83	.48	±.02	.46 - .50
2--------	9-28-83	1.39	±.07	1.32 -1.46
3--------	9-28-83	1.50	±.08	1.42 -1.58
4--------	9-28-83	1.59	±.08	1.51 -1.67
5--------	11-9-83	.104	±.005	.009- .109
6--------	11-9-83	.98	±.05	.93 -1.03