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Surface-Water/Ground-Water Relations in the Lemhi River Basin, East-Central Idaho

Water-Resources Investigations Report 98–4185

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By Mary M. Donato

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In cooperation with the
Bureau of Reclamation

Boise, Idaho
1998

U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

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CONVERSION FACTORS

Multiply	By	To obtain
acre	4,047	square meter
acre-foot (acre-ft)	1,233	cubic meter
cubic foot per day (ft^3/d)	0.02832	cubic meter per day
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
cubic foot per second per square mile [$(ft^3/s)/mi^2$]	0.01093	cubic meter per second per square kilometer
foot (ft)	0.3048	meter
foot per day (ft/d)	0.3048	meter per day
foot per mile (ft/mi)	0.1894	meter per kilometer
inch (in.)	2.54	centimeter
inch per year (in/yr)	25.4	millimeter per year
mile (mi)	1.609	kilometer
square foot (ft^2)	0.09290	square meter
square mile (mi^2)	2.590	square kilometer

Sea level: In this report, “sea level” refers to the National Geodetic Vertical Datum of 1929—a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

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By Mary M. Donato

Abstract

This report summarizes work carried out in cooperation with the Bureau of Reclamation to provide hydrologic information to help Federal, State, and local agencies meet the goals of the Lemhi River Model Watershed Project. The primary goal of the project is to maintain, enhance, and restore anadromous and resident fish habitat in the Lemhi River, while maintaining a balance between resource protection and established water uses. The main objectives of the study were to carry out seepage measurements to determine seasonal distributed gains and losses in the Lemhi River and to estimate annual ground-water underflow from the basin to the Salmon River.

In 1997, seepage measurements were made during and after the irrigation season along a 60-mile reach of the Lemhi River between Leadore and Salmon. Except for one 4-mile reach that lost 1.3 cubic feet per second per mile, the river gained from ground water in early August when ground-water levels were high. Highest flows in the Lemhi River in early August were about 400 cubic feet per second. In October, when ground-water levels were low, river losses to ground water were about 1 to 16 cubic feet per second per mile. In October, highest flows in the Lemhi River were about 500 cubic feet per second, near the river's mouth.

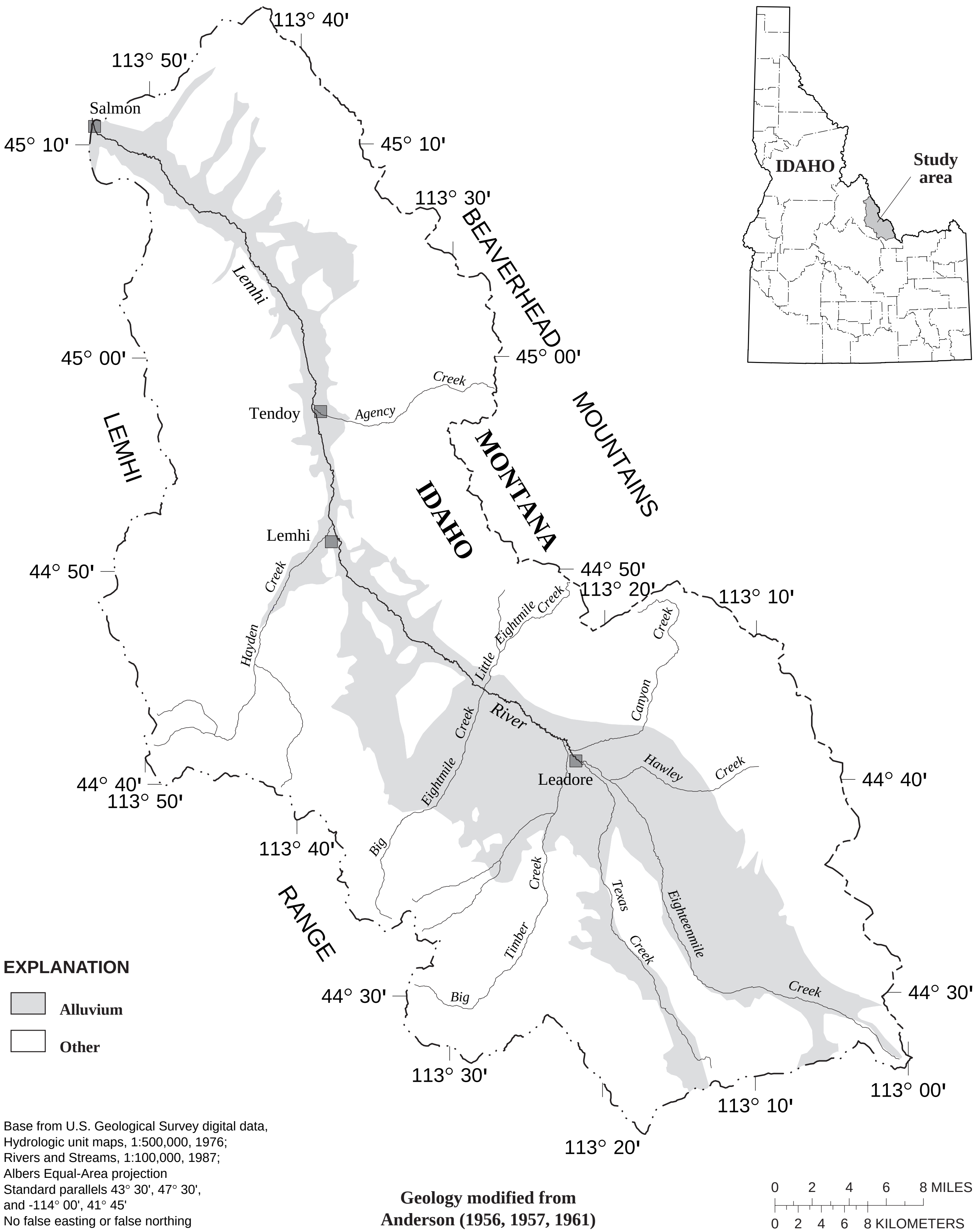
Annual ground-water underflow from the Lemhi River Basin to the Salmon River was estimated by using a simplified water budget and by using Darcy's equation. The water-budget method contained large uncertainties associated with estimating precipitation and evapotranspiration. Results of both methods indicate that the quantity of ground water leaving the basin as underflow is small, probably less than 2 percent of the basin's total annual water yield.

INTRODUCTION

The Lemhi River Basin, which encompasses about 1,270 mi^2 in east-central Idaho (fig. 1), is part of Idaho's Model Watershed Project. Established in 1992 and coordinated by several Federal, State, and local organizations, the goal of the Lemhi River Model Watershed Project is to maintain, enhance, and restore habitat for anadromous and resident fish in the Lemhi, Pahsimeroi, and East Fork Salmon Rivers while maintaining a balance between resource protection and established water uses (Idaho Soil Conservation Commission, 1995).

This report summarizes work undertaken in cooperation with the Bureau of Reclamation (BOR) to provide hydrologic information to help participating entities, including local water users, the Lemhi Irrigation District, and the Natural Resources Conservation Service (NRCS), manage water resources in the basin and to meet the goals of the Lemhi River Model Watershed Project. The report incorporates new hydrologic data collected by the U.S. Geological Survey (USGS) in 1997, well and streamflow data collected by the BOR during 1993–97, existing well and streamflow data in the USGS data bases, and information from previous reports. New data presented here include distributed gains and losses measured in the Lemhi River between Leadore and Salmon in August and October 1997 and estimates of annual ground-water underflow from the lower Lemhi River Basin to the Salmon River, into which the Lemhi River flows at Salmon.

Previous studies on the hydrology of the basin include a reconnaissance study of water resources in the upper part of the basin by Crosthwaite and George (1965). Haws and others (1977) addressed problems related to water-rights adjudication, and Ott Water Engineers (1986) studied the basin's hydrology with regard to fishery needs. A recently completed report by the BOR (Spinazola, 1998) presents a spreadsheet-based model that allows the effect of pumping wells on



Base from U.S. Geological Survey digital data,
Hydrologic unit maps, 1:500,000, 1976;
Rivers and Streams, 1:100,000, 1987;
Albers Equal-Area projection
Standard parallels 43° 30', 47° 30',
and -114° 00', 41° 45'
No false easting or false northing

Geology modified from Anderson (1956, 1957, 1961)

Figure 1. Lemhi River Basin study area, east-central Idaho.

Lemhi River flows in the upper part of the basin to be evaluated.

The Lemhi Irrigation District, in cooperation with the BOR and the NRCS, collected water-level data from nearly 80 wells in the Lemhi River Basin from December 1995 to March 1998. A compilation of these data was made available for use during this study.

GEOHYDROLOGY OF THE LEMHI RIVER BASIN

The Lemhi River, a tributary of the Salmon River, occupies an elongate north-northwest-trending valley in east-central Idaho near the Montana border, between the Lemhi Range and the Beaverhead Mountains (fig. 1). The Lemhi River Basin ranges in elevation from about 7,000 ft to about 4,000 ft above sea level at the mouth of the Lemhi River at Salmon, Idaho. This study addresses mainly the part of the basin downstream from Leadore (elevation 5,964 ft).

The bedrock geology of the basin is dominated by metamorphic, volcanic, intrusive, and sedimentary rocks that range in age from Middle Proterozoic to Tertiary (Anderson, 1956, 1957, 1961). Unconsolidated sediments in the basin consist of Holocene alluvial deposits associated with the Lemhi River and its tributaries, as well as older Quaternary alluvial terrace, alluvial fan, and glacial deposits. These sediments compose the principal water-bearing units in the basin.

Alluvial deposits consist primarily of gravel with intercalated sand and silt. The gravel is generally well sorted and is derived mainly from resistant quartzite, dolomite, and volcanic rocks exposed in the vicinity. Finer grained sand, silt, and clay are derived mainly from poorly consolidated Tertiary lakebed deposits and other units exposed along the flanks of the basin.

Terrace gravels of three different ages and at different elevations above the valley floor were mapped by Anderson (1956, 1957, 1961). They generally are composed of coarse, bouldery gravels derived from rocks that constitute the Lemhi Range and Beaverhead Mountains. Some might be Wisconsin-age glacial outwash.

Alluvial fans are present on the margins of the valley at the mouths of gulches and streams. Glacial moraine and outwash deposits consist of heterogeneous mixtures of igneous and sedimentary rock fragments derived from the surrounding mountains and are widespread throughout the area.

The thickness and three-dimensional shape of the alluvial deposits on the basin floor are not well defined; estimated thickness at locations where data were available is shown in figure 2. Drillers' lithologic logs indicate the depth to bedrock in 20 wells. Another 33 wells bottom in alluvium and, therefore, the logs indicate a minimum thickness of the alluvium at those locations. Alluvium downstream from approximately the USGS streamflow gaging station near Lemhi is generally less than 60 ft thick, whereas in several places in the upper part of the basin, the alluvium is at least 200 ft thick. In a zone immediately downstream from Lemhi, the alluvium appears to be less than 20 ft thick and about 3,300 ft wide. This constriction of the aquifer between Lemhi and Tendoy, where bedrock rises to shallow depths and the alluvium is thin, forms a natural (but not necessarily complete) hydrologic barrier to ground-water flow. In this report, the term “upper basin” refers to that part of the Lemhi River Basin upstream from this constriction, and “lower basin” refers to that part of the basin downstream from the constriction. The somewhat arbitrary position of this boundary is shown in figure 2.

More than 800,000 acre-ft of precipitation falls on the Lemhi River Basin annually. Precipitation correlates positively with elevation; about 7 in/yr falls on the valley floor, more than 42 in/yr on parts of Lemhi Range and Beaverhead Mountains (fig. 3). The nearest National Weather Service precipitation gage with a long-term record (1917 to present) is in Salmon, where average annual precipitation is 9.3 in.; about 30 percent of the total falls in May and June.

Residents of the Lemhi River Basin use water primarily for agricultural and domestic purposes. Seventy-two diversions direct water from the Lemhi River and its tributaries into an extensive system of canals for irrigating crops (primarily alfalfa) and watering stock. Nearly 90,000 acres of cropland are irrigated in the basin. A large part of the water diverted for irrigation returns to the river by way of surface- and ground-water flow. Consequently, much of the water in the Lemhi River and its tributaries is diverted and applied more than once as it flows downstream. Water is diverted for irrigation mainly in early May through late September.

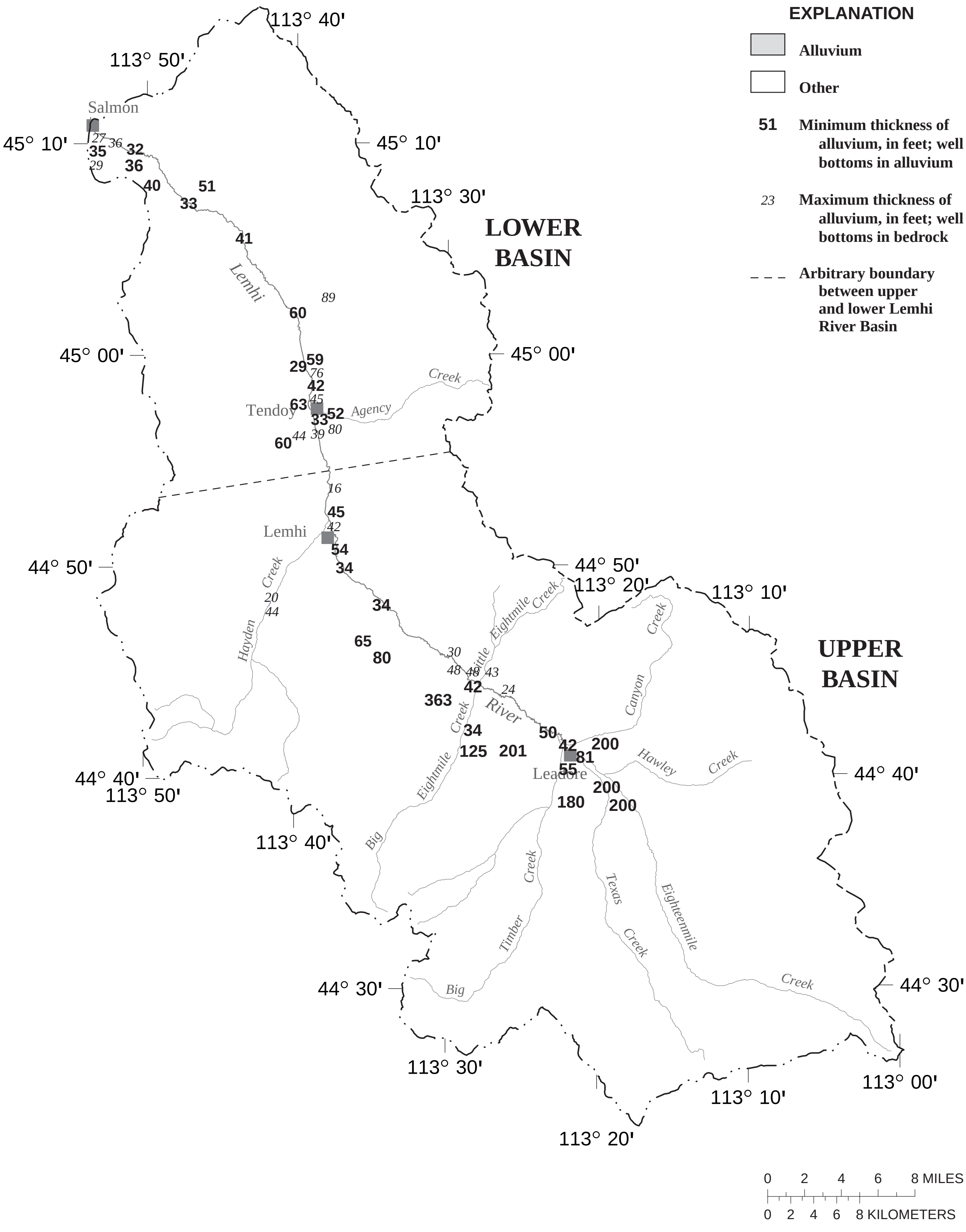


Figure 2. Estimated thickness of alluvium in the Lemhi River Basin, east-central Idaho.

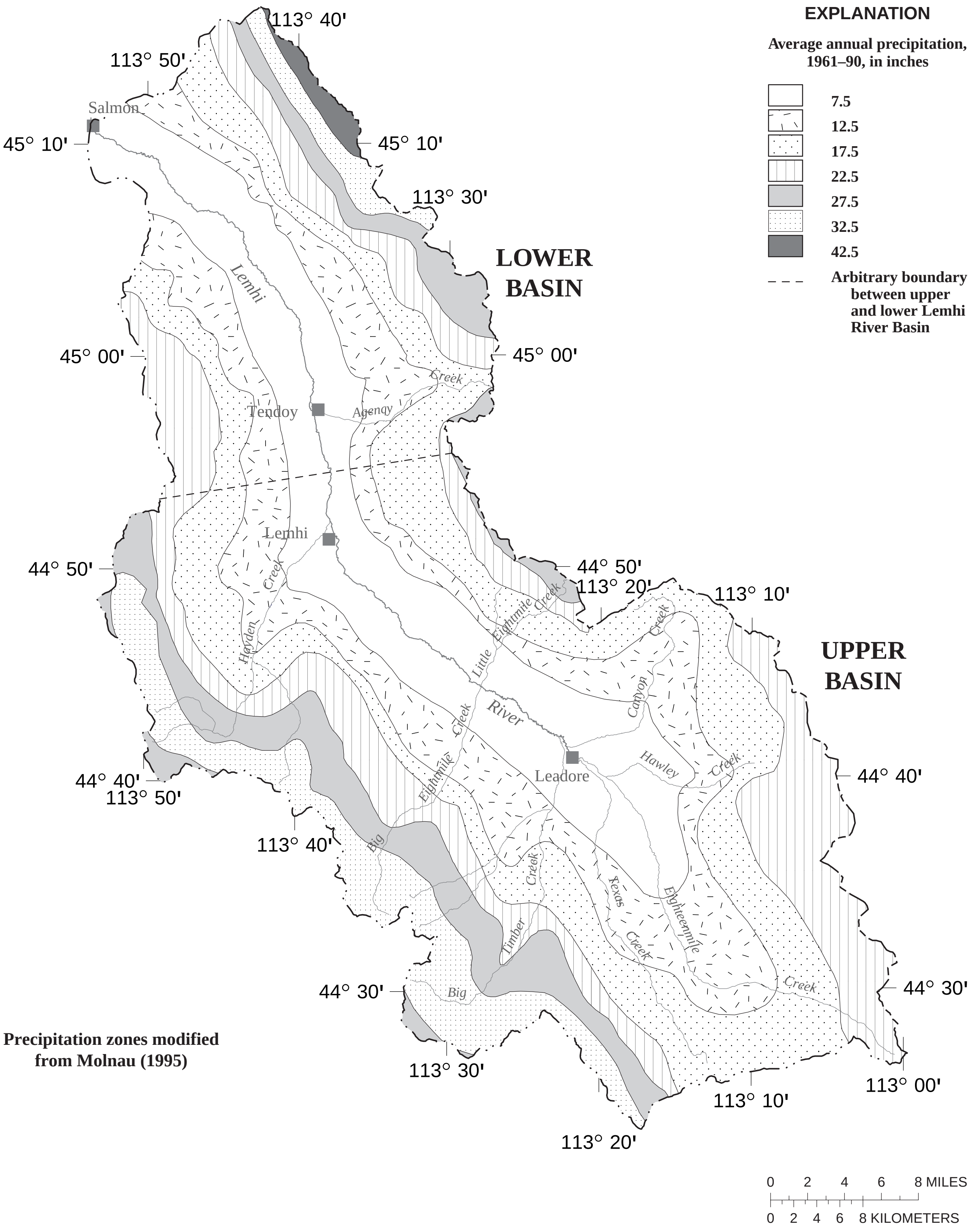


Figure 3. Average annual precipitation in the Lemhi River Basin, east-central Idaho, 1961–90.

SURFACE WATER

The headwaters of the Lemhi River are near Leadore, where Canyon, Hawley, Eighteenmile, Texas, and Big Timber Creeks flow together (fig. 1). Downstream from the headwaters, flow in the Lemhi River is augmented by the tributaries of Big and Little Eightmile Creeks, Hayden Creek, and Agency Creek. Presently (1998), seven gaging stations are operated on the Lemhi River (table 1; fig. 4). The USGS maintains gaging stations 13305000, Lemhi River near Lemhi, and 13305310, Lemhi River below L–5 diversion near Salmon. A third USGS gaging station (not shown in fig. 4), Lemhi River at Salmon (13305500), was discontinued in 1943. The BOR installed two gaging stations in 1993 and an additional three in 1996; these gaging stations are not operated during the winter. The BOR also has monitored flow at the mouth of Hayden Creek, a major tributary of the Lemhi River, since 1996. In addition to discharge, water temperature is recorded at the USGS gaging station near Lemhi and at two of the BOR gaging stations (table 1).

Streamflow in the Lemhi River is highest during May through July and usually peaks in early June. Hydrographs of average daily discharge at the USGS gaging station at Lemhi River near Lemhi for 1968–97 and for 1993–97 are shown in figure 5. A hydrograph of daily discharge at the USGS gaging station below L–5 diversion near Salmon is also shown. Average daily discharge in 1993–97 at the Lemhi gaging station was higher than the long-term average during the summer, an important factor in the calculation of the ground-water underflow.

Methods for Determining Distributed Gains and Losses in the Lemhi River

The USGS conducted two seepage runs in the Lemhi River Basin in 1997, one during and one after the irrigation season. The purpose of the seepage runs was to determine seasonal gains and losses in the river along the 60-mi reach from Leadore to Salmon. Seepage runs identify shorter reaches of the river that gain from or lose to ground water at a given time and that can be particularly sensitive to depletion when little water is available.

During a seepage run, flow in the river, all diversions, and all returns are measured to estimate distributed river gains from and losses to ground water. A snapshot of the hydrologic condition of the river is obtained as the measurements are made within a short time period to minimize errors that result from changes in flow over time. Gaining or losing reaches are identified by comparing flow at upstream and downstream ends of a reach after adjusting for inflows (tributaries and irrigation returns) and outflows (diversions) within the reach. Water not accounted for at the downstream end of the reach is assumed to be ground-water discharge to the reach; a deficit indicates that the river is losing to ground water.

Measurements of distributed gains and losses in the Lemhi River were made twice: during August 4–8, 1997, and again during October 27–31, 1997. These dates were chosen to allow comparison between flows during times when diversions for agricultural irrigation were active and when they were inactive.

Table 1. Streamflow gaging stations on the Lemhi River, east-central Idaho

[D, discharge; T, temperature; $^{+}$, 1997 data were not available at the time of this report; $^{\#}$, summertime discharge only; *, includes estimated wintertime discharge. Complete data available from the Bureau of Reclamation. Gaging station locations shown in figure 4]

Agency	Name	Period of record	Parameters recorded	Mean annual discharge (acre-feet)
USGS	13305000–Lemhi River near Lemhi	1967–present	D,T	191,586
USGS	13305310–Lemhi River below L–5 diversion near Salmon	1993–present	D	203,339
BOR	Lemhi River at Steel Bridge near L–3A diversion	1993–present	D,T	157,108^{*+}
BOR	Lemhi River near L–1 diversion	1996–present	D	293,164*
BOR	Lemhi River at Barracks Lane	1993–present	D,T	25,538$^{\#+}$
BOR	Lemhi River at McFarland Campground	1996–present	D	47,020$^{\#+}$
BOR	Lemhi River in City of Leadore on Highway 29	1996–present	D	10,600$^{\#+}$

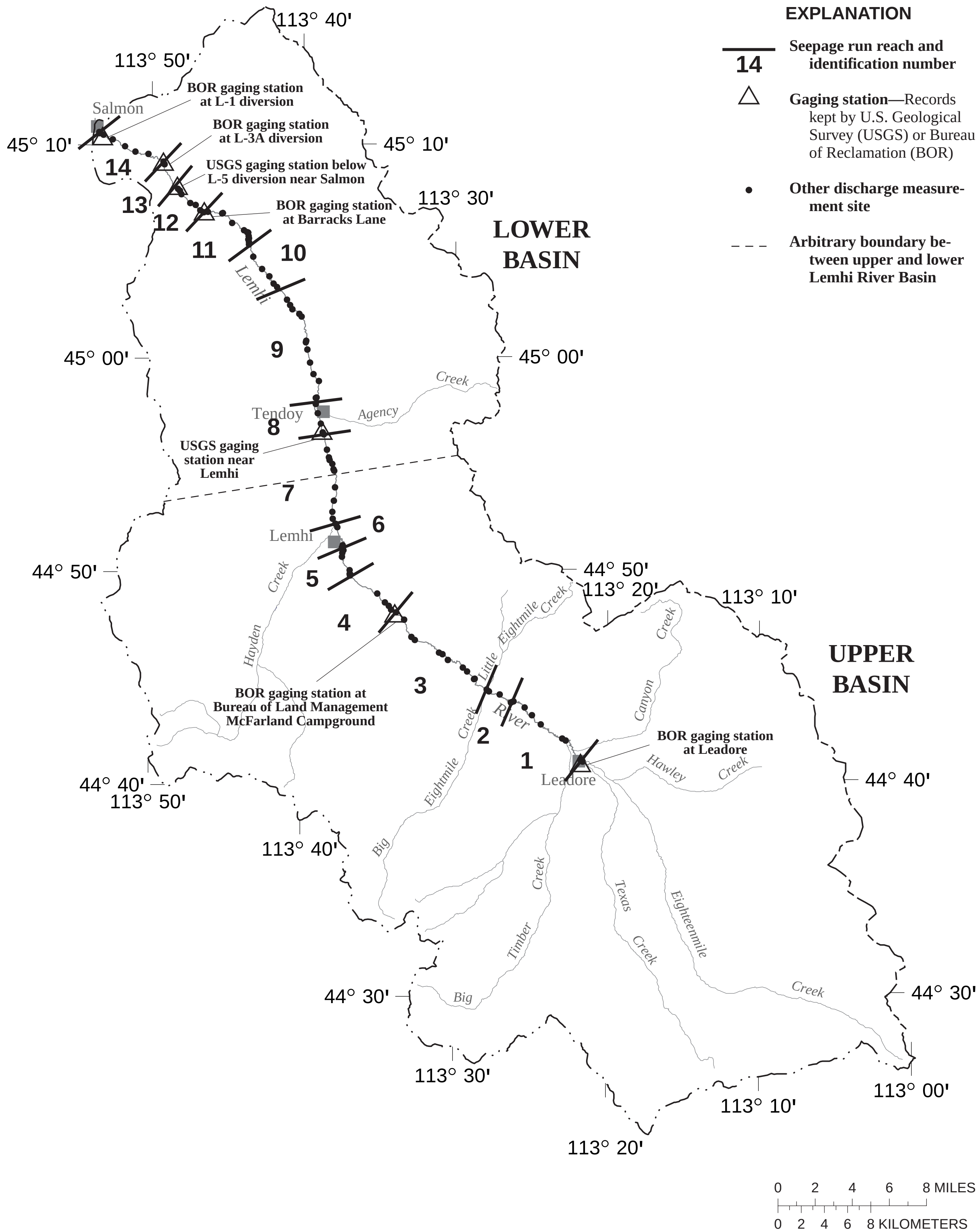


Figure 4. Seepage run reaches, gaging stations, and discharge measurement sites in the Lemhi River Basin, east-central Idaho, August and October 1997. (Data listed in appendices 1 and 2)

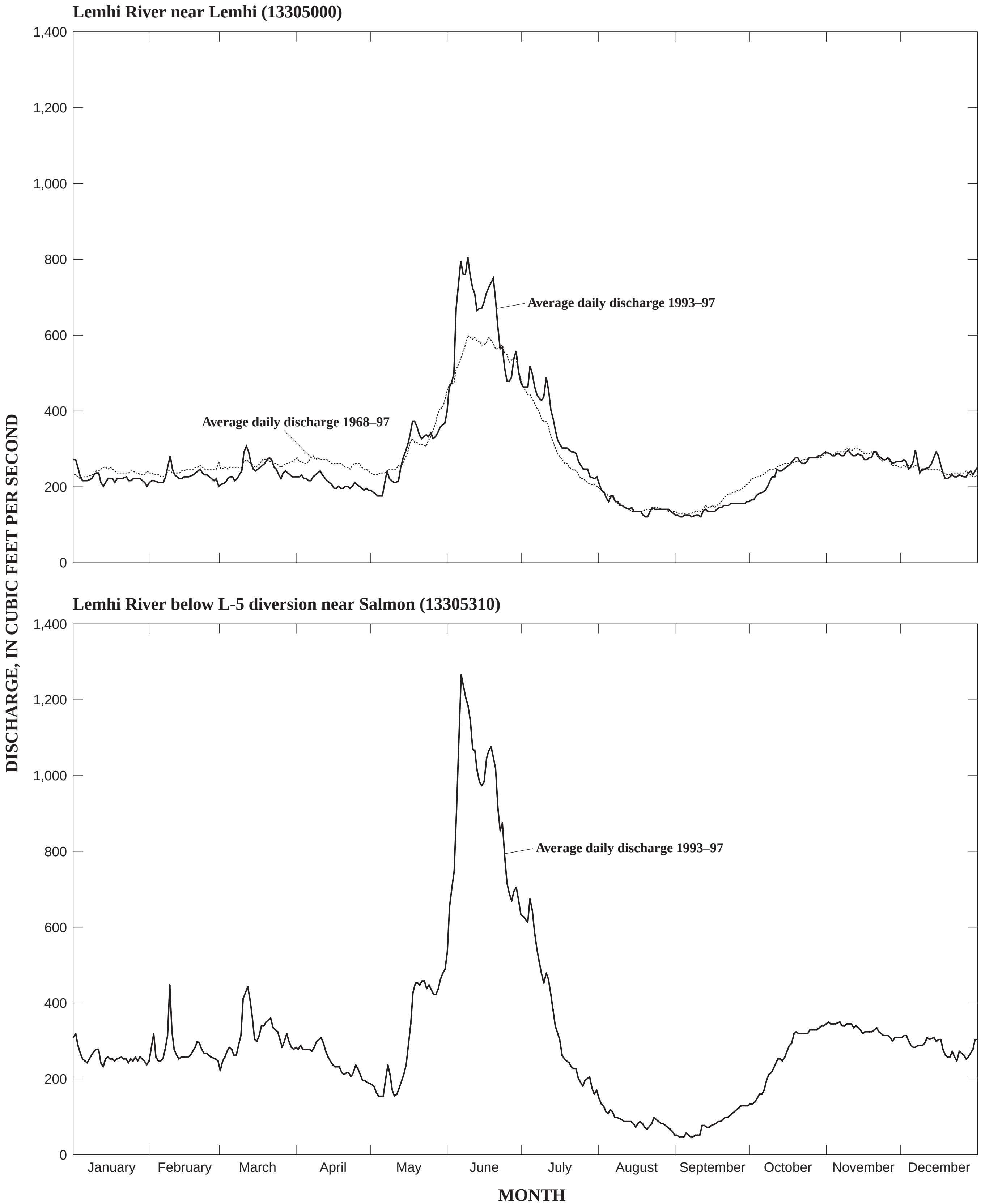


Figure 5. Average daily discharge, 1993 through 1997, in relation to long-term average, 1968–97, at two U.S. Geological Survey gaging stations in the Lemhi River Basin, east-central Idaho. (Locations shown in figure 4)

The Lemhi River was divided into 14 reaches (numbered from the upstream end; see fig. 4) between Leadore and Salmon on the basis of such factors as number of inflows and outflows, degree of detail desired, and access. A total of 117 measurements were made during the August seepage run. The number of measurements within a reach ranged from 6 to 14. In October, only about 50 of the 117 previously measured sites were remeasured because most of the diversions had been discontinued for the year.

Discharge measurements were made using standard USGS procedures as outlined in a report by Rantz and others (1982) using Price AA and Pygmy meters. Discharge measurement sites on the Lemhi River are shown in figure 4 and listed in table 2. All measurements differentiated between inflow, diversion, or main channel, and were rated subjectively for adequacy on the basis of flow and cross-section conditions and the measurer's evaluation of how close the measurements were to the actual flow (within 2 percent, excellent;

Table 2. Summary of results of August and October 1997 seepage runs in the Lemhi River, east-central Idaho

[See Appendices 1 and 2 for complete results. Gains and losses are from and to ground water; results have been adjusted for diversions and returns. Locations of reaches shown in figure 4; gains and losses shown in figure 7. USGS, U.S. Geological Survey; BOR, Bureau of Reclamation; BLM, Bureau of Land Management; ft^3/s, cubic feet per second; mi, mile]

Reach number and description	August				October			
	Gain or loss (-) (ft^3/s)	Reach length (mi)	Gain or loss (-) (ft^3/s /mi)	Percent gained or lost (-)	Gain or loss (-) (ft^3/s)	Reach length (mi)	Gain or loss (-) (ft^3/s /mi)	Percent gained or lost (-)
1. BOR gaging station at Leadore to Big Springs inflow	76.5	7.6	10.1	225	74.9	7.6	9.9	103.6
2. Big Springs inflow to Little Eightmile Creek	26.2	2.1	12.5	29.7	8.8	2.1	4.2	6.3
3. Little Eightmile Creek to BOR gaging station at BLM McFarland Campground	3.43	8.2	0.4	2.3	-20.0	8.2	-2.4	-9.3
4. BOR gaging station at BLM McFarland Campground to highway bridge above L-44 diversion	1.42	3.8	0.4	0.9	2.8	3.8	0.7	1.1
5. Highway bridge above L-44 diversion to Lemhi	20.3	1.8	11.3	11.1	-22.8	1.8	-12.7	-8.8
6. Lemhi to 0.1 mile downstream from Hayden Creek Road	16.1	1.6	10.1	7.6	47.0	1.6	29.4	17.9
7. 0.1 mile downstream from Hayden Creek Road to USGS gaging station (13305000)	41.6	5.6	7.4	18.9	-18.9	5.6	-3.4	-5.9
8. USGS gaging station (13305000) to highway crossing below L-30 diversion	84.2	2.2	38.3	23.5	54.3	2.2	24.7	15.0
9. Highway crossing below L-30 diversion to highway bridge 0.15 mile upstream from L-19 diversion	66.0	7.2	9.2	16.2	-5.2	7.2	-0.7	-1.2
10. Highway bridge 0.15 mile upstream from L-19 diversion to highway bridge 0.7 mile upstream from Baker intersection	26.2	3.5	7.5	6.4	-33.5	3.5	-9.6	-7.8
11. 0.7 mile upstream from Baker intersection to BOR gaging station at Barracks Lane	-5.51	4.1	-1.3	-1.4	32.2	4.1	7.8	8.1
12. BOR gaging station at Barracks Lane to USGS gaging station (13305310)	7.22	1.8	4.0	2.2	-29.5	1.8	-16.4	-6.5
13. USGS gaging station (13305310) to BOR gaging station at L-3A diversion	30.4	1.8	16.9	12.1	53.0	1.8	29.4	13.0
14. BOR gaging station at L-3A diversion to BOR gaging station at L-1 diversion	116	4.7	24.7	42.2	22.4	4.7	4.8	4.8
Net totals (rounded)	510	56			165	56		

5 percent, good; 8 percent, fair; greater than 8 percent, poor). Nonmeasurable flow (for example, nonchannelized overland flow) was estimated visually.

Results

Gains and losses in each of the 14 measured reaches of the Lemhi River in August and October are summarized in table 2. The complete data are provided in appendices 1 and 2 (back of report). To facilitate comparison among reaches, which range in length from less than 2 to about 8 mi, gains or losses per mile of river and gains or losses as a percentage of total flow (percent gained or lost) were determined.

In August, during the peak of the irrigation season, all reaches of the Lemhi River were gaining from ground water except reach 11, a 4-mi reach upstream from the BOR gaging station at Barracks Lane. The measured loss to ground water along reach 11 was only slightly more than 1 (ft^3/s)/mi. Reach 8 showed the greatest gain, about 38 (ft^3/s)/mi.

In October, after most irrigation had ceased, 6 of the 14 reaches (reaches 3, 5, 7, 9, 10, and 12) lost to ground water. Losses were about 1 to 16 (ft^3/s)/mi. The greatest gains, nearly 30 (ft^3/s)/mi, were in reaches 6 and 13.

During the summer seepage run, a total of 650 ft^3/s was being diverted from the river between Leadore and Salmon. Inflows, including irrigation returns, springs, and tributary streams, totaled 428 ft^3/s. Net river gain from ground water at this time was about 510 ft^3/s. During the October run, about 48 ft^3/s was being diverted, inflows totaled 314 ft^3/s, and the net gain was about 165 ft^3/s.

Streamflow gains and losses are controlled by the hydraulic gradient between the aquifer and the river. For an unconfined aquifer, this depends on the elevation of the water table with respect to the stream surface. The results of the seepage measurements indicate that at the time of the August measurements, the hydraulic gradient was toward the river in most locations. This is most likely because the water table is raised by ground-water recharge from flood and sprinkler irrigation during the summer. When irrigation stops, the

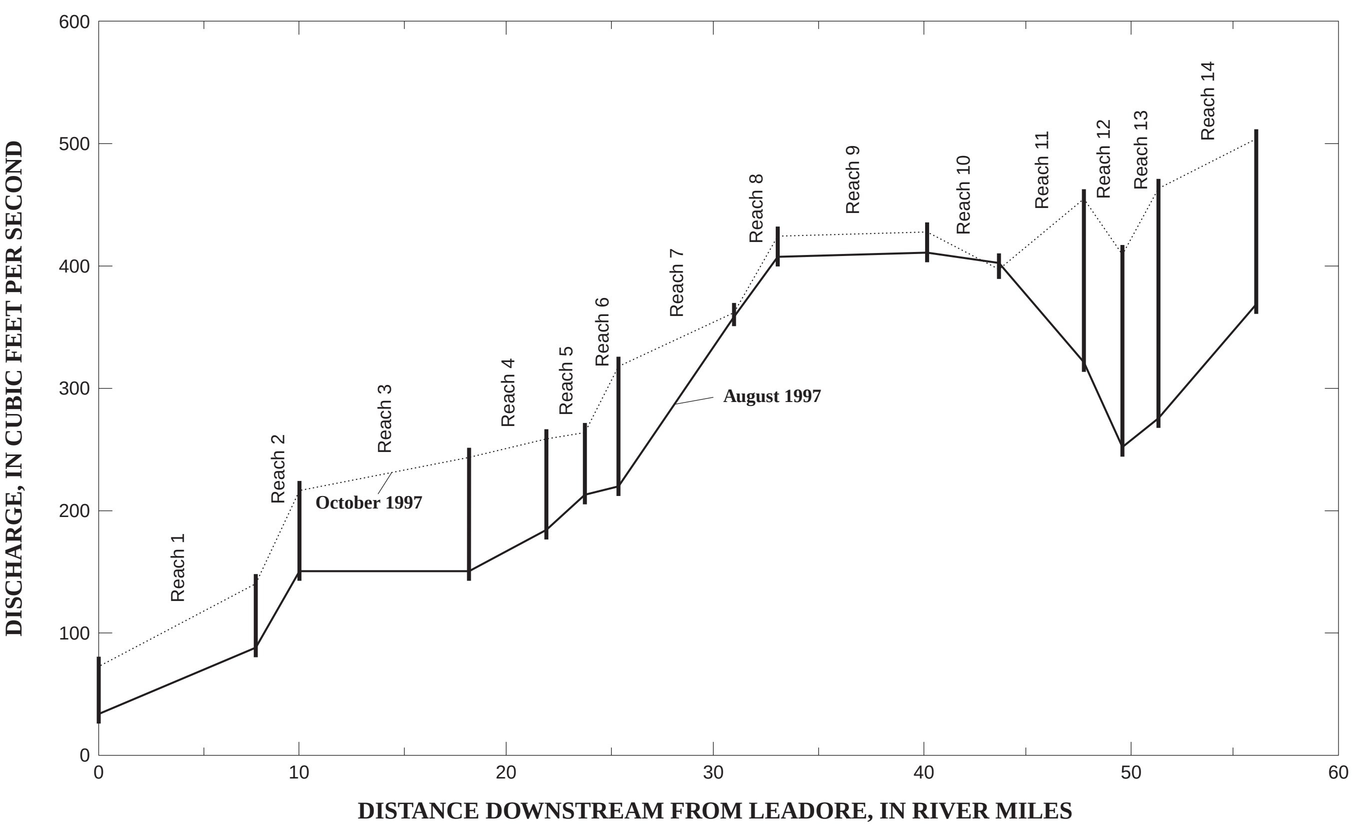


Figure 6. Measured instantaneous discharge in the Lemhi River, east-central Idaho, August and October 1997. (Locations of reaches shown in figure 4)

ground-water levels drop, and the gradient between the aquifer and the river decreases. Consequently, streamflow gains are reduced. Seasonal fluctuations in the water table are reflected by water-level changes measured in wells.

Figure 6, a graph of discharge in the Lemhi River in relation to distance downstream from Leadore, illustrates that maximum discharge in August was in reaches 8 through 10, as a result of the contributions of Agency and Hayden Creeks, two large tributaries. In October, maximum discharge was in reach 14, immediately upstream from the confluence of the Lemhi and Salmon Rivers.

Gains and losses for each reach, in cubic feet per second per mile and as a percentage of total flow, are shown in figure 7. Reaches 3, 5, 7, 9, 10, and 12 have seasonal "reversals"; they gain water in August and lose water in October. Reach 11 is the opposite; it loses water in August and gains water in October. Within this reach, about 113 ft^3/s, more than 25 percent of the river's total flow, is diverted within about 4 mi. Net water loss in the reach is relatively small, composing less than 2 percent of the river's flow at that point. During October, this reach showed a net gain of about 32 ft^3/s.

The Lemhi Irrigation District estimated outflows at 76 diversions (L–1 through L–63) in 1996 and 1997. Most diversions were measured twice a month, and a monthly average was estimated. The estimated diversions totaled 600 ft^3/s in August 1997 (Rick Sager, Lemhi Irrigation District, oral commun., 1998). This amount compares well with diversions measured during the summer seepage measurements, which totaled about 650 ft^3/s. The Irrigation District's November estimate was about 15 ft^3/s, compared with about 50 ft^3/s measured during the late October seepage run.

GROUND WATER

Ground water in the Lemhi River Basin primarily is stored in and transmitted through the Quaternary alluvial deposits of the Lemhi River and its tributaries, alluvial fans, and, to a lesser degree, glacial deposits. Wells in the basin are completed primarily in the alluvium and are used mainly for domestic purposes. Eight wells are used for irrigation; most are in the upper basin, near Leadore. On the basis of water-level measurements made by the Lemhi Irrigation District between 1995 and the present time, the water table lies 10 to 30 ft below land surface in most of the lower basin at midsummer. In most of the upper basin, ground-water levels are 20 to 50 ft below land surface during midsummer; water levels are 40 to 140 ft below land surface in a few deep wells in the upper part of the basin, upstream from Big Timber Creek. Water-level contours for June and November 1996 are shown in figure 8.

Ground-water fluctuations generally are influenced by pumping wells, geologic conditions, proximity to lakes and streams, and seasonal and long-term variations in precipitation, irrigation, and evapotranspiration. Although not evident in figure 8 because of the large contour interval and wide spacing of wells, large seasonal fluctuations in water levels are shown by many, but not all, wells in the Lemhi River Basin. The application of water to nearby agricultural fields causes ground-water levels to rise on a seasonal basis. Water levels also fluctuate because of ground-water pumping. An example of seasonal ground-water level changes caused by surface water for irrigation is given in figure 9. The water level responds almost immediately at the onset of irrigation, rises about 20 ft in early May, remains high through September, and gradually declines during the winter. Some wells do not respond as markedly, if at all, to application of water to agricultural fields. In general, wells responded similarly in 1996 and 1997.

Net annual fluctuations in water levels in nearly 80 wells were determined by finding the difference between the highest and lowest water levels for the calendar year. The results for 1996 and 1997 are plotted in figure 10. Although factors such as well depth, aquifer thickness, or well location could affect how strongly a well responds, no clear relation was observed. Perhaps the differences in fluctuations can be attributed to local variability in aquifer properties, such as clay content, but currently available data do not permit any conclusions to be drawn.

GROUND-WATER UNDERFLOW

Ground-water underflow to the Salmon River from the Lemhi River Basin is an important component of the basin's annual water budget. Annual underflow was estimated using two methods. The first, which is a generalized water-budget method, requires two important and related assumptions: (1) essentially all the water yielded by the upper basin can be measured at the USGS gaging station near Lemhi, and (2) underflow from the upper basin to the lower basin can be assumed

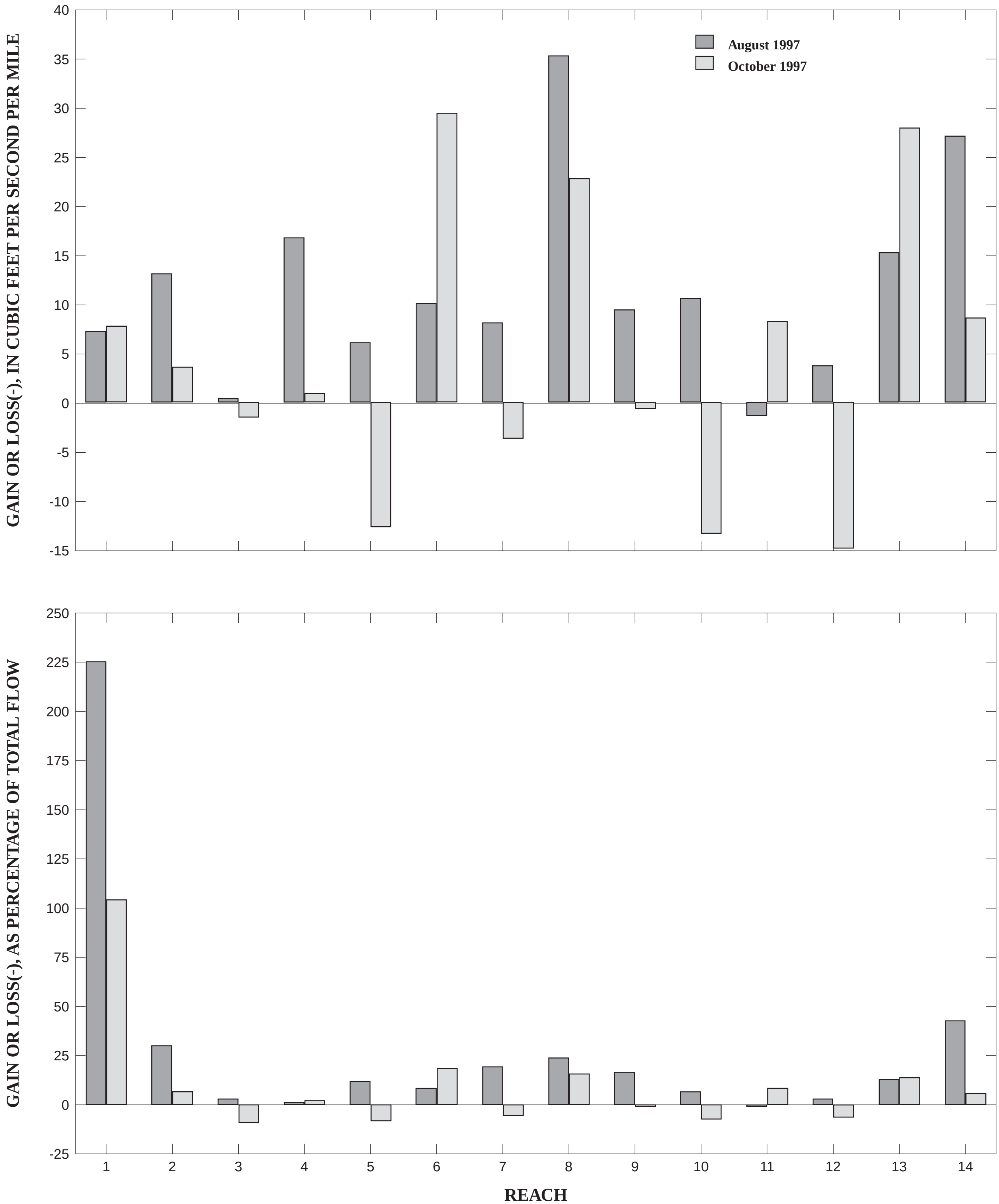


Figure 7. Gains and losses, in cubic feet per second per mile and as a percentage of total flow in the Lemhi River, east-central Idaho, August and October 1997.

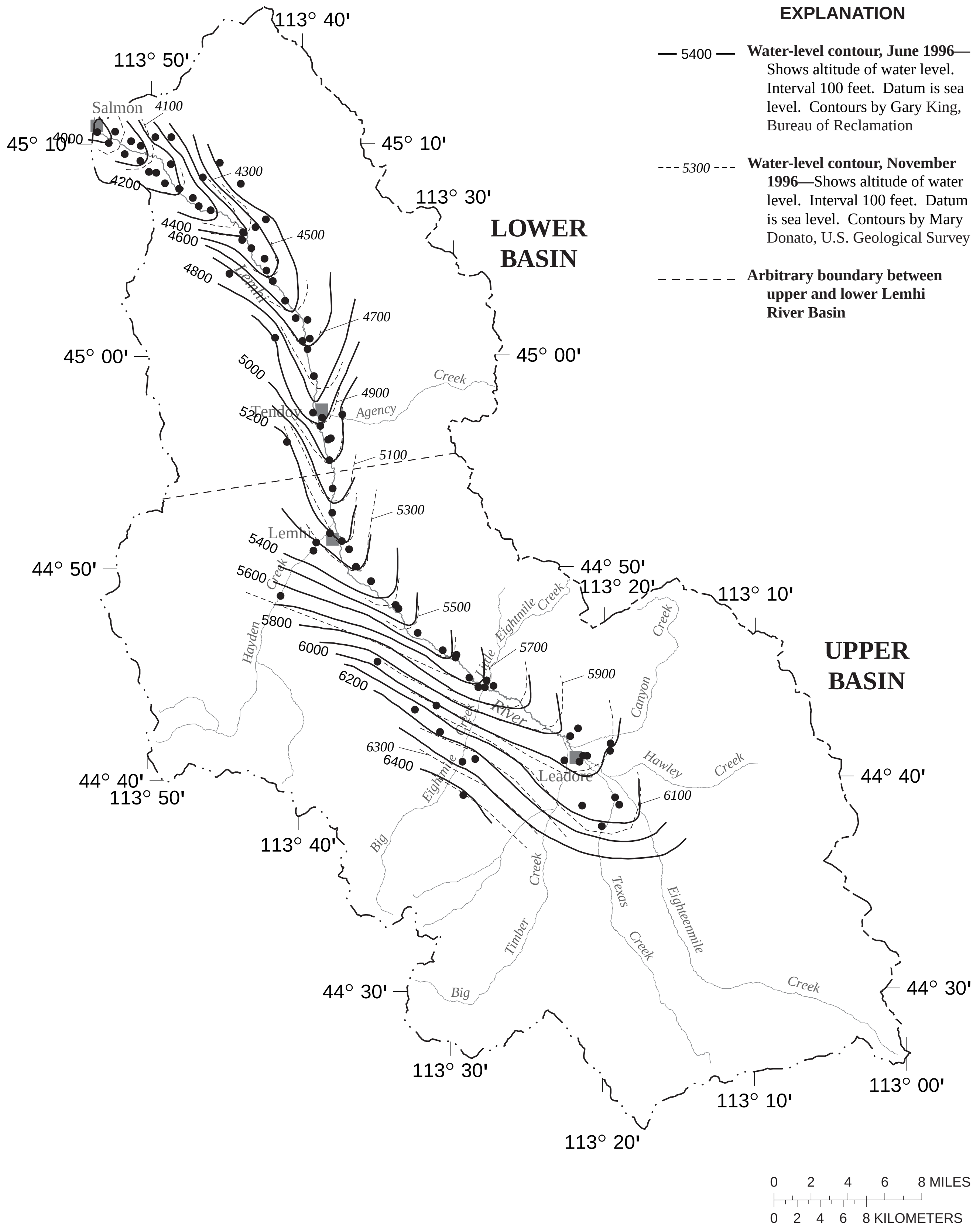


Figure 8. Ground-water level contours in the Lemhi River Basin, east-central Idaho, June and November 1996.

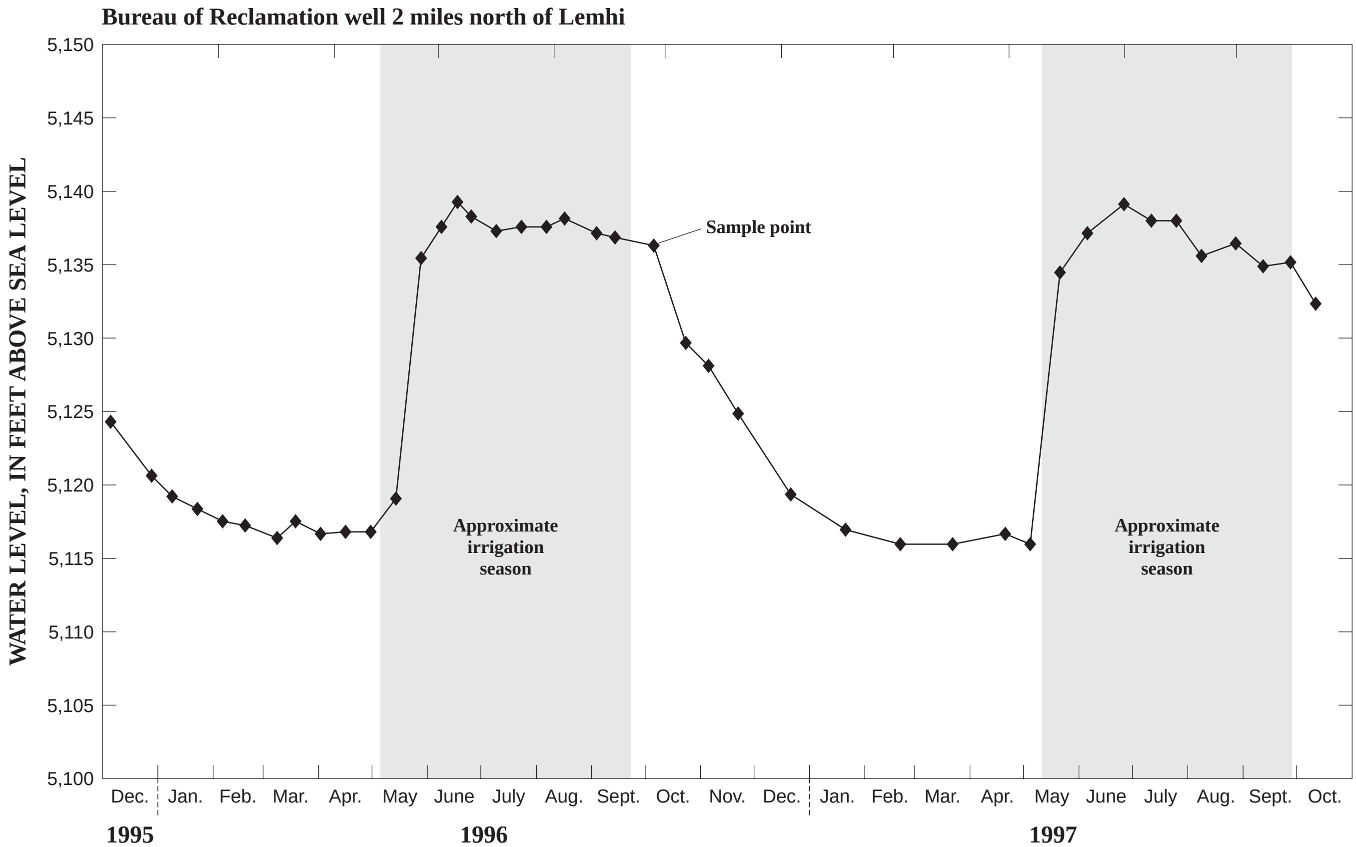


Figure 9. Water level in Bureau of Reclamation well in the Lemhi River Basin, east-central Idaho, December 5, 1995, to October 11, 1997.

to be negligible at that point. These assumptions are reasonable because, as discussed previously, surficial deposits of alluvium narrow significantly and are inferred to thin considerably in the area immediately downstream from Lemhi (Anderson, 1961), while impermeable bedrock is inferred to be present at shallow depths. These assumptions also allow water originating within the upper basin to be included within the lower basin's water budget, thus simplifying the computation.

The second method of estimation uses Darcy's equation to compute the amount of water discharged by the aquifer, using an assumed value of hydraulic conductivity, an estimated hydraulic gradient, and an inferred aquifer cross-section area based on drillers' logs.

Water Budget

Annual underflow from the lower basin to the Salmon River was estimated using a modified water-budget method, expressed by the following relation, which is a form of the hydrologic equation (inflow = outflow ± changes in storage:

$$Q_{\mathrm{Lemhi\ gage}} + \mathrm{precipitation} = \mathrm{underflow} + Q_{\mathrm{mouth}} + \mathrm{ET} \pm \Delta S.$$

Rearranging terms,

$$\mathrm{Underflow} = Q_{\mathrm{Lemhi\ gage}} - Q_{\mathrm{mouth}} + \mathrm{precipitation} - \mathrm{ET} \pm \Delta S,$$

where

$Q_{\mathrm{Lemhi\ gage}}$ = annual discharge at the USGS gaging station 13305000, Lemhi River near Lemhi, in cubic feet per second;

Q_{mouth} = annual discharge at the BOR gaging station at L–3A diversion, in cubic feet per second;

ET = evapotranspiration (crop consumptive use), in inches per year; and

ΔS = change in aquifer storage (may be positive or negative), in cubic feet.

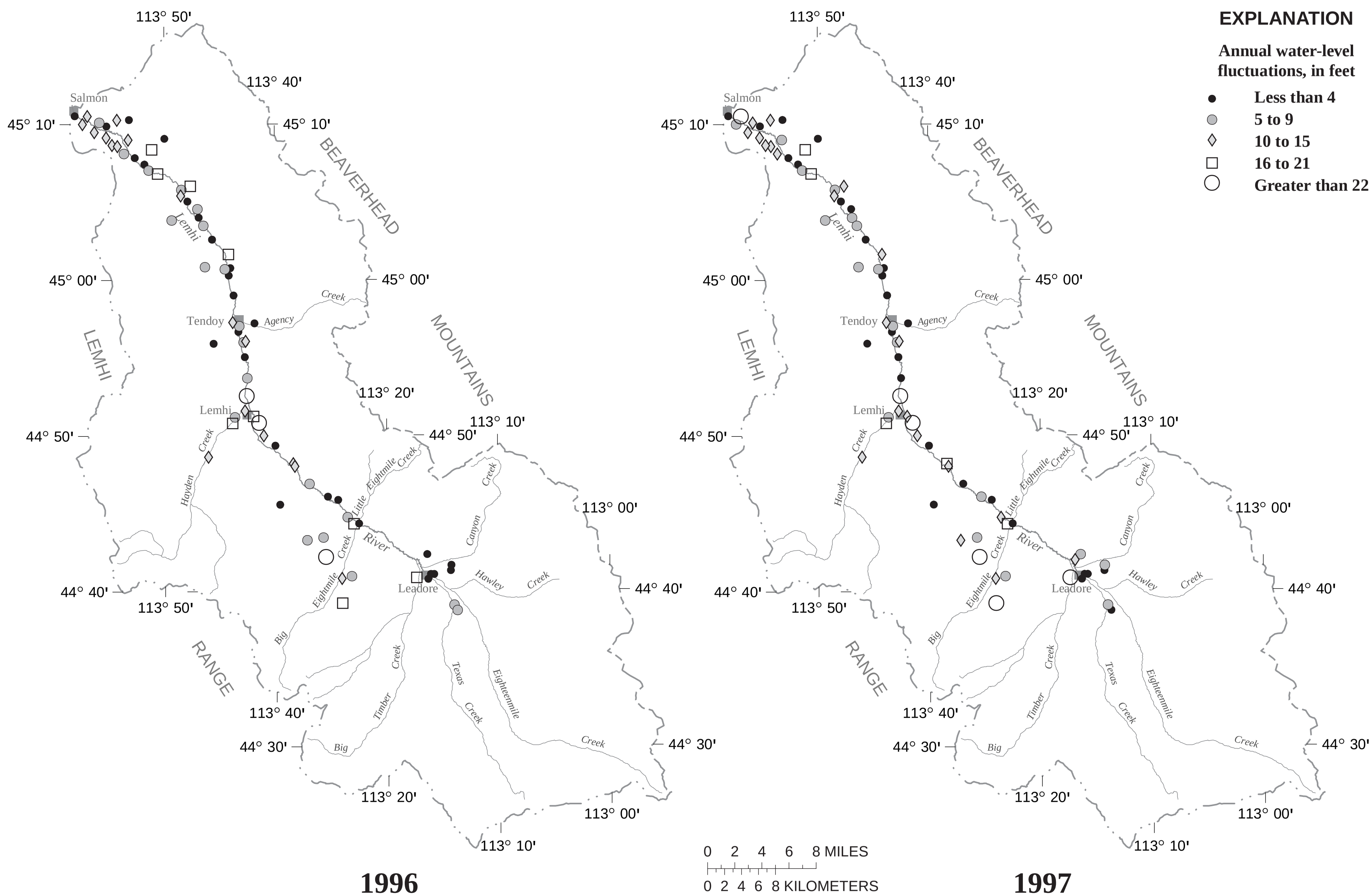


Figure 10. Annual water-level fluctuations in wells in the Lemhi River Basin, east-central Idaho, 1996 and 1997.

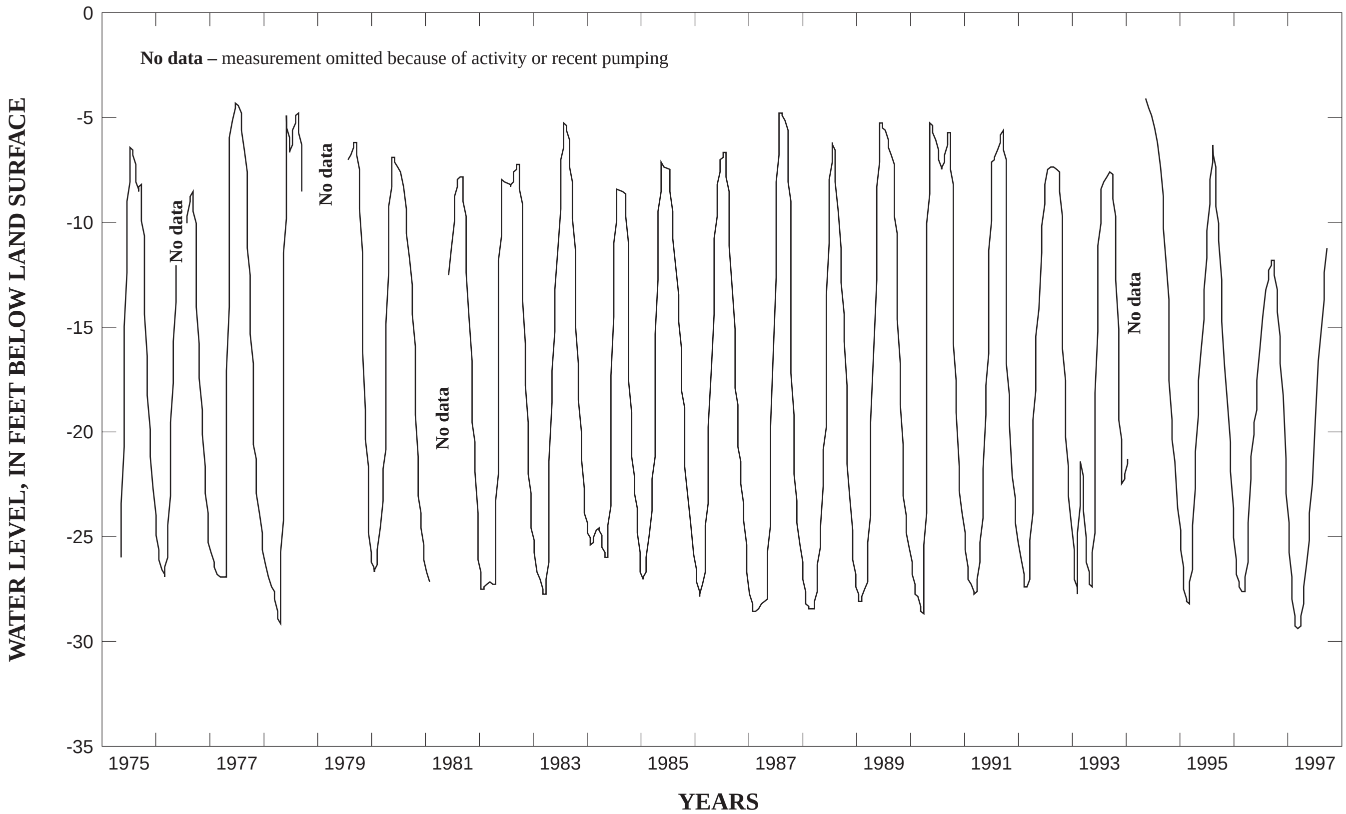


Figure 11. Water-level fluctuations in a long-term U.S. Geological Survey monitoring well in the Lemhi River Basin, east-central Idaho, May 1975 to September 1997.

Net changes in storage were assumed to be zero ($\Delta S = 0$) over the calendar year, an assumption shown to be valid by inspection of water-level data from long-term USGS monitoring wells in the Lemhi River Basin (hydrograph for one of these wells shown in fig. 11).

DISCHARGE

The ideal measurement of surface-water outflow from the basin would be discharge at the mouth of the Lemhi River at Salmon (Q_{mouth}). However, recent data for Q_{mouth} are unavailable; the USGS gaging station at Salmon (13305500, Lemhi River at Salmon) was discontinued in 1943. No gaging stations existed on the lower reaches of the Lemhi River until 1993, when BOR installed five gaging stations between Salmon and Leadore. Consequently, discharge data from the most downstream BOR gaging station, near L–3A diversion (period of record March 15, 1993, to present), were used as a proxy for annual discharge at the mouth of the Lemhi River. This gaging station is approximately 5 mi upstream from the mouth of the Lemhi River. None of the BOR gaging stations are operated during winter. Daily flows between the last measurement in the fall and the first measurement in the spring were assumed to be approximately constant and to equal the average of those two measurements. Historical discharge data from the Lemhi gaging station indicate that (except for infrequent storms) discharge does not vary substantially between November and March.

Surface-water inflow to the lower basin ($Q_{Lemhi\ gage}$) is measured at USGS gaging station 13305000, Lemhi River near Lemhi. Daily discharge data are available for December 1, 1938, to June 30, 1939; May 1, 1955, to September 30, 1963; and August 25, 1967, to the present. Because overlapping discharge data for $Q_{Lemhi\ gage}$ and Q_{mouth} are limited to calendar years 1993–97, the annual averages for those years were used. For the Lemhi River near Lemhi gaging station,the average for that period is within 2 percent of the long-term average annual discharge (191,586 acre-ft).

PRECIPITATION

Rainfall varies greatly throughout the lower basin; some higher elevations receive more than 40 in. of precipitation and lower elevations receive less than 10 in. annually. Therefore, applying a single annual rainfall value to the entire lower basin would introduce considerable error. The source of long-term average annual rainfall data was the Lemhi River Basin part of the statewide isohyetal map (Molnau, 1995), which portrays approximately 30-year average precipitation data (fig. 3). The data were analyzed in the form of a GIS (geographic information system) coverage obtained from the Idaho State Climatologist. The coverage was clipped to an area representing only the lower part of the basin. Each rainfall zone was assigned a value equal to the average value of the isohyetal lines bounding that zone. For example, the zone bounded by the 10- and 15-in. isohyetal lines was assigned a value of 12.5 in. The lowest zone, whose upper boundary is the 10-in. isohyetal line, was assigned a value of 7.5 in. The acreage of each zone was multiplied by the assigned value and converted to acre-feet; results were summed to obtain the total precipitation for the lower basin. Total average annual precipitation estimated by using this method was about 299,100 acre-ft for the lower basin.

The above estimates of precipitation are not considered to be highly reliable for this type of water-budget calculation. If long-term average discharge data were available, it would be appropriate to use long-term average precipitation data. However, this study must rely on discharge data from the last several years only. Combining average precipitation data with time-specific discharge data introduces a large degree of uncertainty into the results.

EVAPOTRANSPIRATION

The term evapotranspiration (ET) is synonymous with consumptive use of water by crops and other vegetation. It is a measure of the water transpired by plants, retained in plant tissue, and evaporated from adjacent soil surfaces over a specific period of time. ET varies throughout the year and from year to year, depending on precipitation, air temperature, stage of plant growth, radiation, humidity, barometric pressure, wind speed, relative humidity, and other factors. ET is commonly given in units of inches or millimeters per day.

The ET component of the underflow estimate is poorly defined. Calculating ET is a complex and imprecise procedure; a rigorous calculation of ET was beyond the scope of this study. Instead, estimates of ET for irrigated cropland in the lower Lemhi River Basin were obtained from charts in the Idaho Irrigation Guide (Soil Conservation Service [now the Natural Resources Conservation Service], 1985). The charts are based on a modified Blaney-Criddle method, which is well suited for estimating seasonal consumptive use. A detailed explanation of the method is given in the NRCS Idaho Irrigation Guide (1985). An alfalfa-grass combination was chosen as the predominant crop, and Climatic Area III was used as an approximation for the lower Lemhi River Basin (Bob Minton, Natural Resources Conservation Service, oral commun., 1997). The estimated average ET in the lower basin is 24.6 in/yr. This is lower than a previous estimate by Haws and others (1977) of about 33 in/yr.

The NRCS data represent the period April 20 through October 15 only. Comparison of these figures with archived total annual ET data for selected Agrimet stations in eastern Idaho (BOR’s Agrimet system) revealed that, although ET is highest during the summer months, these months accounted for only about 80 percent of the total annual ET. Therefore, the consumptive use was adjusted to an annual figure by dividing the April-to-October sum by 0.8.

Few data exist for rangeland ET. A study that modeled ET and surface energy budgets in the Reynolds Creek Experimental Watershed in southwestern Idaho yielded annual ET values of 14 to 20 in. for various types of vegetation, including low sagebrush, mountain big sagebrush, and aspen (Flerchinger and others, 1996). On the basis of these data, an estimate of 14 in/yr, representative of low sagebrush, was selected as the rangeland ET value for the lower Lemhi River Basin. No data were available as to the type of vegetation in forested land in the Lemhi Range and Beaverhead Mountains. Estimates of forest ET in the literature range from about 14 in/yr (Calder, 1978) to between 9 and 10 in/yr (Hart and Lomas, 1979). For simplicity, an ET value of 12 in/yr was used for forested land.

Applying the above ET estimates to the appropriate land-use types resulted in a total ET value of about 279,000 acre-ft/yr for the lower basin, as shown in the following table.

Land-use type	Number of acres	ET (feet)	Total ET (acre-feet per year)
Forest.	39,950	1.00	39,950
Irrigated cropland	33,170	2.05	68,000
Rangeland	147,650	1.16	171,275
Total	220,770		279,225

Uncertainties in ET values for all land-use types, particularly for rangeland and forest, are high. Estimates of ET are average values for general land-use types and are more appropriate for long-term, highly generalized calculations. For example, the ET figures have not been adjusted for annual variation in ET, even though ET is highly variable from year to year, depending on weather and soil conditions. Given the large areas involved, the total annual ET easily could be in error by as much as 10 to 20 percent or more.

RESULTS

$$Q_{\text{Lemhi gage}} - Q_{\text{mouth}} + \text{precipitation} - \text{ET} = \text{underflow}$$

$$194{,}784 - 207{,}244 + 299{,}100 - 279{,}225 = 7{,}415.$$

(all values in acre-feet)

The resultant underflow value represents approximately 1.5 percent of the annual basin yield. Given the large uncertainties in precipitation and ET, the results of the water-budget method to estimating underflow must be interpreted with caution. Because the Lemhi River between the USGS gaging station near Lemhi and the BOR gaging station near L–3A diversion is a gaining reach, the underflow can easily be a negative number if ET is determined to be greater than precipitation. This scenario is easy to imagine, given the large uncertainties in both these values. Therefore, the most appropriate conclusion to draw from this exercise is that underflow from the lower Lemhi River Basin is probably small.

Darcy's Equation

A more direct method of estimating ground-water underflow uses Darcy's equation:

$$Q = -KA\frac{dh}{dl} ,$$

where

Q = underflow, in cubic feet per day ;
K = hydraulic conductivity, in feet per day;
$\frac{dh}{dl}$ = hydraulic gradient, dimensionless (feet per feet); and
A = cross-sectional area of aquifer through which discharge occurs, in square feet.

A maximum hydraulic conductivity of 40 ft/d was assumed, based on a reported conductivity for comparable sand and gravel aquifer materials in the Basin and Range Province of the Western United States (Bedinger and others, 1986). This value is within the range of estimates made by Spinazola (1998) on the basis of drillers' logs for wells in the upper part of the Lemhi River Basin.

The hydraulic gradient near the mouth of the Lemhi River was estimated from figure 8 to be 0.01 to 0.02 (about 50 to 100 ft/mi). The gradient was estimated along flowlines subparallel to the Lemhi River.

The cross-sectional area of the aquifer was estimated by using a maximum thickness of 40 ft (fig. 2), determined from drillers' logs, and assuming the aqui-

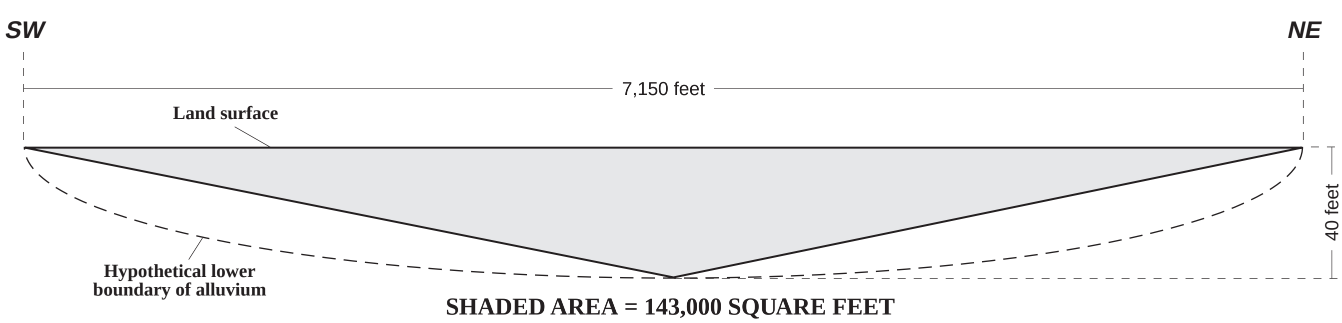


Figure 12. Schematic cross section showing probable distribution of alluvium in the Lemhi River Basin, near Salmon, east-central Idaho.

fer simulates a shallow, triangular cross section (fig. 12). The width of the aquifer near the mouth of the Lemhi River is about 7,150 ft, resulting in a cross-sectional area of about 143,000 ft^2. Because the aquifer cross section is probably saucer shaped, not exactly triangular, the area may be slightly underestimated; using a larger area would increase the underflow estimate proportionately. If some underflow occurs through surrounding bedrock (Miocene sedimentary rocks), the cross-sectional area would also be larger.

Conservative estimates of underflow, using minimum reasonable values for cross-sectional area and hydraulic gradient, are 500 to 1,000 acre-ft/yr. Using a maximum width, but not depth, at the mouth of the basin, and using a maximum gradient of 0.02, estimated underflows would be about 3,000 acre-ft/yr. Young and Harenberg (1973) estimated underflow from the adjacent Pahsimeroi River Basin, where alluvial deposits are similar in composition but probably thicker, at about 1,450 acre-ft/yr. Use of Darcy's equation corroborates results of the water-budget method: annual underflow from the Lemhi River Basin to the Salmon River is small and probably represents less than 2 percent of the basin's total annual yield.

SUMMARY AND CONCLUSIONS

A comprehensive hydrologic model of the Lemhi River Basin is not yet available, and much additional data are needed to complete such a model. This report combines new and previously collected data to describe several parts of the Lemhi River hydrologic system in a semiquantitative way. Information presented will provide the basis for future investigations into the complex interactions between ground and surface water in the Lemhi River Basin.

Lemhi River seepage measurements described seasonal distributed gains and losses along the 60-mi reach from Leadore to Salmon. Estimates of annual underflow from the Lemhi River Basin to the Salmon River were made using a water-budget method and Darcy's equation. Results of both methods indicate that underflow probably represents less than 2 percent of the basin's total annual yield.

Ground-water level measurements during 1995–97 showed that seasonal fluctuations are highly variable. Wells that respond to application of water for irrigation do so almost immediately because water levels are shallow. Seasonal fluctuations are as much as 20 ft, though water levels in many wells change little for a variety of reasons. Likely explanations of this variability include differences in recharge from precipitation and irrigation, ground-water pumping, and local lithologic changes in clay content or perched zones in the aquifer.

Although this study gives some insight as to the complex interactions of ground and surface water in the basin, understanding of the hydrologic system is still incomplete. Additional work, including geophysical studies to explore the three-dimensional shape of the aquifer, is needed. Seismic profiling at carefully selected transects across the alluvial deposits to determine their thickness and uniformity, especially in the vicinity of Lemhi, would contribute greatly to understanding the nature of ground-water flow between the upper and lower Lemhi River Basin. Opportunities to study lithologic logs and to perform aquifer tests in future newly drilled wells should be taken whenever they arise.

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APPENDICES

APPENDIX 1. COMPLETE RESULTS OF LEMHI RIVER SEEPAGE RUN, AUGUST 4–8, 1997

[Gains and losses are from and to ground water; results have been adjusted for diversions and returns. Locations of reaches shown in figure 4; gains and losses shown in figure 7. BOR, Bureau of Reclamation; BLM, Bureau of Land Management; USGS; U.S. Geological Survey; Q, discharge; G, good; F, fair; P, poor; NR, not rated; ft, feet; ft^3/s, cubic feet per second; mi, mile.]

Site name	Remarks	Gage height (ft)	Q (ft3/s)	Rated	Q out (ft^3/s)	Q in (ft^3/s)	Cumulative Q (ft^3/s)	Gain or loss (-) (ft^3/s)	Cumulative gain or loss (-) (ft^3/s)	Reach length (mi)	Gain or loss (-) ($ft^3/s/mi$)	Percent gained or lost (-)
Reach 1—BOR gaging station at Leadore to Big Springs inflow												
Beginning of Reach 1	Gaging station at Leadore	1.56	34.0	F			34.0					
L-63 diversion		2.80		G	24.2		9.80					
Timber Creek from L-63				F		17.4	27.2					
L-62 diversion		1.11		F	9.21		18.0					
L-61 diversion	Off				0		18.0					
L-60 diversion	Off				0		18.0					
L-59 diversion	Off				0		18.0					
L-58C diversion		1.47		F	6.48		11.5					
End of Reach 1	Bridge upstream from inflow at Big Springs	0.99	88.0	G			11.5	76.5	76.5	7.6	10.1	225
Reach 2—Big Spring inflow to Little Eightmile Creek												
Beginning of Reach 2	Bridge upstream from inflow at Big Springs	0.99	88.0	G			88.0					
Inflow	Big Springs	0.93		G		53.0	141					
L-58B diversion				F	8.30		133					
L-58A diversion		0.68		F	7.86		125					
End of Reach 2	Near Little Eightmile Creek	-0.22	151.0	G			125	26.2	103	2.1	12.5	29.7
Reach 3—Little Eightmile Creek to BOR Gaging Station at BLM McFarland Campground												
Beginning of Reach 3	Near Little Eightmile Creek	-0.22	151.0	G			151					
L-57 diversion		1.05		F	5.10		146					
L-58 diversion		0.31		F	0.21		146					
L-54 diversion		1.32		P	1.25		144					
L-52 diversion		0.66		F	1.50		143					
L-51A diversion					0		143					
L-51 diversion					9.60		133					
L-50 diversion					0		133					
Inflow	Little Springs			G		23.7	157					
Inflow	End of Little Springs			G		19.2	176					
L-49 diversion	Measured about 50 ft upstream from drop box			G	15.0		161					
L-47 diversion					0		161					
L-46A diversion		1.32		G	17.6		144					
Inflow	Near BLM McFarland Campground			P		3.93	148					
End of Reach 3	BOR gaging station at BLM McFarland Campground	2.22	151	G			148	3.43	106	8.2	0.42	2.27
Reach 4—BOR gaging station at BLM McFarland Campground to highway bridge upstream from L-44 diversion												
Beginning of Reach 4	BOR gaging station at BLM McFarland Campground	2.22	151	G			151					
L-45D diversion	BLM McFarland Campground, L-45D and L-45C			F	26.3		125					
L-45C diversion					0		125					
L-45B diversion	Upstream from L-45A diversion				0		125					
Inflow	Between L-45A & L-45B diversions			NR		3.88	129					
L-45A diversion		1.58		F	0.06		129					
Inflow	Combined with L-45A diversion						129					
L-45 diversion		1.58		G	9.11		165					
Inflow	Bottom of reach 4 (inflow prior)			F		17.10	183					
End of Reach 4	Highway bridge upstream from L-44 diversion (measured	3.95184		G			183	1.42	108	3.8	0.37	0.94
Reach 5—Highway Bridge upstream from L-44 to Lemhi												
Beginning of Reach 5	Highway Bridge upstream from L-44 diversion	3.95	184	G			184					
L-44 diversion				G	9.41		175					
Inflow				G		19.30	194					
L-43C diversion	Measure at mouth of culvert			G	4.53		189					
L-43B diversion	Measure 50 ft before fish screen				0		189					

Appendix 1. Complete results of Lemhi River seepage run, August 4-8, 1997 (continued)

Site name	Remarks	Gage height (ft)	Q (ft3/s)	Rated	Q out (ft^3/s)	Q in (ft^3/s)	Cumulative Q (ft^3/s)	Gain or loss (-) (ft^3/s)	Cumulative gain or loss (-) (ft^3/s)	Reach length (mi)	Gain or loss (-) ($ft^3/s/mi$)	Percent gained or lost (-)
Reach 5—continued												
Inflow				G		10.40	200					
L-43A diversion		2.49			7.10		193					
End of Reach 5	Lemhi	-3.98	213	G			193	20.3	128	1.8	11.3	11.1
Reach 6—Lemhi to 0.1 mile downstream from Hayden Creek Road												
Beginning of Reach 6	Lemhi	-3.92	213	G			213					
L-43 diversion	Across river and downstream from Lemhi Store				0		213					
L-42 diversion		1.18		G	24.3		189					
Inflow	Seepage from Hayden Creek			F		15.20	204					
End of Reach 6	Highway crossing upstream from Hayden Creek		220				204	16.1	144	1.6	10.1	7.56
Reach 7—0.1 Mile downstream from Hayden Creek Road to USGS gaging station 13305000												
Beginning of Reach 7	Highway crossing upstream from Hayden Creek		220	G			220					
Inflow	Hayden Creek	2.49		F		161	381					
L-40 diversion	Measured about 500 ft downstream from fish screen	2.6		NR	11.7		369					
L-39 diversion		1.99		F	3.73		366					
L-38 diversion				P	3.32		362					
L-37 diversion				F	14.2		348					
L-35A diversion					0		348					
L-35 diversion		2.8		F	3.88		344					
Inflow				P		1.50	346					
L-34 diversion		1.5		F	1.51		344					
Diversions	Sprinklers downstream from L-34A diversion			P	1.00		343					
L-33 diversion	Measured about 500 ft downstream from fish screen	0.92		G	6.71		336					
L-32 diversion		1.18		G	10.5		326					
L-31A diversion	Measured about 500 ft downstream from screen	1.37		G	9.50		316					
End of Reach 7	USGS gaging station Lemhi near Lemhi	4.03	358	G			316	41.6	185	5.6	7.42	18.9
Reach 8—USGS Gaging Station 13305000 to highway crossing downstream from L-30 diversion												
Beginning of Reach 8	USGS gaging station Lemhi River near Lemhi	4.03	358	G			358					
L-31B diversion				P	0.68		357					
L-31 diversion		1.41		G	13.4		344					
L-30A diversion					0		344					
Inflow	Agency Creek	0.52		F		8.75	353					
L-30 diversion				F	28.9		324					
End of Reach 8	Highway bridge downstream from L-30 diversion		408	F			324	84.2	270	2.2	38.3	23.5
Reach 9—Downstream from L-30 diversion to highway bridge 0.15 mi upstream from L-19 diversion												
Beginning of Reach 9	Highway bridge downstream from L-30 diversion		408				408					
L-29 diversion	Muleshoe Ranch				0		408					
L-28 diversion		0.71		G	13.5		395					
Inflow	Across from L-27 diversion			G		8.68	403					
L-27 diversion		0.46		G	8.71		394					
Inflow				G		3.30	398					
L-26 diversion	Bitter Root Ranch	0.45		P	0.30		397					
L-24 diversion		-0.25		F	1.39		396					
L-25 diversion		0.44		F	5.19		391					
Inflow	Kenney Creek	0.67		F		2.50	393					
L-23 diversion					0		393					
L-22 diversion				NR	38.5		355					
L-21 diversion				G	10.9		344					
L-20 diversion					0		344					
End of Reach 9	Highway Bridge 0.15 mi upstream from L-19 diversion	6.90	410	F			344	66.0	336	7.2	9.17	16.2

Appendix 1. Complete results of Lemhi River seepage run, August 4-8, 1997 (continued)

Site name	Remarks	Gage height (ft)	Q (ft3/s)	Rated	Q out (ft^3/s)	Q in (ft^3/s)	Cumulative Q (ft^3/s)	Gain or loss (-) (ft^3/s)	Cumulative gain or loss (-) (ft^3/s)	Reach length (mi)	Gain or loss (-) ($ft^3/s/mi$)	Percent gained or lost (-)
Reach 10—0.15 mi upstream from L-19 diversion to highway bridge 0.7 mi upstream from Baker intersection												
Beginning of Reach 10	Highway Bridge 0.15 mi upstream from L-19 diversion	6.90	410	F			410					
L-19 diversion	Measured about 100 ft downstream from fish screen	0.99		F	5.90		404					
L-18 diversion					0		404					
L-17 diversion				G	14.0		390					
L-15 diversion		2.20		NR	10.8		379					
Inflow				F		3.70	383					
L-14 diversion		1.97		G	6.20		377					
End of Reach 10	Highway bridge 0.7 mi upstream from Baker intersection		403	G			377	26.2	362	3.5	7.49	6.39
Reach 11—0.7 mi A175 upstream from Baker intersection to BOR gaging station at Barracks Lane												
Beginning of Reach 11	Highway bridge 0.7 mi upstream from Baker intersection		403				403					
Inflow	Withington Creek			G		1.23	404					
Diversion		0.32		F	25.7		379					
Inflow	Sandy Creek			F		12.10	391					
Inflow	Wimpey Creek	0.83		F		8.74	399					
Inflow	Upstream side of Wimpey Creek			G		0.70	400					
L-12 diversion		1.55		G	3.23		397					
L-11 diversion		2.64		G	23.4		373					
L-10 diversion		1.38		F	19.0		354					
L-9 diversion				P	22.1		332					
L-8A diversion		2.00		G	19.2		313					
Inflow	Upstream from Barracks Lane			P		6.43	320					
Inflow	Left bank 10 ft upstream from gaging station at Barracks lane			G		6.94	327					
End of Reach 11	BOR gaging station at Barracks Lane	0.98	321	G			327	-5.51	356	4.1	-1.34	-1.37
Reach 12—BOR gaging station at Barracks Lane to USGS gaging station 13305310												
Beginning of Reach 12	BOR gaging station at Barracks Lane	0.98	321	G			321					
L-8 diversion	Measure about 200 ft downstream from fish screen			G	3.59		317					
L-7 diversion		0.86		G	35.0		282					
L-6 diversion		1.09		G	36.1		246					
L-5 diversion				F	1.53		245					
End of Reach 12	USGS gaging station 13305310	2.54	252	G			245	7.22	364	1.8	4.0	2.2
Reach 13—USGS gaging station 13305310 to BOR gaging station at L-3A diversion												
Beginning of Reach 13	USGS gaging station 13305310	2.54	252	G			252					
Inflow	Not measurable, overland flow, estimated			P		3.00	255					
L-3A diversion				G	10.4		245					
End of Reach 13	BOR gaging station at L-3A diversion	1.78	275	G			245	30.4	394	1.8	16.9	12.1
Reach 14—BOR gaging station at L-3A diversion to BOR gaging station at L-1 diversion												
Beginning of Reach 14	BOR gaging station at L-3A diversion	1.78	275	G			275					
L-3B diversion		4.61		F	2.70		272					
L-3 diversion		1.34		G	33.4		239					
L-2 diversion				F	2.91		236					
Inflow				G		16.40	252					
L-1 diversion	Not measurable, estimated			P	0.50		252					
End of Reach 14	BOR gaging station at L-1 diversion	1.68	368	G			252	116	510	4.7	24.7	42.2
TOTALS								510		56.0	151	

APPENDIX 2. COMPLETE RESULTS OF LEMHI RIVER SEEPAGE RUN, OCTOBER 27–31, 1997

[Gains and losses are from and to ground water; results have been adjusted for diversions and returns. Locations of reaches shown in figure 4; gains and losses shown in figure 7. BOR, Bureau of Reclamation; BLM, Bureau of Land Management; USGS, U.S. Geological Survey; Q, discharge; G, good; F, fair; P, poor; NR, not rated; ft, feet; ft^3/s, cubic feet per second; mi, mile.]

Site name	Remarks	Gage height (ft)	Q (ft3/s)	Rated	Q out (ft^3/s)	Q in (ft^3/s)	Cumulative Q (ft^3/s)	Gain or loss (-) (ft^3/s)	Cumulative gain or loss (-) (ft^3/s)	Reach length (mi)	Gain or loss (-) ($ft^3/s/mi$)	Percent gained or lost (-)
Reach 1—BOR gaging station at Leadore to Big Springs inflow												
Beginning of Reach 1	BOR gaging station at Leadore	1.71	72.3	F			72.3					
L-63 diversion		2.40		G	15.7		56.6					
Spring in Leadore				G		21.1	77.7					
L-62 diversion				F	12.6		65.1					
L-61 diversion	Off—no measurement						65.1					
L-60 diversion	Off—no measurement						65.1					
L-59 diversion	Off—no measurement						65.1					
L-58C diversion	Off—no measurement						65.1					
End of Reach 1	Bridge upstream from inflow at Big Springs	1.15	140	G			65.1	74.9	74.9	7.6	9.9	104
Reach 2—Big Spring inflow to Little Eightmile Creek												
Beginning of Reach 2	Bridge upstream from inflow at Big Springs	1.15	140	G			140					
Big Springs Inflow				G		53.9	194					
L-58B diversion	Off—no measurement						194					
L-58A diversion	Off—no measurement						194					
Inflow	Little Eightmile Creek			F		13.3	207					
End of Reach 2	Near Little Eightmile Creek		216	NR			207	8.80	83.7	2.1	4.2	6.3
Reach 3—Little Eightmile Creek to BOR gaging station at BLM McFarland Campground												
Beginning of Reach 3	Near Little Eightmile Creek		216	NR			216					
L-57 diversion	Off—no measurement						216					
L-58 diversion	Off—no measurement						216					
L-54 diversion	Off—no measurement						216					
L-52 diversion	Off—no measurement						216					
L-51A diversion	Off—no measurement						216					
L-51 diversion	Off—no measurement						216					
L-50 diversion	Off—no measurement						216					
Inflow	Little Springs			F		30.6	247					
Inflow	End of Little Springs			G		5.97	253					
L-49 diversion	Off—no measurement						253					
L-47 diversion	Off—no measurement						253					
L-46A diversion	Off—no measurement						253					
Inflow	Inflow on Meyers Lane			F		6.91	259					
Inflow	Near BLM McFarland Campground			F		4.53	264					
End of Reach 3	BOR gaging station at BLM McFarland Campground	2.63	244	G			264	-20.0	63.7	8.2	-2.4	-9.3
Reach 4—BOR gaging station at BLM McFarland Campground to highway bridge upstream from L-44 diversion												
Beginning of Reach 4	BOR gaging station at BLM McFarland Campground	2.63	244	G			244					
L-45D diversion	Off—no measurement						244					
L-45C diversion	Off—no measurement						244					
L-45B diversion	Off—no measurement						244					
Inflow	No measurement						244					
L-45A diversion	Off—no measurement						244					
Inflow	McKinney Lane			G		3.58	248					
L-45 diversion	Off—no measurement						248					
Inflow	Bottom of reach 4 (inflow prior)			F		8.66	256					
End of Reach 4	Highway bridge upstream from L-44 diversion (measured ownstream from wooden bridge		259	G			256	2.76	66.5	3.8	0.7	1.1

Appendix 2. Complete results of Lemhi River seepage run, October 27–31, 1997 (continued)

Site name	Remarks	Gage height (ft)	Q (ft3/s)	Rated	Q out (ft^3/s)	Q in (ft^3/s)	Cumulative Q (ft^3/s)	Gain or loss (-) (ft^3/s)	Cumulative gain or loss (-) (ft^3/s)	Reach length (mi)	Gain or loss (-) ($ft^3/s/mi$)	Percent gained or lost (-)
Reach 5—Highway Bridge upstream from L-44 diversion to Lemhi												
Beginning of Reach 5	Highway bridge upstream from L-44 diversion		259	G			259					
L-44 diversion	Off—no measurement						259					
Inflow	Inflow upstream from L-43C diversion			G		19.4	278					
L-43C diversion	Off —no measurement						278					
L-43B diversion	Off—no measurement						278					
Inflow	Inflow upstream from L-43A diversion			F		7.44	286					
L-43A diversion	Off—no measurement						286					
End of Reach 5	Lemhi		263	NR			286	-22.8	43.6	1.8	-12.7	-8.8
Reach 6—Lemhi to 0.1 mi downstream from Hayden Creek Road												
Beginning of Reach 6	Lemhi		263	NR			263					
L-43 diversion	Off—no measurement						263					
L-42 diversion	Off—no measurement						263					
Inflow	Inflow downstream from fish trap			F		8.03	271					
End of Reach 6	Highway crossing upstream from Hayden Creek		318	F			271	47.0	90.6	1.6	29.4	17.9
Reach 7—0.1 mi downstream from Hayden Creek Road to USGS gaging station 13305000												
Beginning of Reach 7	Highway crossing upstream from Hayden Creek		318	F			318					
Hayden Creek (Inflow)	Hayden Creek at BOR gaging station	1.80		F		61.9	380					
L-40 diversion	Off—no measurement						380					
L-39 diversion	Off—no measurement						380					
L-38 diversion	Off—no measurement						380					
L-37 diversion	Off—no measurement						380					
L-35A diversion	Off—no measurement						380					
L-35 diversion	Off—no measurement						380					
Inflow	Off—no measurement						380					
L-34 diversion	Off—no measurement						380					
Diversions	Off—no measurement						380					
L-33 diversion	Off—no measurement						380					
L-32 diversion	Off—no measurement						380					
L-31A diversion	Off—no measurement						380					
End of Reach 7	USGS gaging station Lemhi near Lemhi	3.98	361	F			380	-18.9	71.7	5.6	-3.4	-5.9
Reach 8—USGS gaging station 13305000 to highway crossing downstream from L-30 diversion												
Beginning of Reach 8	USGS gaging station Lemhi River near Lemhi	3.98	361	F			361					
L-31B diversion							361					
L-31 diversion							361					
L-30A diversion							361					
Inflow	Agency Creek	0.64		G		12.8	374					
L-30 diversion		0.26		F	3.05		371					
End of Reach 8	Highway bridge downstream from L-30 diversion		425	F			371	54.3	126	2.2	24.7	15.0
Reach 9—Downstream from L-30 diversion to highway bridge 0.15 mi upstream from L-19 diversion												
Beginning of Reach 9	Highway bridge downstream from L-30 diversion		425	F			425					
L-29 diversion	Off—no measurement						425					
L-28 diversion	Off—no measurement						425					
Inflow	Across from L-27—estimated			P		1.00	426					
L-27 diversion							426					
Inflow	Probst Inflow			G		3.42	429					
L-26 diversion	Off—no measurement						429					
L-25 diversion	Off—no measurement						429					
L-24 diversion	Off—no measurement						429					
Inflow	Kenney Creek	0.83		F		3.74	433					
L-23 diversion	Off—no measurement						433					
L-22 diversion	Off—no measurement						433					
L-21 diversion	Off—no measurement						433					
L-20 diversion	Off—no measurement						433					
End of Reach 9	Highway bridge 0.15 mi upstream from L-19 diversion		428	F			433	-5.16	121	7.2	-0.7	-1.2

Appendix 2. Complete results of Lemhi River seepage run, October 27–31, 1997 (continued)

Site name	Remarks	Gage height (ft)	Q (ft3/s)	Rated	Q out (ft^3/s)	Q in (ft^3/s)	Cumulative Q (ft^3/s)	Gain or loss (-) (ft^3/s)	Cumulative gain or loss (-) (ft^3/s)	Reach length (mi)	Gain or loss (-) ($ft^3/s/mi$)	Percent gained or lost (-)
Reach 10—0.15 mi upstream from L-19 diversion to highway bridge 0.7 mi upstream from Baker intersection												
Beginning of Reach 10	Highway bridge 0.15 mi upstream from L-19 diversion	428	F			428						
L-19 diversion	Off—no measurement						428					
Inflow	Snook's inflow			G		3.45	431					
L-18 diversion	Off—no measurement						431					
L-17 diversion	Off—no measurement						431					
L-15 diversion	Off—no measurement						431					
L-14 diversion	Off—no measurement						431					
End of Reach 10	Highway bridge 0.7 mi upstream from Baker intersection		398	F			431	-33.5	87.3	3.5	-9.6	-7.8
Reach 11—0.7 mi upstream from Baker intersection to BOR gaging station at Barracks Lane												
Beginning of Reach 11	Highway bridge 0.7 miles upstream from Baker intersection	398	F			398						
Inflow	Above L-13 diversion—Withington Creek			P		0.39	398					
L-13 diversion				P	0.88		398					
Inflow	Sandy Creek			P		12.5	410					
Inflow	Wimpey Creek	0.75		F		5.96	416					
Inflow	Upstream side of Wimpey Creek						416					
L-12 diversion	Off—no measurement						416					
L-11 diversion	Off—no measurement						416					
L-10 diversion	Off—no measurement						416					
L-9 diversion	Off —no measurement						416					
L-8A diversion	Off—no measurement						416					
Inflow	Upstream from Barracks Lane—estimated			P		2.0	418					
Inflow	Left bank 10 ft above BOR gaging station at Barracks Lane		G		3.87	422						
End of Reach 11	BOR gaging station at Barracks Lane	1.23	454	G			422	32.2	119	4.1	7.8	8.1
Reach 12—BOR gaging station at Barracks Lane to USGS gaging station 13305310												
Beginning of Reach 12	BOR gaging station at Barracks Lane	1.23	454	G			454					
L-8 diversion	Off—no measurement						454					
L-7 diversion				G	14.5		440					
L-6 diversion	Off—no measurement						440					
L-5 diversion	estimated			P	1.0		439					
End of Reach 12	USGS gaging station (13305310)	2.91	409	G			439	-29.5	90.0	1.8	-16.4	-6.5
Reach 13—USGS gaging station 13305310 to BOR gaging station at L-3A diversion												
Beginning of Reach 13	USGS gaging station (13305310)	2.91	409	G			409					
Inflow	Not measurable, overland flow, estimate			P		1.00	410					
L-3A diversion							410					
End of Reach 13	BOR gaging station at L-3A diversion	2.20	463	F			410	53.0	143	1.8	29.4	13.0
Reach 14—BOR gaging station at L-3A diversion to BOR gaging station at L-1 diversion												
Beginning of Reach 14	BOR gaging station at L-3A diversion	2.20	463	F			463					
L-3B diversion	Off—no measurement						463					
L-3 diversion	Off—no measurement						463					
Inflow	Curley Creek			F		4.29	467					
L-2 diversion	Off—no measurement						467					
Inflow	Inflow from L-7 diversion			G		14.3	482					
L-1 diversion	Off—no measurement						482					
End of Reach 14	BOR gaging station at L-1 diversion		504	G			482	22.4	165	4.7	4.8	4.8
TOTALS								165		56	66	