

# **Preliminary Evaluation of Hydrogeology and Ground-Water Quality in Valley Sediments in the Vicinity of Killarney Lake, Kootenai County, Idaho**

*By* T.B. Spruill

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## CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATED WATER-QUALITY UNITS

Multiply	By	To obtain
foot (ft)	0.3048	meter
foot per day (ft/d)	0.3048	meter per day
foot squared per day <sup>1</sup> (ft <sup>2</sup> /d)	0.09290	meter squared per day
gallon per day (gal/d)	0.003785	cubic meter per day
inch (in.)	25.4	millimeter
mile (mi)	1.609	kilometer
million gallons per day (Mgal/d)	0.04381	cubic meter per second

Temperature in degrees Celsius (°C) can be converted to degrees Fahrenheit (°F) as follows:

$$^{\circ}\text{F} = (^{\circ}\text{C}) (1.8) + 32$$

Water temperatures are reported to the nearest 0.5°C.

**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.

### Abbreviated Water-Quality Units Used in Report:

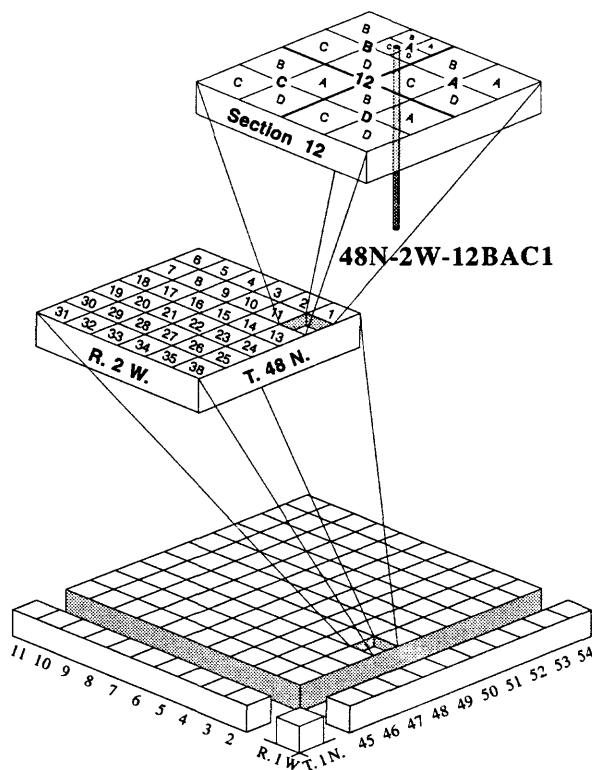
μeq	microequivalent
μg	microgram
μg/g	microgram per gram
μg/L	microgram per liter
μS/cm	microsiemens per centimeter at 25 degrees Celsius
meq/L	milliequivalent per liter
mg/L	milligram per liter
ppm	parts per million

---

<sup>1</sup>Alternate inch-pound form: cubic foot per day per square foot times foot of aquifer thickness [(ft<sup>3</sup>/d)/ft<sup>2</sup>]ft.  
 Alternate metric form: cubic meter per day per square meter times meter of aquifer thickness [(m<sup>3</sup>/d)/m<sup>2</sup>]m.

## SITE-NUMBERING SYSTEM

The U.S. Geological Survey in Idaho numbers well locations within the official rectangular subdivisions of the public lands, with reference to the Boise base line and Meridian. For example, the first segment (48N) of site number 48N-2W-12BAC1 designates the township north or south, the second (2W), the range east or west, and the third (12), the section in which the site is located. Letters (BAC) following the section number indicate the site's location within the section and are assigned in counterclockwise order beginning with the northeast quarter. The first letter (B) denotes the 1/4 section (160-acre tract), the second (A) denotes the 1/4-1/4 section (40-acre tract), and the third (C) denotes the 1/4-1/4-1/4 section (10-acre tract). The last number (1) is a serial number assigned when the site was inventoried.



Surface-water sites are assigned a 15-digit number based on the grid system of latitude and longitude; for example, 473054116331600. The first six digits denote degrees, minutes, and seconds of latitude; the next seven digits denote degrees, minutes, and seconds of longitude; and the last two digits (assigned sequentially) identify sites within a 1-second grid.

# **Preliminary Evaluation of Hydrogeology and Ground-Water Quality in Valley Sediments in the Vicinity of Killarney Lake, Kootenai County, Idaho**

**By T.B. Spruill**

## **ABSTRACT**

A study of the hydrogeology and ground-water quality in valley sediments along the Coeur d'Alene River in the vicinity of Killarney Lake in Kootenai County, Idaho, was done to determine whether ground water in this area posed possible human health and environmental concerns. Six monitoring wells and one piezometer were installed in valley sediments east of Killarney Lake. Water levels were measured in all monitoring wells, in the piezometer, and at four surface-water sites. Water samples were collected from four of the monitoring wells and analyzed for major ions, nutrients, trace elements, and total organic carbon. A water sample from Killarney Lake was analyzed for selected trace elements only; a sample from the Coeur d'Alene River at Cataldo was analyzed for major ions and trace elements.

Ground water in valley sediments flows from the valley wall to the Coeur d'Alene River in the vicinity of Killarney Lake. Sparse information from hydraulic, augering, and geophysical data indicates that ground water in the vicinity of Killarney Lake probably has little effect on the quality of water in either Killarney Lake or the Coeur d'Alene River. This conclusion is based on an estimation of ground-water discharge to the river using hydraulic conductivity values between  $1.0 \times 10^{-2}$  and  $6.3 \times 10^{-2}$  feet per day, calculated from slug-test data from three monitoring wells installed for this study; a ground-water-flow gradient of 0.0015 or less, determined from the water-level contour map; and an assumed valley sediment thickness of about 400 feet along a 4-mile reach adjacent to the Killarney Lake area. The estimated discharge through such a reach would be approximately 2,800 gallons per day. Additional coring and geophysical work is necessary to better define the hydrogeology of the valley sediments and to determine the relation between water in the sediments and water in the underlying bedrock.

Ground water in the vicinity of Killarney Lake is of variable quality and contains several trace elements in concentrations that exceed the U.S. Environmental Protection Agency primary and secondary drinking-water regulations and aquatic life criteria. Sources of these trace elements, including arsenic, cadmium, iron, lead, manganese, and zinc are (1) valley sediments contaminated with mine tailings, (2) naturally occurring eroded material derived from Belt Series rocks, and (3) possibly, volcanic ash deposits. Ground-water quality in the valley sediments is variable because of (1) seasonal mixing with dilute river water and precipitation in the upper part of the sediments, (2) slow ground-water velocity, and (3) varied lithologic materials that have different chemical and physical characteristics.

Two classes of chemical reactions characterize the geochemistry of water in the valley sediments. The first, sulfide oxidation, takes place from land surface to the water table, where sulfide deposits are exposed to air and oxygenated water. Trace elements and hydrogen ions are released into solution and lower the water pH sufficiently to dissolve additional trace elements from the sulfides. These reactions are especially prevalent in the wetland, where sulfides from tailings in the shallow sediments are exposed to periodic flooding. The second, and probably the most important reaction, is dissolution of manganese and iron oxides. Dissolution takes place in a geochemically reducing environment where sediments are always saturated, dissolved carbon is abundant, hydraulic conductivity of the sediments is low, and flushing with oxygenated recharge water is infrequent. Dissolution of manganese and iron oxides, which allows several trace elements that are sorbed on the oxide surface to dissolve when the oxides are dissolved, probably occurs throughout the lower Coeur d'Alene River Valley.

## INTRODUCTION

Killarney Lake is one of several lateral lakes near and in the flood plain of the Coeur d'Alene River in southeastern Kootenai County, Idaho (fig. 1). Much of the flood plain of the Coeur d'Alene River has been affected by deposition of mine tailings from operations in the Coeur d'Alene Mining District. Ioannou (1979) reported that the first indication of a contamination problem was in the 1930's, when farmers along the lower Coeur d'Alene River downstream from the confluence of the South Fork Coeur d'Alene River (fig. 1) became concerned about crop losses caused by deposition of mine tailings on their fields. Trees in the valley began to die as well (Ioannou, 1979).

Sediments contaminated with mine tailings have been documented in the lower Coeur d'Alene River Valley at Cataldo (Galbraith, 1971; Roy F. Weston, Inc., 1989), Dudley, Killarney Lake, Thompson Lake (Roy F. Weston, Inc., 1989), and the mouth of the Coeur d'Alene River (Maxfield and Wai, 1971). A comprehensive study of the areal distribution of trace elements in the valley sediments, vegetation, and animals in the early 1970's (Keeley, 1976) attributed the occurrence of contaminated sediments in Coeur d'Alene Lake to wind- and river-borne wastes from mining activities in the Kellogg-Smelterville area (fig. 1).

The U.S. Bureau of Land Management (BLM) administers three parcels of land adjacent to Killarney Lake (fig. 1). The Killarney Lake area is used extensively by the public for recreational purposes and by waterfowl for nesting. Mine tailings in valley sediments may provide a source for contaminants in ground and surface water. The resulting degraded water quality may pose both human health and environmental concerns.

The BLM is interested in developing water supplies for camping facilities and expanding the recreational potential of Killarney Lake. Planning for development of the water resource will require information on whether water in valley sediments in the vicinity of Killarney Lake is contaminated and if use of the

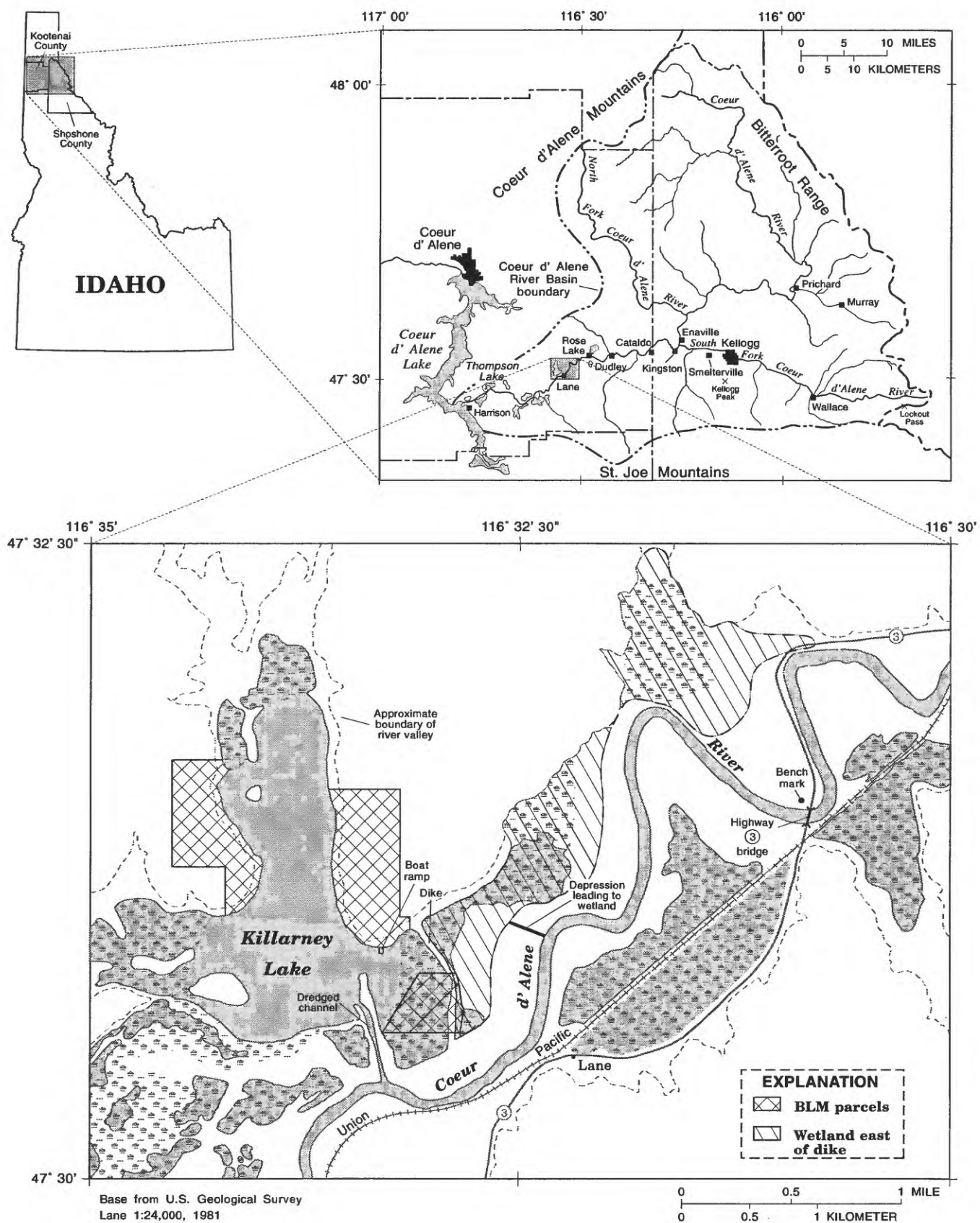


Figure 1. Location of study area.



water poses human health and environmental concerns. If the ground water is contaminated, there is a need to determine whether a monitoring network is necessary and, if so, what types of information are needed.

To address expressed concerns and data needs, the U.S. Geological Survey (USGS), in cooperation with the BLM, conducted a study of hydrogeologic conditions and ground-water quality in the vicinity of Killarney Lake.

## **Purpose and Scope**

This report describes the results of a study to provide information for a preliminary evaluation of hydrogeologic conditions and ground-water quality in the vicinity of Killarney Lake. Results of the study will be used to evaluate the need for continued monitoring of ground-water quality and to determine the usability of and possible environmental concerns about ground water underlying BLM tracts. This study was restricted generally to unconsolidated valley sediments.

Existing hydrogeologic information was reviewed and new hydrogeologic and water-quality data were collected to:

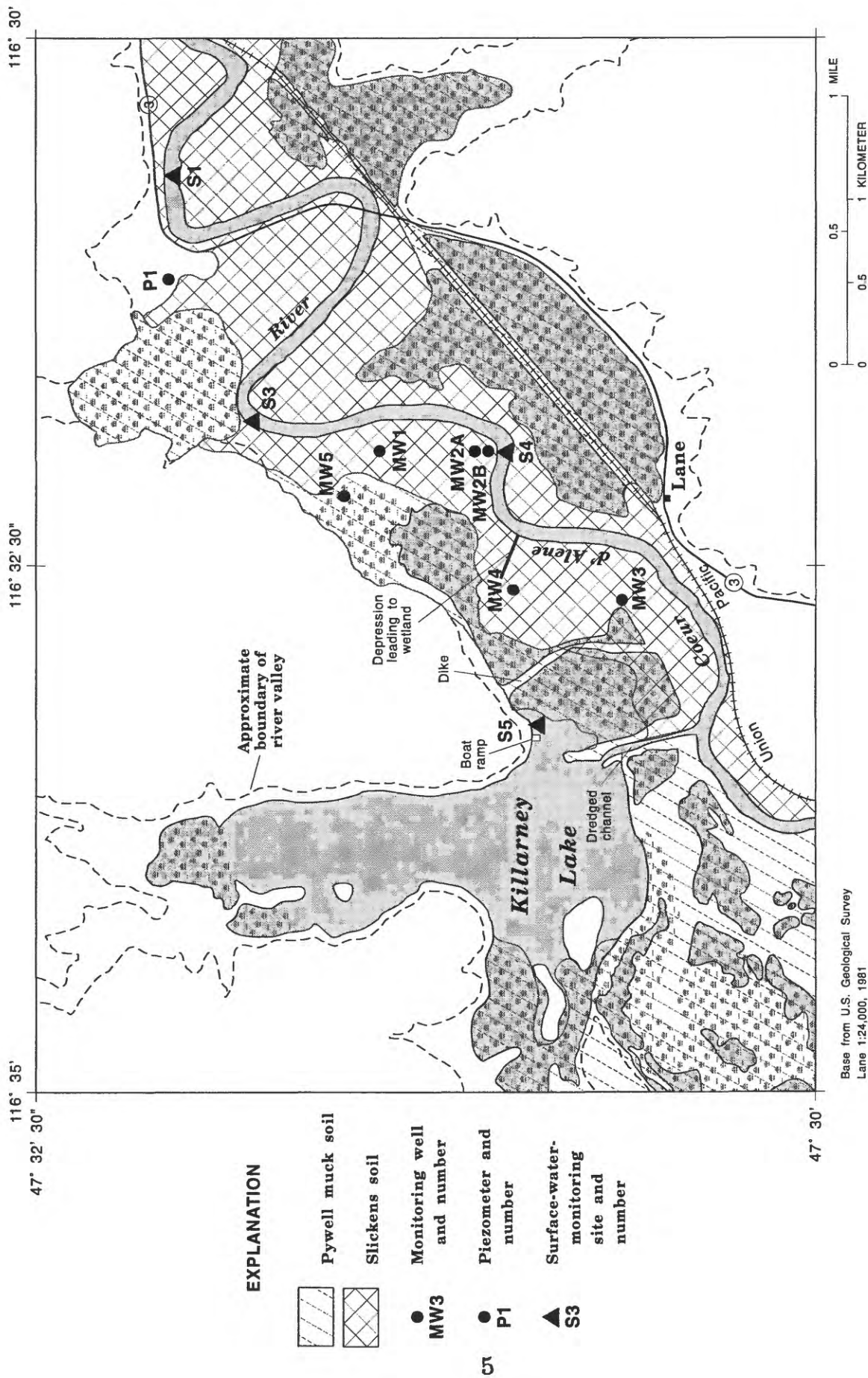
(1) evaluate the hydrogeology and ground-water quality in valley sediments along the Coeur d'Alene River in the vicinity of Killarney Lake;

(2) evaluate, insofar as the sparse data allowed, the relations among the ground-water system, the wetland southeast of Killarney Lake, the Coeur d'Alene River, and Killarney Lake; and

(3) evaluate ground-water quality in valley sediments in the vicinity of Killarney Lake with respect to drinking-water standards and possible environmental concerns.

## **Description of Study Area**

The study area is located in the western part of the Northern Rocky Mountains Physiographic Province (Fenneman, 1931). The Coeur d'Alene River drains the Coeur d'Alene Mountains, which are considered part of the Bitterroot Range (Hobbs and others, 1965). Vertical relief between the valley floor and ridge tops in the vicinity of Killarney Lake ranges between 1,000 and 1,500 ft above sea level. Annual precipitation is about 30 in., primarily rainfall in the spring and early fall and snow in the winter (Hobbs and others, 1965). Soils on the flood plain (fig. 2) consist of fine, poorly drained organic material (Pywell muck) and accumulations of poorly drained mine tailings and organic material (Slickens). The mine tailings were deposited during times of high flows in the Coeur d'Alene River (U.S. Soil Conservation Service, 1981).



**Figure 2.** Alluvial soil types and locations of monitoring wells, piezometer, and surface-water-monitoring sites (modified from U.S. Soil Conservation Service, 1981).

Surficial rocks in the vicinity of Killarney Lake are primarily very fine-grained argillite and quartzite of the Belt Series of Precambrian age, which are drained by the Coeur d'Alene River, and Holocene alluvium, which composes the upper part of the valley sediments. Most of the valley sediments probably were eroded from Belt Series rocks of the Bitterroot Range. In the upper part of the Coeur d'Alene River Valley, such as along the South Fork where mining occurred, valley sediments consist of coarse sand, gravel, cobbles, and boulders tens of feet thick near Wallace (Hobbs and others, 1965) and fine-grained silt and clay about 400 ft thick 2.5 mi west of Rose Lake (Norbeck, 1974). No other information pertaining to thickness of valley sediments in the vicinity of Killarney Lake was available. On the basis of the assumption that deposits thicken toward Coeur d'Alene Lake, valley sediments in the vicinity of Killarney Lake are probably at least 400 ft thick.

Only one BLM parcel, a wetland southeast of Killarney Lake (fig. 1), is underlain by a sequence of valley sediments in which wells could be installed. However, most of this parcel is submerged or waterlogged, difficult to access with augering equipment, and too small to yield meaningful information pertaining to ground- and surface-water hydrology of the area. Areas most easily accessible to augering equipment and vehicles were east of and adjacent to a dike (fig. 1), owned by the Idaho Department of Fish and Game, on the southeast side of the lake.

## **Monitoring-Well Installation**

Six monitoring wells (MW1, MW2A, MW2B, MW3, MW4, and MW5) and one piezometer (P1) were installed in March 1990 (fig. 2). MW1, MW2A, and MW2B were installed using a trailer-mounted power auger. At the selected location, a 4-in. hole was augered to the desired completion depth, all auger flights were removed, and casing and screen were inserted into the open hole. Geologic information was recorded during the well-installation process. Clean sand was placed into the hole and packed around the screen so that the sand extended about 1 ft above the top of the screen. MW1 was completed with 1.5-in.-diameter Schedule-40 polyvinyl chloride (PVC) casing and 2 ft of 0.010-in.-slot, 1.5-in.-diameter PVC screen. MW2A and MW2B were completed with 2-in.-diameter Schedule-40 PVC casing and 2 ft of 0.020-in.-slot, 2-in.-diameter PVC screen. MW2B has an additional 2 ft of stainless steel/galvanized screen (sandpoint) at the bottom of the casing. Bentonite was poured into the hole around the casing to within about 5 ft of land surface. The monitoring wells then were completed by filling the annulus around the casing to land surface with cement.

Because it was difficult to drive to MW3, MW4, and MW5 sites (fig. 2), monitoring wells at these sites were installed using a hand auger. These wells were completed in essentially the same fashion as MW2A and MW2B. The piezometer (P1, fig. 2), a 1.25-in.-diameter black steel pipe with a 2-ft galvanized steel sandpoint, was driven to a depth of about 3 ft. All wells were developed by

surging with a bailer. General information on monitoring wells, piezometer, and surface-water-monitoring sites is presented in table 1. Details of well construction for monitoring wells are included in table 5 (back of report).

After all wells and the piezometer were installed, top-of-casing and land-surface altitudes were determined by a level survey. Altitudes of all ground-water- and surface-water-monitoring sites, except S5 (fig. 2), were tied to an Idaho Department of Transportation bench mark near the Highway 3 bridge about 2 mi northeast of Lane (fig. 1). Altitude of Killarney Lake stage at S5 was estimated from a roadbed altitude reported on a 1981 U.S. Geological Survey 7.5-minute topographic map. Levels were run from the centerline of the road to a measuring point about 50 ft from the boat ramp (fig. 2).

**Table 1.** General information on monitoring wells, piezometer, and surface-water-monitoring sites

Site identification No.	Location	Name	Total depth (feet below land surface)	Altitude of top of casing or measuring point (feet above sea level)
473130116315501	48N-2W-12BAD1	MW1	18	2,133.6
473105116315801	12CAD1	MW2A	20	2,138.0
473105116315002	12CAD2	MW2B	33	2,138.1
473040116324001	14AAD1	MW3	8	2,133.8
473100116323501	11DDA1	MW4	8	2,136.8
473133116321001	12BAC1	MW5	8.5	2,134.5
473207116310301	1W- 6CAA1	P1	3	2,133.2
473205116304100	6CD	S1		2,139.3
473125116304700	2W-12ABA	S3		2,136.4
473102116315800	12DBC	S4		(1)
473054116331600	11CDD1	S5		<sup>2</sup> 2,140

<sup>1</sup>Water surface determined from top-of-casing altitude for MW2A.

<sup>2</sup>Altitude estimated from roadbed altitude reported on 1981 U.S. Geological Survey 7.5-minute topographic map.

## Water-Level Measurements

To construct a water-level contour map, determine vertical and lateral hydraulic gradients, and determine the relations among Killarney Lake and water in the valley sediments and the river, water-level altitudes were measured in all monitoring wells, the piezometer, and at selected surface-water-monitoring

sites (S1, S3, S4, fig. 2). All water levels in monitoring wells and the piezometer were measured using a steel tape. Temporary altitude markers were established at surface-water sites, and levels were transit surveyed to establish surface-water altitudes. Water-level measurements were reported to within 0.1 ft for all monitoring wells and surface-water sites S1, S3, and S4 (table 2). Transit survey from the bench mark to the measuring point at S5 was not possible because of poor weather. Altitude of the lake at S5 (fig. 2) was determined by transit survey from the measuring point to the lake surface. The actual altitude of the lake is estimated to be within 1 ft of the reported value.

## **Water-Quality Sampling Procedures**

Water samples for chemical analysis were collected from MW2A, MW2B, MW4, and MW5 by using the following procedure: After measuring the water level with a steel tape, each well was purged by removing all water from the well casing and allowing it to refill enough to collect a sample, usually within 4 to 6 hours. Samples then were collected using a Teflon bailer suspended by a nylon cord. The bailer had a bottom check valve and was rinsed thoroughly with deionized water before each use. Samples first were collected for onsite analysis of specific conductance, pH, temperature, dissolved oxygen, and alkalinity. Samples then were collected for laboratory analysis of major ions, nutrients, trace elements, and total organic carbon. Water samples collected from Killarney Lake at the boat ramp (S5) were analyzed for selected trace elements only. Samples were prepared and analyzed according to prescribed procedures (U.S. Geological Survey, 1989). Samples for major ions, nutrients, and trace elements were filtered through a 0.45-micron filter. All samples were analyzed by the U.S. Geological Survey National Water Quality Laboratory in Arvada, Colo.

An equipment blank was used to verify that no trace-element contamination occurred from the filtration apparatus. All trace elements analyzed for in the blank sample were less than reporting limits.

## **HYDROGEOLOGY**

Hydrogeology of the lower Coeur d'Alene River Valley is not well understood. Little information is available on the extent and physical and hydraulic characteristics of the valley sediments. Most of the information on thickness of the valley sediments is from surface geophysical surveys. No deep drill hole with a detailed description of the lithology of valley sediments near Killarney Lake was available. The principal published information pertaining to hydrogeologic characteristics consists of maps showing water-table configuration and thickness of valley sediments from near Wallace to approximately 2.5 mi west of Rose Lake (Norbeck, 1974). These maps show that the thickness of valley sediments along the main stem of the Coeur d'Alene River ranges from about 70 ft south of the river near Cataldo to a maximum of 414 ft west of Rose Lake. Thickness estimates of valley sediments along the main stem west of Cataldo were based primarily on seismic or resistivity measurements made during Norbeck's (1974) study.

**Table 2.** Depth to water

Site identification No.	Location	Name	Date measured (1990)	Depth to water (feet below measuring point)
473130116315501	48N-2W-12BAD1	MW1	3- 9 3-23 5-30	5.0 5.0 3.7
473105116315801	12CAD1	MW2A	3- 9 3-23 5-30	6.8 7.0 6.2
473105116315002	12CAD2	MW2B	3- 9 3-21 5-30	11.3 9.0 7.1
473040116324001	14AAD1	MW3	3- 9 3-23 5-30	5.2 3.9 1.9
473100116323501	11DDA1	MW4	3-22 3-23 5-30	4.9 4.8 4.1
473133116321001	12BAC1	MW5	3- 9 3-21 5-30	3.9 4.3 3.5
473207116310301	1W- 6CAA1	P1	3- 9 3-23 5-30	2.4 2.6 2.4
473205116304100	6CD	S1	3-10 3-23 5-30	12.7 11.3 9.0
473125116304700	2W-12ABA	S3	3-23 5-30	8.7 6.4
473102116315800	12DBC	S4	5-30	8.8
473054116331600	11CDD1	S5	3-10 5-30	10.0 8.7

Although some drillers' logs were available for wells in the Killarney Lake area (Roy F. Weston, Inc., 1989), logs for wells deeper than 25 ft and completed in valley sediments were not available. Lithologic descriptions from drillers' logs and logs presented in this report (table 5, back of report) indicate that the valley sediments less than 35 ft below land surface are composed of silt and clay. No drill-hole data were available to assess the lithology deeper than about 35 ft; consequently, data were not adequate to prepare a reliable hydrogeologic cross section in the vicinity of Killarney Lake.

Surface geophysical data allow qualified estimates to be made of the thickness and lithology of the valley sediments. Electrical resistivity data presented by Norbeck (1974) for the vicinity 2 mi west of Rose Lake indicate three layers of correspondingly different lithologic materials: a shallow layer from land surface to about 70 ft with a resistivity of 300 ohm meters, a middle layer about 345 ft thick with a resistivity of about 200 ohm meters, and a bedrock layer at about 415 ft with a resistivity of 1,470 ohm meters. The lower resistivity of material in the middle layer indicates the presence of more conductive material such as clay and silt relative to the shallow layer. The shallow layer's resistivity of 300 ohm meters is still much less resistive than material at Cataldo, where resistivity was 600 ohm meters (Norbeck, 1974), indicating less conductive and, therefore, more sandy or gravelly material. These data indicate that valley sediments near Killarney Lake are composed of much finer, less transmissive sediments than valley sediments upstream near Cataldo.

Slug or bailer tests provided useful information about the hydraulic properties of the valley sediments. After static water level was measured, several liters of water were removed by bailing, and periodic water-level measurements were made to measure recovery. The change in water level,  $H$ , was computed by subtracting the static water level from each measurement made after bailing. A dimensionless value,  $H/H_0$ , was computed by dividing each  $H$  by  $H_0$  (the maximum  $H$  measured at the beginning of the test).

The recovery curve ( $H/H_0$  as a function of time) was matched to a set of standard curves (Cooper and others, 1967), and the time ( $t$ ), in seconds, was noted at the point where  $Tt/r^2 = 1$ . On the basis of the well radius ( $r = 2$  in., or 0.166 ft), transmissivity, ( $T$ ), was computed from the following:

$$T = 1.0 r^2/t \quad (1)$$

Hydraulic conductivity,  $k$  (in feet per day), was computed by dividing  $T$  by the screened interval (in feet).

Slug tests were done in MW2A, MW2B, and MW5 to determine hydraulic properties. Results of these tests are given in table 6 (back of report).

Estimates of hydraulic conductivity from slug tests ranged from about  $1.0 \times 10^{-2}$  ft/d for MW2B to  $6.3 \times 10^{-2}$  ft/d for MW5, indicating that the transmissive characteristics of the shallow valley sediments are extremely low. Hydraulic conductivities of 1 ft/d or less are indicative of clay (Lohman, 1979, p. 53). Well yields from materials tested probably would be inadequate even for domestic supplies.

The altitude of ground water in the valley sediments near Killarney Lake during March and May 1990 (figs. 3, 4) indicates that ground water flows toward the Coeur d'Alene River and confirms Norbeck's (1974) findings. Ground-water gradients in the vicinity of Killarney Lake are very low. This information, coupled with estimates of hydraulic conductivity and an assumed porosity of about 40 percent, based on estimates made by Todd (1959) for clay and silt, indicates that ground-water velocities in the valley sediments are extremely slow and less than  $10^{-4}$  ft/d. Thus, even though ground water discharges to the river, the volume of discharge is very small. Assuming the lithology of the valley fill materials is homogeneously fine grained, the sediments are 400 ft thick,  $k = 0.03$  ft/d, and the gradient is 0.0015, then discharge to the river in the 4-mi reach between site S1 and the dredged channel (fig. 2) would be about 2,800 gal/d.

The water-level mound shown in figures 3 and 4 between Killarney Lake and site S4 on the Coeur d'Alene River may be caused by the inflow of surface water during times of high river stage into the wetland east of a dike shown in figure 1. The water-level altitude in MW4 was higher than altitudes at either Killarney Lake or the river during March and May 1990. After water enters the wetland, the low hydraulic conductivity of wetland sediments prevents rapid drainage. Heterogeneities in the sediment lithology (for example, tighter clays in certain locations) also could account for observed differences in water-level altitudes in the monitoring wells.

The relations among the wetland, Killarney Lake, and the river are indicated by the altitude of ground water in the valley sediments (figs. 3, 4) and the altitude of water in the lake and river. In March and May 1990, the lake-surface altitude of Killarney Lake was about the same as the altitude of ground water in the valley sediments in the wetland but was higher than the river stage. However, several days before the May measurement, the river apparently flowed at a higher stage and emptied into the lake and wetland through the depression downstream from site S4 (fig. 2). As river discharge and, therefore, river stage, slowly lowered, the lake eventually discharged to the river. On May 30, 1990, water was observed flowing from Killarney Lake into the wetland across the dike (fig. 5). The lake-surface altitude also was slightly higher than the river stage at the outlet of the dredged channel. River stage was based on the average decrease in altitude between S1 and S3 and estimated to be about 2,130 ft. The presence of the dredged channel between the Coeur d'Alene River and Killarney Lake indicates that, at times of low or moderate river stage, the lake empties into the river, and at times of high river stage, the river drains to the lake.

However, downstream from Rose Lake, valley sediments are probably finer grained than upstream sediments and similar to sediments near Killarney Lake. Because the Coeur d'Alene River is often in backwater from Coeur d'Alene Lake as far upstream as Rose Lake, evaluation of river gains and losses is extremely difficult. On the basis of available data, the lower Coeur d'Alene River gains from ground water in valley sediments. Gains are probably negligible (as demonstrated in previous paragraphs) because of the low transmissivity of the fine-grained sediments.

The lake, wetland, and river are a dynamic system. Ground water in the valley sediments, the principal topic of this study, is essentially "trapped" for long



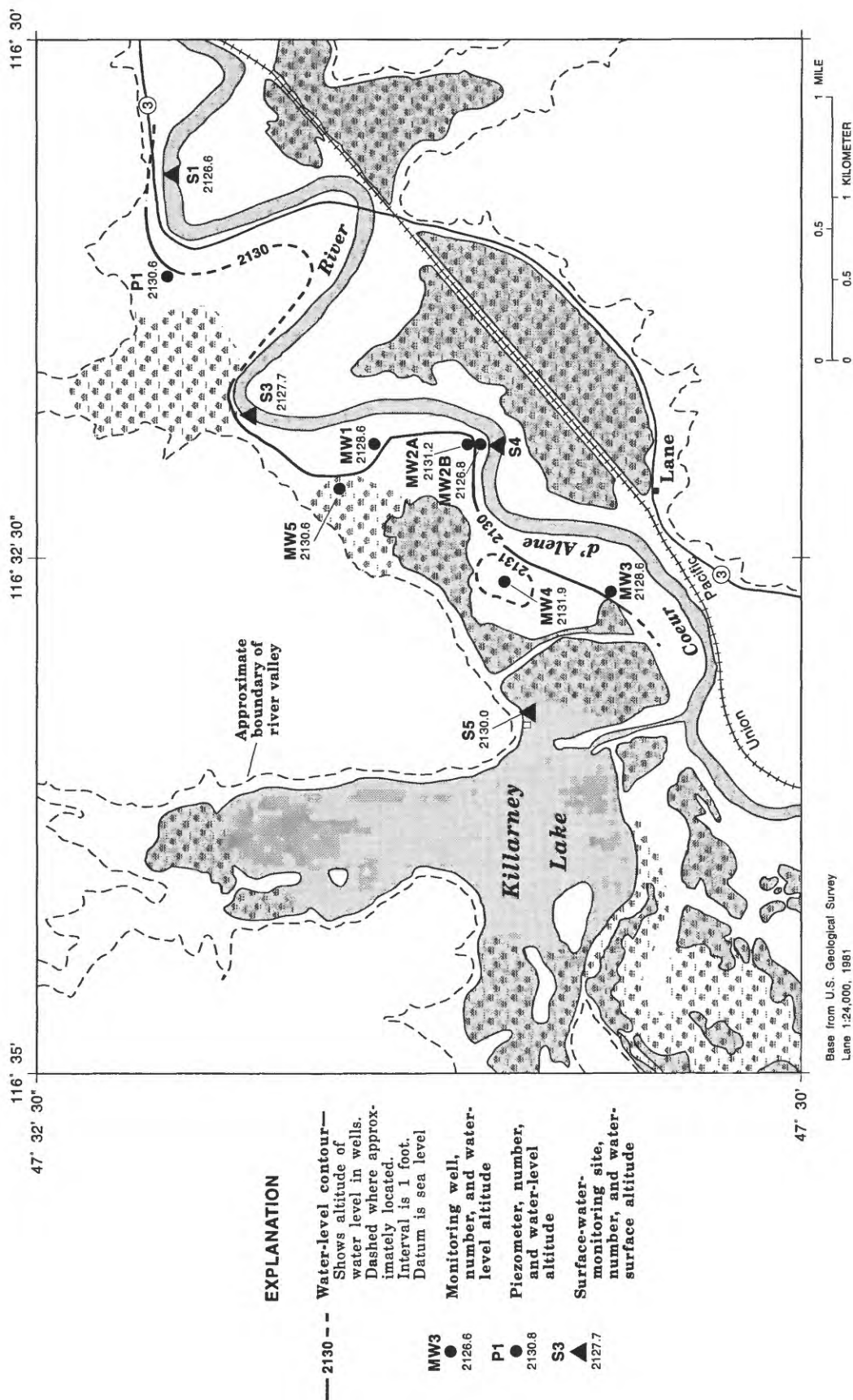


Figure 3. Altitude of ground water in the valley sediments, March 1990.

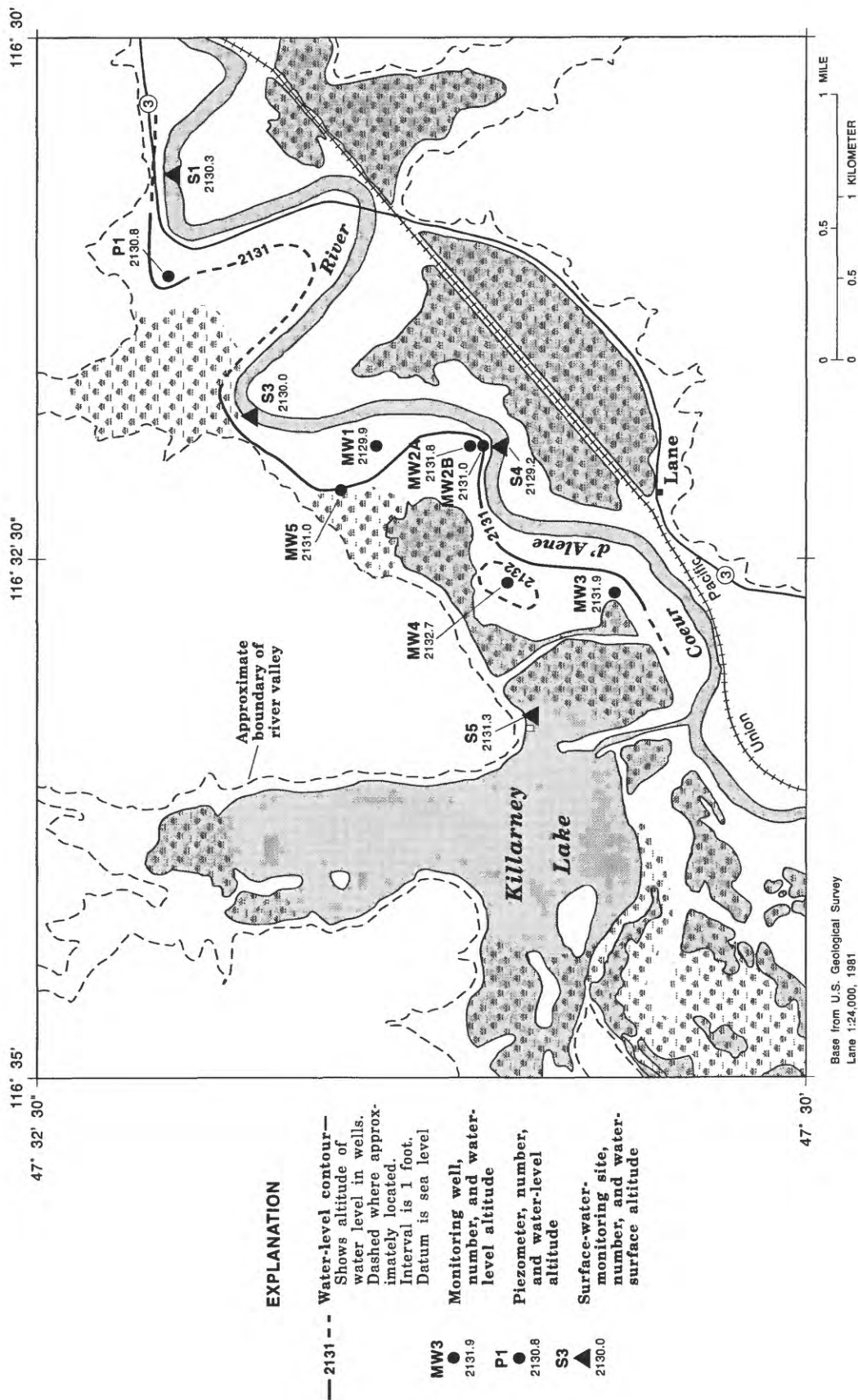


Figure 4. Altitude of ground water in the valley sediments, May 1990.



**Figure 5.** Water flowing from Killarney Lake (left) to wetland (right), May 30, 1990.

periods of time and, therefore, is not readily exchanged with either the river or lake. The valley sediments frequently are flooded during high river stage, particularly during spring snowmelt and periodically throughout the spring. After the river stage drops, some water trapped in topographic lows on the flood plain percolates slowly into the sediments, but most evaporates, particularly in late spring and early summer.

As river stage drops, some ground water (although practically negligible quantities) flows laterally to the river. Ground-water velocities are extremely slow—water moving through the shallow sediments from MW5 to MW1 (approximately 1,500 ft) under a gradient of 0.0015 would take approximately 500,000 years, assuming a porosity of about 40 percent and hydraulic conductivity of 1 ft/d. Measured hydraulic conductivity was much less than 1 ft/d. As the river rises and falls, the shallow ground-water system, particularly the upper few feet, is constantly undergoing mixing of river water or precipitation with water moving downward from the previous occurrence of recharge. The head difference of about 5 ft between MW2A and MW2B demonstrates downward movement and supports this interpretation.

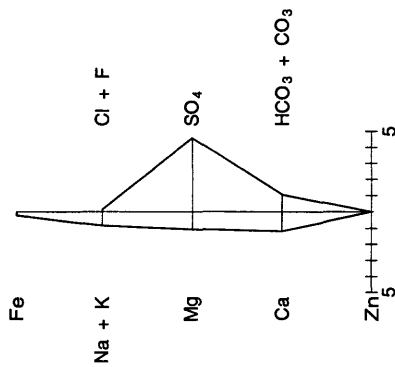
Periodic flooding and the low hydraulic conductivity of valley sediments account for the downward gradient observed in MW2A and MW2B. Water in the valley sediments is always in flux and essentially never equilibrates, making definition of the water table difficult. The low water-table gradient shown in figures 3 and 4 strongly indicates that water in valley sediments underlying the wetland has little or no hydrologic influence on either the river or lake.

The relation between water in the valley sediments and water in the underlying bedrock is not known. Although most residents in the vicinity of Killarney Lake have wells completed in fractured bedrock, none of the wells on the flood plain reached bedrock. Without additional data on the hydraulic properties of the underlying bedrock, the relation between water in the unconsolidated valley sediments and water in the bedrock cannot be evaluated.

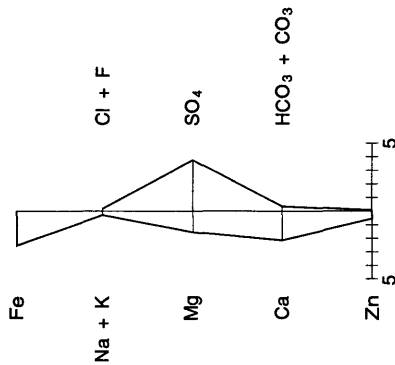
## GROUND-WATER QUALITY

A survey of ground-water quality was limited to water in shallow sediments underlying the wetland east of the dike near Killarney Lake (fig. 2). Survey results indicate that water quality in the valley sediments is highly variable. This is partly the result of very slow movement of water through the valley sediments and partly the result of hydrologic and geochemical conditions. Water-chemistry data from four monitoring wells and Killarney Lake near the boat ramp (S5, fig. 2) are given in table 7 (back of report). In MW2A, MW2B, MW4, and MW5, field specific conductance ranged from 496 to 2,800  $\mu\text{S}/\text{cm}$ ; field pH (standard units) ranged from 6.2 to 7.3; and field alkalinity ranged from 18 to 212 mg/L. Water from the Coeur d'Alene River, collected for comparative purposes on March 8, 1990, was characterized by a specific conductance of 66  $\mu\text{S}/\text{cm}$ , a pH of 7.3, and an alkalinity of 26 mg/L. Water from Killarney Lake near the boat ramp had a specific conductance of 54  $\mu\text{S}/\text{cm}$  and a pH of 7.0, similar to water in the Coeur d'Alene River. Water types, as characterized by Stiff diagrams (fig. 6), also

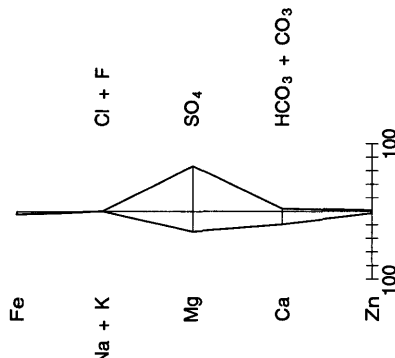
(MW2A) 48N-2W-12CAD2  
3/21/90



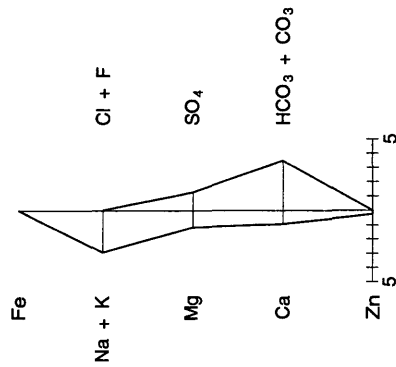
(MW2B) 48N-2W-12CAD1  
3/21/90



(MW4) 48N-2W-11DDA1  
3/22/90



(MW5) 48N-2W-12BAC1  
3/21/90



Coeur d'Alene River near Cataldo  
3/8/90

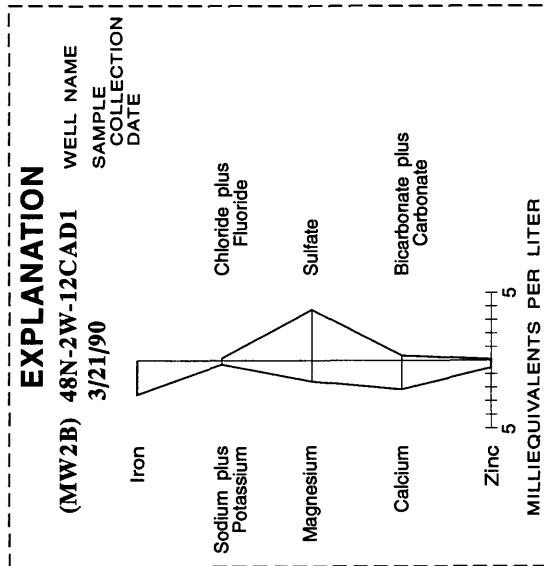
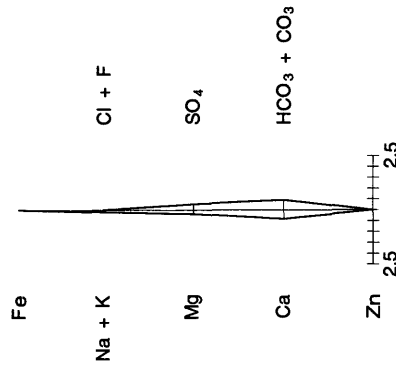


Figure 6. Stiff diagrams showing chemical water types. (Diagrams are at variable scales)

indicate that the major ionic composition of ground water in the valley sediments is variable, whereas surface water (Coeur d'Alene River at Cataldo) is a calcium-bicarbonate type.

Variability of ground-water quality in this area probably is the result of (1) precipitation and periodic inundation of valley sediments by relatively dilute, oxygenated recharge water from the Coeur d'Alene River—data collected between October 1986 and May 1989 (fig. 7) indicate that specific conductance of the Coeur d'Alene River at Cataldo did not exceed 180  $\mu\text{S}/\text{cm}$ ; (2) localized differences caused by the variety of chemical and physical properties of the soils and sediments in the valley; and (3) a variety of geochemical reactions that allow desorption and (or) remobilization of trace elements from sediments. Some of the processes that might control ground-water quality are discussed in this section.

Sediments in the lower Coeur d'Alene River Valley are composed primarily of quartz ( $\text{SiO}_2$ ) and siderite ( $\text{FeCO}_3$ ), the chief gangue minerals associated with ores in the Coeur d'Alene Mining District (Reece and others, 1978). The principal ores are galena ( $\text{PbS}$ ) and sphalerite ( $\text{FeZnS}$ ). Zinc and lead sulfides also are present in the valley sediments (Reece and others, 1978). Oxidation of sulfide ore deposits in mined areas is usually the reason for poor water quality. Typically, pH is low and sulfate and trace-element concentrations in mine-waste-affected water are larger than background concentrations. Mining effects on water quality usually are evaluated by describing the oxidation of sulfide minerals in the presence of oxygen-creating acid conditions through hydrolysis of the metal ion. An example using pyrite ( $\text{FeS}_2$ ) is given in a report by Stumm and Morgan (1981, p. 470). The production of acidity through hydrolysis reactions and the precipitation of iron oxyhydroxide creates favorable pH conditions for the dissolution of many trace elements such as cadmium, chromium, lead, zinc, and several others contained in ore deposits.

Oxidation reactions involving sulfides are restricted primarily to sphalerite, galena, and pyrite, which are present in surficial sediments of the wetland. These sulfide minerals probably are in stream-deposited tailings because they are in ore deposits in the Coeur d'Alene Mining District (Fryklund, 1964). Orange-stained wetland soils and water, probably due to precipitation of iron oxyhydroxides, were observed several hundred feet east of the dike (fig. 1). Oxidation of sulfides in valley sediments most likely occurs from land surface to the water table, where oxygen is abundant and several sulfide minerals are present. Orange clays observed from the ground surface to a depth of about 6 ft (table 5, back of report), particularly in MW3 and MW4, indicate aerobic weathering of pyrite. However, water from the four wells measured during this study had pH values greater than 6.2, which indicates no active oxidation or metal hydrolysis reactions. An oxidized rind may have formed on the sulfide minerals and prevented continued oxidation.

Several possible reactions involving cadmium, lead, and zinc sulfides have been summarized by Marcy (1979). Although oxidation of lead sulfide could occur, solubility of lead salts is low and  $\text{Pb}^{++}$  would be less than 0.2 mg/L under oxidizing conditions.  $\text{FeZnS}$ , the other major sulfide mineral present, also could undergo several reactions that are thermodynamically possible. Once  $\text{ZnS}$  has

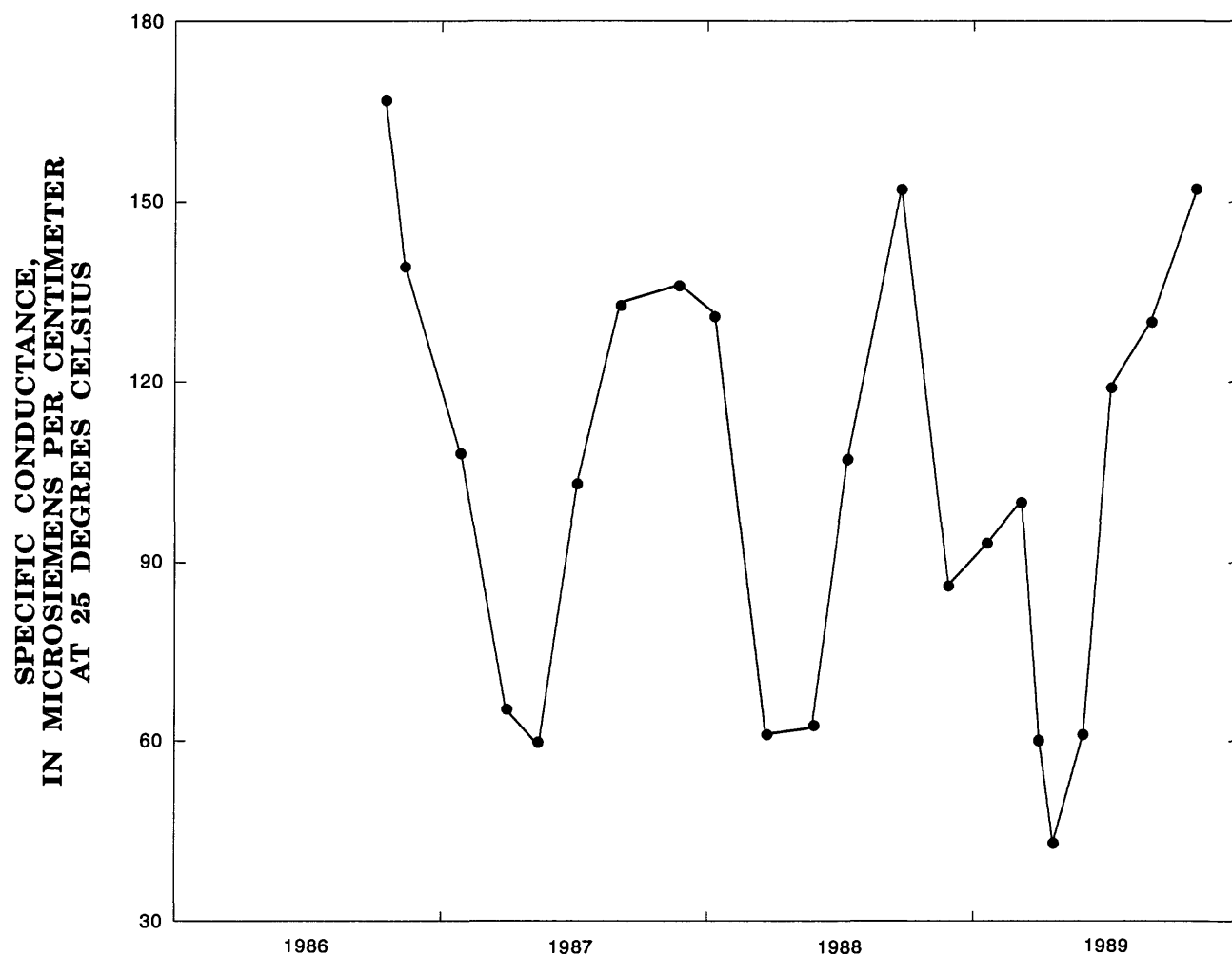


Figure 7. Specific conductance of the Coeur d'Alene River at Cataldo, 1986-89.

oxidized, zinc and sulfate ions are produced. Upon evaporation,  $\text{ZnSO}_4$  is deposited as a salt. A white powder was observed on surficial soils in the wetland east of Killarney Lake. The powder probably was derived from water with large amounts of dissolved cadmium, manganese, sulfate, and zinc. Galbraith (1971) and Marcy (1979) described a similar white powder near Smelterville in the vicinity of mines along the South Fork Coeur d'Alene River. This white powder is composed primarily of sulfate (55 percent), zinc (22 percent), magnesium (4 percent), manganese (3 percent), cadmium (0.4 percent), and minor amounts of chloride bicarbonate, several trace elements, potassium, and sodium (Marcy, 1979). Dissolved trace elements and other inorganic ions derived from oxidation reactions are formed at land surface in the vicinity of tailings and in shallow ground water during spring recharge. The resulting salts are concentrated by evaporative processes in the summer.

Where oxygen is absent, either through depletion by microbial oxidation of carbon or lack of transport from ground surface to deep parts of the aquifer, trace-element chemistry probably is controlled by reducing conditions. Under such conditions, as much as 50 mg/L of iron can be in solution as ferrous iron ( $\text{Fe}^{++}$ ) when pH is between 6 and 8 (Hem, 1985). Manganese ( $\text{Mn}^{++}$ ) behaves similarly—about 55 mg/L can be in solution when pH is between 6.1 and 6.7 (Hem, 1985). Concentrations of iron and manganese in ground water can be larger than those predicted by thermodynamic equilibria theory because of the existence of iron and manganese oxyhydroxides in a colloidal phase or as an organometallic complex.

The existence of organic compounds in the form of humic and fulvic acids, pigments, amino acids, uronic acids, and hydrophilic acids allows for complexation of many trace elements (Thurman, 1985). For example, if each milligram per liter of dissolved organic carbon (DOC) can bind 1  $\mu\text{eq}$  of a trace element, only 2 mg/L of dissolved organic carbon could account for more than 200  $\mu\text{g/L}$  (where 1  $\mu\text{eq}$  of lead = 103.5  $\mu\text{g}$ ) of lead in solution, which is otherwise relatively insoluble except at very low pH (less than 5). Although DOC was not measured during this study, the large concentrations (more than 20 mg/L) of total organic carbon (TOC) in water samples from all monitoring wells indicate that significant amounts of trace elements could be bound by associated DOC. Additional research is needed to determine the importance of organic chelation in controlling trace-element concentrations.

Factors governing the geochemistry of water in the valley sediments near Killarney Lake are complex and a detailed explanation is beyond the scope of this report. However, an examination of chemical data for water and aquifer material from monitoring wells (table 3) implies that dissolution of iron and manganese oxides controls concentrations of cadmium, copper, iron, lead, and zinc. A positive correlation ( $p < 0.05$ ), using a Spearman correlation analysis (Conover, 1980), exists between dissolved manganese and each trace element in the soil, as well as pH and alkalinity (table 3). Manganese is the only dissolved trace element that is positively correlated to all trace elements in the soil. These data indicate that as manganese goes into solution, probably as  $\text{Mn}^{++}$ —typically the most common form of the ion (Hem, 1985)—each trace element is desorbed from the manganese oxide and also enters into solution. Dissolution of either manganese or iron oxyhydroxides can increase concentrations of other trace elements in the



Table 3. Spearman correlation matrix for chemical properties, dissolved constituents, and dissolved trace-element concentrations in soils from MW2A, MW2B, MW4, and MW5

[\*, correlation significant at 10 percent ( $\alpha = 0.10$ ); mg/L, milligrams per liter;  $\mu\text{g/L}$ , micrograms per liter;  $\mu\text{g/g}$ , micrograms per gram]

	pH (stand- ard units)	Alka- linity (mg/L as $\text{CaCO}_3$ )	Nitro- gen, ammo- nia, dis- solved (mg/L)	Sulfate, dis- solved (mg/L)	Cad- mium, dis- solved ( $\mu\text{g/L}$ )	Iron, dis- solved ( $\mu\text{g/L}$ )	Lead, dis- solved ( $\mu\text{g/L}$ )	Man- ga- nese, dis- solved ( $\mu\text{g/L}$ )	Zinc, dis- solved ( $\mu\text{g/L}$ )	Cad- mium, in soil ( $\mu\text{g/g}$ )	Lead, in soil ( $\mu\text{g/g}$ )	Zinc, in soil ( $\mu\text{g/g}$ )	Iron, in soil ( $\mu\text{g/g}$ )
pH	1.0000	*1.0000	*0.80000	0.4000	*0.80000	0.4000	0.63246	*1.00000	*0.80000	*0.94868	*0.80000	*0.80000	*0.80000
Alkalinity	1.0000	1.0000	*8.0000	.4000	*8.0000	.4000	.63246	*1.00000	*8.0000	*9.4868	*8.0000	*8.0000	*8.0000
Nitrogen, ammonia, dissolved	*8.0000	*8.0000	1.0000	*8.0000	*1.0000	*8.0000	*9.4868	*8.0000	*1.00000	.63246	.4000	.4000	.4000
Sulfate, dissolved	.4000	.4000	*8.0000	1.0000	*8.0000	*1.0000	*9.4868	.4000	*8.0000	.31623	.20000	.20000	.20000
Cadmium, dissolved	*8.0000	*8.0000	*1.0000	*8.0000	1.0000	*8.0000	*9.4868	*8.0000	*1.00000	.63246	.4000	.4000	.4000
Iron, dissolved	.4000	.4000	*8.0000	*1.0000	*8.0000	1.0000	*9.4868	.4000	*8.0000	.31623	.20000	.20000	.20000
Lead, dissolved	.63246	.63246	*9.4868	*9.4868	*9.4868	*9.4868	1.00000	.63246	*9.4868	.50000	.31623	.31623	.31623
Manganese, dissolved	1.0000	*1.0000	*8.0000	.4000	*8.0000	.4000	.63246	1.00000	.80000	*9.4868	*8.0000	*8.0000	*8.0000
Zinc, dissolved	*8.0000	*8.0000	*1.0000	*8.0000	*1.0000	*8.0000	*9.4868	*8.0000	1.00000	.63246	.4000	.4000	.4000
Cadmium, in soil	*9.4868	*9.4868	.63246	.31623	.63246	.31623	.50000	*9.4868	.63246	1.00000	*9.4868	*9.4868	*9.4868
Lead, in soil	*8.0000	*8.0000	.4000	.20000	.4000	.20000	.31623	*8.0000	.4000	*9.4868	1.00000	*1.00000	*1.00000
Zinc, in soil	*8.0000	*8.0000	.4000	.20000	.4000	.20000	.31623	*8.0000	.4000	*9.4868	*1.00000	1.00000	*1.00000
Iron, in soil	*8.0000	*8.0000	.4000	.20000	.4000	.20000	.31623	*8.0000	.4000	*9.4868	*1.00000	*1.00000	1.00000

water. Trace elements sorbed to the metal oxide surfaces can be desorbed, which results in an increase in aqueous concentrations (Jenne, 1968). Horowitz (1991) stated that it has long been known that iron and manganese oxides in sediments are excellent scavengers of trace elements from solution. Where geochemical conditions are suitable for dissolution of iron or manganese oxyhydroxides, the sorbed metals can be released, or desorbed, back into the water. Correlations presented in table 3 additionally indicate that zinc is correlated to pH, alkalinity, dissolved ammonia, sulfate, and all dissolved trace elements shown, indicating that all minerals entering into solution are associated with the zinc-bearing mineral being desorbed.

Large concentrations of trace elements in water in the tailings-rich sediments are persistent for long periods of time. Oxides of iron and manganese in the poorly transmissive sediments prevent dynamic mixing of oxygenated recharge water with older water at depth. At depth, reducing conditions in the organic-rich sediments can be attributed to microbial depletion of oxygen. In addition, dissolution of manganese oxides and accompanying desorption of associated trace elements could account for large concentrations of trace elements in the water where concentrations in the sediments are practically at background levels.

More information on mineralogic identification and elemental analysis of valley sediments is needed to confirm postulated redox and sorption/desorption mechanisms. This information will assist in evaluating the feasibility of controlling concentrations of trace elements in ground water. If large concentrations of trace elements are extensive in shallow soils, where oxygen is abundant for acid-producing sulfide-oxidation reactions (Keeley, 1976; Roy F. Weston, Inc., 1989), and if iron or manganese oxyhydroxides are extensive and important in controlling trace-element chemistry of the oxygen-deficient ground water in the valley sediments, there may be no feasible way to control trace-element concentrations in ground water in the sediments. The described mechanisms would be important factors in evaluating environmental effects of tailings in the valley sediments. The chemistry of water from four monitoring wells installed in the study area—MW2A, MW2B, MW4, and MW5—is described in the following paragraphs.

Water from MW5, located near the valley wall (fig. 2), appears to be least affected by mine tailings (Pywell muck, fig. 2). Water from this well is characterized by moderate specific conductance (496  $\mu\text{S}/\text{cm}$ ); a large concentration of dissolved oxygen (2.8 mg/L); and concentrations of most trace elements (3  $\mu\text{g}/\text{L}$  of cadmium, less than 10  $\mu\text{g}/\text{L}$  of lead, and 880  $\mu\text{g}/\text{L}$  of zinc) that are less than U.S. Environmental Protection Agency (1990) maximum contaminant levels (table 4). The water is a sodium-bicarbonate-sulfate type (fig. 6), indicating that other factors, in addition to mine tailings, control water quality. Discharge of ground water from rocks forming the valley wall could account partially for the observed ionic composition. Water containing more calcium or other cations and sulfate would be expected if mine tailings were the major controlling factor. Dissolved solids in shallow ground water in the wetland indicates oxidizing conditions. The corresponding small concentrations of most trace elements and pH of about 6.9 indicate a lack of oxidizable metal sulfides. Although concentrations of most

trace elements were less than U.S. Environmental Protection Agency (1990) primary drinking-water regulations (standards that are enforceable for public water supplies), the 330  $\mu\text{g/L}$  of arsenic was much greater than the 50  $\mu\text{g/L}$  U.S. Environmental Protection Agency maximum contaminant level (MCL) for this constituent (table 4). Arsenopyrite and pyroclastic rocks common in the Western United States (Welch and others, 1988) could be the source of dissolved arsenic. Volcanic ash is present in soils of the area (U.S. Soil Conservation Service, 1981). However, the presence of measurable concentrations of sulfide (0.6 mg/L) and dissolved ammonia-nitrogen (0.45 mg/L), and concentrations of dissolved iron (4,500  $\mu\text{g/L}$ ) and manganese (4,700  $\mu\text{g/L}$ ) that exceed U.S. Environmental Protection Agency secondary drinking-water regulations (table 4) indicate reducing conditions. The mixing of different water types, which would create nonequilibrium conditions, or the existence of mildly oxidizing or reducing conditions could account for the observed water chemistry.

**Table 4.** U.S. Environmental Protection Agency maximum contaminant levels of selected trace elements in drinking water

[\*, primary standard]

Trace element	Maximum contaminant level (micrograms per liter)
Arsenic	50*
Cadmium	10*
Iron	300
Lead	50*
Manganese	50
Mercury	2*
Zinc	5,000

Water from MW2A is from the upper few feet of the saturated zone and, on the basis of small concentrations of ammonia (0.06 mg/L) and detectable dissolved oxygen (0.9 mg/L), reflects oxidizing conditions. The specific conductance of this water was moderate (514  $\mu\text{S/cm}$ ). Concentrations of arsenic, cadmium, lead, and zinc were less than 1990 U.S. Environmental Protection Agency MCL's, whereas iron and manganese concentrations were much greater (7,000 and 1,200  $\mu\text{g/L}$ , respectively). Oxidizing conditions at the observed pH (6.2) do not allow oxides of either manganese or iron to dissolve at concentrations sufficient to codissolve other trace elements present in the sediments. Trace-element concentrations (table 7, back of report) are less than background concentrations and indicate that

tailings are not present in the vicinity of this well. Although multiple samples were not collected, seasonal concentrations of trace elements could conceivably be larger when conditions are favorable for dissolution of iron and manganese oxides. Such conditions presumably would be in the summer when oxygenated recharge water is not available and oxygen is depleted through microbial respiration or other processes.

Water from MW4 exhibits extreme effects of mine tailings on water quality. Reducing conditions are indicated by the large concentration of dissolved ammonia, calcium-sulfate type water with large concentrations of sulfate (3,000 mg/L) and dissolved solids (3,480 mg/L). Dissolution of iron and manganese oxyhydroxides could release large concentrations of trace elements. The pH of 7.3 indicates that most of the sulfides deposited during floods are almost entirely weathered to oxidation products (for example, iron or manganese oxyhydroxides). Concentrations of cadmium and lead in water from MW4 exceeded the U.S. Environmental Protection Agency primary MCL's, whereas iron, manganese, and zinc exceeded the secondary MCL's established for these constituents (table 4).

The white powder on sediments in the Coeur d'Alene River Valley is primarily zinc sulfate (Marcy, 1979) and indicates that once dissolved salts of zinc and other metals have formed by an oxidation reaction, these salts can enter solution seasonally and for indefinite periods of time, particularly in the absence of a flushing and removal mechanism. Zinc sulfate is highly soluble in cold water (Weast, 1984) and can enter solution during wet periods and be concentrated by evaporative processes during the summer. Because of the high toxicity of zinc to aquatic organisms, particularly in water with hardness of less than 100 mg/L, the production of soluble zinc salts poses extreme hazards to both plants and animals.

The large concentrations of several trace elements (31 ppm cadmium; 100 ppm copper; 5,000 ppm lead; 84,000 ppm iron; and 110,900 ppm zinc) in the sediment sample from this borehole strongly indicate the presence of mine tailings. Similar concentrations in mine-contaminated sediments were reported in several previous studies (Keeley, 1975; Reece and others, 1978; Roy F. Weston, Inc., 1989). The orange clays observed in these samples to a depth of about 6 ft (table 5, back of report) indicate the presence of large amounts of iron and manganese oxyhydroxides, the weathering products from metal sulfide oxidation.

Water from MW2B exemplifies ground-water quality in valley sediments and reflects reducing geochemical conditions. Dissolved-oxygen concentrations were small or absent (0.1 mg/L or less), and ammonia (1.1 mg/L) and trace-element concentrations (tens to thousands of micrograms per liter) were typically large. Again, the mechanism that probably best explains the observed water chemistry is dissolution of iron and manganese oxyhydroxides and consequent codissolution of sorbed trace elements under reducing conditions with a water pH slightly lower than neutrality (6.5). The iron-sulfate type water (fig. 6) in this well also strongly indicates reducing conditions. Nevertheless, sediments from this borehole did not indicate the presence of tailings. With the exception of iron, concentrations of other trace elements analyzed (cadmium, copper, lead, and zinc) were less than 100 mg/kg (or parts per million). Significant concentrations

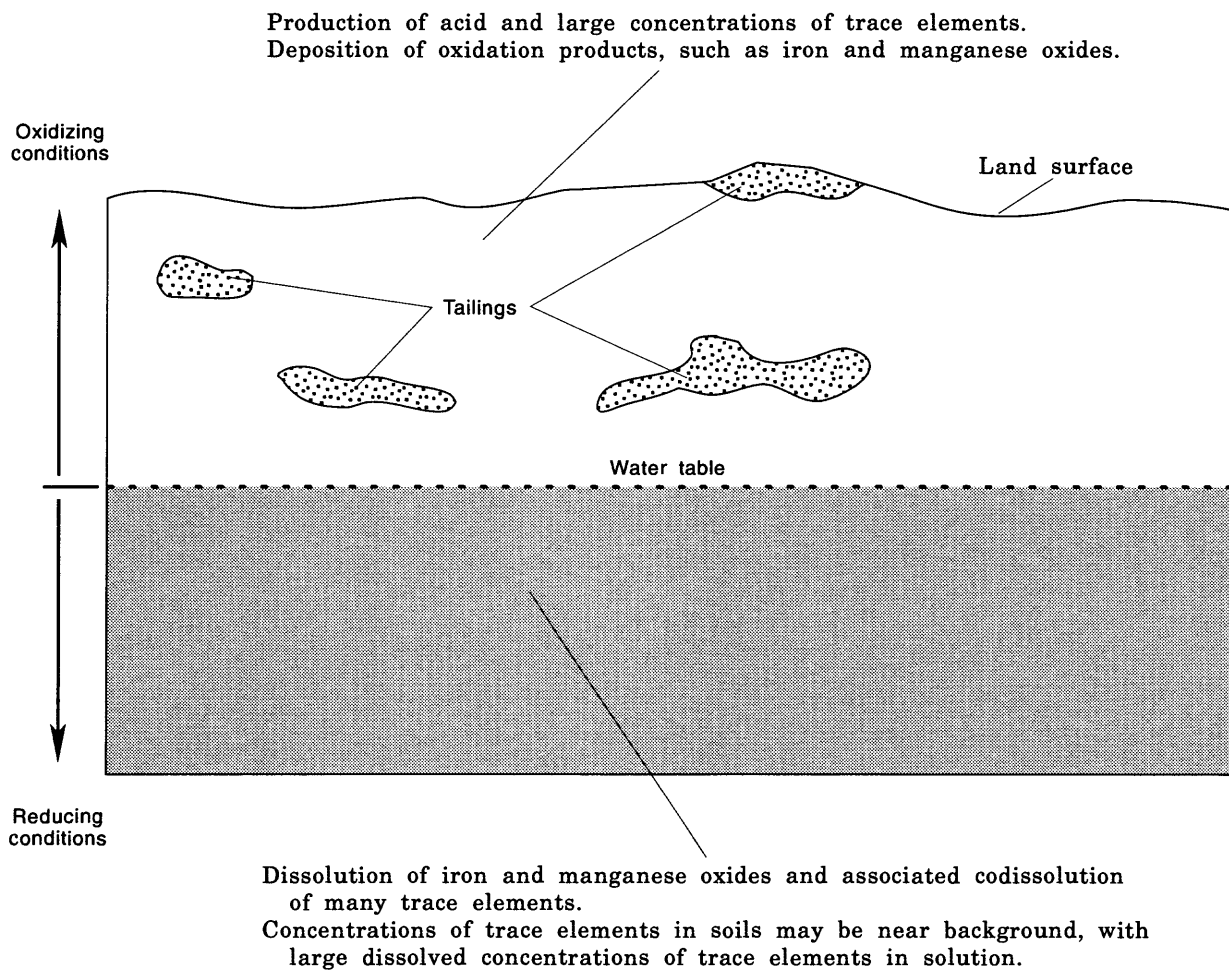
of cadmium (11 µg/L) and zinc (9,300 µg/L) in water from MW2B indicate that large dissolved concentrations of trace elements are possible where iron and manganese oxyhydroxides can dissolve, even when background concentrations in the sediments are small.

Ground-water quality in the vicinity of Killarney Lake is variable and concentrations of several trace elements exceeded the U.S. Environmental Protection Agency's primary or secondary MCL's (table 4). Sources of these trace elements, including arsenic, cadmium, iron, lead, manganese, and zinc are (1) valley sediments contaminated with mine tailings; (2) naturally occurring material derived from Belt Series rocks; and (3) possibly, volcanic ash deposits. Two classes of chemical reactions characterize the geochemistry of water in the valley sediments. The first, sulfide oxidation, occurs when sulfide deposits in the unsaturated zone are exposed to air and oxygenated water (fig. 8). Trace elements are released when hydrogen ions are released into solution, lowering the pH sufficiently to dissolve many trace elements from the sulfides. These reactions are especially prevalent in the wetland where sulfides from tailings in the shallow sediments are exposed to periodic flooding. The second, and probably the most important reaction process in ground water, occurs where (1) sediments are always saturated; (2) dissolved carbon is abundant; (3) hydraulic conductivity of the sediments is low; and (4) flushing with oxygenated recharge water is infrequent, creating a geochemically reducing environment. These conditions allow dissolution of manganese and iron oxides, which probably are present throughout the lower Coeur d'Alene River Valley (perhaps partially as oxidation products from sulfides in the upper 10 ft or so of the valley sediments). The dissolution of manganese and iron oxides allows several trace elements that are sorbed on oxide surfaces to dissolve when the oxides are dissolved (fig. 8). Further research is necessary to confirm mineral phases present in the valley sediments and to fully evaluate the extent and environmental effects associated with the quality of water in the valley sediments.

## WATER-QUALITY CONCERNS

Water in valley sediments near Killarney Lake is not suitable for drinking on the basis of MCL's. Water in wells installed in valley sediments near Killarney Lake for this study contained concentrations of arsenic, cadmium, and lead that exceeded current (1990) primary MCL's. At present, water from valley sediments in the Killarney Lake area does not appear to be used by humans because few, if any, wells are completed in the valley sediments. However, downstream from where the South Fork Coeur d'Alene River enters the valley near Cataldo (fig. 1), ground water is used for domestic purposes (Norbeck, 1974). Even though Norbeck (1974) had ground-water samples analyzed for cadmium and lead with negative results for most wells, the detection limit was 20 µg/L for cadmium and 100 µg/L for lead, which is two times greater than 1990 primary MCL's for these constituents. Water in several supply wells contained concentrations of cadmium and lead that exceeded MCL's.

Even though water in valley sediments along the Coeur d'Alene River near Killarney Lake contains large concentrations of various trace elements, the effect of ground-water discharge on quality of water in the river and in Killarney Lake



**Figure 8.** Conceptualization of major reaction processes controlling water chemistry in valley sediments near Killamey Lake.

probably is insignificant because of the small quantity of water exchanged. Additional hydraulic, augering, water sampling, and geophysical work is needed to confirm this assessment. Effects of ground-water discharge on water quality in the Coeur d'Alene River cannot be verified unless the river is monitored in the Killarney Lake area. Even then, it is unlikely that effects would be measurable, because flow in the river is so much greater than the estimated ground-water discharge. Even at low flow, at least 323 Mgal/d (about 500 ft<sup>3</sup>/s) flows past Cataldo, upstream from Killarney Lake, compared to an estimated 3,000 gal/d of ground-water discharge to a 4-mi reach of the river. Because ground-water discharge to either the river or the lake is minimal, direct effects of ground-water quality on fish and wildlife habitat are probably also minimal in the vicinity of Killarney Lake. The major chemical effect in the river would be precipitation of iron and manganese hydroxides onto the streambed and banks as ground water discharges to the river. The oxidation of sulfides in the wetland could affect wildlife and plants, and the dissolution of oxides under reducing conditions could allow large concentrations of toxic trace elements to dissolve at the sediment/water interface of lateral lakes and Coeur d'Alene Lake.

## SUMMARY AND CONCLUSIONS

The flood plain of the Coeur d'Alene River, on which Killarney Lake is located, has been affected by mine tailings from the Coeur d'Alene Mining District. Killarney Lake is used extensively by the public for recreational activities and by waterfowl for nesting. The U.S. Bureau of Land Management, which manages several parcels of land in the vicinity of Killarney Lake, is concerned that ground water in valley sediments might be contaminated and pose human health and environmental concerns.

Data from seven shallow wells (3 to 33 ft deep) installed for this study indicate that shallow valley sediments in the vicinity of Killarney Lake are composed of clay and silt with a hydraulic conductivity between  $1.0 \times 10^{-2}$  and  $6.3 \times 10^{-2}$  ft/d. Small hydraulic gradient (0.0015) and low hydraulic conductivity of the valley sediments indicate that ground water, although containing large concentrations of certain trace elements, probably has little effect on the chemical quality of water in either Killarney Lake or the Coeur d'Alene River. The volume of ground water discharged to surface water is small. Discharge to the river between S1 and the dredged canal that connects the Coeur d'Alene River with Killarney Lake was calculated to be about 2,800 gal/d, compared to hundreds of millions of gallons per day flowing down the Coeur d'Alene River during low-flow periods. However, to better define the hydrogeology of the area, more coring and geophysical work would be necessary.

Ground-water quality in valley sediments along the Coeur d'Alene River in the vicinity of Killarney Lake is highly variable because of frequent flushing with river water and precipitation in shallow, aerated zones and lack of aerated recharge water in deeper zones. Slow ground-water velocities (less than  $10^{-3}$  ft/d) in the fine-grained valley sediments and varied lithologic materials allow the existence of many different water types under different geochemical conditions. Ground water will contain detectable concentrations of constituents where there is a source and where geochemical conditions are favorable for mineral

dissolution and other geochemical processes. In general, two classes of chemical reactions characterize geochemistry of ground water in the valley sediments; both allow large concentrations of trace elements to exist in solution: (1) oxidation of metal sulfides where sulfide deposits are exposed to air and oxygenated water; and (2) dissolution of iron and manganese oxides under reducing conditions and codissolution of sorbed trace elements from the oxyhydroxide surface.

Because of the large TOC in water samples (more than 20 mg/L), microbial respiration processes associated with metabolism of carbon compounds could cause depletion of dissolved oxygen and create a reducing environment. Although not measured, large concentrations of dissolved organic carbon could bind metal ions—as much as 1  $\mu$ eq/L of metal per mg/L of DOC can be bound.

Ground water in the vicinity of Killarney Lake contains concentrations of arsenic, cadmium, and lead that exceed primary MCL's for drinking water established by the U.S. Environmental Protection Agency; therefore, water from the valley sediments may pose potential human health concerns if used for drinking. Concentrations of iron, manganese, and zinc exceed secondary MCL's. Currently (1990), few, if any, wells are completed in valley sediments near Killarney Lake.

Because of the dispersed nature of sediments contaminated with mine tailings, and because large concentrations of trace elements are possible in water in valley sediments in most of the study area and along the main stem of the Coeur d'Alene River, long-term monitoring of the area around Killarney Lake does not appear warranted. However, the U.S. Bureau of Land Management, or possibly other Federal or State agencies involved with environmental regulation, may wish to confirm possible contamination of water in the valley sediments. Confirmation would require installation of several wells screened at various depths and additional water-quality and sediment-core sampling.

Water supplies for campgrounds or recreation areas cannot be obtained from the valley sediments without posing possible health risks because water from this source may contain concentrations of trace elements that exceed primary and secondary drinking-water regulations established by the U.S. Environmental Protection Agency. If wells intended for public supply are completed in Belt Series rocks, detailed water-quality sampling for arsenic, cadmium, lead, and zinc would provide information necessary to evaluate possible health risks. Dissolved oxygen and major ions such as calcium, magnesium, sodium, potassium, bicarbonate, sulfate, chloride, ammonia, and total organic carbon also would provide indications of deleterious water quality and could be used to evaluate possible sources for identified contamination problems. Because of possible localized fractures in the bedrock and possible movement of contaminated water from sediments into the bedrock, wells would be less likely to produce contaminated water if located as far from lake or valley sediments as possible. One or two wells completed in the bedrock would be necessary to assess the hydraulic connection between the valley sediments and the bedrock.



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## SUPPLEMENTARY INFORMATION

**Table 5.** Well logs and well completion records

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MW1

Location .....	48N-2W-12BAD1
Site identification number .....	473130116315501
Total well depth.....	18 feet
Casing type.....	PVC, Schedule 40
Casing diameter.....	1.5 inches
Screen type.....	PVC, slotted
Screen opening .....	0.010 inch
Open interval.....	16–18 feet
Drilling method .....	Power auger
Date completed.....	3-7-90

Log description	Interval (feet)
Clay, red, wet.....	0 – 1
Silt/clay, fine.....	1 – 15
Clay, gray, very tight.....	15 – 21

## MW2A

Location .....	48N-2W-12CAD1
Site identification number .....	473105116315801
Total well depth.....	20 feet
Casing type.....	PVC, Schedule 40
Casing diameter.....	2 inches
Screen type.....	PVC, slotted
Screen opening .....	0.020 inch
Open interval.....	18–20 feet
Drilling method .....	Power auger
Date completed.....	3-7-90

Log description	Interval (feet)
Clay, red.....	0 – 0.5
Silt/clay, dark brown, fine .....	.5 – 4.5
Silt, light brown .....	4.5 – 20

**Table 5.** Well logs and well completion records—Continued

## MW2B

Location .....	48N-2W-12CAD2
Site identification number .....	473105116315002
Total well depth.....	33 feet
Casing type.....	PVC, Schedule 40
Casing diameter.....	2 inches
Screen type.....	PVC, slotted, stainless/galvanized
Screen opening .....	0.020 inch
Open interval.....	27 feet; 30–33 feet
Drilling method .....	Power auger
Date completed.....	3-8-90

Log description	Interval (feet)
Clay, red.....	0 – 0.5
Silt, dark brown.....	.5 – 4.5
Silt, light brown.....	4.5 – 21
Silt, gray, with fine sand/clay.....	21 – 35

## MW3

Location .....	48N-2W-14AAD1
Site identification number .....	473040116324001
Total well depth.....	8 feet
Casing type.....	PVC, Schedule 40
Casing diameter.....	2 inches
Screen type.....	PVC, slotted
Screen opening .....	0.020 inch
Open interval.....	6–8 feet
Drilling method .....	Hand auger
Date completed.....	3-9-90

Log description	Interval (feet)
Clay, red.....	0 – 3
Clay, gray, fine, silty.....	3.0 – 4.5
Clay, dark gray, with streaks of orange.....	4.5 – 6.0
Silt/clay, light gray, very fine-grained, tight...	6.0 – 8.0

**Table 5.** Well logs and well completion records—Continued

MW4	
Location .....	48N-2W-11DDA1
Site identification number .....	473100116323501
Total well depth.....	8 feet
Casing type.....	PVC, Schedule 40
Casing diameter.....	2 inches
Screen type.....	PVC, slotted
Screen opening .....	0.020 inch
Open interval.....	6–8 feet
Drilling method .....	Hand auger
Date completed.....	3-9-90
Log description	Interval (feet)
Clay, orange .....	0 – 1
Clay, orange, with fine silt/sand.....	1 – 4
Clay, gray, silty, fine, water-saturated .....	4 – 8
MW5	
Location .....	48N-2W-12BAC1
Site identification number .....	473133116321001
Total well depth.....	8.5 feet
Casing type.....	PVC, Schedule 40
Casing diameter.....	2 inches
Screen type.....	PVC, slotted
Screen opening .....	0.020 inch
Open interval.....	6.5–8.5 feet
Drilling method .....	Hand auger
Date completed.....	3-9-90
Log description	Interval (feet)
Clay, orange, wet .....	0 – 1.5
Silt/clay, dark brown, cohesive, organic .....	1.5 – 3.5
Clay, light medium-brown .....	3.5 – 7.5
Clay, light greenish-gray .....	7.5 – 8.5

**Table 6. Slug-test data**

[ $h$ , instantaneous water level, in feet below measuring point;  $H$ ,  $h$ -SWL (static water level), in feet;  $H_0$ ,  $H$  at  $t = 0$ , in feet;  $T$ , transmissivity, in feet squared per day;  $t$ , time, in seconds;  $r$ , radius of well, in inches;  $k$ , hydraulic conductivity, in feet per day]

MW2A				MW2B				MW5			
Time (seconds)	$h$ (feet)	$H$ (feet)	$H/H_0$	Time (seconds)	$h$ (feet)	$H$ (feet)	$H/H_0$	Time (seconds)	$h$ (feet)	$H$ (feet)	$H/H_0$
0	18.59	13.02	1.00	0	29.20	13.41	1.00	0	10.93	6.67	1.00
300	18.50	12.93	.99	300	29.09	13.30	.99	300	10.76	6.50	.97
600	18.27	12.70	.97	600	29.01	13.22	.99	600	10.60	6.34	.95
900	18.15	12.58	.96	900	28.95	13.16	.98	900	10.49	6.23	.93
1,200	17.98	12.41	.95	1,200	28.86	13.07	.98	1,200	10.35	6.09	.91
1,500	17.80	12.23	.94	1,500	28.77	12.98	.97	1,500	10.24	5.98	.90
1,800	17.65	12.08	.93	1,800	28.69	12.90	.96	1,800	10.07	5.81	.87
2,100	17.48	11.91	.91	2,100	28.61	12.82	.96	2,100	9.87	5.61	.83
2,400	17.33	11.76	.90	2,400	28.56	12.77	.95	2,400	9.71	5.45	.81
2,700	17.13	11.56	.89	2,700	28.49	12.70	.95				
3,000	17.04	11.47	.87	3,000	28.40	12.61	.94				
3,300	16.89	11.32	.87	3,300	28.33	12.54	.93				
SWL = 5.57 feet below measuring point				<sup>2</sup> SWL = 15.79 feet below measuring point				SWL = 4.26 feet below measuring point			
<sup>1</sup> $Tt/r^2 = 1$ at 35,000 seconds				<sup>1</sup> $Tt/r^2 = 1$ at 50,000 seconds				<sup>1</sup> $Tt/r^2 = 1$ at 10,700 seconds			
$T = 0.071 \text{ ft}^2/\text{d}$ $k = 3.5 \times 10^{-2} \text{ ft/d}$				$T = 0.050 \text{ ft}^2/\text{d}$ $k = 1.0 \times 10^{-2} \text{ ft/d}$				$T = 0.125 \text{ ft}^2/\text{d}$ $k = 6.3 \times 10^{-2} \text{ ft/d}$			

<sup>1</sup>From Cooper and others (1967).

<sup>2</sup>Not static.

**Table 7. Chemical analyses of water samples**

[Record number, a unique identification number assigned to each water-quality record in the U.S. Geological Survey, Idaho District, QWDATA database; time of collection, in military hours; value, actual concentration of constituent or property, in units shown under column, "Constituent analyzed"; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25°C; mg/L, milligrams per liter; µg/L, micrograms per liter; <, less than]

Record number	99001625
Site identification number	473105116315801
Site location and name	48N-2W-12CAD1 (MW2A)
Date and time of collection	3-21-90, 1810 hrs

Value	Constituent analyzed
514.....	Specific conductance, field (µS/cm)
436.....	Specific conductance, laboratory (µS/cm)
6.2.....	pH, field (standard units)
6.0.....	pH, laboratory (standard units)
5.0.....	Air temperature (°C)
8.0.....	Water temperature (°C)
.9.....	Oxygen, dissolved, field (mg/L)
43.....	Calcium, dissolved (mg/L as Ca)
19.....	Magnesium, dissolved (mg/L as Mg)
5.7.....	Sodium, dissolved (mg/L as Na)
2.0.....	Potassium, dissolved (mg/L as K)
22.....	Bicarbonate, field (mg/L as HCO <sub>3</sub> )
18.....	Alkalinity, field (mg/L as CaCO <sub>3</sub> )
8.0.....	Alkalinity, fixed endpoint titration to pH 4.5, laboratory (mg/L as CaCO <sub>3</sub> )
.8.....	Sulfide, total (mg/L as S)
180.....	Sulfate, dissolved (mg/L as SO <sub>4</sub> )
6.5.....	Chloride, dissolved (mg/L as Cl)
.10.....	Fluoride, dissolved (mg/L as F)
51.....	Silica, dissolved (mg/L as SiO <sub>2</sub> )
357.....	Solids, residue on evaporation at 180°C, dissolved (mg/L)
.01.....	Nitrogen, nitrite, dissolved (mg/L as N)
<.1.....	Nitrogen, nitrite plus nitrate, dissolved (mg/L as N)
.06.....	Nitrogen, ammonia, dissolved (mg/L as N)
.5.....	Nitrogen, ammonia plus organic, dissolved (mg/L as N)
.32.....	Phosphorus, total (mg/L as P)
<.02.....	Phosphorus, dissolved (mg/L as P)
40.....	Aluminum, dissolved (µg/L as Al)
4.....	Antimony, dissolved (µg/L as Sb)
3.....	Arsenic, dissolved (µg/L as As)
25.....	Barium, dissolved (µg/L as Ba)
<.5.....	Beryllium, dissolved (µg/L as Be)
1.0.....	Cadmium, dissolved (µg/L as Cd)
<5.....	Chromium, dissolved (µg/L as Cr)
30.....	Cobalt, dissolved (µg/L as Co)
<10.....	Copper, dissolved (µg/L as Cu)
7,000.....	Iron, dissolved (µg/L as Fe)
<10.....	Lead, dissolved (µg/L as Pb)
6.....	Lithium, dissolved (µg/L as Li)
1,200.....	Manganese, dissolved (µg/L as Mn)
<.1.....	Mercury, dissolved (µg/L as Hg)
<10.....	Molybdenum, dissolved (µg/L as Mo)



Table 7. Chemical analyses of water samples—Continued

Record number	99001625
Site identification number	473105116315801
Site location and name	48N-2W-12CAD1 (MW2A)
Date and time of collection	3-21-90, 1810 hrs

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Value	Constituent analyzed
<1.....	Silver, dissolved (µg/L as Ag)
180.....	Strontium, dissolved (µg/L as Sr)
<6.....	Vanadium, dissolved (µg/L as V)
420.....	Zinc, dissolved (µg/L as Zn)
100.....	Carbon, organic, total (mg/L as C)

Table 7. Chemical analyses of water samples—Continued

Record number	99002054
Site identification number	473105116315002
Site location and name	48N-2W-12CAD2 (MW2B)
Date and time of collection	3-21-90, 1515 hrs

Value	Constituent analyzed
520.....	Specific conductance, field ( $\mu\text{S}/\text{cm}$ )
522.....	Specific conductance, laboratory ( $\mu\text{S}/\text{cm}$ )
6.5.....	pH, field (standard units)
6.2.....	pH, laboratory (standard units)
9.5.....	Water temperature ( $^{\circ}\text{C}$ )
11.0.....	Air temperature ( $^{\circ}\text{C}$ )
.1.....	Oxygen, dissolved, field ( $\text{mg}/\text{L}$ )
24.....	Calcium, dissolved ( $\text{mg}/\text{L}$ as Ca)
13.....	Magnesium, dissolved ( $\text{mg}/\text{L}$ as Mg)
17.....	Sodium, dissolved ( $\text{mg}/\text{L}$ as Na)
3.9.....	Potassium, dissolved ( $\text{mg}/\text{L}$ as K)
66.....	Bicarbonate, field ( $\text{mg}/\text{L}$ as $\text{HCO}_3$ )
54.....	Alkalinity, field ( $\text{mg}/\text{L}$ as $\text{CaCO}_3$ )
<1.....	Alkalinity, fixed endpoint titration to pH 4.5, laboratory ( $\text{mg}/\text{L}$ as $\text{CaCO}_3$ )
.6.....	Sulfide, total ( $\text{mg}/\text{L}$ as S)
220.....	Sulfate, dissolved ( $\text{mg}/\text{L}$ as $\text{SO}_4$ )
3.8.....	Chloride, dissolved ( $\text{mg}/\text{L}$ as Cl)
.1.....	Fluoride, dissolved ( $\text{mg}/\text{L}$ as F)
62.....	Silica, dissolved ( $\text{mg}/\text{L}$ as $\text{SiO}_2$ )
487.....	Solids, residue on evaporation at $180^{\circ}\text{C}$ , dissolved ( $\text{mg}/\text{L}$ )
.02.....	Nitrogen, nitrite, dissolved ( $\text{mg}/\text{L}$ as N)
<.1.....	Nitrogen, nitrite plus nitrate, dissolved ( $\text{mg}/\text{L}$ as N)
1.1.....	Nitrogen, ammonia, dissolved ( $\text{mg}/\text{L}$ as N)
1.4.....	Nitrogen, ammonia plus organic, dissolved ( $\text{mg}/\text{L}$ as N)
.08.....	Phosphorus, dissolved ( $\text{mg}/\text{L}$ as P)
20.....	Aluminum, dissolved ( $\mu\text{g}/\text{L}$ as Al)
4.....	Antimony, dissolved ( $\mu\text{g}/\text{L}$ as Sb)
13.....	Arsenic, dissolved ( $\mu\text{g}/\text{L}$ as As)
77.....	Barium, dissolved ( $\mu\text{g}/\text{L}$ as Ba)
<.5.....	Beryllium, dissolved ( $\mu\text{g}/\text{L}$ as Be)
11.....	Cadmium, dissolved ( $\mu\text{g}/\text{L}$ as Cd)
<5.....	Chromium, dissolved ( $\mu\text{g}/\text{L}$ as Cr)
20.....	Cobalt, dissolved ( $\mu\text{g}/\text{L}$ as Co)
<10.....	Copper, dissolved ( $\mu\text{g}/\text{L}$ as Cu)
56,000.....	Iron, dissolved ( $\mu\text{g}/\text{L}$ as Fe)
30.....	Lead, dissolved ( $\mu\text{g}/\text{L}$ as Pb)
5.....	Lithium, dissolved ( $\mu\text{g}/\text{L}$ as Li)
1,500.....	Manganese, dissolved ( $\mu\text{g}/\text{L}$ as Mn)
<.1.....	Mercury, dissolved ( $\mu\text{g}/\text{L}$ as Hg)
<10.....	Molybdenum, dissolved ( $\mu\text{g}/\text{L}$ as Mo)
10.....	Nickel, dissolved ( $\mu\text{g}/\text{L}$ as Ni)
<1.....	Silver, dissolved ( $\mu\text{g}/\text{L}$ as Ag)
130.....	Strontium, dissolved ( $\mu\text{g}/\text{L}$ as Sr)
11.....	Vanadium, dissolved ( $\mu\text{g}/\text{L}$ as V)
9,300.....	Zinc, dissolved ( $\mu\text{g}/\text{L}$ as Zn)
24.....	Carbon, organic, total ( $\text{mg}/\text{L}$ as C)

Table 7. Chemical analyses of water samples—Continued

Record number	99001626
Site identification number	473100116323501
Site location and name	48N-2W-11DDA1 (MW4)
Date and time of collection	3-22-90, 1410 hrs

Value	Constituent analyzed
2,800.....	Specific conductance, field ( $\mu\text{S}/\text{cm}$ )
3,480.....	Specific conductance, laboratory ( $\mu\text{S}/\text{cm}$ )
7.3.....	pH, field (standard units)
6.0.....	pH, laboratory (standard units)
5.0.....	Air temperature ( $^{\circ}\text{C}$ )
5.0.....	Water temperature ( $^{\circ}\text{C}$ )
360.....	Calcium, dissolved ( $\text{mg}/\text{L}$ as Ca)
330.....	Magnesium, dissolved ( $\text{mg}/\text{L}$ as Mg)
6.5.....	Sodium, dissolved ( $\text{mg}/\text{L}$ as Na)
5.9.....	Potassium, dissolved ( $\text{mg}/\text{L}$ as K)
260.....	Bicarbonate, field ( $\text{mg}/\text{L}$ as $\text{HCO}_3$ )
212.....	Alkalinity, field ( $\text{mg}/\text{L}$ as $\text{CaCO}_3$ )
62.....	Alkalinity, fixed endpoint titration to pH 4.5, laboratory ( $\text{mg}/\text{L}$ as $\text{CaCO}_3$ )
.8.....	Sulfide, total ( $\text{mg}/\text{L}$ as S)
3,000.....	Sulfate, dissolved ( $\text{mg}/\text{L}$ as $\text{SO}_4$ )
4.7.....	Chloride, dissolved ( $\text{mg}/\text{L}$ as Cl)
<.1.....	Fluoride, dissolved ( $\text{mg}/\text{L}$ as F)
18.....	Silica, dissolved ( $\text{mg}/\text{L}$ as $\text{SiO}_2$ )
3,480.....	Solids, residue on evaporation at $180^{\circ}\text{C}$ , dissolved ( $\text{mg}/\text{L}$ )
.02.....	Nitrogen, nitrite, dissolved ( $\text{mg}/\text{L}$ as N)
.3.....	Nitrogen, nitrite plus nitrate, dissolved ( $\text{mg}/\text{L}$ as N)
4.8.....	Nitrogen, ammonia, dissolved ( $\text{mg}/\text{L}$ as N)
4.5.....	Nitrogen, ammonia plus organic, dissolved ( $\text{mg}/\text{L}$ as N)
<.01.....	Phosphorus, dissolved ( $\text{mg}/\text{L}$ as P)
<10.....	Aluminum, dissolved ( $\mu\text{g}/\text{L}$ as Al)
5.....	Antimony, dissolved ( $\mu\text{g}/\text{L}$ as Sb)
13.....	Arsenic, dissolved ( $\mu\text{g}/\text{L}$ as As)
42.....	Barium, dissolved ( $\mu\text{g}/\text{L}$ as Ba)
<2.....	Beryllium, dissolved ( $\mu\text{g}/\text{L}$ as Be)
62.....	Cadmium, dissolved ( $\mu\text{g}/\text{L}$ as Cd)
1.....	Chromium, dissolved ( $\mu\text{g}/\text{L}$ as Cr)
180.....	Cobalt, dissolved ( $\mu\text{g}/\text{L}$ as Co)
2.....	Copper, dissolved ( $\mu\text{g}/\text{L}$ as Cu)
76,000.....	Iron, dissolved ( $\mu\text{g}/\text{L}$ as Fe)
300.....	Lead, dissolved ( $\mu\text{g}/\text{L}$ as Pb)
28.....	Lithium, dissolved ( $\mu\text{g}/\text{L}$ as Li)
94,000.....	Manganese, dissolved ( $\mu\text{g}/\text{L}$ as Mn)
<.1.....	Mercury, dissolved ( $\mu\text{g}/\text{L}$ as Hg)
<30.....	Molybdenum, dissolved ( $\mu\text{g}/\text{L}$ as Mo)
140.....	Nickel, dissolved ( $\mu\text{g}/\text{L}$ as Ni)
<1.....	Silver, dissolved ( $\mu\text{g}/\text{L}$ as Ag)
1,300.....	Strontium, dissolved ( $\mu\text{g}/\text{L}$ as Sr)
<18.....	Vanadium, dissolved ( $\mu\text{g}/\text{L}$ as V)
69,000.....	Zinc, dissolved ( $\mu\text{g}/\text{L}$ as Zn)
94.....	Carbon, organic, total ( $\text{mg}/\text{L}$ as C)

Table 7. Chemical analyses of water samples—Continued

Record number	99001587
Site identification number	473133116321001
Site location and name	48N-2W-12BAC1 (MW5)
Date and time of collection	3-21-90, 1205 hrs

Value	Constituent analyzed
496.....	Specific conductance, field ( $\mu\text{S}/\text{cm}$ )
493.....	Specific conductance, laboratory ( $\mu\text{S}/\text{cm}$ )
6.9.....	pH, field (standard units)
6.8.....	pH, laboratory (standard units)
11.0.....	Air temperature ( $^{\circ}\text{C}$ )
8.5.....	Water temperature ( $^{\circ}\text{C}$ )
2.8.....	Oxygen, dissolved, field ( $\text{mg}/\text{L}$ )
19.....	Calcium, dissolved ( $\text{mg}/\text{L}$ as Ca)
14.....	Magnesium, dissolved ( $\text{mg}/\text{L}$ as Mg)
65.....	Sodium, dissolved ( $\text{mg}/\text{L}$ as Na)
1.3.....	Potassium, dissolved ( $\text{mg}/\text{L}$ as K)
210.....	Bicarbonate, field ( $\text{mg}/\text{L}$ as $\text{HCO}_3$ )
176.....	Alkalinity, field ( $\text{mg}/\text{L}$ as $\text{CaCO}_3$ )
173.....	Alkalinity, fixed endpoint titration to pH 4.5, laboratory ( $\text{mg}/\text{L}$ as $\text{CaCO}_3$ )
.6.....	Sulfide, total ( $\text{mg}/\text{L}$ as S)
61.....	Sulfate, dissolved ( $\text{mg}/\text{L}$ as $\text{SO}_4$ )
1.0.....	Chloride, dissolved ( $\text{mg}/\text{L}$ as Cl)
.40.....	Fluoride, dissolved ( $\text{mg}/\text{L}$ as F)
56.....	Silica, dissolved ( $\text{mg}/\text{L}$ as $\text{SiO}_2$ )
342.....	Solids, residue on evaporation at $180^{\circ}\text{C}$ , dissolved ( $\text{mg}/\text{L}$ )
.01.....	Nitrogen, nitrite, dissolved ( $\text{mg}/\text{L}$ as N)
<.1.....	Nitrogen, nitrite plus nitrate, dissolved ( $\text{mg}/\text{L}$ as N)
.45.....	Nitrogen, ammonia, dissolved ( $\text{mg}/\text{L}$ as N)
.9.....	Nitrogen, ammonia plus organic, dissolved ( $\text{mg}/\text{L}$ as N)
.14.....	Phosphorus, dissolved ( $\text{mg}/\text{L}$ as P)
20.....	Aluminum, dissolved ( $\mu\text{g}/\text{L}$ as Al)
11.....	Antimony, dissolved ( $\mu\text{g}/\text{L}$ as Sb)
330.....	Arsenic, dissolved ( $\mu\text{g}/\text{L}$ as As)
54.....	Barium, dissolved ( $\mu\text{g}/\text{L}$ as Ba)
<.5.....	Beryllium, dissolved ( $\mu\text{g}/\text{L}$ as Be)
3.0.....	Cadmium, dissolved ( $\mu\text{g}/\text{L}$ as Cd)
<5.....	Chromium, dissolved ( $\mu\text{g}/\text{L}$ as Cr)
7.....	Cobalt, dissolved ( $\mu\text{g}/\text{L}$ as Co)
<10.....	Copper, dissolved ( $\mu\text{g}/\text{L}$ as Cu)
4,500.....	Iron, dissolved ( $\mu\text{g}/\text{L}$ as Fe)
<10.....	Lead, dissolved ( $\mu\text{g}/\text{L}$ as Pb)
<4.....	Lithium, dissolved ( $\mu\text{g}/\text{L}$ as Li)
4,700.....	Manganese, dissolved ( $\mu\text{g}/\text{L}$ as Mn)
<.1.....	Mercury, dissolved ( $\mu\text{g}/\text{L}$ as Hg)
<10.....	Molybdenum, dissolved ( $\mu\text{g}/\text{L}$ as Mo)
20.....	Nickel, dissolved ( $\mu\text{g}/\text{L}$ as Ni)
<1.0.....	Silver, dissolved ( $\mu\text{g}/\text{L}$ as Ag)
130.....	Strontium, dissolved ( $\mu\text{g}/\text{L}$ as Sr)
<6.....	Vanadium, dissolved ( $\mu\text{g}/\text{L}$ as V)
880.....	Zinc, dissolved ( $\mu\text{g}/\text{L}$ as Zn)
66.....	Carbon, organic, total ( $\text{mg}/\text{L}$ as C)

Table 7. Chemical analyses of water samples—Continued

Record number	99001708
Site identification number	473054116331600
Site location and name	48N-2W-11CDD1 (S5; Killarney Lake)
Date and time of collection	3-23-90, 1355 hrs

Value	Constituent analyzed
54.....	Specific conductance, field ( $\mu\text{S}/\text{cm}$ )
1.....	Arsenic, dissolved ( $\mu\text{g}/\text{L}$ as As)
1.....	Cadmium, dissolved ( $\mu\text{g}/\text{L}$ as Cd)
5.....	Cadmium, total recoverable ( $\mu\text{g}/\text{L}$ as Cd)
<10.....	Copper, dissolved ( $\mu\text{g}/\text{L}$ as Cu)
3.....	Copper, total recoverable ( $\mu\text{g}/\text{L}$ as Cu)
180.....	Iron, dissolved ( $\mu\text{g}/\text{L}$ as Fe)
600.....	Iron, total recoverable ( $\mu\text{g}/\text{L}$ as Fe)
30.....	Lead, dissolved ( $\mu\text{g}/\text{L}$ as Pb)
40.....	Lead, total recoverable ( $\mu\text{g}/\text{L}$ as Pb)
<10.....	Nickel, dissolved ( $\mu\text{g}/\text{L}$ as Ni)
1.....	Nickel, total recoverable ( $\mu\text{g}/\text{L}$ as Ni)
<1.....	Selenium, dissolved ( $\mu\text{g}/\text{L}$ as Se)
220.....	Zinc, dissolved ( $\mu\text{g}/\text{L}$ as Zn)
200.....	Zinc, total recoverable ( $\mu\text{g}/\text{L}$ as Zn)