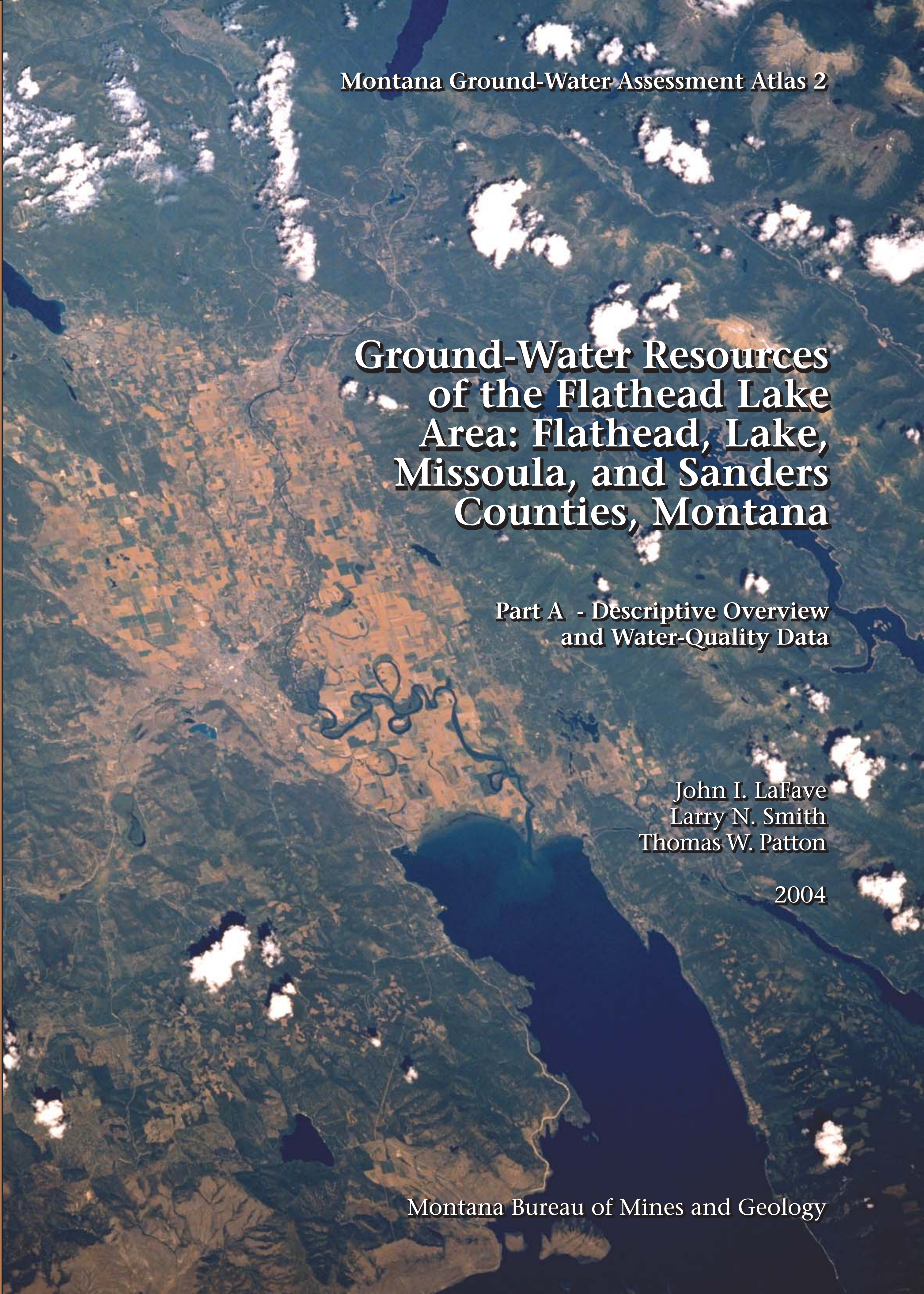


Montana Ground-Water Assessment Atlas 2

# Ground-Water Resources of the Flathead Lake Area: Flathead, Lake, Missoula, and Sanders Counties, Montana

## Part A - Descriptive Overview and Water-Quality Data

John I. LaFave
Larry N. Smith
Thomas W. Patton

2004

Montana Bureau of Mines and Geology

**Montana Ground-Water Assessment Atlas 2**

# Ground-Water Resources of the Flathead Lake Area: Flathead, Lake, Missoula, and Sanders Counties, Montana

## Part A*—Descriptive Overview and Water-Quality Data

**by**

**John I. LaFave**
**Larry N. Smith**
**Thomas W. Patton**

*The atlas is published in two parts: Part A contains a descriptive overview of the study area, along with water-quality data and an illustrated glossary to introduce and explain many specialized terms used in the text; Part B contains the 11 maps referenced in this document. The maps offer expanded discussions about many aspects of the hydrogeology of the Flathead Lake area. Parts A and B are published separately and each map in Part B is also available individually.

**Front Cover**: *Flathead Lake and the valley to the north are featured in this north–northeast-looking, low-oblique photograph*. Formed by glacial damming of the Flathead River during the last ice age, Flathead Lake is 30 miles long and 12 to 14 miles wide. The small city of Kalispell is barely discernible north–northwest of the lake. Kalispell is a center for tourism, trade, and the production of livestock, grain, fruit, timber, and aluminum. The Flathead River drains into Flathead Lake, forming a conspicuous delta in the northeast part of the lake. Southwest of Kalispell are the small Foy Lakes; Whitefish Lake is to the north. Near the top center of the photograph are Glacier National Park and Lake McDonald. Image courtesy of Earth Science and Image Analysis Laboratory, NASA Johnson Space Center (http://eol.jsc.nasa.gov). Photo number: STS028-90-18.

**Back Cover:** *Flathead Lake, Mission Range, and Swan Range, Montana, October 1994*.
Flathead Lake is surrounded by the snow-capped Mission Range on the east, the city of Polson and the Mission Valley on the south, and the Salish Mountains on the west. North is to the upper left. Numerous agricultural field patterns are visible south of the lake in Mission Valley and in the Little Bitterroot River Valley southwest of the lake. Swan Lake and the Swan River valley separate the Mission Range on the west from the Swan Range on the east in the upper part of the photograph. Image courtesy of Earth Science and Image Analysis Laboratory, NASA Johnson Space Center (http://eol.jsc.nasa.gov). Photo number: STS068-170-060.

# Contents

## Figures

## Tables



## Maps in Part B*



*Maps in Part B are published separately and can be obtained from the Montana Bureau of Mines and Geology Publication Sales Office, (406) 496-4167.

# Preface

## The Montana Ground-Water Assessment Act

In response to concerns about the management of ground water in Montana, the 1989 Legislature instructed the Environmental Quality Council (EQC) to evaluate the State's ground-water programs. The EQC task force identified major problems in managing ground water that were attributable to insufficient data and lack of systematic data collection. The task force recommended implementing long-term monitoring, systematic characterization of ground-water resources, and a computerized database. Following these recommendations, the 1991 Legislature passed the Montana Ground-Water Assessment Act (85-2-901 et seq., MCA) so that the quality of decisions related to ground-water management, protection, and development might be improved. The Act established three programs at the Montana Bureau of Mines and Geology (MBMG) to address ground-water information needs in Montana:

- the **ground-water monitoring program:** to provide long-term records of water quality and water levels for the State's major aquifers;
- the **ground-water characterization program:** to map the distribution of, and document the water quality and water-yielding properties of, individual aquifers in specific areas of the State; and
- the **ground-water information center (GWIC):** to provide readily accessible information about ground water to land users, well drillers, and local, State, and Federal agencies.

Program implementation is overseen by the Ground-Water Assessment Steering Committee. The Steering Committee includes representatives from water agencies in State and Federal government, and representatives from local government and water user groups. The committee also provides a forum through which units of State, Federal, and local government can coordinate functions of ground-water research.

## Montana Ground-Water Assessment Atlas Series

This atlas is the second of a series that will systematically describe Montana's hydrogeologic framework. Figure 1 shows the characterization-area boundaries as defined by the Steering Committee and the active study areas at the time of this report; an atlas is planned for each area. The atlas is published in two parts: Part A contains a descriptive overview of the study area along with water-quality data and an illustrated glossary to introduce and explain many specialized terms used in the text; Part B contains 11 maps that offer expanded discussions of the hydrogeology. Parts A and B are published separately, and each map in Part B is also available individually. The overview and maps are intended for interested citizens and others who may make decisions about ground-water use but who are not necessarily specialists in hydrogeology.

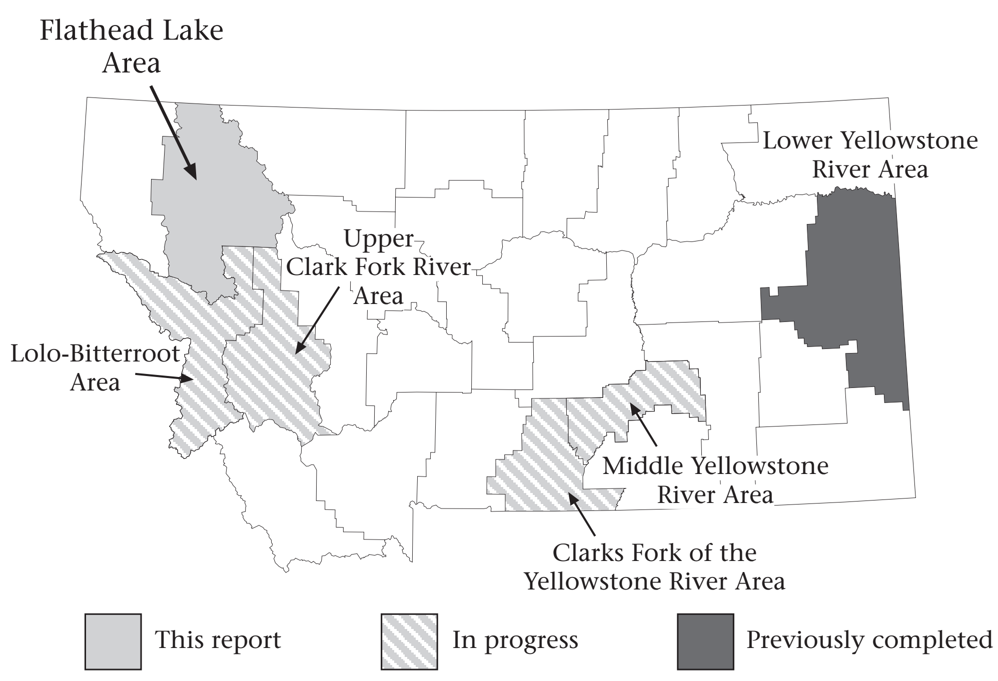



Figure 1. The Flathead Lake area Ground-Water Assessment Atlas is the second atlas prepared by the Ground-Water Characterization Program.

# Introduction

The Flathead Lake area ground-water characterization study (Flathead and Lake Counties, and the parts of Missoula and Sanders Counties within the Flathead Indian Reservation) was conducted as part of the Montana Ground-Water Assessment Program by the MBMG. Most ground water being used in the Flathead Lake area occurs in the unconsolidated sediments at various depths within intermontane valleys, in lithified bedrock that is fractured, or in a few consolidated sedimentary rock units. The objectives of the study were to describe ground-water conditions including use, occurrence, availability, levels, and quality. Ground water is an important resource in the Flathead Lake area, where most homes, farms, and ranches and many municipalities rely on wells to provide drinking water. The basic information presented in this report should help local landowners and public officials make decisions regarding ground-water development, protection, and management.

Because of the variability of the geology and ground-water flow in the intermontane valleys, the discussion of hydrogeology has been divided into 11 subareas (fig. 2), generally confined to the major valleys within the study area. The largest subareas, and those with the greatest amount of ground-water development, are Kalispell (north of Flathead Lake), Mission (south of Flathead Lake), and the Flathead Lake perimeter (east and west perimeters of Flathead Lake). Other subareas north of Flathead Lake are Coram (Flathead River valley above Bad Rock Canyon), North Fork (North Fork of the Flathead River), Smith (Ashley Creek valley, McGregor Creek valley, and the headwaters of the Little Bitterroot River), and Swan (Swan River valley above Big Fork). Other subareas south of Flathead Lake include Camas Prairie (Camas Prairie Basin), Irvine Flats (the Irvine Creek drainage), Jocko (the Jocko Valley), and Little Bitterroot (Little Bitterroot River valley below Niarada).

## Purpose and Scope

This atlas (Part A) and the associated maps (Part B) summarize and interpret basic geologic and regional hydrogeologic conditions for the Flathead Lake area. Part A describes the most-used hydrologic units that occur in each of the 11 subareas. The amount of data and the interpretations available for each subarea are proportional to the subarea's size, the number of wells within it, and its population density. The subareas are discussed in order of decreasing number of water wells.

The maps in Part B, which show potentiometric surfaces and dissolved-constituents concentrations, portray conditions at the end of 2000. The data used to compile these maps are stored in the MBMG's GWIC database. Because the GWIC database is continually updated, the latest information can be retrieved and used to enhance the interpretations presented here. Copies of the individual maps in Part B are available through the MBMG, in either paper or digital format.

Water levels in the Flathead Lake area continue to be monitored in a network of about 90 wells maintained by the Ground-Water Monitoring Program and the Confederated Salish and Kootenai Tribes; updated hydrographs and data from these wells can be viewed at the GWIC website (http://mbmggwic.mtech.edu).

## Methods of Investigation

Lithologic descriptions from about 17,000 well logs were analyzed and geologic units were assigned to water-well records in the GWIC database. The lithologic descriptions prepared by water-well drillers are the largest source of information for mapping subsurface units. Although the quality of the descriptions vary, the large number of water-well logs make it possible to discern patterns and consistencies in the data. Water-well logs were used to prepare maps and cross sections showing location, depth, and thickness of the principal hydrogeologic units. Field mapping to measure and describe geologic exposures was completed in selected areas. Most of the hydrologic field work was conducted during the spring, summer, and fall of 1996, except in the Little Bitterroot subarea where recent, detailed data were already available (Abdo, 1997). Program staff visited more than 850 wells to measure water levels, estimate specific capacities, and collect basic water-quality parameters (temperature, pH, and specific conductance). Wells were located in the field to the nearest 2.5 acres (appendix A).

Water-level data were obtained from several sources to assess the magnitude and timing of water-level fluctuations. Between 1996 and 1998 water levels were measured daily or monthly in a network of 58 wells in Flathead County. In addition, quarterly water-level data collected by the Montana Ground-Water Monitoring Program and the Confederated Salish and Kootenai Tribes monitoring networks were evaluated. Historic water-level data from the GWIC database were also used to assess long-term variations in order to improve

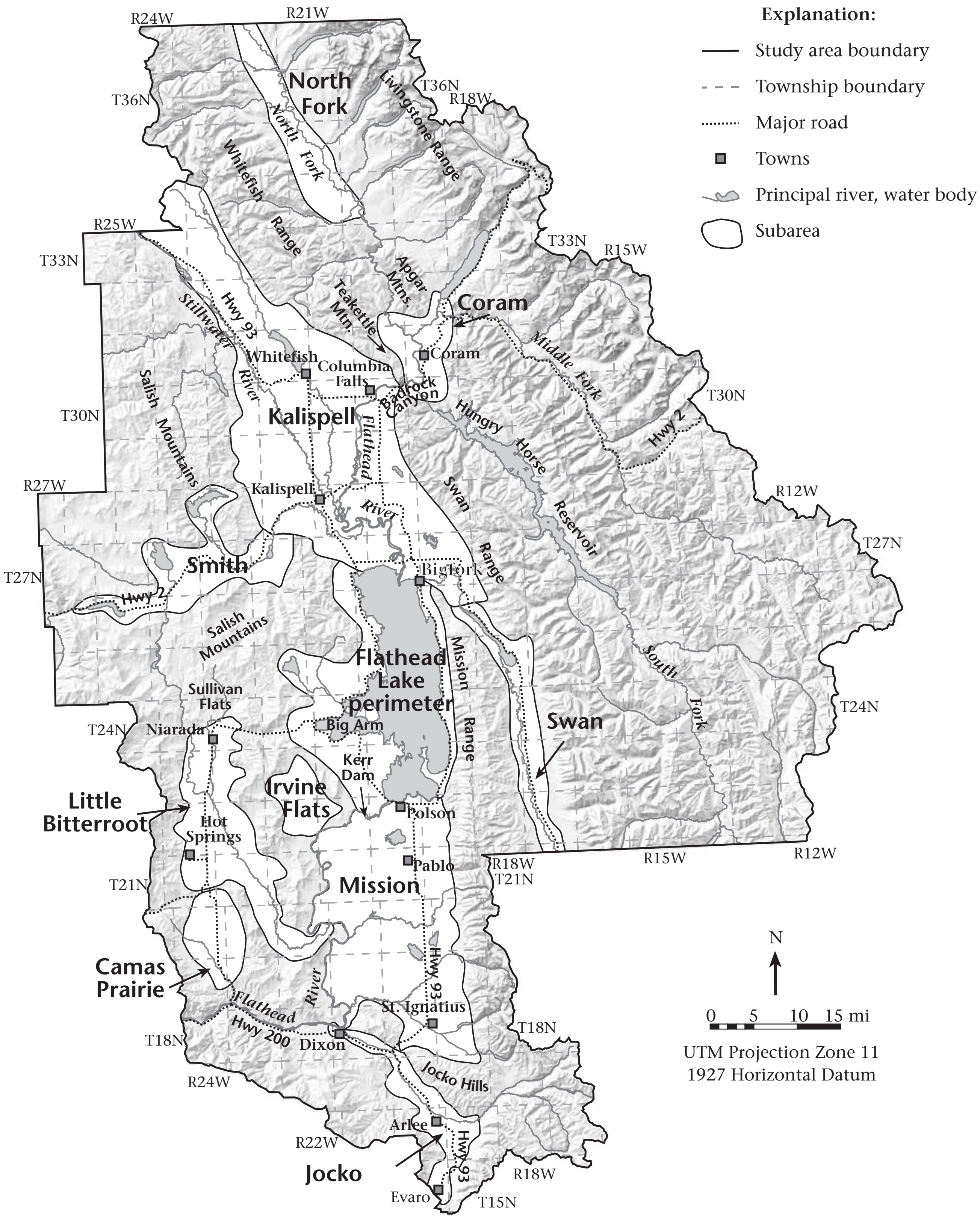



Figure 2. The Flathead Lake area ground-water characterization study covers all of Flathead and Lake Counties, and the parts of Missoula and Sanders Counties within the Flathead Indian Reservation. The 11 hydrogeologic subareas described in the atlas are shown, as are geographic names used in the text.

understanding of the effects of climate, development, and water use on ground-water supplies.

## Water-Quality Sampling

A principal objective was to describe the ground-water quality of the major aquifers in the Flathead Lake area. In the fall of 1995 and summer of 1996, field staff collected 158 water-quality samples from domestic, stock, public supply, and dedicated ground-water monitoring wells; 20 additional wells were sampled in the spring of 2000. Sample sites were selected to obtain a uniform areal distribution of samples and to obtain samples along ground-water flow paths. The samples were analyzed for major cations (calcium, magnesium, sodium, and potassium), major anions (bicarbonate, chloride, and sulfate), nitrate, and trace elements (including fluoride, iron, manganese, arsenic, and selenium); selected wells were sampled for analysis of environmental isotopes (carbon-14, carbon-13, deuterium, oxygen-18, and tritium) and radon. Samples for nitrate-only analyses were collected from 56 additional wells (appendix C). For background on the nomenclature, meaning, and interpretation of these analyses see the appropriate sections in the glossary.

Major ions, trace metals, and radon were analyzed by the MBMG Analytical Laboratory; tritium analyses were done by the University of Waterloo Environmental Isotope Laboratory or the University of Arizona Isotope Laboratory; carbon-14, carbon-13, deuterium, and oxygen analyses were done by Geochron Laboratory or the University of Arizona Isotope Laboratory. The analytical results are presented in appendices C and D.

To ensure acquisition of a representative sample of ground water, samples were bottled only after field parameters stabilized during pumping and at least three well-casing volumes of water had been removed. Where possible, field measurements of specific conductance, pH, alkalinity, redox potential, and water temperature were obtained.

The quality of the analytical data was evaluated by collection and analysis of duplicate samples at 12 sites. Comparison of the dissolved-constituents concentrations reported for the primary samples and their duplicates shows good agreement (fig. 3); the percentage differences for the major ions detected at concentrations greater than 1 mg/L were small (median values less than 2.5 percent). The charge balances of the major-ion data were also evaluated to ensure data quality. A difference between the total-cation and total-anion milliequivalent concentrations of less than or equal to 10 percent was considered acceptable for this study.

## Data Set and Data Analysis

Analytical data from samples collected in this study were supplemented by 247 existing ground-water analyses collected since 1975 and stored in the GWIC database. Only analyses with complete

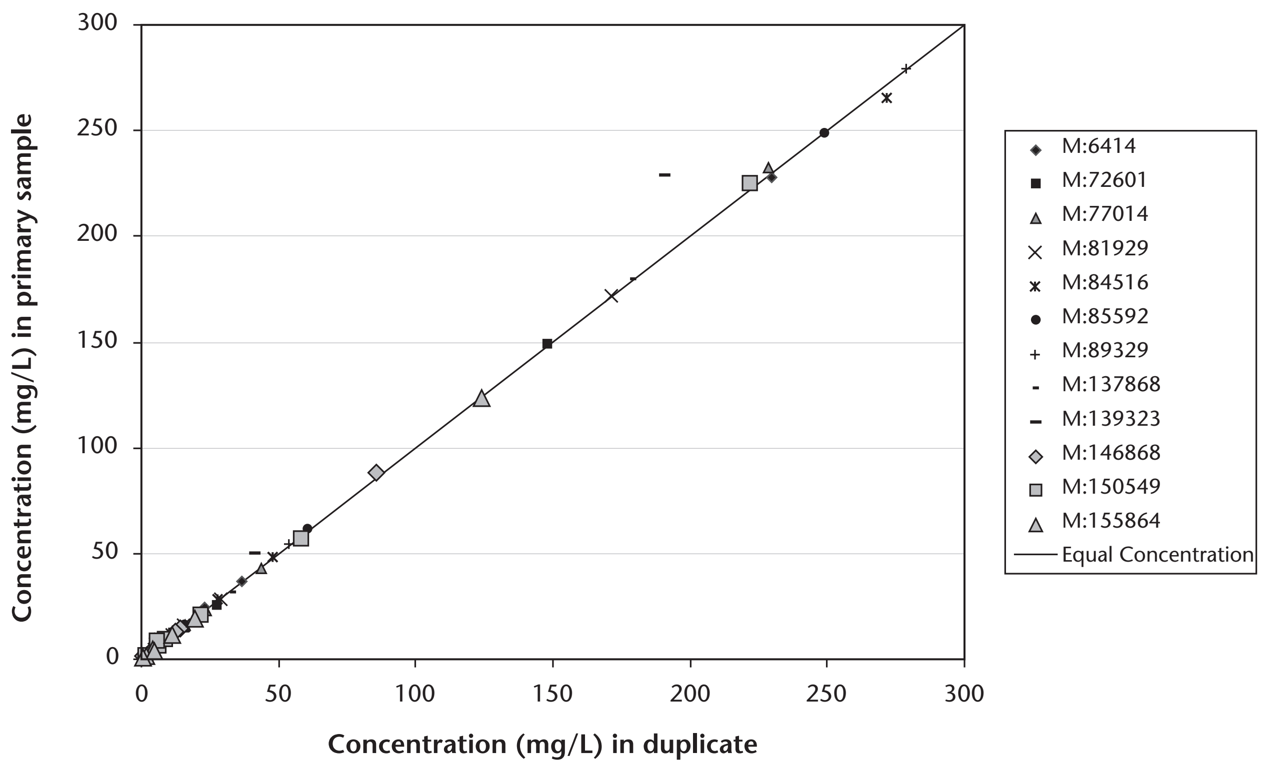



Figure 3. Comparisons of major-ion concentrations between samples and their duplicates show good agreement, indicating good laboratory accuracy.

major-ion determinations having cation/anion milliequivalent charge balances within 10 percent and known aquifer sources were included. In addition, 105 nitrate-only analyses were evaluated. In cases where multiple analyses were available for a well, the most recent was used. The total water-quality data set (new and historical data) contains representative samples from all the major hydrogeologic units in the Flathead Lake area; 102 analyses are from shallow aquifers, 83 are from intermediate aquifers, 105 are from deep alluvial aquifers, 49 are from the Lonepine aquifer, and 79 are from bedrock aquifers.

Water-quality summaries for each subarea include standard measures of statistical minimum, maximum, and median values, and statistical box plots that present the median, or 50th percentile, the 5th percentile, the interquartile range between the 25th and 75th percentiles, and the 95th percentile. Where applicable, the water-quality data were compared with U.S. Environmental Protection Agency (EPA) primary, secondary, and proposed maximum contaminant levels (MCL, SMCL, and PMCL) for drinking water. These standards are the permissible levels allowable in public water supply systems. Constituents for which MCLs have been set may pose a health threat at elevated concentrations. Secondary levels are set for aesthetic reasons—elevated concentrations of these constituents may be a nuisance (bad taste, odor, or staining) but do not normally pose a health risk.

## Previous Investigations

Previous studies concerning ground-water resources in the Flathead Lake area have included regional resource investigations in some of the intermontane valleys, characterization of the effects of irrigation on water supply, and description of pollution in shallow, unconfined aquifers. The first major evaluation of the ground-water resources of the Kalispell subarea was that of Konizeski and others (1968). Noble and Stanford (1986) discussed ground-water resources and water-quality issues in the unconfined Evergreen aquifer along the Flathead River valley. Uthman and others (2000) completed a reconnaissance investigation of the ground-water resources in the northern part of the Kalispell valley. Various aspects of the ground-water resource in the Mission subarea have been evaluated by Boettcher (1982) and Slagle (1988). Makepeace and Goldbach (1994) and Makepeace and Mladenich (1995) delineated many aquifers on the Flathead Indian Reservation. Slagle (1992) studied problems associated with irrigation in the southern part of the area. Thompson (1988) and Makepeace (1989) studied the hydrogeology of the Jocko Valley. The artesian, geothermal, and geochemical conditions of the Lonepine aquifer in the Little Bitterroot subarea have been assessed by Meinzer (1916), Donovan (1985), and Abdo (1997). Geographic, geologic, and hydrologic summaries of several basins in the study area are presented in Kendy and Tresch (1996), Briar and others (1996), Clark and Dutton (1996), and Tuck and others (1996).

## Description of Study Area

The study area includes Flathead and Lake Counties and parts of Missoula and Sanders Counties within the Flathead Indian Reservation (fig. 4). The area covers about 7,800 sq mi: 55 percent under Federal or State ownership, 27 percent in private ownership and 13 percent tribally owned. Much of the Federal, tribal, and State-held land is mountainous, undeveloped, and essentially uninhabited. The Flathead Lake area is part of the Northern Rocky Mountains physiographic province, where north- to northwest-trending mountain ranges separate intermontane valleys. Most of the valley areas contain low-relief grassy and wooded terrain into which modern streams have cut 50 to 100 ft; the Flathead River valley is deeply entrenched and is as much as 500 ft below the main valley floor downstream of Flathead Lake. Areas of greatest relief are along the west-facing fronts of the Swan and Mission Ranges. The highest points are mountain tops in the Mission Range, 12 of which exceed 9,000 ft above mean sea level. The lowest point, at 2,500 ft above sea level, is along the Flathead River where it exits the Flathead Indian Reservation in Sanders County. The Flathead River drains the entire area, except a small area of western Flathead County that lies within the Kootenay River drainage.

## Cultural Features

The population of the study area in 2000 was about 101,000 people. The five principal urban centers in decreasing order of population are Kalispell, Evergreen, Whitefish, Polson, and Columbia Falls. The urban centers account for 33 percent of the area's residents (U.S. Census data). The rest of the area's population is primarily suburban, in small towns, or spread across rural acreage at an average of 15 persons per square mile (outside of federally owned land). Most people work in retail, manufacturing, accommodation and food services, and the health care and social services fields (U.S. Census data). Almost 20 percent of the land is used for farming or ranching. Extractive industries are mostly limited to mining of sand and gravel aggregate in the valleys.

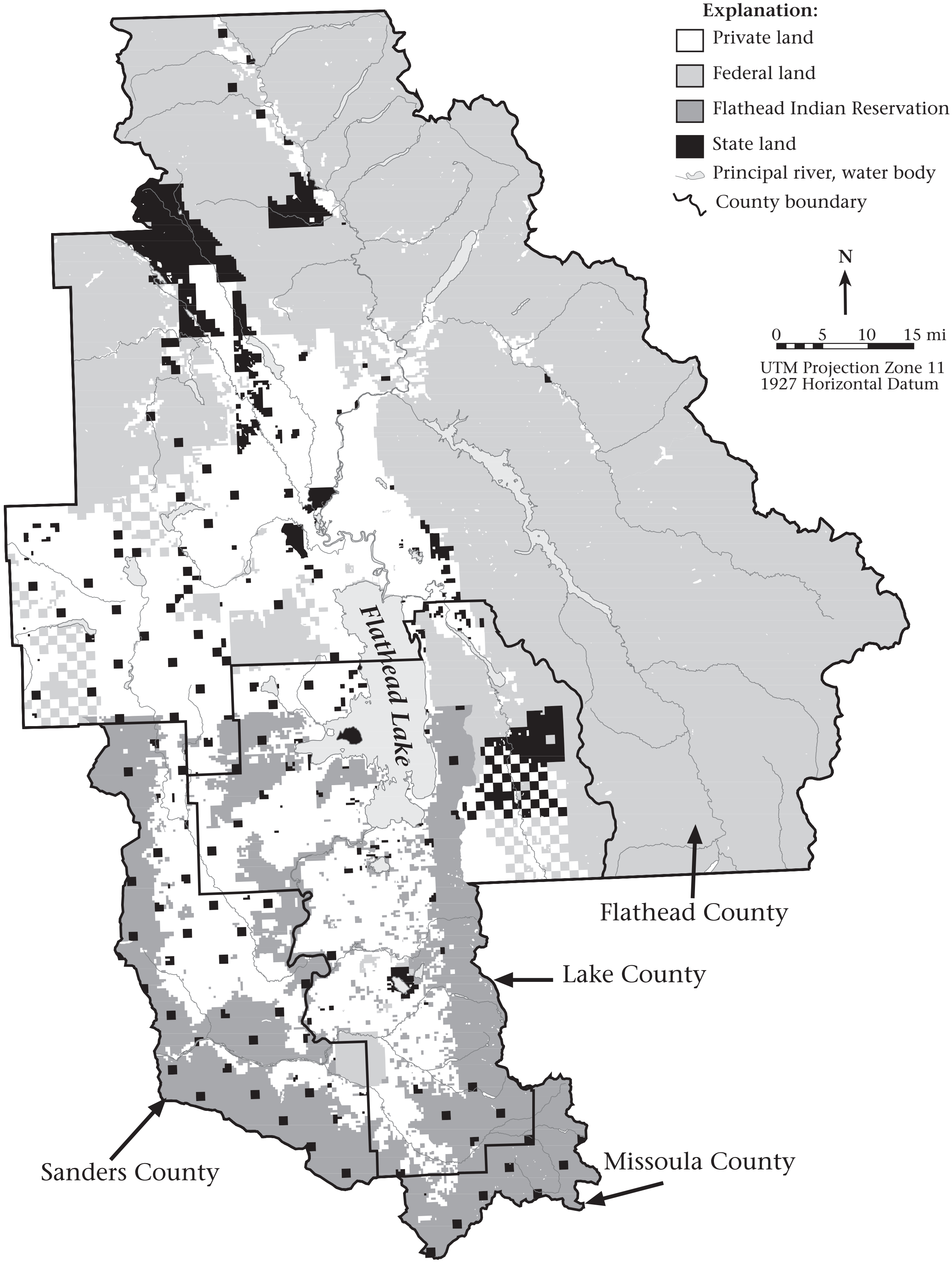



Figure 4. Lands controlled by the Federal and State governments and the Confederated Salish and Kootenai Tribes of the Flathead Indian Reservation cover most of the study area. Most wells are on privately held lands within the major valleys.

## Climate

Annual precipitation ranges widely between the semiarid valleys, which receive 11–16 in of moisture, to mountainous areas that may receive as much as 100 in of precipitation, mostly as snow. Average monthly minimum temperatures (period of record 1899–2001) at the Kalispell airport range from about 14°F in January to 50°F in July. Average monthly maximum temperatures range from 29°F in January to about 80°F in July and August (fig. 5). Extreme temperatures commonly are as low as -30°F in the winter but can be greater than 100°F in the summer (Western Regional Climate Center, 2002: Montana Climate Summaries).

Mean annual precipitation reported at five long-term stations in the Coram, Kalispell, Mission, and Little Bitterroot subareas and at Olney in the Stillwater River drainage ranges from a low of 11.3 in at Lonepine (period of record 1918–69) to a high of 33.5 in at Hungry Horse Dam (period of record 1948–2000; Western Regional Climatic Center: Montana Climate Summaries, 2002). Basin-wide mean annual precipitation, estimated from precipitation models for the Flathead River watershed above Perma, Montana (just downstream of the study area), is about 36 in/yr. The wettest months are May and June followed by the year-end months of November and December (fig. 5). Winter precipitation falls mostly as snow.

## Water Use

In order of decreasing volume, predominant uses of water in Flathead and Lake Counties are irrigation, public water supply, industrial, private-system domestic, and livestock (fig. 6). Solley and others (1998) estimated that ground water supplied about 5 percent of all water used during 1990, and that 38 percent of it was used for domestic purposes. However, 63 percent of all water used for domestic purposes came from ground water.

Estimated annual water use in Flathead and Lake Counties during 1995 (fig. 6) was about 45,000 acre-ft, of which only about 2,500 acre-ft came from ground water (Solley and others, 1998). The 1995 estimated total for both surface and ground water used is only about 5 percent of the average annual discharge of the Flathead River at Perma between 1983 and 1999.

## Water Balance

A water balance is a measure of gains and losses and of changes in storage of a hydrologic system over time. The water balance assumes that surface water, ground water, and atmospheric water are linked by inflows and outflows. An annual water balance accounts for the distribution of water within an area and defines pathways by which water enters and leaves. For a given watershed where the surface-water and ground-water divides coincide and for which there are no external inflows or outflows of ground water, the water balance equation for an annual period takes the form (Freeze and Cherry, 1979):

$$P = R + E + \Delta S_S + \Delta S_G,$$

where $P$ is the average annual precipitation, $R$ the surface-water runoff, $E$ the evapotranspiration (includes evaporated surface and soil water, and water transpired from plants), $\Delta S_S$ the change in storage of the surface-water reservoir, and $\Delta S_G$ the change in storage of the ground-water reservoir. If average surface-water and ground-water storage, based on several years of record, show that there are no long-term changes ($\Delta S_S$ and $\Delta S_G = 0$), then the equation simplifies to:

$$P = R + E.$$

The boundary of the Flathead Lake study area is roughly coincident with the drainage area of the Flathead River (fig. 7). The Flathead River exits the study area near Perma where the river flows over Belt Supergroup bedrock; therefore, it is a location with negligible ground-water underflow where streamflow measurements provide a good indication of the total amount of runoff leaving the study area. A gross water balance for the drainage basin was calculated by estimating average annual precipitation (period 1961–90) from a GIS coverage developed by Oregon State University and the Oregon Climate Service (Daly and others, 1994, 1997; Daly and Taylor, 1998). Annual surface-water runoff data were obtained from the U.S. Geological Survey gaging station at Perma (U.S. Geological Survey, 2002). Subtraction of the average annual surface-water runoff from the average annual precipitation provides an estimate of average annual evapotranspiration. The above equation and the stated assumptions present a simplified, broad-scale treatment of the water balance for the study area. It must be emphasized that there can be a great deal of variability in precipitation, runoff, and evapotranspiration in both time and location (table 1).

About 18 in of water, or half of the annual precipitation in this watershed, is lost to evapotranspiration. Evapotranspiration includes crop water use, riparian and forest vegetation uptake, and evaporation from Flathead Lake and other surface-water bodies.

# Geologic Framework

The Flathead Lake area is characterized by high mountain ranges and downdropped intermontane valleys. Tectonics, erosion, and glaciation have resulted in the deposition of complex sequences of sedimentary materials within the intermontane valleys. Descriptions of basin-fill materials and stratigraphic relationships for the Flathead Lake area are summarized in fig. 8, the generalized geology is presented in fig. 9, and vertical relationships between the units are portrayed in geologic cross sections in fig. 10.

## Geologic History/Setting

The oldest rock unit in the region, the Precambrian Belt Supergroup (1.4 to 1.5 b.y. old), is a thick sequence of metasedimentary rocks that

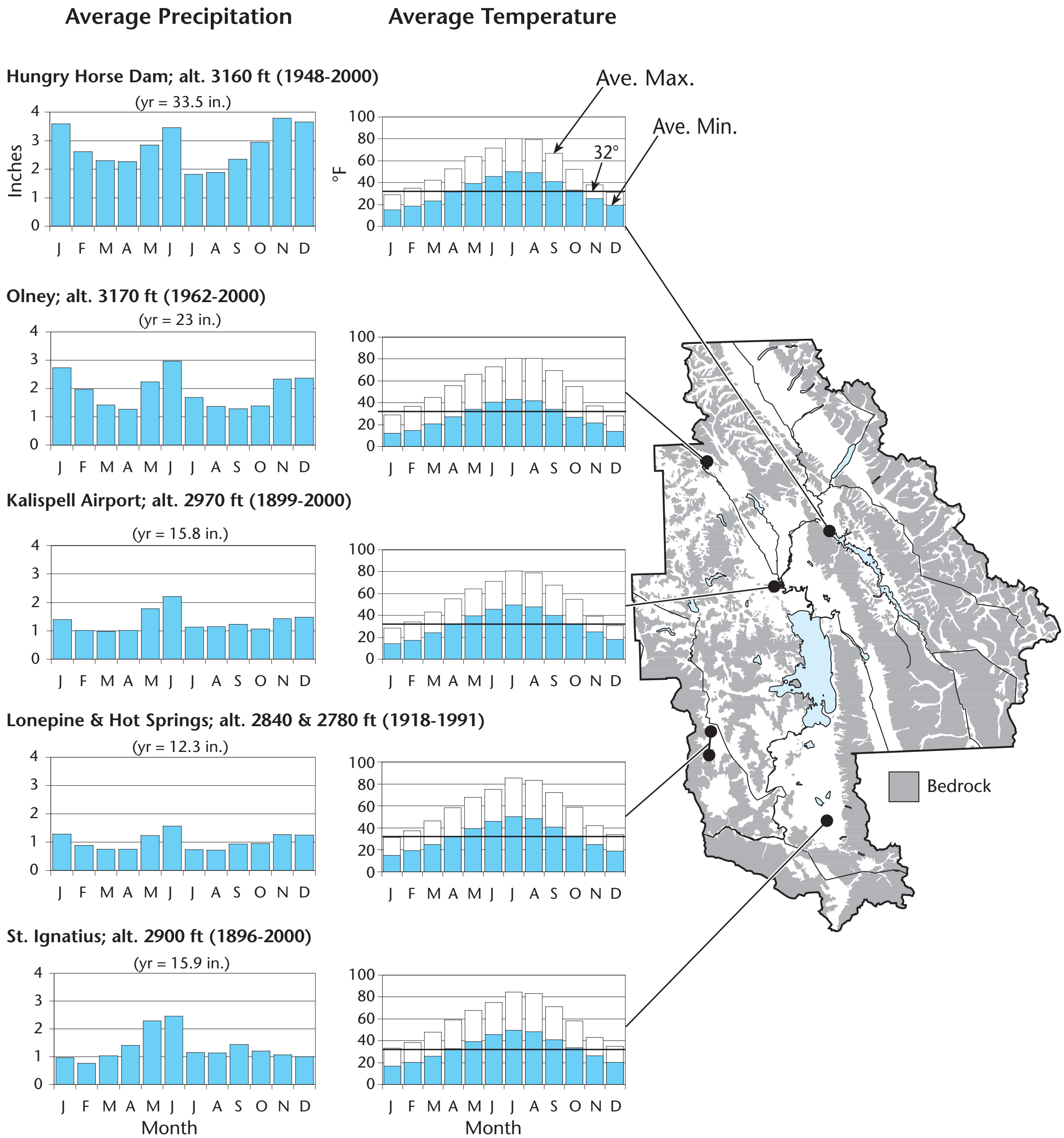



Figure 5. It is generally warmer and drier in the southern and western parts of the Flathead Lake area, and cooler and wetter in the northern and eastern parts. In general, the wetter and cooler locations are at higher altitudes; however, orographic effects of surrounding mountain ranges also play a role in determining climate.

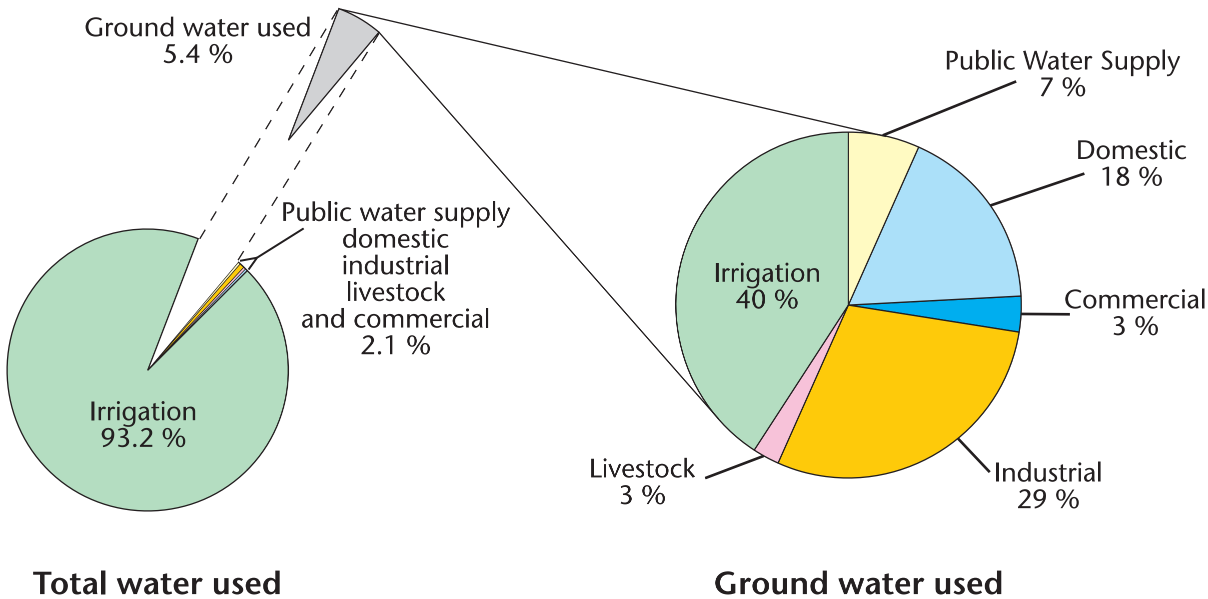



Figure 6. In 1995, ground water was estimated to account for 5.4 percent of all water used in the area. Most ground water is used for irrigation, industrial, and domestic supplies (data from http://water.usgs.gov/watuse/spread95/mtco95.txt).

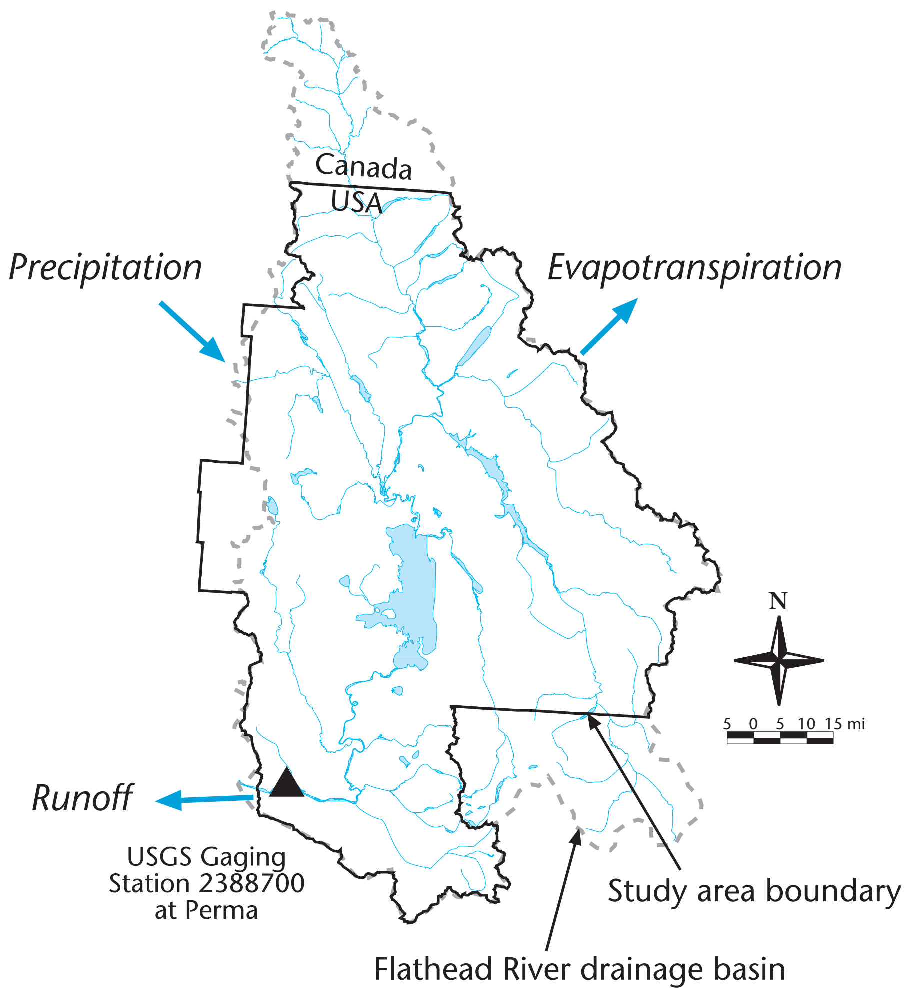



Figure 7. The Flathead River drainage basin divide upstream of Perma roughly coincides with the study area boundary. Precipitation is the source of water entering the drainage basin. Water leaves the basin as surface runoff and as evapotranspiration.

Table 1. Water balance summary for the Flathead River drainage basin upstream of Perma, Montana

| Drainage Area (sq mi) | Average Annual Precipitation (in) | Average Annual Discharge (cubic ft) | Average Annual Discharge (in) | Calculated Average Annual Evapotranspiration (in) | Calculated Average Annual Evapotranspiration (% of precip.) |
|---|---|---|---|---|---|
| 8,795 | 36.4 | $3.7 \times 10^{11}$ | 18.1 | 18.3 | 50 |

forms the mountains and underlies the valleys throughout the study area (figs. 8, 9, 10). The Belt rocks are generally fine-grained clastic rocks (sandstone, siltstone, and mudstone) and carbonate rocks (limestone and dolomite) that have been subjected to low-grade metamorphism. Because the Belt rocks are consistently well-consolidated, they are referred to as "bedrock" in this report. Where exposed, they are commonly fractured, and display bedding surfaces (fig. 11).

Compressive tectonic forces thrust the Belt rocks eastward beginning about 110 m.y. ago and the compression uplifted, folded, and fractured the rocks. As the compressive forces relaxed 40–50 m.y. ago, extension opened northwest–southeast valleys such as the North Fork of the Flathead River and the Stillwater River valley. Around 15–20 m.y. ago the direction of extension changed, creating north–south-oriented valleys, most notably the Kalispell and Mission valleys (Constenius, 1996). Evidence that extension of the region, uplift of mountains, and subsidence of valleys continue is presented by numerous earthquakes that still occur within the study area (Stickney, 2000).

Between 2 and 50 m.y. ago (Tertiary time), thick sequences of sediments accumulated in the valleys. In the Flathead Lake area, more than 3,000 ft of basin-fill sediments, mostly of Tertiary age, are known to occur on top of the Belt rocks in some valleys (Konizeski and others, 1968; LaPoint, 1971; Boettcher, 1982; Slagle, 1988; Miller, 2003). Large differences in depths to Belt rocks show that structural subsidence and subsequent deposition of sediments varied greatly from valley to valley. In general, basin-fill deposits north of Flathead Lake are thicker than those south of the lake (Part B, map 7). Tertiary rocks as described in this report are not included under the term "bedrock" because they are poorly to moderately consolidated; they do not display fractures in outcrop.

Despite their thickness and widespread deposition within the valleys, there are relatively few surface exposures of Tertiary sedimentary rocks in the study area. The lower Tertiary Kishenehn Formation crops out in places along the North Fork of the Flathead River valley. The Formation is composed mostly of sandstone, siltstone, and mudstone with a lesser amount of conglomerate and localized beds of carbonaceous shale, lignite (coal), and oil shale (Constenius, 1981, 1988, 1989). Similar deposits are at land surface near Coram (fig. 12). As much as 1400 ft of partially consolidated Tertiary sedimentary rock has been penetrated in a few drill holes in the Kalispell and Swan subareas. Other sequences of Tertiary-age clayey conglomerates are exposed locally and buried at depth in the Jocko, Mission, Irvine Flats, Little Bitterroot, Coram, and Camas Prairie subareas (fig. 13). Volcanic ash layers in these deposits are probably related to activity in the Hog Heaven volcanic field located in the central Salish Mountains (P.C. Ryan, 1998, 1999, written commun.). Volcanic and intrusive rocks of the Hog Heaven volcanic field show that not all deposition during Tertiary time was a result of erosion of the surrounding mountains (Lange and Zehner, 1992). These rocks are exposed at the surface north of the Little Bitterroot subarea and west of Flathead Lake.

Deposition continued during Quaternary time (2 m.y. ago to present). Although distinguishing Tertiary from Quaternary sediment using subsurface data is difficult, about 100 well logs in the Kalispell and Mission valleys that penetrated from 500 to 850 ft of unconsolidated sand, gravel, and silt suggest that possibly as much as 1,000 ft of unconsolidated alluvium (water-transported gravel, sand, silt, and clay), lake sediments, and glacial deposits fill these valleys. Alluvial sand and gravel occur beneath glacial deposits, generally at depths greater than 50 to 100 ft below the land surface. For the purposes of this report, these alluvial units are called the deep alluvium (see Part B, maps 2, 3, 8, 10; fig. 8). The deep alluvium represents materials deposited by streams prior to the onset of glaciation, streams that existed in front of advancing glaciers, or streams that occupied the valleys between times of glaciation. Alluvium beneath glacial deposits can be recognized in all of the subareas, but is thickest and most commonly encountered in the Kalispell, Little Bitterroot, and Mission subareas.

The best descriptions of the deep alluvium have come from a few exposures along the Flathead River near Coram (fig. 14), and from several detailed lithology logs of water wells in the Kalispell subarea. Contacts between the deep alluvium and overlying glacial deposits are not always distinct because some of the upper beds of the alluvium interfinger with the glacial deposits. The alluvium is composed of 1- to 10-ft-thick beds

| Period | Epoch | Kalispell, North Fork, Coram, Smith, Swan, and Flathead Lake Perimeter Subareas | | Mission, Little Bitterroot, Jocko, Irvine Flats, and Camas Prairie Subareas | |
|---|---|---|---|---|---|
| Quaternary | Holocene | Shallow alluvium | Sand and gravel with minor silt and clay within modern stream valleys and in broad alluvial and eolian sheets. | | |
| Quaternary | Holocene / Pleistocene | Ancestral Flathead Lake deposits<br>transitional<br>Glacial-lake deposits | Brown and gray, laminated, calcareous fine sandy silt, clayey silt, and minor clay; upper surfaces are mostly broad and even; deposited from suspension in a lake that was initially pro-glacial; exposed as the lake sill was downcut and postglacial erosion occurred. | Glacial Lake Missoula sediments | Brown and gray beds of silty and clayey gravel (diamicton), laminated silt and clay, and minor amounts of sand and gravel. Bedding along canyon walls of the Flathead River from Kerr Dam downstream to near Moiese is laterally continuous. Deposition is interpreted to have been in Glacial Lake Missoula (Levish, 1997); some diamictons (till) in Polson moraine and Valley View Hills were deposited by glacial ice; some till may also occur in subsurface in the Mission valley. |
| Quaternary | Pleistocene | Till | Gravel and boulders in a matrix of gray and brown dense sand mud (diamicton); some stratified sand and gravel deposited by, or near, glacial ice; clasts are typically rounded and subrounded metacarbonate, quartzite, argillite, and diorite; more resistant clasts are commonly striated; forms cores of many glacial landforms such as drumlins and moraines. | | |
| Quaternary | Pleistocene | Deep alluvium | Brown, yellowish brown, and gray stratified coarse-grained sand and gravel conglomerate; rare calcium carbonate cement; clasts of quartzite, argillite, and metacarbonate. | Deep alluvium | Sand and gravel, similar to deep alluvium in Kalispell valley, in subsurface of Mission and Little Bitterroot River valleys; deposited by streams possibly before and during glacial advance. |
| | | | | | *local or basin-wide unconformities* |
| Tertiary | Eocene-Miocene(?) | Tertiary sedimentary rocks and some volcanic rocks | **Sedimentary rocks:** Brown and orange medium and coarse-grained pebbly sandstone; pebble and cobble conglomerate; carbonaceous shale with carbonized wood; gray, yellow, and orange mudstone; and orange clayey gravel (diamicton). Gravel clasts of argillite, quartzite, and siltstone are mostly well rounded. Sandstone and conglomerate beds have channelized, erosional bases. Diamicton unit locally infills fractures in Belt Supergroup bedrock.<br><br>**Volcaniclastic rocks:** sandstones, conglomerates, breccias, diamictons, and tuff (compacted deposit of volcanic particles) that contain small to large percentages of Belt Supergroup gravel- and sand-sized particles (Lange and Zehner, 1992). | | |
| | | | *unconformity* | | |
| Proterozoic | | Belt Supergroup | Numerous stratigraphic units composed mostly of metamorphosed siltstones, carbonates, and quartz sandstones (Johns, 1970; Winston, 1986; Harrison and others, 1986, 1992) and minor amount of igneous rocks (McGimsey, 1985). Most bedding thicknesses range from less than 1 inch in metasiltstones to a few feet to tens of feet in metacarbonates and quartzites. | | |

Figure 8. Geologic units important to the hydrogeology of the Flathead Lake area mostly are unconsolidated to semi-consolidated sand, gravel, silt, and clay within the valleys. Bedrock of the Belt Supergroup contains aquifers developed in fractures.

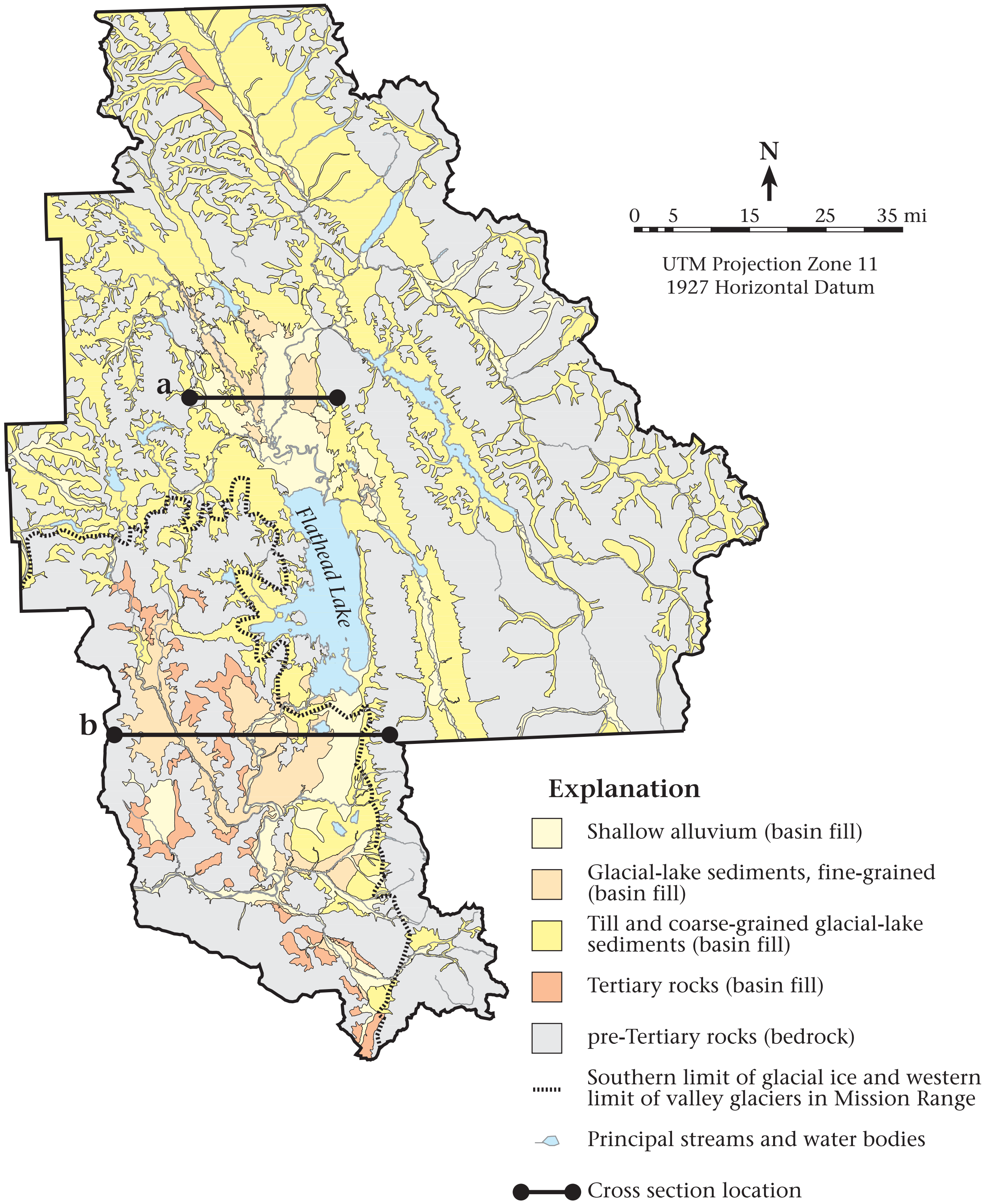
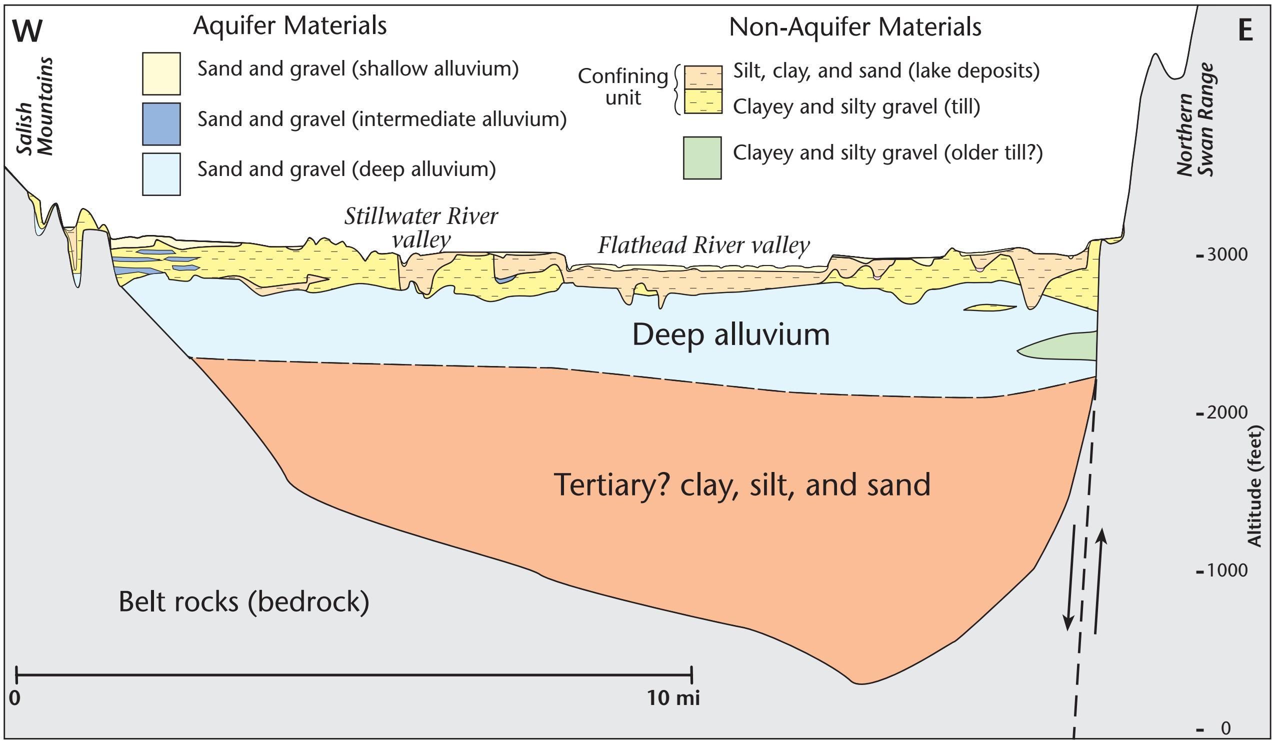



Figure 9. Generalized geologic map of the Flathead Lake area. Surficial geologic deposits were significantly influenced by glaciers that terminated at the southern end of Flathead Lake near Polson. Much of the area south of the glacial terminus was inundated by Glacial Lake Missoula. Locations of cross sections (fig. 10) are shown.

**a** Kalispell valley




**b** Mission and Little Bitterroot River valleys

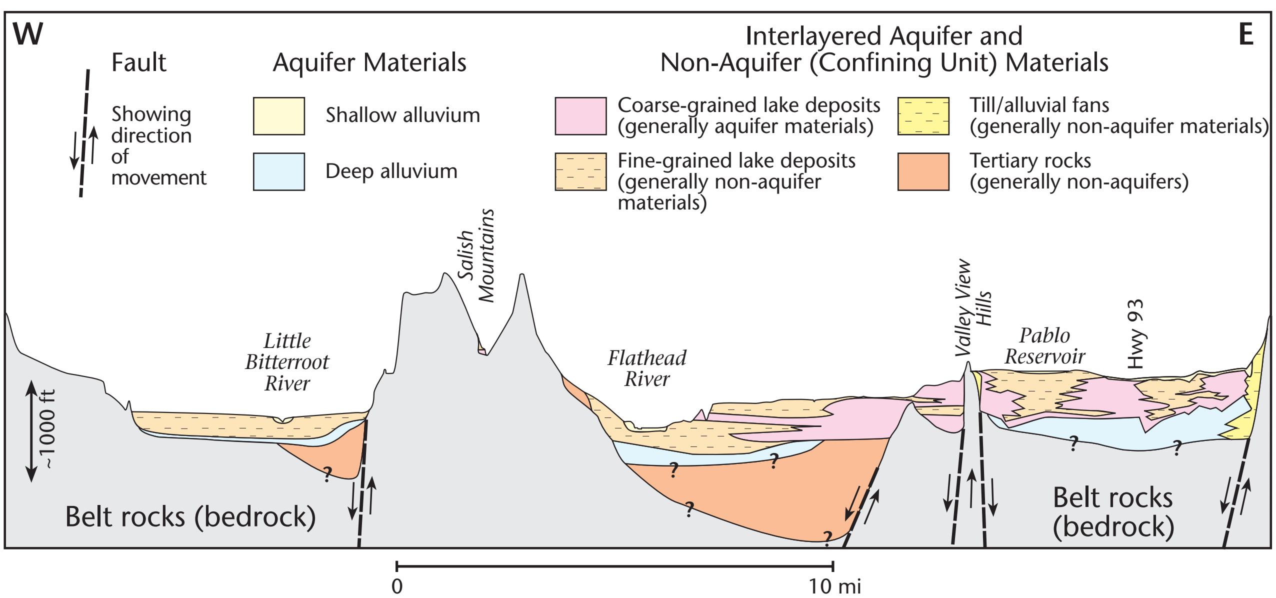



Figure 10. (a) A nearly valley-wide confining unit separates shallow and deep alluvial units in the Kalispell valley. (b) Coarse-grained (aquifer) and fine-grained (local confining unit) glacial-lake sediments separate shallow and deep alluvial units in the Mission and Little Bitterroot River valleys. Locations of sections are in fig. 9.

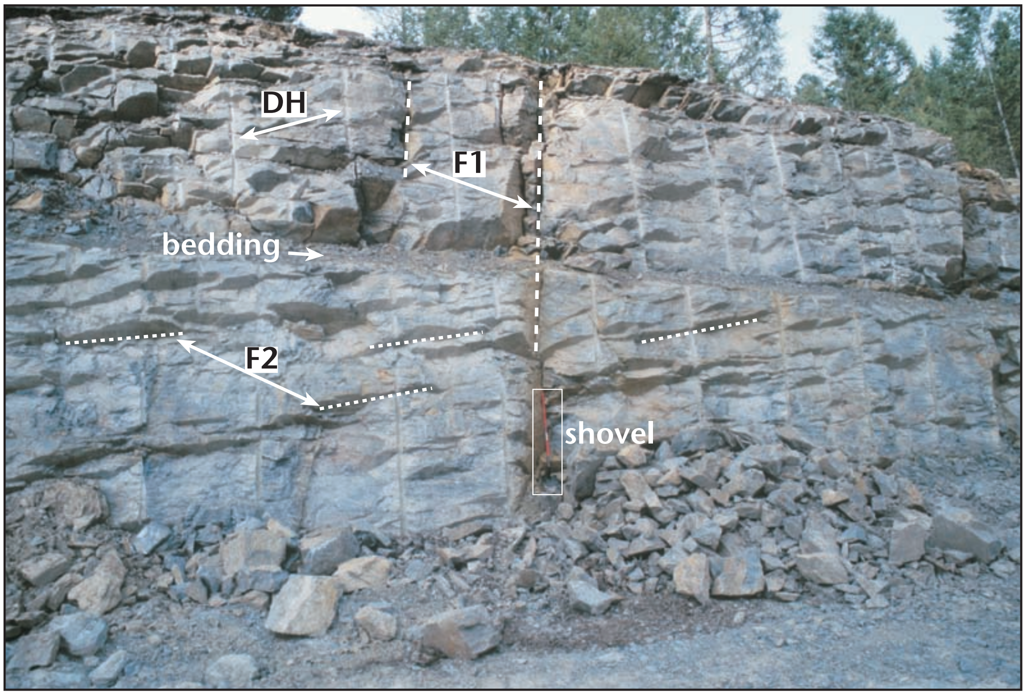



Figure 11. Belt Supergroup rock (bedrock) underlies mountains and foothills along the perimeters of the valleys and yields water to wells through fractures and bedding planes. Two sets of fractures in this roadcut are shown as F1 and F2. Drill holes used to create the roadcut (denoted by DH) are analogous to water wells that intersect fractures in the subsurface; note shovel for scale (location T. 27 N., R. 21 W., sec. 6).

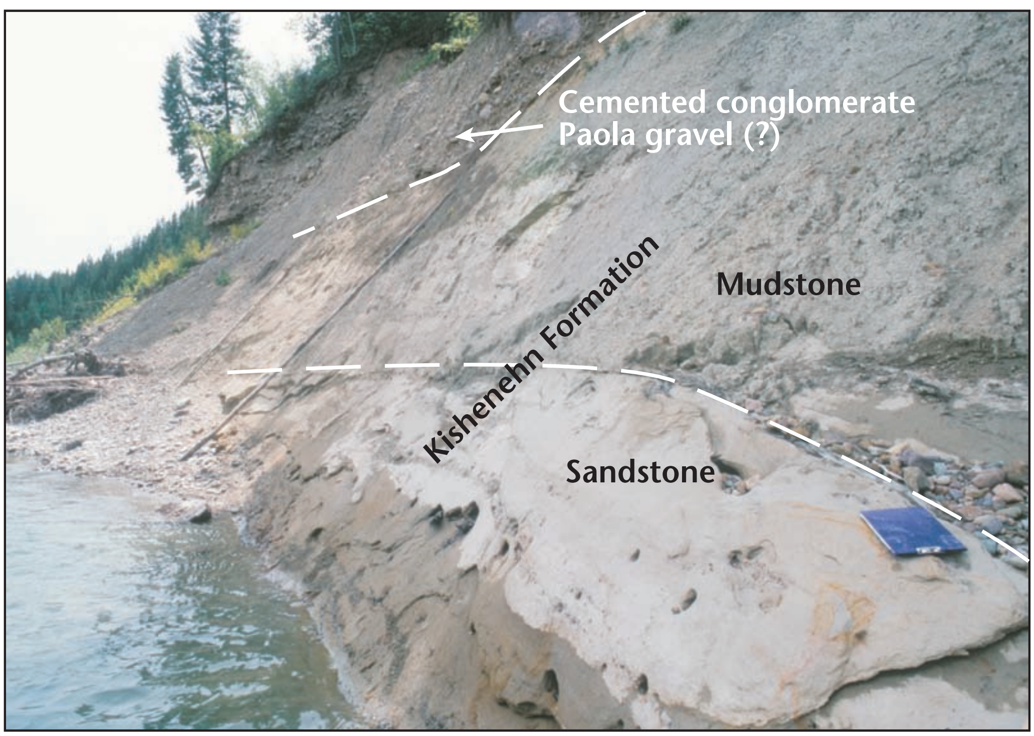



Figure 12. The Kishenehn Formation is made up of sandstone, mudstone, conglomerate, and some coal. Sandstone in this outcrop along the Flathead River near the town of Coram contains carbonized wood fragments. Calcium-carbonate cemented gravelly deposits in the distance may be exposures of the Miocene-aged Paola gravel; notebook in the fore-gound is 13 in by 9 in (location along the Flathead River, T. 31 N., R. 19 W., sec. 19 A).

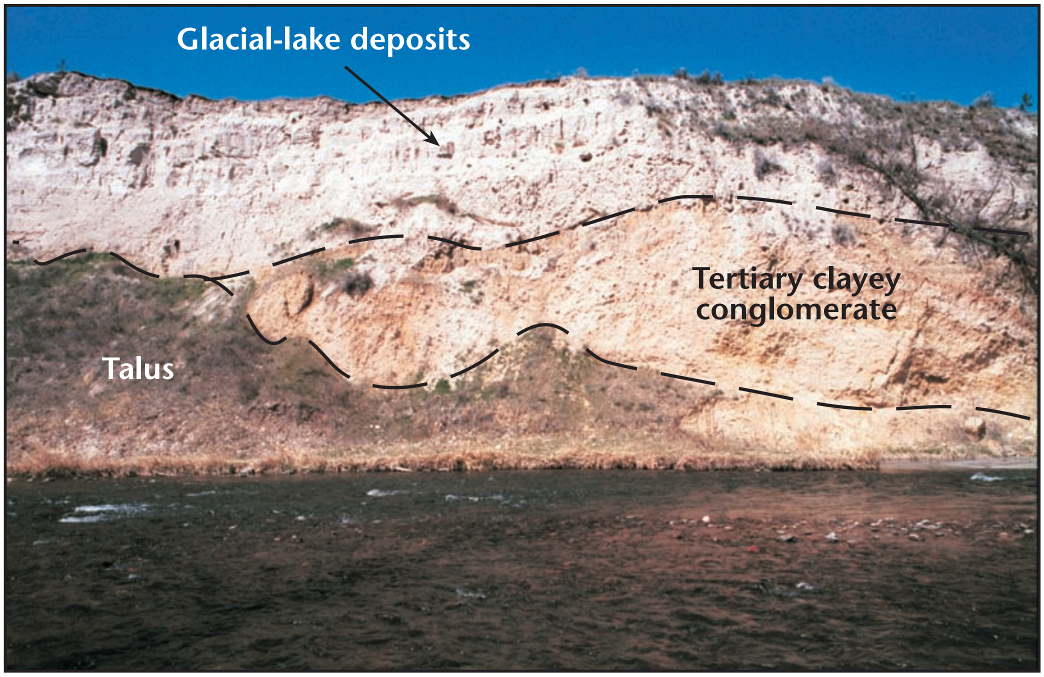



Figure 13. Tertiary sedimentary rocks in the Valley Creek area of the Jocko subarea include conglomerate, siltstone, and volcanic ash. Volcanic ash from a nearby exposure (near the confluence of Valley Creek and the Jocko River, T. 17 N., R. 20 W., sec. 8) yielded a radiometric age of 37 m.y. before present and is similar to the age of rocks in the Hog Heaven volcanic field in northwestern Lake County (P.C. Ryan, written commun., 1998).

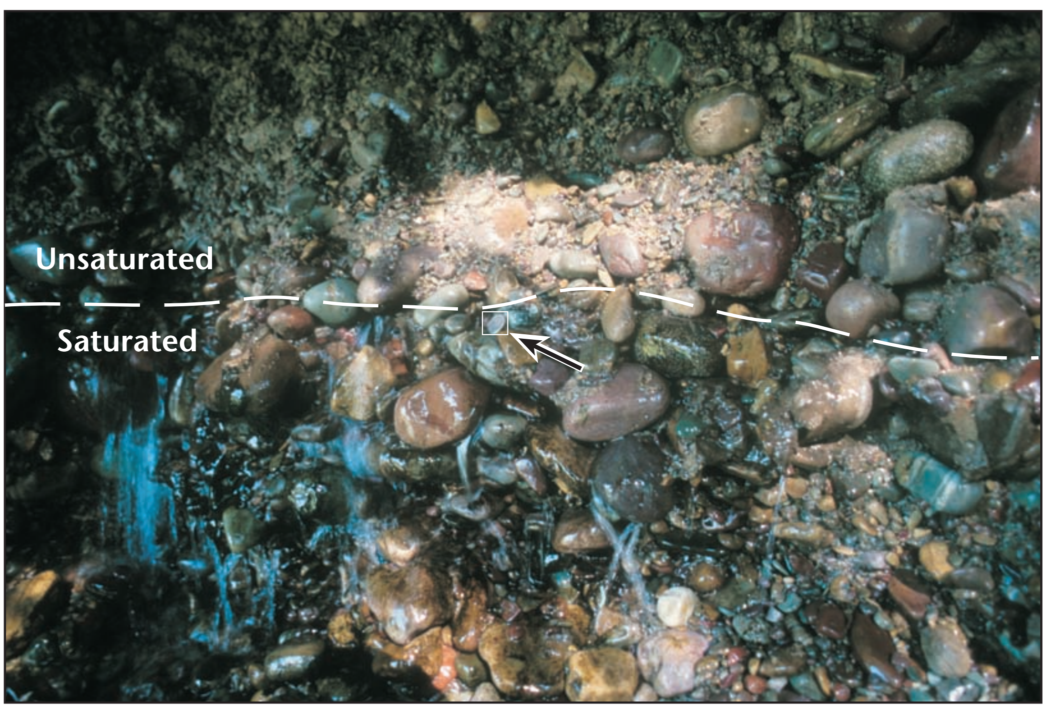



Figure 14. Sand and gravel exposed beneath till along the Flathead River north of Hungry Horse likely were deposited by streams in front of the advancing glacier and are the deep alluvium of the Coram subarea. These deposits are analogous to the deep alluvium in the Kalispell subarea and the deep alluvium in the Mission and the Little Bitterroot subareas. At this location, the deposits are saturated below the white dashed line; a quarter dollar for scale is shown by the white and black arrow (location T. 30 N., R. 19 W., sec. 5).

of interlayered gravel, sandy gravel, and medium- and coarse-grained sand, with lesser amounts of silt and clay. Clasts are commonly rounded and subrounded cobbles of quartzite, argillite, limestone, dolomite, and various igneous rocks. Cementation of either the clasts or the sand grains is not common; it was not present in cuttings examined during the drilling of nine observation wells in the Kalispell subarea (Uthman and others, 2000). However, partial cementation by calcium carbonate was observed locally in outcrops in the Coram subarea, and in drill cuttings collected 3 mi west of Lake Blaine (Shapley, 1990), and has been reported in other water-well logs.

The most important geologic events during the Quaternary age were the advance and retreat of glaciers that occurred between about 2 m.y. and 15,000 yr ago. The glaciers deposited materials that cover other Quaternary deposits, most Tertiary deposits, and some Belt Supergroup rocks in the mountains. Although ice likely advanced and retreated more than once, deposits of the most recent advance are at land surface in much of the Kalispell, Swan, Coram, North Fork, and Smith subareas. The impact of the glaciation extended beyond the actual area of the ice itself. South of Polson, the valleys and many of the foothills were flooded by Glacial Lake Missoula, a lake that was temporarily dammed by the Purcell lobe of the Cordilleran ice sheet near the present Montana/Idaho border (Pardee, 1910; Levish, 1997; Alt, 2001).

The terminus of the last southward advance (about 15,000–20,000 yr ago) of the Cordilleran ice sheet's Flathead lobe is marked by the Polson moraine, a prominent east–west set of hills that stretches between Kerr Dam and the Mission Range (Alden, 1953; Smith and others, 2000). At the time the Flathead lobe reached its maximum southward advance, Glacial Lake Missoula had inundated the valleys farther to the south. The occupation of the areas north of the Polson moraine by glacial ice and areas to the south by Glacial Lake Missoula led to generally different glacial sedimentary sequences north and south of the Polson moraine.

North of Polson the near-surface geologic deposits are dominated by till, outwash, and glacial-lake sediments. Till is "sediment that has been transported and deposited by or from glacial ice with little or no sorting by water" (Dreimanis, 1989) and includes thick beds of compact silty and clayey matrix with gravel and boulders that were deposited directly from glacial ice. An example of massive glacial till in the Kalispell subarea is found along the Foys Lake road (fig. 15a). Till that has been slightly modified by moving water is exposed in a gravel pit in the north-central Kalispell valley (fig. 15b). Within the Flathead Lake area, till is typically described in well logs as gravelly beds, in which clasts are embedded in a silty or clayey matrix. Till includes areally limited silty, clayey, and gravelly sand bodies deposited by water, debris flows, ice melt-out, or other processes adjacent to or within melting ice. Glacial re-advance across these ice-marginal sediments, or the melting of ice blocks next to or beneath them, often causes them to be eroded, rotated, and faulted. Ice marginal deposits within or near till are found at many locations in the Kalispell subarea (fig. 16).

Outwash refers to glacial-meltwater stream sediments that are composed largely of sand and gravel. Extensive fans or aprons of outwash can form along the advancing, retreating, or stationary margins of a glacier. Notable deposits of outwash are exposed on the east and west sides of the Kalispell valley (Part B, map 6).

In places north of Polson, glacial-lake silt and clay overlie till. As the Flathead lobe retreated northward, an "ancestral Flathead Lake" was dammed behind the Polson moraine and occupied much of the Kalispell valley. While this lake was present, silts and clays were deposited over till. At most locations where both till and glacial-lake beds have been observed, lake beds directly overlie the till without intervening glacial outwash sand and gravel deposits (fig. 17). The abrupt contact shows that the glacial lake flooded areas north of the Polson moraine immediately after the glacier withdrew. Deposits of the "ancestral Flathead Lake" are well-exposed at the land surface along the Stillwater River drainage, northwest of Kalispell.

South of Polson, Quaternary deposits in most of the valleys are dominated by silt, clay, and gravel units that were deposited in Glacial Lake Missoula (fig. 18a). During the Glacial Lake Missoula high stand, significant quantities of sediment from the Flathead lobe and the valley glaciers along the Mission Range washed into the lake. Laminated beds of silt and clay, silty sand, and silty gravel occur throughout the Mission, Jocko, and Little Bitterroot subareas (fig. 8, Part B, map 10). Laminated sediments formed where silt and clay suspended in the water column settled out in areas distant from sediment sources (fig. 18b). Sandy silt, gravelly sand, and gravelly silt beds have been recognized within or near the laminated sediments at many locations, which shows that sediment sources such as glacial-meltwater inflows were numerous and that some deposits were sorted and redeposited by strong in-lake currents. In places, isolated gravel clasts are found within the fine-grained sediments. Deformation

Figure 15. Till units in the Kalispell subarea have varied amounts of unsorted and sorted sediment. (a) Till is massive in areas where the boulder-, gravel-, silt-, and clay-sized debris were deposited directly by glacial ice (roadcut southwest of Kalispell along Foys Lake road, T. 28 N., R. 21 W., sec. 23 D); (b) some till shows stratification of pebble clasts because of reworking by flowing water. Note the characteristic plugging of spaces between pebbles by silt and clay (exposure in the Carlson Gravel Pit on Whitefish Stage road, T. 30 N., R. 21 W., sec. 21).

of the sediments below the clasts indicates that they were dropped onto the lake floor from melting ice (fig. 18c). Thin layers of poorly sorted gravel in lake deposits may represent local debris flows or annual meltwater events (fig. 18c). The upper surfaces of the glacial-lake deposits generally form broad areas of low relief. In well logs, glacial-lake deposits are described as thick clay or silt sequences with few, if any, gravel-sized clasts.

The glaciers completely melted about 15,000 yr ago, and since then the Flathead River and its tributaries have been primarily removing sedi-

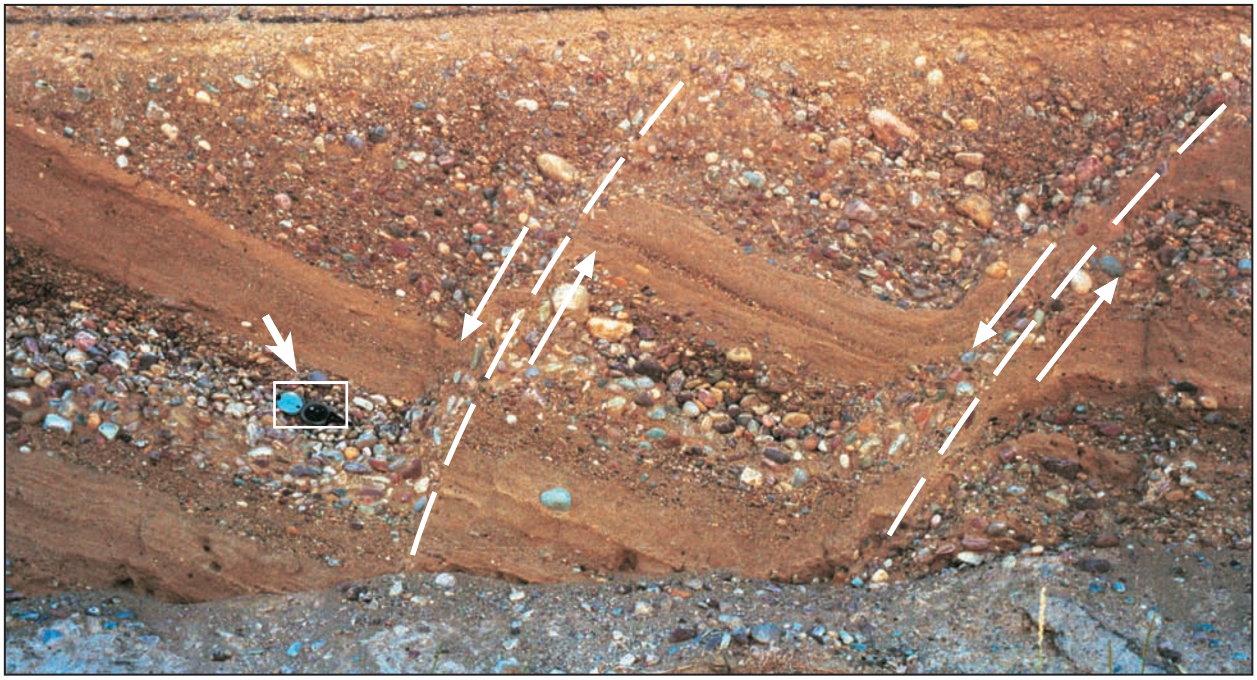


Figure 16. Glacial deposits include many sediment types that accumulated on or near glacial ice. Later faulting of the bedding (shown by dashed lines and arrows) may have resulted from advance of ice or melting of ice blocks next to or beneath the sediments. White arrow and box show location of a compass for scale (exposures in the McElroy and Wilken gravel pit, T. 28 N., R. 21 W., sec. 8, N ½).

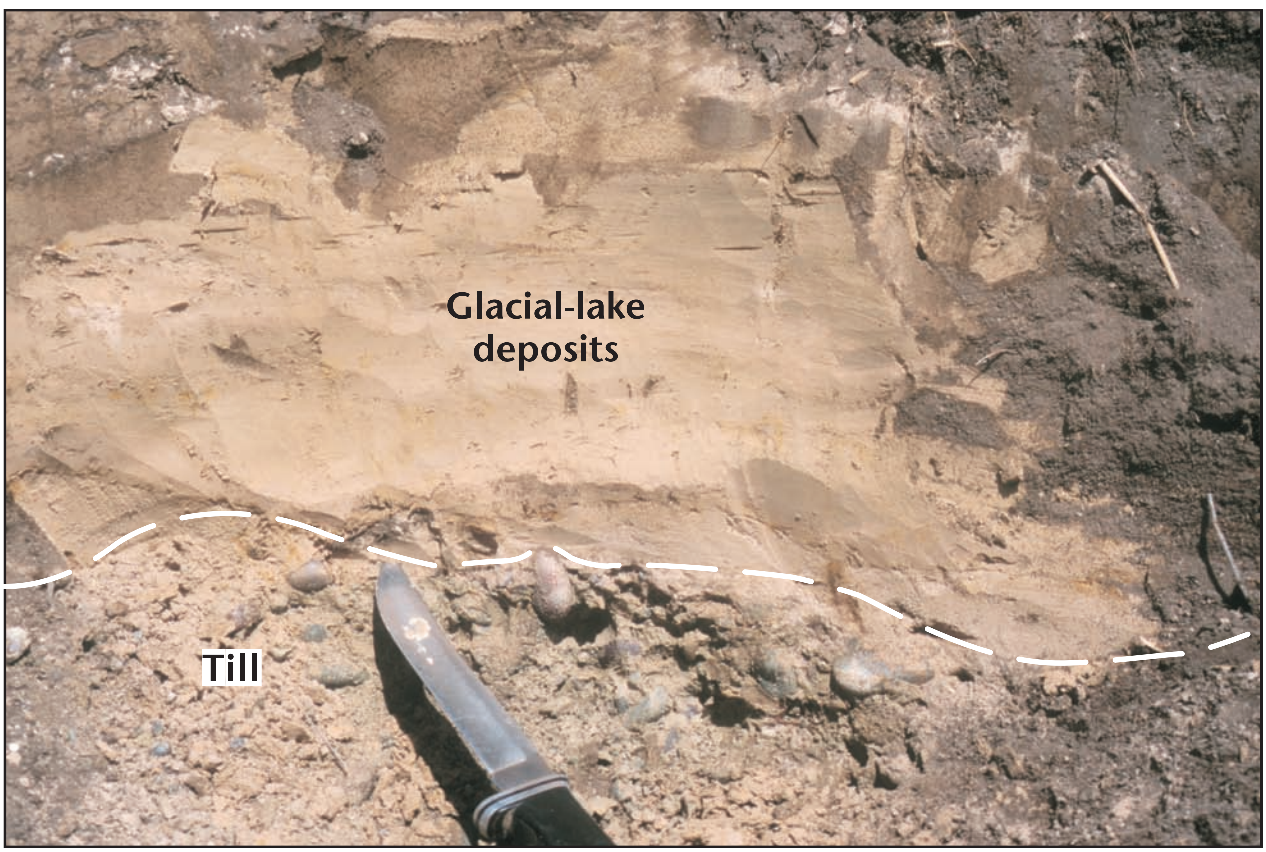
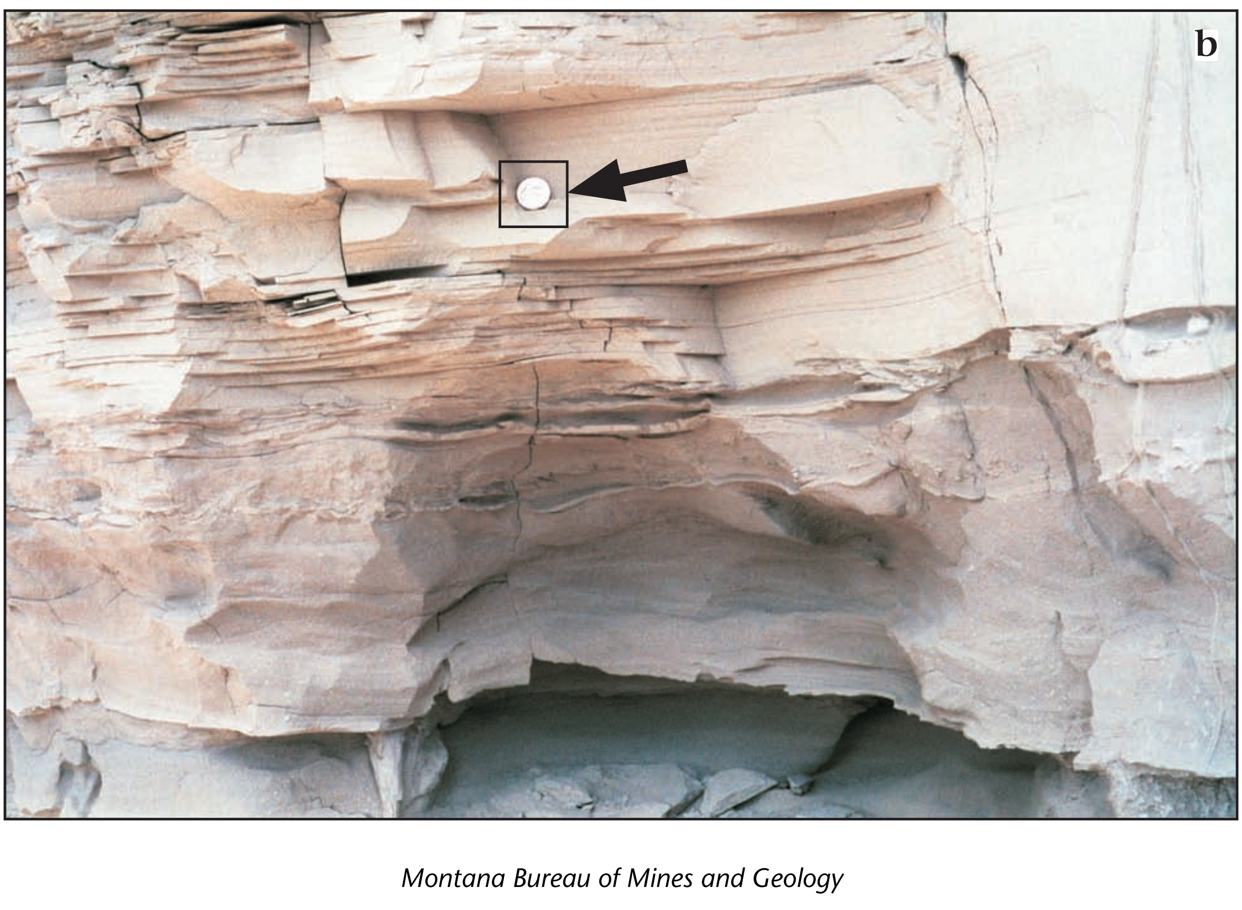



Figure 17. Glacial-lake sediments directly overlie till in many areas, indicating that lakes immediately in front of the glacier quickly inundated till as the ice front receded (from roadcut on the west side of Whitefish River, T. 30 N., R. 21 W., sec. 22).


a


b

C

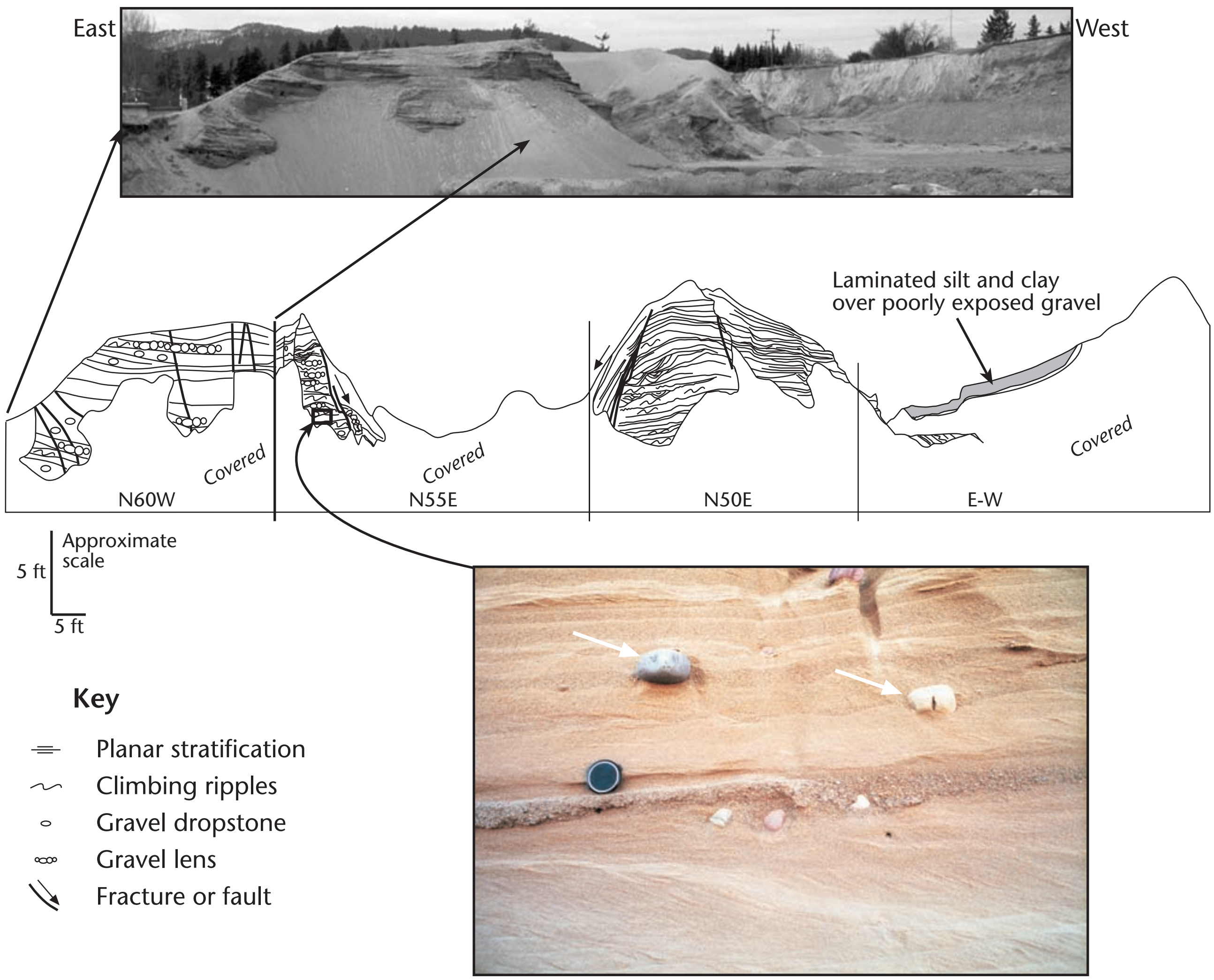



Figure 18. Glacial-lake sediments in the Kalispell and Mission subareas are mostly laminated silt and clay, indicating deposition of fine sediments dispersed in the water bodies. (a) Glacial-lake sediments are well-exposed along the Flathead River canyon downstream of Kerr Dam. The apparently massive, gray beds are made up of laminated silt and clay, and thick, coarse-grained beds of silty gravel (T. 20 N., R. 21 W., sec. 18). (b) Glacial-lake deposits south of Flathead Lake include laminated silt and clay; dime for scale (glacial-lake deposits in the Jocko Valley, on Hwy. 93 roadcut, T. 17 N., R. 20 W., sec. 16). (c) Some glacial-lake beds include gravel-sized clasts dropped onto the lake bottoms from melting icebergs (shown by arrows in the close-up photo; 52-mm lens cap for scale). The clasts are 2 to 4 in. in diameter (exposure in McElroy and Wilken gravel pit near Kalispell, T. 28 N., R. 21 W., sec. 8).

ments from the valleys. Downcutting through the Polson moraine by the Flathead River occurred shortly after deglaciation. Consequently, modern streams have locally removed some glacial-lake deposits north of Flathead Lake, exposing glacial till along the Flathead and Stillwater Rivers. As downcutting streams widened they deposited alluvium along their channels and floodplains. Most stream valleys in the area are lined with alluvial materials that range from 10 ft to several tens of feet in thickness. The shallow alluvium between the Whitefish and Flathead Rivers in the Kalispell subarea is generally more than 50 ft thick, and is an example of deposition that has occurred since deglaciation (Part B, map 11). Stream levels south of the Polson moraine also dropped rapidly during deglaciation. The Flathead River in the Mission valley cut a canyon almost 500 ft in depth soon after the glaciers retreated (Levish, 1997). South of Polson significant recent bodies of alluvium have been deposited along Mud and Post Creeks (Part B, map 11).

## Hydrogeologic Setting

Ground water is a plentiful and vital resource throughout the Flathead Lake area. Although a general hydrogeologic setting applicable to all subareas is discussed here, detailed descriptions of hydrogeologic conditions (water-level fluctuations, water-quality summaries, and aquifer-development statistics) are included in individual subarea sections throughout the atlas. In this atlas "basin fill" refers to unconsolidated Quaternary deposits and to Tertiary sedimentary deposits within the intermontane valleys; "bedrock" refers to Belt Supergroup rocks.

The occurrence and movement of ground water is controlled by the geologic framework and topography. Multiple aquifers occur in the basin-fill materials and in the surrounding bedrock of each subarea. The Quaternary portions of basin-fill materials contain the most widely used and prolific aquifers in the Flathead Lake area. Figure 19 uses the geologic framework introduced in fig. 8 to show how geologic units relate to the important aquifers. The five main hydrogeologic units in most subareas are: (1) shallow alluvium exposed at or occurring just below the land surface (shallow aquifers); (2) clayey and silty till and glacial-lake sediments (non-aquifers or confining units); (3) alluvium within or below the confining units (intermediate or deep alluvial aquifers); (4) Tertiary sedimentary deposits; and (5) fractured bedrock. The generalized vertical and horizontal relationships among the hydrogeologic units are shown in fig. 20. This suggested hydrogeologic framework fits all but the Flathead Lake perimeter subarea, where the primary aquifer is fractured bedrock; in that subarea aquifers developed in other materials occur only locally.

### Shallow Aquifers

Shallow aquifers occur in unconsolidated alluvial deposits (shallow alluvium) along stream valleys, in areas of surficial outwash, or in water-saturated bedrock near land surface (figs. 8, 21). Beach and deltaic sediment of the ancestral Flathead Lake and stabilized wind-blown sand may also support shallow aquifers. Shallow alluvial deposits consist primarily of permeable sand and gravel with lesser amounts of silt and clay, and are generally at or near land surface. The areal distribution of shallow alluvium is shown in Part B, map 11. The median thickness of shallow alluvium as described from well logs is 40 ft, but individual values range to more than 200 ft (see Part B, map 11).

Shallow aquifers are present in all the subareas. Ground water in these aquifers occurs under unconfined conditions and the water table is typically within 50 ft of the land surface. Shallow aquifers are important sources of water locally, but are generally limited in areal extent to floodplains associated with rivers and streams, and to glacial outwash (see Part B, maps 6, 11). In topographically low areas where bedrock is at the surface, typical of small valleys along the foothills, ground water may occur in the bedrock within 50 ft of the land surface and be under unconfined conditions; in these locations the fractured bedrock also is considered a shallow aquifer.

Ground water in the shallow aquifers is characterized by localized flow where water moves from local drainage divides (topographic highs) toward nearby valley bottoms. Water enters (recharges) the aquifers by direct infiltration of precipitation, leakage from irrigation ditches, and stream losses—especially along mountain fronts. It is common for high-gradient, entrenched mountain streams to lose water at the point where they enter the valleys because of decreased gradients and the change in geologic materials as they traverse from bedrock (relatively impermeable) onto basin fill (relatively permeable). The Swan and Mission Range fronts are examples where this occurs.

Ground water leaves (discharges) the shallow aquifers through springs and seeps along valley bottoms, gaining reaches of perennial streams, transpiration by plants, and pumpage from wells. In places along the east side of the Kalispell valley, the Lost Creek fan area, and the Mud Creek drainage east of Pablo, shallow alluvium is interlayered with underlying deep alluvium, providing a hydrologic connection between shallow and deep alluvial aquifers.

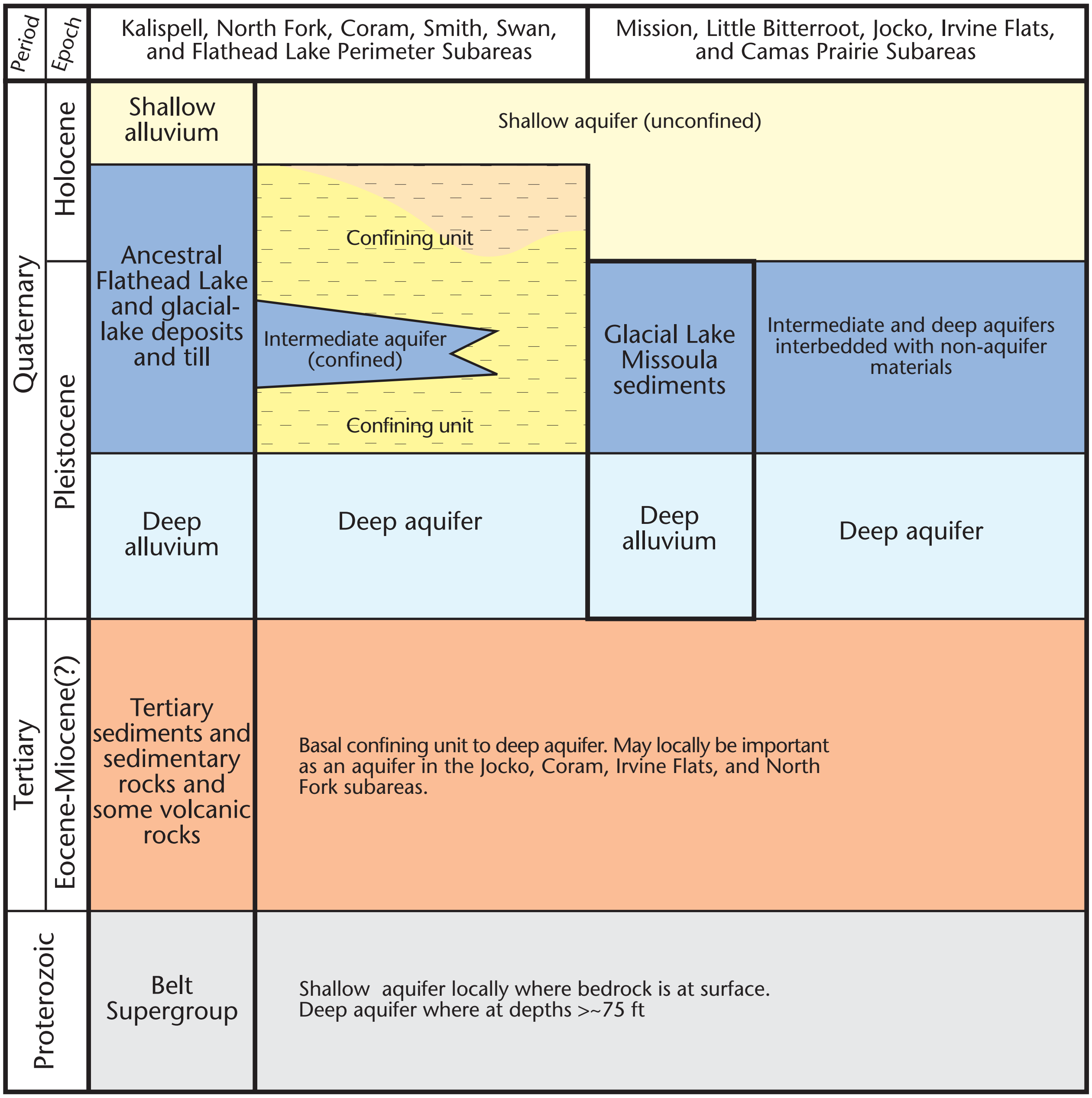



Figure 19. The primary hydrogeologic units in the Flathead Lake area are shallow aquifers in shallow alluvium, intermediate aquifers encased by confining units, deep alluvial aquifers that occur beneath confining units, and bedrock aquifers in fractured Belt Supergroup rocks. Shallow and deep flow systems that exist within subareas may include more than one hydrogeologic unit.

## Confining Units

Confining units, composed mostly of till and glacial-lake deposits, have low permeability and impede the movement of ground water. Throughout the Flathead Lake area confining units are present at a range of depths; they are exposed at the land surface, separate unconfined aquifers from more deeply buried confined aquifers, and separate confined aquifers at different depths (fig. 19). In the Kalispell subarea, clayey till is the principal material confining large areas of the deep alluvial and intermediate aquifers. However, within the Stillwater and Flathead River drainages, glacial-lake deposits also make up part of the confining units. In contrast, discontinuous confining units at various depths characterize the fill of the Mission subarea. The confining units range from tens to hundreds of feet in thickness, but within the Flathead Lake perimeter, Mission, and Jocko subareas they may not be continuous. Well-log data were sufficient to map the thickness of the confining unit only in the Kalispell subarea (Part B, map 9).

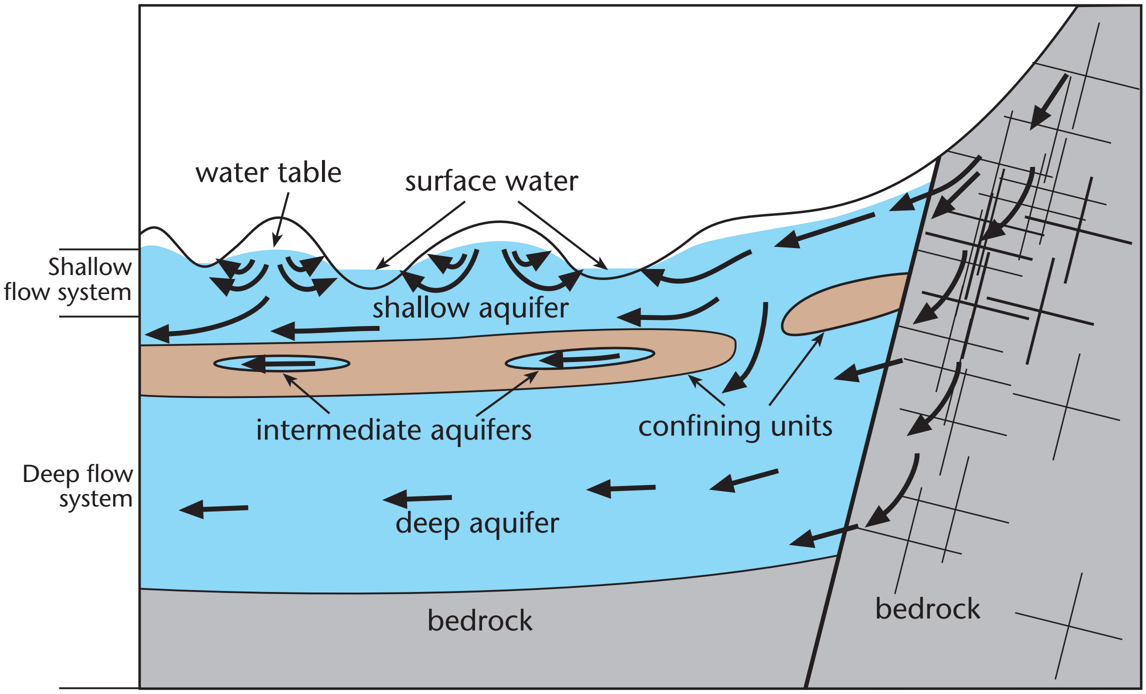



Figure 20. Schematic diagram showing vertical relationships between the aquifers and nonaquifers in the Flathead Lake area. Shallow aquifers occur in shallow alluvium. Confining units in till or glacial-lake deposits in many, but not all, areas separate shallow aquifers from deep alluvial aquifers. Intermediate aquifers are within the confining zones where local sand and gravel units occur, and are commonly of limited geographic extent. Deep alluvial or bedrock aquifers occur either in pre-glacial sand and gravel deposits below the confining units or in fractured bedrock, respectively. In a few subareas aquifers sometimes occur in Tertiary materials (not shown).

Figure 21. Shallow alluvium is mostly sand and gravel deposited by glacial meltwater streams (outwash) or modern streams. Measuring staff (marked with arrows) is 5 ft tall (gravel pit along Berne Rd., T. 30 N., R. 20 W., sec 15).

### Intermediate and Deep Alluvial Aquifers

For this report, intermediate aquifers are defined as distinct water-bearing sand and gravel horizons bounded above and below by confining units; intermediate aquifers are generally local features of variable thickness that cannot be correlated across large distances. Intermediate aquifers occur in all the subareas, generally at depths greater than about 75 ft below land surface. The aquifers are in sand and gravel deposits and are generally confined to semi-confined by overlying low-permeability till or glacial-lake deposits. In some places they interfinger with, or are hydraulically connected to, other intermediate aquifers or deep alluvial aquifers.

Deep alluvial aquifers are sequences of sand and gravel (deep alluvium) that are widespread and correlative beneath the confining units. Deep aquifers are extensively used in the Kalispell, Little Bitterroot, and Mission subareas. The intermediate and deep alluvial aquifers are the most utilized aquifers in the Flathead Lake area, and form the major ground-water flow systems in many subareas.

### Tertiary Aquifers

Most Tertiary sedimentary rocks consist of shale and mudstone, and are confining units or marginal aquifers. In a few subareas, especially the North Fork, the Tertiary sedimentary rocks contain discontinuous, permeable water-saturated sandstones and conglomerates that locally serve as aquifers. Although there are apparently great thicknesses of Tertiary deposits in many of the subareas, the materials generally occur at great depths, preventing them from being encountered by water wells or used as aquifers. Within the Flathead Lake area, only 1 percent of all wells are completed in Tertiary units, and average reported well yields are less than half the average yields reported for wells completed in other aquifers.

### Bedrock Aquifers

In general, within the Flathead Lake area there is sufficient fracture permeability in bedrock (Belt Supergroup rocks) to yield water to wells. However, the number, size, and orientation of the openings are unpredictable and can change abruptly over short distances (fig. 11). Differences in fracture density result in large variations in well yield from place to place. Where bedrock fractures are directly connected to the land surface, bedrock aquifers can be susceptible to surface sources of contamination. However, in many areas ground water in the bedrock occurs under confined conditions where the bedrock is covered by low-permeability deposits or where the water-bearing fractures occur at depth and the water is under pressure. On a regional scale, it appears that bedrock fractures are interconnected.

Potentiometric-surface mapping shows that ground water in the bedrock along valley margins also is in hydraulic communication with intermediate and deep alluvial aquifers (see Part B, maps 2, 4). Because the mountains trap most of the moisture received in the study area, water moving from the mountains to deeply buried valley deposits by way of fracture systems is an important source of ground-water recharge to the valleys (fig. 20).

## Ground-Water Flow Systems

A ground-water flow system consists of a single aquifer or a combination of aquifers and confining beds that function regionally to transmit ground water from recharge areas to discharge areas. Shallow ground-water flow systems are generally limited to single shallow aquifers where ground water is under unconfined conditions, and correspond closely to the areas of shallow alluvium. Ground water flows from higher topographic positions over short distances (generally <2 mi) to nearby streams or lakes. Where shallow aquifers are in hydrologic connection with underlying aquifers they can serve as important sources of recharge to deep flow systems.

Deep ground-water flow systems are present in the Kalispell and Mission subareas, where ground water flows from high altitudes in mountainous bedrock aquifers along the valley margins (regional topographic highs, which serve as drainage basin divides) toward discharge areas in deep and intermediate sand and gravel aquifers in the valley bottoms (regional topographic lows). In the Kalispell and Mission subareas the deep ground-water flow systems are overlain by shallow, local flow systems. While the shallow and deep flow systems are generally separated by confining units, the separation is not present in all areas and shallow and deep systems may be locally hydraulically connected.

# Hydrogeology of Subareas

## Kalispell

The Kalispell subarea (fig. 2) is a north–northwest-trending intermontane basin that lies north of Flathead Lake and is bounded by the Whitefish Range to the north and the Swan and Salish Ranges to the east and west, respectively. It is the largest basin in the study area, covering about 700 sq mi and home to about 70,000 people.

The Kalispell valley has a flat floor where surface elevations range from just less than 2,900 ft above sea level at Flathead Lake to 3,000 ft near Whitefish and Columbia Falls. The Swan Range, with peaks higher than 7,000 ft above sea level, rises abruptly from the east side of the valley floor; peaks in the Whitefish Range are generally between 5,500 and 6,500 ft above sea level, and peaks in the Salish Mountains to the west are generally less than 5,000 ft above sea level. The valley is drained by the Flathead River and its tributaries, Ashley Creek, the Stillwater River, the Whitefish River, and the lower reaches of the Swan River. Ground water, obtained from the basin fill and the bedrock that frames the valley, supplies most municipal, domestic, and agricultural water needs.

Exposed sediments in the Kalispell subarea are mostly till, glacial-lake deposits, outwash, and post-glacial alluvium deposited along the major stream courses (see Part B, map 6). Partially consolidated siltstone, carbonaceous shale, sandstone, and conglomerate also occur in the subsurface northwest of Columbia Falls and northeast of Whitefish, and are possibly equivalent to the Tertiary Kishenehn Formation. These rocks have been penetrated by a few water wells and by a hydrocarbon-exploration well. Geophysical surveys provide estimates of depths to lithified bedrock of about 3,000 ft in the Kalispell valley west of the northernmost Swan Range, and about 800 ft near the northern end of Flathead Lake (see Part B, map 7). The accumulation of more than 3,000 ft of basin-fill materials near the central axis of the valley suggests that part of the sedimentary fill was likely deposited during Tertiary time. However, drilling has not penetrated the entire basin-fill thickness in most of the valley.

There are more wells completed in the Kalispell subarea than in all the other subareas in the Flathead Lake area combined. Records from the GWIC database show that almost 10,300 wells have been drilled within the valley (fig. 22). Most of the wells (80 percent) are completed in the unconsolidated shallow, intermediate, and deep alluvial aquifers; the remaining wells are completed in bedrock aquifers around the valley's perimeter. Figure 22 shows that most wells less than 70 ft in depth are completed in shallow aquifers and represent about 25 percent of all wells drilled in the valley. About 75 percent of wells are completed at depths between 100 and 400 ft below land surface in the various aquifers of the deep flow system. Almost 40 percent of wells

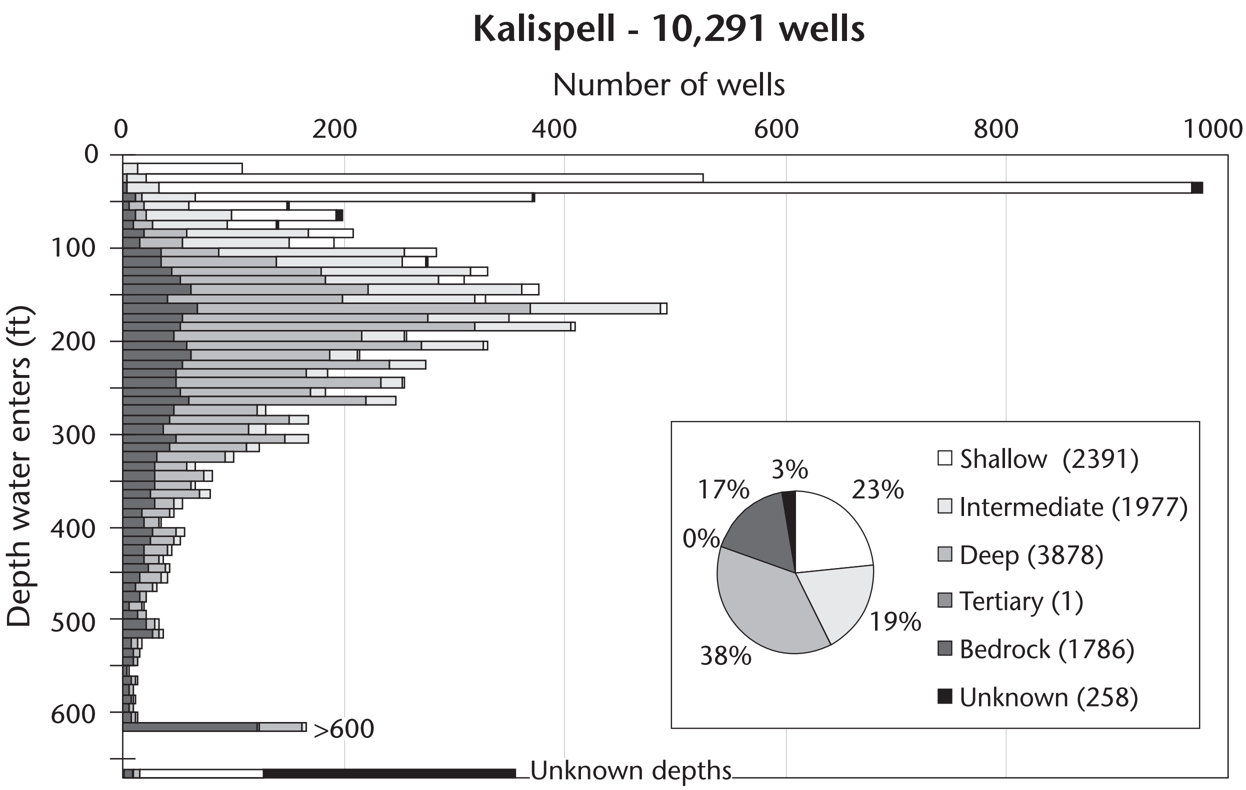



Figure 22. The bimodal distribution of well depths in the Kalispell subarea clearly reflects the use of shallow aquifers, such as the Evergreen aquifer, and also deep alluvial aquifers. The inset pie chart shows the percentages of wells developed in each aquifer. Most wells get water from intermediate, deep alluvial, and bedrock aquifers in the deep flow system.

drilled to depths of more than 100 ft are completed in the deep alluvium.

Designations of aquifers in this report correspond, with some modifications, to aquifers named by Konizeski and others (1968). Shallow aquifers in this report include the “floodplain,” “sand,” and “perched” aquifers of Konizeski and others (1968). The perched aquifers are shallow aquifers that are periodically drained during dry years or seasons. The “shallow” and “deep artesian” aquifers of Konizeski generally correspond to the intermediate and deep aquifers defined here. Recent potentiometric-surface measurements show that the aquifers are generally connected, and the intermediate and deep aquifers are now recognized as parts of a single, confined, deep ground-water flow system. The Precambrian aquifer of Konizeski and others (1968) is called the bedrock aquifer in this report.

## Shallow Aquifers

Shallow aquifers and locales that are especially important in the Kalispell subarea (fig. 23) are the alluvium between the Flathead and Whitefish Rivers [informally known as the Evergreen aquifer (Noble and Stanford, 1986)], the alluvium and glacial outwash on the east side of the Kalispell subarea between the Swan Range and the Flathead River (east-side aquifers), the delta vicinity immediately north of Flathead Lake (Delta aquifer), and the glacial outwash of the Lost Creek fan west of the Stillwater River (Lost Creek aquifer). In addition to supplying water to wells, the east-side aquifers and the Lost Creek aquifer may provide recharge to the deep ground-water flow system. Scattered occurrences of shallow aquifers outside those named are mostly along stream valleys.

Yields from shallow aquifers (fig. 24a) are comparable to those from other units but exhibit the most variability; the median reported yield from 1,730 wells is 30 gallons per minute (gpm), but 230 reported yields are greater than 100 gpm. Median depths in the Evergreen and east-side aquifers are 25 and 35 ft, respectively, and in many places the shallow aquifers rest on relatively impermeable till and glacial-lake deposits that separate them from more deeply buried intermediate and deep alluvial aquifers. The rate of ground-water development in shallow aquifers has been steady at about 200 wells per 5-yr period; more than 1,000 wells have been drilled during the past 25 yr (fig. 24b). The ability to complete shallow, highly productive wells makes the near-surface aquifers attractive.

Shallow aquifers are intrinsically susceptible to surface sources of contamination. The water table is commonly within 20 ft of the land surface. The aquifer materials are highly permeable, allowing rapid movement of water (and any associated contamination) from the land surface to the aquifer. Furthermore, as the land surface in the valley becomes more developed, potential sources of point and non-point source contamination will increase.

### Evergreen Aquifer

The Evergreen aquifer, composed of shallow alluvium overlying low-permeability silt and clay, occupies approximately 40 sq mi between the Whitefish and Flathead Rivers (fig. 23). The median reported well depth is about 25 ft, but maximum reported depths to water are about 30 ft. The aquifer is very productive, with reported yields reaching 1,500 gpm, although the median reported yield is 30 gpm. The median reported static water level from 860 wells is 12 ft below the land surface. Ground water flows southward through the aquifer toward the confluence of the Whitefish and Flathead Rivers.

Permeability in the Evergreen aquifer can be very high. Two aquifer tests reported by Konizeski and others (1968) yielded a transmissivity of 174,200 $ft^2$/day (appendix B); Noble and Stanford (1986) estimated the bulk transmissivity of the aquifer to be in the range of 120,000 to 241,200 $ft^2$/day.

Median monthly altitudes for long-term water-level measurements in the Evergreen aquifer (fig. 25) show that water levels rise annually 1 to 1.5 ft during the spring and early summer months, peaking in May or June in response to recharge from runoff, snowmelt, and rainfall. Water levels decline during the late summer when river flows decline and evapotranspiration and ground-water usage are highest. Water levels are lowest during the winter when recharge from the Flathead River and other sources is minimal. Comparison of monthly median water levels from wells with the monthly average flow of the Flathead River at Columbia Falls (fig. 25) shows good correlation between the timing of high water levels and Flathead River discharge. The correlation is in agreement with Noble and Stanford (1986), who showed that water-level fluctuations in the Evergreen aquifer appeared to be closely tied to the stage of the Flathead River. Deviations from the general pattern may occur during years of extremely high or low precipitation (e.g., 1996 precipitation was 60 percent above average), or changes in flow in the Flathead River.

The hydrographs do not show long-term water-level declines or increases, suggesting that the Evergreen aquifer is in hydraulic equilibrium: the water entering and leaving the aquifer on an

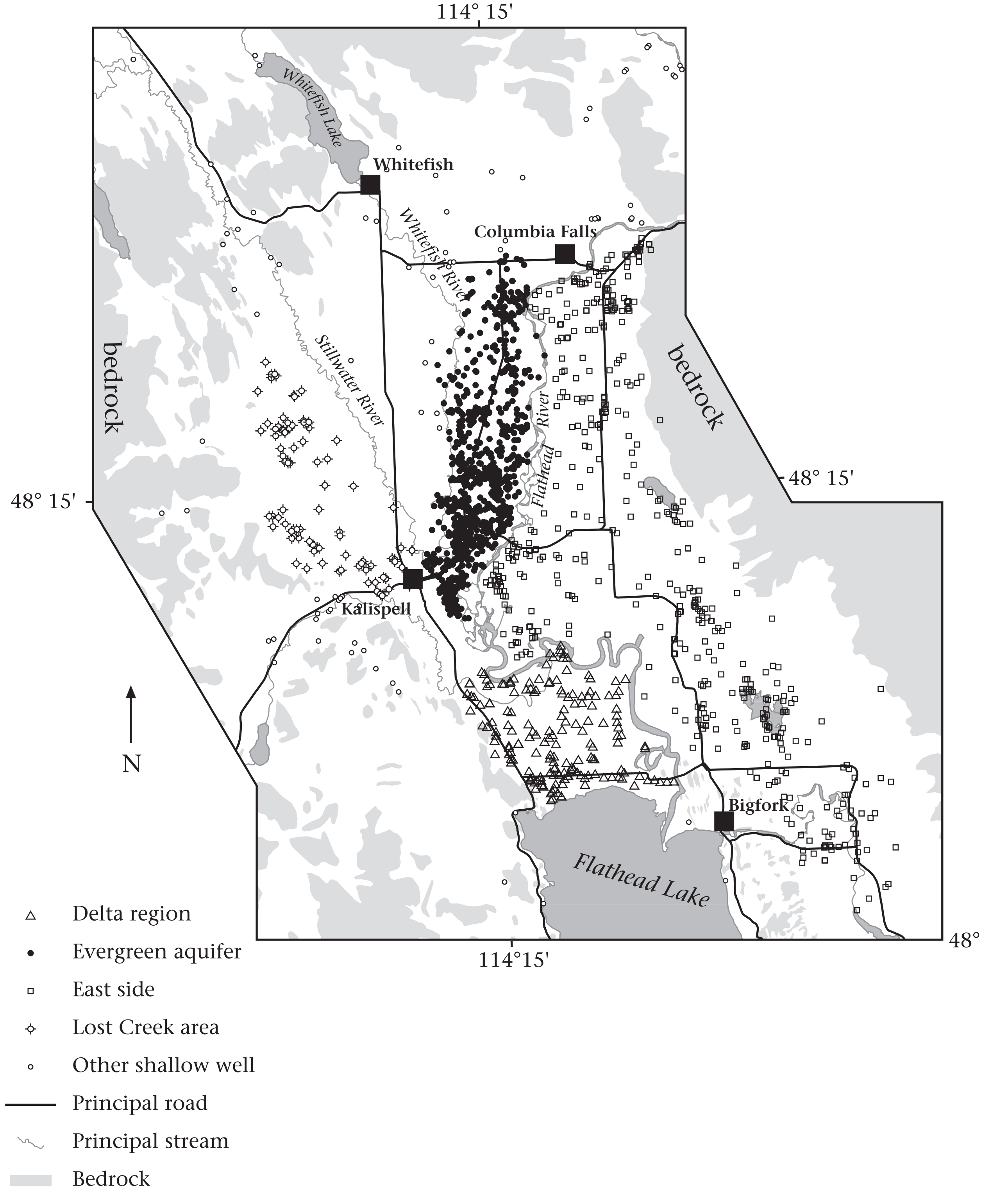



Figure 23. Shallow aquifers provide water to many wells in the Kalispell subarea. Well-defined shallow aquifers include: (1) the Delta region, between the north shore of Flathead Lake and the Flathead River; (2) the Evergreen aquifer between the Flathead and Whitefish Rivers, which is the most developed shallow aquifer in the Kalispell subarea; (3) the east side between the Flathead River and the foothills of the Swan Mountains; and (4) the Lost Creek fan west of the Stillwater River near the Salish Mountains. Most other places where shallow aquifers have been developed are along stream valleys.

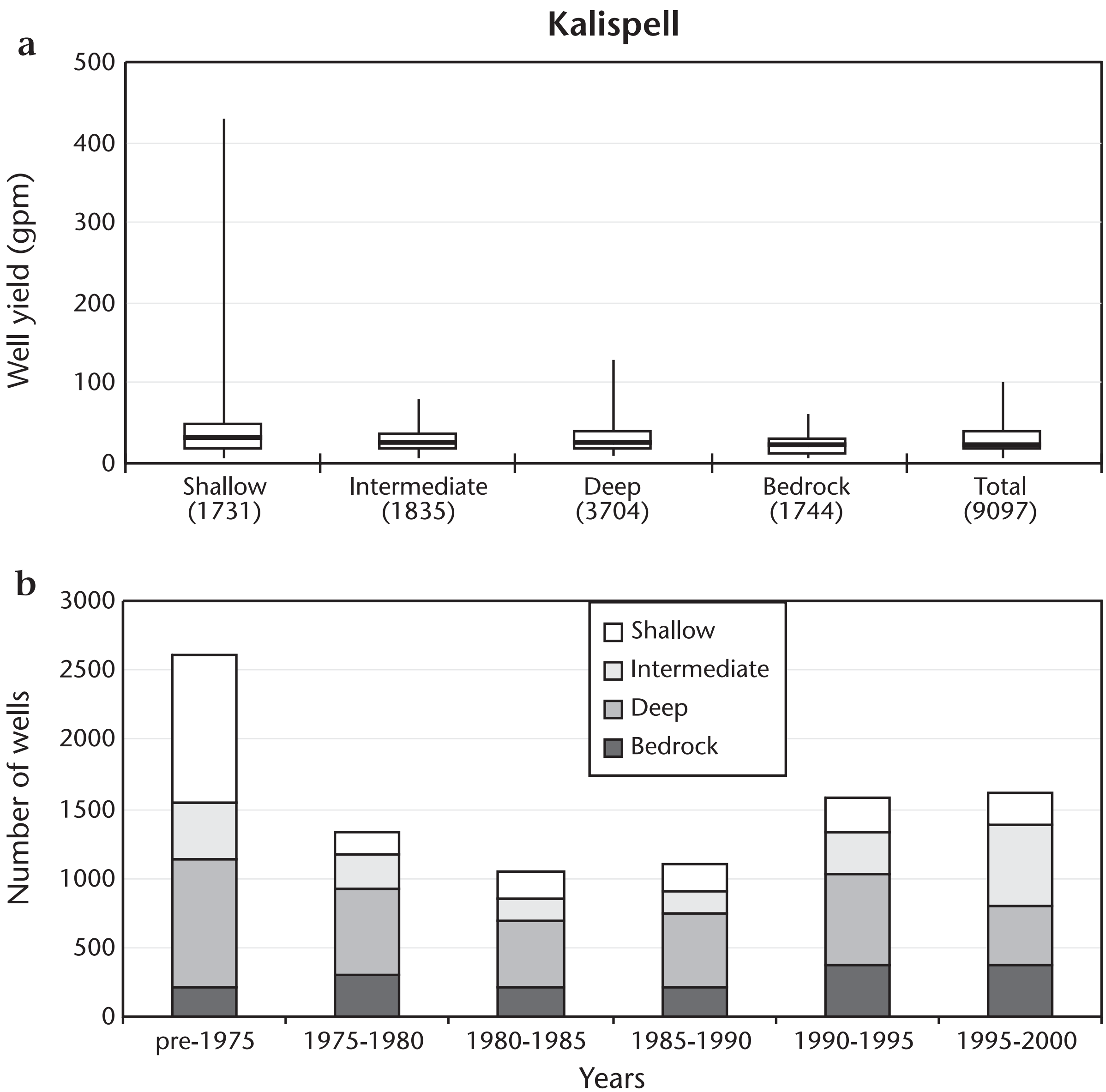



Figure 24. (a) Reported yields from aquifers within the Kalispell subarea are summarized by box plots. Most wells in each aquifer have reported yields of less than 50 gpm, and 5 of those wells have reported yields of greater than 3,000 gpm. Yields are lowest in wells completed in bedrock. The box plots show the distribution of values within each group. Tall boxes and long vertical lines show that the values vary widely. Short boxes and short lines show that the values are less variable. The upper end of the vertical line in each plot shows the value of the 95th percentile (95 percent of the data in the set were below this value). The top and bottom of each box show the values of the 75th percentile (75 percent of the data in the set were below this value) and the 25th percentile (25 percent of the data in the set were below this value), respectively. The bottom end of the lower vertical line in each plot shows the concentration of the 5th percentile (5 percent of the data in the set were below this value). The horizontal line within each box is the value of the 50th percentile (half the data in the set were below this value). (b) Since 1985 there has been a steady increase in the number of wells completed in the Kalispell subarea.

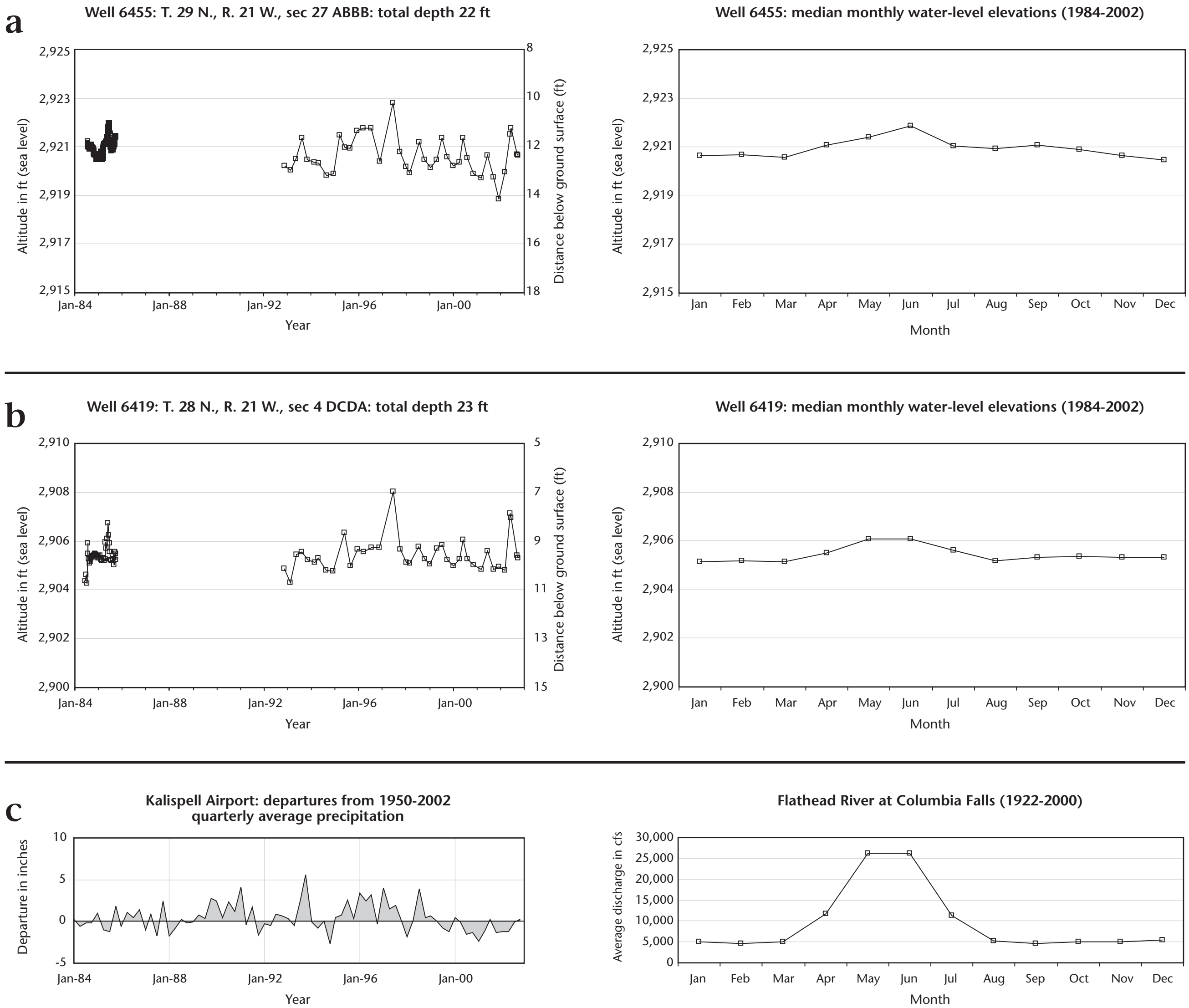


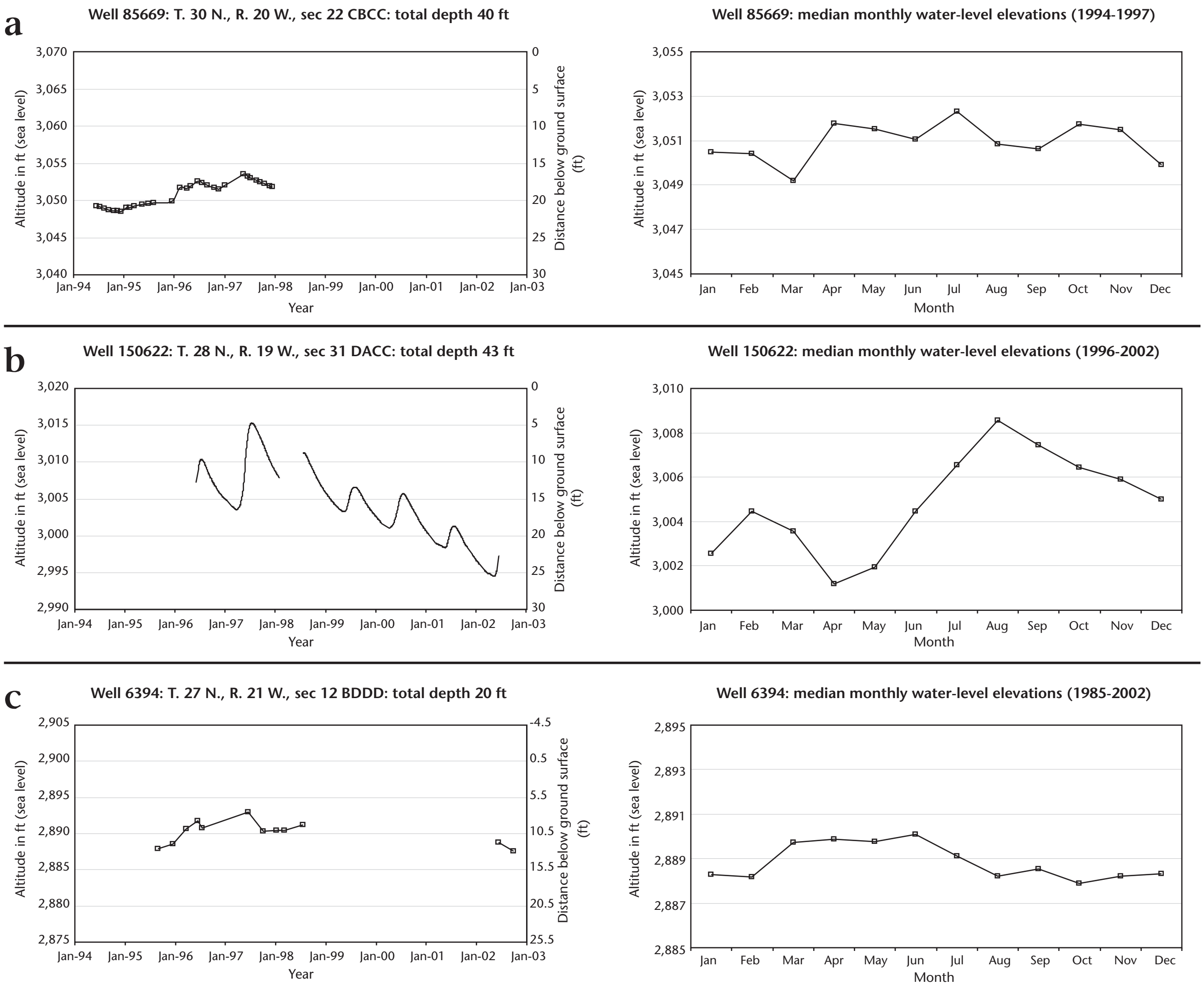

Figure 25. Hydrographs from wells completed in the Evergreen aquifer show consistent annual water-level responses that appear to be strongly influenced by surface water. No long-term declining or increasing trends are apparent in the records. (a) Well 6455; (b) well 6149; (c) average precipitation and discharge. Data for the Flathead River discharge at Columbia Falls from http://waterdata.usgs.gov/nwis/discharge.

annual basis is consistent (fig. 25). The water levels (representing aquifer storage) do not appear sensitive to climatic change, further suggesting that the aquifer is closely connected to discharge in the Flathead and possibly the Whitefish Rivers. Even though more than 800 wells have been completed in the Evergreen aquifer, the hydrographs show no evidence of impact from pumpage.

### East-Side Aquifers

Aquifers along the east side of the Kalispell subarea occur in alluvium associated with the Flathead and lower Swan Rivers, surficial sand deposits (ice-contact stratified drift), and glacial outwash (Lake Blaine–Echo Lake vicinity). These shallow aquifers supply water to more than 500 wells (fig. 23). The surficial sand and outwash are locally interbedded with glacial-lake deposits and till, making the thickness and extent of the aquifers variable and difficult to define. Ground-water flow is generally from the western front of the Swan Range toward the Flathead River. Based on potentiometric surface, water quality, and geologic mapping (Part B, maps 2, 5), the east-side shallow aquifers appear to be hydraulically connected to the deep ground-water flow system and are important recharge sources to that system. Well depths in the east-side aquifers are as much as 160 ft, but the median is 35 ft. The median reported static water level is 20 ft below the ground surface. Wells reportedly yield as much as 1,000 gpm with a median yield of 25 gpm.

Water levels in the east-side shallow aquifers appear to have regular seasonal cycles and also respond to long-term climatic conditions (fig. 26). Water-level data from a surficial aquifer located



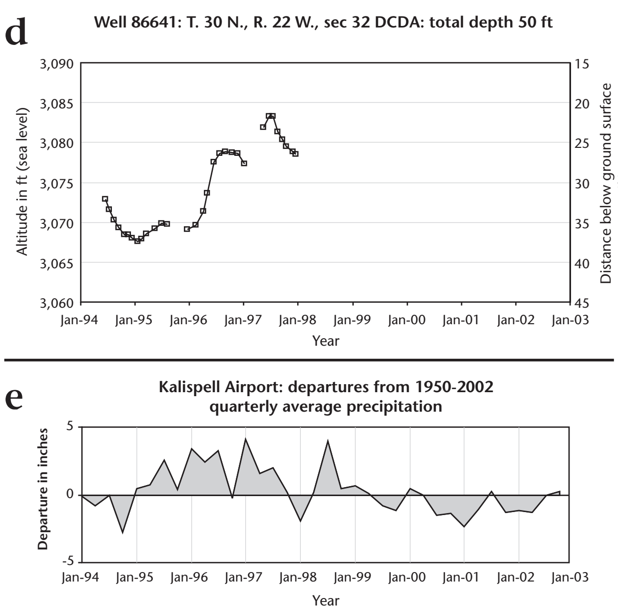




Figure 26. Water levels in shallow aquifers reflect seasonal precipitation and long-term climatic trends; however, the magnitude of water-level change in the shallow aquifers is not consistent. Measurements from shallow aquifers show that water levels rose similarly in response to the high precipitation period from 1995 to 1998: (a) an aquifer about 1.5 mi south of Columbia Falls (well 85669); (b) a shallow aquifer near Lake of the Woods (well 150622); (c) a shallow aquifer in the Delta region (well 6394); and (d) a shallow aquifer in the vicinity of the Lost Creek fan (well 86641). During the subsequent low precipitation period, water levels have declined in the well near Lake of the Woods, which has been consistently monitored since 1998. (e) Average precipitation.

about 1.5 mi south of Columbia Falls show that water levels generally peak in April or May and fluctuate no more than 3 ft annually. Data from a surficial aquifer in the Many Lakes area near the Lake of the Woods show that water levels generally change about 8 ft per year, peaking in July or August. Together, the hydrographs demonstrate response to climatic conditions. Water levels generally rose during a wet period that ended in 1997–98, but have generally fallen during the dry climatic cycle that began in 1998–99.

### Delta Aquifer

The Delta aquifer consists of fine- to medium-grained sand deposited between the north end of Flathead Lake and the Flathead River (fig. 23), and is hydraulically separate from the Evergreen and east-side surficial aquifers. Ground-water flow direction in the Delta aquifer is controlled by seasonal stages in the Flathead River and Lake; generally flow is from the aquifer to the river and lake when lake and river levels are low, and from the lake and river into the aquifer when lake and river levels are high (Konizeski and others, 1968). Noble and Stanford (1986) conducted four aquifer tests in the Delta aquifer and reported transmissivities ranging from 1 to 3,700 $ft^2$/day (appendix B). Depths for about 135 wells completed in the aquifer are as much as 75 ft below land surface, but the median depth is 26 ft. The median reported depth to water is 16 ft. The productivity of the Delta aquifer is generally lower than that reported for other shallow aquifers; the maximum reported yield is 500 gpm and the median reported yield is 15 gpm.

Limited monitoring between 1985 and 1998, and since 1995 (well 6394), shows no long-term change in water levels, indicating water in storage has remained stable. Monthly median water levels show that water levels rise about 2 ft beginning in March and remain elevated through June of each year. Beginning in July, water levels fall about 2 ft and remain at the lower level until the following March (fig. 26).

### Lost Creek Fan

The Lost Creek outwash fan is a thick accumulation of shallow alluvium deposited by glacial meltwater near the mouth of Lost Creek in secs. 8 and 17 of T. 29 N., R. 22 W. (Smith and others, 2000). More than 100 wells are completed in the aquifer (fig. 23); well depths are as much as 120 ft with a median of 40 ft. The median reported depth to water is 30 ft. Reported well yields are as much as 1,000 gpm, with a median yield of 25 gpm. Konizeski and others (1968) have shown that ground-water flow in the shallow aquifer near Lost Creek is generally to the east. In addition to eastward ground-water flow, water-level, water-quality, and well-log data from shallow and deep wells suggest that shallow ground water may be in hydraulic connection with the underlying deep alluvium and that downward components of flow may be an important recharge source for the deep ground-water flow system (see Part B, maps 2, 9).

Water levels from the northern part of the Lost Creek fan suggest that ground-water storage is influenced by climate (fig. 26). The hydrograph from a well measured between 1994 and 1997 shows an annual water-level cycle that rises from minimums each January to maximums each June. The annual cycle is overprinted on a period of generally rising water levels that ends in 1997 with a seasonal peak 13 ft higher than that in 1995. The rising water levels correspond with a wet climatic period that ended in mid-1997.

## Intermediate and Deep Alluvial Aquifers

Intermediate aquifers are found near the base of glacial deposits (confining units) that separate shallow alluvial from deep alluvial aquifers. The intermediate aquifers are discrete water-bearing sand and gravel horizons separated by layers of silt and clay. Individual intermediate aquifers may have different water levels, suggesting hydraulic separation from each other and from the underlying deep alluvial aquifer. However, on a regional valley-wide scale, the local head differences between individual intermediate aquifers are minor. Water-level data also suggest that on a regional scale sufficient hydraulic continuity exists between intermediate aquifers and the deep alluvial aquifer to allow their consideration as a single ground-water flow entity. The “shallow artesian” aquifers of Konizeski and others (1968) correspond to some of the intermediate aquifers.

The deep alluvial aquifer occurs as a nearly continuous layer of sand and gravel (the deep alluvium) that underlies most of the Kalispell subarea. The deep alluvium rests on bedrock and/or Tertiary sedimentary rocks and is overlain, either abruptly or transitionally, by till and glacial-lake deposits.

The intermediate and deep alluvial aquifers are the most utilized sources of water in the valley, and well-log records show that about 60 percent of all wells in the Kalispell subarea are completed in these units. Wells completed in sand and gravel deposits greater than 100 ft, but less than about 200 ft, below land surface (fig. 22) may obtain water from either an intermediate aquifer or the deep alluvial aquifer. At depths greater than about 200 ft, almost all wells in the valley get water from the deep alluvial aquifer. Away from the margins of the valley, no well completely penetrates the deep alluvium, even though some are more than 400 ft deep. Most wells completed in intermediate aquifers are in the eastern and northern parts of the valley (fig. 27). In the central part most wells are completed in the deep alluvial aquifer.

Development of intermediate and deep alluvial aquifers has accelerated during the past 25 yr. Cumulative drilling through 1975 had produced about 1,300 well completions. Between 1975 and 2000 at least 4,200 new wells (168 wells per year) were drilled, resulting in a more than four-fold increase in the total number of wells (fig. 24b).

The intermediate and deep alluvial aquifers are highly productive. The median reported well yield is about 25 gpm (fig. 24a), but there are more high-yield wells in the deep alluvial aquifer than

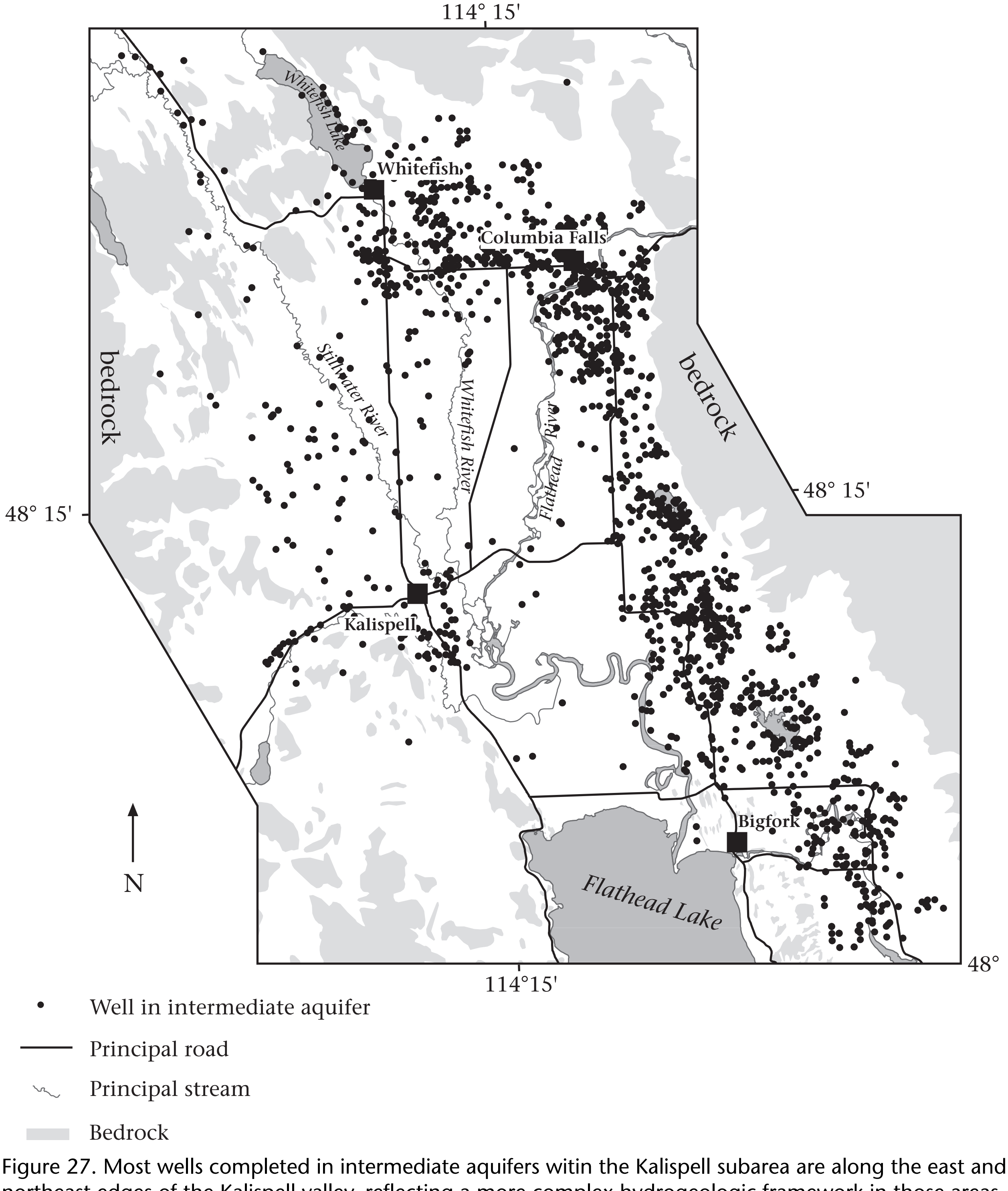



Figure 27. Most wells completed in intermediate aquifers witin the Kalispell subarea are along the east and northeast edges of the Kalispell valley, reflecting a more complex hydrogeologic framework in those areas than in the valley center.

in intermediate aquifers; 7 percent (248) of the wells completed in the deep alluvial aquifer have reported yields greater than or equal to 100 gpm and 36 wells have reported yields of 1,000 gpm or more. Only 3 percent (61) of intermediate aquifer wells have reported yields greater than or equal to 100 gpm and only 4 wells have reported yields greater than 1,000 gpm. Based on data from 11 aquifer tests compiled from previous work, transmissivities in the deep alluvial aquifer range from 48 to 30,800 $ft^2$/day (appendix B) with an average of 9,500 $ft^2$/day. Aquifer test data for intermediate aquifers is scarce. Only one transmissivity value (375 $ft^2$/day) has been reported among the many wells completed in intermediate aquifers.

### Water Levels

Annual water-level fluctuations in the deep alluvial aquifer vary with place and time, but there are two general patterns: (1) a "runoff" response where water levels rise in the spring and early summer and then drop during the late summer, fall, and winter; and (2) a "pumping" response where water levels drop sharply in the late summer, quickly recover during the fall, and remain stable during the winter. The patterns are best displayed in hydrographs from wells with water-level recorders (fig. 28), but can also be observed in many hydrographs based on monthly measurements.

There is a distinct spatial pattern to the two responses (fig. 29). The runoff response has generally been observed in wells near the edge of the valley close to areas where the deep alluvial aquifer may be open to recharge, or in the southern part of the valley near Flathead Lake. The pumping response has generally been observed in wells near the middle of the valley where the deep alluvial aquifer is fully confined. The general correspondence between the locations of wells where the pumping response has been observed and the locations of irrigation and public supply wells that have reported yields of more than 300 gpm (fig. 29) suggests that water-level fluctuations in a large part of the deep alluvial aquifer are controlled by summertime pumpage.

The pumping response developed during the 1970s and is documented by two long-term water-level records (fig. 30). From 1963 to 1967, median monthly water levels in well 702938 (location in fig. 29) followed a runoff pattern: rising during the spring and early summer to peaks in June before declining during the fall and winter to lows each December and January. Maximum annual water-level change was generally less than 4 ft. From 1968 to 1981, median monthly water levels in the same well documented a pumping pattern: water levels were highest in January and lowest in July. The change in pattern was accompanied by annual fluctuations of as much as 10 to 15 ft. Water-level monitoring in well 702938 ceased in 1981, but data from a nearby well (figs. 29, 31) show that the pumping response continues to the present, and in this area is as much as 25 ft. A second long-term water-level record also documents the change from the runoff to the pumping response in the deep alluvial aquifer. From 1963 to 1972, water levels from a 278-ft-deep well centrally located in the valley north of Kalispell (well 131524 in figs. 29, 30) followed a runoff response. Water levels peaked in June and July and were lowest in March. The annual fluctuation was generally less than 2 ft. From 1973 to 2002, water levels followed a pumping response, generally peaking in June and falling to annual lows in August. Annual water-level fluctuations were as much as 8 ft.

Coincident with the development of the pumping response in the central part of the Kalispell subarea, a steady downward movement in water levels began in about 1973 (fig. 30). The downward trend apparently ceased in 1991. The decline between 1973 and 1991 may be related to increased pumpage in the valley. The Department of Natural Resources and Conservation water-rights database shows that the number of water rights requested for wells greater than 75 ft deep, to be used for irrigation in Flathead County, peaked during the 1970s, and has declined significantly since then, with a brief surge in the late 1980s (fig. 32). Similarly, the GWIC database shows that the greatest number of irrigation wells with reported yields of more than 300 gpm were installed between 1970 and 1980. The increased pumping withdrawals from the high-capacity wells have resulted in a decrease in ground-water storage, as indicated by the lowered water levels. That the declining trend in water levels stopped in 1991 suggests that the aquifer reached a new state of equilibrium; water is not being depleted from the aquifer on an annual basis, characterized by large annual water-level fluctuations in response to seasonal pumpage.

Increased demand placed on the aquifer during the 1970s and 1980s has apparently not resulted in a persistent cone of depression or serious water-level declines. However, most long-term records do show a slight downward trend during the past 10–20 yr and larger observed annual water-level fluctuations in current measurements than those observed earlier.

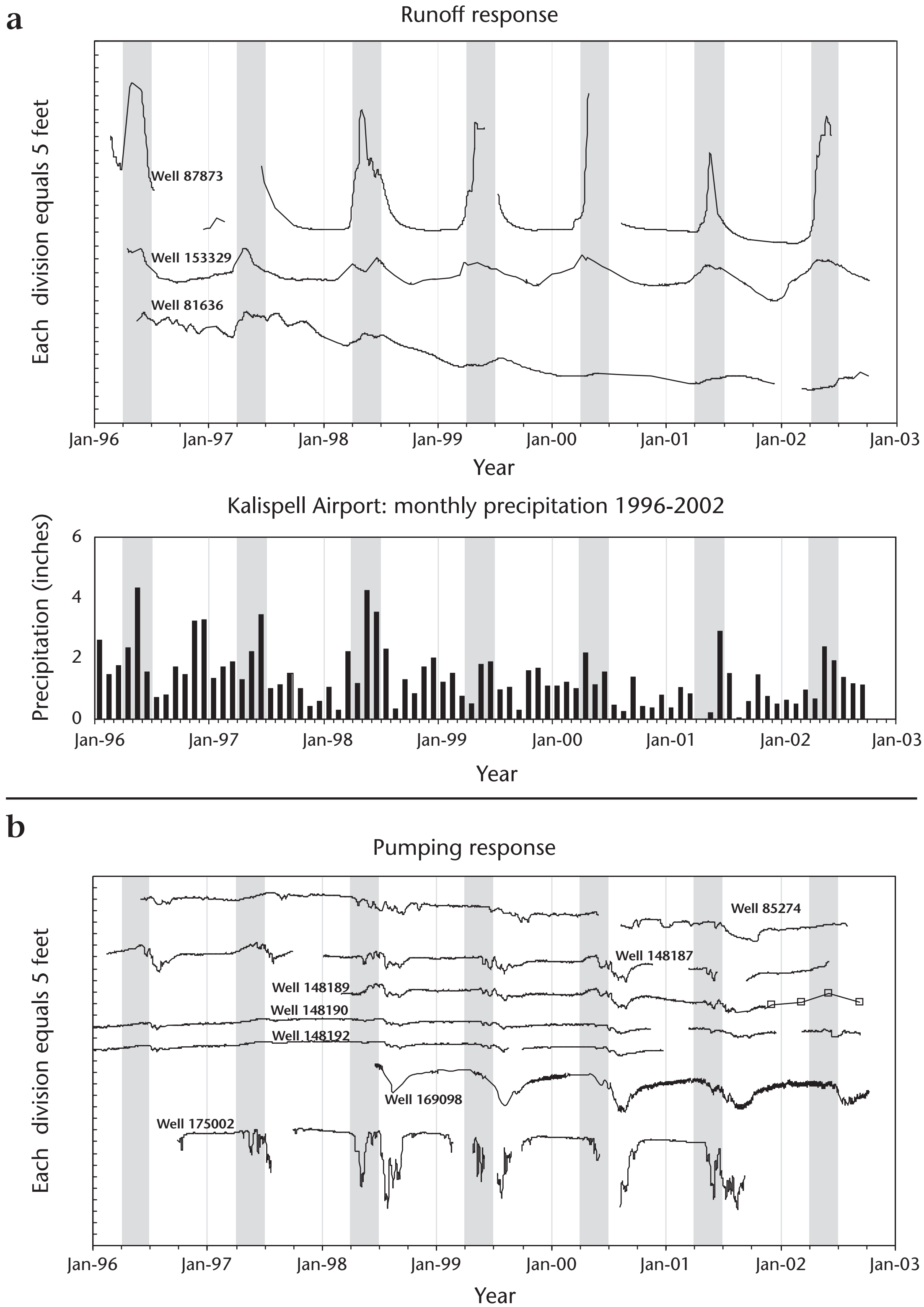



Figure 28. There are two general patterns to the water-level response in the deep alluvial aquifer. (a) Runoff response is generally synchronized with annual precipitation and runoff. Water levels are highest in the spring (shaded periods), decline during the summer months, and reach annual lows during the winter. (b) In the pumping response the lowest annual water levels occur during the late summer but then rise during the fall and winter to peaks in the midwinter and early spring.

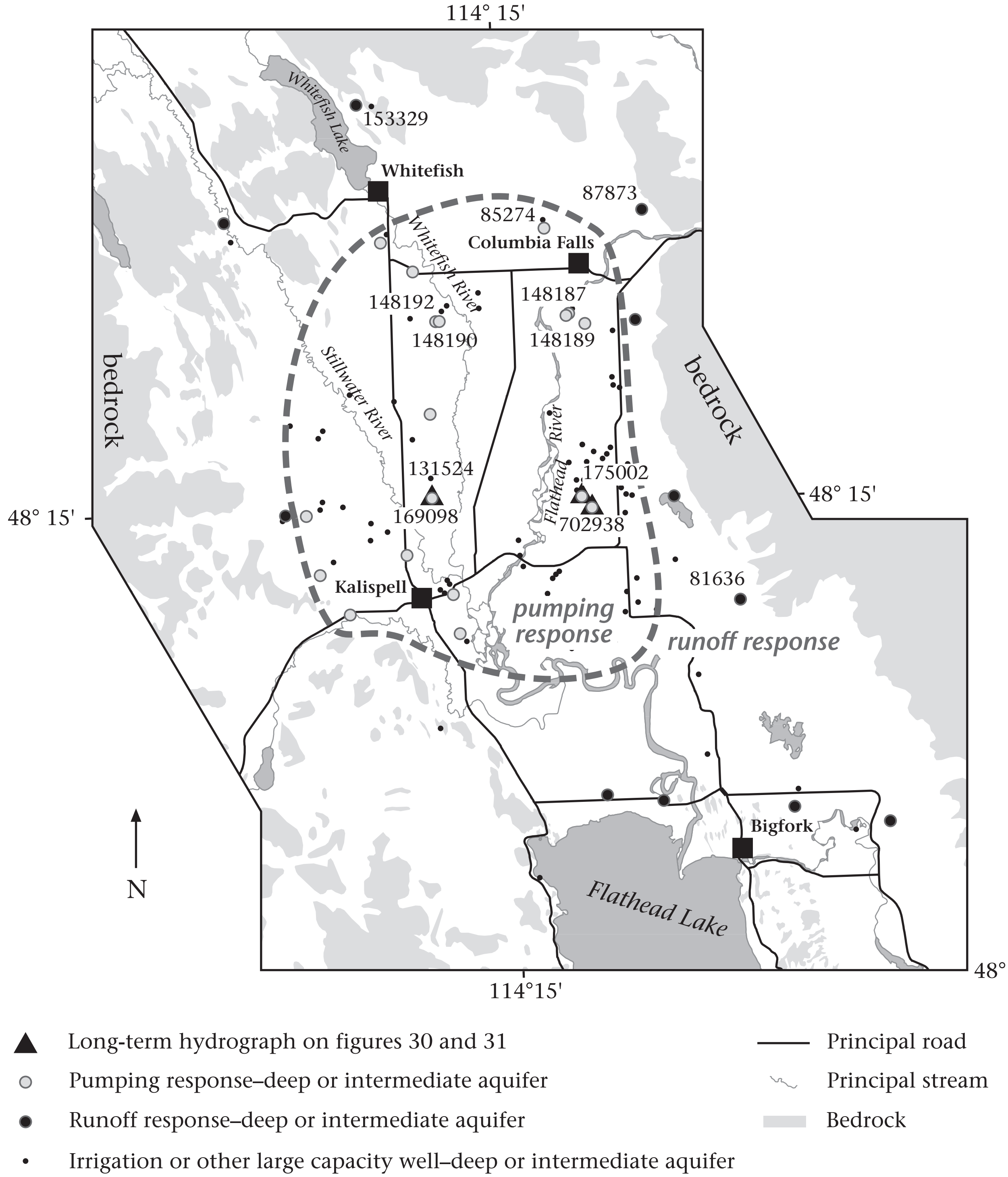
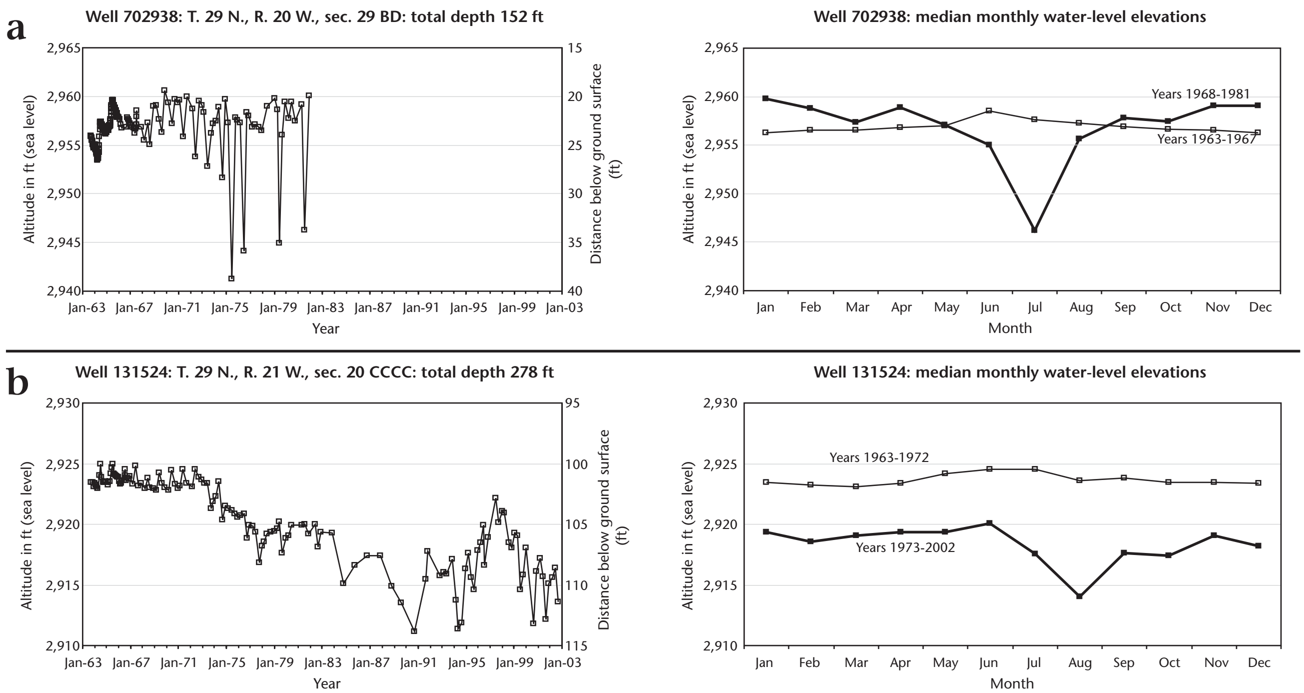



Figure 29. Wells that display a runoff response are generally near the edges of the Kalispell valley. Most wells that display a pumping response are in the center of the Kalispell valley near reported locations of high-capacity wells (reported yields greater than 300 gpm), population centers, irrigated fields, and where deep or intermediate aquifers are under confined conditions. The locations of wells with hydrographs in figs. 30 and 31 are marked with triangles.



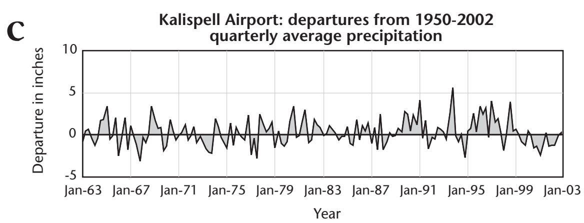
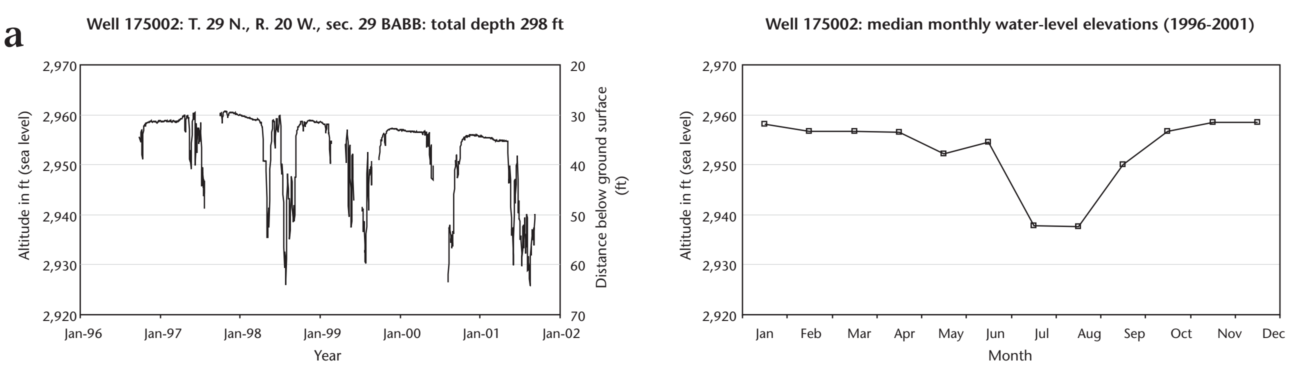




Figure 30. Development of ground-water use has changed the annual pattern of water levels in wells. Before 1967 monthly median water levels for well 702938 (a) peaked each July. After 1967, water levels in July were at their annual low. Monthly water-level medians for well 131524 (b) show the pumping response after about 1973. The locations of the wells are shown in fig. 29. (c) Average precipitation.



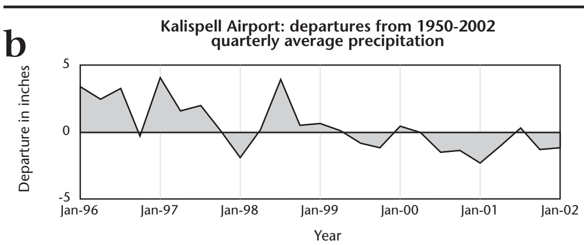




Figure 31. (a) Recent water-level measurements from a well completed in the deep alluvial aquifer less than 0.25 mi distant from well 702938 (see location in fig. 29) show that the pumping response continues, with annual fluctuations of about 25 ft. (b) Average precipitation.

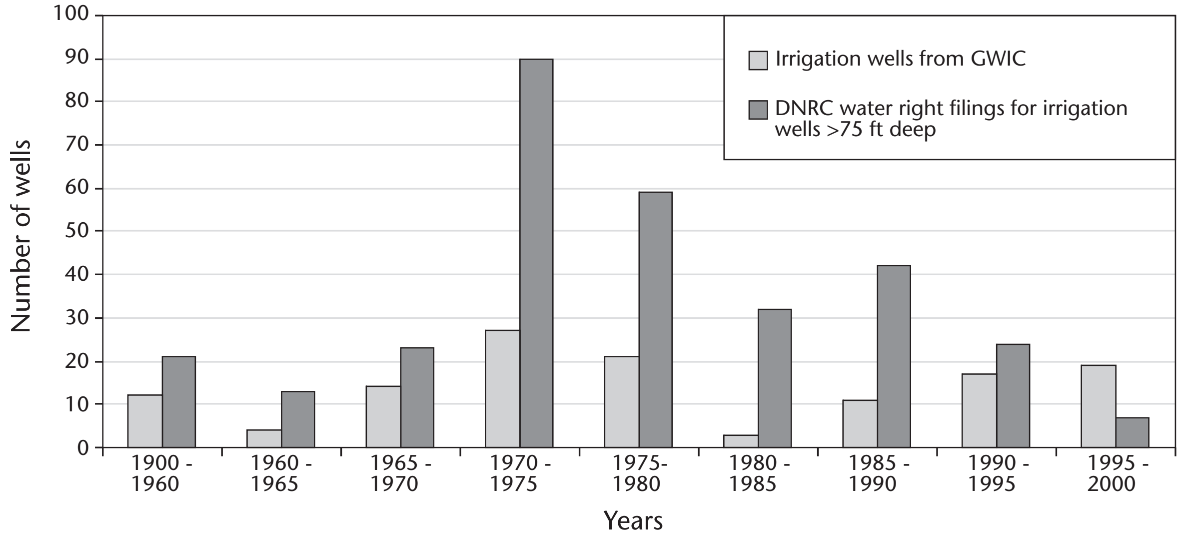



Figure 32. Water rights filings for wells greater than 75 ft deep with irrigation claimed as their primary use, and completion dates from wells producing more than 300 gpm [data from Ground-Water Information Center (GWIC), 2002] show that many irrigation and large-capacity wells entered service during the 1970s.

The observed change in the hydraulic conditions of the deep alluvial aquifer shows the need for continued long-term monitoring to allow remedial steps by users if downward water-level trends begin again or become severe. Adverse consequences of long-term water-level declines include not only a reduced amount of water available for use but also an increased potential to induce near-surface contamination into the deep aquifer, and an increased potential to induce leakage from, and depletion of, lakes and streams.

## Bedrock Aquifers

Potentiometric and water-quality data show that aquifers developed in the fractured bedrock along the margins of the Kalispell subarea are in hydraulic connection with the deep sand and gravel deposits of the valley (see Part B, map 2). However, the hydraulic character of bedrock aquifers is notably different from that of the deep alluvium. Ground water in bedrock moves primarily through fractures (see fig. 11) and not through intergranular spaces as in the sand and gravel deposits. Fractures in the bedrock are commonly irregularly distributed, so ground-water occurrence is difficult to predict, and well yields vary widely.

Wells completed in bedrock must generally be deeper than wells completed in alluvial aquifers in order to provide adequate water for most purposes. Most bedrock wells are between 100 and 400 ft deep (fig. 22), although there are 27 wells with reported depths of more than 1,000 ft. Well yields from bedrock are typically lower than those from wells completed in alluvial deposits; the maximum reported yield is 600 gpm (compared to 3,000 gpm in the alluvial sediments), and the median yield is 20 gpm (fig. 24a).

The bedrock has become one of the most utilized aquifers in the valley. By 1975 only 216 wells were reportedly completed in bedrock, roughly 8 percent of all wells in the valley. The subsequent 25 yr have seen a more than eight-fold increase in the number of bedrock wells along the valley perimeter. About 74 wells per year were completed in the bedrock between 1990 and 2000 (fig. 24b). By 2002 nearly 17 percent of wells (about 1,800) were completed in bedrock. The emergence of the bedrock as an important aquifer reflects development in the mountainous perimeter that surrounds the subarea.

## Deep Ground-Water Flow System

The intermediate, deep alluvial, and bedrock aquifers form a mappable regional ground-water flow system in which ground water moves away from the mountains along the valley margins toward the center of the valley, and then southward toward Flathead Lake (see Part B, map 2). Ground water is generally under confined conditions and is the principal source of municipal, domestic, irrigation, and stock water in the Kalispell subarea. The geologic framework, potentiometric surface maps, and water quality of the deep flow system are discussed in detail in Part B, maps 2, 3, and 6–9.

## Water Quality

Ground water in the Kalispell subarea is chemically consistent and of very high quality. Little variability in water composition exists between the different aquifers, and the water meets most U.S. EPA standards for natural constituents in public drinking-water supplies. Summary statistics for water quality are presented in table 2, and graphical summaries of the water composition in the different aquifers are presented in figs. 33 and 34. Additional information about water quality in the Kalispell subarea and spatial distributions in water quality are available in Part B, map 3. Background information about the nomenclature and meaning of water-quality data is in the glossary.

The predominant ions in water from all aquifers in the Kalispell subarea are calcium and bicarbonate, followed by magnesium, sodium, sulfate, and chloride. Median concentrations of the major constituents are mostly consistent between the different aquifers; however, water quality in the deep alluvial aquifer appears less variable than that of the other aquifers. There are slight variations in calcium and sulfate, which appear to have lower concentrations in water from the deep alluvial and bedrock aquifers than in water from the shallow and intermediate aquifers. Also, the median bicarbonate concentrations are slightly lower in the deep alluvial and bedrock aquifers than in the shallow and intermediate aquifers, but the difference is not significant. Figure 33 shows that the concentration of dissolved constituents varies little between the aquifers in the Kalispell subarea and is generally low (the median concentration from each aquifer was less than 410 mg/L), indicating that the water is of very good quality.

Tri-linear plots in fig. 34 clearly show the chemical consistency of the water. Most of the samples are tightly clustered in the calcium bicarbonate field except for a few anomalous samples from the deep alluvial aquifer. The anomalous samples are from locations scattered throughout the Kalispell subarea that form no noticeable spatial pattern.

### Iron and Manganese

The highest concentrations of iron and manganese were detected in shallow alluvial aquifers. However, the median concentrations were mostly consistent in all aquifers (table 2). The U.S. EPA's SMCL for public drinking water supplies (0.3 mg/L for iron, and 0.05 mg/L for manganese) was commonly exceeded. Iron concentrations in about 20 percent (11 of 56) of samples from the shallow alluvium and 25 percent (5 of 20) of samples from the deep alluvial aquifer exceeded the SMCL for iron, but the concentration exceeded the standard in only one sample from the intermediate and bedrock aquifers.

Manganese concentrations exceeded 0.05 mg/L in 30 percent (17 of 56) of samples from shallow and deep alluvial aquifers, and in 37 percent (6 of 16) of samples from intermediate aquifers. However, only 15 percent (3 of 20) of samples from bedrock aquifers contained manganese concentrations that exceeded the SMCL.

Iron concentrations greater than 0.3 mg/L pose no health threat but will stain clothing and fixtures and are a nuisance. The frequency of iron concentrations above the SMCL in the shallow and deep alluvial aquifers in the Kalispell subarea suggests that iron staining is common in water from these aquifers and that if another aquifer (bedrock or intermediate) is available at a location the problem might be avoided.

### Nitrate

Nitrate concentrations (reported as milligrams per liter of nitrogen throughout this report) in ground water of the Kalispell subarea are generally low. Although none of the samples collected for this study exceeded the EPA's 10 mg/L health standard, the median concentration and ranges of nitrate concentrations varied between aquifers (fig. 33).

Nitrate was detected in 91 percent (51 of 56) of the samples from shallow alluvium (table 2), but the median concentration (0.6 mg/L) was low. However, 12 percent (7) of the samples had concentrations exceeding 3.0 mg/L (more than three times the median concentration), indicating potential surface/human sources. Two samples from wells completed in shallow alluvium, collected as part of a previous investigation (Noble and Stanford, 1986), contained nitrate concentrations that exceeded 10 mg/L. The sample with the highest concentration, 18.9 mg/L, was collected in 1988 from a 12-ft-deep well completed in the Evergreen aquifer (see fig. 23 for aquifer location). The other sample was collected in 1984 from a 20-ft-deep well in the Delta vicinity (see fig. 23 for aquifer location), and had a concentration of 11.4 mg/L.

Nitrate was detected in about half (43 of 88) of samples from the deep alluvial and intermediate aquifers (table 2). The maximum concentration detected was 7.7 mg/L, but median nitrate concentrations in both the intermediate and deep alluvial aquifers were below 0.3 mg/L. All samples from deep alluvial or intermediate aquifers that contained nitrate concentrations suggestive of surface contamination sources (above 3 mg/L) were from locations around the edge of the valley where the aquifers are relatively near the land surface and more likely to be under semi-confined or unconfined conditions. Several elevated nitrate concentrations are from wells clustered northwest of Kalispell (Part B, map 3). The wells are completed beneath the Lost Creek fan, a thick accumulation of outwash deposited by glacial meltwater (Smith and others, 2000). These data suggest that a protective layer(s) of till and glacial-lake deposits may be locally absent or discontinuous

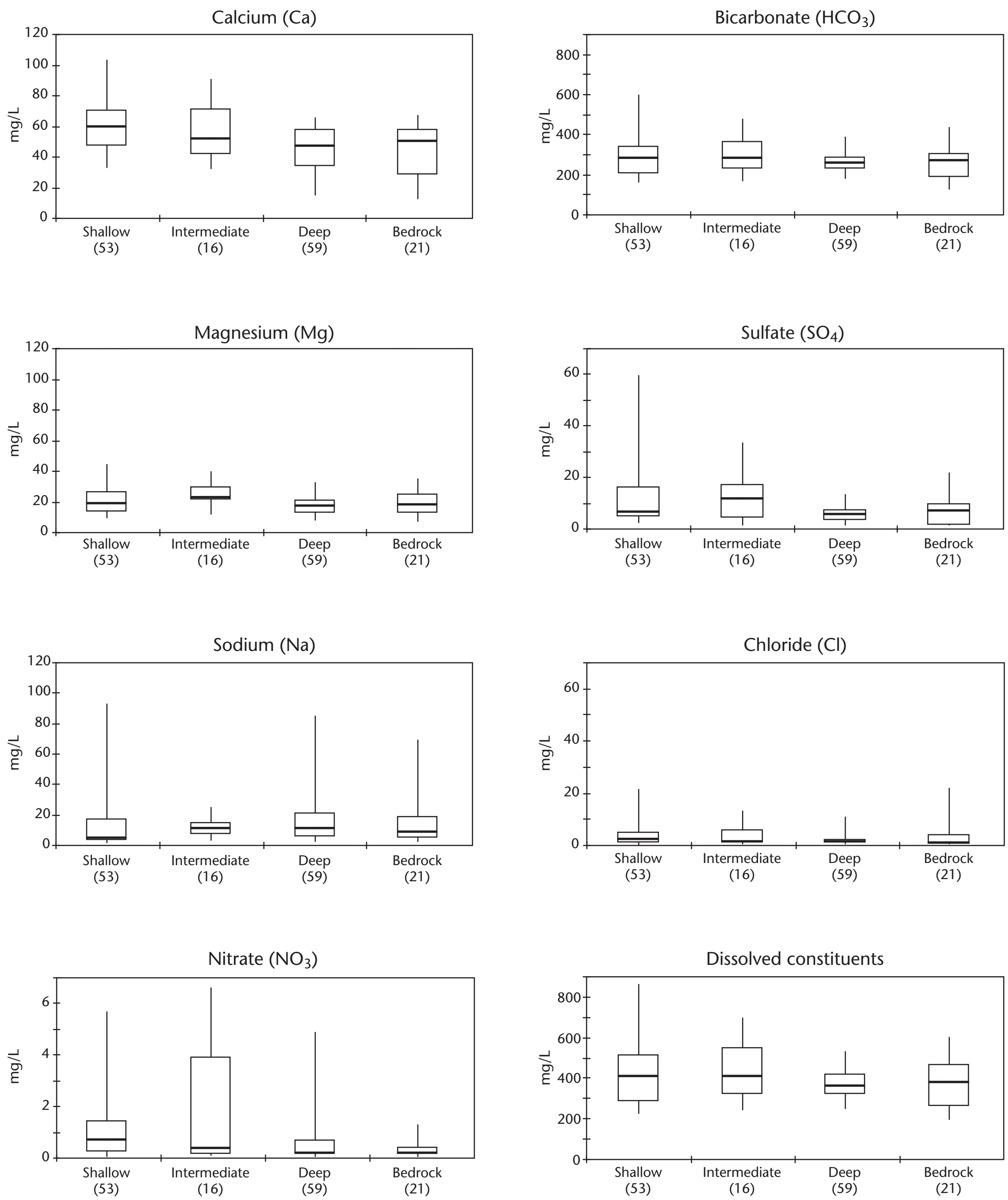



Figure 33. Ground-water quality in the Kalispell subarea is consistent between the shallow, intermediate, deep alluvial, and bedrock aquifers. The major ions in solution in each aquifer are calcium, magnesium, and bicarbonate. For non-quantifiable or non-detectable data, a value of one-half the detection limit was used in the statistical summaries. See fig. 24 for an explanation of the plots.

and that the deep alluvial aquifer may be locally vulnerable to surface contamination.

Nitrate was detected in about half (13 of 25) of the samples from bedrock aquifers (table 2), and the maximum concentration was only 1.4 mg/L.

**Fluoride**

Ground water in the Kalispell subarea generally has low or undetectable concentrations of fluoride (table 2). Fluoride was detected in fewer than half the samples from all aquifers, and the detected concentrations were generally less than 1.0 mg/L. However, two samples, one from the deep alluvial aquifer and one from the bedrock aquifer, exceeded the U.S. EPA's MCL of 4.0 mg/L.

## Kalispell subarea

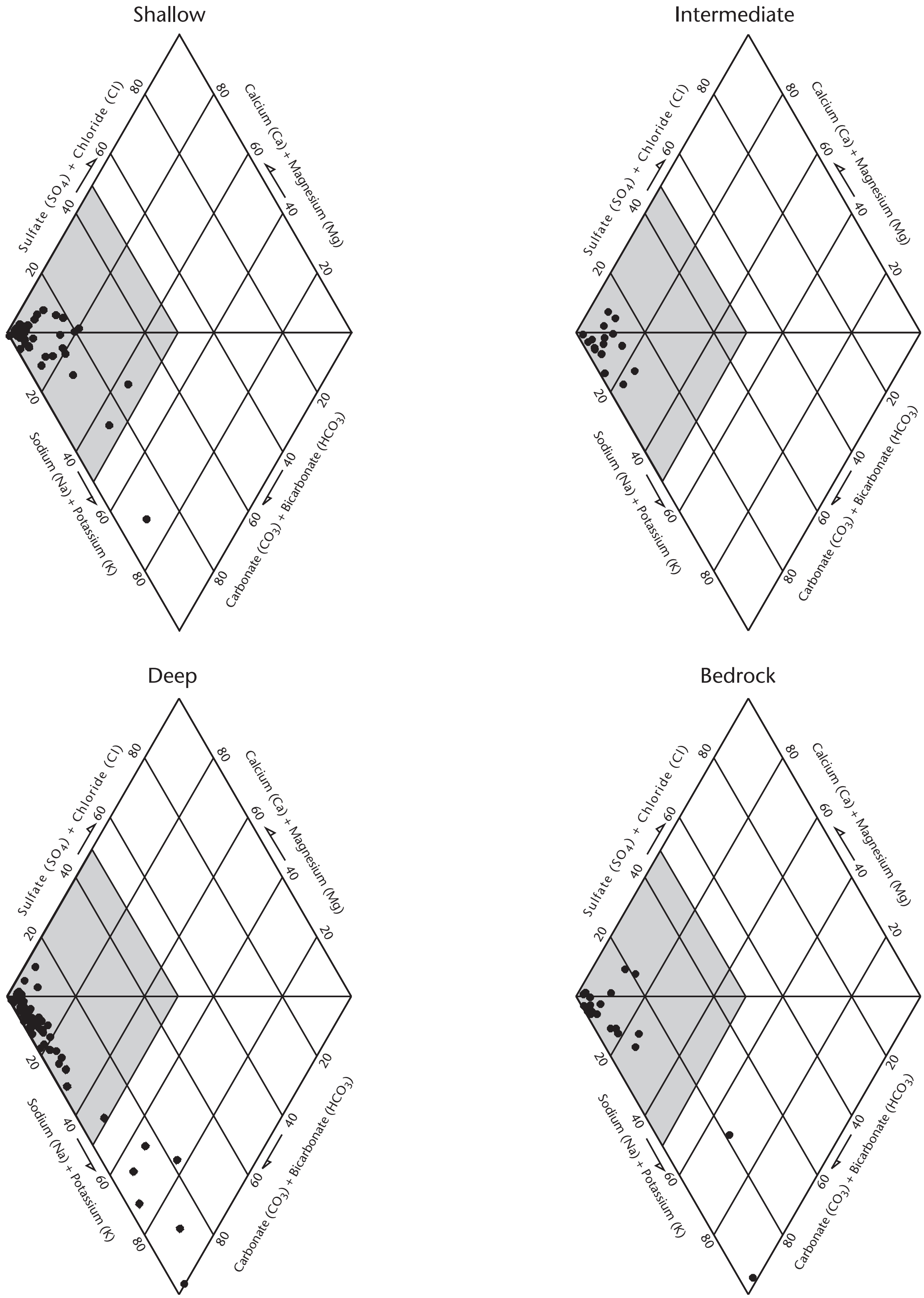



Figure 34. Water from all aquifers in the Kalispell subarea is primarily of the calcium bicarbonate type. However, a few samples from the deep alluvial and bedrock aquifers were of the sodium bicarbonate type.

Table 2. Ground-water quality summary, Kalispell subarea

| Constituent or Property | Number of Detections/ Samples | Minimum | Median | Maximum | USEPA SMCL or MCL |
|---|---|---|---|---|---|
| Shallow aquifers | | | | | |
| Major ions (mg/L) | | | | | |
| Ca | 53/53 | 25.80 | 60.00 | 181.00 | — |
| Mg | 53/53 | 4.69 | 18.60 | 55.00 | — |
| Na | 53/53 | 0.80 | 4.80 | 212.00 | 250 |
| K | 53/53 | 0.20 | 1.20 | 16.30 | — |
| $HCO_3$ | 53/53 | 103.50 | 285.00 | 837.00 | — |
| $SO_4$ | 51/53 | 0.10 | 5.46 | 83.40 | 250 |
| Cl | 53/53 | 0.20 | 2.10 | 59.90 | 250 |
| $NO_3$ | 51/56 | 0.02 | 0.62 | 18.90 | 10 |
| F | 25/53 | <0.10 | 0.10 | 0.60 | 4 |
| Fe | 44/53 | <0.003 | 0.04 | 13.00 | 0.3 |
| Other parameters | | | | | |
| TDS (mg/L) | 53/53 | 95.30 | 258.74 | 895.59 | 500 |
| Dissolved constituents | 53/53 | 147.81 | 406.90 | 1320.28 | — |
| Hardness (as mg/L $CaCO_3$) | 53/53 | 83.73 | 238.42 | 662.28 | — |
| pH | 53/53 | 7.18 | 7.62 | 8.30 | 6.5–8.5 |
| Intermediate aquifers | | | | | |
| Major ions (mg/L) | | | | | |
| Ca | 16/16 | 28.80 | 52.00 | 117.00 | — |
| Mg | 16/16 | 11.30 | 23.05 | 42.20 | — |
| Na | 16/16 | 1.30 | 11.25 | 45.00 | 250 |
| K | 16/16 | 0.73 | 1.40 | 4.40 | — |
| $HCO_3$ | 16/16 | 157.40 | 280.55 | 483.10 | — |
| $SO_4$ | 14/16 | <2.50 | 10.00 | 38.80 | 250 |
| Cl | 16/16 | 0.50 | 1.33 | 20.40 | 250 |
| $NO_3$ | 13/23 | <0.10 | 0.28 | 7.70 | 10 |
| F | 3/16 | <0.05 | 0.19 | 0.20 | 4 |
| Fe | 11/16 | <0.003 | 0.03 | 1.08 | 0.3 |
| Other parameters | | | | | |
| TDS (mg/L) | 16/16 | 154.80 | 265.51 | 461.30 | 500 |
| Dissolved constituents | 16/16 | 243.80 | 408.56 | 706.42 | — |
| Hardness (as mg/L $CaCO_3$) | 16/16 | 118.42 | 224.51 | 417.28 | — |
| pH | 16/16 | 7.20 | 7.66 | 8.00 | 6.5–8.5 |
| Deep alluvial aquifer | | | | | |
| Major ions (mg/L) | | | | | |
| Ca | 58/59 | 0.05 | 47.30 | 70.00 | — |
| Mg | 58/59 | 0.05 | 17.40 | 38.00 | — |
| Na | 59/59 | 1.70 | 11.00 | 402.00 | 250 |
| K | 57/59 | <0.10 | 1.20 | 4.94 | — |
| $HCO_3$ | 59/59 | 109.30 | 256.20 | 1058.00 | — |
| $SO_4$ | 47/59 | <2.50 | 5.00 | 28.20 | 250 |
| Cl | 54/59 | <0.50 | 1.10 | 74.90 | 250 |
| $NO_3$ | 30/65 | <0.05 | 0.13 | 6.70 | 10 |
| F | 23/59 | <0.05 | 0.50 | 4.81 | 4 |
| Fe | 48/59 | <0.003 | 0.03 | 4.09 | 0.3 |
| Other parameters | | | | | |
| TDS (mg/L) | 59/59 | 103.79 | 229.25 | 1051.17 | 500 |
| Dissolved constituents | 59/59 | 159.25 | 359.04 | 1587.99 | — |
| Hardness (as mg/L $CaCO_3$) | 59/59 | 55.76 | 195.91 | 328.45 | — |
| pH | 59/59 | 6.70 | 7.70 | 8.88 | 6.5–8.5 |
| Bedrock aquifers | | | | | |
| Major ions (mg/L) | | | | | |
| Ca | 21/21 | 2.10 | 50.00 | 73.00 | — |
| Mg | 21/21 | 1.40 | 18.00 | 37.00 | — |
| Na | 21/21 | 1.02 | 9.00 | 340.00 | 250 |
| K | 21/21 | 0.35 | 0.67 | 5.80 | — |
| $HCO_3$ | 21/21 | 114.90 | 270.80 | 837.00 | — |
| $SO_4$ | 15/21 | <2.50 | 6.20 | 45.00 | 250 |
| Cl | 18/21 | <0.50 | 0.91 | 45.20 | 250 |
| $NO_3$ | 13/25 | <0.05 | 0.18 | 1.40 | 10 |
| F | 4/21 | <0.05 | 0.26 | 6.70 | 4 |
| Fe | 13/21 | <0.003 | 0.01 | 0.34 | 0.3 |
| Other parameters | | | | | |
| TDS (mg/L) | 21/21 | 101.52 | 248.95 | 820.00 | 500 |
| Dissolved constituents | 21/21 | 159.82 | 377.25 | 1244.68 | — |
| Hardness (as mg/L $CaCO_3$) | 21/21 | 11.01 | 195.91 | 307.59 | — |
| pH | 21/21 | 7.20 | 7.70 | 8.65 | 6.5–8.5 |

*Note.* mg/L, milligrams per liter; USEPA, U.S. Environmental Protection Agency; SMCL, Secondary Maximum Contaminant Level; MCL, Maximum Contaminant Level.

### Dissolved Constituents

Dissolved-constituents concentrations in samples of ground water from the Kalispell subarea are generally low (table 2); most were between 300 and 600 mg/L (fig. 33). Water from the shallow alluvium has the greatest variability in dissolved constituents, but the median value (401 mg/L) is slightly less than the median for samples from the intermediate and bedrock aquifers. Water from the deep alluvial aquifer is the most uniform with respect to dissolved constituents and has the lowest median concentration (381 mg/L).

The spatial distribution of dissolved constituents in the deep flow system is presented in Part B, map 3. In the deep flow system, slightly elevated concentrations of dissolved constituents are found in the north and northwest part of the Kalispell subarea (fig. 2), roughly northwest of a line between Bad Rock Canyon (T. 30 N., R. 20 W., sec. 12) and the terminus of Lost Creek (T. 29 N., R. 22 W., sec. 5). The lowest dissolved-constituent concentrations are generally found in the southern part of the valley southeast of a line between Lake Blaine (T. 29 N., R. 20 W., sec. 26) and Kalispell (T. 28 N., R. 21 W., sec. 18) (fig. 2). Intermediate concentrations occur between the areas of high and low concentrations.

Two factors most likely account for the dissolved-constituent distribution. First, the deep flow system in the north part of the valley, especially between Whitefish and Columbia Falls, is in alluvium with interbeds of till and clayey glacial-lake deposits (Part B, map 6). Thus, more dissolved constituents may be leached from the fine-grained sediments in this part of the aquifer than from other areas where the aquifer is composed of coarse-grained sand and gravel. Second, large amounts of recharge enter the ground-water flow system from the east side of the valley. The Swan Range receives more than 60 in of precipitation per year, and south of Lake Blaine the highly permeable east-side shallow aquifers are along the base of the range (Part B, map 6). These conditions are favorable for ground-water recharge. A distinct area of low-dissolved-constituent water extends from the Swan Range out into the center of the valley.

### Environmental Isotopes

Ground water from 23 wells completed in the deep flow system was analyzed for tritium, oxygen-18, and deuterium; 13 of the wells were completed in the deep alluvial aquifer, and 10 were completed in bedrock. For background on the utility of environmental isotopes see the glossary. The depths of the sampled wells ranged from 125 to 1,085 ft, but the tops of the open intervals in each well, or the depths water enters (DWE), ranged from 122 to 866 ft below land surface.

The tritium results (table 3) can be separated into three groups: (1) tritium either not detected or detected at concentrations less than 0.8 TU (15 samples), (2) tritium concentrations between 1.0 and 3.5 TU (5 samples), and (3) tritium concentrations between 12.4 and 17.3 TU (3 samples). The water from group 1 is considered “sub-modern” and recharged the deep flow system before 1952. Most of the concentrations in group 2 are near the 0.8 TU detection limit, suggesting that either the water entered the flow system before the early 1960s peak in atmospheric tritium concentration, or the samples contained a mixture of “modern” and “sub-modern” water. The tritium concentrations in group 3 are consistent with “modern water” recharged since the early 1960s peak in atmospheric concentrations. The samples containing the older water (groups 1 and 2) came from 4 wells completed in bedrock and 4 wells completed in the deep alluvium. No systematic variation in tritium concentrations with depth was recognized, but samples with younger water (group 3) came from wells with DWEs within 250 ft of the land surface.

Tritium concentrations vary spatially within the deep flow system, as shown in fig. 35, indicating variability in ground-water residence times in the deep aquifer. Water from half (7 of 14) of the wells sampled on the east side of the valley contained tritium concentrations greater than 0.8 TU (median DWE of 250 ft), indicating that the samples either were modern water or included a component of modern water. The wells on the east side that did not contain modern water were relatively deep, with a median DWE of 400 ft. Conversely, water from only one of the nine wells sampled in the north, west, and central parts of the valley contained tritium above 0.8 TU. The widespread presence of modern water in the deep flow system on the east side of the valley suggests that the east-side shallow aquifers may be hydraulically connected to the deep alluvial aquifer, and that downward leakage from the shallow aquifers between Lake Blaine and Echo Lake is an important source of recharge. The absence of tritium from deep wells (DWE generally greater than 300 ft) on the east side suggests that the deep flow system is stratified with the more active ground-water flow occurring at depths less than 250 to 300 ft below land surface.

The $\delta^{18}O$ results for ground water sampled in the Kalispell subarea (table 3) plot on or very close to the meteoric water line (fig. 36), showing that the water in the deep flow system originated as

Table 3. Isotope results

| Site No. | Township | Range | Sec. | Tract | Longitude | Latitude | Aquifer | Hydro Unit | Total Depth | Depth Water Enters | Tritium Units (TU) | $\delta^{18}O$ | $\delta$*D | $^{14}C$ (PMC) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Group 1—Tritium <0.8 TU | | | | | | | | | | | | | | |
| 79501 | 26N | 19W | 1 | DACC | -113.9461 | 48.0408 | 112ALVM | deep | 1085 | 866 | <0.8 | -19.00 | -140 | |
| 79587 | 26N | 19W | 11 | BADC | -113.9758 | 48.0341 | 112ALVM | deep | 566 | 566 | <0.8 | -17.40 | -127 | |
| 130530 | 27N | 19W | 25 | ABAD | -113.9475 | 48.0788 | 400RVLL | bedrock | 460 | 460 | <0.8 | -17.50 | -127 | |
| 141558 | 27N | 19W | 35 | DBAC | -113.9705 | 48.0572 | 112ALVM | deep | 327 | 327 | <0.8 | -17.60 | -126 | |
| 141562 | 27N | 20W | 17 | CCBB | -114.1794 | 48.0986 | 112ALVM | deep | 400 | 400 | <0.8 | -18.50 | -139 | 55.21 |
| 81711[1] | 28N | 20W | 13 | AAAD | -114.0727 | 48.1955 | 400RVLL | bedrock | 340 | 320 | 0.3 | -18.00 | -134 | 4.40 |
| 82934 | 28N | 22W | 15 | AAAA | -114.3733 | 48.1963 | 112ALVM | deep | 220 | 175 | <0.8 | -18.80 | -146 | 19.66 |
| 83435 | 29N | 20W | 3 | DDBA | -114.1344 | 48.3013 | 112ALVM | deep | 340 | 340 | <0.8 | -17.30 | -128 | |
| 137868 | 29N | 21W | 22 | CCCB | -114.2638 | 48.2561 | 112ALVM | deep | 277 | 277 | <0.8 | -18.00 | -132 | 31.32 |
| 45316 | 29N | 22W | 32 | DADB | -114.4183 | 48.2308 | 400RVLL | bedrock | 396 | 376 | <0.8 | -20.40 | -155 | |
| 130597[1] | 29N | 23W | 26 | ADDA | -114.4802 | 48.2491 | 400MCRB | bedrock | 260 | 240 | 0.3 | -18.30 | -138 | 58.70 |
| 148484[1] | 30N | 20W | 28 | DCCB | -114.1622 | 48.3288 | 112ALVM | deep | 240 | 240 | 0.2 | -18.50 | -140 | |
| 86565 | 30N | 22W | 21 | DBBC | -114.4041 | 48.3480 | 400MCRB | bedrock | 560 | 493 | <0.8 | -21.60 | -167 | 0.48 |
| 87999[1] | 31N | 21W | 35 | CADD | -114.2508 | 48.4044 | 112ALVM | deep | 204 | 204 | <0.8 | -17.60 | -133 | 50.80 |
| 126317 | 31N | 22W | 34 | ADBB | -114.3775 | 48.4102 | 400MCRB | bedrock | 460 | 460 | <0.8 | -18.10 | -134 | |
| Group 2—Tritium between 1 and 3.5 TU | | | | | | | | | | | | | | |
| 80389 | 27N | 19W | 20 | ACDB | -114.0352 | 48.0891 | 112ALVM | deep | 249 | 249 | 1.0 | -17.20 | -129 | 60.15 |
| 133079 | 27N | 20W | 10 | ADCA | -114.1175 | 48.1188 | 400MCRB | bedrock | 287 | 287 | 3.5 | -16.20 | -123 | |
| 80915 | 27N | 21W | 10 | BBBA | -114.2644 | 48.1238 | 400MCRB | bedrock | 507 | 496 | 1.4 | -18.10 | -134 | |
| 81766 | 28N | 20W | 15 | CBDD | -114.1319 | 48.1863 | 112ALVM | deep | 407 | 407 | 1.6 | -17.10 | -127 | |
| 139705 | 31N | 20W | 10 | ABBD | -114.1397 | 48.4711 | 400MCRB | bedrock | 505 | 505 | 3.4 | -17.30 | -126 | |
| Group 3—Tritium between 12.4 and 17.3 TU | | | | | | | | | | | | | | |
| 79595 | 26N | 19W | 11 | CDBD | -113.9766 | 48.0250 | 112ALVM | deep | 125 | 122 | 12.4 | -16.70 | -124 | |
| 83424 | 29N | 20W | 2 | CCCA | -114.1300 | 48.2997 | 400RVLL | bedrock | 250 | 250 | 17.3 | -17.30 | -129 | |
| 85592 | 30N | 20W | 18 | CDCA | -114.2100 | 48.3569 | 112ALVM | deep | 238 | 238 | 15.9 | -16.90 | -125 | 87.82 |

[1]Tritium analysis performed by the USGS, Menlo Park, CA. $^{14}C$, $\delta^{18}O$, and $\delta D$ measurements performed by the University of Arizona Isotope Lab. Other isotope analyses performed by the University of Waterloo Environmental Isotope Lab; PMC, percent modern carbon.

atmospheric precipitation and that the recharge water has not been affected by evaporation or geothermal exchange. Ground water from wells sampled on the east side of the valley (fig. 37) is relatively more enriched in oxygen-18 than ground water from other parts of the aquifer (they have less negative $\delta^{18}O$ values). The $\delta^{18}O$ values in samples from the 14 east-side wells ranged from -19 to -16.2 per mil, with a median concentration of -17.3 per mil. Samples from nine wells in the north, west, and central parts of the valley contained $\delta^{18}O$ values between -21.6 and -17.6 per mil, and had a median concentration of -18.3 per mil.

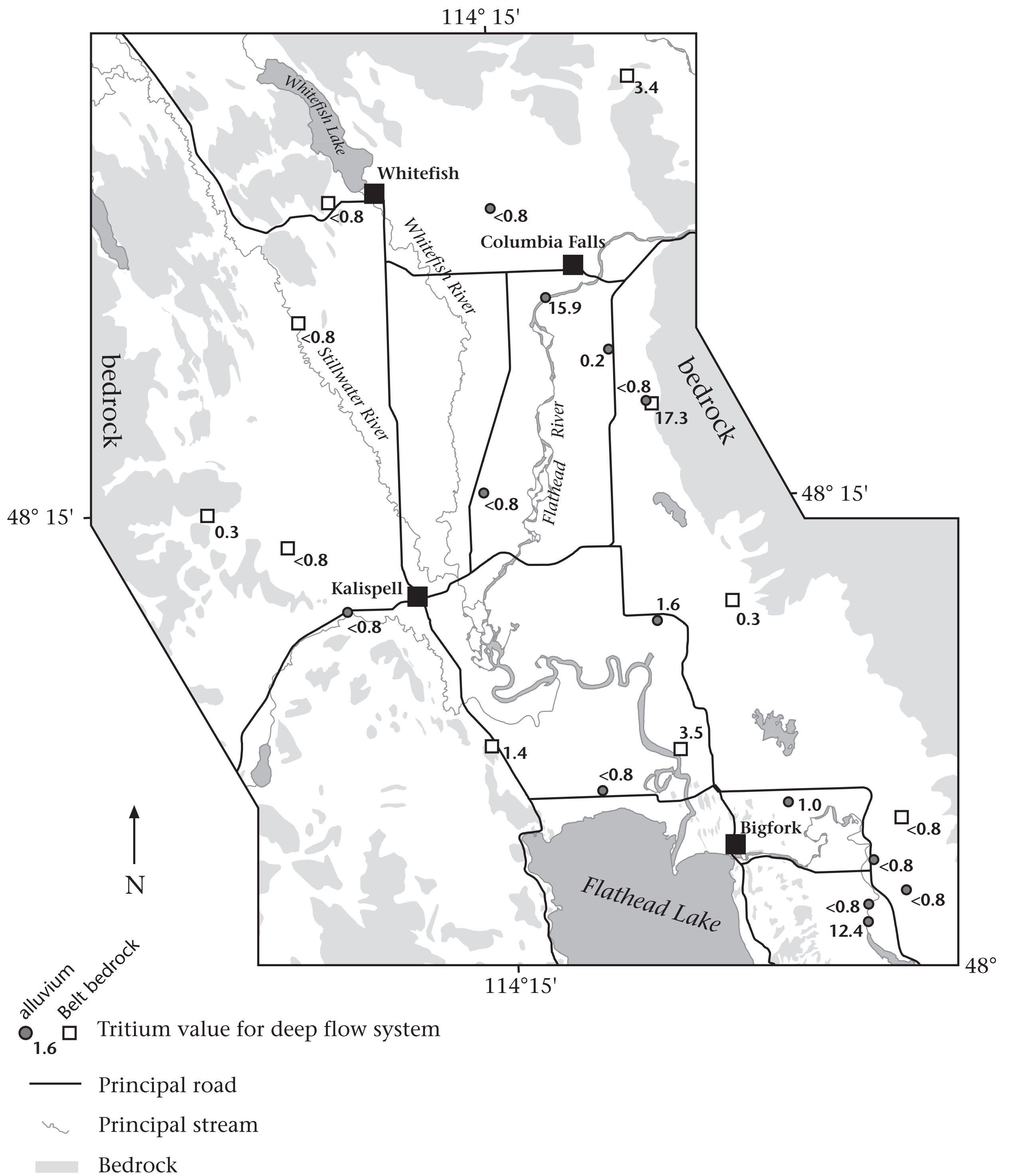



Figure 35. Tritium was generally not detected in the deep flow system, showing that most of the water entered the system before above-ground nuclear testing began in 1952. Values are reported in tritium units.

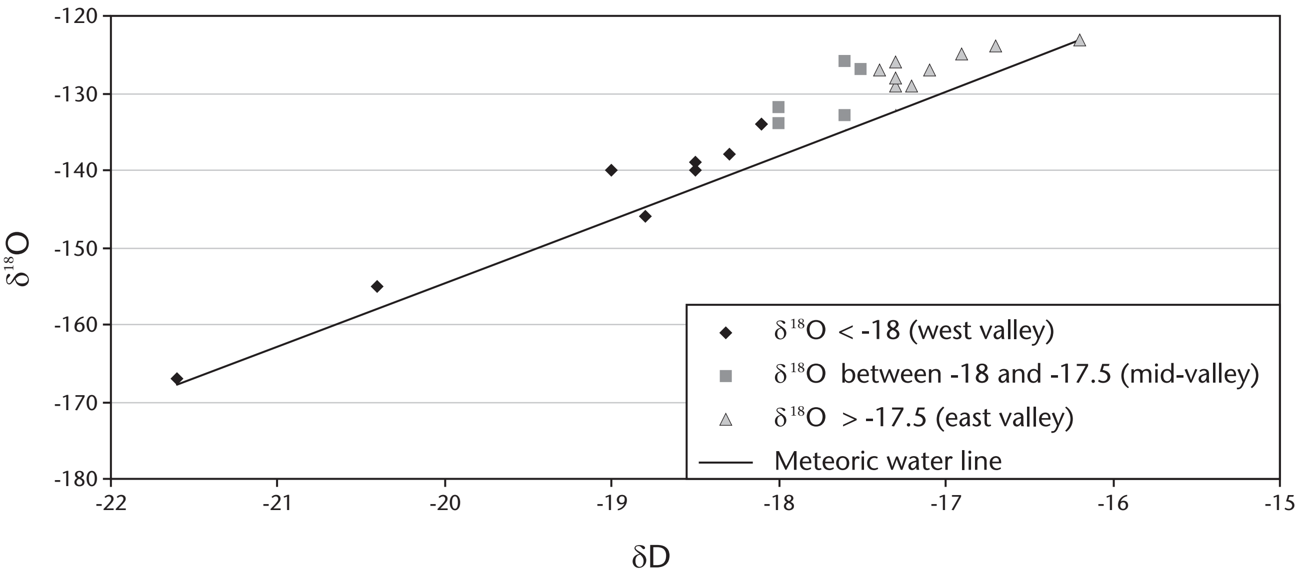



Figure 36. $\delta^{18}O$ and $\delta D$ values in water from the deep alluvial aquifer in the Kalispell subarea plot along the meteoric water line. However, samples from the east side of the valley were isotopically heavier than those on the west side.

The spatial variation of the $\delta^{18}O$ values (fig. 37) in the deep flow system roughly correlates with the distribution of relatively young water shown by the tritium results in fig. 35. The plot of tritium concentrations vs. $\delta^{18}O$ values in fig. 38 illustrates the relationship, showing that samples enriched in $\delta^{18}O$ (greater than -17.5 per mil) generally had detectable tritium (7 of 9 samples), while samples depleted in $\delta^{18}O$ (less than or equal to -17.5 per mil) did not. The comparison shows that the younger water (with detectable tritium) along the east side of the valley is more enriched in oxygen-18 than the older water (no detectable tritium) in the western and central parts of the valley.

Nine wells from the deep flow system were sampled for carbon-14; three wells were completed in bedrock and six wells were completed in the deep alluvial aquifer (fig. 39). The well depths ranged from 204 to 560 ft and DWEs were between 204 and 493 ft. Of the nine samples, seven had carbon-14 activities ranging from 19.66 to 87.82 percent modern carbon (PMC). The two samples with the highest PMC activities were from wells where the water also contained detectable tritium; the sample from well 80389 (total depth 249 ft) had a carbon-14 activity of 60.15 and tritium of 1.0 TU, suggesting that the water may be a mixture of older and younger water. The sample from well 85592 (total depth 238 ft) had a carbon-14 activity of 87.82 PMC and a tritium of 15.9 TU, indicating that water from the well is modern.

The oldest ground water (lowest PMC values) came from two wells completed in the bedrock, but on opposite sides of the valley (fig. 39). Well 86565, in the Stillwater River drainage, is completed open hole between 498 and 560 ft below the surface. Well 81711, on the east side of the valley near the Swan Range, is perforated between 320 and 340 ft below the surface. The low carbon-14 activities and the absence of detectable tritium in the water from these wells indicates that the water is very old and was probably recharged more than 10,000 yr ago. The results suggest that ground-water flow in the deep bedrock may be more stagnant than in shallower units and that the more active ground-water flow in the deep flow system occurs primarily within 300 ft of the land surface.

No strong spatial distribution in the carbon-14 activities is apparent. However, the results are roughly consistent with the tritium and oxygen-18 results. A plot of $\delta^{18}O$ vs. carbon-14 (fig. 40) shows that $\delta^{18}O$ is more depleted with decreasing carbon-14 concentration: the more depleted the $\delta^{18}O$ isotopic signature, the older the water. With a few exceptions, samples from wells on the east side contained greater PMC than did water from wells in the west and central parts of the valley. Taken together, the isotope results suggest that ground-water recharge and ground-water flow rates in the deep flow system are greater on the east side of the Kalispell valley than the west side.

### Radon

Radon in household air has been linked to lung cancer, and a minor source of the gas can be well water. The U.S. EPA estimates that less than 2 percent of radon in household air comes from

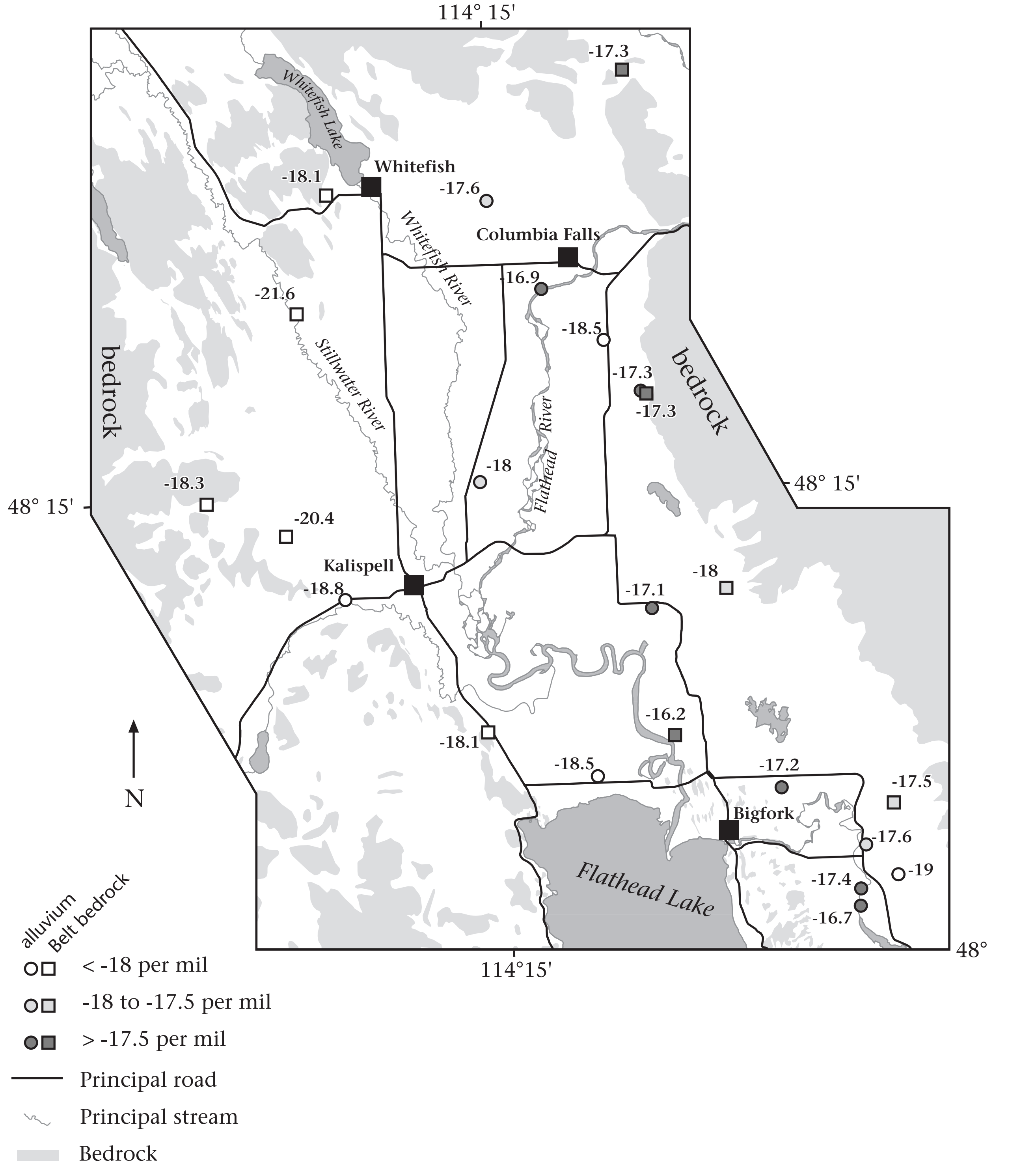



Figure 37. The distribution of the δ18O in the deep alluvial aquifer in the Kalispell subarea is not uniform; ground water on the west side of the valley is depleted in δ18O with values generally less than -18 per mil, whereas water on the east side of the valley is enriched with δ18O values greater than -17.5 per mil. The variance suggests different recharge processes, and/or differences in the rate of ground-water movement (and ground-water age) between the different parts of the flow system.

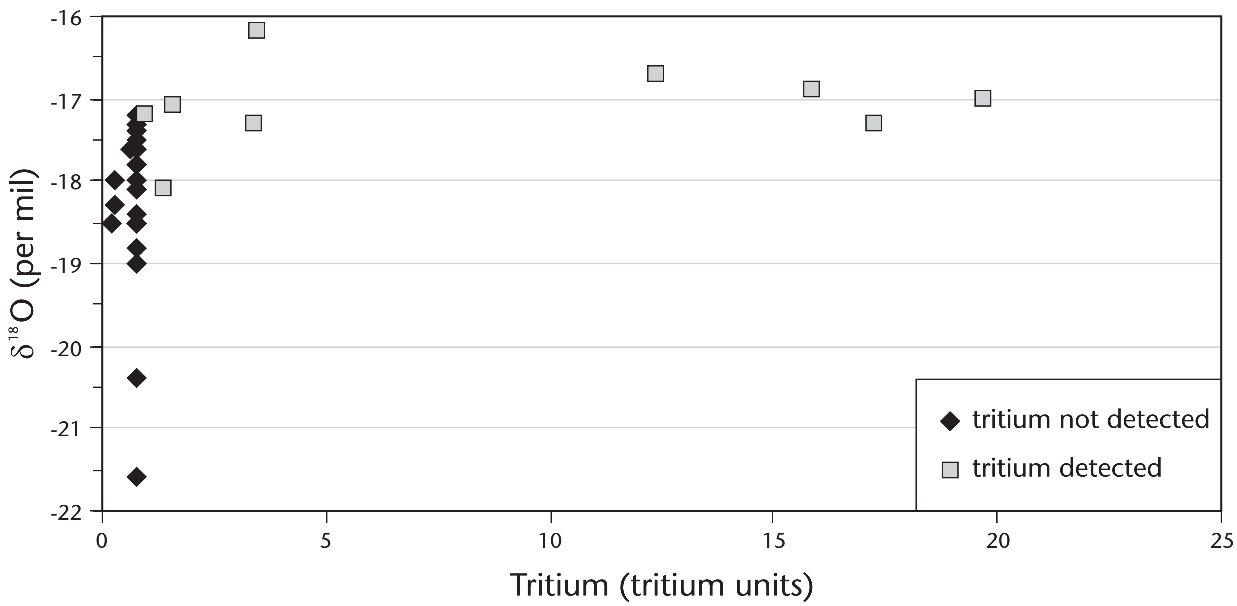



Figure 38. Most ground-water samples from the Kalispell subarea that had detectable levels of tritium also were enriched in $\delta^{18}O$, suggesting that younger water occurs on the east side of the valley (see figs. 36, 37).

radon in water. For the current study, samples for radon analysis were collected from 29 wells in the Kalispell subarea (1996–2000); data from 14 other wells sampled between 1992 and 1995 are also available (appendix D). Of the 43 samples, only one had a concentration less than the proposed public supply system MCL of 300 pCi/L; most were greater than 500 pCi/L, and the median concentration was 830 pCi/L. In a statewide survey, 73 percent of radon samples from ground water had concentrations greater than 300 pCi/L (Miller and Coffey, 1998). Radon concentrations in ground water from the Kalispell subarea show a strong correlation to aquifer materials. The median radon concentration in water from the bedrock (1,370 pCi/L) is about twice as high as the median radon concentration in water from the basin-fill deposits (675 pCi/L).

## Summary (Kalispell Subarea)

Water levels in wells completed in shallow alluvium and near the edges of the deep flow system show annual responses consistent with runoff patterns, where water levels rise in response to recharge from precipitation or stream discharge during the spring and summer months before falling to seasonal lows in the winter months. Water levels from the central part of the deep flow system show annual responses consistent with summertime pumping, where water levels fall to lows in July and August of each year before recovering to highs in the fall and winter months. The onset of the pumping response appears to have occurred in the 1970s and early 1980s.

Inorganic water-quality data show that ground water in the Kalispell subarea is of generally good quality with dissolved-constituent concentrations between 300 and 600 mg/L. Potential water-quality problems are related to high iron concentrations in some aquifers, which can cause staining of clothing and fixtures. Nitrate concentrations are above expected background levels in the Lost Creek fan vicinity. Radon concentrations in the deep flow system are generally above the recommended MCL for public drinking water supplies.

The geographic variation in oxygen-18, tritium, and carbon-14 results and in dissolved-constituents concentrations suggests that recharge to the deep flow system is nonuniform. West-side ground water is older and slightly more mineralized than east-side ground water, and the flow system is more active on the east side. Surface water and shallow ground water entering the deep flow system from the west-facing slopes of the Swan Range are important recharge sources. Much of the deep flow system is protected by low-permeability till and glacial-lake deposits, but water-quality, water-level, and well-log data indicate that in at least two locales the deep flow system is open to the land surface and potentially easily contaminated. Near the Lost Creek fan, downward water-level gradients—in a thick accumulation of surficial outwash that rests on the deep alluvium without well-defined intervening zones of till or glacial-lake deposits—indicate that shallow aquifers may be directly connected to the deep flow system. Elevated nitrate concentrations in the

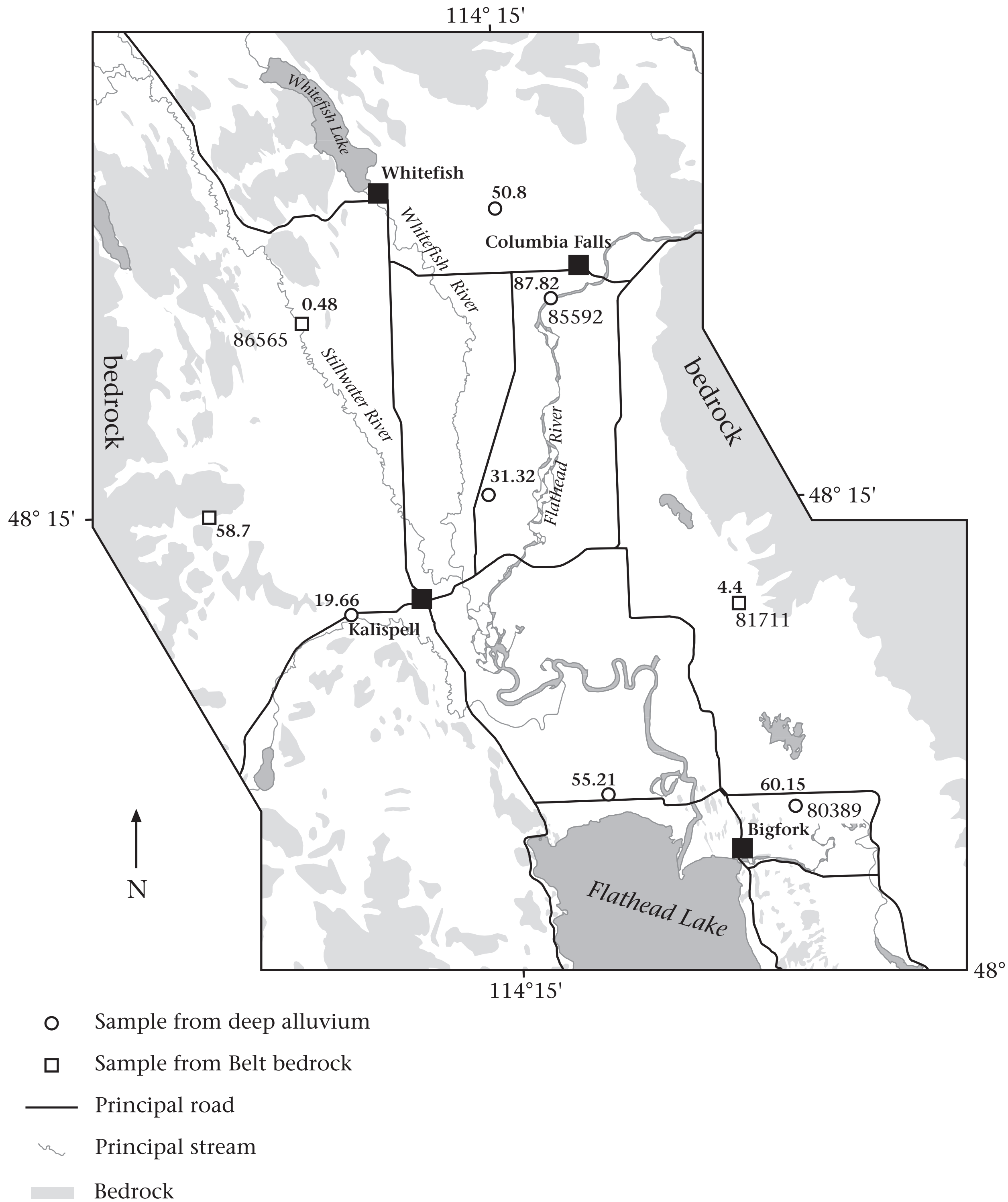



Figure 39. The distribution of carbon-14 in the deep alluvial aquifer parallels the distribution of other isotopes in the Kalispell subarea. Overall, the younger water (higher percentage of modern carbon) occurs on the northeast and east side of the valley. Locations with well-identification numbers are referred to in the text.

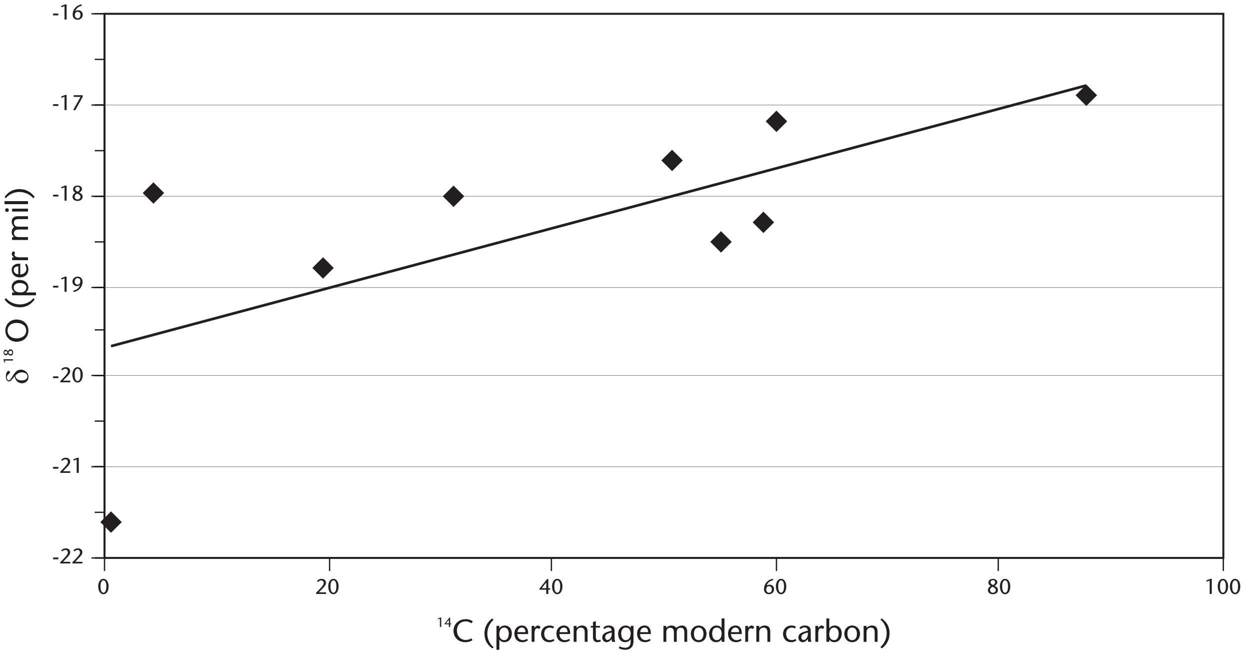



Figure 40. Water with a greater percentage of modern carbon from the deep alluvial aquifer also has the greatest $\delta^{18}O$ values, indicating that younger water is enriched in $\delta^{18}O$ and that older water is more depleted in $\delta^{18}O$.

Lost Creek vicinity area show that ground water has been impacted by surface sources of contamination. Near the east-side aquifers, high tritium values in some deep wells show that the water has entered the deep flow system since the atmospheric tritium peak in the 1960s.

## Mission

The Mission subarea (fig. 2) includes part of the north-trending, intermontane valley bounded by the Salish Mountains to the west, the Mission Range to the east, and the Jocko Hills to the south; Flathead Lake and the Polson moraine mark the northern boundary. The Flathead River below Kerr Dam drains the Mission subarea and marks most of its western boundary. The valley floor generally slopes to the south–southwest toward the Flathead River, away from the Polson moraine (fig. 41), and southward to where the Flathead River exits the valley (altitude 2,600 ft). The Valley View Hills and Moiese Hills, which are cored by bedrock (Belt rocks), protrude from the western part of the valley floor. Near Ronan, bedrock is within 300 to 400 ft of the valley floor, but bedrock is about 2,000 ft below the surface in the structurally deepest parts of the Mission subarea (Part B, map 7).

Shallow alluvium in the Mission subarea includes sand and gravel with minor silt and clay deposited along modern stream valleys. It also includes near-surface glacial outwash that was deposited as glaciers advanced into and retreated from the area. Thicknesses of shallow alluvium are greatest northeast of Pablo Reservoir, just southeast of where Highway 93 cuts through the Polson moraine, where a significant source of meltwater and outwash entered the Mission valley during glaciation (Part B, map 11). The basal deposits of the outwash are commonly interbedded with glacial-lake deposits, showing that the outwash was initially deposited into Glacial Lake Missoula. Shallow alluvium, as much as 50 ft in thickness, has been deposited along modern streams that have backfilled the valleys.

Till occurs in the Polson moraine, beneath glacial-lake deposits just north of the moraine, and in minor amounts in a few other locales. In logs for 100 wells that appear to penetrate till, the median thickness is 86 ft. Till also overlies glaciated bedrock in the Valley View Hills south of the Polson moraine, suggesting that earlier glacial advances were more extensive than the last one (Olson, 1998). The distribution of till in the subsurface south of the Polson moraine is unknown because in water-well logs till is difficult to distinguish from bouldery glacial-lake deposits. Localized areas of till also extend a few miles into the Mission valley from west-facing valleys in the Mission Range. North–northeast-trending hills extending from south of Ronan toward the Mission Range, and the northeast-trending bench near Ninepipe and Kicking Horse Reservoirs, may be underlain by till (Alden, 1953; Richmond,

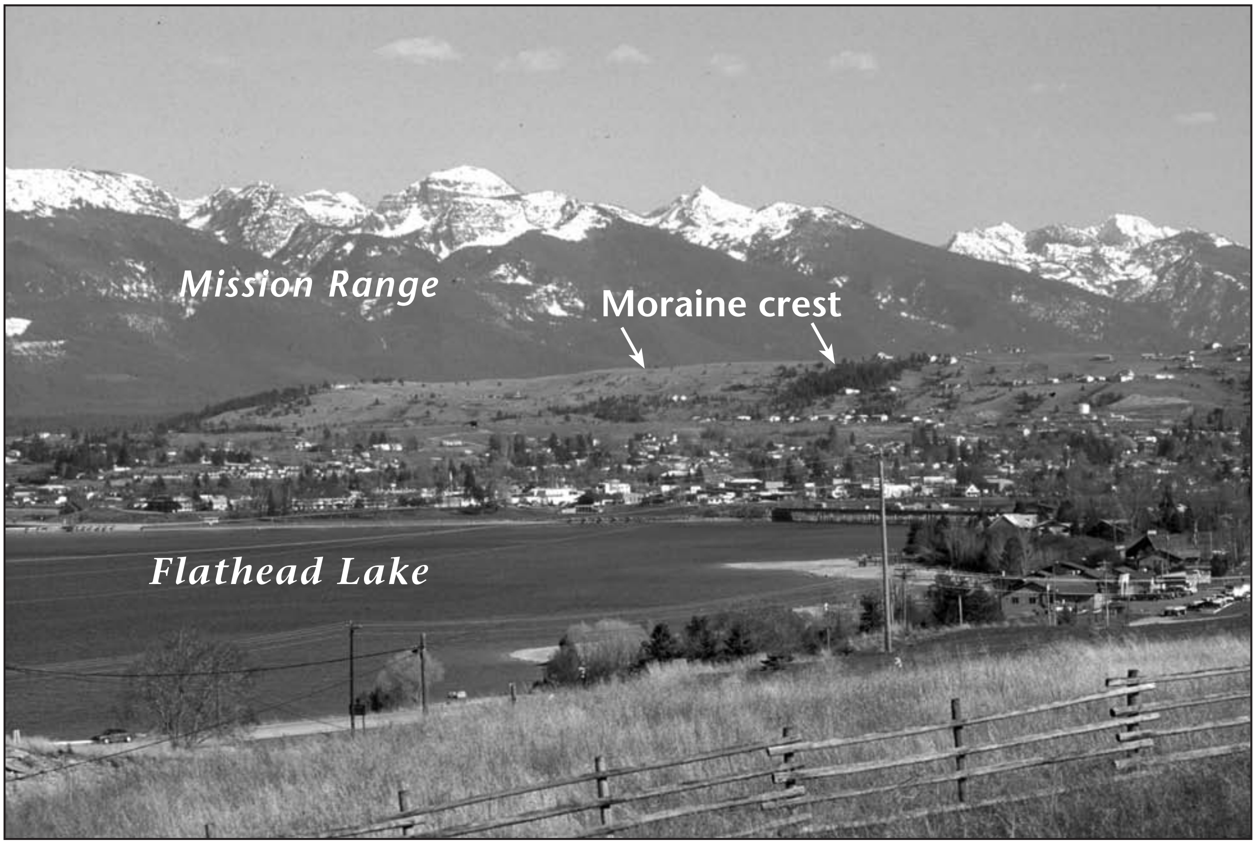



Figure 41. The hills south of Polson are known as the Polson moraine—an accumulation of till and other glacial deposits that was deposited at the southern end of the Flathead glacier. Polson Bay of Flathead Lake is in the foreground; snow-capped peaks of the Mission Range are in the background.

1965, 1986; Richmond and others, 1965; Curry and others, 1977; Stoffel, 1980). Sediments exposed in these areas, however, have recently been interpreted to be glacial-lake deposits (Levish, 1997).

Most of the basin-fill sediments in the Mission subarea are beds of silty and clayey gravel and thick beds of silt and clay with minor silty sand and gravel (fig. 10b) that were deposited in Glacial Lake Missoula. Where exposed along the canyon walls of the Flathead River downstream from Kerr Dam, the glacial-lake sediments are thick beds of gravelly silt and clay containing interbeds of laminated silt and clay, and minor sand (figs. 2, 18a; Levish, 1997). Greater amounts of sand and gravel occur on the eastern side of the Mission valley than either along the Flathead River west of the Valley View and Moiese Hills or in similar deposits in the Little Bitterroot subarea (Part B, map 10).

Determining the contact between the glacial sediments and the underlying deep alluvium is not always possible from drillers' logs. Interfingering between the deposits makes correlation from well logs difficult, especially in the northern and southern parts of the Mission subarea where wells do not reach bedrock. The glacial-lake sediments are as much as 800 ft thick but their median thickness is 160 ft on logs for the 700 wells that penetrate the unit.

The deep alluvium in the Mission subarea (fig. 8) lies beneath the glacial-lake sediments in many areas. The alluvium was deposited by streams before or during glacial advance into the region. The deep alluvium, not exposed at the surface but recognized at depths between 100 and 600 ft below land surface on well logs, consists of gravel, sand, and minor silt. Where it is greater than 20 ft thick, wells commonly produce more than 40 gpm. Only a few wells have been drilled entirely through the deep alluvium into underlying Tertiary deposits or bedrock. In these wells the alluvium is as much as 77 ft thick; however, most wells are completed only 10 to 20 ft below the top of the deep alluvium (Part B, map 10). Consolidated silt, clay, sandstone, and conglomerate of probable Tertiary age underlie the deep alluvium and have been encountered in some wells in the southern Mission subarea (Slagle, 1988).

The GWIC database contains records for about 2,000 wells completed in the Mission subarea; most (88 percent) are completed in unconsolidated deposits (shallow alluvium, glacial-lake

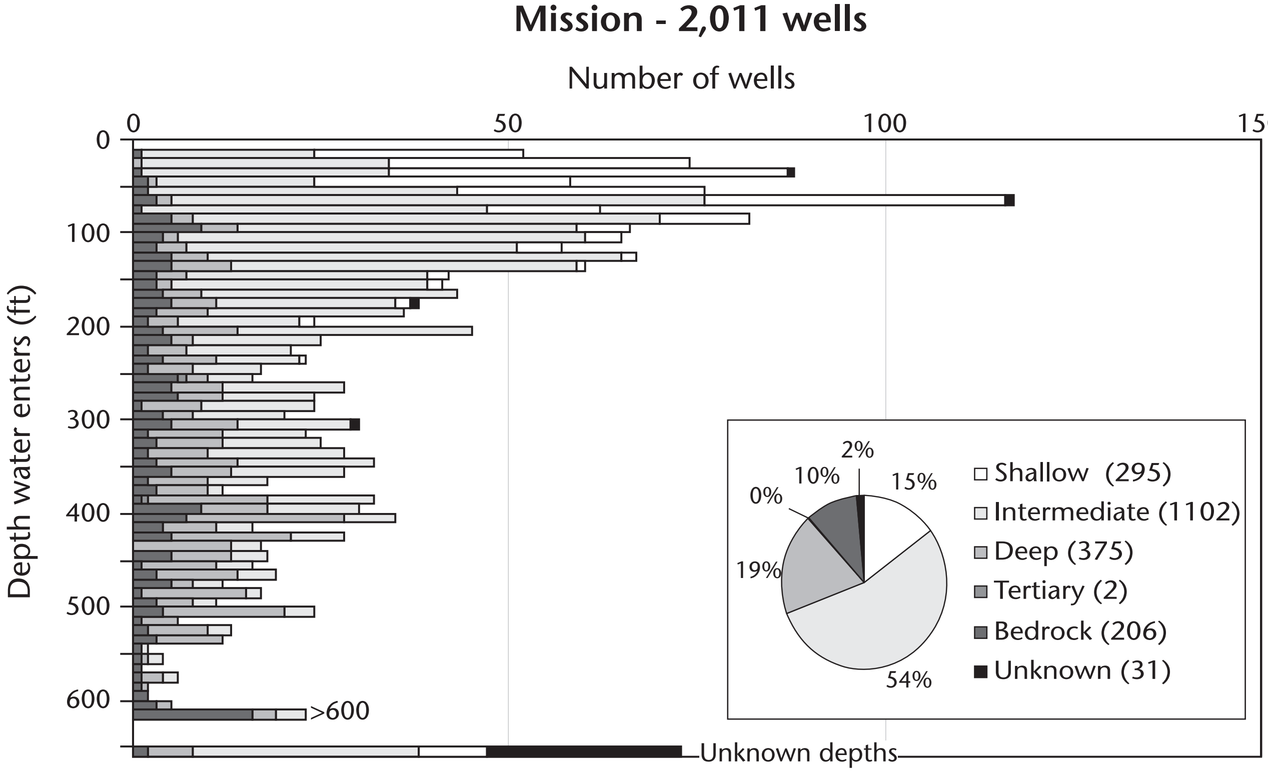



Figure 42. Almost all wells in the Mission subarea are completed in shallow, intermediate, and deep alluvial aquifers. The inset pie chart shows the percentages of wells developed in each aquifer. Most wells in shallow aquifers are less than 75 ft deep. Wells completed in intermediate aquifers range to more than 400 ft deep; however, most are less than 250 ft deep. The deep alluvial aquifer is generally encountered below 250 ft. The intermediate, deep alluvial, and bedrock aquifers are part of the deep flow system.

sediments, and deep alluvium; fig. 19) and about 10 percent are completed in bedrock (fig. 42). Wells supply water to all rural homes and municipalities in the valley.

## Shallow Aquifers

Aquifers in the Mission subarea include shallow aquifers in shallow alluvium and in near-surface bedrock, intermediate aquifers (interbedded with non-aquifer materials) in the glacial-lake sediments, deep alluvial aquifers, and bedrock aquifers. Non-aquifer materials in the glacial-lake sediments are confining units.

Only 15 percent of the wells in the Mission subarea are completed in shallow aquifers. Reported well depths range to more than 100 ft; however, most wells are less than 75 ft deep, and the median depth is 40 ft. The shallow aquifers in alluvium are typically productive. Reported yields for 222 wells ranged from 1 to 950 gpm, with a median of 25 gpm (fig. 43). Almost 20 percent of the wells (40) have reported yields of 100 gpm or more. Aquifer tests for two wells completed in outwash in the southwestern part of the Mission subarea near the Flathead River resulted in transmissivities of 10,000 and 13,000 $ft^2$/day (appendix B).

Development of the shallow aquifers has been minimal for decades; in the period between 1990 and 2000, fewer wells were drilled in shallow aquifers than in any of the other hydrogeologic units (fig. 43). Despite their productivity, shallow aquifers are more susceptible to contamination than other aquifers. Between 1990 and 2001, about 40 percent of the 62 wells drilled were monitoring wells related to a source, or potential source, of contamination. Most shallow wells have been completed in the alluvium associated with Mud, Post, and Mission Creeks (fig. 44).

### Water Levels

Water levels in shallow aquifers undergo regular seasonal change, but the timing and magnitude of the changes differ (fig. 45). Near the southwestern flank of the Moise Hills and near the town of St. Ignatius, water levels typically peak in the late summer or early fall, decline during the winter, and reach minimum levels in the early spring (wells 73475 and 133880). This pattern differs from that in shallow aquifers in the Kalispell subarea (fig. 25), where water levels peak in late spring or early summer in response to streamflow and precipitation.

Comparison of ground-water levels and irrigation ditch use suggests that irrigation water is an important source of recharge (fig. 45). Water levels rise when the ditches are in use and fall when the ditches are inactive. Similar observations have been reported by others (Boettcher, 1982; Slagle, 1988). Although the timing of the annual water-level response is similar in these two shallow aquifers, the magnitudes are very different. Water levels near the southwestern flank of the Moiese Hills, about 0.25 mi from where bedrock crops out, fluctuate 5 to 15 ft per year (well 133880). However, near St. Ignatius, more distant from the bedrock and more centrally located in the eastern part of the Mission valley, water levels typically fluctuate less than 2 ft per year (well 73475).

Water levels in a shallow aquifer associated with Dry Creek (well 6024, fig. 45), southeast of St. Ignatius, peak in mid-August and reach seasonal lows in April. The pattern is similar to but lags behind the runoff response pattern observed in the Kalispell subarea. This well is located adjacent to and slightly upgradient of the Pablo Canal, but water-level response does not correspond directly to times when the ditch is in use. Water levels reach a seasonal low after the onset of irriga-

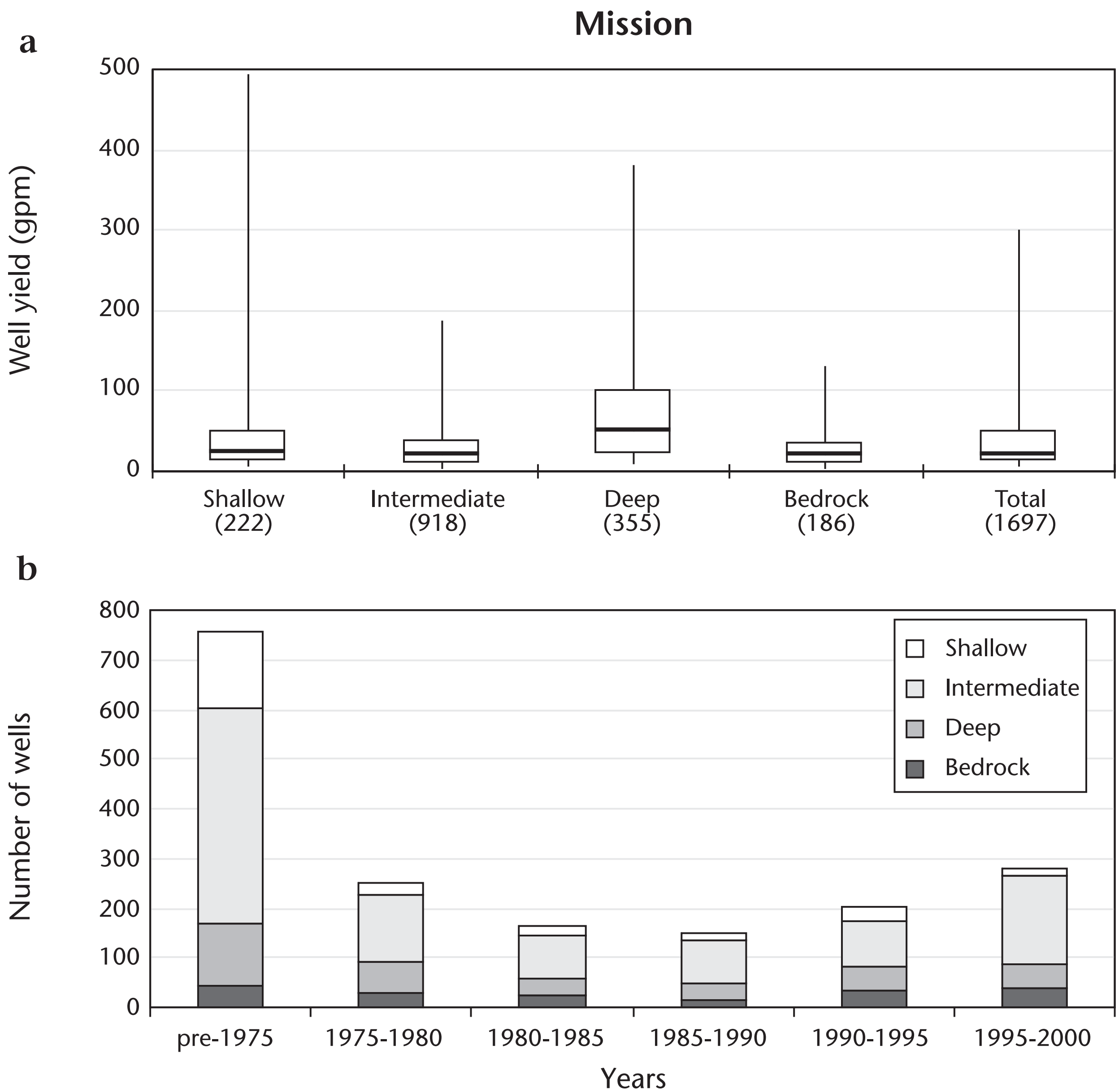



Figure 43. (a) Most wells in aquifers other than the deep alluvial aquifer have reported yields of less than 50 gpm. Wells completed in shallow aquifers display the widest range in yields, but wells completed in the deep alluvial aquifer have the highest median yield. See fig. 24 for an explanation of the plots. (b) Since 1985 there has been a steady increase in the number of wells completed in intermediate and bedrock aquifers.

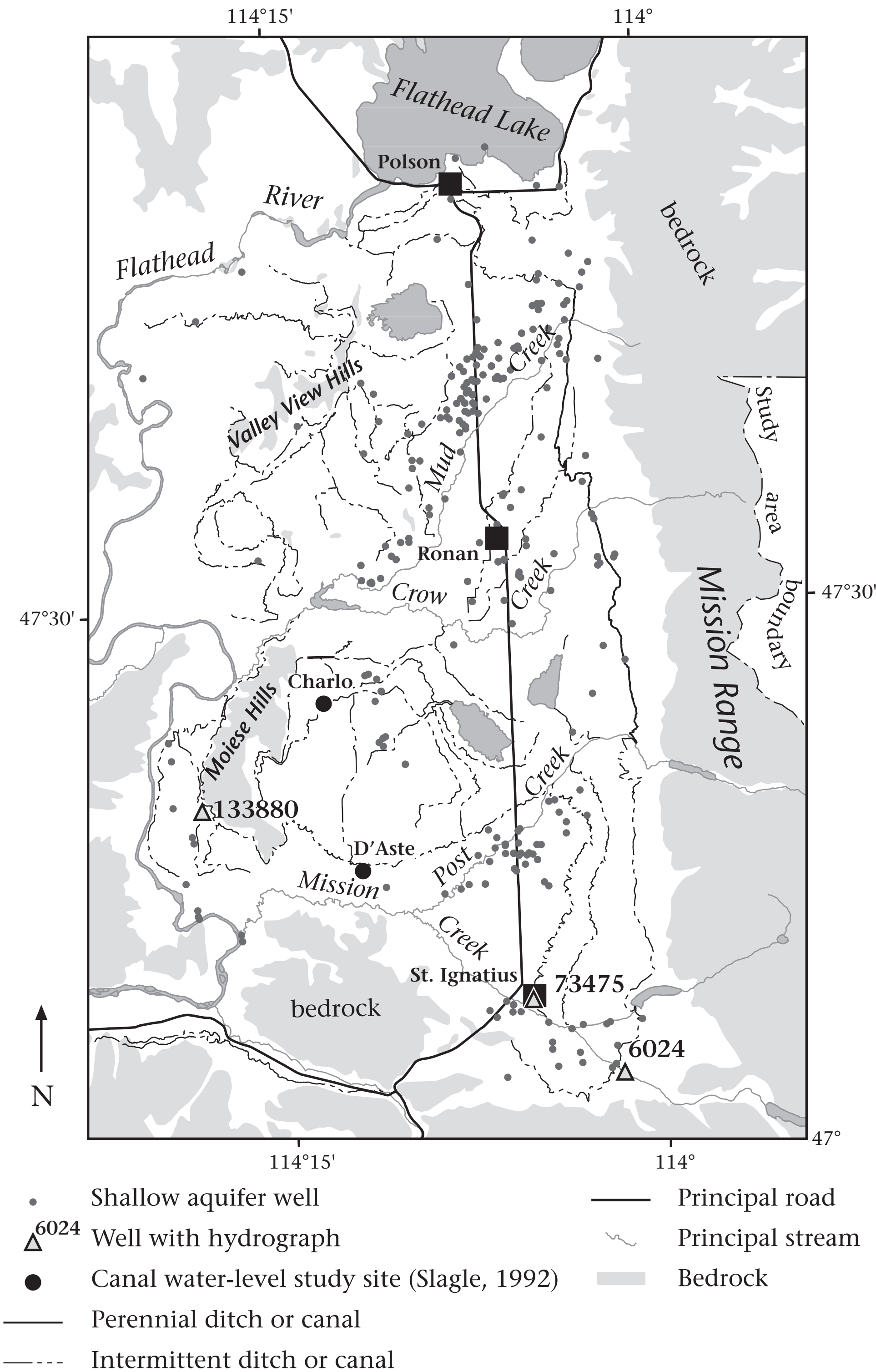
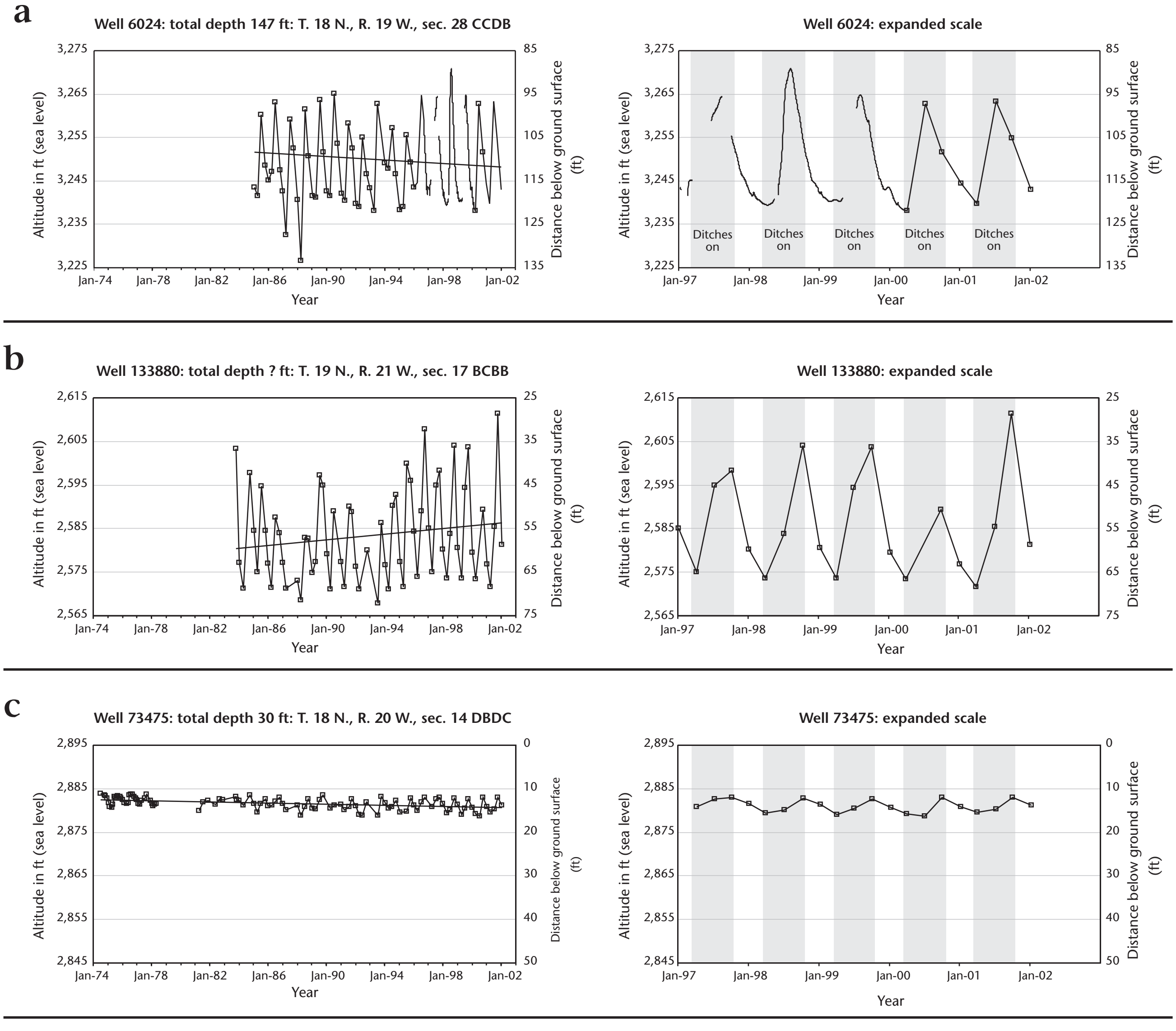



Figure 44. Most wells completed in shallow aquifers within the Mission subarea are near Mud Creek and Post Creek. Well locations for hydrographs presented in fig. 45 are also shown.

tion, but rise, peak, and then fall while water is flowing in the ditch. The response suggests that leakage from Dry Creek controls the magnitude and timing of ground-water-level change.

Water levels in shallow aquifers near the southeast and south central part of the valley (wells 73475 and 6024) have declined slightly since records have been kept; however, the trend in the shallow aquifer in the southwest part of the valley near the Moiese Hills (well 133880) is slightly upward (fig. 45). The trends do not appear significant, less than 5 ft of change over the period of record, suggesting that these shallow aquifers are in a state of stable equilibrium indicating no substantial increases or decreases in the amount of water in aquifer storage.



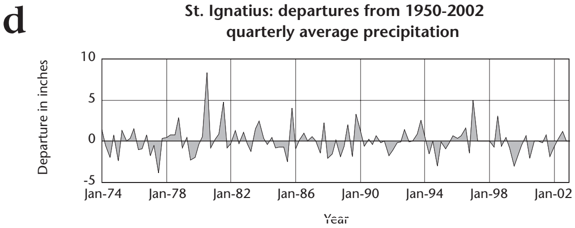




Figure 45. Seasonal changes in these wells range from less than 5 to more than 20 ft per year. Long-term trends appear slightly downward near St. Ignatius (well 73475; c, well 6024; a), and upward near the Moiese Hills (well 133880; b). Expanded-scale plots for each well show how annual water-level changes correspond with periods when irrigation ditches contain water. Water levels in wells 133880 and 73475 generally rise throughout each irrigation season, responding to leakage from irrigation ditches and irrigated fields. The locations of these wells within the Mission subarea are shown in fig. 44. (d) Average precipitation. Measurements courtesy of the Confederated Salish and Kootenai Tribes.

## Deep Ground-Water Flow System

The intermediate, deep alluvial, and bedrock aquifers form a deep ground-water flow system in the Mission subarea. Ground-water flow is generally away from the Mission Range, which serves as the major recharge area, and westward toward the Flathead River. North of the Polson moraine, ground water flows toward Flathead Lake. The Moiese and Valley View Hills, which are bedrock highs, divert ground-water flow in the western part of the valley. Ground-water flow from the northern part of the valley converges toward the lower reaches of Crow Creek, while in the southern part of the valley flow converges toward the lower reaches of Mission Creek. A potentiometric surface map for the deep flow system is presented in Part B, map 4.

Ground water in the deep flow system is under confined to semi-confined conditions. Recharge occurs by downward percolation through the overlying units. Shallow aquifers associated with the Mud, Spring, Post, and Mission Creek drainages are likely important avenues of recharge to the deep flow system. In addition, leakage from irrigation canals provides much of the recharge water (Slagle, 1992).

## Intermediate and Deep Alluvial Aquifers

Almost 55 percent of the wells in the Mission subarea are completed in intermediate aquifers, making these aquifers the most utilized source of ground water (fig. 42). The intermediate aquifers occur as many discontinuous layers of sand and gravel within the glacial-lake sediments and are separated by low-permeability layers of clayey glacial-lake deposits (confining units). Most of the intermediate aquifers are buried at depths between 50 and 250 ft below the surface (fig. 42). Although the intermediate aquifers are generally not contiguous over large areas, they have sufficient hydraulic continuity to be considered a single ground-water flow entity on a valley-wide scale. Well yields in the intermediate aquifers are as much as 1,500 gpm, with a median of 20 gpm (fig. 43). About 10 percent (99) have yields of 100 or more gpm. The rate of development has increased steadily since 1985 (fig. 43).

The deep alluvial aquifer in the Mission subarea generally occurs at depths greater than about 250 ft but does not underlie the entire valley. The aquifer is most developed in the area between Highway 93 and the Moiese and Valley View Hills (fig. 46). Well depths are as much as 750 ft with a median of 375 ft (fig. 42). The aquifer is highly productive; yields are as much as 2,400 gpm, with a median of 50 gpm and average of 100 gpm (fig. 43). Almost one-third (100) of the wells completed in the deep alluvial aquifer have reported yields of 100 gpm or more. Development of the aquifer has increased somewhat since 1985, with from 30 to 40 wells completed per year.

Aquifer tests from three wells completed in the intermediate or deep alluvial aquifers show that transmissivities range over an order of magnitude from 2,100 to 22,000 $ft^2$/day (appendix B).

## Bedrock Aquifer

Two distinct areas where bedrock aquifers are important are: (1) the Mission Range front on the east and southeast side of the valley, and (2) near the Valley View and Moiese Hills to the west (fig. 47). Near the Mission Range, the wells are completed in mountainous areas where bedrock is close to or at the land surface. Near the Moiese and Valley View Hills, many wells are completed in bedrock beneath several hundred feet of silty and clayey basin-fill sediments generally devoid of aquifers.

Depths for wells completed in bedrock are highly variable, ranging from less than 100 to more than 1,000 ft, but as shown in fig. 42, no particular depth is most common. About 20 percent of wells completed in bedrock are more than 500 ft deep. Yields from bedrock wells, although lower than yields from wells completed in the intermediate and alluvial aquifers, are generally adequate for domestic purposes. Although the maximum reported yield is 2,000 gpm, fewer than 8 percent (16) of the wells have reported yields greater than 100 gpm, and almost 20 percent (36) of the bedrock wells have reported yields less than 10 gpm. The median yield is 20 gpm (fig. 43). The rate of wells drilled into bedrock has increased in the period between 1990 and 2000, and almost 40 percent (77) of all bedrock wells were installed during this time (fig. 43).

## Water Levels

Water-level fluctuations in the intermediate and deep aquifers appear to be primarily influenced by seasonal pumping. Long-term water-level records from three wells completed at different depths (in deep and intermediate aquifers) and at different locations all have similar patterns: seasonal lows occur in July followed by a period of water-level recovery between July and October. The locations of the three wells are shown in fig. 48, and the hydrographs are shown in fig. 49.

Data from the deep alluvial aquifer a few miles south of Polson (fig. 49, well 133895) shows a pumping response and some long-term decline. A chart of quarterly medians shows that water levels are lowest in the summer and highest in the fall. Median water levels in 2000 and 2001 were about 7 ft lower then they were in 1983–87.

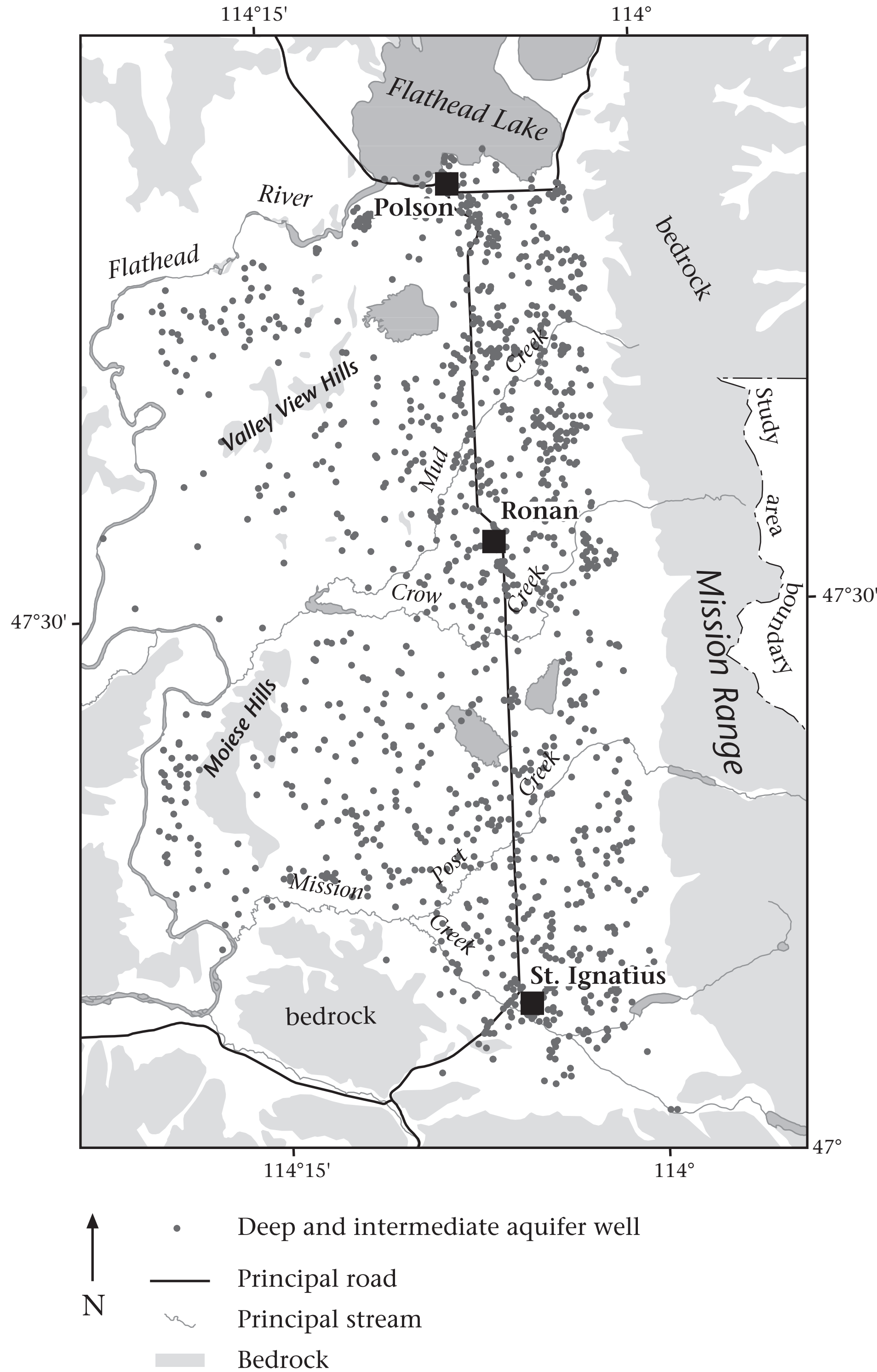



Figure 46. Wells are completed in intermediate and deep alluvial aquifers throughout the Mission subarea, but most of the deep alluvial aquifer wells are completed between Highway 93 and the Moiese and Valley View Hills.

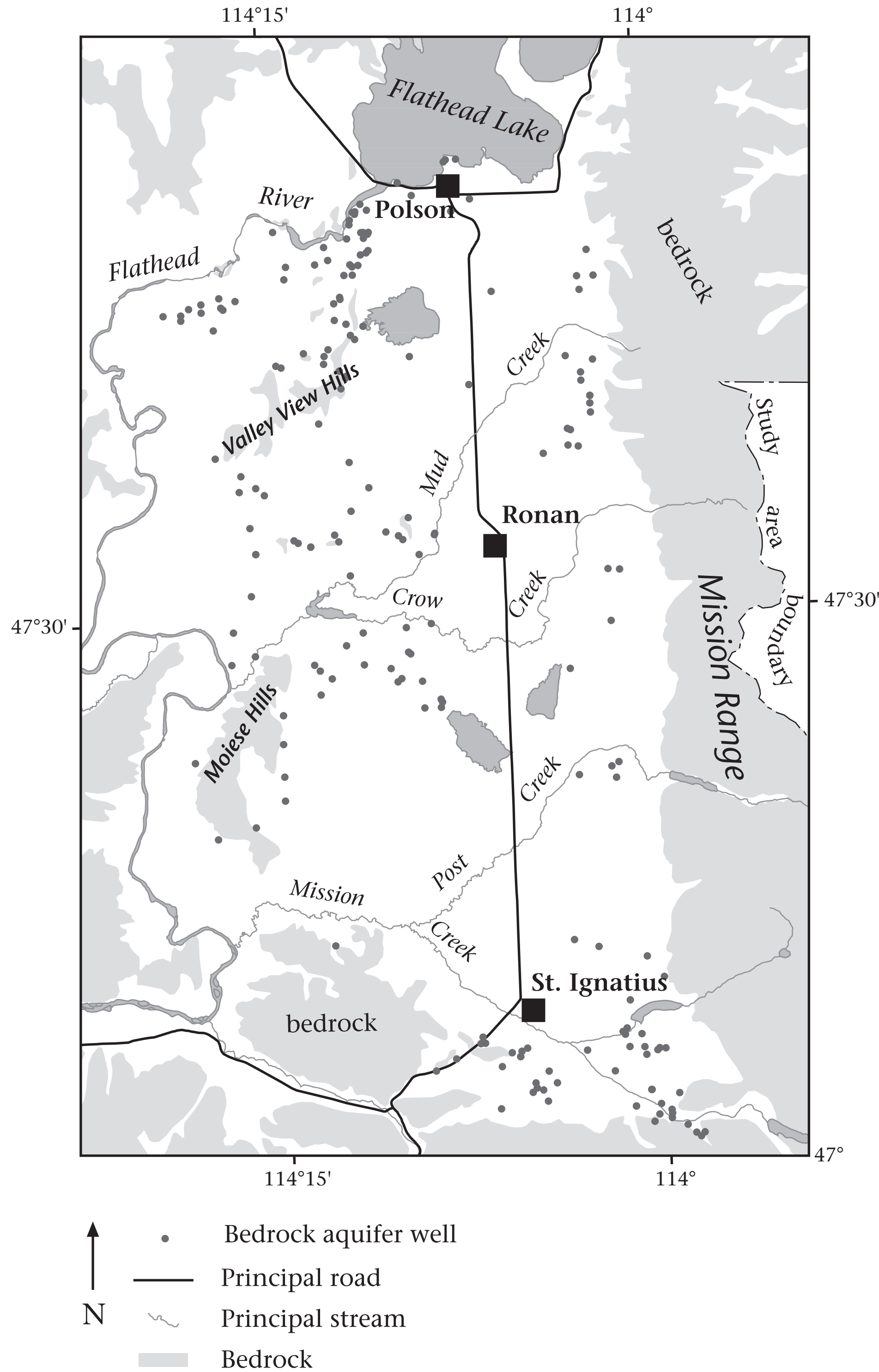



Figure 47. Wells are completed in bedrock along the Mission Range front on the east side of the Mission subarea, and near the Valley View Hills and Moiese Hills along the west side of the subarea. Bedrock wells represent about 10 percent of all wells in the subarea.

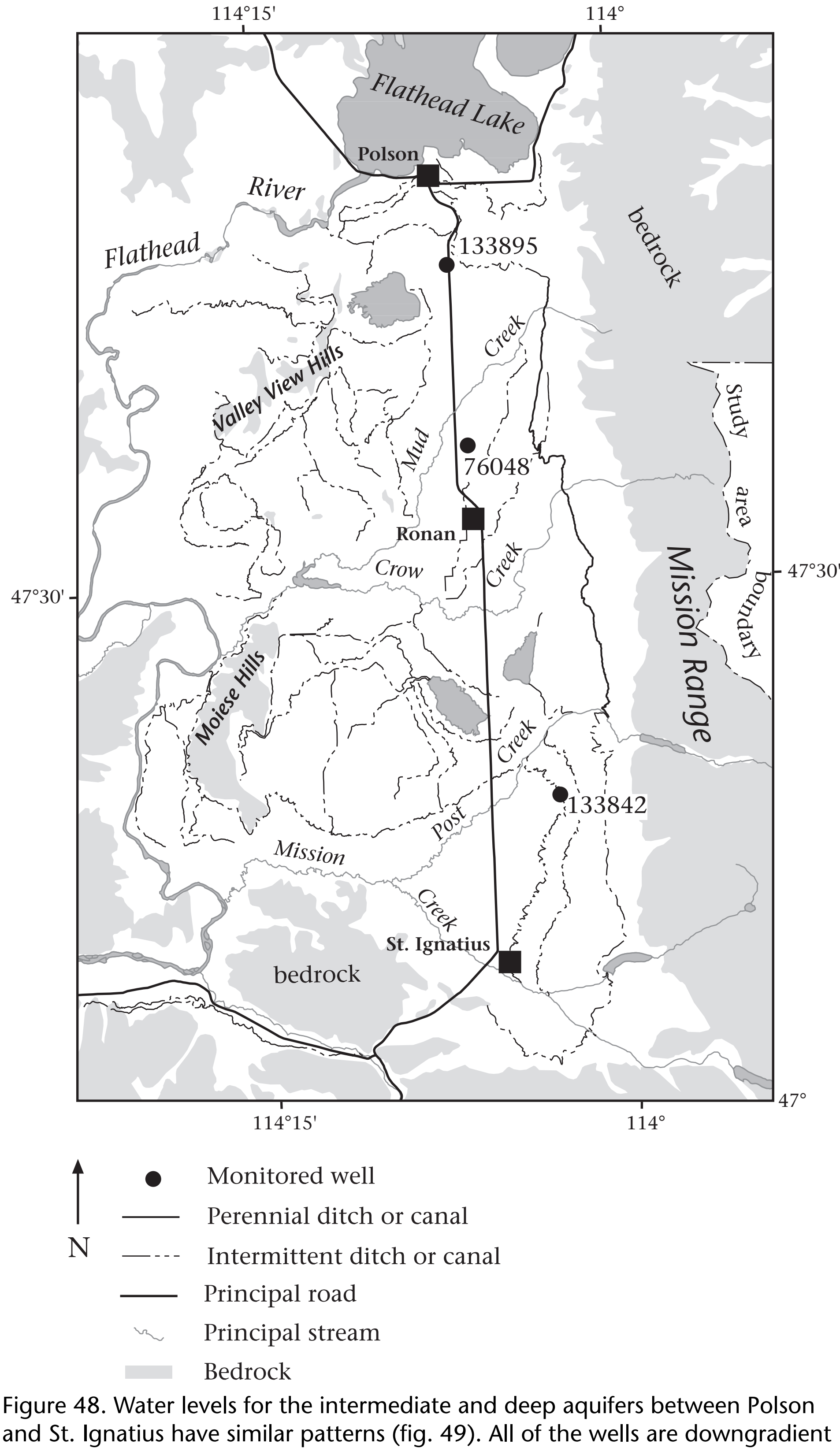
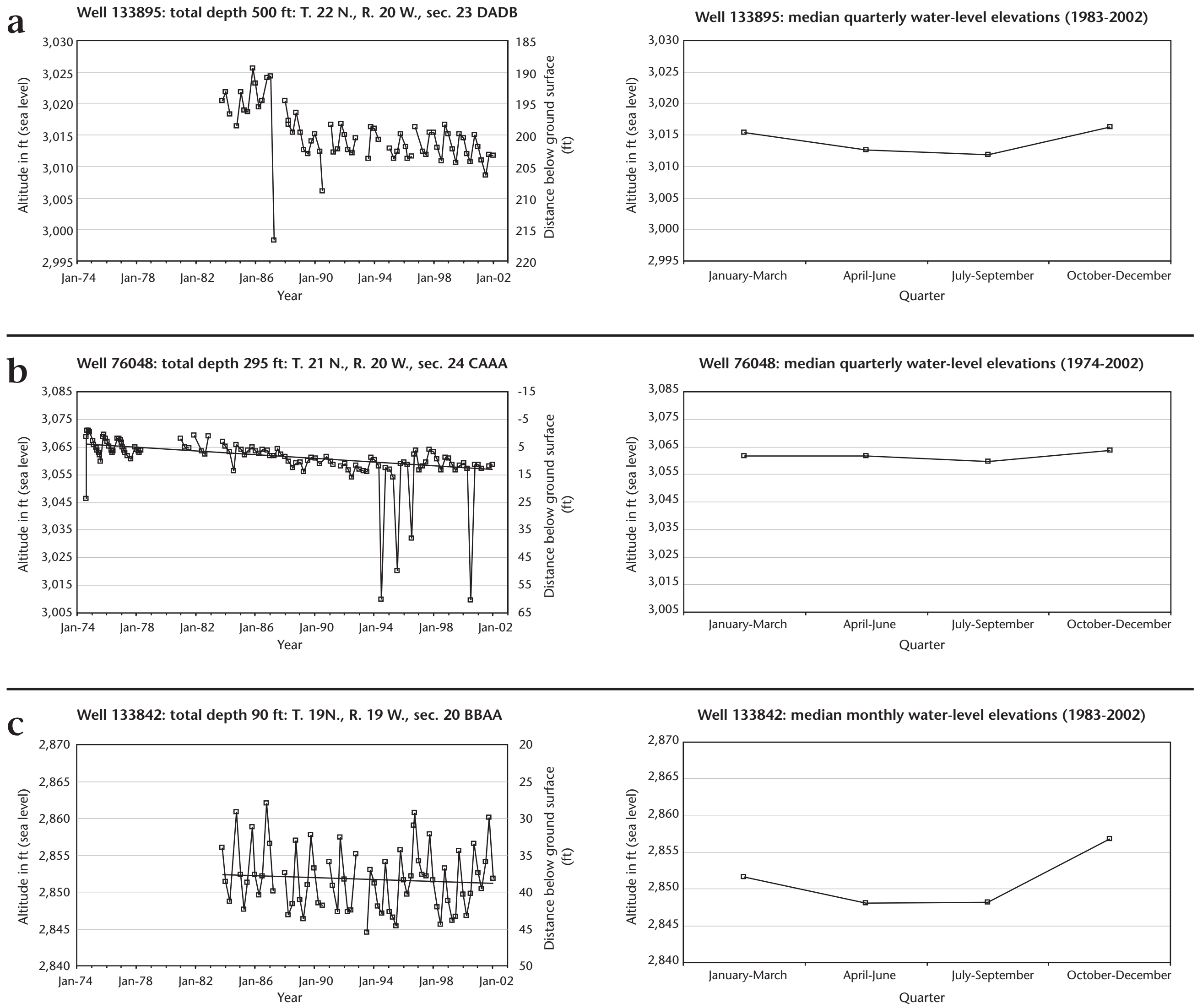



Figure 48. Water levels for the intermediate and deep aquifers between Polson and St. Ignatius have similar patterns (fig. 49). All of the wells are downgradient of irrigation canals.



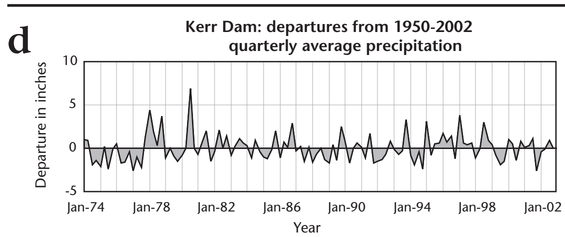




Figure 49. Water levels in wells completed in intermediate and deep alluvial aquifers in the Mission subarea are affected by pumping, but long-term declining trends are insubstantial. (a) Water levels in well 133895 appear to have declined from a peak in 1986 and 1987; the decline appears to have ceased around 1990. (b) Well 76048 is completed at 295 ft below land surface in an intermediate aquifer and is 8 ft south of an active irrigation well. A long-term slight downward trend occurs in the record with current water levels being about 10 ft lower than they were in 1974. (c) Water levels in well 133842, completed 90 ft below the land surface in an intermediate aquifer, show little long-term change between 1983 and 2001. All three wells have annual lows that occur in the mid-summer and annual highs that occur in the fall. (d) Average precipitation. Measurements courtesy of the Confederated Salish and Kootenai Tribes.

Water levels in an intermediate aquifer (fig. 49, well 76048) also show a pumping response of about 10 ft annually and a slight downward long-term trend. This well is about 2 mi north of Ronan (fig. 48) and 8 ft south of an active irrigation well. Pumping in the adjacent well causes the sharp downward spikes in the recent part of the record. The quarterly water-level medians in this well are similar to those of well 133895. Water levels from another intermediate aquifer (fig. 49, well 133842) fluctuate annually 5 to 10 ft, and the record shows a slight long-term downward trend. Quarterly medians mimic those in the other two examples.

Irrigation canals and laterals cross most of the valley, and all but one of the monitored wells are downgradient from one or more canals (fig. 48). The late-season rise in water levels observed in the deep and intermediate aquifers may reflect not only cessation of summertime pumpage, but recharge from irrigation ditch leakage.

## Water Quality

Ground water in the aquifers of the Mission subarea is chemically uniform and of very high quality, and generally meets U.S. EPA standards for natural constituents in public drinking water supplies. The predominant ions in the water are calcium and bicarbonate followed by magnesium and sodium. The most common secondary anion is sulfate, but concentrations are generally low. Median dissolved constituents in water from all the aquifers are about 500 mg/L.

Water quality in the Mission subarea was evaluated using results from 91 water-quality analyses; 32 were analyzed as part of this study, and the remaining data came from samples collected during previous investigations. Most of the results (68) are from intermediate, deep alluvial, and bedrock aquifers in the deep flow system, and 23 results are from shallow aquifers (table 4). In addition, dissolved-constituents concentrations were determined from specific conductance measurements made in an additional 154 wells.

### Iron and Manganese

Concentrations in 3 of 23 samples (13 percent) from shallow aquifers, and 6 of 55 samples (11 percent) from intermediate and deep alluvial aquifers exceeded the SMCL (0.3 mg/L iron) for public drinking water supplies. However, none of the 13 samples from the bedrock aquifer exceeded the iron standard. The secondary standard of 0.05 mg/L for manganese was exceeded in 3 of 23 samples (13 percent) from shallow aquifers and 14 of 54 samples (26 percent) from the intermediate and deep alluvial aquifers. No water samples from the bedrock exceeded the manganese standard. Iron concentrations in water greater than 0.3 mg/L pose no health threat, but will stain clothing and fixtures and are a nuisance. Staining of clothing or fixtures by water from intermediate and deep alluvial aquifers, while not common, will occur.

### Nitrate

Nitrate concentrations in ground water of the Mission subarea are generally low. Although one historical analysis had a nitrate concentration above the U.S. EPA's 10 mg/L health standard (10.6 mg/L in well 6139, sampled in 1988), none of the samples collected for this study had nitrate concentrations greater than 4.0 mg/L, and 78 percent (25 of 32) had concentrations that were less than 1.0 mg/L or that were not detectable. Most historical analyses available for the Mission subarea also had nitrate concentrations of less than 1.0 mg/L.

Almost all samples from shallow aquifers contained detectable levels of nitrate. Concentrations in water from shallow aquifers were low (fig. 50), but generally greater than concentrations in water from the intermediate, deep alluvial, and bedrock aquifers. The median nitrate concentration in water from shallow aquifers was 0.8 mg/L, and half of the samples (13 of 27) had concentrations between about 0.4 and 1.2 mg/L. Ninety-two percent of the samples (24 of 27) had concentrations less than 6.0 mg/L; however, the concentration in one sample was 10.6 mg/L. Five samples (19 percent) had concentrations exceeding 3.0 mg/L, indicating potential surface/human sources.

Nitrate was detected in 35 of 40 water samples (89 percent) from wells completed in intermediate aquifers and in 11 of 18 water samples (56 percent) from wells completed in deep alluvial aquifers. The maximum concentration observed was 3.8 mg/L; median concentrations in both the intermediate and deep alluvial aquifers were less than 0.3 mg/L (fig. 50). The low median concentration suggests that intermediate and deep alluvial aquifers have generally not been affected by nitrate contamination and that silts and clays in the glacial-lake sediments protect the aquifers.

Of the 16 nitrate analyses for wells completed in bedrock, 5 (31 percent) had concentrations greater than 1.0 mg/L, with a maximum concentration of 3.5 mg/L and a median concentration of 0.4 mg/L.

### Dissolved Constituents

Dissolved-constituents concentrations in water from shallow aquifers vary more widely than concentrations in water from intermediate, deep alluvial, and bedrock aquifers (fig. 50). Additionally, the water in east-side shallow aquifers is less mineralized and has a different composition

Table 4. Ground-water quality summary, Mission subarea

| Constituent or Property | Number of Detections/ Samples | Minimum | Median | Maximum | USEPA SMCL or MCL |
|---|---|---|---|---|---|
| **Shallow aquifers** | | | | | |
| Major ions (mg/L) | | | | | |
| Ca | 23/23 | 21.70 | 41.10 | 81.00 | — |
| Mg | 23/23 | 5.70 | 16.10 | 59.50 | — |
| Na | 23/23 | 0.79 | 9.80 | 221.00 | 250 |
| K | 23/23 | 0.14 | 2.20 | 10.20 | — |
| $HCO_3$ | 23/23 | 112.20 | 270.00 | 617.00 | — |
| $SO_4$ | 21/23 | <0.25 | 4.00 | 360.80 | 250 |
| Cl | 20/23 | <0.50 | 4.00 | 90.00 | 250 |
| $NO_3$ | 25/27 | <0.02 | 0.76 | 10.60 | 10 |
| F | 12/23 | <0.10 | 0.50 | 4.90 | 4 |
| Fe | 17/23 | <0.002 | 0.01 | 3.05 | 0.3 |
| Other parameters | | | | | |
| TDS (mg/L) | 23/23 | 97.97 | 278.29 | 1073.93 | 500 |
| Dissolved constituents (mg/L) | 23/23 | 154.90 | 415.54 | 1333.66 | — |
| Hardness (as mg/L $CaCO_3$) | 23/23 | 89.99 | 171.91 | 444.66 | — |
| pH | 23/23 | 7.48 | 8.09 | 8.50 | 6.5–8.5 |
| **Intermediate aquifers** | | | | | |
| Major ions (mg/L) | | | | | |
| Ca | 37/37 | 5.70 | 33.80 | 79.00 | — |
| Mg | 37/37 | 1.80 | 14.10 | 41.00 | — |
| Na | 37/37 | 0.70 | 12.50 | 97.30 | 250 |
| K | 36/37 | <0.20 | 1.50 | 4.80 | — |
| $HCO_3$ | 37/37 | 42.90 | 180.80 | 466.00 | — |
| $SO_4$ | 32/37 | <0.10 | 4.70 | 184.00 | 250 |
| Cl | 31/37 | <0.50 | 1.60 | 47.50 | 250 |
| $NO_3$ | 35/40 | 0.02 | 0.35 | 5.80 | 10 |
| F | 21/37 | <0.10 | 0.20 | 1.80 | 4 |
| Fe | 18/37 | <0.002 | 0.01 | 1.90 | 0.3 |
| Other parameters | | | | | |
| TDS (mg/L) | 37/37 | 41.07 | 173.21 | 607.13 | 500 |
| Dissolved constituents (mg/L) | 37/37 | 62.84 | 265.61 | 770.00 | — |
| Hardness (as mg/L $CaCO_3$) | 37/37 | 30.13 | 142.43 | 366.02 | — |
| pH | 37/37 | 6.16 | 7.91 | 8.20 | 6.5–8.5 |
| **Deep alluvial aquifer** | | | | | |
| Major ions (mg/L) | | | | | |
| Ca | 18/18 | 15.00 | 30.85 | 49.70 | — |
| Mg | 18/18 | 5.10 | 11.55 | 30.00 | — |
| Na | 18/18 | 4.50 | 12.90 | 167.00 | 250 |
| K | 18/18 | 0.20 | 1.35 | 3.80 | — |
| $HCO_3$ | 18/18 | 93.90 | 170.20 | 553.80 | — |
| $SO_4$ | 12/18 | 1.00 | 2.60 | 35.10 | 250 |
| Cl | 12/18 | <0.50 | 1.75 | 36.95 | 250 |
| $NO_3$ | 11/18 | <0.05 | 0.13 | 2.20 | 10 |
| F | 5/18 | 0.04 | 0.50 | 2.00 | 4 |
| Fe | 12/18 | <0.002 | 0.02 | 2.04 | 0.3 |
| Other parameters | | | | | |
| TDS (mg/L) | 18/18 | 83.83 | 169.68 | 553.38 | 500 |
| Dissolved constituents (mg/L) | 18/18 | 131.47 | 281.68 | 834.38 | — |
| Hardness (as mg/L $CaCO_3$) | 18/18 | 69.60 | 116.36 | 223.36 | — |
| pH | 18/18 | 7.60 | 7.96 | 8.20 | 6.5–8.5 |
| **Bedrock aquifer** | | | | | |
| Major ions (mg/L) | | | | | |
| Ca | 13/13 | 1.90 | 37.80 | 73.30 | — |
| Mg | 13/13 | 0.10 | 14.70 | 33.50 | — |
| Na | 13/13 | 2.20 | 22.10 | 83.10 | 250 |
| K | 13/13 | 0.30 | 1.00 | 3.40 | — |
| $HCO_3$ | 13/13 | 84.70 | 229.10 | 448.50 | — |
| $SO_4$ | 13/13 | 1.10 | 8.30 | 39.30 | 250 |
| Cl | 13/13 | 0.30 | 2.40 | 12.10 | 250 |
| $NO_3$ | 14/16 | 0.02 | 0.44 | 3.50 | 10 |
| F | 7/13 | 0.05 | 0.20 | 2.80 | 4 |
| Fe | 5/13 | <0.002 | 0.04 | 0.30 | 0.3 |
| Other parameters | | | | | |
| TDS (mg/L) | 13/13 | 82.98 | 231.08 | 429.45 | 500 |
| Dissolved constituents (mg/L) | 13/13 | 125.96 | 348.79 | 657.02 | — |
| Hardness (as mg/L $CaCO_3$) | 13/13 | 5.16 | 148.72 | 256.29 | — |
| pH | 13/13 | 7.68 | 8.17 | 8.50 | 6.5–8.5 |

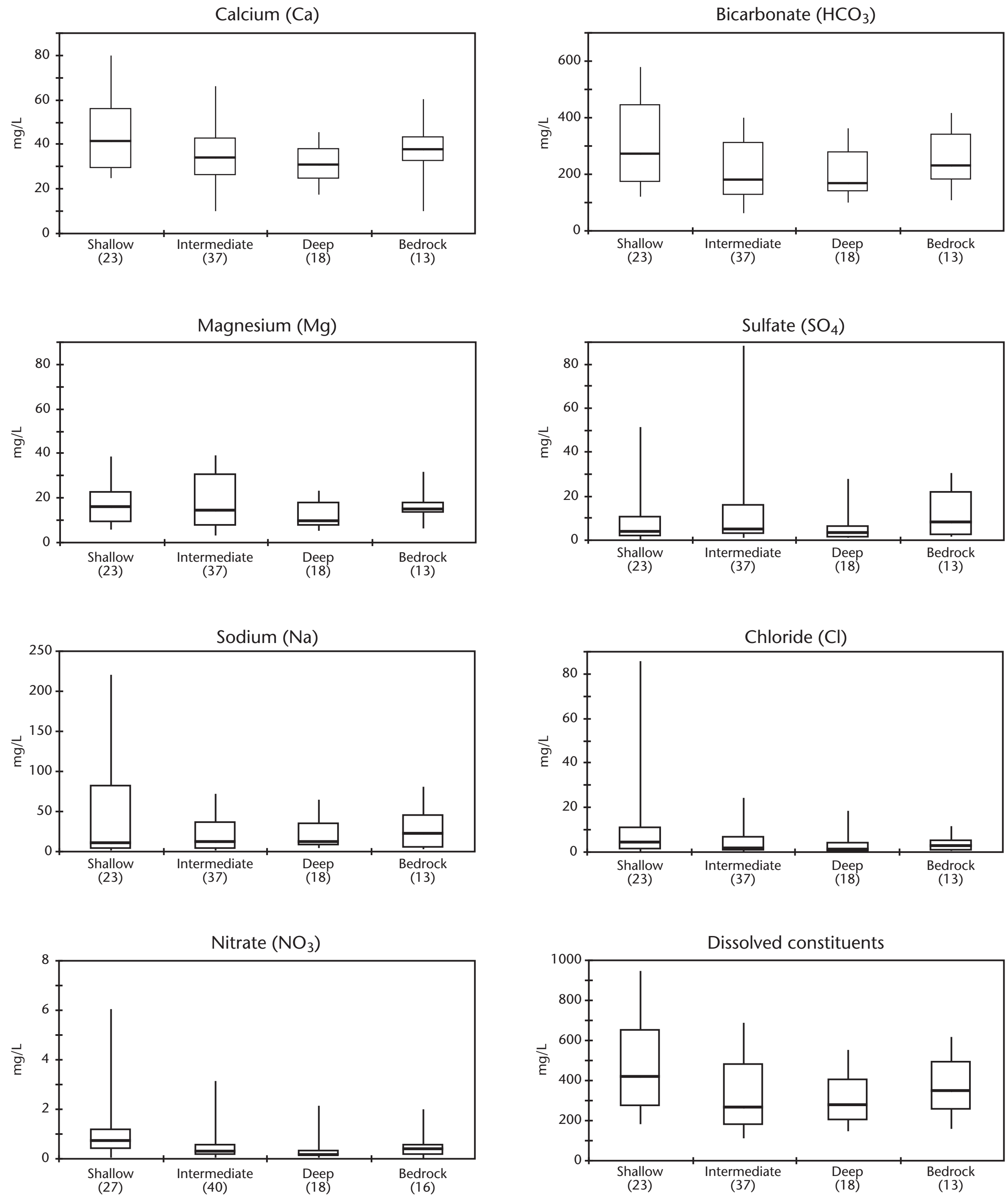



Figure 50. Water quality varies little between aquifers in the Mission subarea. The major ions in solution in each aquifer are calcium, magnesium, sodium, and bicarbonate. For non-quantifiable or non-detectable data, a value of one-half the detection limit was used in the statistical summaries. See fig. 24 for an explanation of the plots.

than water in west-side shallow aquifers. Samples from the east-side shallow aquifers have a strong calcium-bicarbonate signature (fig. 51) with median dissolved-constituents concentrations of about 360 mg/L (fig. 52). On the east side of the valley near the Mission Range, recharge to shallow aquifers is tied closely to direct leakage of water from streams entering the valley. Conversely, median dissolved-constituents concentrations in samples from shallow aquifers on the west side of the valley near the Flathead River are more mineralized, with a median concentration of 525 mg/L (fig. 52). The difference in dissolved-constituents concentrations is caused by increased amounts of sodium, bicarbonate, and in some samples, chloride; the relative amounts of calcium and magnesium are about the same in all the samples. The increased levels of dissolved constituents in west-side shallow aquifers likely result from more mineralized recharge sources such as irrigation return flows or upward leakage from deep alluvial and intermediate aquifers.

The distribution of dissolved constituents and the water quality in the deep flow system is discussed in detail in Part B, map 5. Overall, dissolved constituents in the intermediate, deep alluvial, and bedrock aquifers reflect the hydrology of the deep flow system, with water temperatures increasing and water chemistry evolving along flow paths from the Mission Range on the east to the Flathead River on the west.

Measurements of ground-water temperatures show a wedge of relatively cool water (less than 11°C or 52°F) along the flanks of the Mission Range, whereas ground-water temperatures downgradient, near the discharge area along the Flathead River, are generally greater than 13°C (55°F). The increase in temperature along flow paths coincides with increased dissolved constituents from less than about 300 mg/L to greater than 500 mg/L.

#### Radon

Radon in household air has been linked to lung cancer, and a minor source of the gas can be well water. The U.S. EPA estimates that less than 2 percent of radon in household air comes from radon in water. During the period 1992–96, eight samples for radon were collected from intermediate or deep alluvial aquifers in the Mission subarea; one sample was from a shallow alluvial aquifer (appendix D). Of the nine samples, only one had a concentration less than the proposed MCL of 300 pCi/L; most were greater than 900 pCi/L. The median radon concentration was 1,270 pCi/L.

### Summary (Mission Subarea)

Water levels in shallow, intermediate, deep alluvial, and bedrock aquifers in the Mission subarea are generally controlled by seasonal pumping, infiltration of water from irrigation projects, and stream leakage. Water levels in shallow aquifers peak in the late summer or early fall and, in intermediate and deep alluvial aquifers, in the mid- to late fall. The water-level peaks in the intermediate and deep alluvial aquifers probably lag behind those in the shallow aquifers because of intervening low-permeability beds in the glacial-lake sediments.

Inorganic water-quality data show that the ground water in the Mission subarea is generally of good quality, with dissolved-constituents concentrations ranging from about 300 to 500 mg/L. Nitrate concentrations in water samples are generally low and do not approach health standard levels. Water-level, water-quality, and well-log data suggest that intermediate and deep alluvial aquifers are generally protected from surficial sources of contamination. Shallow aquifers will be sensitive to local contamination threats because of permeable materials and near-surface water tables.

## Flathead Lake Perimeter

The Flathead Lake perimeter subarea consists of the east and west edges of Flathead Lake (fig. 2). The north edge of Flathead Lake is included in the Kalispell subarea and the south edge of the lake (except for Finley Point and Polson Bay) is included in the Mission subarea. Most of the Flathead Lake perimeter subarea is occupied by Flathead Lake, at an altitude of about 2,888 ft above sea level. The land surface rises from the east side of the lake to peaks of more than 7,000 ft in the Mission Range. West of the lake, topography has less relief and peaks are generally only about 4,000 ft above sea level. Most development of the ground-water resource is within a few miles of the lake.

### Aquifers

Various thicknesses of unconsolidated surficial deposits rest on bedrock along the east and west shores of Flathead Lake. Deposits of post-glacial alluvium (median thickness 17 ft from well logs), discontinuous accumulations of till (median thickness 50 ft), glacial-lake deposits (median thickness 55 ft), and deep alluvium generally thicken toward the shoreline of Flathead Lake and toward the centers of tributary stream valleys near the lake. The thickest accumulations of deep alluvium are in pre-glacial drainages developed in bedrock and in areas where outwash accumulated in front of advancing glaciers. Along Highway 93 on the west side of Flathead Lake a few exposures

## Mission subarea

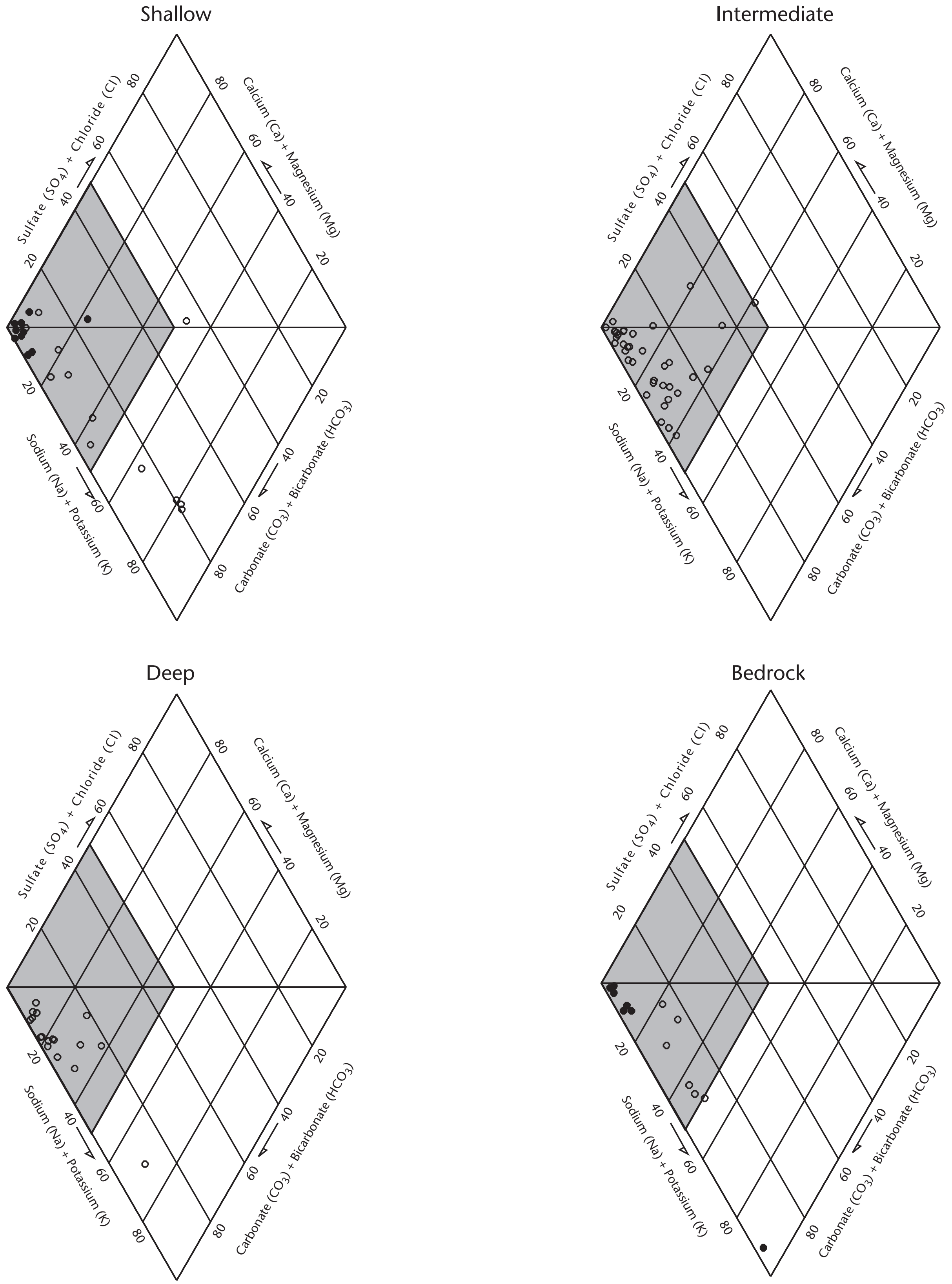



Figure 51. Water from all aquifers in the Mission subarea is primarily of the calcium bicarbonate type. In samples from shallow and bedrock aquifers on the west side of the valley the water is slightly more enriched in sodium and bicarbonate (open circles) than in samples from the east side of the valley (solid circles).

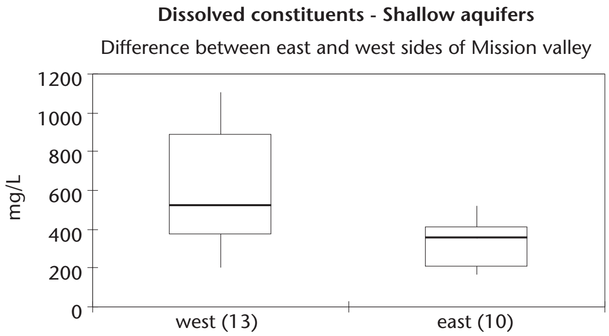



Figure 52. Concentrations of dissolved constituents in samples from shallow aquifers in the Mission subarea are greater in ground water on the west side of the Mission valley than in ground water on the east side, which is near recharge areas. See fig. 24 for an explanation of the plots.

of yellowish orange, clayey, sedimentary deposits rest on weathered bedrock (Part B, map 6). These sedimentary rocks are probably Tertiary in age (P.C. Ryan, written commun., 1998), and may correlate with deeply buried Tertiary deposits in the Kalispell and Mission subareas.

Deep and intermediate alluvial aquifers host 17 percent of the total number of wells (fig. 53), and 80 percent of those wells are concentrated in the Finley Point, Polson Bay, Big Arm, Dayton Valley, and Woods Bay areas. Yields are reported to be as high as 1,000 gpm, but the median yield is 40 gpm for wells completed in the deep alluvial aquifer and 33 gpm for wells completed in the intermediate alluvial aquifer (fig. 54a). Depths for wells completed in deep and intermediate alluvial aquifers are as much as 542 ft with a median depth of 150 ft (fig. 53); most wells deeper than 300 ft are in the middle of Finley Point.

Bedrock underlies all of the surficial deposits and is the primary aquifer in the Flathead Lake perimeter; almost 80 percent of all wells are completed in bedrock (figs. 53, 55). The bedrock aquifer is relatively evenly developed on the east and west sides of the lake; about 1,100 wells have been drilled on the west and about 400 wells on the east (the east side of the lake has about half of the shoreline miles as the west side). The bedrock aquifer produces water from fracture permeability. The occurrence of saturated fractures is variable, causing some wells to be deeper than 1,000 ft, although the overall median depth is 240 ft (fig. 53). Wells are generally deeper on the west side of the lake (median depth 255 ft) than on the east side (median depth 200 ft). In particular, the bedrock aquifer between the towns of Somers and Lakeside hosts many deep wells; 110 of the 240

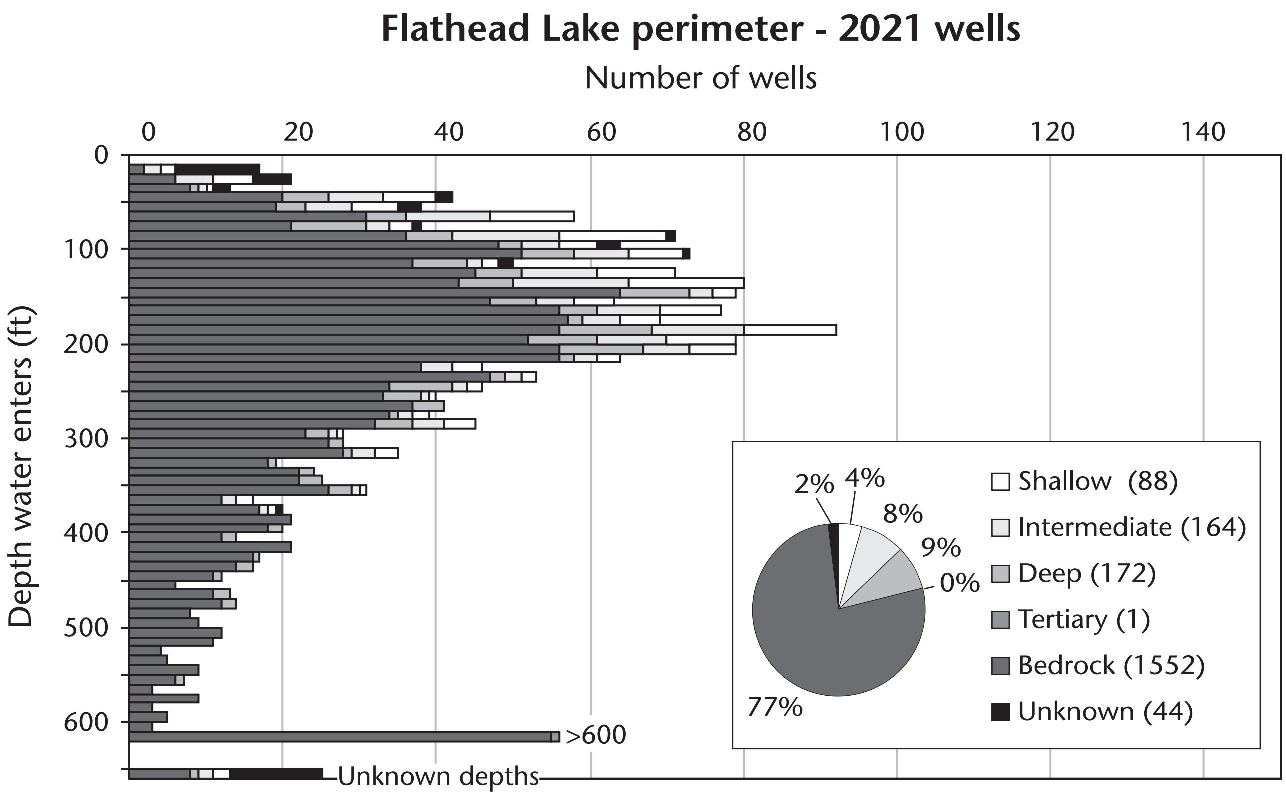



Figure 53. Well depths in the Flathead Lake perimeter subarea vary widely but are generally deeper than in other subareas. Many wells have depths greater than 600 ft. The inset pie chart shows that almost 80 percent of the wells are completed in bedrock.

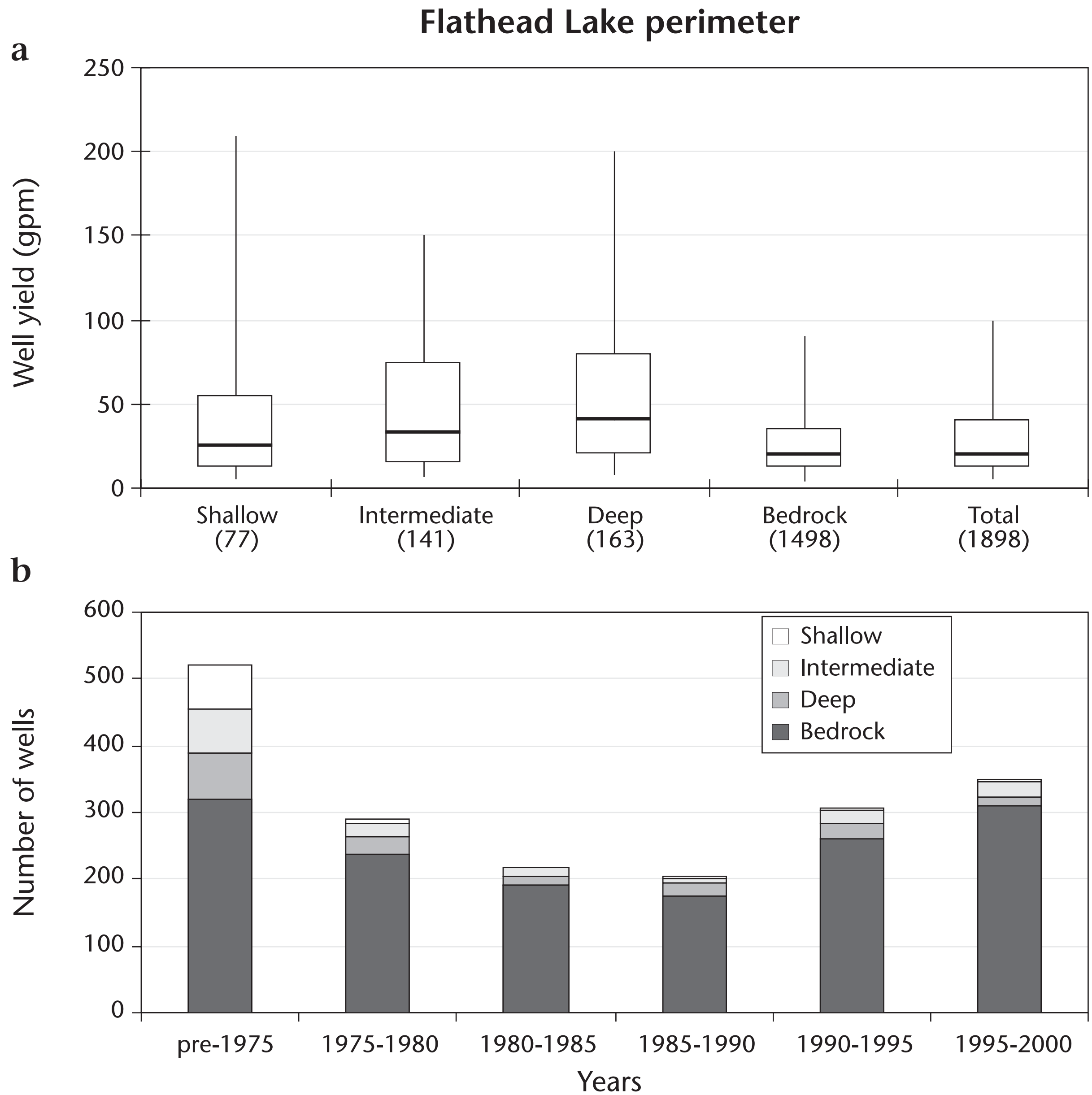



Figure 54. (a) Wells completed in the unconsolidated deposits (shallow, intermediate, and deep alluvial aquifers) generally have higher reported yields than wells completed in bedrock. See fig. 24 for an explanation of the plots. (b) New well construction declined between 1975 and 1990, but has increased steadily since 1990.

wells completed in this locale are between 300 and 1,000 ft deep.

Yields from the bedrock are not as high as those from the alluvial aquifers but are generally adequate for domestic uses; the maximum reported yield is 850 gpm, and the median is 20 gpm (fig. 54a). Despite the difference in median well depths in the bedrock aquifer on either side of the lake, there is little difference in median well yields. The bedrock aquifer is undergoing extensive development, with the number of wells completed in bedrock around Flathead Lake having doubled since 1985 (fig. 54b).

## Water Levels

Water-level records are available for seven wells in the Flathead Lake perimeter subarea. Water levels in three wells within a few miles of each other northwest of Polson (fig. 55) illustrate differing seasonal and long-term water-level responses for intermediate and deep alluvial aquifers and bedrock aquifers.

Fractured bedrock aquifers inherently have small storage capacities, therefore water levels in these aquifers are sensitive to drought and pumping effects. Between 1983 and 1996 water levels in a 300-ft-deep bedrock well (well 77922, fig. 55)

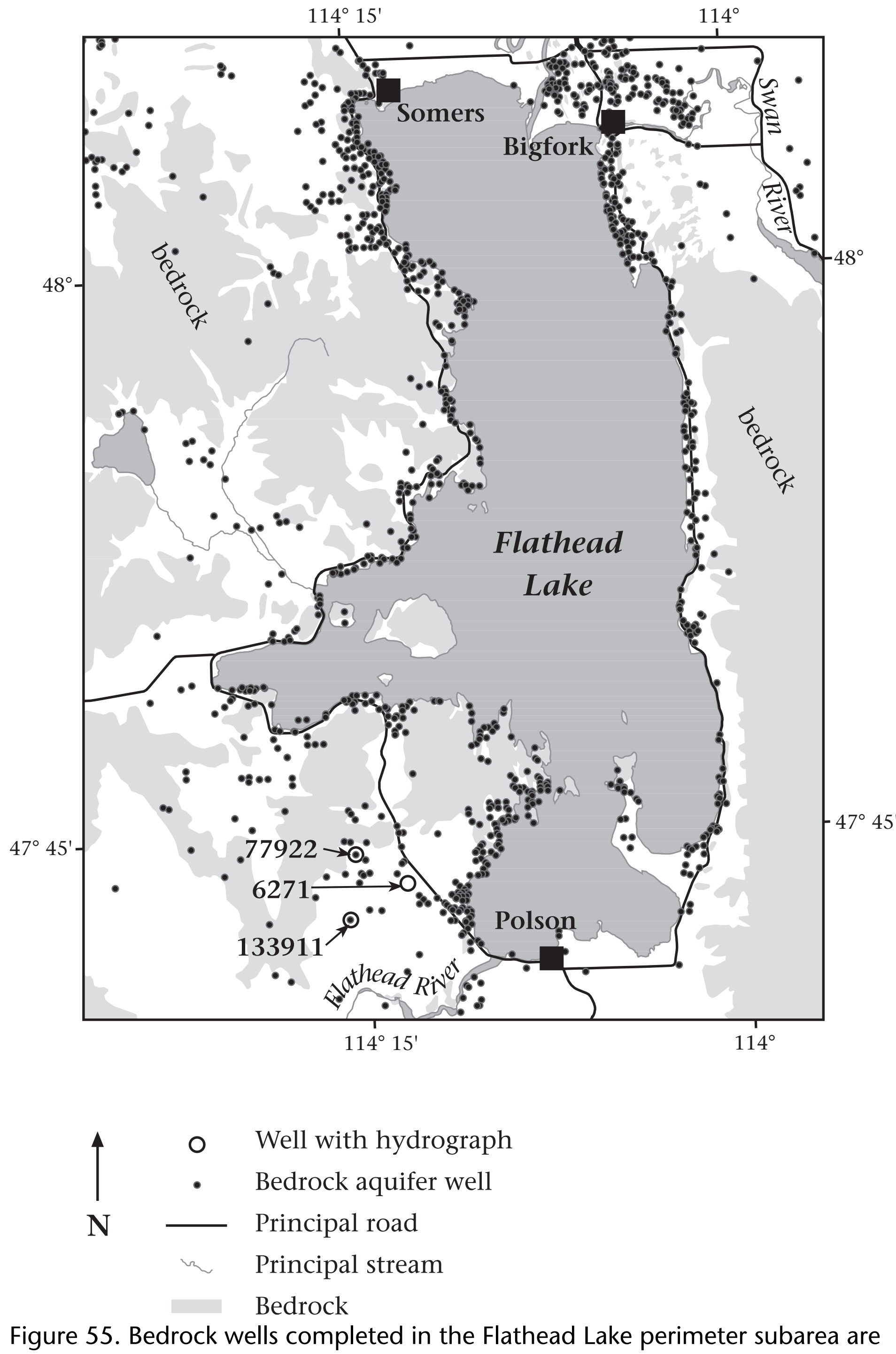



Figure 55. Bedrock wells completed in the Flathead Lake perimeter subarea are clustered near the edges of Flathead Lake.

declined at a rate of about 3.5 ft per year, or slightly more than 40 ft in 12 yr (fig. 56). The data seem to show that the bedrock aquifer near this well was being steadily depleted. In 1997, water levels responded to above-average precipitation during the 1996–97 winter and spring; in less than 1 yr, water levels recovered more than 40 ft and in 1998 were higher than they were in 1983. The quick upward response was caused by the large amount of recharge derived from the wet climatic period and the small storage capacity in the aquifer. Since reaching a peak in October 1997, water levels have dropped at a rate of about 7 ft/yr (25 ft in 3.5 yr), roughly twice the rate of decline exhibited before 1997.

Water-level records were also studied for two nearby wells apparently completed in unconsolidated deposits to the south and southeast of well 77922 (wells 133911 and 6271, fig. 55). The driller's log for well 133911 provides no lithologic

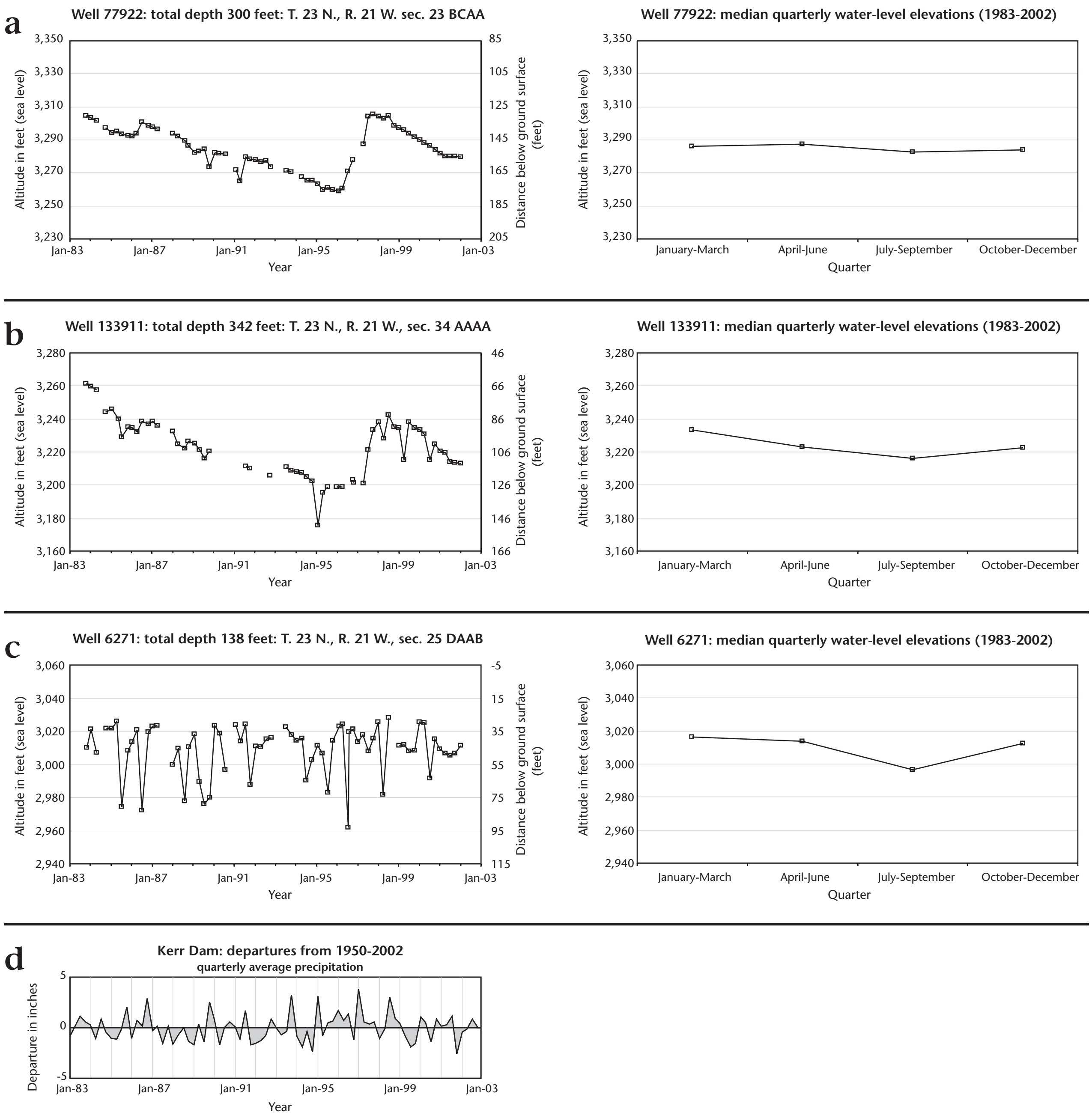



Figure 56. (a) Water levels in the bedrock northwest of Polson (well 77922) declined about 45 ft between 1983 and 1996. In 1997 and 1998 they rose rapidly to near 1983 levels before beginning to decline again. The large water-level fluctuations are typical of bedrock aquifers where ground-water storage is related to secondary fractures. (b) The water-level response near the base of the unconsolidated deposits (well 133911, 342 ft deep) is similar to the response for nearby bedrock (well 77922, fig. 56). A long-term decline of about 60 ft was interrupted in 1997 by a water-level rise of about 35 ft. Since 1997, water levels have steadily fallen. (c) Water levels in an intermediate aquifer (well 6271) show no long-term trend but exhibit a pumping seasonal pattern; the quarterly medians reveal that the seasonal low occurs in July, with water levels recovering during the fall and winter months. (d) Average precipitation.

information, but the well is located near the mapped edge of local unconsolidated deposits and is probably completed near their contact with bedrock. Annual water-level fluctuations are generally about 5 ft and quarterly medians show that the lowest levels occur in July and the highest levels occur in January. Water levels in this well declined steadily at 4.5 ft/yr (60 ft) between 1983 and 1996. In 1997 the water level began to rise, recovered more than 30 ft between April and October, and peaked in July 1998. Since then, water levels have dropped more than 20 ft. The similarity between the water-level records in this well and well 77922, located 1.7 mi to the north, indicates that water levels in the deep alluvial aquifer near well 133911 are strongly controlled by recharge to adjacent bedrock uplands; it may also be possible that this well is actually completed in the bedrock aquifer.

In an intermediate aquifer at a depth of 138 ft (well 6271) annual water-level fluctuations are about 50 ft (fig. 57); quarterly medians show that the lowest levels occur in July and the highest levels occur in January. Although the annual pattern may be influenced by undocumented pumping in the measured well, the median water levels apparently show a pumping water-level response where levels drop during the late summer and recover during the fall and winter. The record from this well does not show the recharge response characteristic of the bedrock aquifer, and the lack of any decreasing or increasing trend suggests that ground-water recharge and discharge are in balance.

## Water Quality

Based on analytical results from 15 ground-water samples from wells completed in bedrock and 17 from wells completed in intermediate and deep alluvial aquifers (appendix C), ground water in the Flathead Lake perimeter subarea is good quality and meets U.S. EPA public drinking water supply standards for natural constituents. The predominant ions are calcium, bicarbonate, magnesium, and sodium; dissolved-constituents concentrations in water from all the aquifers are generally less than 700 mg/L.

Analytical results for water samples from bedrock aquifers show more variation than do results from the unconsolidated aquifers. Calcium and sodium concentrations vary the most (fig. 57). The dissolved-constituents concentrations in water from bedrock aquifers (median concentration 425 mg/L) are greater than concentrations in water from unconsolidated deep and intermediate aquifers (median concentration 335 mg/L).

### Nitrate

Nitrate was detected in 13 of 21 samples (62 percent) from bedrock aquifers. One sample, collected in 1984 from a well about 1 mi southwest of Somers, had a concentration of 12.2 mg/L, greater than the U.S. EPA health standard of 10 mg/L for constituents in public drinking water supplies. Another sample, collected in 1996, had a concentration of 9.2 mg/L, very close to the health standard. In the remaining 19 samples the highest reported concentration was 1.9 mg/L; the median nitrate concentration in water samples from bedrock was 0.3 mg/L.

In samples from the deep alluvial and intermediate aquifers nitrate was detected in 15 of 19 analyses (79 percent); however, the maximum concentration detected was 1.3 mg/L and the median concentration was 0.2 mg/L.

### Radon

Radon in household air has been linked to lung cancer, and a minor source of the gas can be well water. The U.S. EPA estimates that less than 2 percent of radon in household air comes from radon in water. Results from water samples collected for radon from four bedrock wells ranged from 1,082 to 3,720 pCi/L, with a median concentration of 1,565 pCi/L (appendix D).

# Smith

The largest part of the Smith subarea is the broad, flat-floored, 10-mi-long Smith Valley drained by Ashley Creek, which flows east–northeast into the Kalispell subarea (fig. 2). West of the Smith Valley, the middle portion of the subarea is drained by the headwaters of the Little Bitterroot River; the western portion of the subarea is drained by McGregor Creek. Topography and drainage within the Smith subarea were heavily modified by a west–southwest-flowing tongue of the Flathead glacier and a series of tongues of a glacier that flowed east out of the Kootenai River drainage. Bedrock underlies the subarea at depths as great as 400 ft in the valleys (Part B, map 7).

## Aquifers

Sand and gravel at land surface were deposited either as glacial outwash or by modern streams (reported on 30 percent of well logs). Most of the shallow alluvial deposits (shallow aquifers) are in the Smith Lake, Ashley Lake, and Marion areas. Localized areas of alluvium (intermediate aquifers) lie beneath or within till, but above bedrock. Twenty to 300 ft of clay and sandy silt occur upstream of Smith Lake, near the town of Marion, near Little Bitterroot Lake, and near Lake Rogers (reported on 12 percent of well logs in these areas). The clayey deposits near Smith Lake are inter-

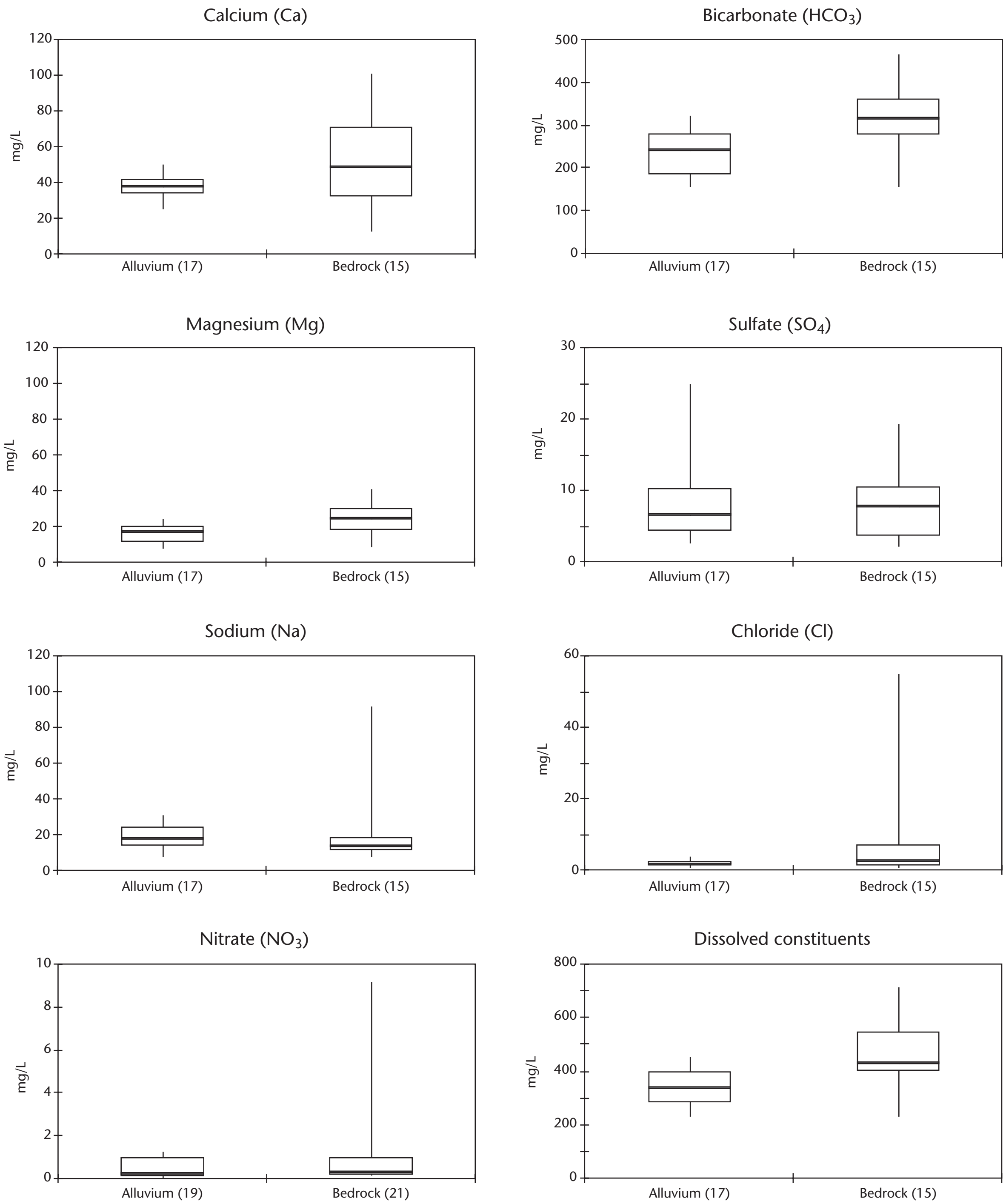



Figure 57. Ground water from bedrock in the Flathead Lake perimeter subarea is more mineralized than water from the unconsolidated deposits. However, the general chemical compositions vary little between the two units. For non-quantifiable or non-detectable data, a value of one-half the detection limit was used in the statistical summaries. See fig. 24 for an explanation of the plots.

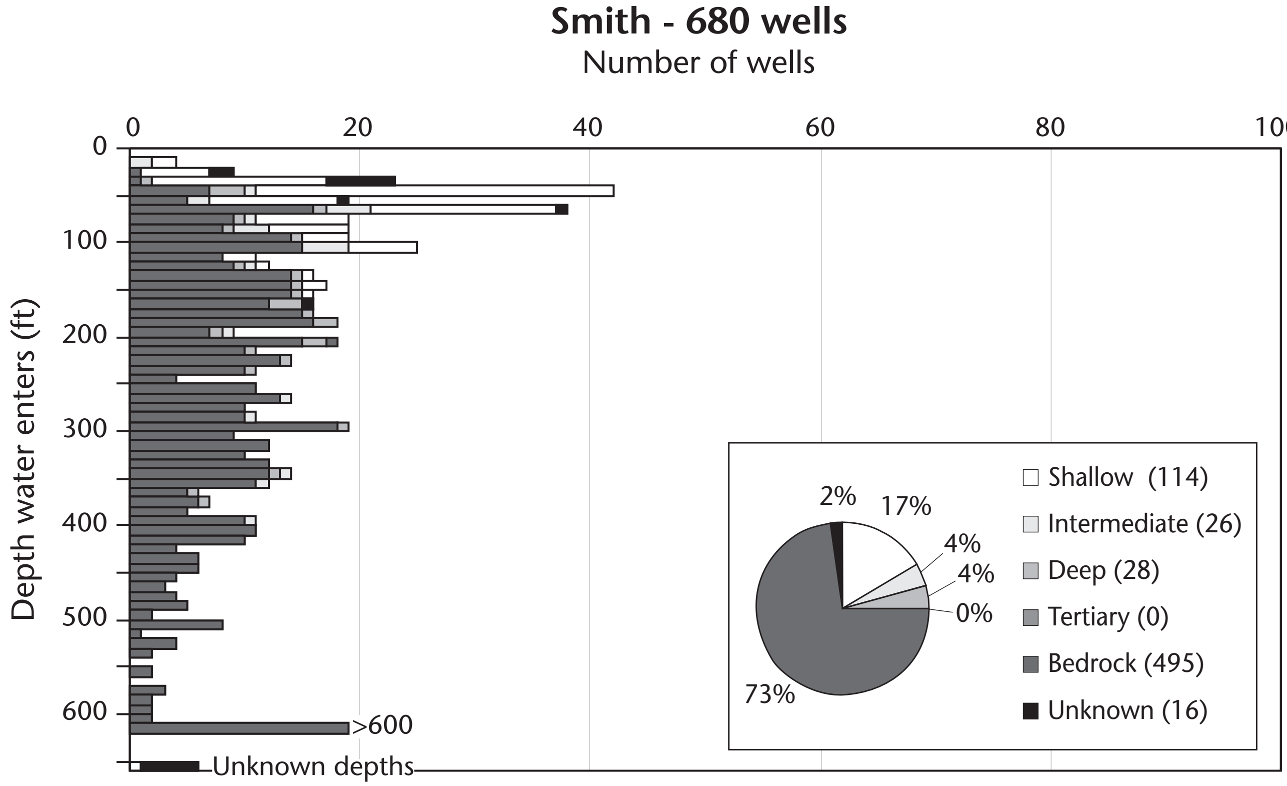



Figure 58. Most wells completed in shallow aquifers in the Smith subarea are less than 100 ft deep; the depths of wells completed in bedrock are variable and result from great topographic relief and variations in the depth of water-bearing fractures. The inset pie chart shows that most of the wells in the Smith subarea are completed in bedrock.

preted to be deposits of ancestral Flathead Lake. The clay and silty sand near Little Bitterroot and Rogers Lakes may be either deposits of small lakes dammed behind local terminal moraines or Tertiary sedimentary rocks. Till overlies bedrock in most of the stream valleys in the subarea and mantles most of the hills surrounding the valleys. Till was encountered in 70 percent of all wells in the Smith subarea and had a median thickness of 40 ft.

Bedrock aquifers have been developed by 73 percent of wells (about 500 of 680) completed in the Smith subarea. Shallow aquifers serve 114 wells (17 percent). Intermediate and deep alluvial aquifers (fig. 58) host only about 8 percent (54 wells). The median reported yield from the shallow and deep alluvial aquifers is 30 gpm. Although wells completed in intermediate aquifers have a similar range of reported yields, the median is only 15 gpm. The median reported yield from bedrock aquifers is 10 gpm (fig. 59a).

Some shallow aquifers have been penetrated by wells as deep as 138 ft, but the median well depth in the shallow aquifers is 44 ft. Well logs show that in intermediate and deep aquifers the median well depth is 132 ft below land surface, but a few wells are as much as 390 ft deep (fig. 58). Bedrock aquifers contain wells that range from 33 to more than 1,300 ft, but the median depth is 280 ft. The wide range of depths for wells completed in bedrock aquifers reflects varied topography and the highly varied depths to water-producing fractures in the bedrock. Reported water levels for shallow, intermediate, and deep alluvial aquifers are all similar and the median depth to water is about 25 ft below land surface. Water levels in the bedrock aquifer range from flowing at the land surface (10 wells) to 280 ft below land surface; the median depth to water in bedrock is 45 ft.

The rate of ground-water development to supply water to residences and seasonal homes in the Smith subarea has increased markedly since 1990; about 60 percent of wells have been installed since then and most are completed in bedrock. Installation of shallow alluvial wells also increased between 1995 and 2000 (fig. 59b). The rapid rate of development coupled with the predominance of bedrock and shallow alluvium as the major aquifers creates the potential for contamination from septic systems. Because water can move rapidly along cracks and fractures in shallow bedrock aquifers, and because the shallow alluvial aquifers are unconfined, both are sensitive to contamination from surface sources.

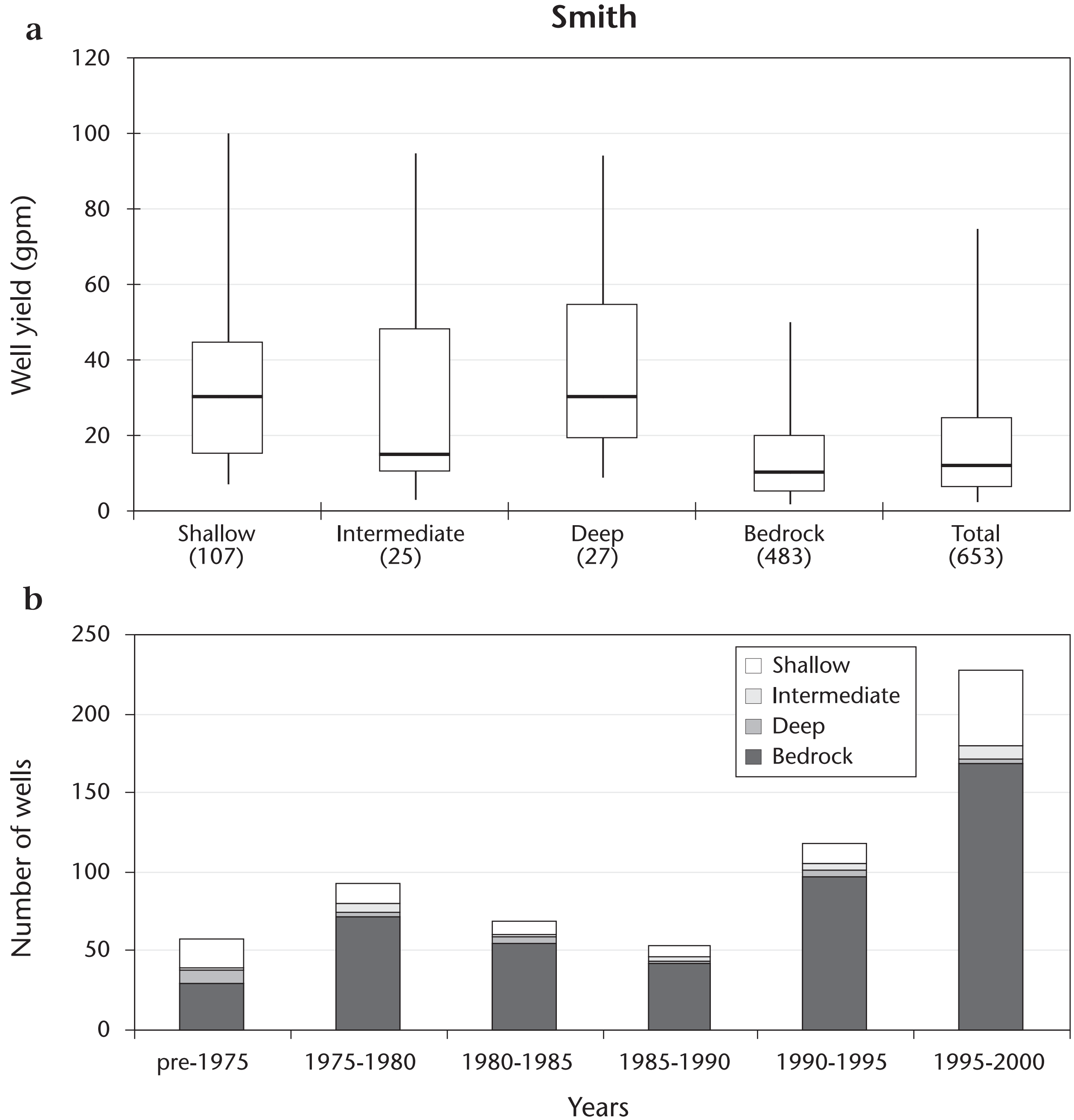



Figure 59. (a) Although yields from all the aquifers in the Smith subarea are suitable for domestic purposes, they are generally higher from the shallow, intermediate, and deep alluvial aquifers than from the bedrock. See fig. 24 for an explanation of the plots. (b) There has been a sharp increase in the number of wells installed in the Smith subarea since 1990, reflecting the development of residential and seasonal homes. Most new wells are being completed in bedrock.

## Water Quality

The five chemical analyses of ground water from the Smith subarea demonstrate some of the highest quality of ground water in the entire Flathead Lake study area (appendix C). The three samples from basin-fill aquifers had dissolved concentrations less than 100 mg/L; concentrations in the two bedrock samples ranged from 171 to 240 mg/L. The lack of appreciable amounts of soluble minerals in the basin-fill sediments and the surrounding bedrock from which they are sourced most likely accounts for the high-quality water.

# Jocko

The Jocko subarea is a northwest-trending valley bordered on the northeast by a steep escarpment at the foot of the Jocko Hills and on the southwest and southeast by a series of low hills (fig. 2). The confluence of the Jocko River and Valley Creek marks the northern end of the Jocko Valley, but the subarea also includes the Jocko River valley downstream to its confluence with the Flathead River.

## Aquifers

Shallow water-bearing alluvium is common in the Jocko subarea along the Jocko River and its terraces, and in alluvial fans that emanate from Schley, McClure, and Agency Creeks on its southeastern side. Significant accumulations of sand and gravel occur in more than half of wells; the median thickness of shallow alluvium is 35 ft.

Till was deposited locally in the Jocko subarea, where glaciers advanced northwestward onto the valley floor from drainages to the east and southeast. Till from previous glacial events may be more extensive in the subsurface, but incomplete mapping makes interpretation difficult. Clay, silt, and sandy silt deposits of Glacial Lake Missoula are common only in the northern part of the valley along the base of the Jocko Hills and in the Valley Creek drainage. Well data were insufficient to differentiate and map most of the glacial-lake sediments. Deeply buried sand and gravel deposits (deep aquifers) occur locally but are difficult to distinguish from intermediate sand and gravel deposits (intermediate aquifers) included within the glacial-lake sediments or from coarse-grained sediments within Tertiary deposits (Tertiary aquifers). Tertiary sedimentary rocks along Finley and Valley Creeks may correlate with reddish-colored clayey and silty conglomerates in the bottom portions of the deepest boreholes in the Jocko subarea (Part B, map 10).

The most utilized ground-water sources in the Jocko subarea are shallow aquifers (40 percent of well completions) and intermediate aquifers (37 percent of well completions); the bedrock aquifer, mostly near the southwestern valley margin, accounts for only 17 percent of the 650 wells completed in the subarea. Deep alluvial aquifers and Tertiary sediments have been little developed and support very few wells (fig. 60).

Shallow aquifers are most heavily developed in the middle and west–northwest parts of the valley, whereas intermediate aquifers are developed primarily in the east–southeast. Shallow aquifers reportedly yield up to 1,000 gpm to wells, but the median yield is 20 gpm. The median reported yield from intermediate aquifers is 15 gpm. Bedrock and Tertiary aquifers have the lowest median yields, 10 gpm (fig. 61a).

Shallow aquifers in the Jocko area are generally within 60 ft of the land surface; however, the

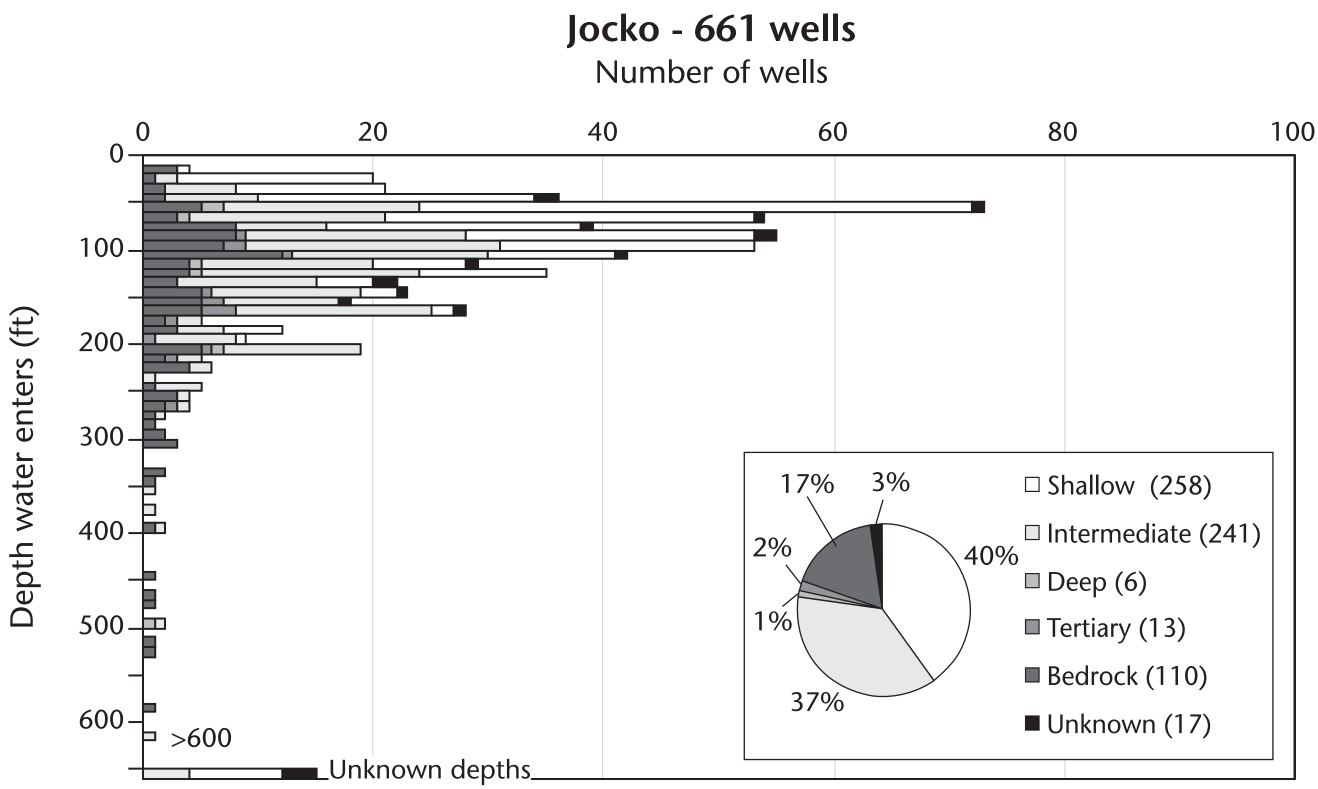



Figure 60. Most of the wells in the Jocko subarea are less than 200 ft deep, and are completed in shallow and intermediate aquifers.

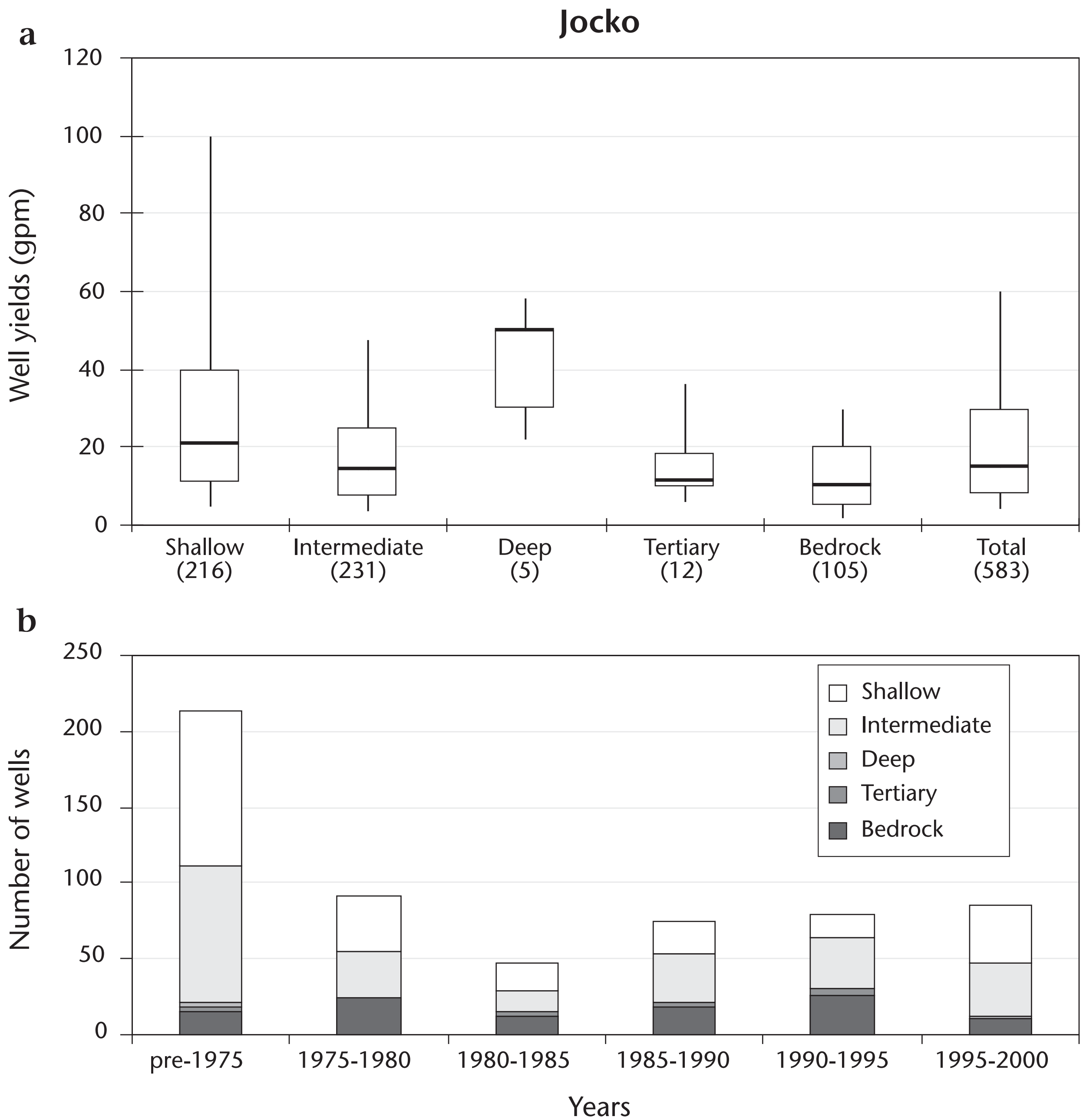
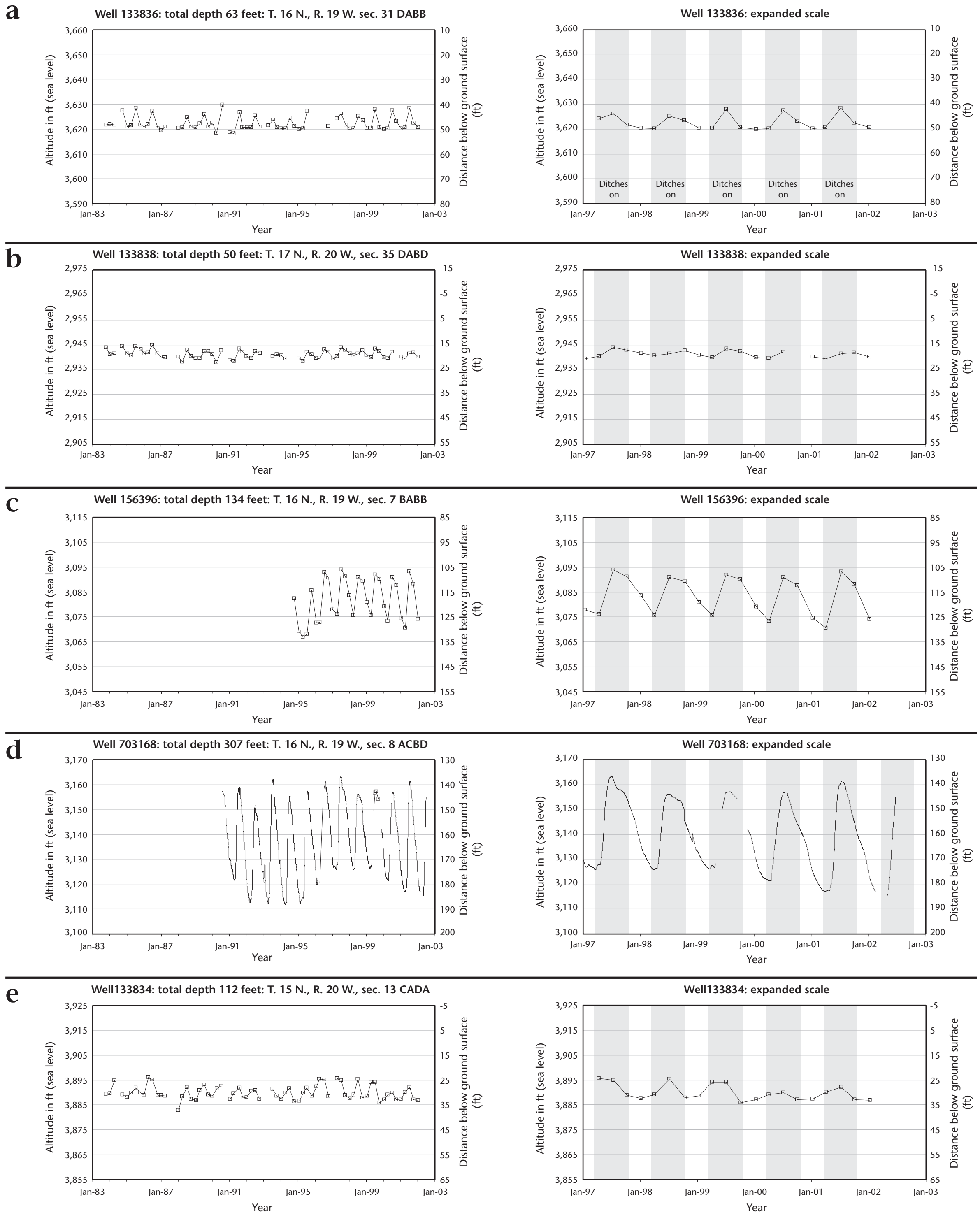



Figure 61. (a) Well yields reported for shallow aquifers in the Jocko subarea are greater than those for other aquifers, but are also the most variable. A few wells completed in deep alluvial aquifers, however, have reported yields near 40 gpm. See fig. 24 for an explanation of the plots. (b) Since 1985 the number of new wells drilled every 5 yr in the Jocko subarea has increased slowly.

deepest shallow aquifer well, completed in outwash deposits, is 190 ft deep. Intermediate and deep alluvial aquifers are generally encountered at depths less than 300 ft; the median well depth in these aquifers is 120 ft. Most of the wells completed in the bedrock and Tertiary aquifers are less than 400 ft deep and have a median depth of 180 ft. The rate of ground-water development in the Jocko subarea has increased slowly, with 75–90 wells being drilled each 5-yr period between 1985 and 2000 (fig. 61b).

## Water Levels

Water levels are closest to the land surface in shallow wells near the river, but are at greater depths in the intermediate, deep alluvial, and bedrock aquifers. The median reported distances to water are 26 ft in shallow aquifers, 60 ft in intermediate and deep alluvial aquifers, 46 ft in bedrock aquifers, and 70 ft in Tertiary aquifers. Ground-water flow is controlled by topography and is generally away from the valley margins toward the Jocko River (Part B, map 4).



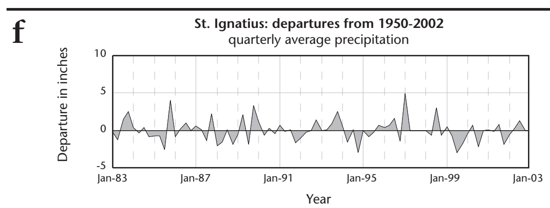




Figure 62. (a–e) Water-level fluctuations in wells completed in shallow and intermediate aquifers in the Jocko subarea are from less than 5 to more than 20 ft per year. Most of the hydrographs suggest irrigation canal recharge, with water levels that rise in the summer and remain elevated into the fall. Water-level peaks in deep alluvial fan materials near where the Jocko River enters the valley (well 703168; d) appear to be directly connected to surficial sediments and closely match high flows in the river. A water-level record for the intermediate aquifer (well 133834; e) shows that water levels are stable and that seasonal fluctuations are less than 10 ft per year. Water levels in this well start to rise each year before the ditches are turned on, indicating that they may be influenced by surface runoff. (f) Average precipitation.

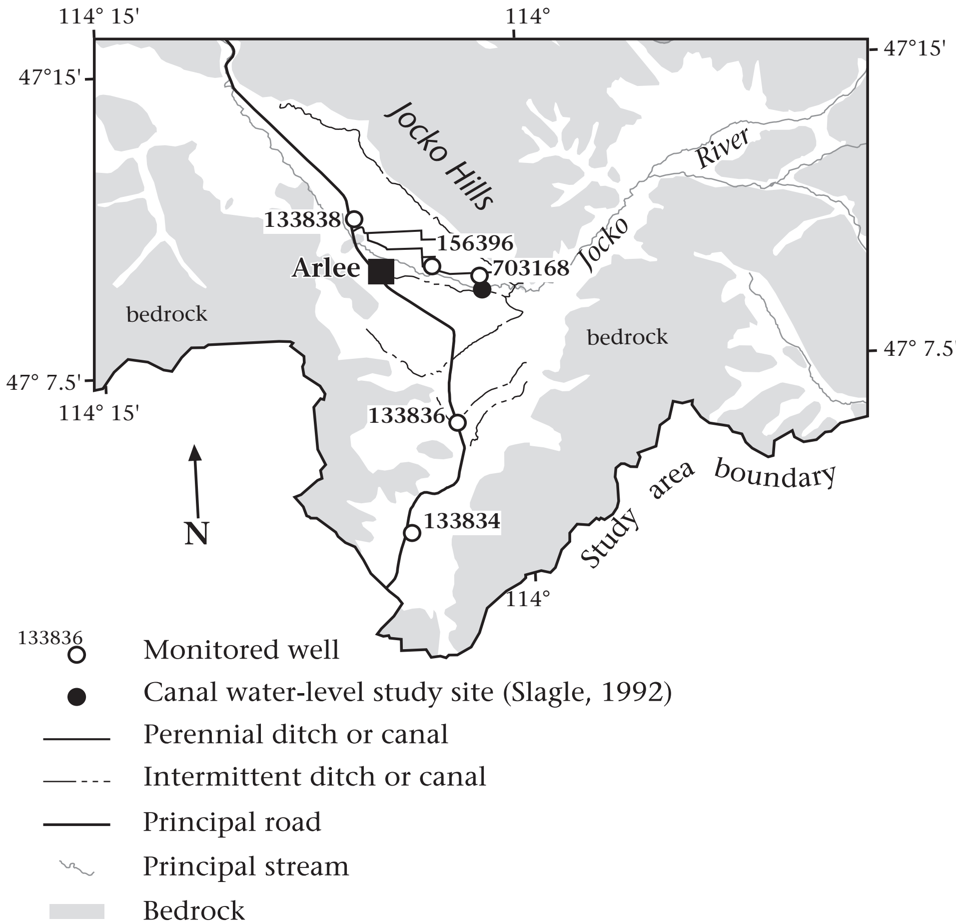



Figure 63. Four of the five wells monitored in the Jocko subarea are within the network of irrigation canals.

Water levels in the shallow aquifers rise from lows in late winter or early spring to peaks in midsummer, and then fall slowly during the fall and winter months (fig. 62). The magnitude of the annual fluctuation varies from less than 5 ft (wells 133836 and 133838) to as much as 20 ft (well 156396). The slow decline in water levels during the late summer and fall and the proximity of the monitored wells to irrigation canals (fig. 63) suggests that canal leakage is an important source of recharge. None of the available records show long-term water-level increases or decreases.

Annual water-level fluctuations in a deep aquifer (well 703168, fig. 62) occur at the same time as those observed in shallow aquifers, but are as much as 40 ft. This well is completed in alluvial fan deposits <0.25 mi north of the Jocko River near where it enters the valley. Correspondence between water-level changes and flow in the river indicates that leakage from the stream may influence water levels in this well.

Water levels in an intermediate aquifer upgradient from the irrigation canal network (well 133834, fig. 62) peak in the spring and early summer and then drop sharply in the fall; the magnitude of the annual fluctuations is less than 5 ft (fig. 62).

### Water Quality

Based on the results of 28 complete ground-water analyses (10 from shallow aquifers, 10 from intermediate and deep alluvial aquifers, 7 from bedrock aquifers, and 1 from a Tertiary aquifer), ground water in the Jocko subarea is of good quality and meets U.S. EPA standards for natural constituents in drinking water supplies (appendix C). The predominant ions are calcium, bicarbonate, and magnesium; dissolved-constituents concentrations in water from all the aquifers are generally less than 500 mg/L (fig. 64). Water from bedrock aquifers appears to be the least mineralized, with a median dissolved-constituents concentration of about 150 mg/L. Shallow aquifers are slightly more mineralized, with a median dissolved-constituents concentration of 230 mg/L. The concentrations of major ions are consistent between the different aquifers but are most variable in water from bedrock. None of the samples exceeded the secondary standards for sodium, chloride, or sulfate or the primary health standard for nitrate.

## Coram

The Coram subarea includes the Flathead River valley east of Bad Rock Canyon and south of the Apgar Mountains and Glacier National Park (fig. 2). This subarea encompasses intersecting down-faulted valleys of the South and North Forks of the Flathead River and an erosional valley where the Middle Fork of the Flathead River cuts through bedrock. The valleys of the South and North Forks locally contain Tertiary sedimentary rocks and conglomerates of the Kishenehn Formation.

### Aquifers

Sand and gravel (shallow aquifers) are at the surface along floodplains and terraces near the Flathead

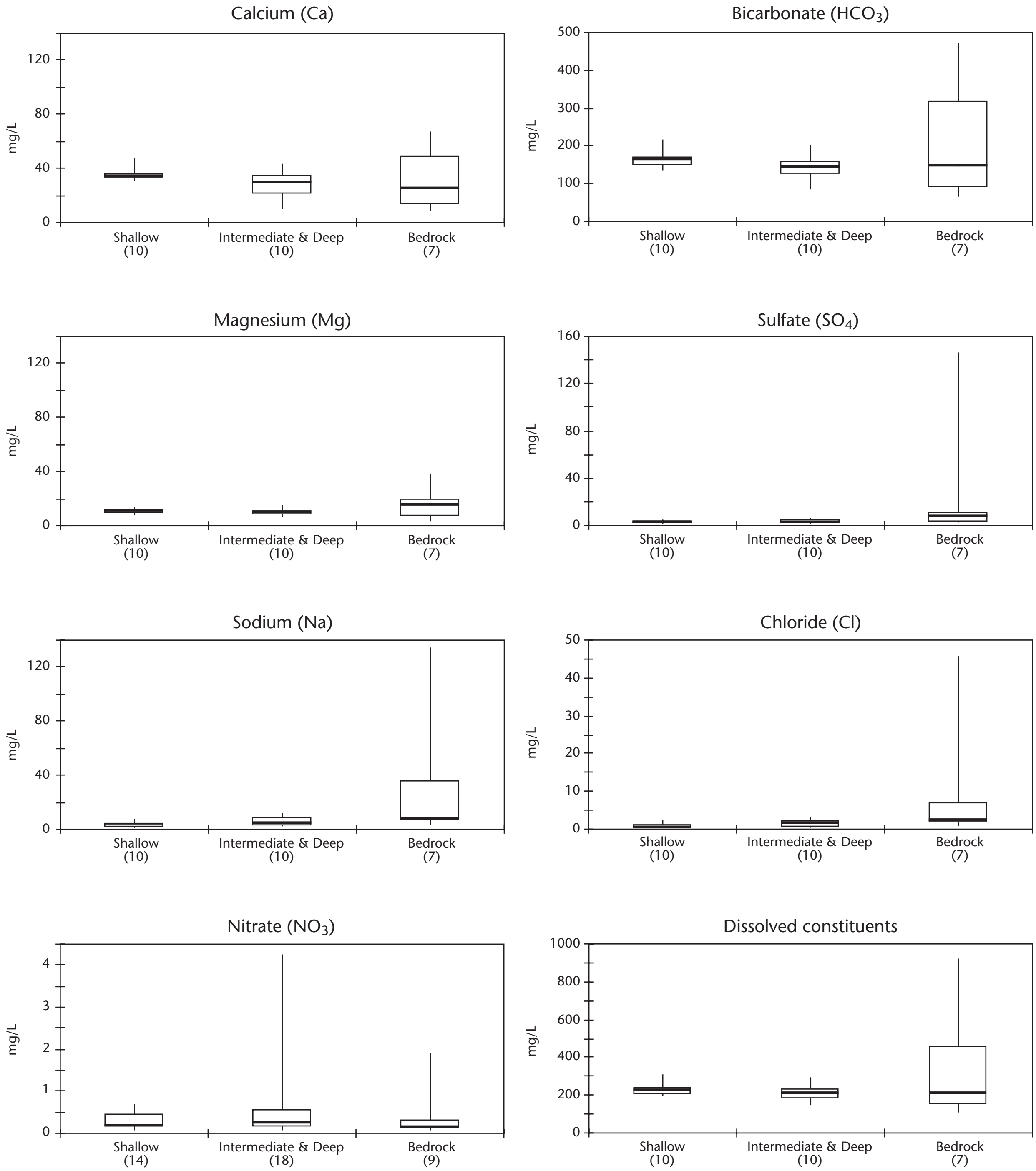



Figure 64. Water quality in aquifers of the Jocko subarea is consistent, but median dissolved solids are lowest in water from bedrock. Water from all of the aquifers is of the calcium-magnesium-bicarbonate type. See fig. 24 for an explanation of the plots.

River and its various tributaries. Glacial outwash also underlies broad terraces about 100 ft above the Flathead River valley. About 30 percent of logs for wells drilled in the Coram subarea encounter shallow alluvium at land surface. The sand and gravel deposits have a median thickness of about 30 ft.

Till was deposited by glaciers that flowed down the valleys of the South, Middle, and North Forks of the Flathead River. The glaciers met east of Teakettle Mountain (fig. 2) and flowed west–southwest around and over the mountain into the Kalispell valley. Most of the Coram subarea is covered by till; 60 percent of the area well logs report it. The till, with a median thickness of 30 ft, overlies Tertiary sedimentary rocks or bedrock in most parts of the valleys, but locally overlies deep alluvium.

Alluvium (deep aquifers) occurs locally below the till in a few exposures along the Flathead River, and is also reported on well logs from west of Hungry Horse to Martin City, and locally north of Coram. The deep alluvium appears to rest on Tertiary rocks. It may have been deposited as outwash in front of a glacier advancing down the valley, along a distinct channel cut in Tertiary sedimentary rocks.

In the Coram subarea, the deep alluvium is the primary source of ground water and hosts about half of the reported 571 wells (fig. 65). The remainder of the wells are completed in shallow alluvium (25 percent), intermediate aquifers within till (11 percent), bedrock aquifers (9 percent), and Tertiary rock (4 percent).

The deep alluvial aquifer is the most productive, with reported well yields of as much as 1,200 gpm and a median yield of 25 gpm. Shallow aquifers have a median well yield of 20 gpm. Intermediate aquifers are generally associated with till, and their highest reported yields are only about 50 gpm with a median reported yield of 12 gpm. Wells in bedrock reportedly produce as much as 75 gpm and have a median of 12 gpm. Yields from wells completed in Tertiary rocks are the lowest reported in the Coram subarea but are still sufficient for domestic purposes; most yields are less than 15 gpm and the median is 10 gpm. Figure 66a summarizes the reported yields from wells.

The deep alluvial and intermediate aquifers in the Coram subarea are generally encountered within 200 ft of the land surface (fig. 65). The median static water level is 35 ft below the land surface for intermediate aquifer wells and 45 ft for deep alluvial wells. Shallow aquifers are generally within 50 ft of the land surface (median well depth in shallow aquifers is 37 ft); the median

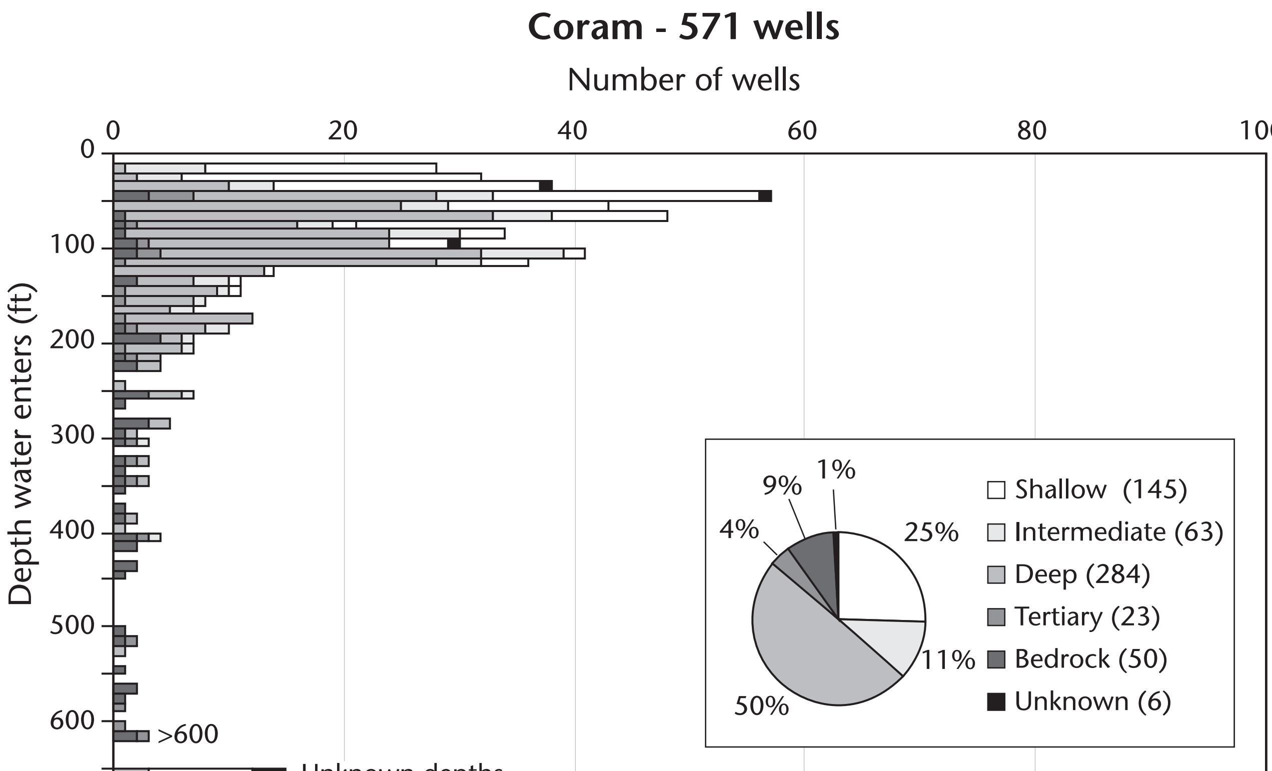



Figure 65. Most of the wells in the Coram subarea are less than 150 ft deep. Depths of those completed in bedrock show the most variability, ranging from less than 50 to more than 500 ft. The inset pie chart shows that 75 percent of wells in the subarea are completed in shallow aquifers or deep alluvial aquifers.

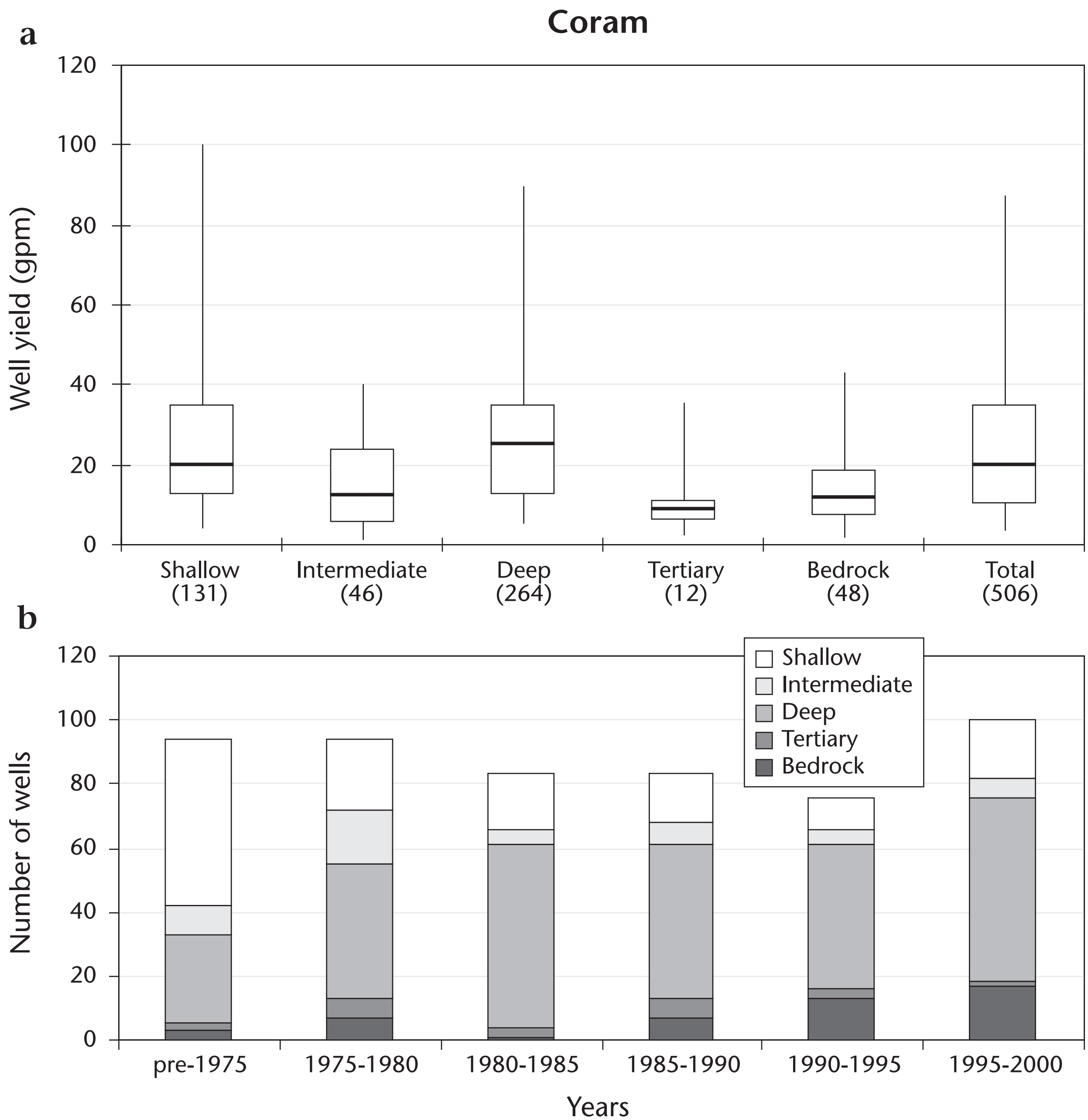



Figure 66. (a) Shallow and deep alluvial aquifers produce the best yields in the Coram subarea based on well-log reports. For an explanation of the plots see fig. 24. (b) The rate of well construction changed little

static water level is about 15 ft below the land surface. Wells completed in bedrock are generally the deepest of all groups; depths range to as much as 800 ft and the median depth is 300 ft. Wells completed in the Tertiary sediments range to as much as 700 ft deep, with a median depth of 180 ft.

Between about 1980 and 1995 the rate of ground-water development in the Coram subarea was steady, with between 75 and 85 wells drilled per 5-yr period. However, between 1995 and 2000 the rate increased by 25 percent to about 100 wells per 5-yr period. The increase is due to the development of permanent and seasonal homes (fig. 66b).

## Water Quality

Results from analyses of 12 ground-water samples (3 samples from this study and 9 historical samples) show that ground water in the Coram subarea is of good quality and meets U.S. EPA drinking water standards for public drinking water supplies. The predominant ions in the ground water are calcium, bicarbonate, and magnesium; the dissolved constituents in ground water from all the aquifers are generally less than 400 mg/L.

None of the samples exceeded the secondary standards for sodium, chloride, or sulfate or the primary health standard for nitrate. Nitrate was not detected in any of the samples above 1 mg/L. Radon in household air has been linked to lung cancer, and a minor source of the gas can be well water. The U.S. EPA estimates that less than 2 percent of radon in household air comes from radon in water. Radon concentrations in samples from three wells completed in deep alluvial and intermediate aquifers ranged from 210 to 490 pCi/L.

## Little Bitterroot

The Little Bitterroot River valley extends to the northwest from the Flathead River in the Mission valley, through the town of Hot Springs, to the canyon of the Little Bitterroot River near Niarada. Included in the subarea are some tributary valleys south of Niarada, such as Sullivan and Garceau Gulches (fig. 2).

The Little Bitterroot River valley is probably a fault-controlled depression, but the valley-bounding faults have not been identified. Above bedrock is a variety of Tertiary volcanic and volcanic-dominated sedimentary rocks related to igneous activity in the Hog Heaven Range, just north of Niarada (Lange and Zehner, 1992). The sequence of Tertiary rocks is exposed in drainages north of Niarada and in the headwaters of tributaries east and west of the Little Bitterroot River, including Sullivan, Rattlesnake, and Garceau Gulches. Consolidated silt, clay, sandstone, and conglomerate of probable Tertiary age have been penetrated by wells in the Little Bitterroot valley (Slagle, 1988). Till has not been recognized within the valley, but the valley was flooded by Glacial Lake Missoula.

### Aquifers

Shallow alluvium (shallow aquifers) occurs within the Little Bitterroot subarea along the floodplain of the Little Bitterroot River and near small tributary streams. The shallow alluvium is neither thick nor extensive.

Thick beds of laminated silt and clay and a few beds of silty sand and silty gravel deposited in Glacial Lake Missoula underlie the land surface and shallow alluvial deposits throughout the Little Bitterroot subarea (figs. 8, 20). The glacial-lake sediments rest on deep alluvium. Well-log evaluations of the percentage of sand or gravel show that the glacial-lake deposits in the Little Bitterroot subarea contain more fine-grained materials than those in the eastern Mission valley (Part B, map 10). These results suggests that this part of Glacial Lake Missoula was relatively distant from inputs of glacial meltwater and sediment. Meltwater discharges through the Big Draw and Sullivan Flats must not have been as great as they were in the Mission valley.

Boreholes in the Little Bitterroot subarea occasionally penetrate saturated sand beds, called “heaving” or “quick” sands by some drillers, which are somewhat permeable to water. Aquifers in sandy and gravelly beds (intermediate aquifers) encased by silty beds mostly occur along the west side of the valley near the town of Hot Springs and along the northern and eastern edges of the valley.

An extensive unit of sand and gravel (deep alluvium) overlies bedrock and probably Tertiary sedimentary rocks within much of the Little Bitterroot subarea between Niarada and the Flathead River. The unit is not at land surface, but is well-known from water-well drilling and has been named the Lonepine aquifer (Meinzer, 1916; Boettcher, 1982; Donovan, 1985; Briar, 1987; Slagle, 1988; Abdo, 1997). In the few deep wells that completely penetrate the sand and gravel, its thickness is between 20 and 60 ft. Most wells have been completed in the upper 20 ft. The deep alluvium of the Lonepine aquifer most likely was deposited by a pre-glacial or pro-glacial stream system that flowed from north of Niarada to the Flathead River. Briar (1987) showed that the alluvium was not continuous northward from the Little Bitterroot River valley to Sullivan Flats, discounting Meinzer’s (1916) suggestion that the sand and gravel were deposited along an ancestral course of the Flathead River through Big Draw.

The Lonepine aquifer is the main source of water in the subarea and is used extensively for domestic and irrigation supply. Most (58 percent) of the 440 wells in the subarea are completed in this aquifer (fig. 67). Water in the Lonepine aquifer is under artesian conditions and flowing wells are common in areas where water levels rise above the top of the aquifer. The hydraulic properties and water quality of the aquifer have been thoroughly characterized by others (Meinzer, 1916; Boettcher, 1982; Donovan, 1985; Slagle, 1988; Abdo, 1997). Ground water from intermediate aquifers, within the glacial-lake deposits, and from bedrock are also utilized locally. Most intermediate aquifer wells are completed near the valley margin and most of the bedrock wells are completed near the town of Hot Springs.

Yields from the Lonepine aquifer are reported to be as much as 1,000 gpm. The median reported yield is 75 gpm. Yields from bedrock and intermediate aquifers are slightly greater than from similar aquifers in other subareas; reported yields from bedrock are as much as 500 gpm and have a median of 20 gpm. Intermediate aquifers have a median yield of 17 gpm (fig. 68a).

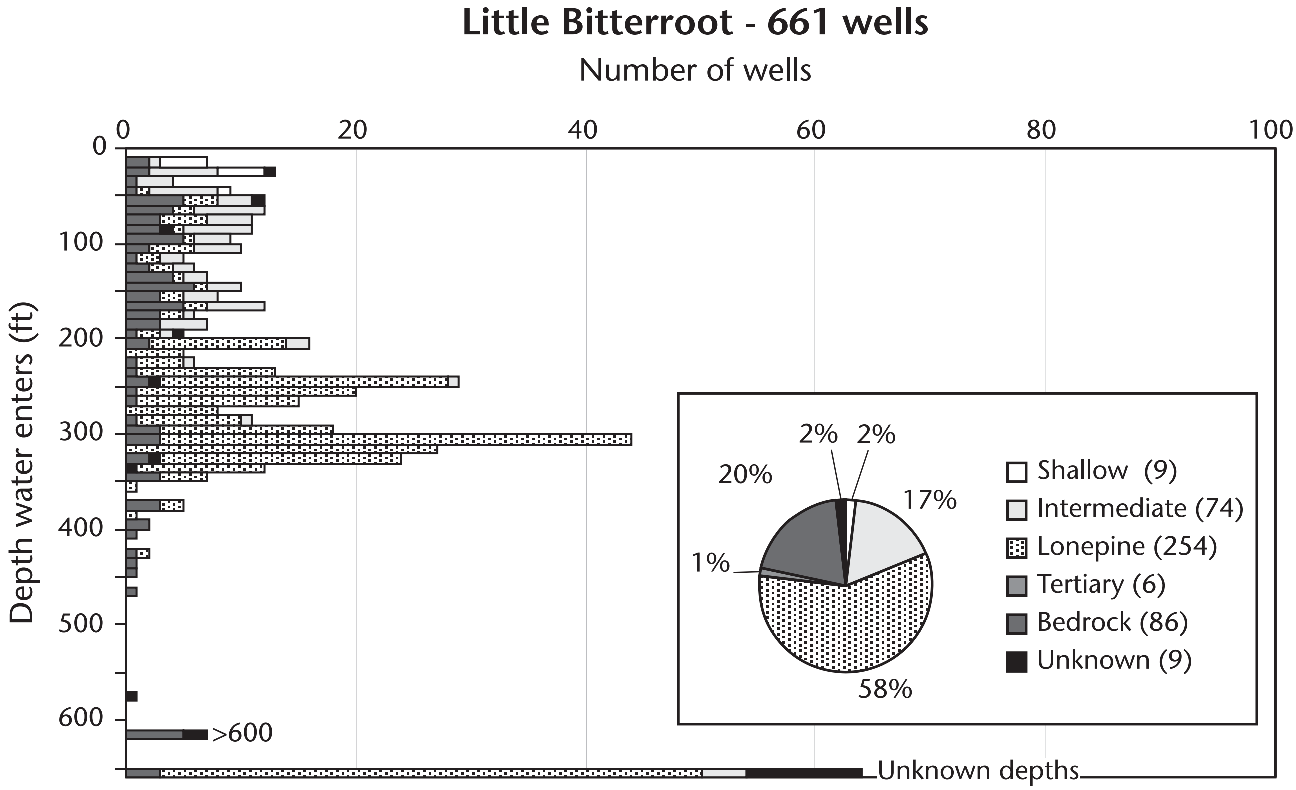



Figure 67. Throughout the Little Bitterroot subarea, wells encounter the Lonepine aquifer at depths between about 200 and 350 ft below land surface. Most wells completed in bedrock are clustered near the town of Hot Springs and are less than 200 ft deep. The inset pie chart shows that the Lonepine aquifer is the most used aquifer in the Little Bitterroot subarea.

Most of the wells in the Lonepine aquifer are between 220 and 320 ft deep; wells in the intermediate aquifers are generally less than 175 ft, while most of the bedrock wells are completed between 50 and 450 ft below land surface in the vicinity of Hot Springs (figs. 67, 69). However, 15 percent of the wells have unknown depths.

The rate of development in the Little Bitterroot subarea has been steady since 1975 at 20 to 30 wells per 5-yr interval (fig. 68b). About 70 percent of the 438 wells in the subarea were constructed before 1975.

## Water Levels

Long-term water-level measurements from three wells completed in the Lonepine aquifer near or within the areas of greatest usage (fig. 69, wells 77168, 6283, and 45118) all show similar trends and patterns. Based on 20 or more years of data, water levels in these wells show long-term declines (fig. 70). Climatic events clearly affect water levels; sharp rises occurred in response to relatively wet years between 1994 and 1997. However, the long-term water-level trend is downward, indicating that artesian pressure in the aquifer is being lost. Undesirable effects of declining water levels include the cessation of flowing conditions, the need to install pumps, or the need to lower pump intakes. Conservation measures such as restricting or plugging freely flowing wells may help stem the rate of water-level decline (Donovan, 1985; Abdo, 1997).

Annual water-level fluctuations in the Lonepine aquifer are between 5 and 10 ft. Water levels drop sharply during the summer growing season, reaching a low in August or September, and then recover during the fall and winter months (fig. 70). The monthly pattern suggests that annual water-level fluctuations are similar to the pumping response seen in the Kalispell subarea (fig. 30).

Water-level measurements from two wells completed in intermediate aquifers along the east edge of the Little Bitterroot valley show annual responses that differ from those of the Lonepine aquifer. Between 1986 and 1996 water levels declined steadily in well 6217; the peak water level in 1995 was 60 ft lower than the 1985 peak (fig. 71). However, the downward trend was interrupted by greater than normal precipitation in 1996 and 1997, which resulted in a water-level rise of more than 50 ft. Since 1998 the water level in well 6217

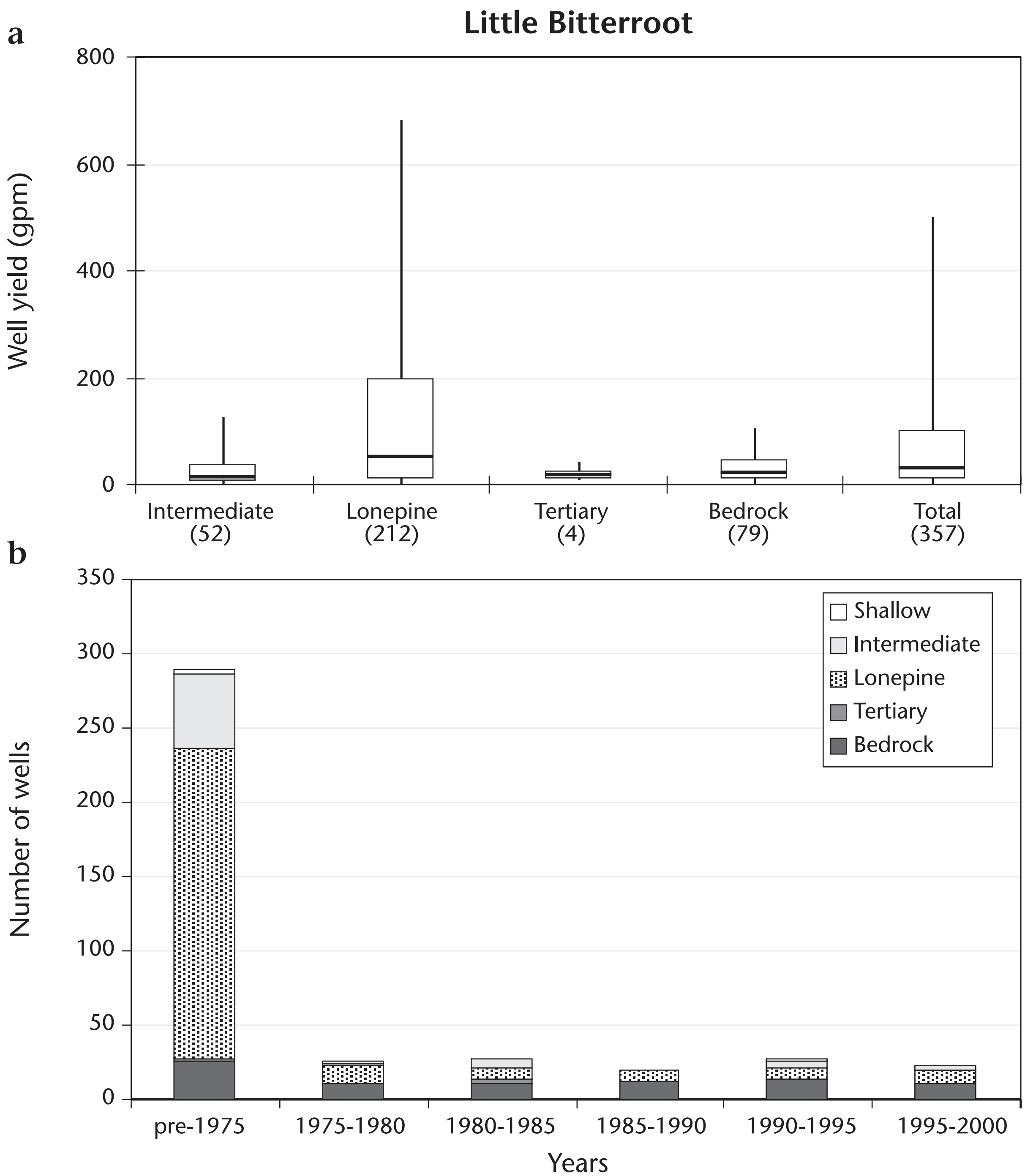



Figure 68. (a) The Lonepine aquifer has the highest median reported well yield in the Little Bitterroot subarea. See fig. 24 for an explanation of the plots. (b) Most of the wells completed in the Little Bitterroot subarea were installed before 1975; fewer than 25 wells were installed per 5-yr period since 1975.

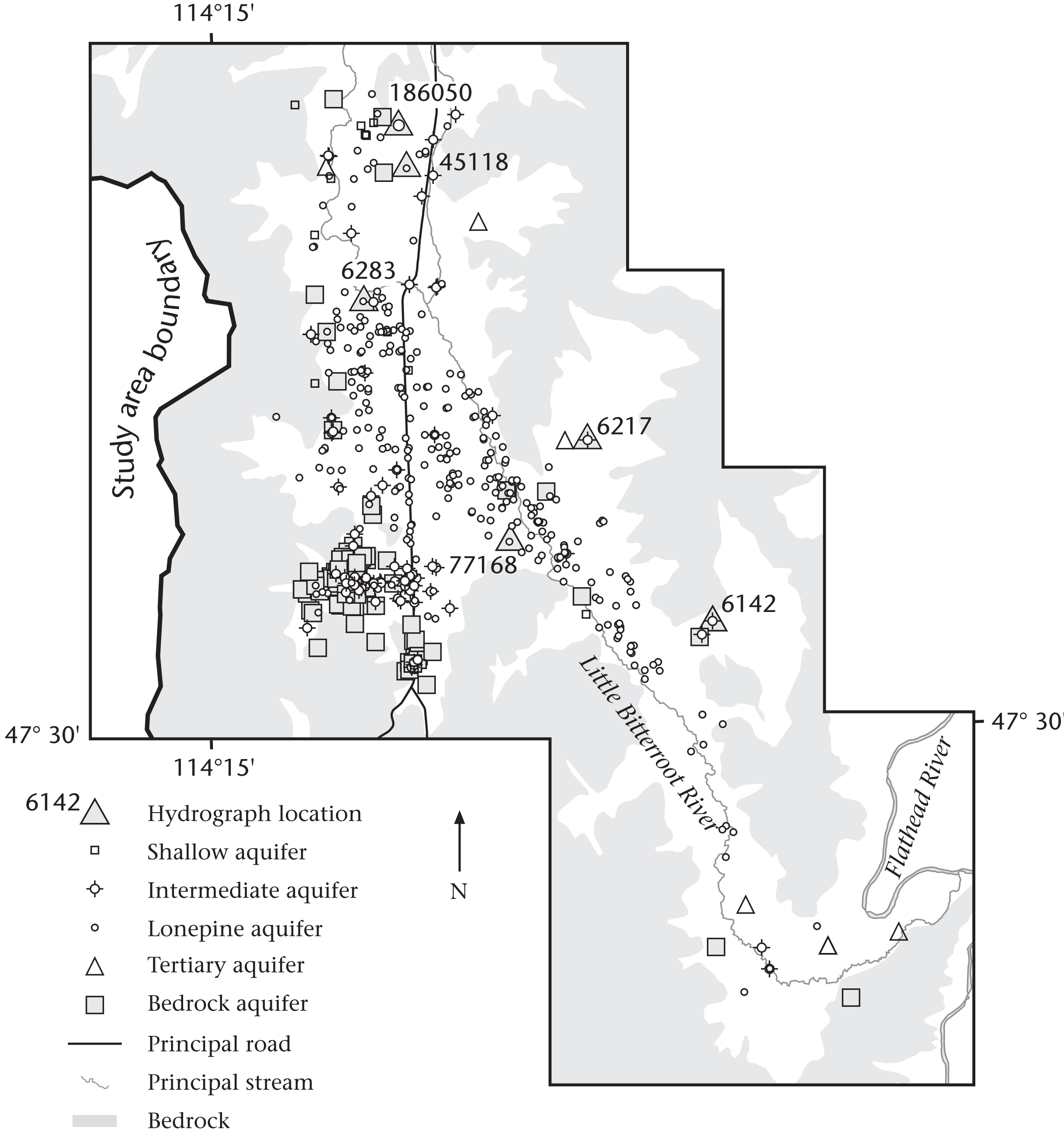



Figure 69. Most wells completed in the Lonepine aquifer are in the center of the valley.

has again declined steadily. Water levels in well 6142 show a similar pattern but the total change in water level was about 40 ft. Quarterly median water levels show that annual fluctuations in wells 6217 and 6142 do not closely match those for the Lonepine aquifer (fig. 70). The intermediate aquifers represented by these wells appear to be more influenced by climatic conditions than by pumping.

Well 186050, reportedly completed in an intermediate aquifer in glacial deposits (the completion depth is unknown), is along the north side of the Little Bitterroot valley. The peak in water level, caused by above average precipitation in 1997–98, shows the influence of climate. However, annual water-level fluctuations at this location are more similar to annual fluctuations in the Lonepine aquifer (fig. 70) than those in the intermediate aquifer wells shown in fig. 71.

## Water Quality

The chemical and geothermal characteristics of ground water in the Little Bitterroot valley (fig. 72) have been extensively described and characterized

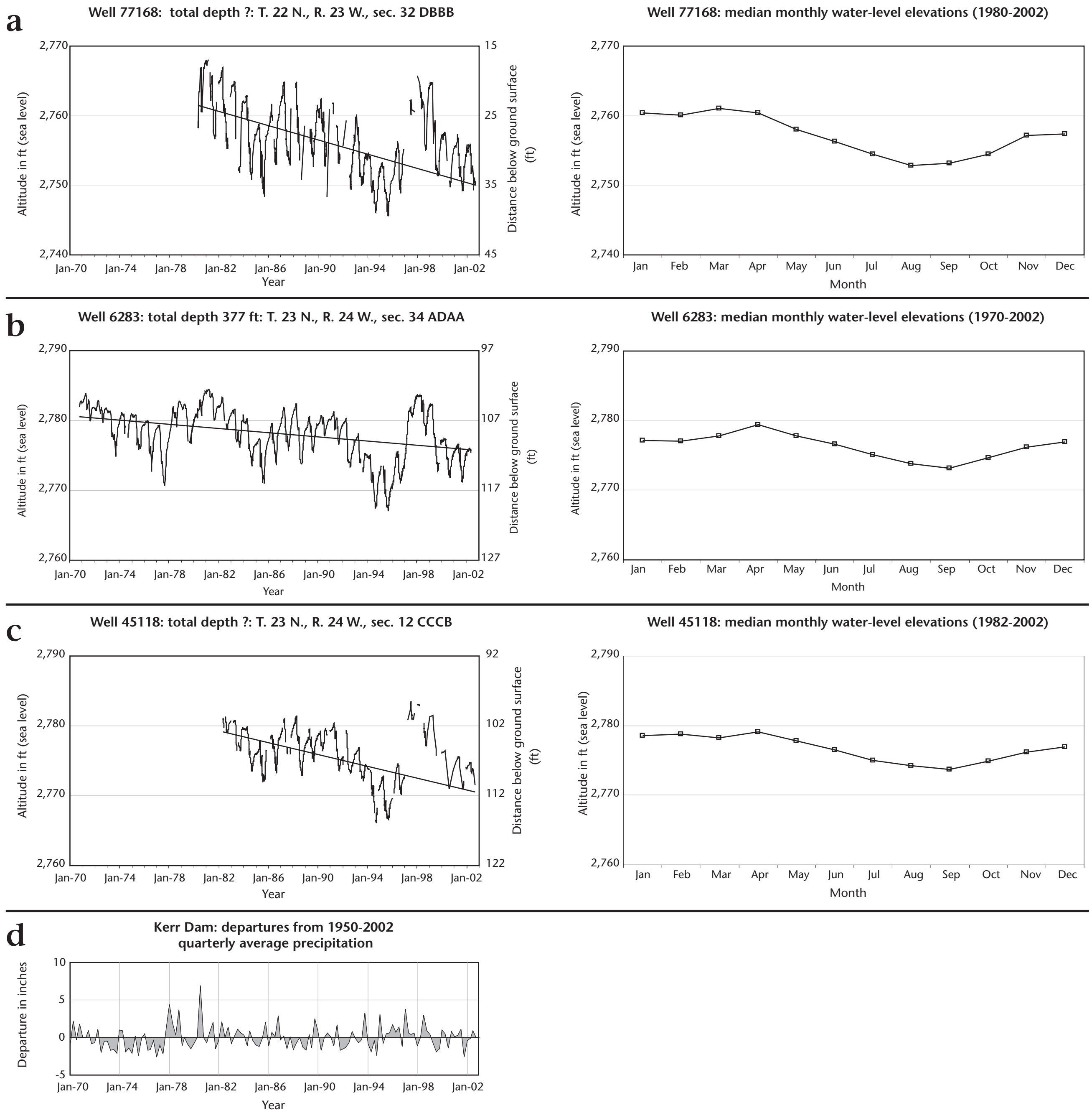



Figure 70. (a–c) Water-level records for the Lonepine aquifer show steady downward trends, suggesting that since 1970 more water is being removed from the aquifer than is being replenished. Median monthly water-level elevations reveal that water levels are controlled by seasonal pumping, with annual water-level lows occurring in the late summer followed by rising water levels during the fall and winter (see the water-levels section for the Kalispell subarea for a discussion of the pumping response). (d) Average precipitation.

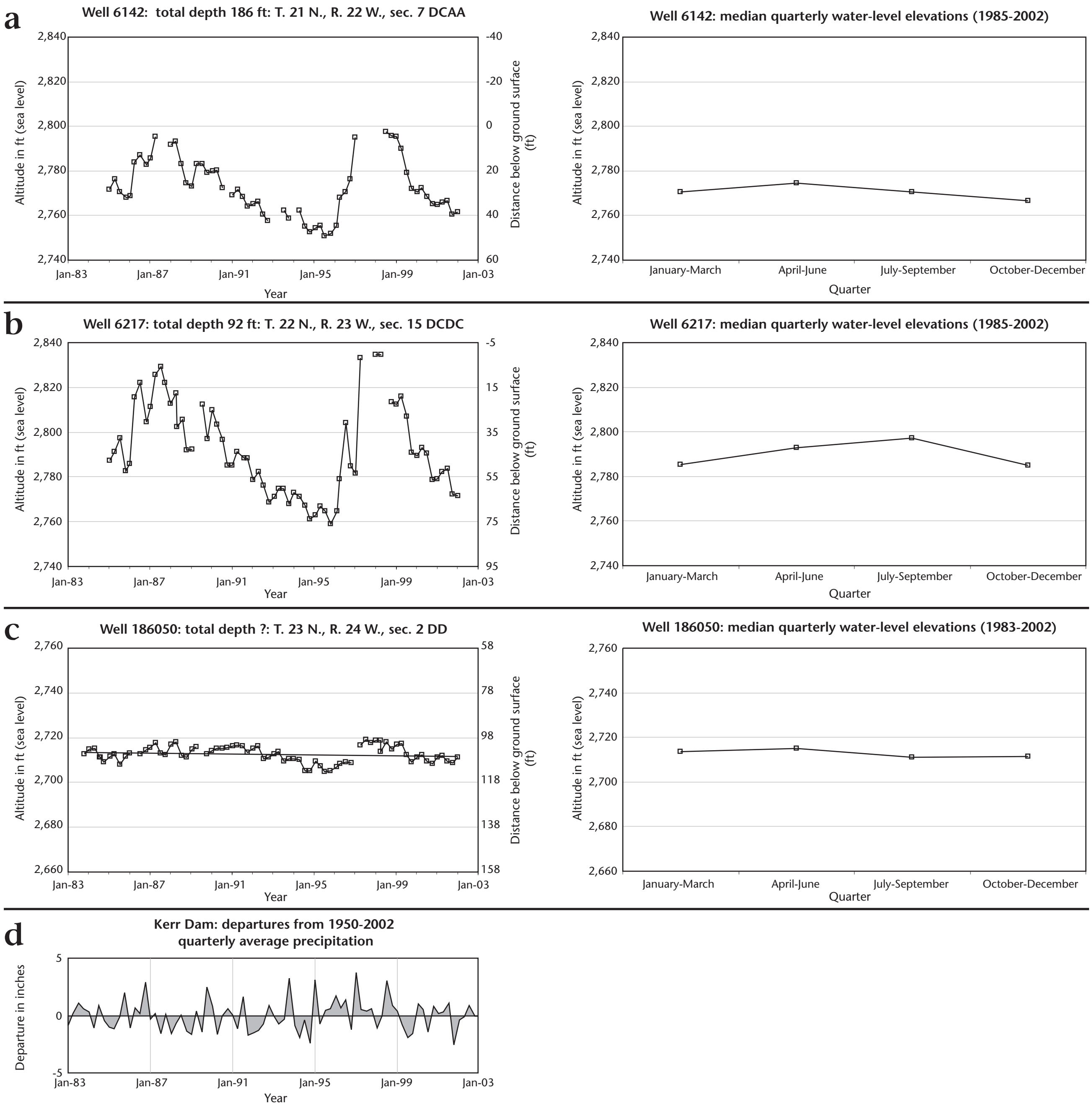



Figure 71. (a–c) Water levels for intermediate aquifers on the east side of the Little Bitterroot subarea show slight decreases over the periods of record and significant responses to climate; they do not show the pumping response common in the Lonepine aquifer. Water levels in an intermediate aquifer near the north end of the Little Bitterroot subarea (well 186050) show little long-term decline. (d) Average precipitation.

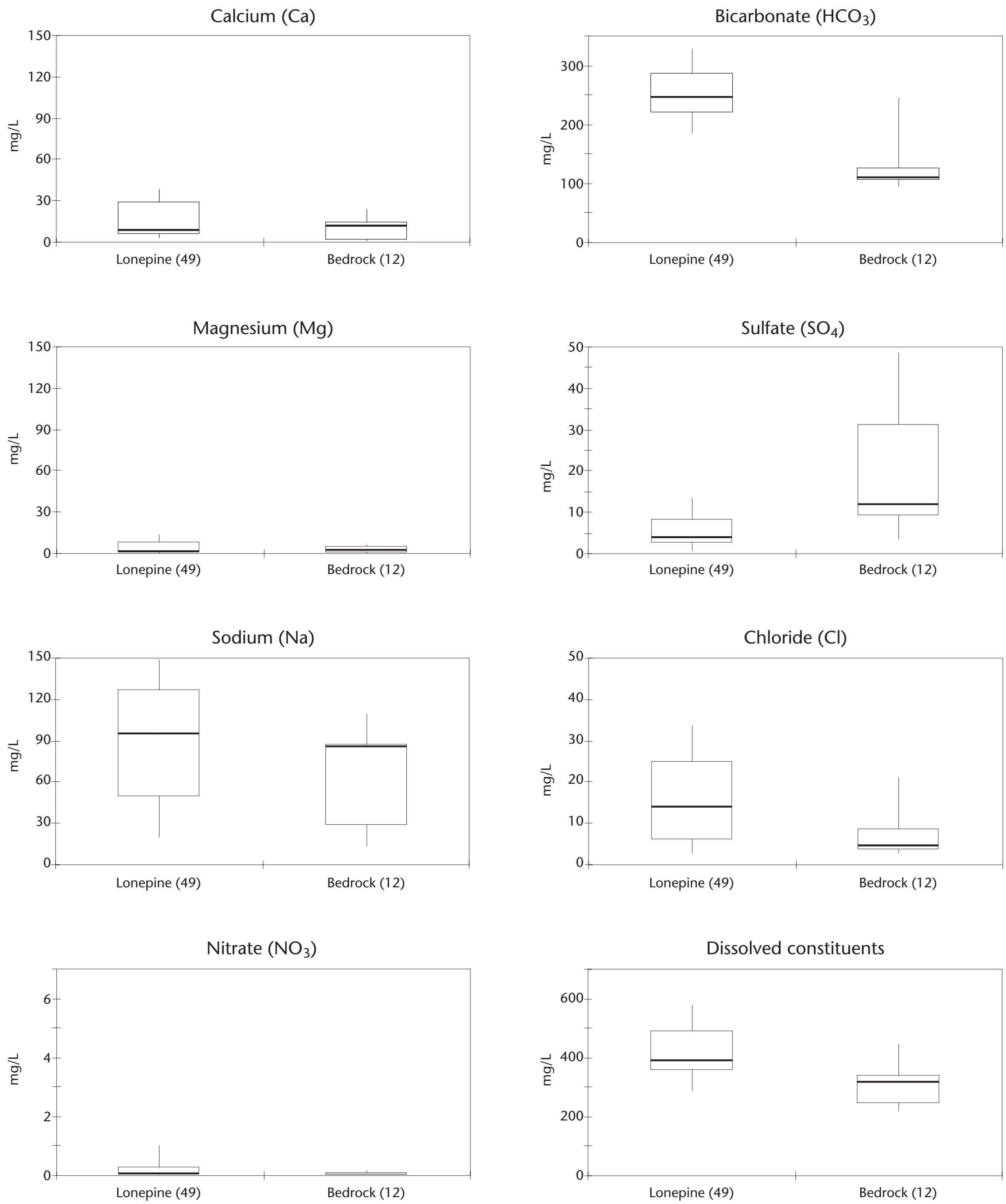



Figure 72. Ground-water quality in the Little Bitterroot subarea's Lonepine aquifer is more mineralized than water in the bedrock, but both aquifers have a distinct sodium-bicarbonate signature. See fig. 24 for an explanation of the plots.

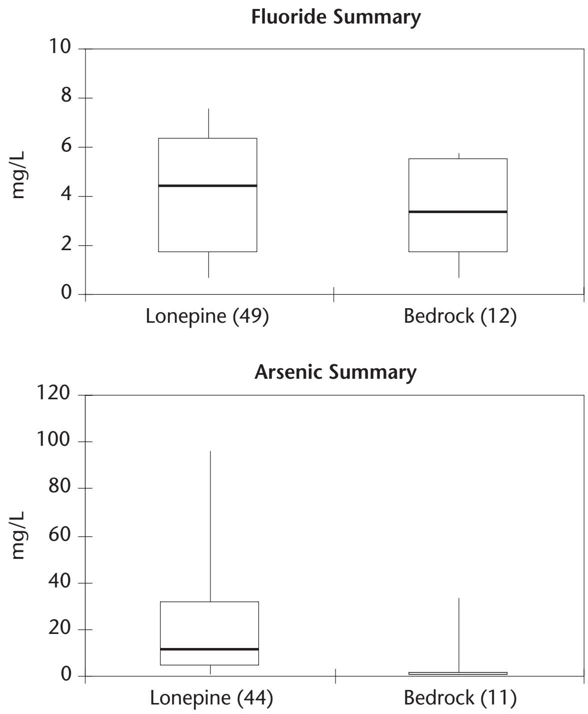



Figure 73. Fluoride and arsenic concentrations in water from the Little Bitterroot subarea locally exceed their respective U.S. Environmental Protection Agency maximum contaminant levels for public drinking water supplies. See fig. 24 for an explanation of the plots.

by Donovan (1985) and Abdo (1997). Relative to ground water in most of the other subareas (figs. 33, 50, 57, 64) ground-water quality in the Little Bitterroot area is notably unique. In the bedrock and Lonepine aquifer, median concentrations of sodium and chloride are 10-fold greater than those in other subareas, while those of calcium and magnesium are significantly less. Median concentrations of sulfate and bicarbonate are similar to those of other areas, and the total dissolved-constituents concentrations are generally less than 500 mg/L. None of the samples evaluated for this study exceeded U.S. EPA secondary standards for sodium, chloride, or sulfate or the primary health standard for nitrate in public drinking water supplies. However, fig. 73 shows that several samples exceeded the health standard for fluoride (4 mg/L) and the proposed standard for arsenic (10 mg/L). Wells with elevated arsenic concentrations (greater than 10 mg/L) occur in a halo around the geothermal area at Wild Horse Hot Springs (Camp Aqua, T. 22 N., R. 23 W., sec. 29). However, arsenic concentrations within the geothermal area itself are depressed (Donovan, 1985). Wells with elevated fluoride concentrations generally occur within the geothermal areas near Wild Horse Hot Springs and the town of Hot Springs.

# Swan

The Swan subarea includes the northern portion of the Seeley-Swan valley within Lake County and south of the northern end of Swan Lake (fig. 2). The Seeley-Swan valley is a narrow fault-bounded depression between the Swan and Mission Ranges. A gravity geophysical survey suggests that as much as 6,500 ft of sediments and sedimentary rocks have accumulated in the valley (Crosby, 1984). The survey suggests that the greatest thickness of basin fill is along the Swan Range and that the fill thickens southward from near Swan Lake to about the Lake County–Missoula County boundary. Much of the basin's sedimentary fill is suspected to have been deposited during Tertiary uplift of mountain ranges and subsidence of the valley floor (Constenius, 1996).

Most water wells in the valley are less than 200 ft deep (fig. 74), so direct knowledge of the basin's sediments is limited. A few wells east of Swan Lake were drilled to between 300 and 700 ft below land surface and were completed in clayey, partially lithified Tertiary(?) sedimentary rocks that contain carbonized plant material. There are insufficient well-log data to allow subsurface mapping of the basin fill.

## Aquifers

Sand and gravel (shallow aquifers) are at land surface near the modern course of the Swan River and in some areas of glacial outwash. About 30 percent of the wells drilled in the subarea penetrated shallow alluvium, which has a median thickness of 20 ft.

Till is common at the land surface in much of the Swan subarea and has been reported in about 80 percent of well logs. Silty and clayey lake deposits were reported in 5 percent of the well logs, all wells drilled near Swan Lake. Apparently, extensive glacial-lake deposits either did not accumulate or were not preserved in the Swan subarea. Sand and gravel deposits (intermediate aquifers), bounded above and below by till, occur near Swan Lake and the Lake County–Missoula County boundary. These alluvial deposits likely represent areas where meltwater deposited sand and gravel, either subglacially or during temporary glacial retreats. Based on lithologic logs, deep alluvium occurs beneath glacial deposits in 44 percent of the water wells in the valley. However, the median penetrated thickness was only 14 ft and the total thickness is unknown.

Intermediate and deep alluvial aquifers are the most utilized source of ground water within the subarea, and 83 percent of the 280 recorded wells

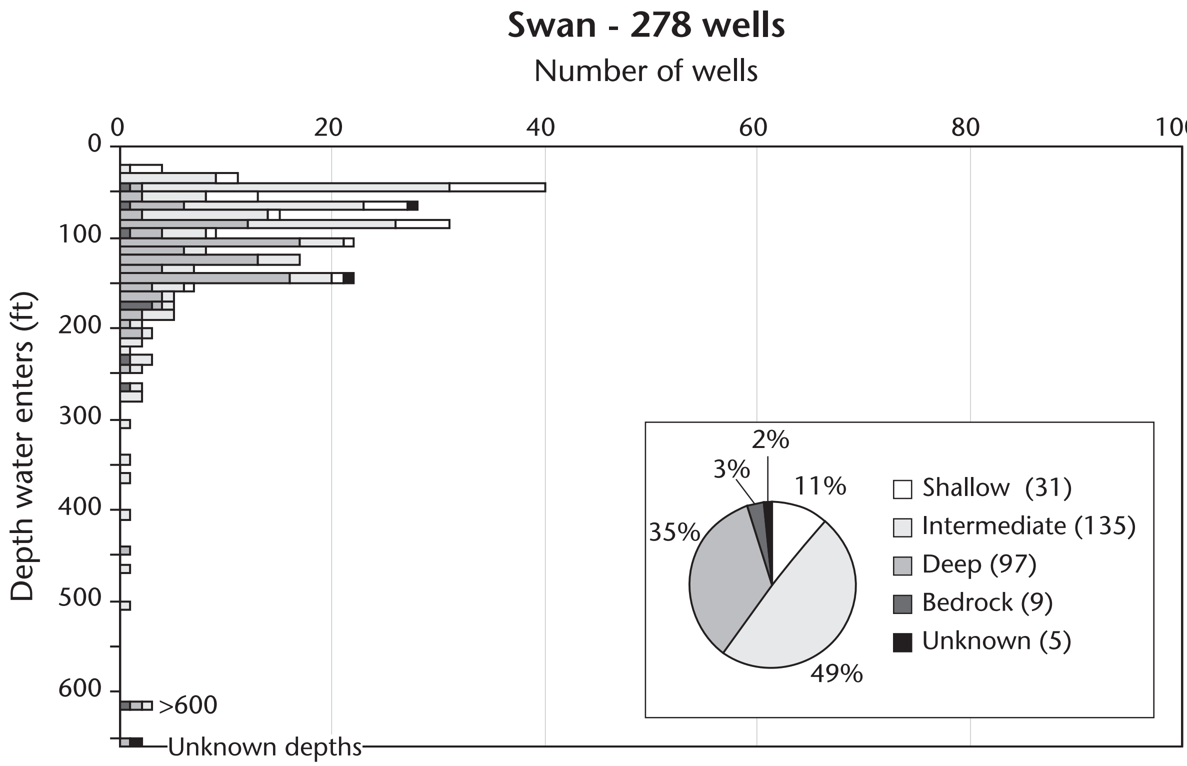



Figure 74. Most wells in the Swan subarea are completed in intermediate aquifers within till, or deep alluvial aquifers below glacial till. Most of them are less than 200 ft deep.

have been completed in these aquifers. Shallow aquifers associated with the Swan River (14 percent of wells) and bedrock aquifers (3 percent of wells) are other commonly used sources.

Yields from aquifers in the Swan subarea generally are greater than those from similar aquifers in all but the Kalispell and Mission subareas. Reported yields from the intermediate aquifers are as much as 150 gpm and have a median of 24 gpm. Wells completed in the deep alluvial aquifer have a median yield of 30 gpm, and those completed in shallow aquifers have a median yield of 25 gpm. The few completed in bedrock all reportedly produce more than 10 gpm and have a median yield of 15 gpm (fig. 75a). Most wells in the Swan subarea are completed at depths of less than 200 ft below land surface; however, some deep alluvial and bedrock aquifer wells are reported to be as much as 700 ft deep. The median well depth in shallow aquifers is 40 ft, but a few wells are as much as 100 ft deep (fig. 74).

Ground-water flow in the Swan subarea is generally away from the high-elevation valley sides toward the topographically low valley center. Based on the limited static water-level measurements, there is no obvious discordance in the water levels between measuring points completed at different depths, suggesting sufficient hydraulic connection between the different hydrogeologic units to map general ground-water flow as a regional, valley-wide, deep ground-water flow system (Part B, map 4).

Unlike most of the other subareas in the Flathead Lake region, the rate of ground-water development in the Swan subarea has not increased since 1985–90. Fifty-nine wells were drilled between 1985 and 1990; between 1990 and 1995 the number had dropped to 48, and between 1999 and 2000 only 46 new wells were drilled (fig. 75b).

## Water Levels

Water levels in most of the Swan subarea aquifers are near the land surface, reflecting confined to semi-confined conditions in the deep and intermediate aquifers. Nine wells reportedly flow; they are located in the topographically low central part of the valley and completed in intermediate or deep alluvial aquifers.

Water-level fluctuations in shallow, intermediate, and deep aquifers (fig. 76) are typically about 3 ft per year. The intermediate aquifer (well 133044) has the least amount of annual fluctuation. The deep aquifer (well 127166) shows a response to the wetter than normal climate between 1995 and 1998.

The water-level record from a shallow aquifer (well 79152, fig. 76) shows typical runoff response where water levels rise in the spring during times of snowmelt and runoff, peak in the early spring–late

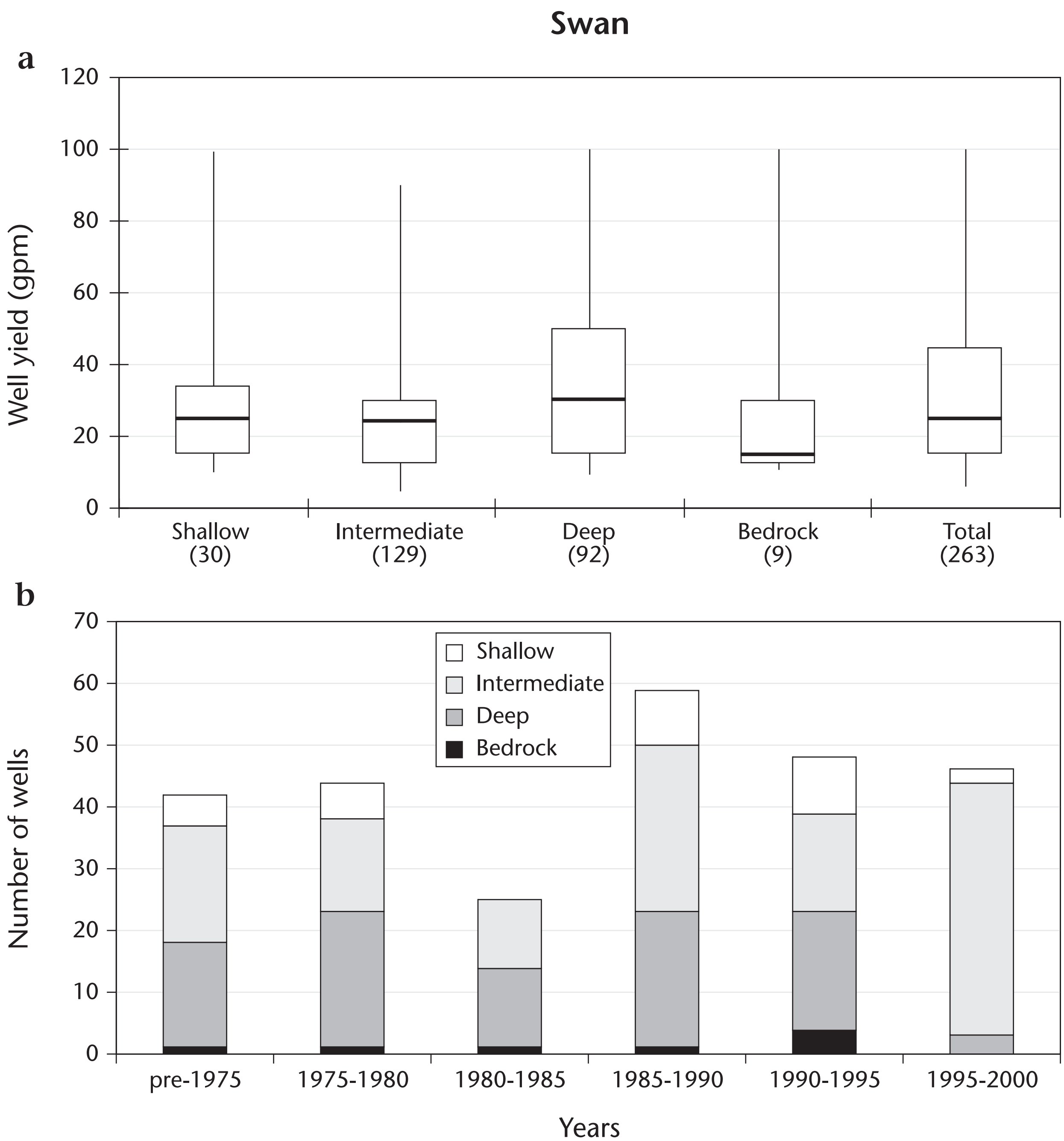



Figure 75. (a) Reported well yields are consistent among all aquifers in the Swan subarea. (b) Between 25 and 60 new wells have been constructed every 5 yr. The overall rate of new well construction appears to have declined since 1990.

summer, and then drop during the late summer, fall, and winter months. Water levels in this well about 1 mi east of the Swan River are probably controlled in part by flow in the river and its nearby tributaries. Comparison of median monthly water-level altitudes with discharge of the Swan River (at U.S. Geological Survey gage 1237000, Swan River above Bigfork, Montana) shows that discharge in the river and water-level altitudes in the well peak in May and June and then reach their lowest levels in October–March of each year.

## Water Quality

Based on the results of nine ground-water analyses (two samples from shallow aquifers, two samples from intermediate aquifers, four samples from deep alluvial aquifers, and one sample from a bedrock aquifer), ground water in the Swan subarea is of good quality and is safe to drink based on the U.S. EPA drinking water standards for public drinking water supplies. The predominant ions in the water are calcium, bicarbonate, and magne-

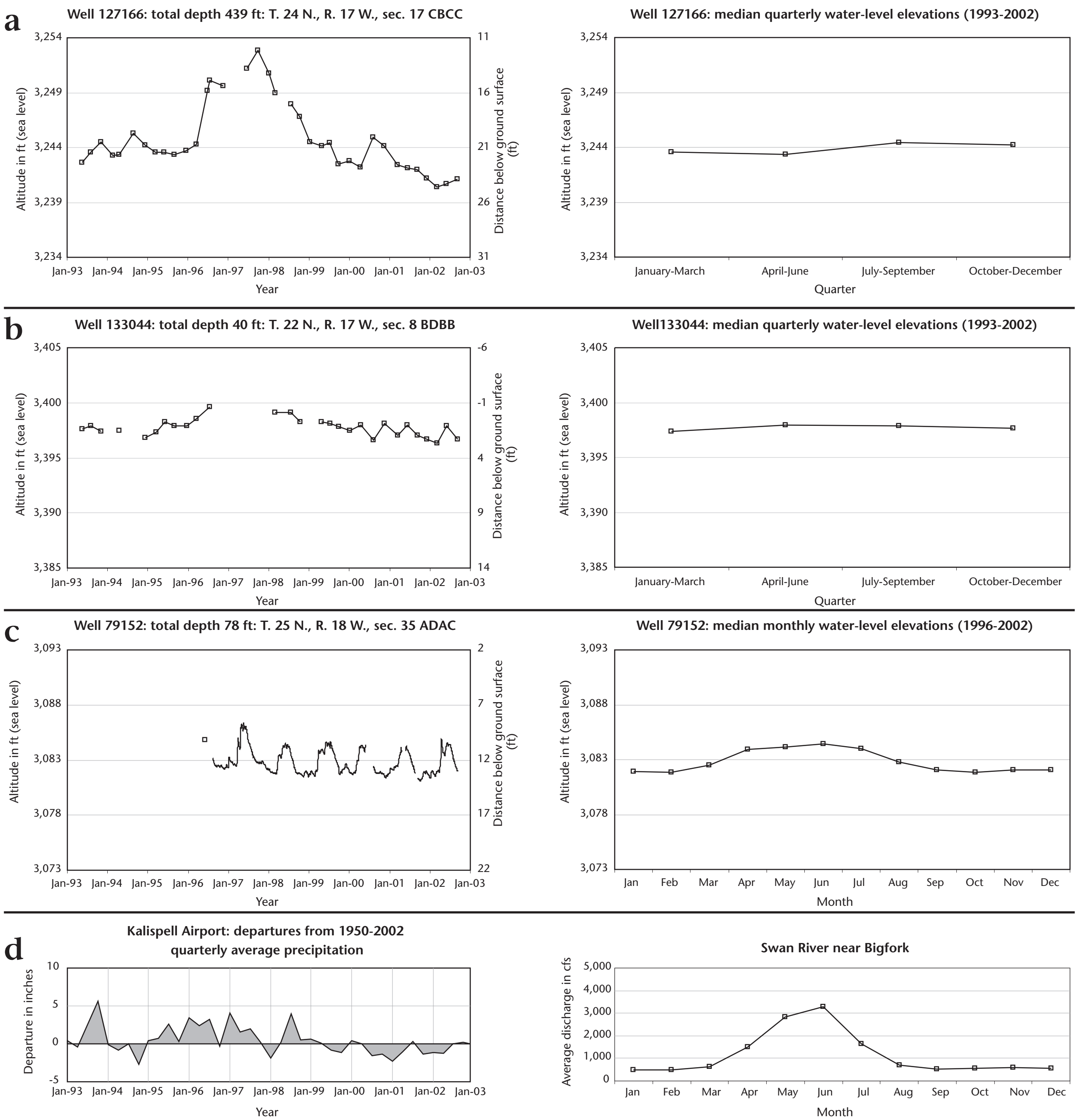



Figure 76. (a) Water levels for a deep alluvial aquifer in the Swan subarea (well 127166) appear to respond to climatic conditions. They began rising in 1996, peaked in 1998, and since have fallen to pre-1996 levels. (b) Water levels for an intermediate aquifer (well 133044) show little seasonal or long-term change. (c) Water levels for a shallow aquifer (well 79152) display a runoff pattern where they reflect annual changes in precipitation and runoff. (d) Average precipitation and discharge.

sium (appendix C); the dissolved constituents in water from all aquifers are generally less than 400 mg/L. None of the samples exceeded the secondary standards for sodium, chloride, or sulfate or the primary health standard for nitrate. Nitrate was detected in only four of the nine samples; however, two of the samples had concentrations of 4.8 and 4.9 mg/L, suggesting a surface source of contamination at those sites near Swan Lake.

## North Fork

The North Fork subarea extends from the Apgar Mountains, where the North Fork of the Flathead River cuts across bedrock, northwest to Canada (fig. 2). The North Fork of the Flathead River valley is bounded on the southwest by the Whitefish Range and on the northeast by the foothills of the Livingston Range in Glacier National Park.

The mountains and some foothills on either side of the valley are composed of bedrock. The valley itself contains Tertiary sedimentary rocks, including the Kishenehn Formation and Paola gravels, together exceeding 11,000 ft in thickness (Constenius, 1981, 1988). They are covered by a package of deep alluvium, till, and shallow alluvium that locally reaches a thickness of 300 ft. Partially consolidated siltstone, carbonaceous shale, sandstone, and conglomerate of the Kishenehn Formation are commonly at or within 100 ft of land surface in much of the valley.

### Aquifers

Sand and gravel (shallow aquifers) occur at land surface in areas along the floodplains of streams and in areas of outwash. Shallow alluvium was logged in about 40 percent of the wells completed in the subarea, with a median thickness of 34 ft.

Till is common at the land surface and locally overlies pre-glacial sand and gravel deposits, Tertiary sedimentary rocks, and bedrock. The till has a median thickness of 110 ft and was reported in about 70 percent of those well logs with interpretable lithologic records. Sand and gravel bounded above and below by till (intermediate aquifers) were reported on well logs in only a few areas.

Deep alluvium (deep alluvial aquifer) locally overlies shale and sandstone of the Kishenehn Formation and has been reported in about 45 percent of the logged wells in the valley. The thickness of the deep alluvial aquifer is typically 20 to 40 ft. The alluvium, which is covered by till, was likely deposited as outwash in front of advancing glacial ice during the most recent glaciation.

The North Fork subarea is unique in the Flathead Lake area in that Tertiary sedimentary rocks are an important source of ground water. There are

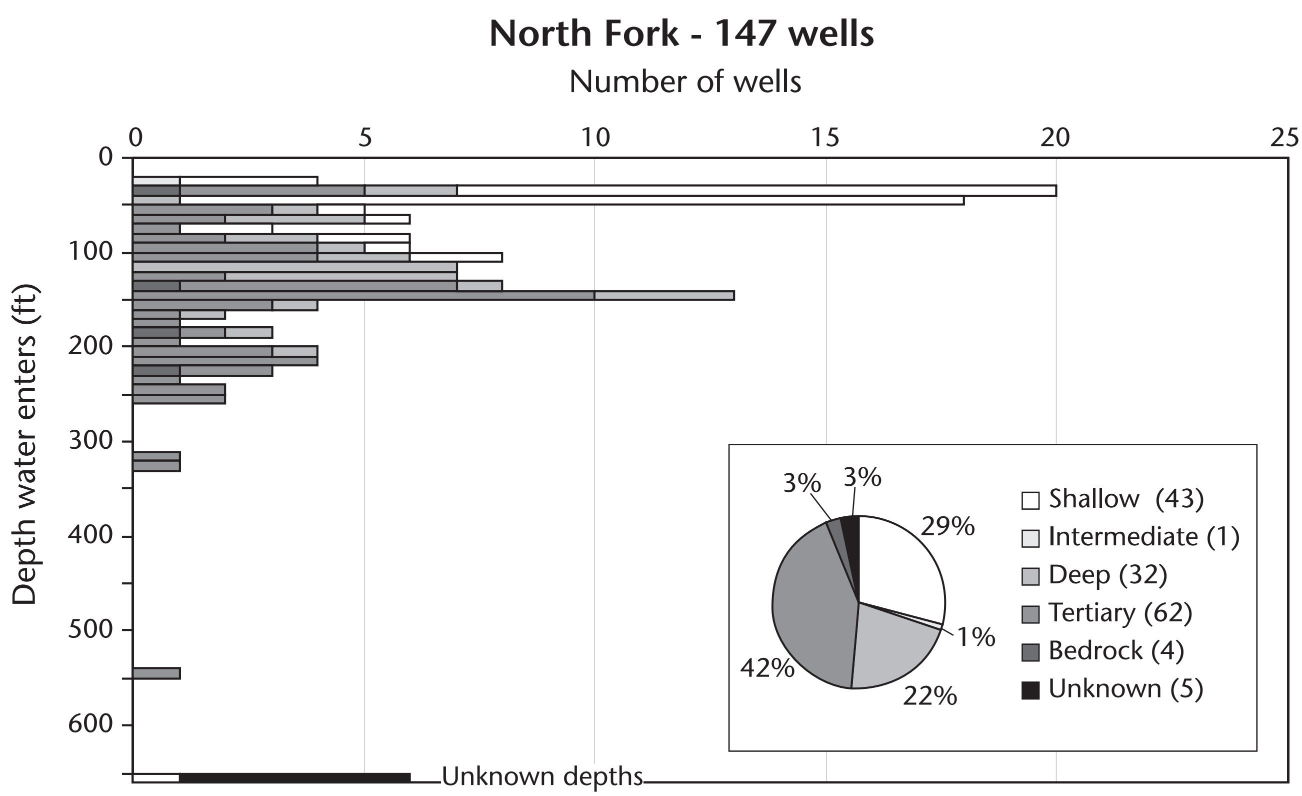



Figure 77. Almost all wells completed in the North Fork subarea are less than 250 ft deep. The inset pie chart shows that about 40 percent of wells are completed in Tertiary aquifers. The subarea is one of the few places in the Flathead Lake area where Tertiary aquifers are relatively important.

records for about 150 wells in the North Fork subarea, most of which are completed in Tertiary sedimentary rocks (42 percent), deep alluvial aquifers (22 percent), or shallow aquifers (29 percent). Wells completed in shallow aquifers are typically along drainages. Wells completed in deep alluvial aquifers are generally outside of modern floodplains and distant from streams. Only 4 percent of the wells are completed in intermediate or bedrock aquifers (fig. 77). Most of the wells completed in Tertiary rocks are on the west side of the northern part of the valley where shallow and deep alluvial aquifers are rare.

Even though Tertiary aquifers are the most used, reported yields are generally less than 15 gpm and the median yield is 9 gpm. Shallow and deep alluvial aquifers have reported median well yields of 25 and 12 gpm, respectively (fig. 78a).

Shallow aquifers are as much as 103 ft thick, but most are found within 50 ft of the land surface and the median reported well depth for

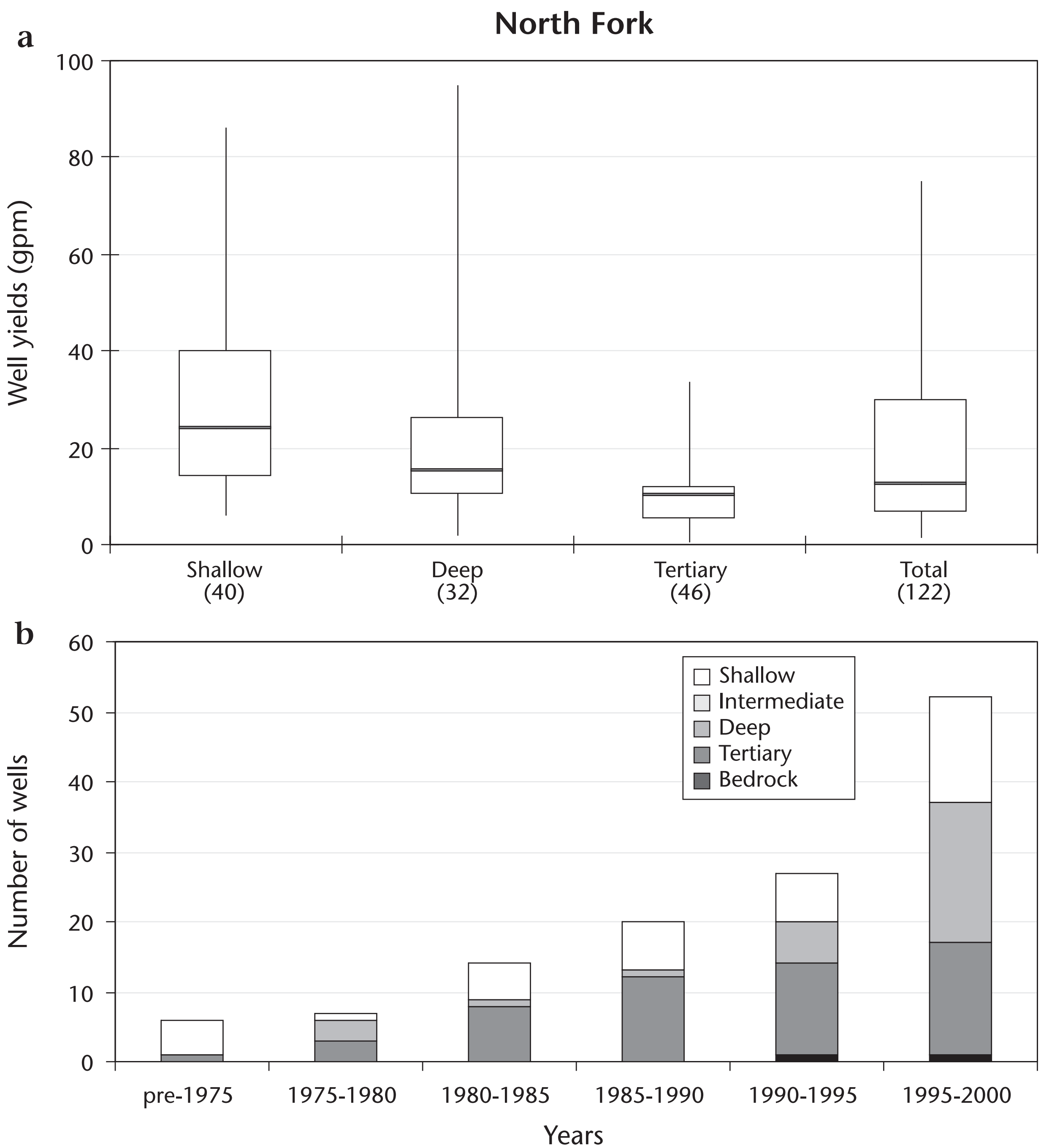



Figure 78. (a) In the North Fork subarea reported yields from wells completed in the Tertiary aquifers are low compared with yields in shallow and deep alluvial aquifers. See fig. 24 for an explanation of the plots. (b) The rate of new well construction has increased rapidly since 1975.

shallow aquifers is 35 ft. The median depth to water for shallow aquifers is 12 ft. Deep alluvial aquifers are as much as 300 ft below land surface, but the median well depth for deep alluvium is 140 ft. The median depth of wells completed in Tertiary deposits is also 140 ft, but the depths range from 34 to 800 ft (fig. 77). Depths to water in the deep alluvial and Tertiary aquifers is similar, at about 200 ft below land surface. The median reported depth to water is 100 ft.

The rate of development of the ground-water resource has shown steady growth and has accelerated since 1995; about 40 percent of all the wells in the North Fork subarea were installed between 1995 and 2000 (fig. 78b).

### Water Quality

Of the three wells sampled in the North Fork subarea, two were completed in shallow aquifers and one in bedrock. The predominant ions in the ground water are calcium, bicarbonate, and magnesium; the dissolved-constituents content is generally less than 400 mg/L. None of the three samples exceeded the U.S. EPA secondary standards for sodium, chloride, or sulfate or the primary health standard for nitrate in public drinking water supplies. Nitrate was not detected in any of the samples.

## Camas Prairie

Camas Prairie Basin is a distinct north–south-oriented elliptical basin drained by Camas Creek in the southeast corner of the Flathead Lake study area (fig. 2). The basin is a low-relief valley surrounded by mountains cored by bedrock. Tertiary(?), red, greenish, and bluish siltstone and mudstone that include a few sandy and gravelly zones are at land surface around part of the valley perimeter. The Tertiary(?) deposits also occur within the valley at depths of 50 to 100 ft below land surface. Because few lithologic logs are available, the subsurface units are incompletely mapped (Part B, map 10).

### Aquifers

Shallow alluvium locally occurs near land surface, overlying glacial-lake sediments. The shallow alluvium is mostly silty sand and sandy gravel transported into the basin by alluvial sheetwash, stream action, and wind. Only a few water-well logs reported shallow alluvium deposits thicker than 10 ft. Locally the topmost unit of glacial-lake deposits in the Camas Basin is a thin veneer of sand and gravel deposited by flood events during catastrophic drainages of Glacial Lake Missoula (Pardee, 1910). Generally the Glacial Lake Missoula deposits

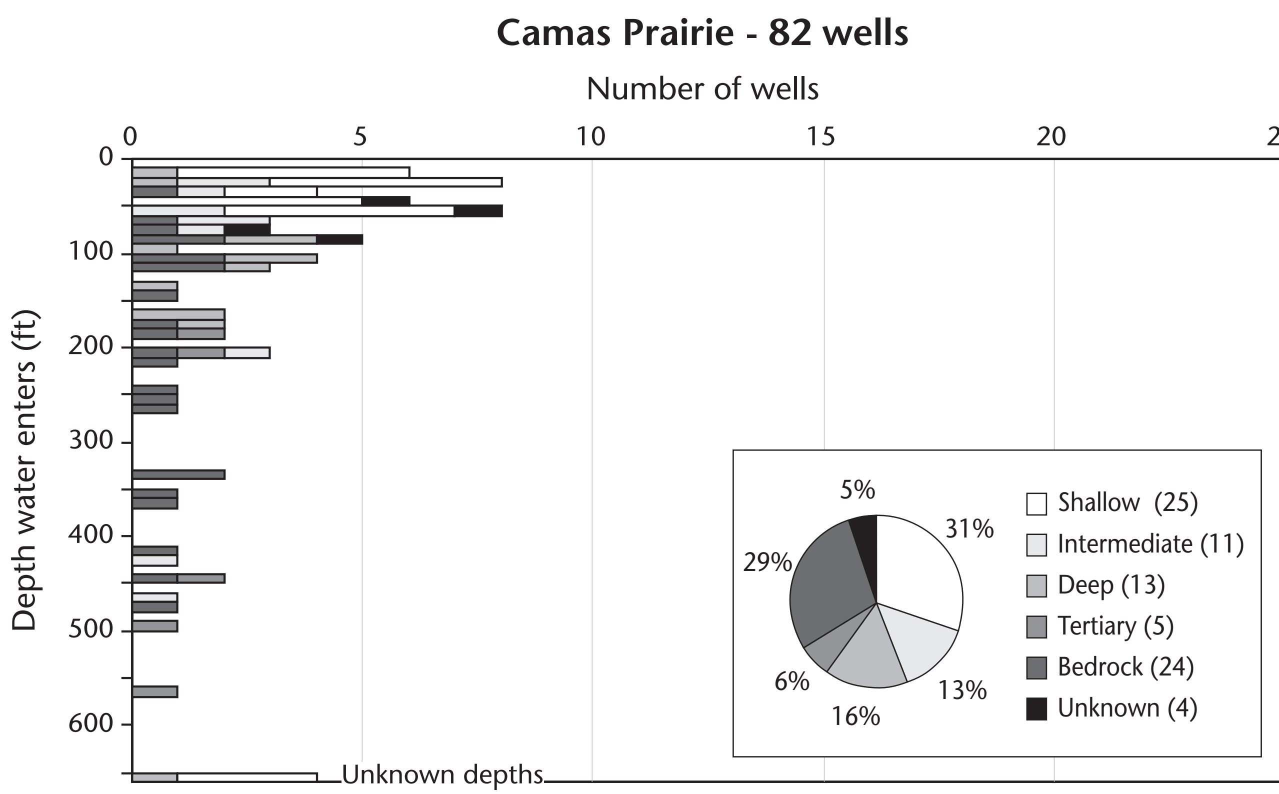



Figure 79. Although many wells in the Camas Prairie subarea are completed at depths of less than 100 ft, well depths are sporadically as much as 500 ft below land surface. The inset pie chart shows that well completions are nearly evenly distributed among shallow, intermediate, deep alluvial, and bedrock aquifers.

in the Camas Prairie subarea are mostly silt and clay beds that are 40 to 60 ft thick based on well-log data. About 30 percent of the well logs in the subarea reported sand and gravel units that were part of the glacial-lake deposits. In some wells in the Camas Prairie subarea, between 15 and 30 ft of sandy and gravelly alluvium occurs underneath glacial-lake deposits and above Tertiary(?) rocks.

Shallow and bedrock aquifers are the most common sources of water in the Camas Prairie subarea. Well records show that only about 80 wells have been drilled in the subarea. Shallow aquifers (31 percent) or bedrock aquifers (29 percent) are the most used; intermediate aquifers within the glacial-lake deposits and deep alluvial aquifers provide water to 13 and 16 percent of

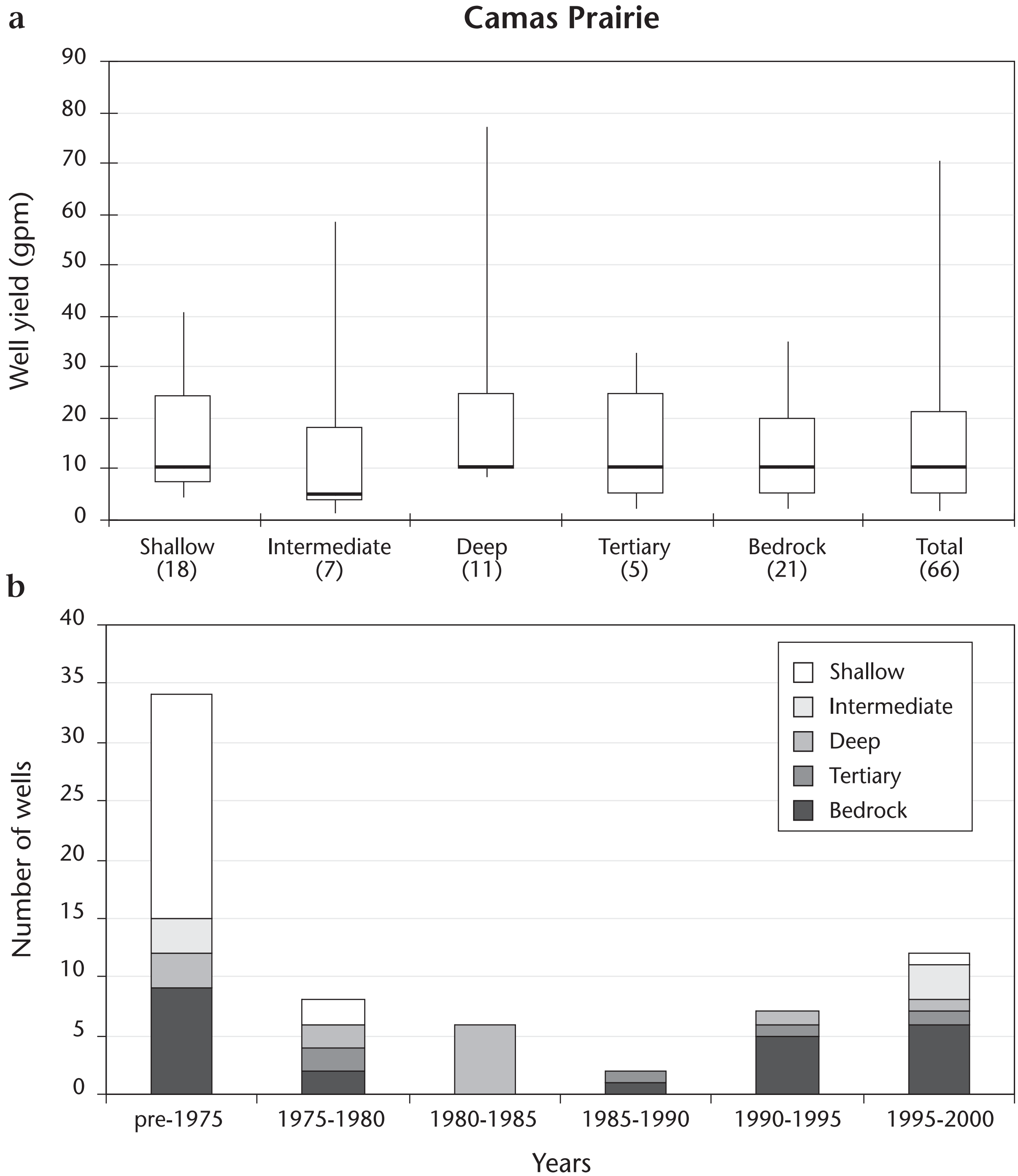



Figure 80. (a) Reported well yields from all aquifers in the Camas Prairie subarea are low compared with those from other subareas in the Flathead Lake area. See fig. 24 for an explanation of the plots. (b) New drilling in the Camas Prairie subarea has been only a few wells per year. Most wells drilled since 1990 have been completed in bedrock.

wells, respectively. Tertiary deposits account for only 6 percent of the wells (fig. 79).

All aquifers in the Camas Prairie subarea appear to be less productive than in other subareas. Intermediate aquifers have a median well yield of only 5 gpm, and the median yield in shallow aquifers is 17 gpm; reported well yields from all aquifers are mostly less than 30 gpm (fig. 80a). However, four wells completed in shallow aquifers have reported yields of greater than 500 gpm.

Shallow aquifers are generally within about 50 ft of the land surface, and all wells completed in them are less than 55 ft deep. The median well depth in shallow aquifers is 34 ft. Intermediate aquifers have a median well depth of 60 ft, and for deep alluvial aquifers the median depth is about 100 ft. Depths to the Tertiary and bedrock aquifers range more widely than depths to the shallow and intermediate aquifers. The median well depth in the bedrock aquifer is 230 ft based on wells that range in depth from 64 to 480 ft. Tertiary aquifers are the deepest in the subarea, with wells that are as much as 560 ft deep and with a median depth of 485 ft (fig. 79).

The rate of ground-water development in the Camas Prairie subarea has remained steady since 1975. However, slightly more than half of the wells have been completed in bedrock around the basin fringe since 1995 (fig. 80b). Aquifer test data for two wells completed in the deep alluvial aquifer near the center of the basin indicate that transmissivities are between 10,200 and 11,700 $ft^2$/day (appendix B).

## Water Levels

Long-term water levels in deep alluvial and bedrock aquifers within the basin appear stable (fig. 81) and annual water-level fluctuations are generally less than 5 ft. Water levels in a deep alluvial aquifer (well 6104) peak in April and generally fall during the summer and fall months. Water levels in bedrock (well 133886) gradually

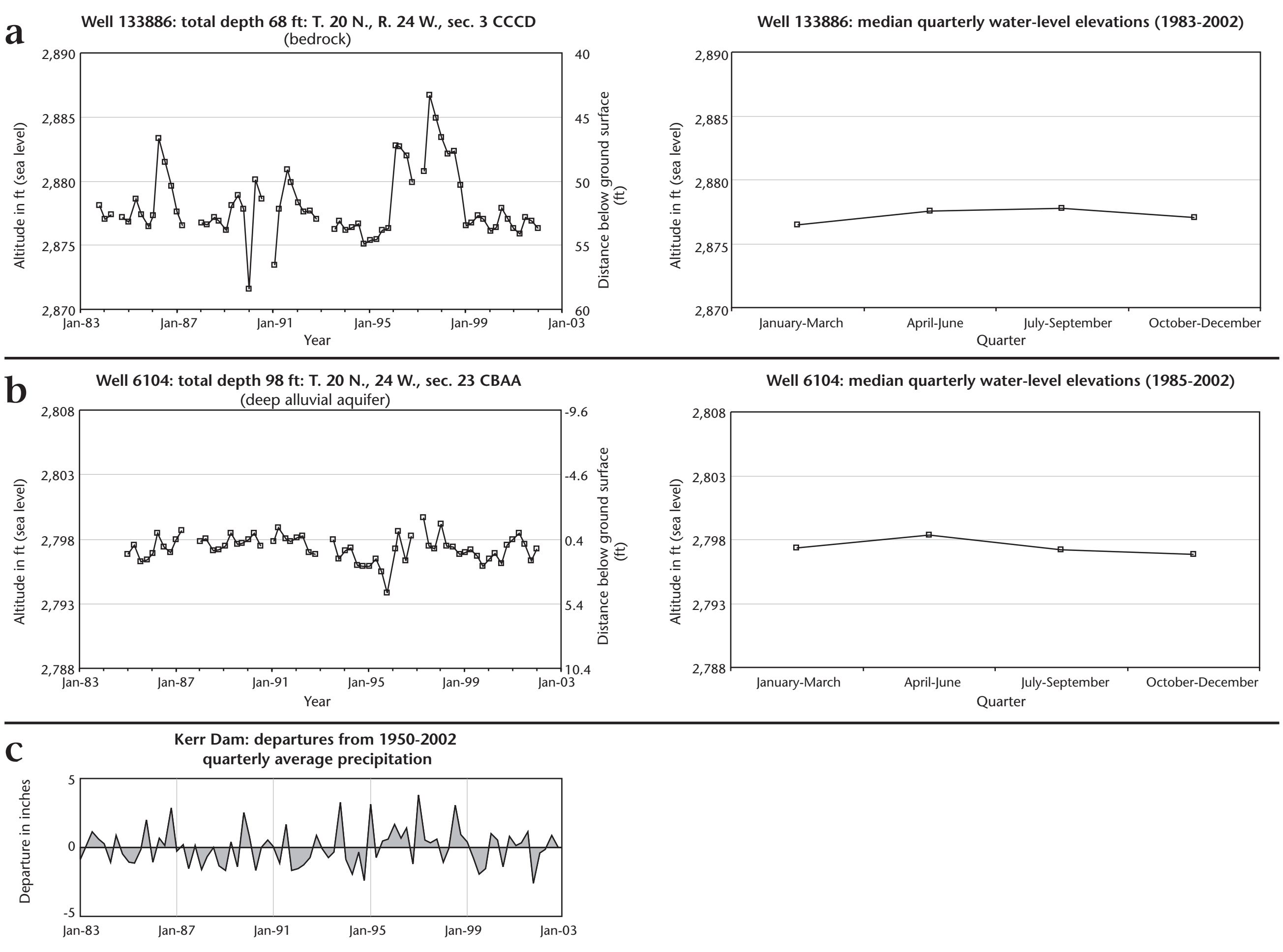



Figure 81. Water levels in bedrock and a deep alluvial aquifer in the Camas Prairie subarea have different seasonal patterns but show no long-term upward or downward trends. (a) Water levels in the bedrock (well 133884) reach their highest altitudes in July. (b) In contrast, water levels in the deep alluvial aquifer (well 6104), near the center of the basin, peak in the spring and then drop during the summer and fall months. (c) Average precipitation.

rise during spring and summer months to peak in July.

### Water Quality

Based on analytical results from 10 samples (6 historical and 4 collected for this study), ground water in the Camas Prairie subarea meets the U.S. EPA standards for drinking water supplies. The predominant ions in the ground water are calcium, bicarbonate, and sodium; the dissolved constituents in ground water from all the aquifers is generally less than 300 mg/L. None of the samples exceeded the secondary standards for sodium, chloride, or sulfate or the primary health standard for nitrate. One sample from a 92-ft-deep well contained nitrate at a concentration of 3.6 mg/L, but nitrate concentrations in all the other samples were less than 1.4 mg/L. The ground-water quality in the Camas Prairie subarea is similar to that in other subareas west of Flathead Lake (particularly the Smith subarea) in that the water contains appreciable dissolved silica and depressed bicarbonate concentrations (appendix C).

## Irvine Flats

Irvine Flats, in the Salish Mountains west of Polson, is a small valley drained by White Earth Creek that flows into the Flathead River downstream from Kerr Dam (fig. 2). It is a low-relief valley surrounded by bedrock-cored mountains. Tertiary, red, light-gray, orange, and white siltstone and mudstone with a few sandy and gravelly interbeds are at land surface in some upper parts of the drainage and occur between 100 and 200 ft below land surface throughout most of the subarea. Surficial sediments are primarily deposits of Glacial Lake Missoula. Because few lithologic logs are available, the subsurface units are incompletely mapped (Part B, map 10).

### Aquifers

Silty sand and sandy gravel (shallow aquifers) are found in limited areas of alluvial sheetwash and small stream floodplains within the Irvine Flats subarea. The shallow aquifers rest on Glacial Lake Missoula sediments consisting of silt, clay, and a few local beds of sand and gravel. The glacial-lake deposits are generally 100 to 200 ft thick where reported on lithologic logs. Less than 10 percent of the glacial-lake deposits are sandy or gravelly and only some of those are permeable enough to be intermediate aquifers. The higher percentage of fine-grained glacial-lake deposits in the Irvine Flats subarea compared to the immediately adjacent Mission subarea is likely due to lesser contributions of glacial meltwater and sedi-

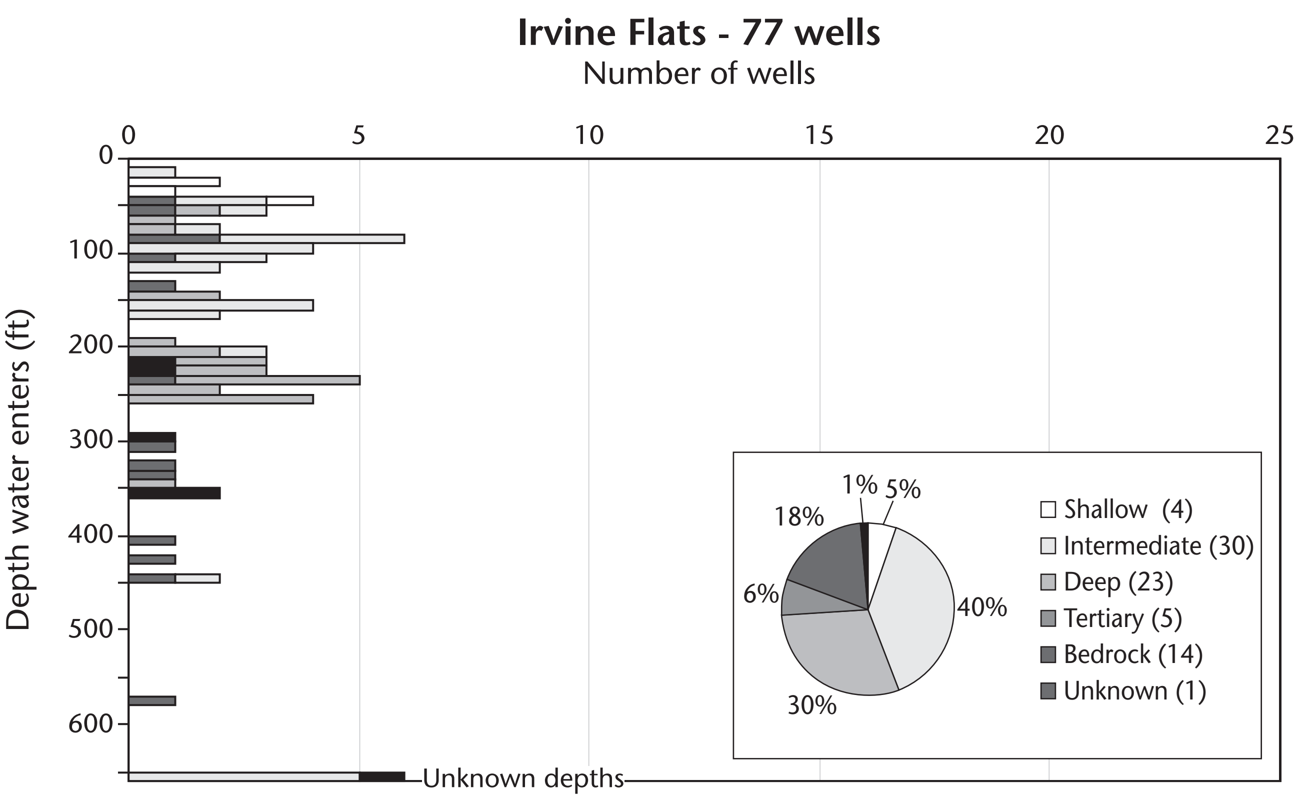



Figure 82. Well depths are mostly less than about 250 ft in the Irvine flats subarea, but some wells are more than 300 ft deep. The inset pie chart shows that most wells in the Irvine Flats subarea are completed in intermediate and deep alluvial aquifers.

ment in Irvine Flats. The glacial-lake deposits locally overlie 10 to 30 ft of deep alluvium.

Intermediate or deep alluvial aquifers support 54 of the 77 wells recorded in the subarea. However, differentiating between the intermediate and deep aquifers is difficult due to the relatively low number of wells that have been completed. Most of the 23 other wells are completed in bedrock aquifers near the margin of the valley; five are completed in Tertiary aquifers (fig. 82).

Based on only 47 reported yields, wells completed in deep alluvial aquifers appear to generally have yields greater than 20 gpm, and in 2 wells yields are reportedly as much as 500 gpm. However, deep aquifer yields also can be relatively low; in the middle of the subarea a cluster of about 10 wells has a maximum reported yield of 5 gpm. Intermediate aquifers have a reported yield of about 20 gpm, and yields for all but 1 well are less than 60 gpm. Bedrock wells are generally not very productive; yields range from 1 to 20 gpm and the median yield was 3 gpm (fig. 83a).

Most of the wells in the Irvine Flats subarea are less than 350 ft deep. Intermediate aquifers have

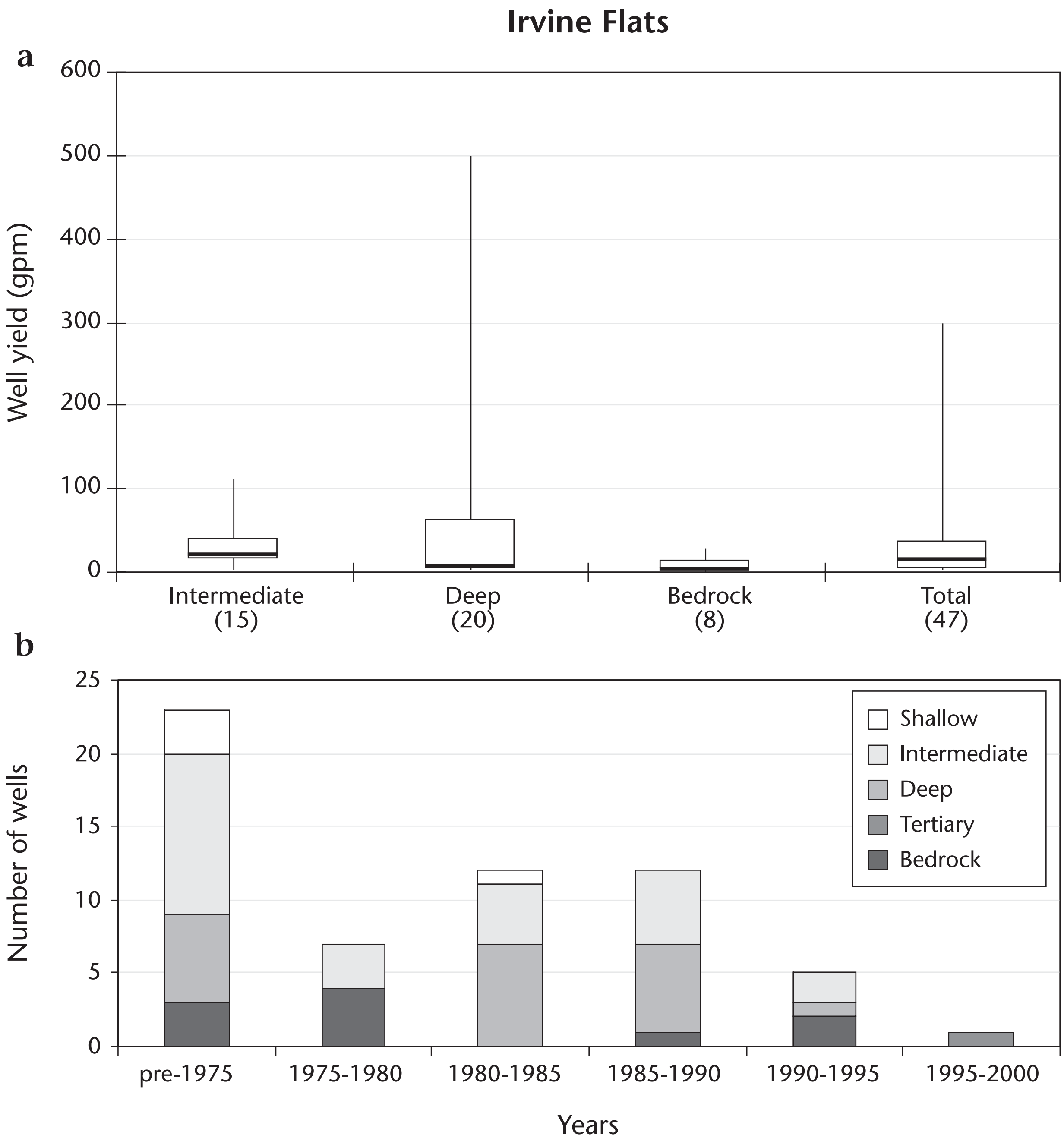



Figure 83. (a) Although a few wells in the deep alluvial and intermediate aquifers in the Irvine Flats subarea have reported yields of greater than 100 gpm, most reportedly produce less than 20 gpm. See fig. 24 for an explanation of the plots. (b) Few wells have been drilled in the Irvine Flats subarea since 1990.

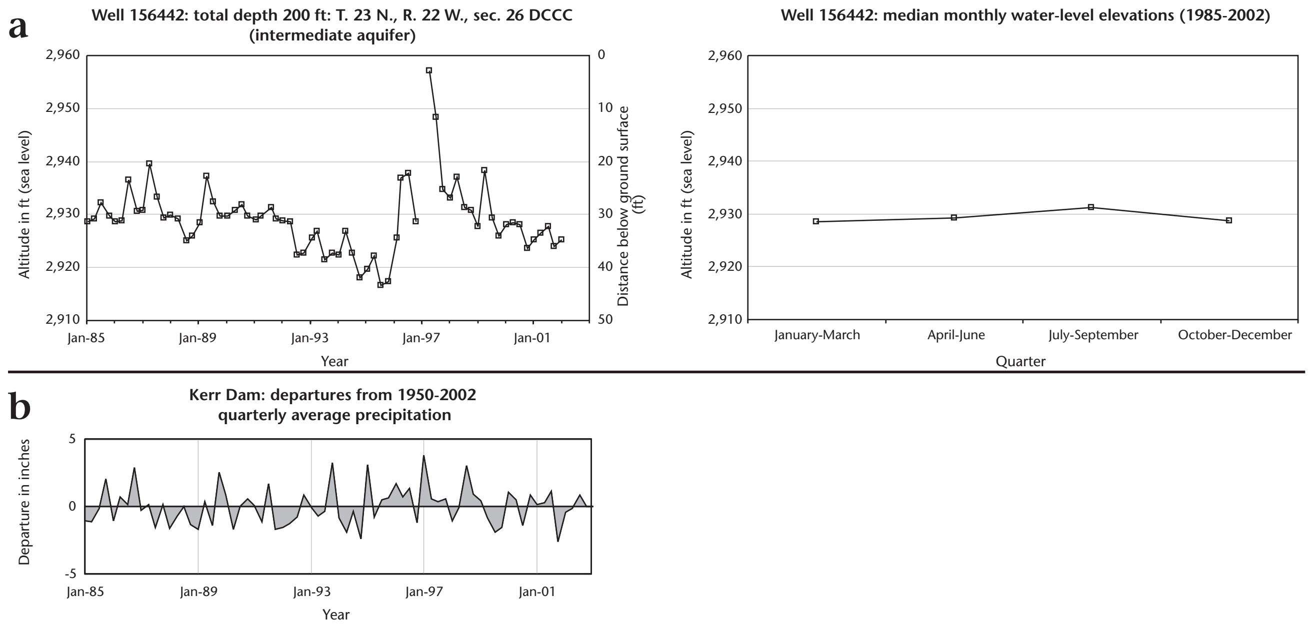



Figure 84. (a) Water levels in a well completed in an intermediate aquifer in the Irvine Flats subarea generally declined between 1985 and 1996. Water levels rose about 35 ft in 1996–97, in response to wetter than normal climatic conditions, before beginning to fall again. (b) Average precipitation.

the shallowest median well depth at about 100 ft; median depths in deep alluvial aquifers are two-fold greater at 215 ft. Wells completed in bedrock range from 7 to 563 ft deep and the median depth is 260 ft (fig. 82). The current rate of ground-water development is low; fewer than 10 wells were installed between 1990 and 2000 (fig. 83b).

## Water Levels

The water level in one well completed in an intermediate aquifer within the Irvine Flats subarea shows a consistent annual pattern, peaking in the spring and dropping during the summer and winter (fig. 84). Although the well is reportedly completed to a depth of 200 ft, it is screened in an intermediate aquifer between 45 and 60 ft below the surface. Between 1989 and 1995, the water level generally declined, but in 1996 and 1997 it rose sharply by more than 40 ft. Since 1997 the water level has again declined. The pattern shows that the water level in this intermediate aquifer responds to climatic conditions (fig. 84).

# Flathead Lake Area Summary

Ground water, contained in the basin-fill deposits and the bedrock around the perimeters of the major valleys, is a critical resource in the Flathead Lake area. The unconsolidated basin-fill deposits consist primarily of Pleistocene alluvial and glacial deposits and Holocene alluvium along modern stream valleys. North of the Polson moraine the glacial deposits are the result of valley-wide glaciation and include outwash, till, and some glacial-lake silts and clay. South of the Polson moraine, Glacial Lake Missoula deposits of silty sand and gravel, silt, and clay are common. Saturated layers of sand and gravel close to the land surface (shallow aquifers) and buried at depth (intermediate and deep alluvial aquifers) within the basin-fill deposits are the most utilized aquifers. Fractured bedrock around the valley margins and in the mountainous areas also supplies water to many wells. Because of the variability in geology, topography, and ground-water flow in the intermontane valleys, the discussion of the ground-water resources was divided into 11 subareas (fig. 2) generally confined to the major valleys within the study area.

Unconfined shallow aquifers are locally important water sources. The shallow aquifers are present in most of the subareas and are generally limited to alluvium along stream valleys and gravelly outwash deposits formed by glacial meltwater. Important shallow aquifers include the Evergreen aquifer between the Flathead and Whitefish Rivers in the Kalispell subarea, the Mud and Post Creek alluvium in the Mission subarea, the Jocko River alluvium in the Jocko subarea, and the Flathead River alluvium downstream of the Kerr Dam. The shallow aquifers are generally very productive. Reported well yields range to more than 2,000 gpm (the median yield is 25 gpm); however, the aquifers are intrinsically susceptible to surface sources of contamination and can be sensitive to climatic (drought) effects.

Intermediate aquifers are distinct water-bearing sand and gravel horizons bounded above and below by till or glacial-lake deposits. They were grouped for this study by their depth and their relation to the low-permeability units. The aquifers are of variable thickness, generally cannot be correlated across large distances, and are usually between 50 and 100 ft below the land surface. Ground water in the intermediate aquifers is under semi-confined to confined conditions.

Intermediate aquifers are present in all the subareas, but are most commonly used along the north and east sides of the Kalispell subarea, in the east and southern parts of the Mission subarea, and in the southeastern part of the Jocko subarea. Well yields from the intermediate aquifers are variable and generally smaller than those from deeper alluvial aquifers; they range from less than 1 to 3,000 gpm. The median yield from intermediate aquifers is 20 gpm.

Deep alluvial aquifers occur in sand and gravel deposits that are widespread beneath the confining units (and intermediate aquifers) in most of the subareas. The deep alluvial aquifers in the Kalispell and Mission subareas are the most productive sources of ground water, and most high-capacity irrigation and water supply wells are completed in them. The deep alluvial aquifers are as much as 75 ft thick in the Mission subarea and more than 400 ft thick in the Kalispell subarea. Reported yields of wells completed in the deep alluvial aquifers are as much as 3,500 gpm but the median yield is 25 gpm. The Lonepine aquifer in the Little Bitterroot subarea is a unique deep alluvial aquifer, both because it is a distinct bed of sand and gravel confined by several hundred feet of overlying glacial-lake clays and because it supports many flowing artesian wells. The Lonepine aquifer is generally less than 60 ft thick but is very productive; reported well yields are as much as 1,100 gpm. The median yield from wells completed in the Lonepine aquifer is 75 gpm.

Significant hydraulic connection exists between the intermediate and deep aquifers on a valley-wide scale in both the Mission and the Kalispell subareas. Potentiometric-surface mapping indicates that in these subareas intermediate and deep aquifers constitute the main ground-water flow systems.

Bedrock (almost entirely Precambrian Belt Supergroup with minor amounts of igneous rocks) forms the mountains that frame the valleys and underlies the basin-fill deposits; it contains sufficient fracture permeability in many places to yield water to wells. However, the permeability is variable due to irregular fracture distribution and differing capabilities of the fractures to transmit water. Therefore, ground-water availability in the bedrock can be problematic; well depths and yields can vary widely across short distances. In the Flathead Lake area, reported well yields from bedrock aquifers range from less than 1 to as much as 850 gpm, with a median yield of 18 gpm. These values are generally lower than yields from the unconsolidated (shallow, intermediate, and deep alluvial) aquifers. Well depths in bedrock aquifers can be more than 2,000 ft; the median depth is 250 ft.

The bedrock has become one of the most utilized aquifers in the Flathead Lake area. Records show about 4,500 wells have been completed in it; almost half (45 percent) have been installed since 1990. Most of the bedrock wells are in the Salish Mountains, along the margins of the major valleys, and in the Flathead Lake perimeter subarea. The emergence of the bedrock as an important aquifer is a result of residential development in mountainous areas and along the valley margins. In the Kalispell and Mission subareas, where there are deep regional ground-water flow systems, the water in the bedrock is in hydraulic connection with deep alluvial aquifers and is therefore generally considered a part of, rather than separate from, the deep flow system.

## Water Levels

Water levels in wells in the Flathead Lake area typically have annual fluctuations that range from 1 to more than 20 ft. The annual fluctuations generally fall into one of three patterns:

"Runoff response," in which water levels generally are highest in the spring, decline during the summer and fall months, and reach lowest levels in winter when recharge is negligible. Many wells completed in shallow aquifers throughout the Flathead Lake area display this type of response.

"Pumping response," in which water levels drop sharply during the summer, reach seasonal lows in the late summer, and recover during the fall and winter months. Wells completed in the deep alluvial aquifers in the Kalispell, Mission, and Little Bitterroot subareas near areas of ground-water-supported irrigation display this response.

"Irrigation response," in which water levels peak in the late spring and early summer, remain elevated during the summer months while irrigation is ongoing, and drop after irrigation ceases. This response is common in shallow aquifers near irrigation canals in the Mission and Jocko subareas.

Historical water-level data from wells in the deep alluvial aquifer in the Kalispell subarea show that water-level responses changed from a runoff to a pumping pattern (both the timing and amount of water-level fluctuation changed) between 1970 and 1979. The new pattern coincides with an increased number of irrigation wells completed in the deep aquifer.

Historical water-level data from the Lonepine aquifer display a steady downward trend, showing that more water is being removed from the aquifer than is being recharged over the long term. Analysis of hydrographs for wells in other subareas shows that water levels increased markedly in most places in response to the above average precipitation in 1996–97; in places, many years of downward decline were reversed, with water levels rising more than 30 ft in less than a year. However, since 1997 water levels in the same wells have declined steadily.

Data from a few wells completed in bedrock aquifers show that water levels typically display a runoff response and are sensitive to long-term precipitation trends. Annual water-level lows have dropped by about 20 ft in most of the monitored bedrock wells since the above-average precipitation period in 1997-1998, reflecting the low storage capacities inherent to fractured bedrock aquifers.

The median water level in wells completed in bedrock aquifers is 57 ft. Fractures in bedrock commonly intersect overlying geologic materials or the land surface. Where ground water is under unconfined conditions and close to the land surface, fractured bedrock aquifers can be susceptible to surface sources of contamination. Care must be taken to properly install and maintain on-site sewage disposal systems and other potential ground-water contamination sources in the areas where fractured bedrock is near the land surface.

## Water Quality

Ground water in the Flathead Lake area is of high quality and is generally suitable for domestic consumption, crop irrigation, and most other uses. Overall, the ground water is characterized by dissolved constituents of less than 500 mg/L; the median is 349 mg/L. The major ions in solution are calcium, magnesium, and bicarbonate. Nitrate did not exceed the U.S. EPA's 10 mg/L maximum contaminant level for public drinking water supplies in any of the samples collected for this study (1993–97). However, four samples from previous investigations had nitrate concentrations greater than 10 mg/L; three of those samples were obtained from wells less than 25 ft deep that were completed in shallow aquifers (two in the Kalispell subarea, one in the Mission subarea). The remaining sample was from a 173-ft-deep well completed in bedrock near Flathead Lake, southwest of Somers. Concentrations of iron and manganese, which occur naturally in geologic materials, exceeded the secondary maximum contaminant level for public drinking water supplies in 10 to 20 percent of the samples collected for this study.

The water in the Lonepine aquifer in the Little Bitterroot subarea differs chemically from ground water in other parts of the Flathead Lake area. The dissolved-constituents concentrations are greater; the median from 49 samples was 490 mg/L. The major ions in solution are sodium and bicarbonate. The major dissolved ions in all other aquifers in that subarea are calcium and bicarbonate. Geothermal water locally enters the Lonepine aquifer from below and has been observed in many wells, notably near Wild Horse Hot Springs and the town of Hot Springs. Near the geothermal locations ground-water temperatures are elevated, water is more mineralized, and the water contains elevated concentrations of arsenic and fluoride.

Although almost all ground-water quality in the Flathead Lake study area is very high, subtle differences can be seen that reflect variations in geologic materials, variations in recharge environments, and variations in water chemistry along the ground-water flow path (Part B, maps 3, 5).

Radon in household air has been linked to lung cancer, and a minor source of the gas can be well water. The U.S. EPA estimates that less than 2 percent of radon in household air comes from radon in water. Radon samples were obtained from 35 wells as part of the Flathead Lake area ground-water characterization. In addition, radon data from 27 other wells sampled between 1992 and 1996 were used to assess background radon concentrations (appendix D). Radon concentrations in 57 of the samples (92 percent) were above the provisional U.S. EPA maximum contaminant level of 300 pCi/L proposed in 1999. The concentrations are related to aquifer materials; the median radon concentration in water samples from bedrock was 1,420 pCi/L but the median radon concentration in water from unconsolidated aquifers was 655 pCi/L.

Isotopic sampling of ground water in the Kalispell subarea indicates that tritium is not present in the deep alluvial aquifer. Tritiated water was present in wells sampled along the valley margins, mostly on the east side of the valley and in the upper part of the ground-water flow system where younger water (recent recharge) would be expected. The lack of tritium in the deep alluvial aquifer indicates that most of that water was recharged before 1953, and that the deep alluvial aquifer is reasonably well-protected from surface sources of contamination. Water with relatively enriched $\delta^{18}O$ occurs in the deep alluvial aquifer on the east side of the valley, suggesting an active flow system and recharge from the Swan Range. Water on the west side of the valley is older; it is more depleted in $\delta^{18}O$ and contains no tritium.

# Acknowledgments

Many well owners graciously allowed collection of the data necessary for this report. The Confederated Salish and Kootenai Tribes, Flathead Basin Commission, and Lake County Conservation District provided guidance and support, and the many people who collected data are gratefully acknowledged. Collection and interpretation of isotopic analyses benefited from the help of Dr. Stan Davis (University of Arizona). Richard Marvin (formerly with the MBMG and currently with the Oregon Department of Water Resources) contributed to the water budget section. Field data were collected by employees of the Confederated Salish and Kootenai Tribes and by permanent and temporary MBMG staff members, including Camela Carstarphen, Michael Richter, Donald Mason, Ginette Abdo, Carolyn Petrie, James Rose, Leonard Rinehart, J. DeOpsomer, and Ryan Bixby. Reviews by Wayne Van Voast, Richard Gibson, and Seth Makepeace improved the clarity and content of this report.

# References

Abdo, G., 1997, Reappraisal of hydrogeology of the Little Bitterroot valley, northwestern Montana: Montana Bureau of Mines and Geology Open-File Report 350, 43 p.

Alden, W.C., 1953, Physiography and glacial geology of western Montana and adjacent areas: U.S. Geological Survey Professional Paper 231, 200 p.

Aller, L., Bennett, T., Lehr, J.H., and Petty, R.J., 1985, DRASTIC: a standardized system for evaluating ground-water pollution potential using hydrogeologic settings: U.S. Environmental Protection Agency, EPA/600/2-85/018, 163 p.

Alt, D., 2001, Glacial Lake Missoula and its humongous floods: Missoula, Mont., Mountain Press, 176 p.

Boettcher, A.J., 1982, Groundwater resources in the central part of the Flathead Indian Reservation: Montana Bureau of Mines and Geology Memoir 48, 28 p.

Bowman, S., 1990, Radiocarbon dating: Berkeley, Calif., University of California Press, 64 p.

Briar, D.W., 1987, Water resource analysis of the Sullivan Flats area near Niarada, Flathead Indian Reservation, Montana: Missoula, Mont., University of Montana, M.S. thesis, 184 p.

Briar, D.W., Lawlor, S.M., Stone, M.A.J., Parliman, D.J., Schaefer, J.L., and Kendy, E., 1996, Ground-water levels of the Northern Rocky Mountains, Montana and Idaho, U.S. Geological Survey Hydrologic Investigations Atlas HA-738-B, 1 sheet, scale 1:750,000.

Clark, D.W., and Dutton, D., 1996, Quality of ground water and surface water in intermontane basins of the Northern Rocky Mountains, Montana and Idaho: U.S. Geological Survey Hydrologic Investigations Atlas HA-738-C, 1 sheet, scale 1:750,000.

Clark, I., and Fritz, P., 1997, Environmental isotopes in hydrogeology: New York, N.Y., Lewis Publishers, 328 p.

Constenius, K.N., 1981, Stratigraphy, sedimentation, and tectonic history of the Kishenehn basin, northwestern Montana: Laramie, Wyo., University of Wyoming, unpubl. M.S. thesis, 116 p.

Constenius, K.N., 1988, Structural configuration of the Kishenehn Basin delineated by geophysical methods, northwestern Montana and southeastern British Columbia: Mountain Geologist, v. 25, no. 1, p. 13–28.

Constenius, K.N., 1989, Reconnaissance paleontologic study of the Kishenehn Formation, northwestern Montana and southeastern British Columbia, *in* French, D.E., and Grabb, R.F., eds., Geologic resources of Montana: Billings, Mont., Montana Geological Society, p. 189–203.

Constenius, K.N., 1996, Late Paleogene extensional collapse of the Cordilleran foreland fold and thrust belt: Geological Society of America Bulletin, v. 108, p. 20–39.

Corbett, M.K., 1994, Groundwater monitoring in the Meadowlake Golf Course, Columbia Falls, Montana: Montana Department of Natural Resources and Conservation, unpublished report, 127 p.

Craig, H., 1961, Isotopic variations in meteoric waters: Science, v. 133, p. 1702–1703.

Crosby, G.W., 1984, Structural–geophysical interpretation of Swan valley, Montana, *in* McBane, J.D., and Garrison, P.B., eds., Northwest Montana and adjacent Canada: Billings, Mont., Montana Geological Society, p. 245–251.

Curry, R.R., Lister, J.C., and Stoffel, K., 1977, Glacial history of Flathead valley and Lake Missoula Floods, *in* Glacial geology of Flathead Valley and catastrophic drainage of Glacial Lake Missoula: Geological Society of America, Rocky Mountain Section 30th Annual Meeting, Field Guide 4, p. 14–38.

Daly, C., and Taylor, G., 1998, United States average monthly or annual precipitation, 1961–90: Water and Climate Center of the Natural Resources Conservation Service, Portland, Oregon: downloaded on 1/26/2000 from http//www.ocs.orst.edu/prism/prism_new.html.

Daly, C., Neilson, R.P., and Phillips, D.L., 1994, A statistical-topographic model for mapping climatological precipitation over mountainous terrain: Journal of Applied Meteorology, v. 33, p. 140–158.

Daly, C., Taylor, G.H., and Gibson, W.P., 1997, The PRISM approach to mapping precipitation and temperature, *in* 10th Conference on Applied Climatology: Reno, Nev., American Meteorological Society, p. 10–12.

Donovan, J.J., 1985, Hydrogeology and geothermal resources of the Little Bitterroot valley, northwestern Montana: Montana Bureau of Mines and Geology Memoir 58, 60 p.

Dreimanis, A., 1989, Tills, their genetic terminology and classification, *in* Goldthwait, R.P., and Matsch, C.L., eds., Genetic classification of glacigenic deposits: Rotterdam, The Netherlands, Balkema, p. 17–84.

Environmental Protection Agency, 1999, Radon in drinking water: questions and answers: EPA fact sheet, EPA 815-F-99-007, 4 p.

Freeze, R.A., and Cherry, J.A., 1979, Groundwater: Englewood Cliffs, N.J., Prentice-Hall, 604 p.

Gary, M., McAfee, R., and Wolf, C.L., 1972, Glossary of geology: Washington D.C., American Geological Institute, 805 p.

Harrison, J.E., Cressman, E.R., and Whipple, J.W., 1992, Geologic and structure maps of the Kalispell 1 x 2-degree quadrangle, Montana, and Alberta and British Columbia: U.S. Geological Survey Miscellaneous Investigations Series Map I-2267, scale 1:250,000.

Harrison, J.E., Griggs, A.B., and Wells, J.D., 1986, Geologic and structure maps of the Wallace 1 x 2-degree quadrangle, Montana and Idaho: U.S. Geological Survey Miscellaneous Investigations Series Map I-1509, scale 1:250,000.

Hem, J.D., 1992, Study and interpretation of the chemical characteristics of natural water (3rd ed.): U.S. Geological Survey Water-Supply Paper 2254, 263 p.

Hendry, M.J., 1988, Do isotopes have a place in ground-water studies?: Groundwater, v. 26, no. 4, p. 410–415.

Johns, W.M., 1970, Geology and mineral deposits of Lincoln and Flathead Counties, Montana: Montana Bureau of Mines and Geology Bulletin 79, 182 p.

Kendy, E., and Tresch, R.E., 1996, Geographic, geologic, and hydrologic summaries of intermontane basins of the Northern Rocky Mountains, Montana: U.S. Geological Survey Water-Resources Investigation Report 96-4025, 233 p.

Konizeski, R.L., Brietkrietz, A., and McMurtrey, R.G., 1968, Geology and ground water resources of the Kalispell valley, northwestern Montana: Montana Bureau of Mines and Geology Bulletin 68, 42 p.

Land and Water Consulting Inc., 1999, Attachment to application for beneficial water use permit, U.S. Fish and Wildlife Service Creston National Hatchery, unpublished.

Lange, I.M., and Zehner, R.E., 1992, Geologic map of the Hog Heaven volcanic field, northwestern Montana: Montana Bureau of Mines and Geology Geologic Map 53, scale 1:50,000.

LaPoint, D.J., 1971, Geology and geophysics of the southwestern Flathead Lake region, Montana: Missoula, Mont., University of Montana, M.S. thesis, 110 p.

Levish, D.R., 1997, Late Pleistocene sedimentation in Glacial Lake Missoula and revised glacial history of the Flathead Lobe of the Cordilleran ice sheet, Mission valley, Montana: Boulder, Colo., University of Colorado, Ph.D. dissertation, 191 p.

Madison, R.J., and Brunett, O.J., 1984, Overview of the occurrence of nitrate in ground water of the United States, *in* National water summary 1984—Water-quality issues: U.S. Geological Survey Water-Supply Paper 2275, p. 93–103.

Makepeace, S.V., 1989, Simulation of ground water flow in a coarse-grained alluvial aquifer in the Jocko Valley, Flathead Indian Reservation, Montana: Missoula, Mont., University of Montana, M.S. thesis, p. 155.

Makepeace, S.V., and Goldbach, W., 1994, Hydrogeologic framework for principal valley-fill aquifers: Flathead Indian Reservation, Montana: Confederated Salish and Kootenai Tribes Natural Resources Department, 13 p.

Makepeace, S.V., and Mladenich, B., 1995, Aquifer vulnerability assessment: Flathead Indian Reservation, Montana: Confederated Salish and Kootenai Tribes Natural Resources Department, 13 p., 5 pls.

McGimsey, R.G., 1985, The Purcell Lava, Glacier National Park, Montana: U.S. Geological Survey Open-File Report 85-543, 191 p.

Meinzer, O.E., 1916, Artesian water for irrigation in the Little Bitterroot Valley, Montana: U.S. Geological Survey Water-Supply Paper 400-B, 37 p.

Miller, C.R., 2003, Gravity survey, modeling and interpretation near Columbia Mountain, Flathead County, Montana, *in* Elfass, S., Norris, G., and Watters, R., eds., Bridge between theory and practice: Proceedings of the 38th Engineering Geology & Geotechnical Engineering Symposium: Reno, Nev., University of Nevada, p. 265–279.

Miller, K.M., and Coffey, M.A., 1998, Radon and you: promoting public awareness of radon in Montana's air and ground water: Montana Bureau of Mines and Geology Information Pamphlet 3, 16 p.

National Research Council, 1993, Ground water vulnerability assessment: Washington D.C., National Academy Press, 204 p.

Noble, R.A., and Stanford, J.A., 1986, Ground-water resources and water quality of unconfined aquifers in the Kalispell valley, Montana: Montana Bureau of Mines and Geology Open-File Report 177, 112 p.

Olson, T., 1998, GIS-based study of late Pleistocene glacial advance, Flathead Indian Reservation, Montana: Montana/Idaho GIS User's Group Conference Program, p. 43–44.

Pardee, J.T., 1910, The Glacial Lake Missoula, Montana: Journal of Geology, v. 18, p. 376–386.

Plummer, L.N., Michel, R.L., Thurman, E.M., and Glynn, P.D., 1993, Environmental tracers for age dating young ground water, *in* Alley, W.M., ed., Regional ground-water quality: New York, Van Nostrand Reinhold, p. 255–294.

Richmond, G.M., 1965, Glaciation of the Rocky Mountains, *in* Wright, H.E., Jr., and Frey, D.G., eds., The Quaternary of the United States: Princeton, N.J., Princeton University Press, p. 217–230.

Richmond, G.M., 1986, Tentative correlation of deposits of the Cordilleran ice-sheet in the northern Rocky Mountains: Quaternary Science Reviews, v. 5, p. 129–144.

Richmond, G.M., Fryxell, R., Neff, G.E., and Weis, P.L., 1965, The Cordilleran ice sheet of the Northern Rocky Mountains, and related Quaternary history of the Columbia Plateau, *in* Wright, H.E., Jr., and Frey, D.G., eds., The Quaternary of the United States: Princeton, N.J., Princeton University Press, p. 231–254.

Shapley, M., 1990, Analysis of Evans Farm's aquifer test east Flathead Valley: Helena, Mont., Montana Department of Natural Resources unpublished report, 26 p.

Slagle, S.E., 1988, Geohydrology of the Flathead Indian Reservation, northwestern Montana: U.S. Geological Survey Water-Resources Investigations Report 88-4142, 152 p.

Slagle, S.E., 1992, Irrigation canal leakage in the Flathead Indian Reservation, northwestern Montana: U.S. Geological Survey Water-Resources Investigations Report 92-4066, 77 p.

Smith, L.N., Blood, L., and LaFave, J.I., 2000, Quaternary geology, geomorphology, and hydrogeology of the upper Flathead valley area, Flathead County, Montana, *in* Roberts, S., and Winston, D., eds., Geologic field trips, western Montana and adjacent areas: Missoula, Mont., Rocky Mountain Section of the Geological Society of America and University of Montana, p. 41–63.

Solley, W.B., Pierce, R.R., and Perlman, H.A., 1998, Estimated use of water in the United States in 1995: U.S. Geological Survey Circular 1200, 79 p.

Stickney, M.C., 2000, Quaternary faults and seismicity in Western Montana: Montana Bureau of Mines and Geology Special Publication 114, scale 1:750,000.

Stoffel, K.L., 1980, Glacial geology of the southern Flathead valley, Montana: Missoula, Mont., University of Montana, M.S. thesis, 149 p.

Thompson, W.R., 1988, Hydrogeology of the Jocko Valley, west–central Montana: Missoula, Mont., University of Montana, M.S. thesis, 82 p.

Tuck, L.K., Briar, D.W., and Clark, D.W., 1996, Geologic history and hydrogeologic units of intermontane basins of the Northern Rocky Mountains, Montana and Idaho: U.S. Geological Survey Hydrologic Investigations Atlas HA-738-A, 2 sheets, scale 1:750,000.

U.S. Geological Survey, 2002, Historical streamflow data for the Flathead River at Perma, Montana: downloaded from http//mt.water.usgs.gov/.

Uthman, W., Waren, K., and Corbett, M., 2000, A reconnaissance groundwater investigation in the upper Flathead River valley area: Montana Bureau of Mines and Geology Open-File Report 414, 146 p.

Vrba, A., and Zoporozec, A., 1994, Guidebook on mapping groundwater vulnerability: International Association of Hydrogeologists, International Contributions to Hydrogeology, v. 16, 131 p.

Western Regional Climate Center, 2002, downloaded from http://www.wrcc.dri.edu/summary/climsmmt.html.

Winston, D., 1986, Belt Supergroup stratigraphic correlation sections, western Montana and adjacent areas: Montana Bureau of Mines and Geology Geologic Map 40.

# Glossary

## (Modified from Gary and others, 1972)

**Alluvium** Sand, gravel, outwash, silt, or clay deposited during recent geological time by a stream or other form of running water.

**Anion** See *Ion*.

**Aquifer** Geologic materials that have sufficient permeability to yield usable quantities of water to wells and springs. Spaces between the sedimentary grains (pore spaces), or openings along fractures, provide the volume (porosity) to store and transmit water within aquifers (fig. G-1). Aquifers are either *unconfined* or *confined*. The water table forms the upper surface of an *unconfined* aquifer; below the water table the pore spaces of the aquifer are completely water-saturated. A layer of low-permeability material such as clay or shale marks the upper surface of a *confined* aquifer. This low-permeability layer is called the confining unit. Below the *confining unit* the aquifer is completely saturated and the water is under pressure (fig. G-2).

**Artesian Aquifer** An artesian or confined aquifer contains water

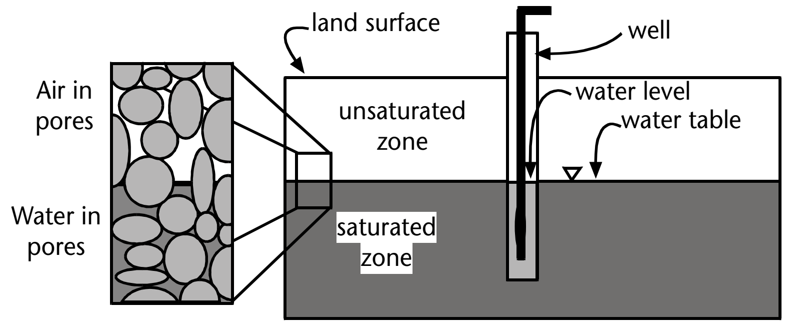



Figure G-1. In the unsaturated zone the pores (openings between grains of sand, silt, and clay and cracks within rocks) contain air and water. In the saturated zone the pores are completely filled with water. The water table is the upper surface of the saturated zone. Wells completed in unconfined aquifers are commonly referred to as water-table wells.

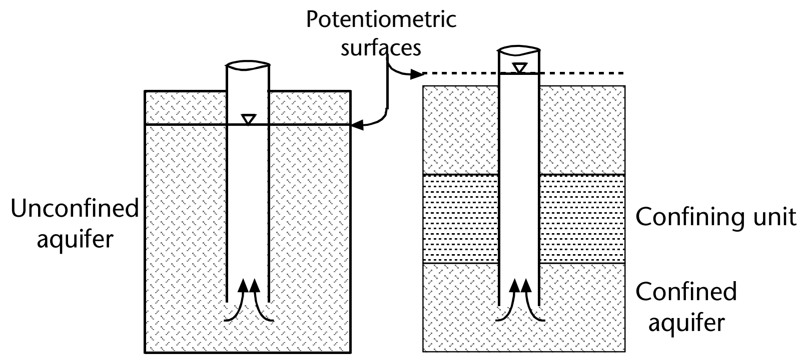



Figure G-2. In an unconfined aquifer, the water table represents a free upper surface. Therefore, water-level changes in an unconfined aquifer will increase or decrease the saturated thickness of the aquifer. In a confined aquifer, the water level in a well will rise to the potentiometric surface, above the top of the aquifer. Water-level changes in a confined aquifer do not change the saturated thickness.

## Aquifer Sensitivity

Aquifer sensitivity describes the potential for an aquifer to be contaminated based on its intrinsic geologic and hydrogeologic characteristics; it is a measure of the relative quickness and ease with which a contaminant from near the land surface could infiltrate to an aquifer of interest (usually the uppermost aquifer). The faster and more easily water moves from the land surface to the aquifer, the more sensitive the aquifer is to potential contamination. Recognition of potentially sensitive ground-water areas is a critical first step in action to prevent ground-water contamination. Preventing contamination is less costly and easier than cleaning up contamination after it occurs.

Some primary factors useful in assessing aquifer sensitivity are the depth below land surface and the permeability of overlying geologic materials. Land areas characterized by high permeability, rapid infiltration, and a shallow water-table aquifer are more sensitive than others. High-permeability materials include alluvium, outwash, and sandy soils. Poorly drained soils and/or low-permeability material at the land surface will restrict infiltration of water and any associated contamination, protecting underlying aquifers. Sensitivity in these areas is lower. Also, a deep water table affords more of an opportunity for contaminants to be naturally filtered before reaching ground water. This atlas offers several tools to assist in making relative judgments of sensitivity. Descriptions of surficial geologic materials can be found on the geologic plates. Distance to water (top of the aquifer) can be estimated from the potentiometric surface maps and topographic maps.

This method of evaluating sensitivity provides an assessment that addresses the relative potential for contamination of ground water. However, factors affecting aquifer sensitivity commonly vary considerably over short distances and the accuracy of any assessment will depend on the amount and quality of available data. Projects that require precise resolution of aquifer sensitivity will require site-specific investigation. For more detailed discussions and procedures concerning aquifer sensitivity see Aller and others (1985), National Research Council (1993), and Vrba and Zoporozec (1994).

that is under pressure. To be classified as artesian, the pressure must be adequate to cause the water level in a well to rise above the top of the aquifer (fig. G-2). Flowing wells, or flowing artesian conditions, occur in areas where the potentiometric surface is higher than the land surface (fig. G-3).

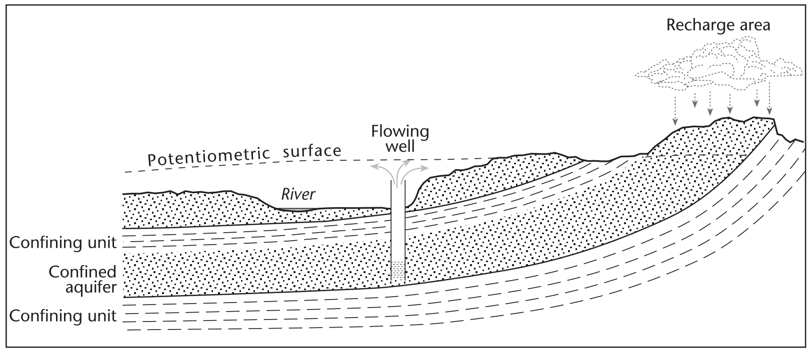



Figure G-3. Artesian conditions develop in confined aquifers when the aquifer, overlain by a low-permeability unit, dips or tilts away from its recharge area. Water percolates down to the water table in the recharge area and moves beneath the confining unit. The artesian pressure is caused by the difference in the level of the water table in the recharge area and at the top of the aquifer. Flowing wells, or flowing artesian conditions, occur in areas where the potentiometric surface is higher than the land surface.

**Bedrock** A general term for consolidated geologic material (rock) that underlies soil or other unconsolidated material.

**Carbon-14** A naturally occurring radioactive isotope of carbon, denoted as $^{14}C$, with a half-life of 5,730 yr. Carbon-14, with six protons and eight neutrons, is heavy compared with the most common isotope of carbon ($^{12}C$). See *Environmental Isotopes*.

**Cation** See *Ion*.

**Cone of Depression** See *Well Hydraulics*.

**Confined Aquifer** See *Aquifer*.

**Cumulative Departure** Cumulative departure from average precipitation is calculated by determining the cumulative difference between the measured precipitation for a month and the average precipitation for that month for the entire period of record. Increasing (positive) cumulative departure indicates periods of greater than average monthly precipitation.

**Deuterium** A stable isotope of hydrogen, with one neutron and one proton, denoted as D or $^{2}H$. Deuterium has approximately twice the mass of the most common isotope of hydrogen, protium ($^{1}H$). See *Environmental Isotopes*.

**Discharge Area** An area where ground water is released from an aquifer, generally characterized by water moving toward the land surface. Springs or *gaining streams* (fig. G-4) may occur in ground-water discharge areas.

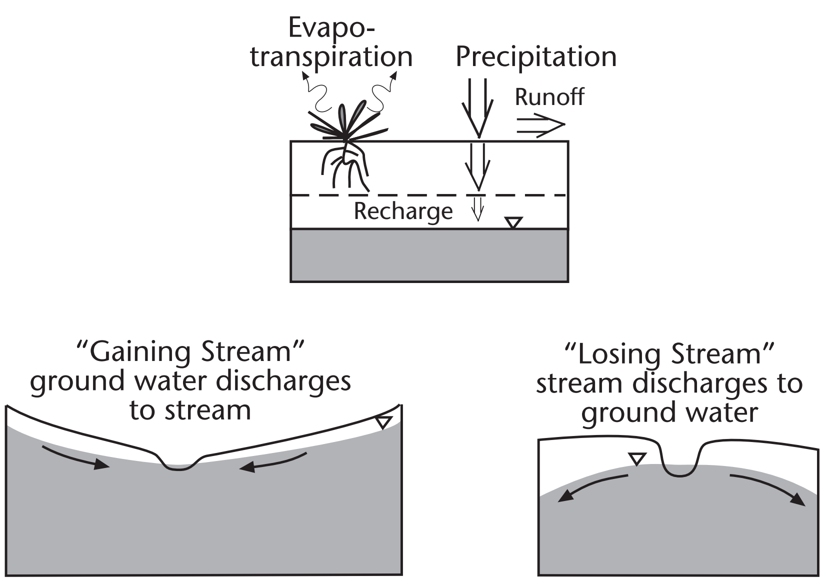



Figure G-4. Water that percolates through the unsaturated zone to the water table is said to recharge an aquifer. Recharge can also occur from surface water bodies (losing streams) where the water levels are higher than those in neighboring aquifers. In contrast, in a gaining stream water levels in the aquifer are above those in the stream and flow is maintained by ground-water discharge.

**Environmental Isotopes** Globally distributed isotopes that occur in nature are called environmental isotopes. See related sidebar.

**Flow System** The aquifers and confining beds that control the flow of ground water from a recharge area to a discharge area constitute a ground-water flow system (fig. G-3). Ground water flows through aquifers from recharge areas, which commonly coincide with areas of high topography, to discharge areas in the topographically low areas. The relative length and duration of the ground-water flow paths are used to classify ground-water systems. A regional system generally consists of deep ground-water circulation between the highest

## Environmental Isotopes

Isotopes of hydrogen, oxygen, and carbon in ground water can provide insight into hydrologic processes and provide independent confirmation of interpretations of ground-water flow made from other hydrologic and chemical data. Isotopic data can also help estimate the age of ground water.

**Tritium** Tritium is a naturally occurring radioactive isotope of hydrogen that has a half-life of 12.43 yr. It is produced in the upper atmosphere where it is incorporated into water molecules and, therefore, is present in precipitation and water that recharges aquifers. Concentrations of tritium are measured in tritium units (TU), where one TU is equal to one tritium atom in $10^{18}$ atoms of hydrogen. Before the atmospheric testing of nuclear weapons began in 1952, natural concentrations of tritium in precipitation were 2 to 8 TU (Plummer and others, 1993). Atmospheric testing of nuclear weapons between 1952 and 1963 released large amounts of tritium into the atmosphere, overwhelming the natural production of tritium; in North America tritium concentrations in precipitation peaked at several thousand TU in 1963–64 (Hendry, 1988). Because of its short half-life, bomb-derived tritium is an ideal marker of recent (post-1952) ground-water recharge. Ground water recharged by precipitation before 1952 will have tritium concentrations reduced because of radioactive decay to less than 1.0 TU, which is at or below the analytical detection limit. Therefore, a ground-water sample with detectable tritium (>0.8 TU) includes water that must have been recharged since 1952 and would be considered "modern." Tritium-free ground water implies recharge before 1952 and is considered "sub-modern" or "older" (Clark and Fritz, 1997).

**Oxygen and Hydrogen Isotopes** Variations in the stable isotopic ratios of oxygen ($^{18}O/^{16}O$) and hydrogen ($^{2}H/^{1}H$) can be useful in assessing or identifying ground-water recharge areas. Concentrations of each isotope are reported as delta (δ) values in per mil (parts per thousand) relative to a standard known as Vienna Standard Mean Ocean Water (VSMOW). These values are denoted as $\delta^{18}O$ and δD for oxygen and hydrogen, respectively. A positive delta value means that the sample contains more of the isotope than the standard; a negative value means that the sample contains less of the isotope than the standard.

When water evaporates from the ocean, the water vapor will be depleted in oxygen-18 ($^{18}O$) and hydrogen-2 [or deuterium (D)] compared with the ocean water because molecules of the lighter isotopes (oxygen-16 and hydrogen-1) evaporate more readily than molecules containing the heavier isotopes. As air masses are transported away from the oceans the isotopic character of the water vapor will sequentially change because of condensation, freezing, melting, and evaporation of molecules of the different isotopes. The two main factors that affect isotopic content of precipitation are the condensation temperature and how much water has already condensed from the initial water in the air mass. The isotopic composition of water that condenses at cooler temperatures (commonly associated with higher altitudes, higher latitudes, or cooler climatic conditions) is lighter than water that condenses at warmer temperatures (commonly associated with lower altitudes, lower latitudes, or warmer climatic conditions). Therefore, at a given locality the $\delta^{18}O$ and δD in the precipitation will depend on factors such as distance from the ocean, altitude, and temperature. Because the isotopic composition of ground water generally reflects the average isotopic composition of precipitation in a recharge area, spatial and temporal variations in the isotopic content of precipitation can be useful in evaluating ground-water recharge sources. Craig (1961) observed another useful relationship, that values of $\delta^{18}O$ and δD of precipitation from around the world plot linearly along a line known as the global meteoric water line (fig. G-5). Ground water that originates as precipitation should also plot along the global meteoric water line. The departure of $\delta^{18}O$ and δD values from the meteoric water line may suggest that the water has been subject to evaporation or geothermal processes. Oxygen-18 and deuterium can be used to help delineate different sources of water to a ground-water flow system.

**Carbon** Carbon-14 is a naturally occurring radioactive isotope of carbon (C) produced in the upper atmosphere, with a half-life of 5,730 yr. Carbon atoms (99 percent are carbon-12 and the remaining atoms are carbon-13 and carbon-14) combine with oxygen to form carbon dioxide ($CO_2$) which cycles throughout the atmosphere and biosphere. A dynamic equilibrium between the formation and decay of carbon-14 results in a constant amount of carbon-14 in the atmosphere and biosphere.

Recharge waters dissolve atmospheric $CO_2$ present in the soil-zone $CO_2$, and move it through the unsaturated zone. As ground water moves below the water table and is cut off from soil-zone $CO_2$, no new carbon-14 can be added to the water. The radioactive carbon at this point in the system is part of the carbonate and bicarbonate anions that are in solution. Radioactive decay will cause the carbon-14 content of the carbon in these anions to decline at a known rate. The basic principle of carbon-14 dating of ground water is to measure the carbon-14 activity in the dissolved inorganic carbon ($HCO_3^-$ and $CO_3^{2-}$ ) and relate that activity to an age using the radioactive decay law. If soil-zone $CO_2$ were, in fact, the only source of dissolved inorganic carbon in ground water, then the technique could be used to assign accurate numerical dates (ages) to the water. Unfortunately, other processes add old, non-radioactive carbon to ground water, such as dissolution of carbonate minerals where the carbon has been locked up in molecules remote from the atmosphere for long periods. The added "dead carbon" dilutes the concentration of carbon-14, increasing the apparent ground-water age. However, measured values of carbon-14 can still convey significant information about relative ground-water ages between pairs of samples along flow paths. Carbon-14 is measured as percent modern carbon (PMC) relative to a 1950 standard (Bowman, 1990); water with a higher PMC value would be younger than water with lower PMC values.

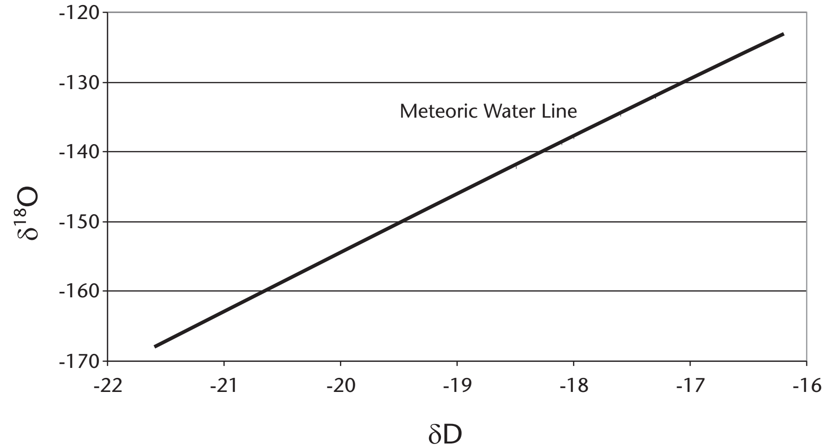



Figure G-5. Values of δ18O and δD in precipitation from around the world plot linearly along a line known as the global meteoric water line (Craig, 1961). Ground water that originates as precipitation should also plot along the global meteoric water line.

surface drainage divides and the largest river valleys. Local and intermediate flow systems consist of shallow ground-water flow between adjacent recharge and discharge areas superimposed on or within a regional flow system.

**Ground Water** Strictly speaking, all water below land surface is "ground water." The water table defines the boundary between the unsaturated (air in pores) and saturated (water in pores) zones (fig. G-1). It is the water from saturated zones that supplies water to wells (and springs) that is called ground water in this atlas.

**GWIC** Ground Water Information Center—repository for water-well logs and ground-water information at the Montana Bureau of Mines and Geology, http://mbmggwic.mtech.edu; 1300 W. Park St., Butte, MT 59701; (406) 496-4336; E-mail: GWIC@mtech.edu.

**Hydraulic Conductivity** Measure of the rate at which water is transmitted through a unit cross-sectional area of an aquifer under a unit gradient; commonly called *permeability*. The higher the hydraulic conductivity (the more permeable the materials) of the aquifer, the higher the well yields will be. The hydraulic conductivity of geologic material ranges over 14 orders of magnitude (fig. G-6).

**Hydrologic Cycle** The constant circulation of water between the ocean, atmosphere, and land is called the hydrologic cycle. The notion of the hydrologic cycle provides a framework for understanding the occurrence and distribution of water on the earth. The important features of the hydrologic cycle are highlighted in fig. G-7. The hydrologic cycle is a natural system powered by the sun and is quantified by the hydrologic budget. Evaporation from the ocean and other surface bodies of water and shallow ground water, and transpiration from plants, bring "clean" water (because most dissolved constituents are left behind) into the atmosphere where clouds may form. The clouds return water to the land and ocean as precipitation (rain, snow, sleet, and hail). The precipitation may subsequently follow many

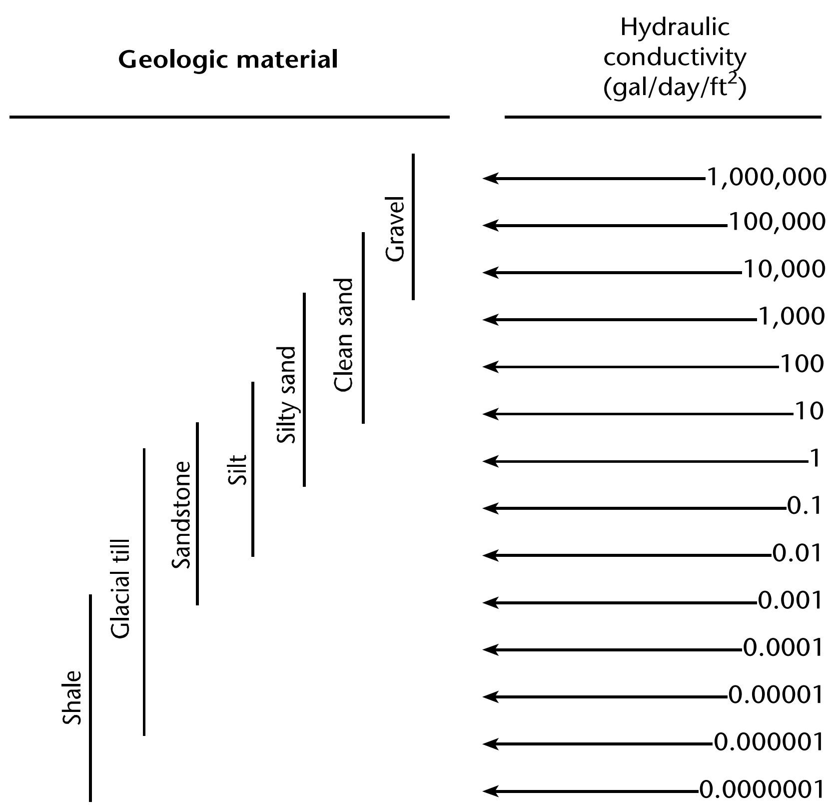



Figure G-6. The range of hydraulic conductivity values for typical geologic materials ranges over several orders of magnitude. Hydraulic conductivities not only differ in different rock types but may also be different from place to place in the same rock (modified from Freeze and Cherry, 1979).

## Major Ions and Constituents

The major cations ($Na^+$, $K^+$, $Ca^{2+}$, $Mg^{2+}$, $Fe^{2+}$, and $Mn^{2+}$) and anions ($HCO_3^-$, $CO_3^{2-}$, $SO_4^{2-}$, $Cl^-$, $NO_3^-$, $F^-$, and $SiO_3^-$) derived from soil and rock make up most of the dissolved materials in ground water.

**Bicarbonate** ($HCO_3^-$) and **carbonate** ($CO_3^{2-}$) occur naturally; bicarbonate is the dominant anion in ground water. Bicarbonate and carbonate are typically derived from dissolution of common carbonate minerals such as calcite and dolomite. Carbonate will only be present as a parameter in ground water when the water's pH is greater than about 8.3.

**Sulfate** ($SO_4^{2-}$) is dissolved from rocks and soils containing gypsum, iron sulfides, and other sulfur compounds. Sulfate can be present in some industrial wastes.

**Chloride** ($Cl^-$) occurs in rocks and soils and is easily dissolved from those sources. It is also present in sewage and is found in natural and industrial brines.

**Fluoride** ($F^-$) is dissolved in low concentrations from most rocks and soils. Elevated concentrations are found in some formations and near hot and warm springs where ground water can contain more than the recommended concentration of fluoride.

**Silica**, by convention, is represented by the oxide $SiO_2$. Dissolved silica is generally derived from the breakdown of quartz and other silicate minerals, which form the bulk of the grains in most sand and gravel deposits (Hem, 1992).

**Sodium** ($Na^+$) and potassium ($K^+$) are metals present in many feldspar and clay minerals that occur in alluvial and glacial deposits. Sodium in water may also be associated with septic effluent, road salt, and industrial discharges. When combined with chloride in water, sodium may impart a salty taste.

**Calcium** ($Ca^{2+}$) and **magnesium** ($Mg^{2+}$) are metals that are also commonly dissolved in natural water. Calcium and magnesium are typically derived from dissolution of common carbonate minerals such as calcite and dolomite. Magnesium is chemically similar to calcium and is found in dolomite and in ferro-magnesian minerals common in metamorphic rocks. Calcium and magnesium have no health standards and elevated concentrations do not pose health risks. However, calcium, magnesium, and bicarbonate contribute to the hardness of water.

**Iron** ($Fe^{2+}$) and **manganese** ($Mn^{2+}$) are essential to plants and animals, but may cause unpleasant taste and odor in water and staining of plumbing fixtures, clothing, or buildings sprayed by irrigation water. Primary sources of iron and manganese in ground water are the dissolution of iron-bearing minerals in aquifers. Iron concentrations in well water may also be increased by corrosion of steel well casings and by bacterial activity in and around well screens or perforations.

**Nitrate** Nitrate ($NO_3^-$) is an essential nutrient for plant life, yet it is a potentially toxic pollutant when present in drinking water at excessive concentrations. Pregnant women and infants less than 1 yr of age are most commonly at risk from nitrate poisoning if they ingest water with nitrate concentrations more than 10 mg/L (as N). Nitrate poisoning can result in methemoglobinemia, or "blue-baby" syndrome, in which the ability of the individual's blood supply to carry oxygen is reduced to the point that suffocation can occur.

Nitrate has natural and human-related sources. However, where nitrate contamination of ground water has been identified, it is usually related to a known or suspected surface-nitrogen source (Madison and Brunett, 1984). It can occur naturally in ground water through the interaction of recharging water with atmospheric nitrogen (nitrogen fixation). It also can be derived from nitrogen-rich geologic deposits (generally marine-deposited shales). Significant human sources of nitrate to ground water include septic systems, agricultural activities (fertilizers, irrigation, dry land farming, livestock wastes), land disposal of wastes, and industrial wastes.

**Dissolved constituents** The amount of dissolved matter in water is commonly reported either as "total dissolved solids" (TDS), the "sum of dissolved constituents," or simply "dissolved constituents." The dissolved constituents are the sum of the major cations (Na, K, Ca, Mg, Fe, and Mn) and anions ($HCO_3$, $CO_3$, $SO_4$, Cl, $SiO_3$, $NO_3$, and F) expressed in milligrams per liter. Dissolved constituents in ground water are a result of the initial chemistry of the recharge water and subsequent interactions of that water with soils and aquifer materials. The total concentration of dissolved matter provides a general indicator of water quality—the lower the total concentration the better the water quality.

Reported values of dissolved constituents differ slightly from reported values of TDS. Total dissolved solids were traditionally measured by weighing the residue remaining after evaporating a known volume of water. However, during evaporation about half the bicarbonate ($HCO_3^-$) was converted to carbon dioxide gas ($CO_2$) which escaped to the atmosphere and did not appear in the residue (Hem, 1992). Therefore, TDS underestimates total dissolved-ion concentration in solution, especially where bicarbonate concentrations are high. For this report the actual concentrations reported for the major constituents are summed and reported as dissolved constituents (rather than TDS), giving a more accurate measure of the total ions in solution. Typically, water does not become too salty to drink until the concentration of dissolved constituents reaches about 2,000 mg/L.

Laboratory measured dissolved-constituents concentrations can be supplemented by estimating dissolved-constituents concentrations from field measurements of specific conductance made during visits to wells. Hem (1992) showed that dissolved constituents (DC) can be estimated from specific conductance (SC) according to the relationship: $DC = A \times SC$, where A is a constant. Based on a straight-line regression between field conductances and laboratory dissolved-constituents values for samples collected in the Flathead Lake area, $A = 0.92$. Specific conductance data are more commonly collected than samples for analyses, and the dissolved-constituents concentrations estimated from the SC data can also be used to better understand the spatial distribution of water quality.

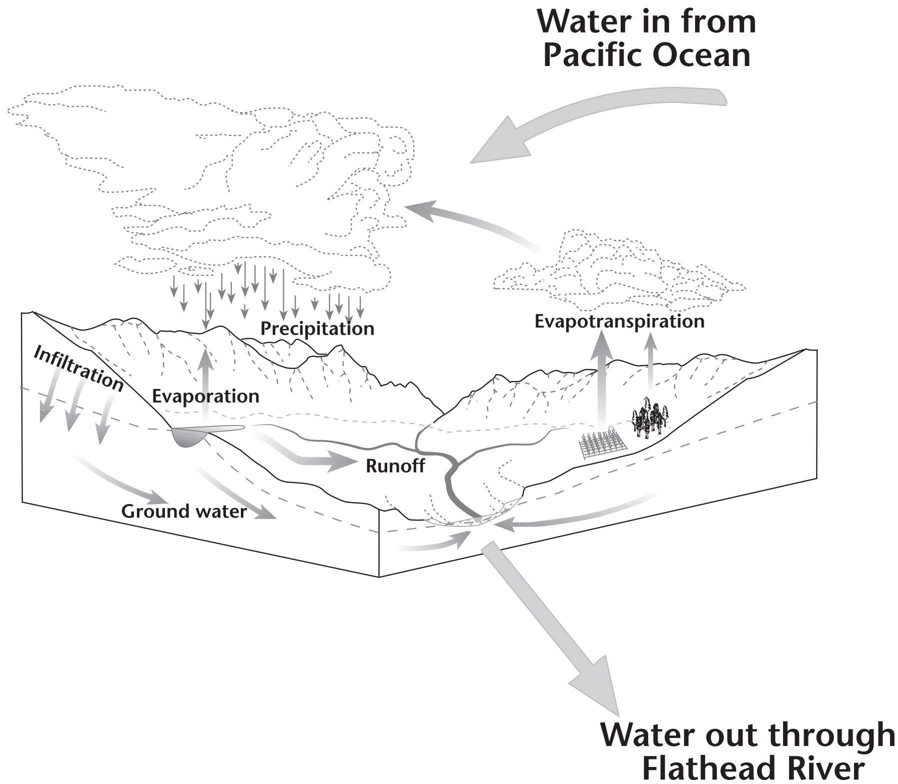



Figure G-7. The constant circulation of water between the ocean, atmosphere, and land is referred to as the hydrologic cycle. In the Flathead Lake area, most of the precipitation that enters the area is returned to the atmosphere by evaporation and evapotranspiration.

by plants, evaporate, infiltrate the ground surface, or run off (overland flow). The water that infiltrates the ground contributes to the ground water part of the cycle, a small but critical item in the hydrologic budget. Ground water flows through the earth until it discharges to a surface-water body (stream, spring, lake, or ocean), or is evaporated, or transpired. Runoff occurs when the rate of infiltration is exceeded. This water contributes directly to streams, lakes, or other bodies of surface water. Water reaching streams flows to the ocean where it is available for evaporation again, perpetuating the cycle.

**Hydrologic Unit** A body of geologic materials that function regionally as a water-yielding unit.

**Ion** An atom or group of atoms that carries a positive (cation) or negative (anion) electric charge. Atoms in liquid solutions are typically ions; these atoms are said to have been *ionized*.

**Isotopes** Atoms of the same element that differ in mass because of differing numbers of neutrons in their nuclei. Although isotopes of the same substance have most of the same chemical properties, their different atomic weights allow them to be separated. For example, oxygen-18 is heavier than oxygen-16, so water molecules containing oxygen-16 evaporate from a water body at a greater rate. See *Environmental Isotopes*.

**Nitrate** A mineral compound described by the anionic structure of $NO_3^-$ that is soluble in water and stable in oxidized environments. Common analysis of the concentration is reported as milligrams per liter of nitrogen (N). Common sources of nitrate are decaying organic matter, sewage, natural nitrate in soil, and fertilizers. See related sidebar.

**Overdraft** Long-term withdrawal of water at rates greater than long-term recharge.

**Oxygen-18** A stable isotope of oxygen, denoted as $^{18}O$, with 8 protons and 10 neutrons. Oxygen-18 is heavy compared with the common isotope of oxygen ($^{16}O$). See *Environmental Isotopes*.

**Permeability** The capacity of a geologic material to transmit fluid (water in this report); also called *hydraulic conductivity*.

**Potentiometric Surface** A surface defined by the level to which water will rise in tightly cased wells (figs. G-1, G-2). The water table is a potentiometric surface for an unconfined aquifer.

**Radioactive Half-Life** The time over which half of a radioactive material (a parent) decays to another elementary material (a daughter product).

**Radon** Radon is a colorless, odorless gas produced by the radioactive decay of uranium found naturally in rocks and soil, and has been linked to lung cancer in humans (EPA, 1999). Radon in indoor air poses a health risk and accumulates by seepage into a structure from the soil and rock beneath its foundation. Water that contains radon is also a source of radon in indoor air, but the U.S. EPA estimates that radon released from drinking water accounts for less than 2 percent of that in indoor air. Currently no drinking water standard for radon exists. However, the U.S. EPA has proposed a 300 picoCuries per liter (pCi/L) MCL for community water systems, and an alternative 4,000 pCi/L MCL for community systems that have a U.S. EPA-approved Multimedia Mitigation Program (EPA, 1999). The proposed MCLs for radon will not apply to private wells.

**Recharge Area** An area where an aquifer receives water, characterized by movement of water downward into deeper parts of an aquifer (fig. G-3).

**Sediment** Solid fragments of rocks deposited in layers on the Earth's surface. Commonly classified by grain size (clay, silt, sand, gravel) and mineral composition (e.g., quartz, carbonate, etc.).

**Storativity** The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head. In an unconfined aquifer the storativity is nearly equivalent to how much water a mass of saturated geologic material will yield by gravity drainage.

**Sum of Dissolved Constituents** The quantity of dissolved material in a sample of water expressed as milligrams per liter. The value is calculated by summation of the measured constituents, which include major cations ($Na^+$, $K^+$, $Ca^{2+}$, $Mg^{9+}$, $Fe^{2+}$, and $Mn^{2+}$) and anions ($HCO_3^-$, $CO_3^{2-}$, $SO_4^{2-}$, $Cl^-$, $NO_3^-$, $F^-$, and $SiO_3^-$) expressed in milligrams per liter. *See Dissolved Constituents.*

**Surface Water** Water at the earth's surface, including snow, ice, and water in lakes, rivers, streams, and oceans.

**Transmissivity** The rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient.

**Tritium** A naturally occurring radioactive isotope of hydrogen, denoted as $^3H$, with a half-life of 12.43 yr. Tritium, with 1 proton and 2 neutrons, has approximately three times the mass of the most common isotope of hydrogen, protium ($^1H$). See *Environmental Isotopes.*

**Unconfined Aquifer** See *Aquifer.*

**Unconsolidated** Sediment that is not generally cemented or otherwise bound together.

**Unsaturated Zone** The subsurface volume above the water table where the pores are filled by air or partly by water and partly by air (see fig. G-1).

**Water Quality** The fitness of water for use, affected by physical and chemical factors. See related sidebar on *Major Ions and Constituents.*

**Water Table** The upper surface of the saturated zone, often the surface of an unconfined aquifer; occurs where the pressure of the water is equal to atmospheric pressure. Below the water table the pore spaces are completely saturated.

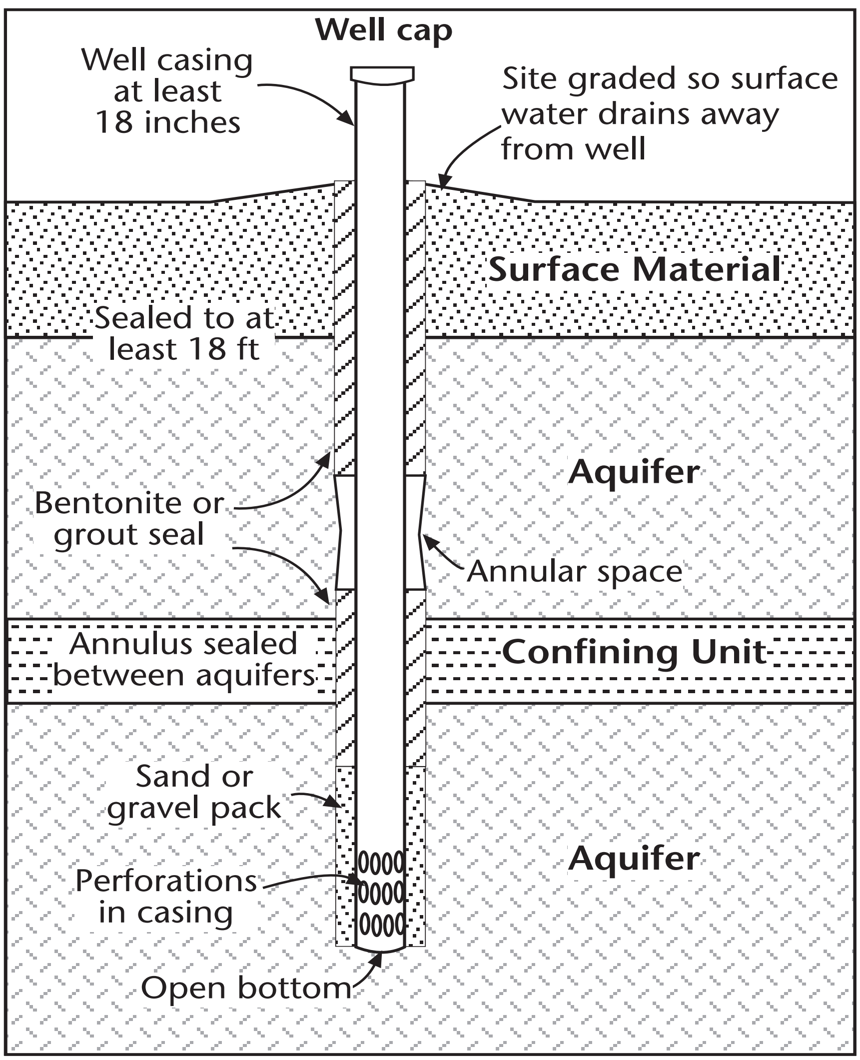



Figure G-8. Properly constructed wells are completed in single aquifers. In order to protect ground-water quality and maintain artesian pressures, wells should not serve as conduits from the surface to ground water or connect separate aquifers.

**Well** A hole drilled or dug to produce ground water or to monitor ground-water levels or quality. A properly designed production well—for domestic, stock-watering or municipal purposes—should produce good-quality, sand-free water with proper protection from contamination. The basic elements of a properly constructed well are shown in fig. G-8.

**Well Hydraulics** The withdrawal of water from a well causes the water level within the well to drop below the static water level in the producing aquifer. The lowering of the water level in the well induces ground water to move from the aquifer to the well. As pumping continues, the water levels in the well and the producing aquifer continue to decline until the rate of inflow equals the rate of withdrawal. The radial decline in the water level of a producing aquifer in response to pumping is called the *cone of depression*; the limit of the cone of depression is called the *zone of influence*. The geographic area containing ground water that flows toward the well is the *zone of capture*.

**Wellhead Protection Area** Zone around a public water supply that is managed to prevent contamination of the water supply. The area typically is delineated based on geologic and hydraulic factors and includes the zone of capture within about a mile of the well (fig. G-9).

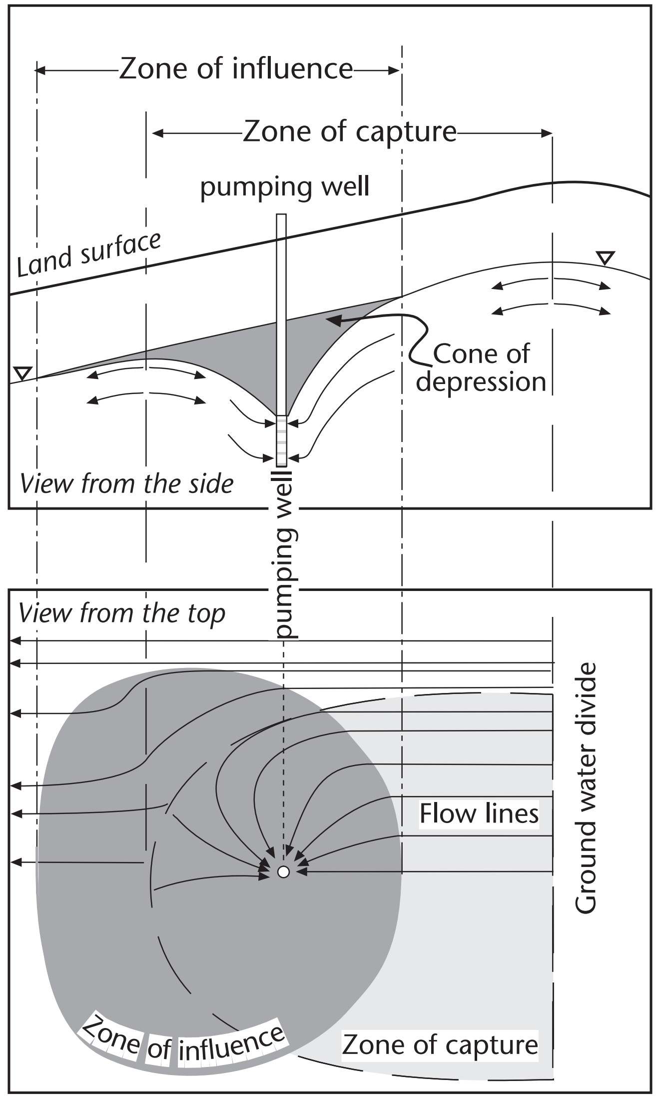



Figure G-9. Withdrawal of ground water will temporarily depress the water level (potentiometric surface) in the region surrounding the well, creating a "cone of depression." The dimensions of the cone of depression, zone of influence, and zone of contribution depend on hydraulic characteristics of the aquifer, potentiometric surface, and discharge rate of the well.

# Appendix A

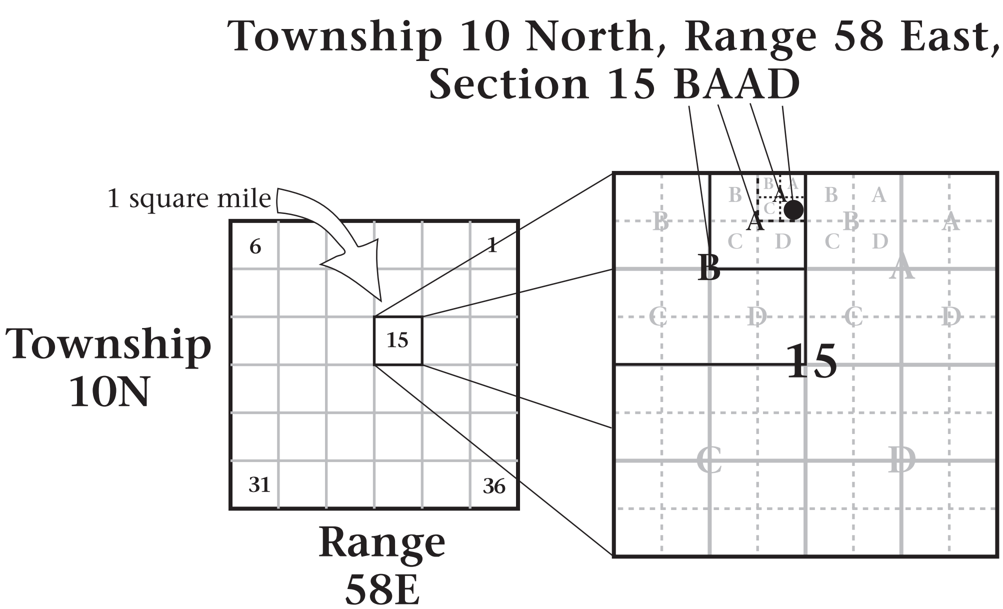
## How to locate a well on a map using GWIC locations

GWIC locations are read from left to right, largest tract to smallest, which is the opposite of legal land descriptions.

GWIC description: 10N 58E 15 BAAD

Legal land description: SE¼ NE¼ NE¼ NW¼ Sec 15 T10N R58E

For example: to find a well located in 10N 58E 15 BAAD, read the tract designations from left to right, largest tract to smallest tract.



Appendix B. Summary of aquifer tests

| Site No. | Town-ship | Range | Sec. | Tract | Longitude | Latitude | Aquifer | Hydro Unit | Total Depth | Perf. From | Perf. To | Transmis-sivity ($ft^2$/day) | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Kalispell subarea | | | | | | |
| 87935 | 31N | 21W | 28 | CC | -114.3022 | 48.4161 | 112ALVM | deep | 246 | | | 74 | Konizeski and others (1968) |
| 125958 | 30N | 20W | 6 | CAD | -114.2090 | 48.3896 | 112VFAL | deep | 743 | 570 | 604 | 160 | Corbett (1994) |
| 85576 | 30N | 20W | 18 | ABAC | -114.2041 | 48.3694 | 112ALVM | deep | 231 | 196 | 221 | 21,200 | Corbett (1994) |
| 134294 | 30N | 20W | 17 | BCC | -114.1957 | 48.3642 | 112ALVM | deep | 304 | 232 | 266 | 30,800 | Corbett (1994) |
| 83862 | 29N | 21W | 4 | DBDA | -114.2705 | 48.3030 | 111ALVM | shallow | 17 | | | 174,200 | Konizeski and others (1968) |
| 702973 | 29N | 21W | 11 | BC | -114.2341 | 48.2963 | 111ALVM | shallow | 19 | | | 174,200 | Konizeski and others (1968) |
| 83491 | 29N | 20W | 7 | CAAB | -114.2092 | 48.2896 | 112VFAL | deep | 454 | 203 | 449* | 17,480 | Shaply (1990) |
| 703040 | 29N | 22W | 17 | DD | -114.4188 | 48.2713 | 111ALVM | shallow | 22 | | | 76,400 | Konizeski and others (1968) |
| 703041 | 29N | 22W | 21 | BB | -114.4133 | 48.2675 | 111ALVM | shallow | 22 | | | 107,200 | Konizeski and others (1968) |
| 702927 | 29N | 20W | 20 | AB | -114.1827 | 48.2672 | 112ALVM | deep | 142 | | | 110 | Konizeski and others (1968) |
| 890685 | 29N | 20W | 29 | BABB | -114.1902 | 48.2545 | 112VFAL | deep | 690 | 591 | 691 | 17,300 | Shaply (1990) |
| 702928 | 29N | 20W | 20 | CA | -114.2561 | 48.2275 | 112TILL | interm. | 100 | | | 510 | Konizeski and others (1968) |
| 81901 | 28N | 21W | 1 | CA | -114.2141 | 48.2169 | 112ALVM | deep | 110 | | | 48 | Konizeski and others (1968) |
| 82268 | 28N | 21W | 12 | AC | -114.2088 | 48.2061 | 112ALVM | deep | 264 | 248 | 262 | 455 | Konizeski and others (1968) |
| 186049 | 28N | 20W | 10 | DDAC | -114.1167 | 48.1986 | 112ALVM | deep | 198 | 181 | 191 | 16,000 | Land and Water (1999) |
| 81774 | 28N | 20W | 16 | AD | -114.1386 | 48.1913 | 112DRFT | interm. | 163 | | | 375 | Konizeski and others (1968) |
| 6416 | 28N | 20W | 32 | BBBD | -114.1769 | 48.1519 | 111ALVM | shallow | 23 | 15 | 20 | 1 | Noble and Stanford (1986) |
| 6417 | 28N | 20W | 32 | DDDD | -114.1580 | 48.1394 | 111ALVM | shallow | 23 | 15 | 20 | 4 | Noble and Stanford (1986) |
| 6386 | 27N | 20W | 7 | DDDD | -114.1802 | 48.1102 | 111ALVM | shallow | 20 | 15 | 20 | 2800 | Noble and Stanford (1986) |
| 6390 | 27N | 20W | 19 | ABBB | -114.1887 | 48.0953 | 111ALVM | shallow | 20 | 15 | 20 | 3700 | Noble and Stanford (1986) |
| | | | | | | | Mission subarea | | | | | | |
| 6024 | 18N | 19W | 28 | CCDB | -114.0294 | 47.2844 | 112OTSH | shallow | 147 | 142 | 147 | 43,600 | Slagle (1988) |
| 6034 | 18N | 21W | 4 | BCDA | -114.2833 | 47.3502 | 112OTSH | shallow | 124 | 103 | 124 | 270 | Slagle (1988) |
| 6035 | 18N | 21W | 5 | ADCB | -114.2925 | 47.3500 | 112ALVM | deep | 320 | 175 | 187 | 42,000* | Slagle (1988) |
| 6050 | 19N | 20W | 30 | BABC | -114.1961 | 47.3827 | 112LKML | interm. | 31 | | | 0.12 | Slagle (1992) |
| 6064 | 19N | 21W | 31 | ADC | -114.3127 | 47.3650 | 112OTSH | shallow | 165 | | | 10,000 | Boettcher (1982) |
| 6066 | 19N | 21W | 31 | DAB | -114.3125 | 47.3622 | 112OTSH | shallow | 189 | | | 13,000 | Boettcher (1982) |
| 6079 | 20N | 20W | 2 | AAC | -114.1002 | 47.5266 | 112DRFT | interm. | 550 | | | 2,100 | Boettcher (1982) |
| 6143 | 21N | 22W | 36 | BDCC | -114.3625 | 47.5380 | 112LKML | interm. | 99 | | | 87 | Slagle (1988) |
| 6202 | 22N | 20W | 2 | CBD | -114.1302 | 47.6941 | 112ALVM | deep | 525 | | | 3,400 | Boettcher (1982) |

*Test average: represents average value from multiple analytical methods.

Appendix B—*Continued.*

| Site No. | Town-ship | Range | Sec. | Tract | Longitude | Latitude | Aquifer | Hydro Unit | Total Depth | Perf. From | Perf. To | Transmis-sivity (ft²/day) | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6268 | 23N | 20W | 29 | BABB | -114.1925 | 47.7327 | 112ALVM | deep | 156 | | | 42* | Boettcher (1982) |
| 76048 | 21N | 20W | 24 | CAAA | -114.1019 | 47.5658 | 112LKML | interm. | 300 | | | 22,000 | Boettcher (1982) |
| 128071 | 21N | 22W | 36 | BDCC | -114.3625 | 47.5380 | 112LKML | interm. | 103 | | | 340 | Slagle (1988) |
| 703278 | 20N | 21W | 25 | CDBD | -114.2161 | 47.4591 | 112LKML | interm. | 27 | site average* | | 0.83 | Slagle (1992) |
| 77923 | 23N | 21W | 23 | CDC | -114.2575 | 47.7336 | 400RVLL | Belt | 301 | 143 | 149 | 2,300 | Boettcher (1982) |
| | | | | | | | Jocko subarea | | | | | | |
| 703174 | 16N | 19W | 8 | DCAA | -114.0227 | 47.1563 | 112OTSH | shallow | 25 | site average* | | 20 | Slagle (1992) |
| | | | | | | | Little Bitterroot subarea | | | | | | |
| 6321 | 24N | 24W | 27 | ABDB | -114.6538 | 47.8166 | 120SDMS | Tertiary | 217 | 157 | 177 | 3.2 | Slagle (1988) |
| 6320 | 24N | 24W | 25 | DADB | -114.6061 | 47.8088 | 112ALVM | deep | 328 | 319 | 326 | 2,300 | Slagle (1988) |
| 6217 | 22N | 23W | 15 | DCDC | -114.5263 | 47.6600 | 112DRFT | interm. | 92 | | | 20,000 | Slagle (1988) |
| 6226 | 22N | 23W | 20 | DCDB | -114.5688 | 47.6452 | 112LONE | deep | 250 | | | 19,000 | Abdo (1997) |
| 703349 | 22N | 23W | 29 | BADD | -114.5719 | 47.6422 | 400PRCD | Belt | 1002 | | | 46,500 | Donovan (1985) |
| 6229 | 22N | 23W | 29 | ACAB | -114.5700 | 47.6411 | 112LONE | deep | 261 | | | 38,700 | Donovan (1985) |
| 76129 | 21N | 23W | 11 | CACC | -114.5130 | 47.5909 | 112LONE | deep | | | | 11,800 | Donovan (1985) |
| 76127 | 21N | 23W | 11 | CBCC | -114.5186 | 47.5909 | 112LONE | deep | | | | 28,000 | Donovan (1985) |
| 6142 | 21N | 22W | 7 | DCAA | -114.4602 | 47.5905 | 112ALVM | deep | 186 | 140 | 170 | 5,600 | Slagle (1988) |
| 6096 | 20N | 22W | 21 | CBDA | -114.4091 | 47.4763 | 112LONE | deep | 331 | 300 | 310 | 11,500 | Slagle (1988) |
| 128070 | 20N | 22W | 28 | ABCB | -114.4033 | 47.4691 | 120SDGR | Tertiary | 665 | 602 | 642 | 18 | Slagle (1988) |
| | | | | | | | Camas Prairie subarea | | | | | | |
| 6103 | 20N | 24W | 23 | CBAA | -114.6208 | 47.4788 | 112ALVM | deep | 99 | 5 | 18 | 10,200 | Slagle (1988) |
| 6104 | 20N | 24W | 23 | CBAA | -114.6211 | 47.4786 | 112ALVM | deep | 98 | 11 | 22 | 11,700 | Slagle (1988) |
| | | | | | | | Irvine Flats subarea | | | | | | |
| 6276 | 23N | 22W | 26 | CBDC | -114.3852 | 47.7255 | 112DRFT | interm. | 80 | | | 36,700 | Slagle (1988) |
| 6214 | 22N | 22W | 24 | DAAA | -114.3488 | 47.6519 | 112DRFT | interm. | 198 | | | 200 | Slagle (1988) |
| 6215 | 22N | 22W | 26 | DDDD | -114.3705 | 47.6313 | 112ALVM | deep | 50 | | | 45,600 | Slagle (1988) |
| | | | | | | | Unassigned | | | | | | |
| 128076 | 24N | 22W | 30 | BCCD | -114.4755 | 47.8125 | 112DRFT | interm. | 460 | | | 540 | Slagle (1988) |

Appendix C. Water-quality data

| Lab No. | Site No. | Township | Range | Sec. | Tract | Longitude | Latitude | Sample Date (yyyymmdd) | County | Total Depth | Hydro Unit | Na | K | Ca | Mg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Kalispell subarea** | | | | | | | | | | | | | | | |
| 2000Q1172 | 131916 | 33N | 23W | 30 | BDAC | -114.619 | 48.598 | 20000523 | FH | 35 | shallow | 1.39 | 0.49 | 25.80 | 4.69 |
| 1997Q0053 | 89329 | 33N | 23W | 32 | DABB | -114.589 | 48.580 | 19960714 | FH | 220 | Belt | 3.90 | 0.35 | 54.00 | 20.50 |
| 1997Q0054 | 89012 | 32N | 23W | 17 | BBCB | -114.568 | 48.543 | 19960910 | FH | 50 | deep | 2.50 | 0.68 | 43.50 | 10.40 |
| 1997Q0005 | 148433 | 31N | 23W | 11 | BCDA | -114.499 | 48.467 | 19960627 | FH | 261 | Belt | 12.00 | 0.92 | 58.00 | 37.00 |
| 1997Q0004 | 88138 | 31N | 23W | 11 | CDBC | -114.497 | 48.461 | 19960630 | FH | 317 | deep | 8.30 | 1.08 | 70.00 | 35.00 |
| 1997Q0006 | 133160 | 31N | 23W | 36 | DBAC | -114.467 | 48.406 | 19960628 | FH | 285 | Belt | 7.50 | 0.97 | 60.00 | 35.60 |
| 2000Q1171 | 88197 | 31N | 23W | 36 | DDDB | -114.461 | 48.401 | 20000523 | FH | 168 | deep | 8.14 | 1.75 | 58.70 | 36.70 |
| 1997Q0047 | 126317 | 31N | 22W | 34 | ADBB | -114.378 | 48.410 | 19960715 | FH | 460 | Belt | 7.50 | 0.67 | 60.00 | 29.80 |
| 1997Q0189 | 122728 | 31N | 21W | 22 | DBBC | -114.272 | 48.435 | 19960809 | FH | 147 | interm. | 10.80 | 0.86 | 42.10 | 22.70 |
| 1997Q0193 | 11914 | 31N | 21W | 28 | ACDB | -114.290 | 48.423 | 19960808 | FH | 147 | deep | 3.20 | 1.10 | 67.20 | 20.10 |
| 1994Q0948 | 87973 | 31N | 21W | 33 | CCDD | -114.288 | 48.399 | 19940421 | FH | 204 | deep | 15.50 | 1.20 | 59.90 | 17.40 |
| 1994Q0950 | 86411 | 30N | 22W | 1 | DCBC | -114.340 | 48.388 | 19940421 | FH | 389 | deep | 24.00 | 0.90 | 21.80 | 17.80 |
| 1996Q0795 | 86565 | 30N | 22W | 21 | DBBC | -114.404 | 48.348 | 19960617 | FH | 560 | Belt | 69.60 | 0.83 | 12.20 | 10.20 |
| 1995Q0569 | 148194 | 30N | 22W | 34 | CBAA | -114.390 | 48.320 | 19950605 | FH | 378 | Belt | 15.30 | 1.90 | 47.80 | 18.60 |
| 1997Q0138 | 120908 | 30N | 22W | 35 | CCDA | -114.368 | 48.314 | 19960726 | FH | 430 | deep | 15.70 | 1.20 | 48.60 | 15.90 |
| 1997Q0148 | 86652 | 30N | 22W | 35 | BDDD | -114.362 | 48.321 | 19000101 | FH | 90 | shallow | 31.30 | 3.00 | 70.00 | 55.00 |
| 1995Q0566 | 148193 | 30N | 22W | 36 | BDCC | -114.345 | 48.322 | 19950605 | FH | 438 | deep | 21.20 | 0.90 | 44.50 | 14.60 |
| 1994Q0947 | 86054 | 30N | 21W | 12 | CCBA | -114.238 | 48.374 | 19940421 | FH | 144 | interm. | 11.70 | 4.40 | 75.00 | 42.20 |
| 1995Q0570 | 148190 | 30N | 21W | 21 | CADBA | -114.297 | 48.346 | 19950606 | FH | 278 | deep | 14.30 | 0.86 | 46.00 | 11.00 |
| 1995Q0567 | 148192 | 30N | 21W | 21 | CACBB | -114.299 | 48.346 | 19950606 | FH | 557 | deep | 12.30 | 0.84 | 59.10 | 23.90 |
| 1995Q0568 | 148191 | 30N | 21W | 21 | CABDD | -114.298 | 48.347 | 19950606 | FH | 398 | deep | 12.80 | 0.68 | 49.50 | 19.70 |
| 1994Q0953 | 86214 | 30N | 21W | 21 | BCCC | -114.291 | 48.349 | 19940420 | FH | 390 | deep | 21.00 | 1.60 | 60.50 | 32.60 |
| 1995Q0565 | 149142 | 30N | 21W | 22 | AADD | -114.263 | 48.343 | 19950606 | FH | 265 | deep | 11.10 | 0.80 | 65.00 | 12.50 |
| 1997Q0195 | 127372 | 30N | 21W | 23 | DDCB | -114.245 | 48.343 | 19960809 | FH | 26 | shallow | 3.00 | 1.60 | 66.00 | 18.60 |
| 1983Q0280 | 6618 | 30N | 21W | 36 | CCCC | -114.239 | 48.313 | 19830524 | FH | 18 | shallow | 1.40 | 0.20 | 38.10 | 8.60 |
| 1997Q0147 | 85245 | 30N | 20W | 5 | CCBA | -114.195 | 48.389 | 19960725 | FH | 57 | interm. | 12.60 | 3.20 | 117.00 | 30.40 |
| 2000Q1227 | 85274 | 30N | 20W | 6 | CBAA | -114.213 | 48.393 | 20000525 | FH | 360 | interm. | 5.96 | 0.93 | 63.90 | 25.30 |
| 1997Q0231 | 40177 | 30N | 20W | 11 | CCDD | -114.126 | 48.371 | 19960824 | FH | 165 | Belt | 2.30 | 0.48 | 62.10 | 25.40 |
| 1997Q0222 | 85468 | 30N | 20W | 15 | BDCB | -114.147 | 48.365 | 19960824 | FH | 288 | deep | 8.20 | 2.30 | 45.80 | 22.40 |
| 1996Q0799 | 85592 | 30N | 20W | 18 | CDCA | -114.210 | 48.357 | 19960618 | FH | 238 | deep | 2.20 | 0.70 | 61.00 | 15.80 |
| 1995Q0472 | 148189 | 30N | 20W | 19 | DAAC | -114.198 | 48.347 | 19950503 | FH | 342 | deep | 4.00 | 1.20 | 47.40 | 21.20 |
| 1995Q0473 | 148188 | 30N | 20W | 19 | DAAD | -114.198 | 48.348 | 19950503 | FH | 518 | deep | 3.20 | 1.00 | 45.10 | 18.20 |
| 1995Q0471 | 148187 | 30N | 20W | 20 | CBBB | -114.196 | 48.348 | 19950503 | FH | 157 | deep | 3.50 | 0.89 | 54.40 | 20.80 |
| 2000Q1173 | 85628 | 30N | 20W | 20 | DCCA | -114.184 | 48.343 | 20000522 | FH | 149 | interm. | 7.05 | 2.02 | 45.70 | 20.30 |
| 2000Q1163 | 85689 | 30N | 20W | 22 | CDAC | -114.144 | 48.344 | 20000522 | FH | 308 | deep | 402.00 | 4.94 | 15.70 | 16.20 |
| 2000Q1176 | 158200 | 30N | 20W | 23 | CCCA | -114.127 | 48.343 | 20000522 | FH | | Belt | 2.43 | 0.65 | 28.50 | 16.30 |
| 1997Q0294 | 84486 | 29N | 22W | 3 | CACD | -114.387 | 48.302 | 19960908 | FH | 142 | interm. | 14.10 | 2.50 | 71.20 | 39.70 |
| 1997Q0295 | 84490 | 29N | 22W | 4 | CADC | -114.408 | 48.303 | 19960908 | FH | 88 | shallow | 6.10 | 2.30 | 60.70 | 28.60 |
| 1997Q0284 | 84516 | 29N | 22W | 7 | DABA | -114.441 | 48.291 | 19960910 | FH | 162 | deep | 6.40 | 1.10 | 47.60 | 27.60 |
| 1997Q0194 | 84528 | 29N | 22W | 8 | DDDA | -114.418 | 48.285 | 19960808 | FH | 88 | shallow | 6.60 | 2.60 | 53.00 | 24.00 |
| 1997Q0296 | 137876 | 29N | 22W | 9 | DBDB | -114.401 | 48.289 | 19960908 | FH | 107 | shallow | 9.10 | 2.20 | 72.10 | 31.60 |
| 1997Q0287 | 148210 | 29N | 22W | 15 | CABC | -114.389 | 48.275 | 19960907 | FH | 75 | interm. | 16.50 | 1.60 | 69.90 | 32.30 |
| 2000Q1164 | 141665 | 29N | 22W | 19 | CDAC | -114.451 | 48.257 | 20000521 | FH | 275 | Belt | 28.70 | 0.55 | 67.80 | 33.60 |
| 1997Q0285 | 84619 | 29N | 22W | 21 | BBCB | -114.415 | 48.268 | 19960906 | FH | 257 | deep | 7.60 | 1.20 | 57.70 | 17.20 |
| 1997Q0292 | 154971 | 29N | 22W | 21 | BBAD | -114.412 | 48.268 | 19960906 | FH | 120 | interm. | 9.40 | 1.60 | 50.60 | 23.40 |
| 1994Q0943 | 84669 | 29N | 22W | 28 | ACCC | -114.405 | 48.248 | 19940421 | FH | 210 | deep | 4.50 | 2.30 | 47.10 | 21.70 |
| 2000Q1161 | 84687 | 29N | 22W | 29 | ADCB | -114.421 | 48.249 | 20000521 | FH | 231 | deep | 6.29 | 1.77 | 56.00 | 17.30 |
| 1997Q0048 | 45316 | 29N | 22W | 32 | DADB | -114.418 | 48.231 | 19960715 | FH | 396 | Belt | 19.00 | 0.53 | 22.00 | 18.00 |
| 1997Q0286 | 84696 | 29N | 22W | 32 | AAAA | -114.419 | 48.239 | 19960906 | FH | 190 | deep | 5.70 | 1.80 | 64.70 | 20.90 |
| 1997Q0185 | 84737 | 29N | 22W | 36 | DAAD | -114.331 | 48.231 | 19960812 | FH | 205 | deep | 14.50 | 1.30 | 49.10 | 14.10 |
| 2000Q1170 | 83875 | 29N | 21W | 5 | CCCD | -114.306 | 48.299 | 20000523 | FH | 260 | deep | 11.00 | 2.44 | 59.20 | 32.40 |
| 1997Q0181 | 702957 | 29N | 21W | 6 | CBBA | -114.328 | 48.306 | 19960812 | FH | 569 | Belt | 19.20 | 1.00 | 56.00 | 12.40 |
| 1984Q0187 | 6444 | 29N | 21W | 9 | ADDD | -114.265 | 48.292 | 19840611 | FH | 18 | shallow | 3.40 | 1.10 | 66.00 | 17.90 |
| 1984Q0186 | 6445 | 29N | 21W | 9 | BDDD | -114.276 | 48.292 | 19840611 | FH | 23 | shallow | 3.20 | 1.80 | 55.60 | 16.00 |
| 1984Q0184 | 6443 | 29N | 21W | 9 | CBBB | -114.295 | 48.291 | 19840611 | FH | 23 | shallow | 4.90 | 0.20 | 84.10 | 23.20 |
| 1984Q0185 | 6442 | 29N | 21W | 9 | CBAA | -114.293 | 48.291 | 19840611 | FH | 23 | shallow | 2.00 | 0.50 | 45.00 | 9.90 |
| 1984Q0189 | 6446 | 29N | 21W | 10 | CAAA | -114.253 | 48.291 | 19840612 | FH | 18 | shallow | 3.80 | 0.90 | 58.50 | 15.30 |
| 1984Q0190 | 6447 | 29N | 21W | 10 | DAAA | -114.243 | 48.291 | 19840612 | FH | | shallow | 1.20 | 1.40 | 40.10 | 9.70 |

| Fe | Mn | Cl | $HCO_3$ | $CO_3$ | $SO_4$ | $NO_3$ | F | $SiO_2$ | TDS | Diss. Constit. | Hard-ness | Temp | Lab pH | Lab S.C. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.20 | < 0.01 | 1.24 | 103.50 | 0.00 | < 2.50 | < 0.50 | <0.05 | 10.40 | 95.30 | 147.81 | 83.73 | 4.7 | 7.96 | 190.0 |
| < 0.01 | < 0.01 | 0.50 | 278.60 | 0.00 | < 2.50 | < 0.05 | <1.00 | 20.50 | 236.57 | 377.92 | 219.22 | 8.3 | 7.40 | 423.0 |
| 0.01 | < 0.01 | 1.60 | 189.10 | 0.00 | < 10.00 | 0.21 | <1.00 | 15.80 | 167.94 | 263.88 | 151.43 | 8.3 | 7.50 | 296.0 |
| 0.01 | < 0.01 | 6.00 | 372.30 | 0.00 | 10.00 | < 0.25 | <1.00 | 16.20 | 323.56 | 512.46 | 297.12 | 8.5 | 7.30 | 540.0 |
| 0.18 | 0.58 | 1.30 | 388.70 | 0.00 | 4.80 | 3.50 | <1.00 | 17.20 | 333.42 | 530.64 | 318.85 | 9.7 | 7.20 | 536.0 |
| 0.03 | < 0.01 | 1.40 | 370.40 | 0.00 | 6.20 | 0.39 | <1.00 | 16.10 | 310.66 | 498.60 | 296.35 | 8.7 | 7.70 | 517.0 |
| 0.42 | 0.15 | 1.06 | 379.20 | 0.00 | 5.58 | < 0.05 | 0.06 | 14.50 | 313.89 | 506.29 | 297.63 | | 7.50 | 594.0 |
| 0.03 | 0.01 | 0.91 | 351.10 | 0.00 | < 2.50 | 0.16 | <1.00 | 18.10 | 290.17 | 468.31 | 272.48 | 10.5 | 7.30 | 518.0 |
| 0.04 | < 0.01 | 1.10 | 241.30 | 0.00 | 6.00 | 4.90 | <1.00 | 20.30 | 227.71 | 350.15 | 198.56 | 8.3 | 7.20 | 399.0 |
| 0.02 | < 0.01 | 0.90 | 310.20 | 0.00 | 3.40 | < 0.25 | <1.00 | 18.40 | 267.21 | 424.61 | 250.53 | 7.9 | 7.90 | 468.0 |
| 2.24 | 0.62 | 1.08 | 314.00 | 0.00 | < 2.50 | < 0.10 | 0.29 | 18.40 | 271.37 | 430.70 | 221.19 | 8.5 | 7.64 | 475.0 |
| 0.89 | 0.04 | 5.40 | 179.00 | 15.40 | < 2.50 | < 0.10 | 0.13 | 1.40 | 176.10 | 266.92 | 127.70 | 11.6 | 8.88 | 324.0 |
| 0.13 | 0.02 | 0.70 | 215.70 | 0.00 | 45.00 | < 0.25 | <1.00 | 11.30 | 256.26 | 365.70 | 72.45 | 11.9 | 7.80 | 414.0 |
| < 0.01 | 0.33 | 0.50 | 277.20 | 0.00 | 10.00 | < 0.25 | 0.26 | 17.70 | 248.95 | 389.60 | 195.91 | | 7.84 | 437.0 |
| 0.17 | < 0.01 | 1.10 | 256.20 | 0.00 | 8.80 | < 0.05 | <1.00 | 18.50 | 236.23 | 366.22 | 186.80 | 9.7 | 7.60 | 396.0 |
| 0.01 | < 0.01 | 11.00 | 521.20 | 0.00 | 16.50 | 3.60 | <1.00 | 16.70 | 463.93 | 728.38 | 401.17 | 9.6 | 7.20 | 781.0 |
| 0.57 | 0.03 | 2.00 | 256.20 | 0.00 | 5.00 | < 0.25 | 0.52 | 13.50 | 229.04 | 359.04 | 171.21 | | 7.78 | 420.0 |
| 0.17 | 0.97 | 1.35 | 477.00 | 0.00 | 9.10 | < 0.10 | 0.19 | 16.70 | 396.75 | 638.78 | 360.97 | 8.1 | 7.57 | 697.0 |
| 0.16 | 0.04 | 1.00 | 238.10 | 0.00 | 7.50 | < 0.25 | 0.15 | 14.50 | 212.80 | 333.61 | 160.14 | | 7.89 | 390.0 |
| 0.45 | 0.16 | 0.50 | 333.30 | 0.00 | 5.00 | < 0.25 | 0.17 | 15.30 | 281.90 | 451.02 | 245.95 | | 7.77 | 497.0 |
| 0.19 | 0.03 | 0.50 | 288.40 | 0.00 | 7.50 | < 0.25 | 0.14 | 15.00 | 248.11 | 394.44 | 204.69 | | 7.62 | 456.0 |
| 0.02 | < 0.01 | 3.00 | 375.00 | 0.00 | 14.90 | 0.18 | 0.13 | 17.70 | 336.59 | 526.86 | 285.25 | 9.5 | 7.63 | 586.0 |
| 0.28 | 0.10 | <0.50 | 280.60 | 0.00 | 5.00 | < 0.25 | 0.07 | 13.30 | 246.39 | 388.76 | 213.76 | | 7.73 | 439.0 |
| 0.01 | < 0.01 | 6.00 | 277.20 | 0.00 | 4.70 | 2.70 | <1.00 | 13.20 | 252.40 | 393.04 | 241.36 | 15.0 | 7.70 | 464.0 |
| < 0.01 | < 0.01 | 1.40 | 152.30 | 0.00 | 4.70 | 1.22 | 0.08 | 5.30 | 136.03 | 213.31 | 130.53 | | 8.05 | 249.4 |
| < 0.01 | < 0.01 | 20.40 | 483.10 | 0.00 | 10.90 | 3.60 | <1.00 | 25.20 | 461.30 | 706.42 | 417.28 | 8.9 | 7.30 | 790.0 |
| 0.10 | 0.01 | 0.90 | 326.70 | 0.00 | 3.87 | 0.25 | <0.05 | 12.60 | 274.75 | 440.51 | 263.69 | | 7.61 | 509.0 |
| < 0.01 | < 0.01 | 0.90 | 292.80 | 0.00 | 6.90 | 1.30 | <1.00 | 14.40 | 258.02 | 406.58 | 259.61 | 7.8 | 8.00 | 425.0 |
| 0.06 | 0.17 | <0.50 | 257.20 | 0.00 | < 2.50 | < 0.25 | <1.00 | 11.30 | 216.94 | 347.44 | 206.56 | 11.1 | 8.10 | 391.0 |
| < 0.01 | < 0.01 | 4.90 | 249.10 | 0.00 | 10.00 | 0.44 | <1.00 | 11.60 | 229.35 | 355.74 | 217.35 | 8.4 | 7.70 | 406.0 |
| 0.18 | 0.03 | 2.00 | 241.60 | 0.00 | 5.00 | 1.00 | 0.08 | 9.60 | 210.70 | 333.29 | 205.62 | 8.5 | 7.58 | 391.0 |
| 0.32 | 0.04 | 1.00 | 226.90 | 0.00 | 5.00 | 0.50 | 0.08 | 9.80 | 196.02 | 311.15 | 187.53 | 9.2 | 7.86 | 353.0 |
| 0.12 | 0.03 | 3.50 | 261.60 | 0.00 | 5.00 | 1.50 | 0.07 | 10.70 | 229.56 | 362.29 | 221.45 | 8.9 | 7.90 | 419.0 |
| 0.24 | 0.22 | 0.73 | 252.50 | 0.00 | 4.48 | < 0.50 | 0.09 | 5.30 | 210.55 | 338.66 | 197.67 | 9.1 | 7.59 | 421.0 |
| 0.27 | 0.06 | 69.50 | 1058.00 | 0.00 | < 25.00 | < 0.50 | 4.81 | 16.50 | 1051.17 | 1587.99 | 105.88 | 10.8 | 7.96 | 1783.0 |
| < 0.03 | < 0.01 | <0.50 | 178.40 | 0.00 | 5.36 | < 0.50 | 0.07 | 9.25 | 150.51 | 241.03 | 138.26 | 8.6 | 7.91 | 292.0 |
| 0.03 | < 0.01 | 11.20 | 374.30 | 0.00 | 32.10 | 6.30 | <1.00 | 17.50 | 379.02 | 568.93 | 341.19 | 9.2 | 7.70 | 640.0 |
| 0.00 | < 0.01 | 3.10 | 301.30 | 0.00 | 27.30 | 2.00 | <1.00 | 17.10 | 295.67 | 448.55 | 269.29 | 9.5 | 7.70 | 480.0 |
| < 0.01 | < 0.01 | 2.10 | 271.80 | 0.00 | 4.50 | 5.10 | <1.00 | 16.70 | 245.05 | 382.96 | 232.46 | 9.2 | 7.60 | 435.0 |
| 0.02 | < 0.01 | 2.30 | 287.90 | 0.00 | 4.80 | 1.30 | <1.00 | 15.30 | 251.78 | 397.86 | 231.13 | 10.2 | 8.10 | 433.0 |
| 0.01 | < 0.01 | 8.90 | 317.70 | 0.00 | 29.80 | 8.20 | <1.00 | 17.40 | 335.97 | 497.17 | 310.10 | 9.6 | 7.80 | 601.0 |
| < 0.01 | < 0.01 | 9.60 | 366.10 | 0.00 | 21.00 | 7.70 | <1.00 | 17.40 | 356.42 | 542.18 | 307.49 | 9.4 | 7.80 | 647.0 |
| < 0.03 | < 0.01 | 7.47 | 436.00 | 0.00 | < 25.00 | 0.62 | <0.50 | 26.40 | 380.02 | 601.24 | 307.59 | 8.2 | 7.44 | 681.0 |
| < 0.01 | < 0.01 | 1.10 | 256.50 | 0.00 | 3.70 | 0.80 | <1.00 | 15.10 | 230.82 | 360.97 | 214.87 | 9.9 | 7.70 | 412.0 |
| < 0.01 | < 0.01 | 0.60 | 271.60 | 0.00 | 16.20 | 5.20 | <1.00 | 15.40 | 256.26 | 394.07 | 222.66 | 8.8 | 7.80 | 472.0 |
| 0.03 | < 0.01 | 2.90 | 255.00 | 0.00 | 4.60 | 2.11 | 0.09 | 14.70 | 225.73 | 355.11 | 206.93 | 9.4 | 7.83 | 419.0 |
| < 0.03 | < 0.01 | 2.17 | 263.00 | 0.00 | 4.24 | < 0.50 | 0.14 | 16.80 | 234.33 | 367.77 | 211.04 | 9.6 | 7.69 | 415.0 |
| < 0.01 | < 0.01 | 2.70 | 183.20 | 0.00 | 16.00 | 0.18 | <1.00 | 32.80 | 201.56 | 294.51 | 129.02 | 12.1 | 7.30 | 325.0 |
| < 0.01 | 0.00 | 1.90 | 283.00 | 0.00 | 4.30 | 0.90 | <1.00 | 17.10 | 256.72 | 400.31 | 247.58 | 9.4 | 7.80 | 455.0 |
| 0.01 | < 0.01 | 1.00 | 227.20 | 0.00 | 6.70 | < 0.25 | <1.00 | 12.10 | 210.76 | 326.04 | 180.64 | 10.9 | 7.80 | 363.0 |
| 0.06 | < 0.01 | 1.58 | 360.60 | 0.00 | 7.31 | 2.87 | 0.06 | 12.40 | 306.98 | 489.94 | 281.18 | 9.5 | 7.40 | 587.0 |
| 0.01 | 0.00 | 3.80 | 262.60 | 0.00 | 8.00 | 0.30 | <1.00 | 13.90 | 244.01 | 377.25 | 190.87 | 11.2 | 7.80 | 427.0 |
| 0.07 | 0.00 | 5.00 | 280.00 | 0.00 | 5.30 | 0.11 | <0.10 | 11.00 | 247.84 | 389.91 | 238.48 | 10.0 | 7.59 | 440.5 |
| 0.35 | 0.06 | 2.20 | 245.60 | 0.00 | 3.80 | 0.93 | 0.10 | 10.40 | 221.45 | 346.06 | 204.69 | 10.7 | 7.66 | 388.5 |
| 0.18 | 0.02 | 0.50 | 371.00 | 0.00 | 6.40 | 1.94 | <0.10 | 10.10 | 314.32 | 502.57 | 305.49 | 9.1 | 7.43 | 537.4 |
| 0.03 | 0.00 | 0.30 | 185.40 | 0.00 | 3.30 | 0.46 | <0.10 | 8.00 | 160.83 | 254.90 | 153.11 | 8.0 | 7.75 | 290.6 |
| 0.04 | 0.00 | 2.50 | 253.80 | 0.00 | 4.80 | 0.81 | <0.10 | 9.60 | 221.29 | 350.06 | 209.05 | 8.1 | 7.64 | 394.0 |
| < 0.01 | 0.01 | 0.20 | 164.90 | 0.00 | 4.40 | 0.60 | <0.10 | 9.10 | 147.98 | 231.65 | 140.05 | 8.5 | 7.55 | 261.8 |

Appendix C—*Continued.*

| Lab No. | Site No. | Township | Range | Sec. | Tract | Longitude | Latitude | Sample Date (yyyymmdd) | County | Total Depth | Hydro Unit | Na | K | Ca | Mg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1997Q0192 | 156026 | 29N | 21W | 11 | DBDA | -114.227 | 48.289 | 19960809 | FH | 35 | shallow | 1.60 | 0.48 | 51.40 | 12.50 |
| 1984Q0373 | 6448 | 29N | 21W | 11 | ADDA | -114.222 | 48.293 | 19840613 | FH | 12 | shallow | 0.80 | 0.30 | 26.60 | 5.90 |
| 1984Q0191 | 6449 | 29N | 21W | 11 | BDCB | -114.237 | 48.292 | 19840612 | FH | | shallow | 1.20 | 0.30 | 43.10 | 10.60 |
| 1983Q0281 | 6450 | 29N | 21W | 11 | DDBC | -114.231 | 48.289 | 19830524 | FH | 31 | shallow | 1.40 | 0.40 | 42.00 | 9.70 |
| 1984Q0376 | 6451 | 29N | 21W | 15 | ADAD | -114.243 | 48.279 | 19840613 | FH | 18 | shallow | 1.80 | 0.80 | 48.20 | 12.80 |
| 1997Q0182 | 148197 | 29N | 21W | 18 | CBBB | -114.328 | 48.276 | 19960812 | FH | 109 | interm. | 10.00 | 1.40 | 49.50 | 22.00 |
| 1994Q0945 | 131524 | 29N | 21W | 20 | CCCC | -114.307 | 48.255 | 19940421 | FH | 278 | deep | 25.70 | 2.10 | 27.90 | 12.50 |
| 1983Q0283 | 6452 | 29N | 21W | 21 | BDAA | -114.276 | 48.265 | 19830524 | FH | | shallow | 2.80 | 0.70 | 53.10 | 13.80 |
| 1997Q0003 | 137868 | 29N | 21W | 22 | CCCB | -114.264 | 48.256 | 19960701 | FH | 277 | deep | 9.10 | 0.80 | 31.70 | 13.50 |
| 1997Q0190 | 6454 | 29N | 21W | 22 | CDDD | -114.254 | 48.255 | 19960808 | FH | 45 | shallow | 10.60 | 1.20 | 30.10 | 14.30 |
| 1994Q0935 | 6453 | 29N | 21W | 22 | ABBB | -114.253 | 48.269 | 19940419 | FH | 23 | shallow | 4.70 | 1.90 | 68.10 | 18.90 |
| 2000Q1221 | 6455 | 29N | 21W | 27 | ABBB | -114.253 | 48.254 | 20000528 | FH | 22 | shallow | 3.68 | 1.71 | 53.30 | 14.60 |
| 1988Q0503 | 6489 | 29N | 21W | 33 | CDDC | -114.277 | 48.226 | 19880611 | FH | 12 | shallow | 28.50 | 2.50 | 70.20 | 26.30 |
| 1988Q0507 | 6470 | 29N | 21W | 33 | CDDC | -114.277 | 48.226 | 19880611 | FH | 18 | shallow | 5.30 | 1.50 | 71.40 | 22.40 |
| 1984Q0380 | 6532 | 29N | 21W | 33 | DCCC | -114.274 | 48.226 | 19840614 | FH | 23 | shallow | 5.80 | 0.90 | 67.20 | 21.60 |
| 1984Q0372 | 6531 | 29N | 21W | 33 | DABA | -114.268 | 48.233 | 19840614 | FH | 20 | shallow | 3.80 | 1.20 | 63.60 | 19.00 |
| 1988Q0519 | 6546 | 29N | 21W | 34 | BABA | -114.257 | 48.240 | 19880612 | FH | 18 | shallow | 2.90 | 0.78 | 46.70 | 11.00 |
| 1988Q0515 | 6566 | 29N | 21W | 34 | BABA | -114.257 | 48.240 | 19880612 | FH | 12 | shallow | 3.20 | 0.70 | 48.90 | 11.20 |
| 1984Q0371 | 6602 | 29N | 21W | 34 | CDDD | -114.254 | 48.226 | 19840613 | FH | 18 | shallow | 2.90 | 0.30 | 48.30 | 11.20 |
| 1984Q0377 | 6534 | 29N | 21W | 34 | ABBB | -114.253 | 48.240 | 19840613 | FH | 23 | shallow | 3.60 | 0.60 | 50.00 | 13.40 |
| 1997Q0045 | 83424 | 29N | 20W | 2 | CCCA | -114.130 | 48.300 | 19960714 | FH | 250 | Belt | 2.30 | 0.38 | 19.70 | 9.60 |
| 1997Q0180 | 83435 | 29N | 20W | 3 | DDBA | -114.134 | 48.301 | 19960812 | FH | 340 | deep | 25.50 | 1.50 | 35.00 | 18.00 |
| 1997Q0051 | 154968 | 29N | 20W | 7 | ABDC | -114.204 | 48.294 | 19960716 | FH | 80 | deep | 13.20 | 3.10 | 68.90 | 38.00 |
| 1997Q0186 | 154870 | 29N | 20W | 25 | CDCA | -114.101 | 48.242 | 19960811 | FH | 345 | deep | 49.80 | 0.73 | 7.00 | 9.30 |
| 2000Q1174 | 83666 | 29N | 20W | 26 | ABCC | -114.119 | 48.252 | 20000522 | FH | 139 | interm. | 3.38 | 0.73 | 33.50 | 12.10 |
| 1994Q0934 | 83716 | 29N | 20W | 29 | ACCD | -114.183 | 48.248 | 19940420 | FH | 338 | deep | 22.30 | 3.50 | 43.10 | 30.50 |
| 1989Q0794 | 890685 | 29N | 20W | 29 | BABB | -114.190 | 48.255 | 19890511 | FH | 690 | deep | 15.00 | 0.50 | 29.80 | 15.40 |
| 1997Q0133 | 83797 | 29N | 20W | 35 | CDDD | -114.121 | 48.226 | 19960726 | FH | 140 | deep | 3.00 | 1.90 | 66.00 | 22.00 |
| 1997Q0130 | 83808 | 29N | 20W | 36 | CBBB | -114.109 | 48.233 | 19960726 | FH | 120 | shallow | 4.30 | 0.31 | 35.00 | 13.60 |
| 1997Q0288 | 82663 | 28N | 22W | 1 | ABDA | -114.335 | 48.224 | 19960907 | FH | 295 | deep | 9.70 | 1.30 | 49.30 | 25.70 |
| 1997Q0297 | 82735 | 28N | 22W | 4 | DAAC | -114.396 | 48.217 | 19960908 | FH | 150 | deep | 22.40 | 1.20 | 47.30 | 16.10 |
| 1978Q0607 | 6426 | 28N | 22W | 11 | CCC | -114.351 | 48.197 | 19780118 | FH | 1306 | Belt | 340.00 | 5.80 | 2.10 | 1.40 |
| 1997Q0293 | 82831 | 28N | 22W | 12 | ACCD | -114.338 | 48.205 | 19960907 | FH | 87 | interm. | 7.30 | 1.40 | 73.40 | 24.10 |
| 1996Q0792 | 82934 | 28N | 22W | 15 | AAAA | -114.373 | 48.196 | 19960613 | FH | 220 | deep | 22.00 | 1.80 | 60.00 | 16.00 |
| 2000Q1165 | 120810 | 28N | 22W | 20 | AADA | -114.416 | 48.179 | 20000521 | FH | 408 | deep | 32.00 | 0.64 | 15.50 | 8.62 |
| 1997Q0290 | 83093 | 28N | 22W | 25 | CCBC | -114.351 | 48.156 | 19960909 | FH | 40 | shallow | 35.30 | 6.10 | 68.80 | 37.70 |
| 1997Q0197 | 81929 | 28N | 21W | 2 | CADC | -114.236 | 48.215 | 19960810 | FH | 87 | interm. | 15.20 | 0.94 | 28.80 | 11.30 |
| 2000Q1229 | 6419 | 28N | 21W | 4 | DCDA | -114.271 | 48.213 | 20000528 | FH | 23 | shallow | 5.86 | 1.37 | 73.60 | 22.30 |
| 1983Q0284 | 6418 | 28N | 21W | 4 | ABAB | -114.273 | 48.226 | 19830524 | FH | | shallow | 4.80 | 1.00 | 64.00 | 20.40 |
| 1984Q0374 | 6420 | 28N | 21W | 8 | DDDD | -114.288 | 48.198 | 19840614 | FH | 23 | shallow | 4.80 | 0.80 | 53.90 | 13.80 |
| 1997Q0143 | 139549 | 28N | 21W | 13 | BCAC | -114.219 | 48.192 | 19960727 | FH | 195 | deep | 9.00 | 0.82 | 31.60 | 16.20 |
| 1995Q0470 | 82381 | 28N | 21W | 17 | DDAC | -114.289 | 48.185 | 19950505 | FH | 229 | deep | 10.90 | 0.92 | 55.10 | 11.70 |
| 1997Q0146 | 130565 | 28N | 21W | 17 | DADA | -114.287 | 48.188 | 19960727 | FH | 76 | interm. | 18.40 | 1.40 | 53.40 | 22.60 |
| 1984Q0846 | 6422 | 28N | 21W | 20 | BBCB | -114.308 | 48.181 | 19840821 | FH | 25 | interm. | 45.00 | 2.20 | 82.40 | 29.60 |
| 1997Q0144 | 82558 | 28N | 21W | 29 | ABDC | -114.294 | 48.165 | 19960726 | FH | 242 | deep | 8.10 | 1.70 | 63.50 | 21.00 |
| 1984Q0845 | 6423 | 28N | 21W | 29 | ACBB | -114.297 | 48.164 | 19840821 | FH | | shallow | 37.80 | 2.20 | 57.90 | 22.80 |
| 2000Q1222 | 81636 | 28N | 20W | 1 | DAAC | -114.072 | 48.217 | 20000526 | FH | 75 | Belt | 1.02 | 0.47 | 38.60 | 14.00 |
| 1996Q0794 | 81711 | 28N | 20W | 13 | AAAD | -114.073 | 48.196 | 19960617 | FH | 340 | Belt | 5.40 | 0.59 | 35.00 | 7.30 |
| 1997Q0123 | 81766 | 28N | 20W | 15 | CBDD | -114.132 | 48.186 | 19960729 | FH | 407 | deep | 8.60 | 1.20 | 35.40 | 18.70 |
| 1996Q0796 | 132436 | 28N | 20W | 26 | DCCB | -114.103 | 48.155 | 19960616 | FH | 273 | deep | 2.10 | 0.62 | 43.60 | 19.40 |
| 1997Q0131 | 6414 | 28N | 20W | 31 | CDCC | -114.194 | 48.139 | 19960729 | FH | 650 | deep | 22.90 | 1.30 | 36.40 | 12.70 |
| 1984Q0528 | 6415 | 28N | 20W | 31 | DDDD | -114.181 | 48.140 | 19840627 | FH | 23 | shallow | 212.00 | 4.50 | 43.70 | 18.00 |
| 1984Q0478 | 6413 | 28N | 20W | 31 | ADDD | -114.180 | 48.147 | 19840626 | FH | 23 | shallow | 24.70 | 1.40 | 75.70 | 26.10 |
| 1984Q0529 | 6417 | 28N | 20W | 32 | DDDD | -114.158 | 48.139 | 19840627 | FH | 23 | shallow | 30.20 | 1.90 | 103.00 | 40.70 |
| 1984Q0479 | 6416 | 28N | 20W | 32 | BBBD | -114.177 | 48.152 | 19840626 | FH | 23 | shallow | 18.00 | 1.50 | 104.00 | 39.00 |
| 1997Q0141 | 81530 | 28N | 19W | 7 | CCCC | -114.071 | 48.197 | 19960726 | FH | 171 | deep | 2.60 | 0.57 | 48.90 | 18.30 |
| 1997Q0008 | 81591 | 28N | 19W | 28 | BBBB | -114.029 | 48.168 | 19960627 | FH | 137 | deep | 2.00 | 0.36 | 33.00 | 26.00 |
| 2000Q1225 | 150622 | 28N | 19W | 31 | DACC | -114.055 | 48.143 | 20000529 | FH | 43 | shallow | 1.11 | 0.63 | 40.20 | 17.30 |
| 1997Q0044 | 80915 | 27N | 21W | 10 | BBBA | -114.264 | 48.124 | 19960714 | FH | 507 | Belt | 9.00 | 0.88 | 54.00 | 17.60 |

| Fe | Mn | Cl | $HCO_3$ | $CO_3$ | $SO_4$ | $NO_3$ | F | $SiO_2$ | TDS | Diss. Constit. | Hard-ness | Temp | Lab pH | Lab S.C. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| <0.01 | <0.01 | 2.60 | 206.20 | 0.00 | 5.10 | 1.10 | <1.00 | 6.40 | 182.77 | 287.39 | 179.80 | 8.0 | 8.00 | 323.0 |
| 0.12 | 0.01 | 0.30 | 108.00 | 0.00 | 3.30 | 0.20 | <0.10 | 4.70 | 95.44 | 150.24 | 90.70 | 9.5 | 7.58 | 175.8 |
| 0.01 | <0.01 | 0.20 | 180.60 | 0.00 | 4.50 | 0.41 | <0.10 | 6.00 | 155.30 | 246.94 | 151.25 | 8.8 | 7.61 | 284.8 |
| <0.01 | <0.01 | 0.50 | 171.30 | 0.00 | 4.90 | 0.39 | 0.06 | 5.40 | 149.15 | 236.07 | 144.80 | | 8.15 | 269.4 |
| 0.04 | 0.01 | 0.60 | 206.00 | 0.00 | 4.60 | 0.68 | 0.10 | 6.40 | 177.53 | 282.06 | 173.04 | 9.0 | 7.61 | 323.2 |
| 0.19 | 0.34 | 1.30 | 252.50 | 0.00 | 11.00 | 0.40 | <1.00 | 15.20 | 235.77 | 363.88 | 214.15 | 10.0 | 7.90 | 403.0 |
| 0.64 | 0.12 | 1.10 | 220.00 | 0.00 | 2.80 | <0.10 | 0.16 | 11.10 | 192.49 | 304.12 | 121.12 | 10.6 | 8.14 | 332.0 |
| <0.01 | <0.01 | 1.70 | 226.70 | 0.00 | 5.00 | 1.37 | 0.06 | 9.40 | 199.62 | 314.65 | 189.39 | | 8.00 | 358.5 |
| 0.01 | <0.01 | 0.80 | 179.30 | 0.00 | 6.00 | 0.32 | <1.00 | 10.90 | 161.46 | 252.44 | 134.72 | 11.5 | 7.50 | 278.0 |
| 0.01 | <0.01 | 1.30 | 184.70 | 0.00 | 5.00 | <0.25 | <1.00 | 10.20 | 163.74 | 257.46 | 134.02 | 12.5 | 7.30 | 315.0 |
| 0.06 | 0.01 | 4.30 | 292.00 | 0.00 | 5.10 | 1.44 | 0.05 | 10.30 | 258.74 | 406.90 | 247.84 | 7.6 | 7.54 | 471.0 |
| <0.03 | <0.01 | 4.65 | 237.90 | 0.00 | 5.46 | 1.37 | <0.05 | 7.05 | 209.02 | 329.72 | 193.18 | 9.8 | 7.62 | 409.0 |
| 0.01 | <0.01 | 14.60 | 287.40 | 0.00 | 15.50 | 18.90 | 0.10 | 19.60 | 339.73 | 485.55 | 283.54 | | 8.30 | |
| 0.00 | 0.00 | 6.80 | 281.00 | 0.00 | 7.90 | 1.91 | 0.20 | 12.90 | 281.75 | 424.33 | 270.48 | 11.0 | 8.06 | |
| 0.06 | 0.01 | 4.10 | 310.00 | 0.00 | 6.90 | 1.13 | 0.10 | 11.30 | 271.85 | 429.14 | 256.70 | 8.4 | 7.45 | 485.8 |
| 0.10 | 0.02 | 3.60 | 286.00 | 0.00 | 5.50 | 1.17 | 0.10 | 9.70 | 248.71 | 393.82 | 237.01 | 9.0 | 7.57 | 448.5 |
| 0.00 | 0.00 | 1.10 | 192.30 | 0.00 | 4.00 | 0.24 | 0.05 | 6.80 | 168.33 | 265.90 | 161.89 | | 8.00 | |
| <0.01 | 0.00 | 1.80 | 200.80 | 0.00 | 4.40 | 0.60 | <0.05 | 6.70 | 176.50 | 278.38 | 168.20 | | 7.90 | |
| 0.04 | 0.00 | 1.00 | 207.00 | 0.00 | 3.80 | 0.32 | <0.10 | 6.20 | 176.04 | 281.07 | 166.70 | 7.6 | 7.70 | 320.2 |
| 0.05 | <0.01 | 0.60 | 222.00 | 0.00 | 4.30 | 0.40 | <0.10 | 7.00 | 189.34 | 301.98 | 180.00 | 7.4 | 7.45 | 341.6 |
| 0.05 | <0.01 | <0.50 | 114.90 | 0.00 | <2.50 | 0.09 | <1.00 | 12.80 | 101.52 | 159.82 | 88.70 | 9.0 | 7.80 | 184.0 |
| 0.15 | 0.16 | 4.20 | 247.10 | 0.00 | 6.00 | <0.25 | <1.00 | 16.70 | 228.95 | 354.33 | 161.48 | 11.1 | 7.70 | 406.0 |
| 0.18 | 0.48 | 1.50 | 420.60 | 0.00 | 14.90 | <0.05 | <1.00 | 19.70 | 367.17 | 580.58 | 328.45 | 9.0 | 7.60 | 584.0 |
| 1.90 | 0.10 | <0.50 | 194.00 | 0.00 | 11.90 | <0.25 | <1.00 | 10.80 | 187.61 | 286.04 | 55.76 | 12.7 | 7.70 | 294.0 |
| <0.03 | <0.01 | 0.78 | 175.40 | 0.00 | 3.92 | <0.50 | <0.05 | 13.90 | 154.80 | 243.80 | 133.45 | | 7.78 | 300.0 |
| 4.09 | 0.27 | 0.70 | 348.00 | 0.00 | 2.30 | <0.10 | 0.13 | 12.00 | 290.33 | 466.90 | 233.16 | 8.5 | 7.91 | 513.0 |
| 0.01 | <0.01 | 1.90 | 204.00 | 0.00 | 7.30 | 0.14 | <0.10 | 10.70 | 181.25 | 284.76 | 137.80 | | 8.24 | 317.8 |
| 0.08 | 0.32 | 4.10 | 280.20 | 0.00 | 28.20 | <0.25 | <1.00 | 15.80 | 279.45 | 421.62 | 255.35 | 9.9 | 7.50 | 460.0 |
| 0.02 | <0.01 | 1.80 | 179.30 | 0.00 | 3.50 | <0.25 | <1.00 | 8.10 | 154.96 | 245.94 | 143.37 | 7.2 | 7.80 | 278.0 |
| <0.01 | <0.01 | 1.80 | 273.00 | 0.00 | 7.00 | 2.80 | <1.00 | 15.60 | 247.70 | 386.22 | 228.88 | 10.1 | 7.90 | 446.0 |
| 0.01 | <0.01 | 1.40 | 248.90 | 0.00 | 5.20 | 6.70 | <1.00 | 18.20 | 241.16 | 367.45 | 184.38 | 10.8 | 7.80 | 390.0 |
| 0.17 | 0.01 | 22.00 | 837.00 | 19.00 | 0.00 | <0.02 | 6.70 | 10.50 | 820.00 | 1244.68 | 11.01 | | 8.65 | 1317.0 |
| 0.17 | 0.92 | 4.70 | 301.70 | 0.00 | 28.60 | <0.25 | <1.00 | 20.90 | 310.18 | 463.26 | 282.48 | 9.5 | 7.50 | 583.0 |
| 1.80 | 0.10 | 4.00 | 294.00 | 0.00 | <2.50 | <0.25 | <1.00 | 25.30 | 275.91 | 431.88 | 215.68 | 10.9 | 7.10 | 488.0 |
| <0.03 | 0.05 | 4.18 | 164.90 | 0.00 | 5.50 | <0.50 | 0.21 | 6.05 | 153.98 | 237.65 | 74.18 | 162.0 | 8.03 | 300.0 |
| <0.01 | <0.01 | 12.70 | 424.10 | 0.00 | 34.50 | 2.60 | <1.00 | 20.40 | 427.05 | 642.24 | 326.97 | 8.8 | 7.90 | 705.0 |
| <0.01 | <0.01 | 1.80 | 171.00 | 0.00 | 4.70 | <0.25 | <1.00 | 10.30 | 157.28 | 244.05 | 118.42 | 12.4 | 8.00 | 280.0 |
| 0.01 | <0.01 | 9.86 | 324.00 | 0.00 | 6.87 | 1.24 | <0.05 | 10.10 | 290.82 | 455.21 | 275.57 | 10.6 | 7.43 | 556.0 |
| <0.01 | <0.01 | 2.10 | 283.50 | 0.00 | 6.50 | 3.70 | 0.07 | 9.90 | 252.15 | 396.00 | 243.77 | | 8.15 | 439.4 |
| 0.07 | 0.00 | 1.80 | 240.00 | 0.00 | 4.50 | 0.56 | <0.10 | 12.40 | 210.89 | 332.67 | 191.39 | 8.4 | 7.76 | 369.1 |
| 0.01 | <0.01 | 1.10 | 201.50 | 0.00 | <2.50 | <0.05 | <1.00 | 9.50 | 167.49 | 269.73 | 145.58 | 10.0 | 7.40 | 312.0 |
| 0.03 | 0.00 | 0.50 | 246.00 | 0.00 | 2.50 | <0.25 | 0.13 | 12.40 | 215.43 | 340.24 | 185.74 | 10.1 | 7.68 | 405.0 |
| 0.06 | <0.01 | 10.00 | 289.50 | 0.00 | 15.00 | 0.38 | <1.00 | 12.30 | 276.16 | 423.05 | 226.36 | 9.0 | 7.80 | 494.0 |
| 0.01 | 0.24 | 4.20 | 477.00 | 0.00 | 38.80 | 0.47 | 0.20 | 16.90 | 455.02 | 697.04 | 327.59 | | 7.86 | 738.6 |
| 0.01 | <0.01 | 9.90 | 287.30 | 0.00 | 13.20 | 0.34 | <1.00 | 15.90 | 275.27 | 421.04 | 245.00 | 10.7 | 7.40 | 491.0 |
| 0.00 | 0.12 | 4.50 | 345.00 | 0.00 | 31.10 | 0.61 | 0.10 | 11.00 | 338.10 | 513.15 | 238.42 | | 8.22 | 593.7 |
| <0.03 | <0.01 | 0.48 | 196.40 | 0.00 | 3.38 | <0.50 | <0.05 | 6.76 | 161.46 | 261.11 | 154.01 | 6.3 | 7.91 | 324.0 |
| 0.02 | <0.01 | 0.69 | 137.30 | 0.00 | 12.00 | 0.81 | <1.00 | 16.40 | 145.88 | 215.55 | 117.44 | 10.4 | 7.80 | 259.0 |
| 0.01 | <0.01 | 0.80 | 201.60 | 0.00 | 5.10 | 3.90 | <1.00 | 7.70 | 180.72 | 283.01 | 165.36 | 8.9 | 7.70 | 312.0 |
| 0.01 | <0.01 | 0.58 | 215.50 | 0.00 | 6.90 | 1.30 | <1.00 | 10.70 | 191.38 | 300.73 | 188.72 | 10.2 | 7.50 | 336.0 |
| 0.36 | 0.13 | 1.70 | 229.80 | 0.00 | 4.90 | <0.25 | <1.00 | 13.70 | 207.30 | 323.89 | 143.16 | 14.0 | 7.90 | 346.0 |
| 0.25 | 0.52 | 5.00 | 706.00 | 0.00 | 49.60 | 0.44 | 0.30 | 21.80 | 704.48 | 1062.70 | 183.21 | 8.0 | 7.30 | 1105.0 |
| 0.06 | 0.12 | 2.10 | 356.00 | 0.00 | 46.70 | 1.87 | 0.30 | 12.40 | 366.84 | 547.47 | 296.45 | 8.0 | 7.61 | 615.0 |
| 0.42 | 1.33 | 5.10 | 497.00 | 0.00 | 83.40 | 0.12 | 0.30 | 21.30 | 532.80 | 784.98 | 424.71 | 8.0 | 7.67 | 830.9 |
| 0.04 | 2.19 | 0.20 | 556.00 | 0.00 | 17.40 | 0.04 | 0.30 | 17.50 | 474.35 | 756.46 | 420.21 | 8.0 | 7.45 | 789.3 |
| 0.01 | <0.01 | 0.60 | 253.80 | 0.00 | <2.50 | 0.13 | <1.00 | 11.60 | 207.73 | 336.51 | 197.43 | 8.3 | 7.60 | 380.0 |
| <0.01 | <0.01 | 0.80 | 226.90 | 0.00 | 5.80 | 0.28 | <1.00 | 9.10 | 189.15 | 304.28 | 189.42 | 8.9 | 7.80 | 321.0 |
| 0.05 | 0.00 | 0.60 | 213.50 | 0.00 | 3.31 | 0.53 | <0.05 | 7.76 | 176.66 | 284.99 | 171.59 | 9.8 | 7.79 | 339.0 |
| <0.01 | <0.01 | 4.10 | 270.80 | 0.00 | <2.50 | 0.42 | <1.00 | 18.40 | 237.86 | 375.26 | 207.28 | 12.0 | 7.30 | 440.0 |

Appendix C—*Continued.*

| Lab No. | Site No. | Township | Range | Sec. | Tract | Longitude | Latitude | Sample Date (yyyymmdd) | County | Total Depth | Hydro Unit | Na | K | Ca | Mg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1984Q0399 | 6393 | 27N | 21W | 12 | ABCC | -114.211 | 48.122 | 19840618 | FH | 480 | deep | 13.10 | 1.80 | 41.70 | 27.00 |
| 1984Q0402 | 6394 | 27N | 21W | 12 | BDDD | -114.212 | 48.117 | 19840619 | FH | 20 | shallow | 8.70 | 1.40 | 46.50 | 54.20 |
| 1984Q0398 | 6392 | 27N | 21W | 12 | AAAA | -114.201 | 48.124 | 19840618 | FH | 28 | shallow | 17.30 | 0.90 | 64.70 | 35.10 |
| 1996Q0800 | 152883 | 27N | 21W | 13 | CDDD | -114.213 | 48.096 | 19960618 | FH | 360 | deep | 16.90 | 2.10 | 57.00 | 12.90 |
| 1984Q0400 | 6395 | 27N | 21W | 13 | CDDD | -114.212 | 48.096 | 19840619 | FH | 22 | shallow | 18.60 | 2.70 | 64.90 | 12.10 |
| 1997Q0191 | 6396 | 27N | 21W | 23 | AAAA | -114.223 | 48.095 | 19960809 | FH | 25 | shallow | 138.10 | 2.30 | 102.40 | 32.40 |
| 1997Q0127 | 80662 | 27N | 20W | 1 | BABC | -114.086 | 48.138 | 19960725 | FH | 180 | interm. | 1.30 | 0.73 | 36.00 | 15.60 |
| 1997Q0126 | 122742 | 27N | 20W | 6 | BABB | -114.195 | 48.139 | 19960727 | FH | 33 | shallow | 8.40 | 1.90 | 84.90 | 20.00 |
| 1984Q0476 | 6386 | 27N | 20W | 7 | DDDD | -114.180 | 48.110 | 19840625 | FH | 23 | shallow | 9.90 | 0.90 | 45.20 | 31.60 |
| 1994Q0937 | 80691 | 27N | 20W | 8 | AAAB | -114.160 | 48.124 | 19940420 | FH | 415 | deep | 169.00 | 3.80 | 25.90 | 11.50 |
| 1984Q0480 | 6387 | 27N | 20W | 9 | CBBC | -114.157 | 48.116 | 19840626 | FH | 23 | shallow | 124.00 | 1.10 | 83.40 | 29.30 |
| 1997Q0122 | 133079 | 27N | 20W | 10 | ADCA | -114.118 | 48.119 | 19960729 | FH | 287 | Belt | 4.90 | 0.49 | 33.00 | 15.00 |
| 1996Q0793 | 80736 | 27N | 20W | 14 | DDCB | -114.097 | 48.097 | 19960616 | FH | 140 | Belt | 10.00 | 1.10 | 50.00 | 22.00 |
| 1984Q0477 | 6389 | 27N | 20W | 16 | CCCC | -114.156 | 48.096 | 19840625 | FH | 23 | shallow | 18.30 | 0.60 | 118.00 | 34.40 |
| 1996Q0797 | 141562 | 27N | 20W | 17 | CCBB | -114.179 | 48.099 | 19960615 | FH | 400 | deep | 12.40 | 1.40 | 45.90 | 19.60 |
| 1984Q0475 | 6390 | 27N | 20W | 19 | ABBB | -114.191 | 48.095 | 19840625 | FH | 18 | shallow | 72.20 | 2.30 | 181.00 | 51.10 |
| 1984Q0401 | 6391 | 27N | 20W | 21 | BDDD | -114.148 | 48.089 | 19840618 | FH | 20 | shallow | 1.40 | 0.30 | 77.90 | 16.80 |
| 2000Q1167 | 80745 | 27N | 20W | 22 | BBBB | -114.136 | 48.095 | 20000520 | FH | 400 | deep | 85.00 | 2.88 | 26.50 | 8.20 |
| 1997Q0049 | 143168 | 27N | 19W | 4 | CABB | -114.022 | 48.132 | 19960716 | FH | 343 | deep | 1.70 | 0.61 | 51.00 | 22.00 |
| 1997Q0128 | 139424 | 27N | 19W | 4 | DBCD | -114.016 | 48.129 | 19960725 | FH | 154 | interm. | 14.80 | 1.30 | 39.90 | 21.70 |
| 1997Q0129 | 139428 | 27N | 19W | 11 | CAAA | -113.975 | 48.117 | 19960726 | FH | 565 | deep | 83.20 | 0.10 | 0.10 | 0.10 |
| 1997Q0132 | 80356 | 27N | 19W | 18 | ABCB | -114.060 | 48.108 | 19960725 | FH | 98 | shallow | 4.60 | 1.40 | 68.00 | 21.30 |
| 1997Q0183 | 80389 | 27N | 19W | 20 | ACDB | -114.035 | 48.089 | 19960813 | FH | 249 | deep | 7.20 | 1.50 | 47.00 | 19.20 |
| 2000Q1226 | 154871 | 27N | 19W | 20 | ACDD | -114.034 | 48.089 | 20000529 | FH | | shallow | 15.90 | 16.30 | 60.00 | 17.00 |
| 1997Q0043 | 130530 | 27N | 19W | 25 | ABAD | -113.948 | 48.079 | 19960714 | FH | 460 | Belt | 13.10 | 0.35 | 12.80 | 12.50 |
| 2000Q1175 | 134212 | 27N | 19W | 25 | BBBC | -113.962 | 48.080 | 20000520 | FH | 108 | deep | 5.55 | 0.49 | 15.80 | 8.98 |
| 1994Q0949 | 80505 | 27N | 19W | 29 | ABAB | -114.019 | 48.080 | 19940421 | FH | 270 | Belt | 7.50 | 1.60 | 52.70 | 26.20 |
| 1997Q0002 | 141558 | 27N | 19W | 35 | DBAC | -113.971 | 48.057 | 19960701 | FH | 327 | deep | 11.80 | 0.10 | 14.00 | 11.80 |
| 1997Q0289 | 79501 | 26N | 19W | 1 | DACC | -113.946 | 48.041 | 19960909 | L | 1085 | deep | 87.80 | 0.25 | 15.40 | 7.60 |
| 1997Q0145 | 79551 | 26N | 19W | 4 | ABBB | -114.016 | 48.051 | 19960729 | L | 99 | Belt | 19.20 | 1.50 | 73.00 | 23.70 |
| 1997Q0277 | 79595 | 26N | 19W | 11 | CDBD | -113.977 | 48.025 | 19960910 | L | 125 | deep | 2.40 | 0.48 | 57.90 | 17.30 |
| 1997Q0276 | 79587 | 26N | 19W | 11 | BADC | -113.976 | 48.034 | 19960910 | L | 566 | deep | 4.50 | 0.46 | 49.60 | 8.10 |
| **Mission subarea** | | | | | | | | | | | | | | | |
| 1997Q0464 | 77061 | 22N | 21W | 25 | DDAD | -114.220 | 47.634 | 19961020 | L | 138 | interm. | 16.70 | 0.70 | 26.00 | 12.00 |
| 1983Q0402 | 6212 | 22N | 21W | 28 | ACD | -114.291 | 47.639 | 19830603 | L | 144 | interm. | 40.40 | 3.10 | 44.50 | 36.30 |
| 1997Q0449 | 703335 | 22N | 21W | 29 | ADDD | -114.306 | 47.639 | 19961021 | L | 639 | Belt | 83.10 | 2.70 | 34.40 | 23.60 |
| 1997Q0443 | 156204 | 22N | 21W | 34 | BABA | -114.277 | 47.631 | 19961016 | L | 440 | deep | 34.70 | 1.60 | 49.70 | 21.40 |
| 1997Q0438 | 77089 | 22N | 21W | 36 | BBAB | -114.237 | 47.631 | 19961015 | L | 108 | deep | 39.00 | 2.60 | 40.00 | 30.00 |
| 1997Q0324 | 131954 | 22N | 20W | 1 | AADA | -114.091 | 47.701 | 19960919 | L | 224 | deep | 8.90 | 1.60 | 40.20 | 17.20 |
| 1984Q0809 | 6202 | 22N | 20W | 2 | CBD | -114.130 | 47.694 | 19840605 | L | 525 | deep | 18.60 | 1.90 | 37.90 | 13.40 |
| 1983Q0395 | 6204 | 22N | 20W | 10 | CAA | -114.146 | 47.681 | 19830601 | L | 165 | interm. | 10.30 | 2.00 | 40.40 | 21.60 |
| 1975Q1303 | 6205 | 22N | 20W | 10 | CAAD | -114.146 | 47.681 | 19750826 | L | 175 | interm. | 6.70 | 2.00 | 27.80 | 16.40 |
| 1997Q0472 | 76966 | 22N | 20W | 12 | BCDB | -114.109 | 47.683 | 19961010 | L | 135 | interm. | 3.40 | 1.70 | 30.10 | 14.00 |
| 1984Q0008 | 6206 | 22N | 20W | 17 | DCAB | -114.184 | 47.664 | 19831212 | L | 440 | Belt | 28.60 | 0.90 | 37.80 | 13.20 |
| 1997Q0459 | 703324 | 22N | 20W | 25 | BABD | -114.105 | 47.644 | 19961009 | L | 300 | interm. | 2.70 | 1.40 | 40.00 | 13.00 |
| 1984Q0819 | 6207 | 22N | 20W | 25 | ABA | -114.098 | 47.645 | 19840608 | L | 1000 | Belt | 2.40 | 1.00 | 41.00 | 10.70 |
| 1997Q0405 | 77014 | 22N | 20W | 30 | AADA | -114.199 | 47.644 | 19961007 | L | 465 | Belt | 22.10 | 0.30 | 43.50 | 16.10 |
| 1997Q0501 | 6209 | 22N | 20W | 31 | CDDB | -114.211 | 47.619 | 19961028 | L | 150 | Belt | 80.00 | 3.00 | 42.00 | 31.00 |
| 1984Q0818 | 6199 | 22N | 19W | 18 | DAA | -114.071 | 47.666 | 19840608 | L | 25 | shallow | 1.70 | 1.70 | 30.20 | 5.70 |
| 1997Q0439 | 155864 | 22N | 19W | 20 | DCDD | -114.054 | 47.646 | 19961022 | L | 120 | interm. | 4.30 | 1.90 | 18.90 | 11.30 |
| 1997Q0447 | 76850 | 22N | 19W | 20 | BAAA | -114.059 | 47.660 | 19961009 | L | 162 | interm. | 1.60 | 0.92 | 29.30 | 5.70 |
| 1997Q0500 | 76860 | 22N | 19W | 21 | BBBA | -114.047 | 47.660 | 19961028 | L | 136 | shallow | 2.10 | 1.10 | 37.10 | 11.10 |
| 1997Q0553 | 76867 | 22N | 19W | 28 | BAAC | -114.040 | 47.644 | 19961106 | L | 110 | shallow | 5.20 | 2.20 | 62.60 | 20.10 |
| 1997Q0502 | 76865 | 22N | 19W | 28 | ABBC | -114.037 | 47.644 | 19961025 | L | 348 | deep | 7.40 | 0.68 | 18.70 | 17.80 |
| 1997Q0445 | 76883 | 22N | 19W | 30 | DAAD | -114.071 | 47.637 | 19961016 | L | 348 | deep | 4.60 | 1.50 | 18.20 | 8.20 |
| 1997Q0471 | 76889 | 22N | 19W | 31 | CCDD | -114.086 | 47.617 | 19961018 | L | 100 | shallow | 1.70 | 1.10 | 53.30 | 6.60 |
| 1997Q0442 | 148567 | 22N | 19W | 32 | DDDC | -114.050 | 47.618 | 19961022 | L | 635 | interm. | 9.40 | 0.64 | 5.70 | 5.30 |
| 1984Q0007 | 6201 | 22N | 19W | 32 | BCDD | -114.064 | 47.624 | 19831206 | L | 300 | deep | 5.70 | 1.00 | 25.20 | 9.70 |
| 1985Q1181 | 6143 | 21N | 22W | 36 | BDCC | -114.363 | 47.538 | 19850724 | L | 99 | interm. | 33.00 | 1.20 | 38.40 | 29.40 |

| Fe | Mn | Cl | $HCO_3$ | $CO_3$ | $SO_4$ | $NO_3$ | F | $SiO_2$ | TDS | Diss. Constit. | Hard-ness | Temp | Lab pH | Lab S.C. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.02 | 0.00 | 0.80 | 297.70 | 0.00 | 5.40 | 0.08 | 0.10 | 14.10 | 250.79 | 401.84 | 215.26 | 12.0 | 7.67 | 435.0 |
| 0.41 | 0.10 | 1.00 | 361.00 | 0.00 | 30.80 | 11.40 | 0.60 | 11.30 | 344.27 | 527.44 | 339.20 | | 7.63 | 660.0 |
| 0.32 | 0.08 | 0.80 | 339.00 | 0.00 | 54.00 | 3.99 | 0.10 | 15.30 | 359.62 | 531.62 | 306.03 | 11.0 | 7.37 | 607.0 |
| 0.03 | 0.18 | 4.90 | 264.30 | 0.00 | 9.30 | < 0.25 | <1.00 | 14.50 | 248.04 | 382.14 | 195.43 | 12.8 | 7.60 | 427.0 |
| 0.11 | 0.08 | 10.60 | 285.00 | 0.00 | 8.70 | 0.42 | 0.10 | 8.40 | 267.13 | 411.73 | 211.86 | 7.7 | 7.60 | 472.6 |
| 7.60 | 0.29 | 44.90 | 356.20 | 0.00 | 40.20 | 0.62 | <1.00 | 16.10 | 560.41 | 741.14 | 389.05 | 9.5 | 7.60 | 1268.0 |
| 0.02 | < 0.01 | 1.00 | 190.60 | 0.00 | < 2.50 | < 0.25 | <1.00 | 9.50 | 158.09 | 254.80 | 154.10 | 10.5 | 7.60 | 306.0 |
| 9.00 | 0.36 | 1.60 | 416.30 | 0.00 | < 2.50 | < 0.25 | <1.00 | 29.00 | 360.23 | 571.46 | 294.32 | 9.2 | 7.30 | 602.0 |
| 0.08 | 0.10 | 0.50 | 309.00 | 0.00 | 16.40 | 0.21 | 0.20 | 12.30 | 269.67 | 426.45 | 242.93 | 8.0 | 7.67 | 455.3 |
| 1.27 | 0.19 | 74.90 | 463.00 | 0.00 | < 2.50 | < 0.10 | 2.67 | 13.30 | 530.62 | 765.54 | 112.01 | 13.1 | 8.07 | 901.0 |
| 2.97 | 0.27 | 9.70 | 633.00 | 0.00 | 68.50 | 0.03 | <0.20 | 18.20 | 649.46 | 970.64 | 328.85 | 8.0 | 7.42 | 1020.0 |
| 0.01 | < 0.01 | 0.60 | 188.90 | 0.00 | < 2.50 | < 0.25 | <1.00 | 10.60 | 157.68 | 253.52 | 144.14 | 9.9 | 7.50 | 302.0 |
| 0.02 | < 0.01 | 15.00 | 231.80 | 0.00 | 22.00 | 1.20 | <1.00 | 22.40 | 257.92 | 375.54 | 215.40 | 9.8 | 7.50 | 443.0 |
| 5.46 | 0.36 | 8.90 | 574.00 | 0.00 | 6.80 | 0.02 | 0.20 | 26.90 | 502.74 | 793.98 | 436.24 | 8.3 | 7.33 | 827.5 |
| 0.01 | 0.00 | 1.20 | 252.50 | 0.00 | 10.50 | 1.10 | <1.00 | 11.40 | 227.91 | 356.03 | 195.29 | 12.2 | 7.50 | 392.0 |
| 13.00 | 0.69 | 59.90 | 837.00 | 0.00 | 80.80 | 0.13 | 0.50 | 21.60 | 895.59 | 1320.28 | 662.28 | 8.0 | 7.18 | 1350.0 |
| 1.32 | 0.27 | 0.20 | 337.00 | 0.00 | 0.10 | 0.05 | 0.10 | 14.20 | 278.68 | 449.67 | 263.67 | 8.1 | 7.38 | 497.2 |
| 1.31 | 0.17 | 23.10 | 312.80 | 0.00 | <25.00 | < 0.50 | 2.16 | 13.10 | 316.51 | 475.22 | 99.92 | 12.6 | 7.95 | 561.0 |
| 0.02 | < 0.01 | <0.50 | 270.40 | 0.00 | < 2.50 | 0.20 | <1.00 | 10.70 | 219.60 | 356.80 | 217.90 | 8.0 | 7.60 | 386.0 |
| 1.08 | 0.21 | 0.50 | 157.40 | 0.00 | < 2.50 | < 0.25 | <1.00 | 9.50 | 166.53 | 246.39 | 188.95 | 7.2 | 7.50 | 408.0 |
| 0.01 | 0.05 | 0.70 | 239.70 | 0.00 | 5.50 | < 0.25 | <1.00 | 19.50 | 227.05 | 348.67 | | 10.7 | 7.80 | 364.0 |
| 0.01 | < 0.01 | 2.00 | 312.30 | 0.00 | 10.00 | < 0.25 | <1.00 | 18.20 | 279.39 | 437.85 | 257.47 | 9.2 | 7.40 | 489.0 |
| 0.05 | 0.03 | 0.80 | 256.20 | 0.00 | 2.60 | < 0.25 | <1.00 | 12.80 | 217.38 | 347.37 | 196.39 | 9.5 | 7.80 | 395.0 |
| 0.39 | 0.16 | 32.30 | 247.40 | 0.00 | 9.72 | 2.48 | 0.07 | 21.80 | 298.47 | 423.99 | 219.79 | 8.0 | 7.45 | 548.0 |
| 0.09 | 0.05 | 0.53 | 125.70 | 0.00 | 8.80 | < 0.05 | <1.00 | 23.80 | 133.99 | 197.77 | 83.41 | 10.2 | 7.20 | 216.0 |
| < 0.03 | < 0.01 | <0.50 | 109.30 | 0.00 | 3.22 | < 0.50 | <0.05 | 15.70 | 103.79 | 159.25 | 76.41 | 8.5 | 7.57 | 191.0 |
| 0.34 | 0.05 | 1.05 | 299.00 | 0.00 | 3.50 | < 0.10 | 0.23 | 20.40 | 260.93 | 412.64 | 239.43 | 9.1 | 7.82 | 448.0 |
| 0.02 | 0.01 | 0.50 | 126.50 | 0.00 | 4.80 | 0.13 | <1.00 | 21.10 | 126.47 | 190.66 | 83.53 | 9.6 | 6.70 | 186.0 |
| 0.89 | 0.10 | 0.50 | 286.70 | 0.00 | 8.10 | 5.50 | <1.00 | 19.30 | 286.70 | 432.17 | 69.74 | 14.6 | 7.80 | 469.0 |
| 0.00 | < 0.01 | 45.20 | 306.90 | 0.00 | 3.10 | 1.40 | <1.00 | 20.50 | 338.83 | 494.55 | 279.83 | 8.8 | 7.50 | 606.0 |
| < 0.01 | < 0.01 | 2.60 | 259.30 | 0.00 | 3.20 | 0.60 | <1.00 | 17.00 | 229.25 | 360.81 | 215.78 | 10.6 | 7.90 | 410.0 |
| < 0.01 | 0.01 | 0.50 | 182.00 | 0.00 | < 2.50 | 4.90 | <1.00 | 13.20 | 170.94 | 263.29 | 157.19 | 9.3 | 7.80 | 285.0 |
| | | | | | | | | | | | | | | |
| < 0.01 | < 0.01 | <0.50 | 170.60 | 0.00 | 9.00 | 0.50 | <0.25 | 30.10 | 179.05 | 265.61 | 114.31 | 11.6 | 8.00 | 289.0 |
| < 0.01 | 0.00 | 10.30 | 357.00 | 0.00 | 32.00 | 3.12 | 0.40 | 15.90 | 362.21 | 543.35 | 260.53 | 13.0 | 7.82 | 625.8 |
| < 0.01 | < 0.01 | 12.10 | 398.20 | 0.00 | 22.10 | 0.40 | <1.00 | 14.60 | 389.18 | 591.23 | 183.03 | 14.0 | 8.00 | 667.0 |
| 1.70 | 2.50 | 4.50 | 316.30 | 0.00 | < 2.50 | < 0.25 | <1.00 | 38.30 | 310.28 | 470.77 | 212.18 | 13.3 | 8.10 | 516.0 |
| < 0.01 | < 0.01 | 14.10 | 300.70 | 0.00 | 35.10 | 2.20 | <1.00 | 17.30 | 328.43 | 481.00 | 223.36 | 10.3 | 8.20 | 561.0 |
| < 0.01 | < 0.01 | 2.50 | 205.00 | 0.00 | 6.50 | 2.10 | <1.00 | 6.80 | 186.79 | 290.81 | 171.17 | 11.6 | 7.80 | 331.0 |
| < 0.01 | 0.07 | 1.10 | 223.50 | 0.00 | 6.80 | 1.45 | 0.30 | 15.20 | 206.82 | 320.23 | 149.79 | 10.0 | 7.96 | 325.7 |
| < 0.01 | < 0.01 | 1.80 | 233.00 | 0.00 | 7.30 | 3.84 | 0.20 | 13.30 | 215.52 | 333.74 | 189.78 | 10.5 | 7.99 | 384.2 |
| < 0.01 | < 0.01 | 0.05 | 174.40 | 0.00 | 4.30 | 0.68 | 0.20 | 11.30 | 155.34 | 243.83 | 136.92 | 10.5 | 6.20 | 278.6 |
| 0.06 | < 0.01 | <0.50 | 150.50 | 0.00 | < 2.50 | 0.50 | <1.00 | 12.90 | 136.80 | 213.16 | 132.78 | 12.4 | 8.10 | 247.0 |
| < 0.01 | < 0.01 | 2.80 | 232.00 | 0.00 | 13.50 | 0.59 | 0.40 | 19.00 | 231.08 | 348.79 | 148.72 | 9.5 | 7.97 | 371.7 |
| < 0.01 | < 0.01 | <0.50 | 172.60 | 0.00 | 4.30 | 3.30 | <1.00 | 5.10 | 154.89 | 242.46 | 153.39 | 10.9 | 8.00 | 318.0 |
| < 0.01 | < 0.01 | 1.00 | 174.40 | 2.00 | 3.40 | 1.87 | <0.10 | 12.00 | 161.38 | 249.87 | 146.42 | 11.0 | 8.38 | 282.8 |
| 0.01 | < 0.01 | 5.10 | 228.80 | 0.00 | 23.60 | 1.10 | <1.00 | 12.30 | 236.89 | 352.98 | 174.89 | 12.0 | 8.30 | 422.0 |
| 0.01 | < 0.01 | 6.00 | 448.50 | 0.00 | 25.00 | 2.20 | <1.00 | 19.30 | 429.45 | 657.02 | 232.47 | 9.9 | 8.30 | 704.0 |
| < 0.01 | < 0.01 | 1.30 | 124.20 | 0.00 | 2.30 | 0.71 | <0.10 | 10.40 | 115.23 | 178.24 | 98.87 | 9.0 | 8.27 | 194.9 |
| 0.01 | < 0.01 | <0.50 | 123.70 | 0.00 | 4.20 | < 0.25 | <1.00 | 11.30 | 112.87 | 175.64 | 93.70 | 9.3 | 8.20 | 205.0 |
| 0.01 | < 0.01 | 1.30 | 116.10 | 0.00 | < 2.50 | 0.61 | <1.00 | 11.10 | 107.77 | 166.68 | 96.62 | 9.4 | 8.00 | 199.0 |
| 0.01 | < 0.01 | <0.50 | 174.00 | 0.00 | < 0.25 | 0.53 | <1.00 | 13.50 | 151.19 | 351.77 | 152.98 | 8.2 | 8.10 | 275.0 |
| 0.01 | < 10.00 | 2.20 | 298.90 | 0.00 | 3.50 | 0.40 | <1.00 | 20.30 | 263.88 | 415.54 | 239.04 | 8.9 | 8.40 | 463.0 |
| 0.04 | 0.03 | <0.50 | 166.90 | 0.00 | < 2.50 | < 0.25 | <1.00 | 25.50 | 152.57 | 285.55 | 124.93 | 9.3 | 7.63 | 260.0 |
| < 0.01 | < 0.01 | <0.50 | 103.20 | 0.00 | 3.30 | 0.33 | <1.00 | 11.80 | 98.78 | 151.14 | 79.20 | 10.0 | 8.20 | 173.0 |
| 0.01 | < 0.01 | <0.50 | 166.40 | 0.00 | 2.50 | 1.30 | <1.00 | 11.20 | 159.69 | 244.12 | 160.26 | 9.5 | 7.70 | 288.0 |
| 0.03 | 0.05 | <0.50 | 69.80 | 0.00 | < 2.50 | < 0.25 | <1.00 | 29.40 | 84.93 | 120.34 | 36.05 | 10.3 | 7.40 | 113.0 |
| < 0.01 | 0.00 | 1.10 | 136.60 | 0.00 | 2.20 | 0.12 | 0.04 | 17.50 | 129.85 | 199.16 | 102.85 | 8.0 | 8.02 | 210.1 |
| 0.10 | 0.32 | 17.30 | 313.00 | 0.00 | 10.50 | 0.57 | 1.00 | 38.50 | 324.58 | 483.40 | 216.90 | 11.0 | 7.66 | 524.7 |

Appendix C—*Continued.*

| Lab No. | Site No. | Township | Range | Sec. | Tract | Longitude | Latitude | Sample Date (yyyymmdd) | County | Total Depth | Hydro Unit | Na | K | Ca | Mg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1997Q0461 | 132368 | 21N | 20W | 11 | DCAD | -114.118 | 47.589 | 19961017 | L | 379 | deep | 8.60 | 0.93 | 15.00 | 8.00 |
| 1983Q0396 | 6134 | 21N | 20W | 11 | ACC | -114.122 | 47.596 | 19830602 | L | 390 | interm. | 12.50 | 0.70 | 14.00 | 6.00 |
| 1975Q1502 | 6135 | 21N | 20W | 14 | ACB | -114.122 | 47.583 | 19750916 | L | 12 | shallow | 3.50 | 2.00 | 55.00 | 8.40 |
| 1997Q0403 | 76014 | 21N | 20W | 16 | DAAD | -114.156 | 47.579 | 19961003 | L | 310 | deep | 29.10 | 1.40 | 30.90 | 7.30 |
| 1997Q0460 | 703291 | 21N | 20W | 17 | BCBB | -114.197 | 47.582 | 19961018 | L |  | interm. | 39.20 | 1.20 | 34.70 | 23.50 |
| 1997Q0400 | 76024 | 21N | 20W | 20 | DCCD | -114.184 | 47.559 | 19961007 | L | 520 | Belt | 57.90 | 1.60 | 36.40 | 13.70 |
| 1997Q0506 | 148511 | 21N | 20W | 22 | BCCA | -114.152 | 47.567 | 19961024 | L | 43 | shallow | 25.00 | 5.00 | 54.20 | 21.70 |
| 1984Q0813 | 6136 | 21N | 20W | 24 | CAA | -114.104 | 47.565 | 19840607 | L | 321 | interm. | 8.00 | 1.60 | 30.70 | 11.50 |
| 1991Q0079 | 122336 | 21N | 20W | 25 | DDDD | -114.092 | 47.544 | 19910516 | L | 26 | interm. | 20.63 | 4.72 | 54.34 | 31.25 |
| 1988Q1082 | 6139 | 21N | 20W | 25 | DBAD | -114.097 | 47.550 | 19880725 | L | 25 | shallow | 3.60 | 2.00 | 76.90 | 16.10 |
| 1988Q1080 | 6138 | 21N | 20W | 25 | DBAD | -114.097 | 47.551 | 19880725 | L | 15 | shallow | 6.60 | 1.40 | 62.60 | 16.70 |
| 1988Q1083 | 6140 | 21N | 20W | 25 | DDDC | -114.092 | 47.544 | 19880725 | L | 30 | shallow | 15.00 | 5.60 | 57.00 | 39.90 |
| 1997Q0467 | 146862 | 21N | 20W | 33 | DDCB | -114.159 | 47.531 | 19961020 | L | 340 | interm. | 24.60 | 1.30 | 27.40 | 24.00 |
| 1976Q0147 | 6141 | 21N | 20W | 33 | AAA | -114.156 | 47.544 | 19760305 | L | 453 | interm. | 17.60 | 1.00 | 29.80 | 10.90 |
| 1983Q1220 | 6130 | 21N | 19W | 20 | CABB | -114.064 | 47.566 | 19831122 | L | 171 | interm. | 5.60 | 3.10 | 48.40 | 30.50 |
| 1997Q0404 | 127147 | 21N | 19W | 28 | DCBD | -114.036 | 47.547 | 19960921 | L | 282 | deep | 4.50 | 0.20 | 19.30 | 5.20 |
| 1983Q0735 | 6131 | 21N | 19W | 28 | DBBB | -114.038 | 47.551 | 19830622 | L | 145 | interm. | 2.40 | 1.20 | 35.60 | 6.90 |
| 1975Q1495 | 6091 | 20N | 21W | 23 | ADD | -114.225 | 47.480 | 19750917 | L | 332 | Belt | 45.00 | 1.40 | 43.60 | 33.50 |
| 1987Q0960 | 2470 | 20N | 21W | 25 | CDBD | -114.216 | 47.459 | 19870922 | L | 44 | interm. | 56.40 | 4.00 | 55.70 | 37.40 |
| 1987Q0961 | 6095 | 20N | 21W | 25 | CDBD | -114.216 | 47.459 | 19870922 | L | 19 | interm. | 74.50 | 4.80 | 57.40 | 39.10 |
| 1988Q1079 | 6078 | 20N | 20W | 1 | ABDC | -114.083 | 47.527 | 19880725 | L | 25 | shallow | 25.00 | 10.20 | 50.70 | 26.20 |
| 1984Q0812 | 6080 | 20N | 20W | 2 | AAC | -114.100 | 47.527 | 19840607 | L | 550 | interm. | 0.90 | 0.30 | 9.10 | 1.80 |
| 1975Q1309 | 6079 | 20N | 20W | 2 | AAC | -114.100 | 47.527 | 19750826 | L | 550 | interm. | 2.90 | 0.80 | 21.30 | 4.20 |
| 1975Q1308 | 6081 | 20N | 20W | 2 | BAB | -114.111 | 47.529 | 19750826 | L | 540 | interm. | 6.60 | 1.10 | 28.50 | 4.20 |
| 1997Q0462 | 132988 | 20N | 20W | 4 | DCCD | -114.147 | 47.516 | 19961017 | L | 500 | deep | 10.50 | 1.10 | 30.80 | 7.50 |
| 1976Q0743 | 6083 | 20N | 20W | 4 | BAA | -114.151 | 47.529 | 19760630 | L | 355 | deep | 12.40 | 1.10 | 30.60 | 6.80 |
| 1988Q1081 | 6085 | 20N | 20W | 7 | ABDD | -114.188 | 47.512 | 19880725 | L | 20 | shallow | 108.00 | 6.20 | 81.00 | 24.30 |
| 1997Q0504 | 74852 | 20N | 20W | 11 | CBDD | -114.113 | 47.505 | 19961024 | L | 399 | deep | 8.00 | 0.89 | 24.10 | 5.10 |
| 1976Q0142 | 6086 | 20N | 20W | 20 | DCD | -114.167 | 47.473 | 19760304 | L | 285 | deep | 39.20 | 1.30 | 44.80 | 18.90 |
| 1976Q0745 | 6087 | 20N | 20W | 28 | AAA | -114.140 | 47.471 | 19760701 | L | 73 | interm. | 71.00 | 4.00 | 43.00 | 35.50 |
| 1976Q0742 | 6088 | 20N | 20W | 30 | DCD | -114.188 | 47.458 | 19760701 | L | 35 | shallow | 217.00 | 4.60 | 80.00 | 59.50 |
| 1976Q0143 | 6072 | 20N | 19W | 7 | DBB | -114.063 | 47.507 | 19760304 | L | 158 | interm. | 2.10 | 1.70 | 10.20 | 3.10 |
| 1983Q1223 | 6073 | 20N | 19W | 16 | BDCB | -114.026 | 47.495 | 19831027 | L | 295 | Belt | 7.10 | 0.80 | 30.70 | 12.80 |
| 1976Q0275 | 6077 | 20N | 19W | 19 | DDA | -114.055 | 47.474 | 19760421 | L | 1182 | Belt | 29.60 | 3.40 | 1.90 | 0.10 |
| 1975Q1508 | 6076 | 20N | 19W | 19 | DAAA | -114.055 | 47.478 | 19750917 | L | 401 | interm. | 2.70 | 0.90 | 24.70 | 7.20 |
| 1976Q0140 | 6056 | 19N | 21W | 6 | BBB | -114.329 | 47.442 | 19760304 | L | 130 | shallow | 134.00 | 3.80 | 41.10 | 16.10 |
| 1976Q0746 | 6057 | 19N | 21W | 10 | ADA | -114.246 | 47.424 | 19760701 | L | 44 | interm. | 37.80 | 3.90 | 79.00 | 41.00 |
| 1976Q0133 | 6058 | 19N | 21W | 14 | BAA | -114.234 | 47.414 | 19760304 | L | 371 | interm. | 52.50 | 1.90 | 26.10 | 39.70 |
| 1984Q0815 | 6060 | 19N | 21W | 19 | ABAA | -114.315 | 47.399 | 19840608 | L | 108 | shallow | 30.20 | 2.50 | 30.80 | 28.70 |
| 1983Q0401 | 6061 | 19N | 21W | 27 | CCD | -114.262 | 47.372 | 19830602 | L | 160 | interm. | 33.30 | 1.50 | 40.00 | 11.00 |
| 1976Q0741 | 6062 | 19N | 21W | 28 | CCA | -114.283 | 47.373 | 19760701 | L | 300 | deep | 167.00 | 3.80 | 35.60 | 15.20 |
| 1983Q1224 | 6063 | 19N | 21W | 30 | ADDC | -114.311 | 47.378 | 19831109 | L | 118 | interm. | 37.30 | 2.10 | 43.10 | 25.80 |
| 1978Q0752 | 6065 | 19N | 21W | 31 | DAB | -114.312 | 47.361 | 19780503 | L | 185 | shallow | 221.00 | 6.60 | 24.60 | 10.10 |
| 1978Q0716 | 6066 | 19N | 21W | 31 | DAB | -114.313 | 47.362 | 19780411 | L | 189 | shallow | 221.00 | 6.90 | 28.00 | 10.00 |
| 1978Q0058 | 6064 | 19N | 21W | 31 | ADC | -114.313 | 47.365 | 19770713 | L | 165 | shallow | 196.00 | 5.80 | 27.00 | 11.00 |
| 1997Q0402 | 74087 | 19N | 21W | 34 | BABD | -114.259 | 47.369 | 19961005 | L | 270 | deep | 36.70 | 1.70 | 32.80 | 19.20 |
| 1984Q0805 | 6045 | 19N | 20W | 5 | BAD | -114.172 | 47.440 | 19840531 | L | 486 | deep | 13.40 | 0.90 | 29.00 | 7.30 |
| 1975Q1497 | 6046 | 19N | 20W | 6 | AAA | -114.182 | 47.442 | 19750916 | L | 18 | shallow | 7.90 | 3.40 | 27.50 | 5.80 |
| 1975Q1505 | 6047 | 19N | 20W | 13 | CCA | -114.092 | 47.402 | 19750918 | L | 64 | interm. | 3.60 | 1.20 | 33.80 | 14.10 |
| 1987Q0957 | 6050 | 19N | 20W | 30 | BABC | -114.196 | 47.383 | 19870922 | L | 54 | interm. | 57.70 | 3.60 | 44.40 | 30.80 |
| 1987Q0958 | 6052 | 19N | 20W | 30 | BABC | -114.196 | 47.383 | 19870922 | L | 19 | interm. | 97.30 | 3.60 | 65.70 | 35.30 |
| 1997Q0503 | 157046 | 19N | 19W | 18 | DCCD | -114.063 | 47.400 | 19961025 | L | 36 | shallow | 9.80 | 1.80 | 45.00 | 19.90 |
| 1997Q0480 | 73868 | 19N | 19W | 20 | BBAA | -114.048 | 47.399 | 19961030 | L | 321 | interm. | 16.80 | 1.60 | 18.80 | 2.30 |
| 1985Q0052 | 6034 | 18N | 21W | 4 | BCDA | -114.283 | 47.350 | 19841014 | S | 124 | shallow | 57.50 | 2.20 | 27.60 | 28.70 |
| 1985Q0050 | 6035 | 18N | 21W | 5 | ADCB | -114.293 | 47.350 | 19841013 | S | 320 | deep | 119.00 | 3.80 | 43.00 | 18.30 |
| 1984Q0811 | 6025 | 18N | 20W | 10 | ADDA | -114.118 | 47.335 | 19840607 | L | 53 | interm. | 12.70 | 0.60 | 68.20 | 17.90 |
| 1984Q0814 | 6029 | 18N | 20W | 14 | DBDD | -114.103 | 47.317 | 19840608 | L | 51 | shallow | 1.50 | 0.80 | 35.00 | 9.30 |
| 1983Q0404 | 6028 | 18N | 20W | 14 | DBD | -114.103 | 47.317 | 19830603 | L | 30 | interm. | 1.40 | 0.20 | 36.80 | 9.60 |
| 1983Q0924 | 6031 | 18N | 20W | 23 | DADA | -114.096 | 47.303 | 19830825 | L | 162 | Belt | 17.90 | 1.20 | 73.30 | 17.80 |

| Fe | Mn | Cl | $HCO_3$ | $CO_3$ | $SO_4$ | $NO_3$ | F | $SiO_2$ | TDS | Diss. Constit. | Hard-ness | Temp | Lab pH | Lab S.C. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.02 | 0.00 | <0.50 | 109.60 | 0.00 | < 2.50 | < 0.25 | <1.00 | 21.10 | 107.69 | 163.30 | 70.38 | 11.9 | 7.80 | 179.0 |
| 0.01 | < 0.01 | 0.50 | 99.40 | 0.00 | 3.70 | 0.14 | 0.40 | 18.70 | 105.62 | 156.06 | 59.65 | 13.0 | 7.24 | 164.6 |
| < 0.01 | < 0.01 | 1.75 | 207.60 | 0.00 | 7.00 | 2.08 | <0.10 | 12.00 | 194.00 | 299.33 | 171.91 | 14.0 | 7.94 | 349.3 |
| 0.08 | 0.22 | 2.40 | 173.50 | 0.00 | 26.30 | < 0.05 | <1.00 | 6.60 | 189.77 | 277.80 | 107.20 | 13.0 | 8.20 | 345.0 |
| 0.52 | 0.11 | 1.60 | 306.50 | 0.00 | 17.50 | < 0.25 | <1.00 | 53.90 | 323.23 | 478.74 | 183.37 | 1.4 | 7.90 | 498.0 |
| 0.30 | 0.01 | 2.40 | 309.00 | 0.00 | 20.00 | < 0.05 | <1.00 | 52.50 | 337.03 | 493.82 | 147.28 | 13.0 | 8.20 | 510.0 |
| 0.02 | < 0.01 | 4.00 | 328.50 | 0.00 | 6.40 | 0.87 | <1.00 | 17.30 | 296.33 | 467.21 | 235.26 | 9.8 | 8.50 | 520.0 |
| < 0.01 | 0.00 | 0.50 | 175.20 | 0.00 | 2.70 | 0.39 | 0.20 | 16.00 | 158.24 | 247.13 | 123.99 | 10.5 | 8.03 | 261.8 |
| 0.02 | 0.20 | 6.90 | 361.10 | 0.00 | 16.00 | 0.54 | 0.92 | 14.80 | 328.83 | 512.05 | 264.31 | 17.0 | 8.02 | 571.6 |
| 0.01 | 0.01 | 6.50 | 253.30 | 0.00 | 11.20 | 10.60 | 0.30 | 26.30 | 278.29 | 406.81 | 258.29 | 11.5 | 7.92 | 502.9 |
| 0.02 | 0.00 | 10.00 | 229.80 | 0.00 | 10.60 | 6.37 | 0.10 | 21.30 | 248.90 | 365.50 | 225.05 | 13.0 | 7.80 | 452.0 |
| < 0.01 | 0.00 | 2.90 | 412.00 | 0.00 | 6.40 | 1.10 | 0.50 | 22.20 | 353.56 | 562.60 | 306.56 | 13.0 | 8.25 | 611.7 |
| 0.04 | 0.01 | 3.00 | 254.40 | 0.00 | 8.50 | < 0.25 | <1.00 | 20.70 | 234.89 | 363.97 | 167.20 | 11.6 | 8.00 | 406.0 |
| < 0.01 | 0.02 | 1.70 | 188.30 | 0.00 | 0.50 | 0.04 | 0.10 | 18.80 | 173.21 | 268.76 | 119.28 | 15.5 | 7.91 | 286.4 |
| 0.00 | 0.00 | 2.30 | 298.70 | 0.00 | 3.50 | 1.60 | 0.20 | 14.00 | 256.35 | 407.90 | 246.39 | 9.0 | 7.69 | 449.6 |
| 0.02 | < 0.01 | <0.50 | 93.90 | 0.00 | < 2.50 | 0.65 | <2.00 | 7.70 | 83.83 | 131.47 | 69.60 | 10.3 | 7.90 | 158.0 |
| < 0.01 | 0.02 | 1.50 | 148.00 | 0.00 | 2.40 | 0.13 | 0.08 | 19.90 | 143.04 | 218.13 | 117.29 | 9.5 | 7.97 | 230.2 |
| < 0.01 | 0.03 | 10.95 | 350.80 | 0.00 | 39.30 | 0.38 | 0.60 | 19.30 | 366.87 | 544.86 | 246.76 | 9.0 | 8.17 | 612.6 |
| 0.09 | 1.30 | 9.40 | 460.00 | 0.00 | 27.90 | 0.02 | 0.20 | 18.00 | 437.31 | 670.71 | 293.02 | 15.5 | 7.69 | 716.5 |
| < 0.01 | 0.03 | 17.00 | 466.00 | 0.00 | 61.00 | 0.39 | 0.20 | 16.50 | 500.58 | 737.03 | 304.26 | 16.0 | 8.15 | 826.5 |
| 0.01 | 0.09 | 12.30 | 270.00 | 0.00 | 54.70 | 0.97 | 0.30 | 16.80 | 330.27 | 467.27 | 234.44 | 13.0 | 8.14 | 597.8 |
| < 0.01 | < 0.01 | 0.60 | 42.90 | 0.00 | 1.30 | 0.24 | <0.10 | 5.70 | 41.07 | 62.84 | 30.13 | 8.0 | 7.91 | 66.2 |
| < 0.01 | < 0.01 | 0.55 | 88.90 | 0.00 | 1.90 | 0.27 | <0.10 | 9.20 | 84.91 | 130.02 | 70.47 | 10.0 | 6.16 | 151.2 |
| < 0.01 | < 0.01 | 0.10 | 119.60 | 0.00 | 3.10 | 0.18 | 0.10 | 13.80 | 116.60 | 177.28 | 88.45 | 11.5 | 6.64 | 197.3 |
| < 0.01 | < 0.01 | <0.50 | 158.40 | 0.00 | < 2.50 | < 0.25 | <1.00 | 19.70 | 147.64 | 228.01 | 107.78 | 12.8 | 8.10 | 253.0 |
| 0.02 | < 0.01 | 0.00 | 158.80 | 0.00 | 3.90 | 0.10 | <0.10 | 15.60 | 148.74 | 229.32 | 104.40 | 13.5 | 7.88 | 252.4 |
| < 0.01 | < 0.01 | 7.70 | 617.00 | 0.00 | 12.80 | 3.32 | 0.40 | 26.30 | 573.96 | 887.02 | 302.28 | 14.0 | 7.71 | 934.1 |
| 1.00 | 0.50 | <0.50 | 113.50 | 0.00 | < 2.50 | < 0.25 | <1.00 | 19.50 | 115.02 | 172.61 | 81.17 | 12.3 | 7.90 | 181.0 |
| 0.01 | < 0.01 | 4.40 | 284.70 | 0.00 | 23.90 | 0.25 | 0.50 | 17.80 | 291.31 | 435.76 | 189.66 | 6.5 | 7.95 | 478.8 |
| 0.04 | < 0.01 | 18.95 | 384.50 | 0.00 | 71.80 | 0.99 | 0.20 | 11.90 | 446.79 | 641.88 | 253.49 | 9.5 | 7.90 | 757.4 |
| 0.01 | < 0.01 | 83.00 | 511.90 | 0.00 | 360.80 | 3.05 | 0.20 | 13.60 | 1073.93 | 1333.66 | 444.66 | 12.5 | 7.76 | 1708.0 |
| 0.05 | < 0.01 | 1.70 | 43.60 | 0.00 | 4.00 | 0.04 | <0.10 | 1.10 | 45.46 | 67.59 | 38.23 | 8.0 | 6.95 | 84.0 |
| < 0.01 | 0.00 | 0.70 | 179.60 | 0.00 | 1.80 | 0.21 | 0.20 | 25.20 | 167.98 | 259.11 | 129.34 | 10.0 | 7.71 | 271.3 |
| 0.04 | < 0.01 | 0.60 | 84.70 | 0.60 | 1.10 | 0.02 | 2.80 | 1.10 | 82.98 | 125.96 | 5.16 | 9.0 | 8.36 | 157.0 |
| < 0.01 | < 0.01 | 0.85 | 113.30 | 0.00 | 4.70 | 0.11 | <0.10 | 6.40 | 103.38 | 160.86 | 91.31 | 9.7 | 7.64 | 188.9 |
| 0.16 | 0.31 | 50.70 | 476.20 | 0.00 | 0.30 | 0.69 | 1.60 | 17.10 | 500.45 | 742.06 | 168.89 | 14.0 | 7.95 | 839.3 |
| 0.03 | < 0.01 | 47.00 | 369.90 | 0.00 | 82.20 | 2.60 | 0.10 | 14.20 | 490.04 | 677.73 | 366.02 | 14.0 | 7.74 | 891.5 |
| 0.02 | < 0.01 | 15.50 | 363.50 | 0.00 | 15.70 | 0.22 | 1.80 | 36.60 | 369.10 | 553.54 | 228.58 | 9.5 | 8.01 | 603.5 |
| < 0.01 | < 0.01 | 6.30 | 285.00 | 0.00 | 16.10 | 0.68 | 0.60 | 32.50 | 288.96 | 433.56 | 195.04 | 12.0 | 8.26 | 459.5 |
| 1.90 | 0.37 | 2.50 | 273.30 | 0.00 | < 0.10 | 0.02 | 0.30 | 11.60 | 237.14 | 375.81 | 145.16 | 11.5 | 7.92 | 396.0 |
| 2.04 | 0.10 | 36.95 | 553.80 | 0.00 | 1.00 | 0.09 | 2.00 | 16.80 | 553.38 | 834.38 | 151.46 | 15.5 | 7.60 | 950.9 |
| < 0.01 | 0.00 | 5.50 | 325.00 | 0.00 | 15.90 | 0.58 | 0.60 | 22.40 | 313.38 | 478.28 | 213.81 | 11.0 | 7.65 | 525.0 |
| 3.05 | 0.17 | 85.80 | 574.00 | 0.00 | 0.20 | 0.07 | 4.90 | 8.90 | 648.15 | 939.39 | 103.00 | 15.0 | 8.17 | 1101.0 |
| 1.00 | 0.05 | 90.00 | 578.00 | 0.00 | 0.20 | 0.03 | 4.80 | 10.10 | 656.80 | 950.08 | 111.08 | 14.5 | 7.93 | 1120.0 |
| 0.69 | 0.04 | 83.00 | 548.00 | 4.30 | 0.50 | < 0.02 | 3.90 | 8.60 | 610.78 | 888.83 | 112.70 | 14.5 | 8.39 | 1023.0 |
| 0.07 | < 0.01 | 7.40 | 279.60 | 0.00 | 4.00 | < 0.05 | <1.00 | 21.70 | 261.32 | 403.19 | 160.93 | 13.5 | 8.20 | 455.0 |
| 0.15 | 0.25 | 2.50 | 160.10 | 0.00 | 3.00 | 0.27 | <0.10 | 14.20 | 149.95 | 231.18 | 102.46 | 13.0 | 7.96 | 249.5 |
| 0.08 | < 0.01 | 3.35 | 120.00 | 0.00 | 7.40 | 0.77 | <0.10 | 14.90 | 130.21 | 191.10 | 92.54 | 12.3 | 7.48 | 220.2 |
| < 0.01 | < 0.01 | 0.30 | 180.80 | 0.00 | 4.80 | 0.16 | <0.10 | 10.40 | 157.42 | 249.16 | 142.43 | 9.5 | 7.96 | 288.0 |
| < 0.01 | 0.50 | 8.20 | 282.10 | 0.00 | 113.90 | 0.28 | 0.40 | 14.00 | 412.97 | 556.10 | 237.64 | 14.5 | 7.75 | 640.7 |
| 0.05 | 0.72 | 47.50 | 321.00 | 0.00 | 184.00 | 0.03 | 0.20 | 14.40 | 607.13 | 770.00 | 309.35 | 17.5 | 8.07 | 954.6 |
| 0.00 | < 0.01 | 1.30 | 259.90 | 0.00 | < 2.50 | 0.76 | <1.00 | 21.20 | 227.80 | 359.67 | 194.27 | 11.1 | 8.10 | 402.0 |
| 0.02 | < 0.01 | 0.60 | 110.30 | 0.00 | 2.60 | 0.30 | <1.00 | 21.70 | 119.06 | 175.03 | 56.41 | 13.3 | 8.00 | 187.0 |
| 0.03 | 0.00 | 6.40 | 347.00 | 0.00 | 20.70 | 0.35 | 1.20 | 31.10 | 346.72 | 522.78 | 187.05 | 11.0 | 8.09 | 572.9 |
| 1.36 | 0.08 | 33.20 | 497.00 | 0.00 | 1.10 | 0.04 | 1.40 | 11.60 | 477.72 | 729.90 | 182.69 | 13.0 | 8.13 | 821.5 |
| < 0.01 | 0.00 | 4.50 | 296.70 | 0.00 | 14.90 | 0.92 | <0.10 | 12.70 | 278.61 | 429.15 | 243.97 | 13.0 | 8.02 | 453.6 |
| < 0.01 | < 0.01 | 0.70 | 153.70 | 0.00 | 3.60 | 0.70 | <0.10 | 6.80 | 134.21 | 212.19 | 125.67 | 11.0 | 7.83 | 235.9 |
| < 0.01 | < 0.01 | 0.60 | 154.40 | 0.00 | 4.80 | 0.53 | 0.06 | 6.30 | 136.35 | 214.69 | 131.40 | 9.5 | 7.69 | 246.1 |
| < 0.01 | < 0.01 | 2.50 | 342.00 | 0.00 | 8.30 | 0.48 | 0.20 | 23.20 | 313.55 | 487.08 | 256.29 | 11.0 | 7.68 | 516.1 |

Appendix C—*Continued.*

| Lab No. | Site No. | Township | Range | Sec. | Tract | Longitude | Latitude | Sample Date (yyyymmdd) | County | Total Depth | Hydro Unit | Na | K | Ca | Mg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1997Q0554 | 137552 | 18N | 20W | 24 | ADBB | -114.079 | 47.308 | 19000101 | L | 80 | shallow | 0.79 | 0.14 | 34.10 | 8.90 |
| 1983Q0925 | 6020 | 18N | 19W | 4 | DDAD | -114.011 | 47.343 | 19830830 | L | 484 | Belt | 2.20 | 0.30 | 32.50 | 16.40 |
| 1997Q0557 | 73348 | 18N | 19W | 5 | AADA | -114.033 | 47.354 | 19961108 | L | 140 | interm. | 0.70 | 0.20 | 26.10 | 14.60 |
| 1997Q0552 | 130504 | 18N | 19W | 21 | DACA | -114.015 | 47.303 | 19961107 | L | 160 | Belt | 4.60 | 0.63 | 51.90 | 14.70 |
| 1983Q0926 | 6023 | 18N | 19W | 22 | CADD | -114.001 | 47.302 | 19830831 | L | 268 | Belt | 5.00 | 0.90 | 15.10 | 13.60 |
| 1985Q0053 | 6024 | 18N | 19W | 28 | CCDB | -114.029 | 47.284 | 19841014 | L | 147 | shallow | 1.20 | 0.40 | 21.70 | 8.70 |
| **Flathead Lake Perimeter subarea** | | | | | | | | | | | | | | | |
| 1984Q0844 | 6397 | 27N | 21W | 26 | CDCC | -114.238 | 48.067 | 19840822 | FH | 173 | Belt | 17.20 | 0.80 | 116.00 | 26.90 |
| 1997Q0198 | 148689 | 26N | 21W | 13 | BBCD | -114.254 | 48.018 | 19960810 | FH | 492 | Belt | 10.50 | 1.70 | 55.50 | 24.30 |
| 1997Q0188 | 132038 | 26N | 20W | 21 | DCCC | -114.180 | 47.992 | 19960811 | FH | 200 | Belt | 11.00 | 1.30 | 63.60 | 29.60 |
| 1997Q0142 | 155428 | 26N | 19W | 6 | BBBB | -114.069 | 48.052 | 19960728 | FH | 111 | Belt | 12.10 | 3.00 | 92.10 | 33.20 |
| 1997Q0184 | 79706 | 26N | 19W | 19 | BDAD | -114.061 | 48.003 | 19960813 | L | 1010 | Belt | 234.00 | 5.10 | 4.00 | 5.50 |
| 1997Q0452 | 78671 | 24N | 22W | 14 | DDDD | -114.371 | 47.834 | 19961019 | L | 235 | deep | 17.50 | 1.80 | 38.00 | 23.50 |
| 1997Q0470 | 78673 | 24N | 22W | 24 | CDCD | -114.362 | 47.820 | 19961011 | L | 300 | Belt | 19.10 | 0.51 | 49.10 | 29.70 |
| 1984Q0807 | 6312 | 24N | 21W | 19 | BCB | -114.349 | 47.830 | 19840605 | L | 314 | deep | 20.30 | 1.80 | 34.20 | 14.60 |
| 1984Q0806 | 6310 | 24N | 21W | 19 | BBD | -114.346 | 47.832 | 19840605 | L | 105 | interm. | 13.60 | 0.90 | 31.00 | 14.10 |
| 1997Q0437 | 78648 | 24N | 21W | 33 | BDDD | -114.296 | 47.798 | 19961011 | L | 245 | deep | 27.40 | 0.83 | 49.00 | 17.00 |
| 1983Q0397 | 6314 | 24N | 21W | 33 | ACC | -114.295 | 47.799 | 19830602 | L | 359 | interm. | 26.80 | 1.00 | 41.90 | 21.80 |
| 1975Q1499 | 6313 | 24N | 21W | 33 | ACC | -114.294 | 47.799 | 19750917 | L | 359 | interm. | 24.00 | 1.00 | 37.90 | 20.30 |
| 1997Q0555 | 78668 | 24N | 21W | 36 | DBCB | -114.229 | 47.796 | 19961107 | L | 767 | Belt | 30.20 | 0.83 | 78.10 | 18.70 |
| 1997Q0226 | 78462 | 24N | 19W | 16 | CADD | -114.038 | 47.838 | 19960822 | L | 120 | deep | 8.00 | 1.30 | 37.40 | 28.80 |
| 1997Q0229 | 137610 | 24N | 19W | 16 | DCAD | -114.033 | 47.836 | 19960822 | L | 360 | Belt | 11.00 | 1.10 | 32.90 | 40.10 |
| 1997Q0221 | 133023 | 24N | 19W | 21 | AACD | -114.031 | 47.831 | 19960822 | L | 565 | Belt | 13.00 | 2.00 | 29.10 | 42.90 |
| 1976Q0747 | 6275 | 23N | 22W | 12 | DDC | -114.352 | 47.762 | 19760701 | L | 10 | interm. | 24.40 | 7.80 | 53.80 | 20.40 |
| 1984Q0808 | 6269 | 23N | 21W | 14 | BBB | -114.261 | 47.761 | 19840605 | L | 300 | Belt | 7.60 | 0.40 | 16.60 | 9.60 |
| 1997Q0451 | 77911 | 23N | 21W | 17 | ABCD | -114.315 | 47.758 | 19961021 | L | 268 | deep | 13.10 | 1.50 | 33.20 | 8.80 |
| 1997Q0450 | 77915 | 23N | 21W | 17 | BCCD | -114.326 | 47.755 | 19961020 | L | 320 | Belt | 14.20 | 1.00 | 30.10 | 11.60 |
| 1997Q0444 | 77933 | 23N | 21W | 24 | DCBB | -114.229 | 47.736 | 19961015 | L | 200 | deep | 13.90 | 1.80 | 42.40 | 18.30 |
| 1997Q0441 | 148613 | 23N | 21W | 25 | AABD | -114.223 | 47.732 | 19961010 | L | 78 | interm. | 14.90 | 1.80 | 47.00 | 22.00 |
| 1983Q0805 | 6271 | 23N | 21W | 25 | DAAB | -114.221 | 47.726 | 19830728 | L | 138 | interm. | 30.70 | 1.90 | 30.60 | 8.10 |
| 1985Q1182 | 6272 | 23N | 21W | 26 | BAC | -114.257 | 47.730 | 19850711 | L | 118 | interm. | 31.30 | 1.80 | 27.50 | 7.10 |
| 1976Q0279 | 6273 | 23N | 21W | 34 | ADAC | -114.265 | 47.713 | 19760422 | L | 1169 | Tertiary | 13.40 | 0.80 | 15.40 | 8.20 |
| 1997Q0468 | 141506 | 23N | 21W | 35 | ABBA | -114.251 | 47.718 | 19961019 | L | 500 | Belt | 13.50 | 0.50 | 34.30 | 17.10 |
| 1976Q0744 | 6274 | 23N | 21W | 35 | BBAA | -114.258 | 47.718 | 19760701 | L | 364 | interm. | 13.20 | 1.50 | 33.40 | 14.40 |
| 1997Q0463 | 77752 | 23N | 20W | 21 | ABBD | -114.164 | 47.746 | 19961019 | L | 282 | Belt | 12.10 | 0.90 | 48.00 | 20.80 |
| 1975Q1493 | 6268 | 23N | 20W | 29 | BABB | -114.193 | 47.733 | 19750918 | L | 156 | deep | 20.60 | 0.60 | 33.60 | 18.30 |
| 1997Q0505 | 77520 | 23N | 19W | 7 | CABB | -114.085 | 47.769 | 19961024 | L | 324 | Belt | 7.10 | 0.75 | 93.80 | 19.50 |
| 1997Q0473 | 157640 | 23N | 19W | 20 | CDBC | -114.064 | 47.734 | 19961017 | L | 100 | interm. | 5.40 | 1.30 | 40.00 | 11.00 |
| 1997Q0457 | 148572 | 22N | 21W | 1 | DCDC | -114.227 | 47.690 | 19961021 | L | 800 | Belt | 24.90 | 2.10 | 42.00 | 24.00 |
| **Smith subarea** | | | | | | | | | | | | | | | |
| 1997Q0481 | 151986 | 28N | 25W | 36 | CCDD | -114.714 | 48.140 | 19961029 | FH | 64 | interm. | 3.60 | 1.20 | 4.50 | 1.60 |
| 1996Q0531 | 83242 | 28N | 25W | 36 | CCDC | -114.714 | 48.139 | 19951018 | FH | 350 | interm. | 3.20 | 0.86 | 2.30 | 0.66 |
| 1996Q0533 | 83241 | 28N | 25W | 36 | CCAB | -114.715 | 48.143 | 19951018 | FH | 90 | interm. | 3.70 | 1.50 | 4.90 | 1.70 |
| 1997Q0011 | 81319 | 27N | 26W | 4 | BADC | -114.959 | 48.136 | 19960630 | FH | 475 | Belt | 26.00 | 1.00 | 18.80 | 5.00 |
| 1997Q0013 | 137653 | 26N | 25W | 6 | CABB | -114.872 | 48.042 | 19960628 | FH | 402 | Belt | 15.00 | 0.90 | 10.60 | 3.30 |
| **Jocko subarea** | | | | | | | | | | | | | | | |
| 1997Q0454 | 6036 | 18N | 21W | 8 | DDBB | -114.293 | 47.331 | 19961016 | S | 450 | Belt | 42.00 | 2.70 | 32.80 | 15.00 |
| 1985Q0051 | 6039 | 18N | 21W | 21 | BCBB | -114.287 | 47.309 | 19841013 | S | 160 | deep | 12.20 | 0.90 | 45.40 | 14.40 |
| 1976Q0277 | 6033 | 18N | 20W | 32 | BCD | -114.177 | 47.277 | 19760422 | L | | shallow | 7.10 | 1.30 | 43.60 | 11.80 |
| 1984Q0804 | 6032 | 18N | 20W | 32 | BCC | -114.181 | 47.278 | 19840531 | L | 88 | shallow | 8.00 | 1.20 | 51.00 | 12.30 |
| 1983Q0922 | 6011 | 17N | 20W | 5 | BBAA | -114.177 | 47.269 | 19830811 | L | 50 | shallow | 4.40 | 0.70 | 36.80 | 10.70 |
| 1983Q0923 | 6012 | 17N | 20W | 18 | DBAD | -114.187 | 47.231 | 19830818 | L | 70 | Belt | 174.00 | 4.90 | 67.80 | 43.50 |
| 1997Q0556 | 73066 | 17N | 20W | 20 | DDAC | -114.162 | 47.213 | 19961114 | L | 200 | Belt | 28.80 | 2.60 | 65.20 | 24.20 |
| 1983Q0927 | 6013 | 17N | 20W | 26 | DCAA | -114.103 | 47.199 | 19830901 | L | 61 | shallow | 2.20 | 0.40 | 30.10 | 10.00 |
| 1975Q1506 | 6014 | 17N | 20W | 29 | ACB | -114.169 | 47.206 | 19750918 | L | 187 | Tertiary | 28.20 | 2.60 | 56.10 | 21.50 |
| 1997Q0513 | 157464 | 17N | 20W | 36 | BCCB | -114.095 | 47.191 | 19961031 | L | 38 | shallow | 1.70 | 0.92 | 32.10 | 14.30 |
| 1983Q0932 | 6008 | 17N | 18W | 29 | CAAC | -113.918 | 47.201 | 19830802 | L | 50 | shallow | 1.40 | 1.70 | 33.90 | 8.40 |

| Fe | Mn | Cl | $HCO_3$ | $CO_3$ | $SO_4$ | $NO_3$ | F | $SiO_2$ | TDS | Diss. Constit. | Hard-ness | Temp | Lab pH | Lab S.C. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.01 | < 0.01 | <0.50 | 137.90 | 0.00 | 2.80 | 0.40 | <1.00 | 6.10 | 121.17 | 191.14 | 121.78 | 9.3 | 8.10 | 228.0 |
| < 0.01 | 0.00 | 0.30 | 185.00 | 0.00 | 2.20 | 0.07 | 0.05 | 11.60 | 156.96 | 250.83 | 148.65 | 9.0 | 7.84 | 280.0 |
| < 0.01 | < 0.01 | <0.50 | 152.00 | 0.00 | < 2.50 | 0.44 | <1.00 | 6.50 | 123.22 | 200.34 | 125.27 | 10.2 | 8.00 | 244.0 |
| 0.04 | 0.01 | 0.70 | 229.10 | 0.00 | 2.70 | < 0.25 | <1.00 | 16.00 | 204.21 | 320.45 | 190.10 | 8.8 | 8.50 | 359.0 |
| < 0.01 | < 0.01 | 1.00 | 122.50 | 0.00 | 2.40 | 0.29 | 0.10 | 19.30 | 118.19 | 180.34 | 93.68 | 11.0 | 7.95 | 196.9 |
| 0.00 | < 0.01 | 0.40 | 112.20 | 0.00 | 4.00 | 0.10 | <0.10 | 6.20 | 97.97 | 154.90 | 89.99 | 8.0 | 8.04 | 190.5 |
| | | | | | | | | | | | | | | |
| < 0.01 | < 0.01 | 57.00 | 363.00 | 0.00 | 22.70 | 12.21 | 0.10 | 20.30 | 452.08 | 636.26 | 400.37 | 9.8 | 7.99 | 826.3 |
| < 0.01 | < 0.01 | 2.50 | 304.50 | 0.00 | 9.00 | 0.30 | <1.00 | 17.10 | 271.14 | 425.64 | 238.60 | 11.2 | 7.70 | 475.0 |
| 0.01 | < 0.01 | 10.10 | 344.50 | 0.00 | 5.50 | 0.40 | <1.00 | 18.40 | 309.65 | 484.45 | 280.64 | 10.5 | 7.60 | 551.0 |
| 0.02 | < 0.01 | 46.00 | 386.00 | 0.00 | 10.10 | 1.50 | <1.00 | 27.60 | 415.82 | 611.67 | 366.62 | 10.0 | 7.40 | 725.0 |
| 0.04 | 0.01 | 54.30 | 570.50 | 0.00 | < 2.50 | < 0.25 | <1.00 | 10.00 | 594.02 | 883.48 | 32.63 | 16.2 | 8.10 | 992.0 |
| < 0.01 | < 0.01 | 3.50 | 239.10 | 0.00 | 30.00 | 0.25 | <1.00 | 7.10 | 239.51 | 360.82 | 191.61 | 10.7 | 8.30 | 434.0 |
| < 0.01 | < 0.01 | <0.50 | 292.20 | 0.00 | 8.00 | 1.90 | <1.00 | 25.40 | 277.73 | 425.99 | 244.85 | 11.2 | 8.10 | 478.0 |
| 0.02 | 0.23 | 2.10 | 213.50 | 0.00 | 16.60 | 0.20 | 0.30 | 14.10 | 209.63 | 317.96 | 145.49 | 11.0 | 7.99 | 307.7 |
| < 0.01 | < 0.01 | 1.90 | 190.80 | 0.00 | 8.20 | 1.04 | 0.30 | 16.40 | 181.44 | 278.25 | 135.44 | 11.5 | 8.04 | 301.3 |
| 3.30 | 2.30 | 1.60 | 322.10 | 0.00 | < 2.50 | < 0.25 | <1.00 | 24.90 | 285.02 | 448.45 | 192.33 | 11.5 | 8.10 | 478.0 |
| 0.50 | 0.16 | 2.10 | 292.80 | 0.00 | 4.30 | 0.03 | 0.60 | 31.40 | 274.83 | 423.39 | 194.35 | 11.5 | 8.09 | 444.4 |
| < 0.01 | < 0.01 | 1.65 | 279.30 | 0.00 | 5.20 | 0.05 | 0.40 | 27.20 | 255.28 | 397.00 | 178.19 | 10.0 | 8.10 | 420.6 |
| 3.00 | 4.30 | 2.50 | 419.70 | 0.00 | < 2.50 | < 0.25 | <1.00 | 24.00 | 368.50 | 581.45 | 271.98 | 8.4 | 8.00 | 616.0 |
| < 0.01 | < 0.01 | 1.30 | 270.00 | 0.00 | 4.30 | 1.20 | <1.00 | 11.80 | 227.11 | 364.10 | 211.93 | 9.7 | 8.00 | 403.0 |
| < 0.01 | < 0.01 | 2.30 | 320.90 | 0.00 | < 2.50 | < 0.25 | <1.00 | 13.80 | 259.48 | 422.30 | 247.20 | 11.0 | 7.90 | 488.0 |
| 0.02 | 0.03 | 3.60 | 313.50 | 0.00 | 17.90 | < 0.25 | <1.00 | 11.30 | 274.36 | 433.43 | 249.24 | 10.5 | 8.00 | 497.0 |
| 0.07 | 0.08 | 2.55 | 324.50 | 0.00 | 7.90 | < 0.02 | 0.20 | 16.20 | 293.25 | 457.90 | 218.31 | 11.5 | 7.88 | 511.0 |
| < 0.01 | 0.00 | 1.50 | 118.10 | 0.00 | 1.50 | 0.20 | 0.20 | 27.00 | 122.84 | 182.77 | 80.96 | 13.0 | 7.80 | 183.6 |
| < 0.01 | < 0.01 | <0.50 | 164.20 | 0.00 | 6.60 | 1.00 | <1.00 | 10.80 | 155.92 | 239.23 | 119.12 | 10.9 | 8.00 | 288.0 |
| 0.00 | 0.00 | <0.50 | 172.00 | 0.00 | 7.60 | 0.60 | <1.00 | 11.80 | 161.80 | 249.07 | 122.91 | 10.5 | 8.10 | 290.0 |
| 0.01 | < 0.01 | 1.60 | 248.60 | 0.00 | 4.10 | 0.80 | <1.00 | 20.00 | 225.42 | 351.55 | 181.20 | 11.0 | 8.10 | 397.0 |
| < 0.01 | < 0.01 | <0.50 | 278.80 | 0.00 | 8.00 | 1.30 | <1.00 | 20.10 | 252.49 | 393.95 | 207.91 | 10.6 | 8.30 | 454.0 |
| 0.14 | 0.21 | 5.60 | 181.30 | 0.00 | 23.50 | 0.02 | 0.50 | 15.40 | 205.98 | 297.97 | 109.75 | 12.0 | 7.67 | 339.3 |
| 0.15 | 0.23 | 3.00 | 168.80 | 0.00 | 22.50 | 0.20 | 0.50 | 15.20 | 192.68 | 278.33 | 97.89 | 10.0 | 7.07 | 335.1 |
| 0.11 | 0.02 | 0.90 | 118.40 | 0.00 | 2.60 | 0.21 | 0.10 | 18.90 | 118.97 | 179.04 | 72.21 | 8.0 | 8.02 | 189.3 |
| < 0.01 | < 0.01 | 0.90 | 201.90 | 0.00 | 4.70 | 0.30 | <1.00 | 27.00 | 197.90 | 300.34 | 156.03 | 12.8 | 8.00 | 326.0 |
| 0.03 | < 0.01 | 1.45 | 194.90 | 0.00 | 10.30 | 0.54 | 0.20 | 16.80 | 187.83 | 286.72 | 142.67 | 12.0 | 7.90 | 326.3 |
| < 0.01 | < 0.01 | <0.50 | 264.10 | 0.00 | 11.00 | 1.00 | <1.00 | 19.10 | 243.14 | 377.14 | 205.47 | 11.4 | 7.90 | 428.0 |
| 0.04 | < 0.01 | 1.35 | 252.70 | 0.00 | 3.20 | 0.02 | 0.60 | 4.40 | 207.20 | 335.41 | 159.22 | 10.2 | 8.09 | 372.1 |
| 0.39 | 0.00 | <0.50 | 361.10 | 0.00 | 7.30 | < 0.25 | <1.00 | 18.40 | 326.06 | 509.28 | 314.48 | 10.0 | 8.10 | 549.0 |
| 0.01 | < 0.01 | <0.50 | 180.60 | 0.00 | 5.90 | < 0.25 | <1.00 | 15.50 | 168.12 | 264.25 | 157.75 | 10.4 | 7.90 | 300.0 |
| < 0.01 | 0.02 | 4.00 | 289.80 | 0.00 | 18.00 | < 0.25 | <1.00 | 15.20 | 274.08 | 421.12 | 203.66 | 12.8 | 8.20 | 482.0 |
| | | | | | | | | | | | | | | |
| 0.12 | < 0.01 | 1.10 | 25.60 | 0.00 | 3.00 | 0.19 | <1.00 | 25.30 | 53.52 | 66.51 | 17.82 | 4.9 | 6.40 | 58.0 |
| 2.70 | 0.03 | 3.00 | 32.50 | 0.00 | 2.50 | < 0.05 | <0.10 | 2.10 | 38.36 | 54.85 | 8.45 | 6.5 | 6.85 | 58.4 |
| 0.13 | 0.01 | 1.50 | 25.60 | 0.00 | 7.50 | 0.35 | <0.10 | 22.20 | 56.12 | 69.11 | 19.23 | 7.1 | 6.66 | 70.8 |
| 1.40 | 0.55 | 4.00 | 151.50 | 0.00 | < 2.50 | 0.29 | <1.00 | 31.10 | 163.02 | 239.89 | 67.52 | 9.6 | 7.30 | 228.0 |
| 0.08 | 0.30 | 2.00 | 72.70 | 0.00 | 12.00 | < 0.05 | <1.00 | 54.40 | 134.40 | 171.29 | 40.05 | 9.5 | 6.40 | 151.0 |
| | | | | | | | | | | | | | | |
| < 0.01 | 0.06 | 8.00 | 266.30 | 0.00 | 8.70 | < 0.25 | <1.00 | 5.50 | 245.95 | 381.07 | 143.64 | 13.0 | 8.30 | 456.0 |
| 0.03 | < 0.01 | 3.30 | 225.50 | 0.00 | 8.30 | 0.28 | 0.10 | 12.40 | 208.40 | 322.82 | 172.63 | 10.0 | 8.01 | 365.7 |
| 0.05 | < 0.01 | 1.25 | 203.50 | 0.00 | 4.10 | 0.18 | 0.10 | 12.30 | 182.03 | 285.28 | 157.44 | 11.0 | 7.91 | 319.0 |
| < 0.01 | < 0.01 | 3.40 | 229.40 | 0.00 | 5.50 | 0.44 | <0.10 | 13.30 | 208.16 | 324.56 | 177.97 | 10.0 | 7.91 | 349.5 |
| < 0.01 | < 0.01 | 1.10 | 172.00 | 0.00 | 4.30 | 0.19 | 0.03 | 11.00 | 153.96 | 241.23 | 135.93 | 10.0 | 7.85 | 269.4 |
| < 0.01 | < 0.01 | 61.80 | 518.00 | 0.00 | 204.00 | 1.69 | 1.20 | 12.40 | 826.49 | 1089.32 | 348.34 | 12.0 | 7.67 | 1311.0 |
| 0.02 | < 0.01 | 6.20 | 370.90 | 0.00 | 13.20 | 0.33 | <1.00 | 20.70 | 343.98 | 532.17 | 262.41 | 10.1 | 7.70 | 591.0 |
| < 0.01 | < 0.01 | 0.30 | 147.40 | 0.00 | 2.90 | 0.14 | 0.05 | 9.20 | 127.91 | 202.70 | 116.32 | 9.0 | 7.85 | 226.9 |
| < 0.01 | < 0.01 | 6.60 | 327.20 | 0.00 | 11.30 | 0.02 | 0.30 | 10.50 | 298.31 | 464.32 | 228.58 | 9.0 | 7.99 | 533.2 |
| 0.01 | < 0.01 | <0.50 | 171.80 | 0.00 | < 2.50 | 0.80 | <1.00 | 9.80 | 144.27 | 235.24 | 153.41 | 8.7 | 8.10 | 283.0 |
| < 0.01 | 0.00 | 0.20 | 146.40 | 0.00 | 2.70 | 0.03 | 0.10 | 7.80 | 128.51 | 202.79 | 119.22 | 9.0 | 7.81 | 224.5 |

Appendix C—*Continued.*

| Lab No. | Site No. | Township | Range | Sec. | Tract | Longitude | Latitude | Sample Date (yyyymmdd) | County | Total Depth | Hydro Unit | Na | K | Ca | Mg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1983Q0921 | 6005 | 16N | 20W | 11 | ADDC | -114.082 | 47.161 | 19830810 | L | 68 | shallow | 1.90 | 1.20 | 34.90 | 8.20 |
| 1997Q0516 | 72742 | 16N | 20W | 12 | AAAD | -114.060 | 47.166 | 19961031 | L | 49 | shallow | 1.70 | 0.89 | 33.20 | 12.90 |
| 1997Q0517 | 143213 | 16N | 20W | 13 | AAAC | -114.062 | 47.152 | 19961031 | L | 78 | shallow | 4.10 | 1.40 | 34.40 | 10.40 |
| 1975Q1504 | 6000 | 16N | 19W | 8 | DCD | -114.023 | 47.153 | 19750918 | L | 155 | interm. | 2.20 | 1.30 | 40.60 | 16.40 |
| 1987Q0963 | 703174 | 16N | 19W | 8 | DCAA | -114.023 | 47.156 | 19870924 | L | 33 | shallow | 1.30 | 0.50 | 30.70 | 6.80 |
| 1997Q0508 | 72601 | 16N | 19W | 9 | BDCA | -114.009 | 47.161 | 19961101 | L | 144 | Belt | 1.80 | 0.97 | 25.40 | 14.90 |
| 1997Q0514 | 703167 | 16N | 19W | 9 | CDBA | -114.009 | 47.156 | 19961101 | L | 137 | interm. | 1.50 | 0.41 | 33.60 | 9.90 |
| 1983Q0743 | 6003 | 16N | 19W | 18 | BBC | -114.058 | 47.149 | 19830726 | L | 80 | interm. | 2.20 | 1.30 | 35.50 | 9.50 |
| 1997Q0518 | 72658 | 16N | 19W | 20 | CADA | -114.028 | 47.129 | 19961101 | M | 482 | deep | 8.40 | 1.60 | 5.70 | 7.50 |
| 1997Q0512 | 72657 | 16N | 19W | 20 | CCCD | -114.036 | 47.125 | 19961031 | M | 139 | interm. | 11.10 | 0.45 | 14.10 | 9.10 |
| 1983Q0739 | 6004 | 16N | 19W | 30 | CDBC | -114.054 | 47.112 | 19830722 | M | 58 | interm. | 2.10 | 1.30 | 27.60 | 11.50 |
| 1983Q0738 | 5991 | 15N | 20W | 13 | BABB | -114.074 | 47.065 | 19830720 | M | 431 | Belt | 7.20 | 0.40 | 8.50 | 3.10 |
| 1983Q0741 | 5992 | 15N | 20W | 13 | DCAA | -114.065 | 47.055 | 19830719 | M | 130 | interm. | 4.90 | 0.40 | 30.40 | 7.80 |
| 1983Q0740 | 5993 | 15N | 20W | 23 | DCAA | -114.086 | 47.041 | 19830712 | M | 70 | Belt | 7.80 | 0.60 | 16.50 | 2.70 |
| 1983Q0742 | 5994 | 15N | 20W | 24 | CBBA | -114.078 | 47.044 | 19830721 | M | 42 | deep | 3.70 | 0.90 | 18.20 | 6.60 |
| 1983Q0737 | 5989 | 15N | 19W | 5 | BCCC | -114.037 | 47.088 | 19830720 | M | 473 | Belt | 6.80 | 0.60 | 10.30 | 9.10 |
| 1983Q0736 | 5990 | 15N | 19W | 7 | BCCC | -114.059 | 47.074 | 19830715 | M | 90 | interm. | 8.40 | 1.70 | 26.50 | 10.40 |
| **Coram subarea** | | | | | | | | | | | | | | | |
| 1981Q1676 | 6683 | 32N | 19W | 26 | BCCC | -114.000 | 48.508 | 19810916 | FH | 30 | interm. | 0.90 | 0.20 | 28.60 | 7.10 |
| 1981Q1675 | 6681 | 32N | 19W | 26 | BBCD | -113.998 | 48.513 | 19810916 | FH | 52 | shallow | 2.90 | 0.70 | 68.90 | 14.00 |
| 1981Q1677 | 6690 | 32N | 19W | 27 | ADAA | -114.002 | 48.511 | 19810917 | FH | 11 | shallow | 2.10 | 0.70 | 60.30 | 12.00 |
| 1981Q1678 | 6703 | 32N | 19W | 27 | ADAD | -114.002 | 48.511 | 19810917 | FH | 10 | shallow | 1.60 | 0.20 | 52.20 | 10.20 |
| 1981Q1679 | 6710 | 32N | 19W | 27 | ADAD | -114.001 | 48.510 | 19810917 | FH | 10 | shallow | 1.30 | 0.10 | 41.60 | 8.50 |
| 1981Q1673 | 6695 | 32N | 19W | 27 | ADAB | -114.004 | 48.511 | 19810916 | FH | 35 | shallow | 1.90 | 0.50 | 56.60 | 11.30 |
| 1981Q1674 | 6714 | 32N | 19W | 27 | ADCD | -114.004 | 48.501 | 19810916 | FH | 35 | shallow | 1.00 | 0.10 | 36.70 | 7.90 |
| 1981Q0439 | 6700 | 32N | 19W | 27 | ADAD | -114.002 | 48.511 | 19810521 | FH | 8 | shallow | 2.10 | 0.10 | 54.60 | 11.00 |
| 1981Q0442 | 6718 | 32N | 19W | 27 | ADDA | -114.001 | 48.510 | 19810521 | FH | 10 | shallow | 1.20 | 0.10 | 56.10 | 11.10 |
| 1997Q0046 | 139705 | 31N | 20W | 10 | ABBD | -114.140 | 48.471 | 19960715 | FH | 505 | Belt | 17.70 | 0.81 | 18.70 | 24.80 |
| 1997Q0223 | 85108 | 30N | 19W | 4 | BBBD | -114.041 | 48.399 | 19960824 | FH | 400 | Belt | 3.60 | 0.54 | 54.30 | 21.70 |
| 1997Q0136 | 120853 | 30N | 19W | 4 | CACC | -114.037 | 48.390 | 19960725 | FH | 100 | deep | 2.30 | 0.36 | 38.00 | 18.00 |
| **Little Bitterroot subarea** | | | | | | | | | | | | | | | |
| 1985Q0045 | 6320 | 24N | 24W | 25 | DADB | -114.606 | 47.809 | 19841010 | S | 328 | deep | 19.80 | 1.80 | 30.30 | 12.90 |
| 1987Q0969 | 6326 | 24N | 24W | 27 | CDCA | -114.661 | 47.806 | 19870918 | S | 49 | shallow | 6.10 | 3.20 | 40.20 | 5.40 |
| 1987Q0968 | 6324 | 24N | 24W | 27 | CDCA | -114.661 | 47.806 | 19870918 | S | 39 | shallow | 5.80 | 3.50 | 37.60 | 6.50 |
| 1985Q0044 | 6321 | 24N | 24W | 27 | ABDB | -114.654 | 47.817 | 19841010 | S | 217 | Tertiary | 34.20 | 5.80 | 27.50 | 10.10 |
| 1983Q1225 | 6327 | 24N | 24W | 27 | DDDD | -114.647 | 47.806 | 19831013 | S | 150 | deep | 10.70 | 1.80 | 26.30 | 6.10 |
| 1995Q0347 | 145008 | 23N | 24W | 2 | CCDB | -114.644 | 47.776 | 19941129 | S | 8 | shallow | 54.20 | 6.50 | 65.70 | 18.10 |
| 1993Q0719 | 6278 | 23N | 24W | 3 | BABA | -114.661 | 47.790 | 19930603 | S | 240 | Belt | 13.40 | 3.60 | 13.80 | 5.00 |
| 1983Q1221 | 6280 | 23N | 24W | 10 | BCDA | -114.664 | 47.769 | 19831024 | S | 38 | interm. | 20.80 | 1.00 | 34.70 | 11.60 |
| 1993Q0754 | 6281 | 23N | 24W | 15 | AABA | -114.651 | 47.760 | 19930604 | S | | deep | 27.50 | 2.20 | 37.10 | 14.80 |
| 1993Q0768 | 140370 | 23N | 24W | 26 | CDCD | -114.640 | 47.718 | 19930607 | S | | deep | 46.70 | 1.20 | 31.20 | 8.20 |
| 1994Q0982 | 141772 | 23N | 24W | 33 | ABAA | -114.674 | 47.717 | 19940504 | S | 375 | Belt | 27.20 | 3.90 | 11.30 | 5.40 |
| 1983Q0399 | 6283 | 23N | 24W | 34 | ADAA | -114.648 | 47.714 | 19830602 | S | 377 | deep | 32.40 | 1.60 | 40.00 | 10.20 |
| 1979Q3765 | 6284 | 23N | 24W | 34 | CBDD | -114.662 | 47.708 | 19791206 | S | 369 | deep | 24.00 | 0.80 | 29.40 | 6.60 |
| 1997Q0352 | 150549 | 23N | 24W | 35 | BADA | -114.637 | 47.715 | 19960920 | S | 319 | deep | 57.10 | 1.70 | 21.00 | 6.20 |
| 1993Q0759 | 6285 | 23N | 24W | 35 | DCCC | -114.635 | 47.703 | 19930604 | S | 297 | deep | 42.20 | 2.30 | 38.40 | 8.40 |
| 1993Q0757 | 6248 | 22N | 24W | 2 | DAAB | -114.628 | 47.696 | 19930607 | S | 306 | deep | 60.00 | 2.50 | 27.00 | 5.60 |
| 1983Q1222 | 6249 | 22N | 24W | 3 | DAAB | -114.649 | 47.696 | 19831025 | S | 330 | deep | 51.10 | 1.80 | 17.70 | 4.40 |
| 1987Q0966 | 6252 | 22N | 24W | 4 | ABBA | -114.677 | 47.703 | 19870922 | S | 10 | interm. | 6.60 | 1.90 | 15.00 | 3.60 |
| 1987Q0965 | 6251 | 22N | 24W | 4 | ABBA | -114.677 | 47.703 | 19870922 | S | 14 | interm. | 8.90 | 1.50 | 29.10 | 10.60 |
| 1993Q0756 | 6253 | 22N | 24W | 10 | ABAB | -114.654 | 47.688 | 19930605 | S | 314 | deep | 23.30 | 2.70 | 29.00 | 8.00 |
| 1993Q0715 | 77214 | 22N | 24W | 12 | ACCC | -114.613 | 47.682 | 19930603 | S | 309 | deep | 56.20 | 2.90 | 30.00 | 5.00 |
| 1993Q0758 | 6255 | 22N | 24W | 16 | DDCD | -114.671 | 47.660 | 19930605 | S | | deep | 30.40 | 1.00 | 9.60 | 2.50 |
| 1993Q0767 | 6256 | 22N | 24W | 23 | ABAB | -114.633 | 47.659 | 19930605 | S | 315 | deep | 23.30 | 1.30 | 34.50 | 9.00 |
| 1979Q3740 | 6257 | 22N | 24W | 24 | ABBD | -114.613 | 47.658 | 19791205 | S | 300 | deep | 97.90 | 1.40 | 6.00 | 0.90 |
| 1994Q0857 | 82513 | 22N | 24W | 26 | ABAA | -114.631 | 47.645 | 19931108 | S | 300 | deep | 19.30 | 1.30 | 34.00 | 8.40 |
| 1994Q0855 | 77279 | 22N | 24W | 34 | DDBA | -114.650 | 47.619 | 19931108 | S | 286 | Belt | 28.70 | 3.10 | 22.30 | 5.70 |
| 1976Q0278 | 6258 | 22N | 24W | 34 | DCC | -114.656 | 47.617 | 19760423 | S | 75 | Belt | 43.20 | 5.60 | 16.40 | 5.20 |

| Fe | Mn | Cl | $HCO_3$ | $CO_3$ | $SO_4$ | $NO_3$ | F | $SiO_2$ | TDS | Diss. Constit. | Hard-ness | Temp | Lab pH | Lab S.C. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| < 0.01 | < 0.01 | 0.80 | 148.80 | 0.00 | 4.10 | 0.51 | 0.10 | 11.60 | 136.67 | 212.17 | 120.90 | 11.0 | 7.47 | 235.9 |
| < 0.01 | < 0.01 | <0.50 | 167.40 | 0.00 | 2.60 | 0.38 | <1.00 | 10.30 | 144.44 | 232.47 | 144.87 | 9.3 | 8.00 | 271.0 |
| 0.02 | < 0.01 | <0.50 | 156.40 | 0.00 | < 2.50 | < 0.25 | <1.00 | 14.90 | 142.28 | 221.64 | 128.70 | 11.3 | 8.10 | 265.0 |
| < 0.01 | < 0.01 | 0.85 | 171.20 | 13.90 | 4.80 | 0.41 | <0.10 | 9.60 | 174.39 | 261.26 | 168.88 | 8.5 | 8.48 | 249.9 |
| < 0.01 | 0.00 | 0.20 | 129.80 | 0.00 | 2.20 | 0.10 | <0.10 | 8.40 | 114.24 | 180.10 | 104.65 | 10.5 | 7.70 | 207.0 |
| < 0.01 | < 0.01 | 0.50 | 148.80 | 0.00 | 7.60 | < 0.25 | <1.00 | 10.20 | 134.18 | 209.68 | 124.75 | 10.2 | 8.20 | 250.0 |
| < 0.01 | < 0.01 | 0.50 | 142.30 | 0.00 | < 2.50 | < 0.25 | <1.00 | 8.60 | 124.17 | 196.37 | 124.65 | 8.3 | 8.10 | 233.0 |
| 0.01 | 0.00 | 1.60 | 161.30 | 0.00 | 2.50 | 0.20 | 0.04 | 11.80 | 144.10 | 225.95 | 127.75 | 10.5 | 7.67 | 248.8 |
| 4.10 | 0.16 | <0.50 | 77.10 | 0.00 | < 2.50 | < 0.25 | <1.00 | 51.30 | 116.74 | 155.86 | 45.10 | 10.4 | 7.80 | 128.0 |
| 0.03 | < 0.01 | <0.50 | 117.60 | 0.00 | < 2.50 | 0.31 | <1.00 | 17.30 | 110.32 | 172.89 | 79.22 | 9.5 | 8.10 | 187.0 |
| 0.02 | 0.01 | 2.60 | 147.90 | 0.00 | 2.60 | 0.19 | 0.04 | 12.50 | 133.31 | 208.35 | 116.25 | 8.0 | 7.74 | 229.8 |
| 0.01 | 0.00 | 2.00 | 59.70 | 0.00 | 1.60 | 0.11 | 0.04 | 13.50 | 65.87 | 96.16 | 33.98 | 10.0 | 8.11 | 95.9 |
| 0.01 | 0.02 | 2.70 | 142.50 | 0.00 | 2.60 | 0.07 | 0.04 | 17.60 | 136.74 | 209.04 | 108.01 | 9.0 | 7.50 | 227.6 |
| 0.02 | 0.00 | 2.40 | 80.60 | 0.00 | 3.10 | 0.07 | 0.02 | 30.40 | 103.31 | 144.21 | 52.31 | 8.0 | 7.11 | 135.5 |
| 0.04 | 0.00 | 1.60 | 93.30 | 0.00 | 3.60 | 0.13 | 0.02 | 16.70 | 97.45 | 144.79 | 72.61 | 8.5 | 7.08 | 157.1 |
| 0.01 | 0.00 | 1.20 | 94.40 | 0.00 | 3.00 | 0.07 | 0.20 | 24.00 | 101.78 | 149.68 | 63.17 | 10.5 | 7.57 | 148.4 |
| 2.28 | 0.36 | 1.80 | 152.30 | 0.00 | 5.00 | 0.02 | 0.09 | 26.90 | 158.47 | 235.75 | 108.98 | 9.5 | 7.32 | 240.4 |
| | | | | | | | | | | | | | | |
| 0.02 | 0.00 | 0.30 | 117.40 | 0.00 | 5.30 | 0.06 | 0.07 | 5.70 | 106 | 166 | 101 | 14.5 | 6.8 | 199 |
| 2.25 | 0.24 | 0.50 | 288.90 | 0.00 | 0.60 | 0.05 | 0.10 | 28.20 | 261 | 407 | 230 | 6.0 | 7.3 | 437 |
| 0.07 | 0.00 | 0.90 | 235.70 | 0.00 | 5.30 | 0.12 | 0.07 | 7.50 | 205 | 325 | 200 | 9.0 | 6.8 | 378 |
| 0.06 | 0.00 | 0.70 | 205.40 | 0.00 | 4.70 | 0.15 | 0.11 | 7.70 | 179 | 283 | 172 | 10.0 | 6.9 | 233 |
| 0.04 | < 0.01 | 0.60 | 164.90 | 0.00 | 4.40 | 0.19 | 0.06 | 7.40 | 145 | 229 | 139 | 10.5 | 7.2 | 275 |
| 0.08 | 0.01 | 0.80 | 245.50 | 0.00 | 4.80 | 0.15 | 0.06 | 8.10 | 205 | 330 | 188 | 8.0 | 7.7 | 387 |
| 0.01 | 0.01 | 0.20 | 144.40 | 0.00 | 4.70 | 0.11 | 0.08 | 5.80 | 128 | 201 | 124 | 8.0 | 7.5 | 240 |
| < 0.01 | < 0.01 | 1.40 | 209.80 | 0.00 | 7.20 | 0.21 | 0.03 | 6.70 | 187 | 293 | 182 | 5.5 | 7.7 | 345 |
| < 0.01 | < 0.01 | 1.10 | 215.20 | 0.00 | 6.40 | 0.21 | 0.04 | 5.60 | 188 | 297 | 186 | 6.0 | 8.8 | 348 |
| 0.01 | < 0.01 | <0.50 | 218.60 | 0.00 | 9.00 | < 0.05 | <1.00 | 10.20 | 189 | 300 | 149 | 9.3 | 7.8 | 343 |
| < 0.01 | < 0.01 | 1.60 | 273.00 | 0.00 | 4.00 | 0.90 | <1.00 | 13.70 | 235 | 373 | 225 | 7.4 | 8.1 | 425 |
| < 0.01 | < 0.01 | 1.40 | 210.20 | 0.00 | 3.90 | < 0.25 | <1.00 | 11.40 | 179 | 286 | 169 | 7.5 | 6.9 | 244 |
| | | | | | | | | | | | | | | |
| 0.06 | 0.01 | 2.60 | 196.20 | 0.00 | 13.90 | 0.39 | 0.20 | 22.40 | 201.11 | 300.66 | 128.76 | 13.0 | 8.13 | 331.2 |
| 0.09 | 0.00 | 1.00 | 162.00 | 0.00 | 6.60 | 0.92 | 0.20 | 26.90 | 170.48 | 252.67 | 122.61 | 10.5 | 7.70 | 255.0 |
| 0.01 | 0.03 | 1.20 | 160.60 | 0.00 | 4.80 | 0.41 | 0.20 | 28.50 | 167.67 | 249.16 | 120.64 | 10.0 | 7.24 | 246.9 |
| 0.07 | 0.06 | 6.40 | 197.40 | 0.00 | 20.70 | 0.08 | 0.50 | 8.80 | 211.81 | 311.96 | 110.24 | 11.0 | 7.61 | 384.1 |
| < 0.01 | 0.00 | 1.90 | 133.50 | 0.00 | 5.60 | 0.40 | 0.30 | 26.20 | 145.07 | 212.80 | 90.78 | 11.0 | 7.39 | 224.2 |
| 0.01 | 0.01 | 10.00 | 359.50 | 0.00 | 40.00 | 1.90 | 0.35 | 34.20 | 408.17 | 590.58 | 238.55 | 9.0 | 7.50 | 627.0 |
| 15.58 | 0.27 | 3.90 | 111.30 | 0.00 | 8.50 | < 0.04 | 0.63 | 38.70 | 158.43 | 214.90 | 55.04 | 14.4 | 6.70 | 191.7 |
| 0.05 | 0.00 | 1.90 | 209.80 | 0.00 | 6.80 | 0.40 | 0.50 | 36.20 | 217.30 | 323.76 | 134.39 | 9.0 | 7.72 | 336.9 |
| < 0.01 | < 0.01 | 4.20 | 240.00 | 0.00 | 13.60 | 0.40 | 0.44 | 26.80 | 245.32 | 367.09 | 153.56 | 14.4 | 7.68 | 395.0 |
| < 0.01 | 0.42 | 5.10 | 229.00 | 0.00 | 9.70 | 0.16 | 2.30 | 17.90 | 235.68 | 351.88 | 111.66 | 15.3 | 8.01 | 408.0 |
| 3.70 | 0.26 | 2.60 | 106.00 | 0.00 | 27.70 | < 0.10 | 0.98 | 32.00 | 167.58 | 221.37 | 50.44 | 14.8 | 7.03 | 221.0 |
| < 0.01 | 0.14 | 4.90 | 231.30 | 0.00 | 12.10 | 0.08 | 0.90 | 19.40 | 235.72 | 353.08 | 141.86 | 14.0 | 7.82 | 394.1 |
| 0.27 | 0.59 | 1.40 | 144.00 | 0.00 | 23.80 | 0.38 | 0.40 | 20.80 | 179.38 | 252.44 | 100.58 | 10.2 | 7.52 | 285.8 |
| 0.17 | 0.33 | 8.30 | 224.50 | 0.00 | 9.00 | < 0.05 | <1.00 | 17.60 | 231.99 | 345.90 | 77.96 | 15.7 | 8.30 | 392.0 |
| 1.30 | 0.42 | 5.70 | 252.00 | 0.00 | 9.30 | < 0.05 | 2.12 | 16.80 | 251.08 | 378.94 | 130.46 | 16.0 | 7.66 | 425.0 |
| 0.68 | 0.26 | 6.90 | 255.00 | 0.00 | 8.00 | < 0.05 | 3.00 | 16.70 | 256.27 | 385.66 | 90.47 | 17.0 | 7.78 | 435.0 |
| 0.04 | 0.18 | 3.40 | 198.90 | 0.00 | 3.70 | 0.01 | 1.70 | 21.60 | 203.61 | 304.53 | 62.31 | 12.0 | 7.89 | 329.8 |
| 0.09 | 0.00 | 1.10 | 72.50 | 0.00 | 5.40 | 0.12 | 0.10 | 6.30 | 76.00 | 112.79 | 52.27 | 13.0 | 7.04 | 127.6 |
| 0.00 | 0.22 | 0.90 | 161.50 | 0.00 | 3.50 | 0.01 | 0.20 | 24.00 | 158.51 | 240.45 | 116.29 | 14.5 | 7.20 | 251.0 |
| 0.17 | 0.33 | 2.60 | 178.00 | 0.00 | 13.10 | < 0.05 | 1.20 | 24.50 | 192.60 | 282.91 | 105.34 | 18.5 | 8.01 | 317.0 |
| 0.83 | 0.26 | 5.90 | 250.00 | 0.00 | 9.30 | < 0.04 | 2.74 | 17.40 | 253.69 | 380.53 | 95.49 | 18.0 | 8.12 | 427.0 |
| 0.01 | 0.02 | 1.70 | 105.00 | 0.00 | 7.30 | < 0.05 | 0.97 | 19.00 | 124.23 | 177.51 | 34.26 | 12.8 | 8.30 | 199.3 |
| 0.87 | 0.24 | 2.70 | 205.00 | 0.00 | 10.60 | < 0.05 | 0.74 | 20.40 | 204.64 | 308.66 | 123.19 | 14.8 | 8.06 | 339.0 |
| 0.48 | 0.10 | 8.00 | 244.00 | 0.00 | 2.70 | 0.90 | 4.40 | 20.90 | 263.88 | 387.68 | 18.69 | 13.8 | 8.10 | 428.0 |
| 1.09 | 0.91 | 2.80 | 179.00 | 0.00 | 14.60 | 0.06 | 0.73 | 21.00 | 192.38 | 283.20 | 119.47 | 13.8 | 7.40 | 311.0 |
| 0.08 | 0.04 | 4.40 | 117.00 | 0.00 | 36.10 | < 0.05 | 2.29 | 31.70 | 192.08 | 251.45 | 79.14 | 14.0 | 7.80 | 281.0 |
| 0.07 | 0.04 | 3.60 | 101.00 | 0.00 | 61.20 | 0.26 | 2.30 | 32.80 | 220.43 | 271.67 | 62.35 | 15.0 | 7.08 | 341.3 |

Appendix C—*Continued.*

| Lab No. | Site No. | Township | Range | Sec. | Tract | Longitude | Latitude | Sample Date (yyyymmdd) | County | Total Depth | Hydro Unit | Na | K | Ca | Mg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1993Q0760 | 6259 | 22N | 24W | 35 | AADA | -114.626 | 47.628 | 19930604 | S | 198 | deep | 76.00 | 2.60 | 26.00 | 13.30 |
| 1993Q0762 | 77293 | 22N | 24W | 36 | BBBB | -114.625 | 47.630 | 19930607 | S | 229 | deep | 49.20 | 3.60 | 41.10 | 13.30 |
| 1997Q0458 | 146868 | 22N | 23W | 1 | DBCB | -114.486 | 47.693 | 19961022 | L | 308 | Belt | 12.40 | 0.83 | 14.00 | 5.20 |
| 1994Q0854 | 6216 | 22N | 23W | 7 | DBDB | -114.591 | 47.679 | 19931108 | S | 229 | deep | 127.00 | 2.00 | 7.50 | 1.30 |
| 1985Q0046 | 6217 | 22N | 23W | 15 | DCDC | -114.526 | 47.660 | 19841011 | L | 92 | interm. | 17.20 | 1.40 | 26.90 | 9.30 |
| 1993Q0546 | 77133 | 22N | 23W | 18 | DDAD | -114.584 | 47.661 | 19930526 | S | 232 | deep | 125.00 | 2.40 | 3.10 | 0.30 |
| 1993Q0541 | 6218 | 22N | 23W | 18 | ACAA | -114.588 | 47.670 | 19930526 | S | 230 | deep | 88.50 | 2.80 | 10.70 | 0.90 |
| 1993Q0550 | 6219 | 22N | 23W | 18 | BBBB | -114.603 | 47.674 | 19930525 | S | 300 | deep | 96.20 | 2.20 | 7.30 | 0.90 |
| 1979Q3741 | 6220 | 22N | 23W | 18 | DDAD | -114.584 | 47.662 | 19791202 | S | 260 | deep | 134.00 | 1.70 | 3.30 | 0.40 |
| 1994Q0853 | 83636 | 22N | 23W | 19 | CBCD | -114.601 | 47.649 | 19931108 | S | 310 | deep | 101.00 | 1.30 | 5.20 | 1.20 |
| 1979Q3766 | 6221 | 22N | 23W | 19 | CBCD | -114.601 | 47.648 | 19791205 | S |  | deep | 102.00 | 1.00 | 5.60 | 1.30 |
| 1976Q0748 | 6222 | 22N | 23W | 19 | DAAA | -114.584 | 47.652 | 19760702 | S | 240 | deep | 139.00 | 3.70 | 5.70 | 0.60 |
| 1993Q0544 | 6225 | 22N | 23W | 20 | CDBC | -114.576 | 47.647 | 19930525 | L | 235 | deep | 142.00 | 3.30 | 4.00 | 0.40 |
| 1979Q3757 | 6223 | 22N | 23W | 20 | BAAD | -114.573 | 47.658 | 19791202 | L |  | deep | 131.00 | 1.30 | 5.50 | 1.40 |
| 1979Q3754 | 6226 | 22N | 23W | 20 | DCDB | -114.569 | 47.645 | 19791202 | L | 250 | deep | 142.00 | 2.10 | 4.40 | 0.40 |
| 1979Q0872 | 6224 | 22N | 23W | 20 | BCCB | -114.581 | 47.654 | 19780906 | L | 240 | deep | 127.00 | 2.70 | 4.60 | 0.70 |
| 1993Q0515 | 6227 | 22N | 23W | 28 | CBBB | -114.561 | 47.637 | 19930524 | L | 230 | deep | 151.00 | 3.50 | 5.00 | 1.00 |
| 1993Q0547 | 121339 | 22N | 23W | 29 | CCCC | -114.581 | 47.631 | 19930526 | L | 285 | deep | 88.10 | 1.50 | 6.40 | 1.40 |
| 1993Q0540 | 6229 | 22N | 23W | 29 | ACAB | -114.570 | 47.641 | 19930526 | L | 261 | deep | 156.00 | 3.30 | 2.90 | 0.30 |
| 1993Q0517 | 6228 | 22N | 23W | 29 | AADB | -114.564 | 47.643 | 19930524 | L | 250 | deep | 146.00 | 3.10 | 3.00 | 0.30 |
| 1993Q0516 | 6231 | 22N | 23W | 29 | ACBB | -114.571 | 47.641 | 19930523 | L | 240 | deep | 156.00 | 3.50 | 2.70 | 0.20 |
| 1993Q0518 | 6237 | 22N | 23W | 29 | BADD | -114.571 | 47.642 | 19930523 | L | 1002 | Belt | 126.00 | 3.80 | 11.10 | 2.00 |
| 1980Q2721 | 121328 | 22N | 23W | 29 | CBBC | -114.581 | 47.636 | 19801016 | L | 280 | deep | 94.70 | 2.80 | 8.70 | 0.50 |
| 1979Q3759 | 77158 | 22N | 23W | 29 | CACA | -114.575 | 47.636 | 19791129 | L | 290 | deep | 117.00 | 1.50 | 2.10 | 0.30 |
| 1979Q3761 | 6234 | 22N | 23W | 29 | BAAC | -114.574 | 47.644 | 19791129 | L | 270 | deep | 144.00 | 2.80 | 4.80 | 1.00 |
| 1993Q0543 | 6245 | 22N | 23W | 30 | DBCD | -114.591 | 47.635 | 19930525 | S | 310 | deep | 92.70 | 0.80 | 2.40 | 0.10 |
| 1993Q0519 | 77161 | 22N | 23W | 30 | AAAD | -114.584 | 47.644 | 19930524 | S | 250 | deep | 116.00 | 2.60 | 3.20 | 0.20 |
| 2000Q1228 | 77168 | 22N | 23W | 32 | DBBB | -114.571 | 47.623 | 20000527 | L |  | deep | 96.00 | 1.36 | 5.27 | 1.45 |
| 1994Q0851 | 139128 | 22N | 23W | 33 | DDCC | -114.545 | 47.617 | 19931109 | L |  | deep | 114.00 | 1.70 | 8.50 | 2.40 |
| 1993Q0763 | 77181 | 22N | 23W | 33 | DAD | -114.541 | 47.620 | 19930606 | L |  | deep | 70.30 | 1.40 | 23.60 | 7.30 |
| 1993Q0765 | 6247 | 22N | 23W | 33 | DDDA | -114.541 | 47.618 | 19930606 | L | 270 | deep | 77.90 | 1.60 | 19.90 | 6.20 |
| 1993Q0548 | 6246 | 22N | 23W | 33 | BABB | -114.555 | 47.630 | 19930527 | L | 286 | deep | 127.00 | 2.60 | 6.90 | 1.30 |
| 1993Q0755 | 6151 | 21N | 24W | 3 | DCBB | -114.656 | 47.605 | 19930607 | S |  | Belt | 93.10 | 1.00 | 1.10 | 0.10 |
| 1993Q0766 | 76173 | 21N | 24W | 3 | BBCA | -114.668 | 47.614 | 19930606 | S | 100 | Belt | 88.00 | 1.50 | 0.80 | 0.10 |
| 1982Q0913 | 6149 | 21N | 24W | 3 | BBB | -114.666 | 47.615 | 19820819 | S | 80 | Belt | 85.80 | 1.70 | 0.60 | 0.10 |
| 1995Q0387 | 76192 | 21N | 24W | 4 | ADA | -114.669 | 47.612 | 19950104 | S | 190 | Belt | 14.30 | 3.50 | 24.70 | 7.50 |
| 1993Q0761 | 6152 | 21N | 24W | 4 | ADAB | -114.670 | 47.612 | 19930606 | S | 370 | Belt | 87.30 | 1.50 | 0.80 | 0.10 |
| 1993Q0764 | 6153 | 21N | 24W | 4 | DABD | -114.671 | 47.608 | 19930605 | S | 420 | Belt | 86.80 | 0.80 | 0.80 | 0.10 |
| 1984Q0803 | 6155 | 21N | 24W | 4 | DBDA | -114.674 | 47.606 | 19840531 | S | 383 | deep | 32.00 | 3.10 | 17.20 | 4.00 |
| 1975Q1306 | 6154 | 21N | 24W | 4 | DBCD | -114.677 | 47.606 | 19750827 | S | 241 | deep | 20.00 | 3.20 | 20.10 | 4.20 |
| 1983Q1015 | 6157 | 21N | 24W | 9 | CABC | -114.684 | 47.593 | 19830922 | S | 46 | interm. | 9.30 | 2.70 | 18.00 | 5.60 |
| 1993Q0718 | 76119 | 21N | 23W | 4 | AADA | -114.541 | 47.614 | 19930604 | L | 240 | deep | 107.00 | 1.60 | 7.60 | 2.20 |
| 1993Q0723 | 6144 | 21N | 23W | 4 | DAAC | -114.542 | 47.608 | 19930604 | L | 250 | deep | 98.60 | 1.80 | 7.90 | 2.20 |
| 1976Q1034 | 6145 | 21N | 23W | 10 | BDD | -114.530 | 47.595 | 19760817 | S | 200 | shallow | 113.00 | 3.50 | 20.00 | 9.40 |
| 1994Q0856 | 6146 | 21N | 23W | 11 | CACC | -114.512 | 47.591 | 19931107 | S | 270 | deep | 30.00 | 1.30 | 30.70 | 9.80 |
| 1993Q0717 | 131952 | 21N | 23W | 14 | ACAB | -114.505 | 47.583 | 19930604 | S | 267 | deep | 19.30 | 1.00 | 37.90 | 12.40 |
| 1976Q0139 | 6147 | 21N | 23W | 14 | ACB | -114.506 | 47.583 | 19760304 | S | 276 | deep | 19.90 | 1.40 | 32.30 | 13.00 |
| 1985Q0049 | 6142 | 21N | 22W | 7 | DCAA | -114.461 | 47.591 | 19841012 | S | 186 | deep | 24.40 | 1.60 | 44.30 | 13.80 |
| 1997Q0453 | 74947 | 20N | 23W | 12 | AAAA | -114.457 | 47.515 | 19961019 | S | 280 | deep | 19.90 | 1.60 | 35.60 | 10.30 |
| 1985Q0055 | 6096 | 20N | 22W | 21 | CBDA | -114.409 | 47.476 | 19841015 | S | 331 | deep | 61.40 | 1.20 | 12.20 | 5.20 |
| 1985Q1189 | 6098 | 20N | 22W | 28 | ABCB | -114.403 | 47.469 | 19850815 | S | 340 | Tertiary | 83.50 | 6.60 | 11.10 | 1.10 |
| **Swan subarea** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1997Q0230 | 79099 | 25N | 18W | 3 | CCCD | -113.876 | 47.951 | 19960825 | L | 166 | Belt | 4.20 | 0.80 | 73.20 | 27.10 |
| 1997Q0225 | 150698 | 25N | 18W | 14 | DDBA | -113.837 | 47.924 | 19960826 | L | 400 | interm. | 13.00 | 0.47 | 29.70 | 12.00 |
| 1997Q0227 | 79148 | 25N | 18W | 26 | ADAB | -113.836 | 47.903 | 19960823 | L | 170 | deep | 6.10 | 0.31 | 60.70 | 18.20 |
| 2000Q1224 | 79152 | 25N | 18W | 35 | ADAC | -113.836 | 47.887 | 20000529 | L | 78 | shallow | 1.53 | 0.43 | 37.90 | 15.70 |
| 1994Q0946 | 127166 | 24N | 17W | 17 | CBCC | -113.816 | 47.836 | 19940418 | L | 439 | deep | 7.80 | 0.90 | 52.20 | 11.60 |
| 1997Q0228 | 77488 | 23N | 17W | 18 | DBDC | -113.824 | 47.749 | 19960823 | L | 132 | deep | 5.30 | 0.67 | 57.40 | 21.40 |
| 1994Q0951 | 133044 | 22N | 17W | 8 | BDBB | -113.810 | 47.683 | 19940418 | L | 40 | interm. | 1.90 | 0.90 | 41.20 | 13.80 |

| Fe | Mn | Cl | $HCO_3$ | $CO_3$ | $SO_4$ | $NO_3$ | F | $SiO_2$ | TDS | Diss. Constit. | Hard-ness | Temp | Lab pH | Lab S.C. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.12 | 0.82 | 24.30 | 303.00 | 0.00 | 4.00 | 0.51 | 4.20 | 39.70 | 340.81 | 494.55 | 119.66 | 12.4 | 8.01 | 552.0 |
| 0.75 | 0.04 | 26.40 | 264.00 | 0.00 | 5.90 | < 0.05 | 1.03 | 29.80 | 301.22 | 435.18 | 157.37 | 15.3 | 7.25 | 502.0 |
| 0.11 | 0.06 | 4.00 | 85.40 | 0.00 | 5.00 | 1.20 | <1.00 | 13.10 | 98.22 | 141.55 | 56.36 | 11.7 | 7.50 | 179.0 |
| 0.21 | 0.11 | 17.30 | 316.00 | 0.00 | 3.50 | < 0.05 | 5.78 | 21.90 | 342.47 | 502.80 | 24.08 | 16.4 | 8.09 | 546.0 |
| 0.04 | 0.01 | 5.60 | 157.60 | 0.00 | 7.80 | 1.06 | 0.20 | 27.20 | 174.46 | 254.42 | 105.45 | 10.0 | 7.91 | 290.4 |
| 0.01 | 0.03 | 17.30 | 277.00 | 9.60 | 3.80 | 0.05 | 6.07 | 27.40 | 331.60 | 472.15 | 8.98 | 23.9 | 8.45 | 554.0 |
| 0.11 | 0.11 | 7.49 | 245.00 | 0.00 | 7.64 | < 0.04 | 3.74 | 21.10 | 263.87 | 388.18 | 30.42 | 22.4 | 8.07 | 453.0 |
| 0.17 | 0.07 | 7.40 | 249.00 | 0.00 | 7.60 | < 0.04 | 3.50 | 18.50 | 266.61 | 392.95 | 21.93 | | 8.05 | 457.0 |
| 0.09 | 0.03 | 19.00 | 287.00 | 8.90 | 2.10 | 1.00 | 4.80 | 28.60 | 345.30 | 490.92 | 9.89 | 20.3 | 8.48 | 537.0 |
| 0.18 | 0.07 | 9.90 | 245.00 | 0.00 | 5.20 | 0.09 | 6.71 | 13.60 | 265.17 | 389.48 | 17.92 | 15.6 | 8.27 | 438.0 |
| 0.74 | 0.07 | 16.50 | 232.00 | 0.00 | 2.70 | 1.00 | 7.00 | 13.50 | 265.70 | 383.41 | 19.33 | 11.8 | 7.74 | 437.9 |
| 0.11 | 0.07 | 28.25 | 331.80 | 0.00 | 1.20 | < 0.02 | 6.10 | 32.90 | 381.08 | 549.43 | 16.70 | 24.0 | 8.18 | 617.2 |
| 0.03 | 0.02 | 30.00 | 318.00 | 8.41 | < 1.00 | 0.06 | 6.69 | 34.60 | 386.16 | 547.51 | 11.63 | 29.4 | 8.57 | 643.0 |
| 0.27 | 0.06 | 25.80 | 318.00 | 0.00 | < 0.10 | 0.10 | 5.30 | 24.90 | 352.28 | 513.63 | 19.50 | 16.1 | 8.05 | 599.1 |
| 0.12 | 0.02 | 30.90 | 328.00 | 0.00 | 0.60 | 1.00 | 5.00 | 36.60 | 384.72 | 551.14 | 12.63 | 32.5 | 8.40 | 635.6 |
| 0.03 | 0.04 | 10.90 | 280.00 | 18.20 | 1.80 | 1.16 | 4.40 | 29.30 | 338.86 | 480.93 | 14.37 | 25.8 | 9.16 | 470.6 |
| 0.03 | 0.06 | 35.30 | 348.00 | 6.70 | 2.57 | < 0.04 | 4.84 | 43.70 | 425.27 | 601.84 | 16.60 | 29.9 | 8.50 | 745.0 |
| 0.29 | 0.11 | 14.00 | 214.00 | 4.10 | 3.65 | < 0.04 | 6.42 | 14.20 | 246.02 | 354.61 | 21.74 | 17.7 | 8.42 | 442.0 |
| < 0.01 | 0.01 | 35.30 | 326.00 | 16.80 | 3.38 | < 0.04 | 5.19 | 43.90 | 427.68 | 593.09 | 8.48 | 47.9 | 8.69 | 687.0 |
| 0.02 | 0.02 | 29.10 | 323.00 | 8.40 | 2.50 | 0.07 | 5.99 | 39.50 | 397.20 | 561.09 | 8.73 | 28.8 | 8.49 | 662.0 |
| < 0.01 | 0.01 | 35.60 | 329.00 | 14.40 | 2.92 | < 0.04 | 5.22 | 44.50 | 427.12 | 594.05 | 7.57 | 44.2 | 8.52 | 708.0 |
| 0.07 | 0.02 | 32.60 | 326.00 | 0.00 | < 1.00 | 0.04 | 3.34 | 37.90 | 377.47 | 542.88 | 35.95 | 41.0 | 8.14 | 633.0 |
| 0.15 | 0.02 | 12.20 | 245.00 | 0.00 | 4.70 | 0.01 | 6.70 | 26.70 | 278.13 | 402.45 | 23.78 | 25.8 | 8.53 | 471.8 |
| 0.22 | 0.02 | 16.00 | 237.00 | 7.90 | 1.50 | 0.86 | 7.60 | 32.40 | 304.15 | 424.40 | 6.48 | 32.6 | 8.71 | 472.4 |
| 0.65 | 0.33 | 31.30 | 314.00 | 3.60 | 1.30 | 0.75 | 7.80 | 41.40 | 394.54 | 553.86 | 16.10 | 38.9 | 8.38 | 593.7 |
| 0.03 | 0.02 | 8.90 | 202.00 | 9.60 | 8.50 | 0.05 | 4.66 | 24.60 | 252.16 | 354.65 | 6.40 | 18.5 | 8.54 | 423.0 |
| < 0.01 | 0.03 | 16.40 | 253.00 | 9.60 | 3.80 | < 0.04 | 7.18 | 29.30 | 313.10 | 441.47 | 8.81 | 26.0 | 8.44 | 530.0 |
| 0.31 | 0.18 | 28.30 | 219.11 | 0.00 | 1.17 | < 0.50 | 8.10 | 14.10 | 264.18 | 375.36 | 19.13 | 18.5 | 8.10 | 497.0 |
| 0.48 | 0.23 | 23.50 | 281.00 | 0.00 | < 1.00 | < 0.05 | 7.38 | 17.20 | 314.38 | 456.95 | 31.10 | 10.8 | 8.08 | 522.0 |
| 0.95 | 0.38 | 13.80 | 270.00 | 0.00 | < 2.50 | 0.06 | 2.90 | 18.80 | 272.85 | 409.85 | 88.98 | 13.7 | 8.16 | 462.0 |
| 0.25 | 0.33 | 17.10 | 263.00 | 0.00 | < 2.50 | 0.06 | 3.32 | 17.40 | 273.97 | 407.42 | 75.21 | 14.2 | 8.00 | 487.0 |
| 0.11 | 0.08 | 24.90 | 290.00 | 6.80 | 2.50 | < 0.04 | 6.38 | 28.80 | 350.55 | 497.69 | 22.58 | 18.7 | 8.38 | 582.0 |
| < 0.01 | < 0.01 | 8.80 | 167.00 | 21.80 | 5.90 | < 0.05 | 5.27 | 44.50 | 263.74 | 348.47 | 2.75 | 15.9 | 9.06 | 417.0 |
| < 0.01 | < 0.01 | 2.70 | 138.00 | 31.70 | 10.60 | < 0.05 | 5.86 | 68.10 | 277.24 | 347.26 | 2.00 | 44.7 | 9.26 | 406.0 |
| < 0.01 | < 0.01 | 9.90 | 109.30 | 34.10 | 9.60 | 0.05 | 5.70 | 69.60 | 270.89 | 326.35 | 1.50 | 51.5 | 9.34 | 381.8 |
| 0.86 | 0.06 | 3.00 | 108.50 | 0.00 | 35.00 | < 0.05 | 0.79 | 33.60 | 176.90 | 231.95 | 92.55 | 11.2 | 6.99 | 309.0 |
| < 0.01 | 0.01 | 8.40 | 100.00 | 41.70 | 17.30 | < 0.05 | 5.70 | 70.90 | 282.87 | 333.61 | 2.00 | 34.8 | 9.44 | 405.0 |
| < 0.01 | < 0.01 | 8.10 | 91.70 | 47.50 | 11.70 | 0.08 | 5.33 | 64.20 | 270.49 | 317.01 | 2.00 | 29.0 | 9.46 | 404.0 |
| 0.07 | 0.02 | 3.10 | 149.30 | 0.00 | 10.70 | 0.11 | 0.20 | 28.10 | 172.15 | 247.90 | 59.41 | 21.0 | 7.99 | 253.6 |
| 0.53 | 0.06 | 2.35 | 124.30 | 0.00 | 3.60 | 0.16 | 1.30 | 22.90 | 139.63 | 202.70 | 67.48 | 13.5 | 6.73 | 220.1 |
| < 0.01 | 0.00 | 1.30 | 89.50 | 0.00 | 17.50 | 0.03 | 0.30 | 30.60 | 129.45 | 174.86 | 68.00 | 8.0 | 6.76 | 179.1 |
| 0.35 | 0.29 | 28.10 | 244.00 | 5.70 | < 0.70 | 0.04 | 7.52 | 12.20 | 293.48 | 417.28 | 28.03 | 14.5 | 8.44 | 525.0 |
| 0.44 | 0.23 | 24.90 | 228.00 | 0.00 | 5.86 | 0.06 | 6.68 | 11.50 | 272.93 | 388.62 | 28.78 | 14.0 | 8.20 | 488.0 |
| 0.02 | 0.38 | 17.45 | 366.90 | 0.00 | 8.60 | 0.53 | 3.50 | 17.50 | 374.62 | 560.78 | 88.63 | 22.5 | 7.83 | 622.3 |
| 0.11 | 0.59 | 6.60 | 202.00 | 0.00 | 8.40 | 0.27 | 1.19 | 20.50 | 208.97 | 311.46 | 116.99 | 12.5 | 7.37 | 340.0 |
| 0.12 | 0.56 | 4.40 | 212.00 | 0.00 | 8.66 | 0.81 | 0.78 | 18.80 | 209.17 | 316.73 | 145.67 | 13.9 | 7.91 | 350.0 |
| < 0.01 | 0.50 | 6.00 | 196.90 | 0.00 | 8.10 | 0.26 | 0.60 | 16.20 | 195.26 | 295.16 | 134.16 | 21.5 | 7.96 | 330.2 |
| 0.02 | 0.00 | 9.60 | 236.90 | 0.00 | 15.10 | 0.74 | 0.20 | 25.60 | 252.07 | 372.27 | 167.42 | 10.0 | 8.06 | 427.1 |
| 0.56 | 0.73 | 4.60 | 211.10 | 0.00 | < 2.50 | < 0.25 | <1.00 | 9.60 | 186.88 | 293.99 | 131.29 | 11.9 | 8.30 | 344.0 |
| < 0.01 | 0.03 | 10.60 | 191.80 | 0.00 | 5.80 | 0.07 | 3.40 | 21.10 | 215.58 | 312.90 | 51.87 | 18.5 | 8.18 | 367.4 |
| 0.83 | 0.09 | 8.80 | 244.90 | 0.00 | 10.30 | 0.55 | 0.60 | 15.50 | 261.76 | 386.02 | 32.24 | 16.0 | 7.34 | 399.2 |
| | | | | | | | | | | | | | | |
| < 0.01 | < 0.01 | 2.40 | 362.60 | 0.00 | 4.10 | < 0.25 | <1.00 | 16.40 | 306.88 | 490.86 | 294.32 | 7.5 | 7.90 | 543.0 |
| 0.88 | 0.07 | <0.50 | 168.10 | 0.00 | < 2.50 | 4.80 | <1.00 | 18.00 | 161.78 | 247.08 | 123.55 | 8.8 | 7.70 | 251.0 |
| < 0.01 | 0.01 | 0.60 | 265.00 | 0.00 | 4.10 | 4.90 | <1.00 | 14.20 | 239.67 | 374.13 | 226.48 | 9.1 | 7.90 | 400.0 |
| 0.01 | < 0.01 | 0.51 | 200.60 | 0.00 | 3.25 | < 0.50 | <0.05 | 6.67 | 164.82 | 266.60 | 159.26 | 6.8 | 7.89 | 322.0 |
| < 0.01 | < 0.01 | 0.40 | 235.00 | 0.00 | 3.00 | 0.15 | 0.09 | 16.50 | 208.41 | 327.64 | 178.09 | | 7.76 | 366.0 |
| 0.02 | < 0.01 | 0.80 | 270.80 | 0.00 | 2.70 | < 0.25 | <1.00 | 14.50 | 236.21 | 373.62 | 231.41 | 8.4 | 7.90 | 411.0 |
| < 0.01 | < 0.01 | 0.30 | 194.00 | 0.00 | 2.10 | 0.09 | 0.07 | 11.30 | 167.23 | 265.66 | 159.68 | 6.5 | 7.79 | 295.0 |

Appendix C—*Continued.*

| Lab No. | Site No. | Township | Range | Sec. | Tract | Longitude | Latitude | Sample Date (yyyymmdd) | County | Total Depth | Hydro Unit | Na | K | Ca | Mg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1997Q0224 | 139323 | 22N | 17W | 21 | CABD | -113.788 | 47.650 | 19960825 | L | 160 | deep | 2.10 | 0.50 | 41.30 | 12.00 |
| 1997Q0220 | 76807 | 22N | 17W | 28 | CDAC | -113.787 | 47.631 | 19960823 | L | 40 | shallow | 2.60 | 0.88 | 46.70 | 14.80 |
| **North Fork subarea** | | | | | | | | | | | | | | | |
| 1997Q0135 | 155927 | 37N | 22W | 5 | ADCB | -114.478 | 49.000 | 19960728 | FH | 25 | shallow | 1.70 | 0.45 | 59.00 | 11.00 |
| 1997Q0137 | 155928 | 35N | 21W | 27 | DABC | -114.284 | 48.765 | 19960727 | FH | 25 | shallow | 1.20 | 0.32 | 38.00 | 9.00 |
| 1997Q0134 | 146276 | 34N | 20W | 19 | CDCD | -114.227 | 48.688 | 19960727 | FH | 152 | Belt | 4.80 | 0.16 | 35.00 | 15.30 |
| **Camas Prairie subarea** | | | | | | | | | | | | | | | |
| 1997Q0357 | 148960 | 20N | 24W | 13 | BAAB | -114.595 | 47.500 | 19960922 | S | 92 | deep | 15.50 | 2.70 | 31.10 | 11.00 |
| 1997Q0354 | 74959 | 20N | 24W | 15 | ABBA | -114.635 | 47.501 | 19960922 | S | 43 | shallow | 12.60 | 0.70 | 33.90 | 10.70 |
| 1997Q0355 | 141447 | 20N | 24W | 15 | CBBB | -114.647 | 47.494 | 19960922 | S | 500 | Tertiary | 21.30 | 1.20 | 17.50 | 1.60 |
| 1997Q0356 | 74961 | 20N | 24W | 18 | DDAC | -114.691 | 47.489 | 19960924 | S | 285 | Belt | 13.50 | 0.50 | 18.00 | 8.10 |
| 1983Q0930 | 6101 | 20N | 24W | 19 | AAAA | -114.691 | 47.486 | 19830908 | S | 100 | Belt | 12.40 | 0.40 | 17.40 | 6.30 |
| 1975Q1500 | 6102 | 20N | 24W | 22 | AAB | -114.630 | 47.486 | 19750917 | S | 66 | interm. | 11.70 | 0.40 | 25.50 | 9.30 |
| 1985Q0048 | 6104 | 20N | 24W | 23 | CBAA | -114.621 | 47.479 | 19841012 | S | 98 | deep | 24.80 | 2.10 | 26.50 | 9.90 |
| 1985Q0047 | 6103 | 20N | 24W | 23 | CBAA | -114.621 | 47.479 | 19841011 | S | 99 | deep | 26.70 | 2.20 | 24.00 | 9.30 |
| 1983Q0929 | 6105 | 20N | 24W | 29 | CDDD | -114.680 | 47.458 | 19830907 | S | 105 | Belt | 12.40 | 0.20 | 13.90 | 5.10 |
| 1983Q0931 | 6070 | 19N | 24W | 4 | AADB | -114.650 | 47.441 | 19830913 | S | 332 | Belt | 50.90 | 0.60 | 0.80 | 0.10 |
| **Irvine Flats subarea** | | | | | | | | | | | | | | | |
| 1985Q1177 | 6276 | 23N | 22W | 26 | BDCC | -114.385 | 47.726 | 19850808 | L | 80 | interm. | 26.40 | 3.10 | 40.70 | 14.80 |
| 1975Q1494 | 6277 | 23N | 22W | 35 | CDB | -114.385 | 47.706 | 19750916 | L | 250 | deep | 22.30 | 1.40 | 41.00 | 10.80 |
| 1985Q0056 | 6214 | 22N | 22W | 24 | DAAA | -114.349 | 47.652 | 19841114 | L | 198 | interm. | 27.80 | 1.20 | 42.90 | 15.60 |
| 1985Q1183 | 6215 | 22N | 22W | 26 | DDDD | -114.371 | 47.631 | 19850809 | L | 50 | deep | 33.70 | 1.90 | 51.40 | 18.20 |
| **Not Assigned** | | | | | | | | | | | | | | | |
| 1997Q0282 | 148645 | 25N | 23W | 26 | BACB | -114.528 | 47.902 | 19960910 | FH | 803 | Belt | 28.60 | 0.44 | 24.60 | 5.20 |
| 1983Q0398 | 6317 | 24N | 23W | 17 | DACD | -114.564 | 47.837 | 19830602 | FH | 250 | deep | 17.40 | 2.70 | 35.20 | 12.40 |
| 1985Q1178 | 128076 | 24N | 22W | 30 | BCCD | -114.476 | 47.813 | 19850730 | L | 460 | interm. | 14.80 | 1.30 | 27.70 | 16.50 |
| 1983Q0928 | 6040 | 18N | 22W | 21 | BADC | -114.406 | 47.310 | 19830902 | S | 59 | deep | 28.80 | 2.80 | 29.60 | 10.00 |

*Note*. Counties: FH, Flathead; L, Lake; M, Missoula; S, Sanders. Mn values reported as 0.00 have detection limits less than 0.009.

| Fe | Mn | Cl | $HCO_3$ | $CO_3$ | $SO_4$ | $NO_3$ | F | $SiO_2$ | TDS | Diss. Constit. | Hard-ness | Temp | Lab pH | Lab S.C. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| < 0.01 | < 0.01 | 1.10 | 190.60 | 0.00 | < 2.50 | < 0.25 | <1.00 | 16.20 | 167.09 | 263.80 | 152.52 | 9.1 | 8.00 | 349.0 |
| 0.06 | < 0.01 | <0.50 | 224.70 | 0.00 | < 2.50 | < 0.25 | <1.00 | 16.40 | 192.13 | 306.14 | 177.53 | 81.0 | 7.80 | 345.0 |
| 0.02 | < 0.01 | <0.50 | 240.00 | 0.00 | < 2.50 | < 0.25 | <1.00 | 6.50 | 196.90 | 318.68 | 192.60 | 7.6 | 7.70 | 357.0 |
| 0.01 | < 0.01 | <0.50 | 152.10 | 0.00 | 10.00 | < 0.05 | <1.00 | 6.10 | 139.58 | 216.75 | 131.93 | 10.5 | 7.60 | 259.0 |
| 0.01 | 0.09 | <0.50 | 163.50 | 0.00 | 26.30 | < 0.25 | <1.00 | 13.90 | 176.24 | 259.20 | 150.37 | 9.1 | 7.80 | 296.0 |
| 0.01 | 0.00 | 5.20 | 162.00 | 0.00 | 13.00 | 3.60 | <1.00 | 41.80 | 203.72 | 285.92 | 122.93 | 13.0 | 8.10 | 307.0 |
| 0.01 | 0.01 | 4.10 | 163.50 | 0.00 | 12.10 | 1.40 | <1.00 | 33.60 | 189.76 | 272.71 | 128.69 | 11.2 | 8.10 | 317.0 |
| 0.27 | 0.04 | 1.40 | 95.40 | 0.00 | 18.40 | < 0.05 | <1.00 | 14.00 | 122.78 | 171.18 | 50.28 | 13.8 | 8.20 | 204.0 |
| 0.03 | 0.02 | 1.20 | 118.30 | 0.00 | 10.00 | < 0.25 | <1.00 | 27.70 | 137.53 | 197.56 | 78.29 | 11.8 | 7.90 | 208.0 |
| < 0.01 | 0.00 | 1.10 | 109.20 | 0.00 | 7.60 | 0.03 | 0.07 | 19.90 | 119.00 | 174.40 | 69.38 | 10.0 | 7.55 | 185.1 |
| 0.06 | 0.05 | 5.45 | 139.30 | 0.00 | 9.10 | 0.14 | 0.30 | 18.70 | 149.32 | 220.00 | 101.95 | 9.0 | 8.01 | 247.6 |
| 0.03 | 0.01 | 4.70 | 170.10 | 0.00 | 18.00 | 0.02 | 0.40 | 44.80 | 215.05 | 301.36 | 106.92 | 10.0 | 7.84 | 319.4 |
| 0.08 | 0.06 | 4.90 | 162.50 | 0.00 | 20.00 | 0.03 | 0.50 | 48.40 | 216.32 | 298.78 | 98.21 | 10.0 | 7.75 | 316.1 |
| < 0.01 | < 0.01 | 1.10 | 90.00 | 0.00 | 7.60 | 0.11 | 0.50 | 31.80 | 117.05 | 162.72 | 55.70 | 11.0 | 7.27 | 161.1 |
| < 0.01 | < 0.01 | 2.50 | 3.20 | 60.00 | 6.60 | 0.02 | 2.30 | 56.40 | 181.70 | 183.32 | 2.00 | 25.0 | 9.78 | 238.2 |
| < 0.01 | < 0.01 | 4.40 | 235.20 | 0.00 | 7.70 | 2.43 | 0.40 | 31.30 | 247.09 | 366.43 | 162.54 | 10.0 | 7.23 | 414.8 |
| 0.08 | < 0.01 | 5.10 | 225.20 | 0.00 | 8.50 | 0.52 | 0.20 | 28.80 | 229.64 | 343.90 | 146.83 | 10.0 | 8.20 | 374.1 |
| 0.59 | 0.13 | 3.10 | 281.60 | 0.00 | 2.30 | 0.03 | 0.50 | 24.60 | 257.49 | 400.37 | 171.33 | 11.5 | 7.87 | 433.4 |
| 0.04 | 0.00 | 7.70 | 302.00 | 0.00 | 13.10 | 0.16 | 0.40 | 37.80 | 313.28 | 466.51 | 203.26 | 9.5 | 7.55 | 510.0 |
| 0.07 | 0.18 | 1.00 | 132.70 | 0.00 | 18.30 | 5.10 | <1.00 | 64.00 | 213.62 | 280.95 | 82.83 | 13.5 | 7.20 | 284.0 |
| < 0.01 | < 0.01 | 3.80 | 171.30 | 0.00 | 27.60 | 0.95 | 0.40 | 39.00 | 223.83 | 310.75 | 138.93 | 14.0 | 8.03 | 337.1 |
| < 0.01 | 0.01 | 2.40 | 181.50 | 0.00 | 11.10 | 0.49 | 0.20 | 17.60 | 181.50 | 273.59 | 137.08 | 13.0 | 7.24 | 314.2 |
| < 0.01 | < 0.01 | 7.90 | 190.30 | 0.00 | 13.10 | 0.63 | 0.30 | 24.40 | 211.60 | 308.16 | 115.07 | 12.0 | 7.37 | 343.6 |

Appendix D. Radon data

| Lab No. | Site No. | Town-ship | Range | Sec. | Tract | Longitude | Latitude | County | Aquifer | Hydro Unit | Total Depth | Radon (pCi/L) | Sample Date |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Kalispell subarea | | | | | | |
| 2000R0059 | 150622 | 28N | 19W | 31 | DACC | -114.0553 | 48.1433 | FH | 112OTSH | shallow | 43 | 470 | 29-May-00 |
| 2000R0049 | 131916 | 33N | 23W | 30 | BDAC | -114.6186 | 48.5977 | FH | 112OTSH | shallow | 35 | 520 | 23-May-00 |
| 2000R0045 | 83666 | 29N | 20W | 26 | ABCC | -114.1194 | 48.2519 | FH | 112DRFT | interm. | 139 | 570 | 22-May-00 |
| 1995R0234 | 139453 | 27N | 20W | 11 | DCAC | -114.1007 | 48.1122 | FH | 112DRFT | interm. | 310 | 570 | 27-Sep-94 |
| 2000R0048 | 85628 | 30N | 20W | 20 | DCCA | -114.1836 | 48.3427 | FH | 112DRFT | interm. | 149 | 830 | 22-May-00 |
| 1997R0182 | 148197 | 29N | 21W | 18 | CBBB | -114.3283 | 48.2758 | FH | 112DRFT | interm. | 109 | 830 | 12-Aug-96 |
| 1995R0220 | 81656 | 28N | 20W | 4 | AD | -114.1392 | 48.2201 | FH | 112ALVM | deep | 280 | 210 | 21-Sep-94 |
| 1997R0180 | 83435 | 29N | 20W | 3 | DDBA | -114.1344 | 48.3013 | FH | 112ALVM | deep | 340 | 370 | 12-Aug-96 |
| 1995R0332 | 144873 | 29N | 22W | 28 | DBBDB | -114.4036 | 48.2459 | FH | 112ALVM | deep | 300 | 450 | 26-Nov-94 |
| 1997R0121 | 6414 | 28N | 20W | 31 | CDCC | -114.1944 | 48.1394 | FH | 112ALVM | deep | 650 | 480 | 29-Jul-96 |
| 1995R0346 | 82066 | 28N | 21W | 5 | DDC | -114.2904 | 48.2106 | FH | 112ALVM | deep | 85 | 500 | 1-Dec-94 |
| 2000R0050 | 88197 | 31N | 23W | 36 | DDDB | -114.4611 | 48.4008 | FH | 112ALVM | deep | 168 | 520 | 23-May-00 |
| 2000R0046 | 85689 | 30N | 20W | 22 | CDAC | -114.1444 | 48.3438 | FH | 112ALVM | deep | 308 | 620 | 22-May-00 |
| 1997R0003 | 137868 | 29N | 21W | 22 | CCCB | -114.2638 | 48.2561 | FH | 112ALVM | deep | 277 | 620 | 1-Jul-96 |
| 1997R0123 | 81766 | 28N | 20W | 15 | CBDD | -114.1319 | 48.1863 | FH | 112VFAL | deep | 407 | 640 | 29-Jul-96 |
| 1995R0502 | 144873 | 29N | 22W | 28 | DBBDB | -114.4036 | 48.2459 | FH | 112ALVM | deep | 300 | 670 | 17-May-95 |
| 1997R0277 | 79595 | 26N | 19W | 11 | CDBD | -113.9766 | 48.0250 | L | 112ALVM | deep | 125 | 680 | 10-Sep-96 |
| 2000R0052 | 83873 | 29N | 21W | 5 | CC | -114.3060 | 48.2997 | FH | 112ALVM | deep | 126 | 700 | 23-May-00 |
| 1995R0465 | 148189 | 30N | 20W | 19 | DAAC | -114.1980 | 48.3472 | FH | 112ALVM | deep | 342 | 710 | 3-May-95 |
| 1992R1081 | 82104 | 28N | 21W | 7 | DDBD | -114.3114 | 48.1994 | FH | 112ALVM | deep | 330 | 754 | 5-Sep-92 |
| 1997R0185 | 84737 | 29N | 22W | 36 | DAAD | -114.3308 | 48.2313 | FH | 112ALVM | deep | 205 | 760 | 12-Aug-96 |
| 1995R0464 | 148188 | 30N | 20W | 19 | DAAD | -114.1975 | 48.3475 | FH | 112ALVM | deep | 518 | 880 | 3-May-95 |
| 1992R1082 | 136133 | 28N | 21W | 17 | CCCA | -114.3066 | 48.1841 | FH | 112ALVM | deep | 382 | 1056 | 5-Sep-92 |
| 1997R0183 | 80389 | 27N | 19W | 20 | ACDB | -114.0352 | 48.0891 | FH | 112ALVM | deep | 249 | 1090 | 13-Aug-96 |
| 2000R0043 | 84687 | 29N | 22W | 29 | ADCB | -114.4208 | 48.2486 | FH | 112ALVM | deep | 231 | 1490 | 21-May-00 |
| 1997R0276 | 79587 | 26N | 19W | 11 | BADC | -113.9758 | 48.0341 | L | 112VFAL | deep | 566 | 1550 | 10-Sep-96 |
| 1995R0468 | 82381 | 28N | 21W | 17 | DDAC | -114.2888 | 48.1847 | FH | 112ALVM | deep | 229 | 1590 | 5-May-95 |
| 1997R0002 | 141558 | 27N | 19W | 35 | DBAC | -113.9705 | 48.0572 | FH | 112ALVM | deep | 327 | 1870 | 1-Jul-96 |
| 1997R0122 | 133079 | 27N | 20W | 10 | ADCA | -114.1175 | 48.1188 | FH | 400MCRB | belt | 287 | 800 | 29-Jul-96 |
| 1995R0466 | 148194 | 30N | 22W | 34 | CBAA | -114.3897 | 48.3204 | FH | 400MCRB | Belt | 378 | 810 | 4-May-95 |
| 1997R0047 | 126317 | 31N | 22W | 34 | ADBB | -114.3775 | 48.4102 | FH | 400MCRB | Belt | 460 | 840 | 15-Jul-96 |
| 1992R1103 | 136130 | 27N | 21W | 25 | BCBA | -114.2205 | 48.0766 | FH | 400MCRB | Belt | 400 | 1037 | 5-Sep-92 |
| 2000R0058 | 81636 | 28N | 20W | 1 | DAAC | -114.0723 | 48.2170 | FH | 400RVLL | Belt | 75 | 1090 | 29-May-00 |
| 1997R0181 | 702957 | 29N | 21W | 6 | CBBA | -114.3275 | 48.3055 | FH | 400RVLL | Belt | 569 | 1130 | 12-Aug-96 |
| 1997R0044 | 80915 | 27N | 21W | 10 | BBBA | -114.2644 | 48.1238 | FH | 400MCRB | Belt | 507 | 1340 | 14-Jul-96 |
| 1995R0333 | 144874 | 27N | 22W | 8 | AB | -114.4573 | 48.1193 | FH | 400MCRB | Belt | 440 | 1370 | 28-Nov-94 |
| 1992R1106 | 136131 | 27N | 21W | 26 | ADCD | -114.2261 | 48.0741 | FH | 400MCRB | Belt | 230 | 1474 | 5-Sep-92 |
| 1997R0046 | 139705 | 31N | 20W | 10 | ABBD | -114.1397 | 48.4711 | FH | 400MCRB | Belt | 505 | 1480 | 15-Jul-96 |
| 2000R0044 | 141665 | 29N | 22W | 19 | CDAC | -114.4511 | 48.2572 | FH | 400RVLL | Belt | 275 | 2340 | 21-May-00 |
| 1997R0045 | 83424 | 29N | 20W | 2 | CCCA | -114.1300 | 48.2997 | FH | 400RVLL | Belt | 250 | 2440 | 14-Jul-96 |
| 1997R0043 | 130530 | 27N | 19W | 25 | ABAD | -113.9475 | 48.0788 | FH | 400RVLL | Belt | 460 | 2790 | 14-Jul-96 |
| 2000R0047 | 158200 | 30N | 20W | 23 | CCCA | -114.1272 | 48.3430 | FH | 400SPKN | Belt | 170 | 6160 | 22-May-00 |
| 1997R0048 | 45316 | 29N | 22W | 32 | DADB | -114.4183 | 48.2308 | FH | 400RVLL | Belt | 396 | 8360 | 15-Jul-96 |
| | | | | | | Mission subarea | | | | | | | |
| 1992R1100 | 6029 | 18N | 20W | 14 | DBDD | -114.1027 | 47.3169 | L | 112OTSH | shallow | 51 | 1407 | 4-Sep-92 |
| 1992R1084 | 76957 | 22N | 20W | 10 | ACBD | -114.1430 | 47.6841 | L | 112DRFT | interm. | 196 | 210 | 4-Sep-92 |
| 1992R1097 | 137945 | 21N | 20W | 2 | BAAA | -114.1236 | 47.6163 | L | 112LKML | interm. | 200 | 1634 | 4-Sep-92 |
| 1992R1090 | 75998 | 21N | 20W | 11 | ACBA | -114.1208 | 47.5980 | L | 112LKML | interm. | 454 | 3176 | 4-Sep-92 |
| 1992R1088 | 75978 | 21N | 20W | 11 | ACBD | -114.1205 | 47.5975 | L | 112LKML | interm. | 408 | 4325 | 4-Sep-92 |
| 1997R0480 | 73868 | 19N | 19W | 20 | BBAA | -114.0483 | 47.3988 | L | 112LKML | interm. | 321 | 1270 | 30-Oct-96 |
| 1997R0324 | 131954 | 22N | 20W | 1 | AADA | -114.0911 | 47.7013 | L | 112ALVM | deep | 224 | 324 | 19-Sep-96 |
| 1992R1107 | 76955 | 22N | 20W | 3 | DBDC | -114.1411 | 47.6930 | L | 112ALVM | deep | 196 | 630 | 5-Sep-92 |
| 1997R0389 | 76014 | 21N | 20W | 16 | DAAD | -114.1558 | 47.5794 | L | 112ALVM | deep | 310 | 990 | 3-Oct-96 |
| | | | | | | Flathead Lake Perimeter subarea | | | | | | | |
| 1992R1111 | 137946 | 26N | 21W | 13 | ABAB | -114.2422 | 48.0204 | FH | 400MCRB | Belt | 612 | 1082 | 5-Sep-92 |
| 1992R1091 | 79859 | 26N | 20W | 18 | BABB | -114.2294 | 48.0200 | FH | 400MCRB | Belt | 323 | 1255 | 5-Sep-92 |
| 1997R0184 | 79706 | 26N | 19W | 19 | BDAD | -114.0613 | 48.0033 | L | 400RVLL | Belt | 1010 | 3720 | 13-Aug-96 |
| 1997R0519 | 78668 | 24N | 21W | 36 | DBCB | -114.2294 | 47.7955 | L | 400RVLL | Belt | 767 | 1880 | 7-Nov-96 |
| | | | | | | Little Bitterroot subarea | | | | | | | |
| 1995R0424 | 6155 | 21N | 24W | 4 | DBDC | -114.6750 | 47.6064 | S | 112ALVM | deep | 383 | 70 | 4-Apr-95 |
| 1995R0388 | 76192 | 21N | 24W | 4 | ADA | -114.6693 | 47.6115 | S | 400PRCD | Belt | 190 | 1930 | 4-Jan-95 |
| | | | | | | Coram subarea | | | | | | | |
| 1995R0351 | 145107 | 30N | 19W | 4 | CAA | -114.0342 | 48.3915 | FH | 112DRFT | interm. | 73 | 490 | 12-Dec-94 |
| 1995R0355 | 85157 | 30N | 19W | 6 | DCAD | -114.0707 | 48.3877 | FH | 112ALVM | deep | 155 | 230 | 12-Dec-94 |
| 1995R0467 | 85170 | 30N | 19W | 8 | BABC | -114.0592 | 48.3844 | FH | 112ALVM | deep | 200 | 210 | 5-May-95 |
| 2000R0060 | 79152 | 25N | 18W | 35 | ADAC | -113.8356 | 47.8868 | L | 111ALVM | deep | 78 | 500 | 29-May-00 |