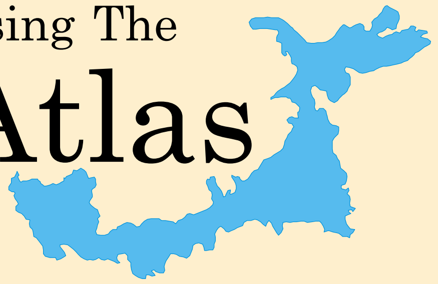
The Spokane Valley-Rathdrum Prairie Aquifer Atlas

Using The

Atlas



If your interest in the Aquifer is general, the authors suggest you page through this document and spend time on those pages that attract your attention.

If you have specific interests, the Atlas is organized into seven sections.

General information about the Aquifer and the region can be found on pages 1 – 5.

The **geology of the Aquifer**, including the recent geologic events that formed the Aquifer, is presented on pages 6 – 9.

Discussions of the **Aquifer water cycle** are found on pages 10 – 11.

Computer modeling of the Aquifer is presented on pages 12 – 15.

Aquifer water quality and **Aquifer issues** are found on pages 16 – 21.

An **Aquifer tour** is described on page 22.

A **glossary of terms** used in this Atlas is found on pages 23 – 24.

Preface

The Spokane Valley-Rathdrum Prairie Aquifer Atlas presents a comprehensive summary of the region's most precious groundwater resource and is a basic reference of the geographic, geologic and hydrologic characteristics of this aquifer.

The Atlas is designed in a narrative format supported by graphs, maps and images. It is intended for broad community use in education, planning, and general technical information. The preparation and publication of the atlas were partially funded by a United States Environmental Protection Agency aquifer wellhead protection grant.

The information was collected and obtained from a variety of sources, including: United States Environmental Protection Agency, Idaho Department of Environmental Quality, Panhandle Health District, Kootenai County Planning Department (Idaho), Spokane County (Washington), United States Geologic Survey and Eastern Washington University.

The Spokane Valley-Rathdrum Prairie Aquifer spans two states (Washington and Idaho) and lies within three counties (Kootenai, Bonner and Spokane). Natural resources, such as the Aquifer, that cross political boundaries are often subject to different, and sometimes conflicting, standards, protection and uses. This Atlas is a joint effort by agencies in both states to create a holistic representation of the Aquifer as both geologic feature and a natural resource used daily by more than 400,000 people.

Political boundaries are absent on the front cover map. The authors intend the reader first view the Aquifer as a continuous natural feature, then investigate the various aquifer elements presented in this Atlas. The authors believe that factual information about the Aquifer will generate greater public understanding of the region's groundwater and lead to continued protection and wise use of this precious and finite resource.

James D. MacInnis, P.E.
Aquifer Task Manager
Idaho DEQ

Jim Blake
Water Quality Program
Spokane County

Brian Painter, P.G.
Aquifer Hydrogeologist
Idaho DEQ

John P. Buchanan, Ph.D.
Professor of Geology
Eastern Washington Univ.

Beatrice B. Lackaff
GIS Specialist
Spokane County

Reanette Boese
Water Quality Program
Spokane County

Printed and distributed in July 2000

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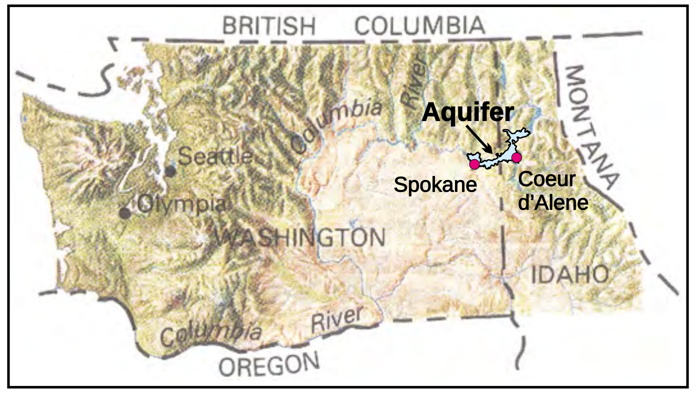
The Aquifer

The sole source of water for most of the people in Spokane County, Washington and Kootenai County, Idaho is a high quality underground water body called the Spokane Valley-Rathdrum Prairie Aquifer. Discovered in 1895, this Aquifer has become one of the most important resources in the region, supplying drinking water to more than 400,000 people. The Aquifer has been studied in considerable detail since 1977, and the results of these investigations have produced programs and regulations designed to insure this aquifer will remain a valued and protected resource for future generations.



Location of the Aquifer in Washington and Idaho

Aquifer Formation

The Spokane Valley and Rathdrum Prairie are ancient geologic features that have, for millions of years, been slowly formed by water flowing towards the Pacific Ocean. During the last Glacial Age, between 12,000 and 1.6 million years ago, a series of catastrophic floods covered this area as a result of the rapid draining of ancient Lake Missoula in Montana when ice dams broke. These floods deposited thick layers of coarse sediments (gravels, cobbles, and boulders) in this area. The saturated portion of these sediments, where void spaces are filled with water, comprises the Aquifer. Waters from adjacent lakes, mountain streams, the Spokane River and precipitation flow through the flood sediments replenishing the Aquifer.

Aquifer Facts

The Aquifer has one of the fastest flow rates in the nation, flowing as much as 50 feet per day in some areas. In comparison, a typical aquifer has a flow rate between a quarter inch and five feet per day.

The Aquifer deposits range from about 150 feet to more than 600 feet deep.

The Aquifer covers 321 square miles.

The total flow of the Aquifer is estimated at 390 cubic feet per second at the Idaho-Washington state line.

The volume of the entire Aquifer is about 10 trillion gallons, making it one of the most productive aquifers in the United States.

Even though contamination has reached the Aquifer, the Aquifer water quality remains very good.

Location and Flow

The Aquifer begins in Idaho between Spirit Lake and the south end of Lake Pend Oreille. The Aquifer water flows south until it reaches the middle of the Rathdrum Prairie, then it turns west and flows into Washington under the Spokane Valley. When the Aquifer water reaches downtown Spokane, most of it turns north, flows under the city and discharges into the Little Spokane River.

Sole Source Designation

In the 1970s area residents became concerned about aquifer water quality. The highly permeable aquifer boulders, gravel and sands, together with permeable overlying soils, make the Aquifer highly susceptible to contamination from the surface. One of the first important steps to protect the Aquifer was taken by the Environmental Protection Agency, when it designated the Spokane Valley-Rathdrum Prairie a "Sole Source Aquifer" in 1978. The Aquifer was the second aquifer in the nation to receive this special designation. This step further increased public awareness for aquifer protection and supported the development of special management practices by local agencies. Presently, aquifer protection efforts are managed by Spokane County's Water Quality Program in Washington and by the Department of Environmental Quality and the Panhandle Health District in Idaho.

Water Quality Monitoring

The first monitoring of the Aquifer water began in October, 1908 in the City of Spokane (see side bar article), but detailed water quality testing in the Aquifer began much later. Present day water quality testing validates in much greater detail the 1908 sampling results: the Aquifer has excellent water and it remains one of the highest quality drinking water sources in the nation.

Since 1977, every three months Spokane County obtains water samples from about 50 wells in Washington. The Panhandle Health District has taken samples from about 28 wells in Idaho since 1974. Testing of these quarterly water samples have shown that:

- contaminant levels in the Aquifer increase as the water moves westward,
- contaminant levels show a direct relationship to human activity,
- contaminants are mostly located in the top few feet in the Aquifer, and,
- overall contaminant levels have increased since 1977.

This monitoring suggests that human activities on the land surface over the Aquifer are deteriorating the aquifer water quality. Contaminants carried to the Aquifer originate as stormwater, septic tank leachate, fertilizer leachate, leaking underground storage tanks and other sources that percolate downward from the surface. Even though contamination has reached the Aquifer, the Aquifer water quality remains very good.

Water Supply

Newspaper articles from the 1890s and 1910s relate that area residents believed the Aquifer was an "inexhaustible supply of pure water." The belief that the Aquifer was unlimited continued until the early 1980s when the U. S. Geological Survey presented the results of a flow model for the Aquifer. The model found that:

- the daily Aquifer flow at the Washington-Idaho border was 320 to 650 million gallons,
- the Aquifer is a reservoir with storage capacity of 10 trillion gallons,
- the average daily water withdrawal is 160 million gallons, and
- the peak summer daily withdrawal is 450 million gallons.

Spokesman-Review, Thursday, May 6, 1909

SPOKANE'S WATER PUREST IN WORLD

Tests Shows Average of Only Seven or Eight Germs to Centimeter

MONTHLY TESTS ARE MADE

City Bacteriologist Frank Rose Reports Results – No Colon Bacilli Found

Showing the Spokane water supply purer than the average of American cities, Frank Rose, city bacteriologist, has made a report of tests from the city well made monthly since last October. The tests are simply counts of the number of bacteria found in a cubic centimeter of water.

The average count shows only seven or eight germs in that amount of water. The test was made from water taken from the drinking fountain at Howard street and Riverside avenue or from water from a faucet in the Rookery building. Speaking of his tests, Dr. Rose said:

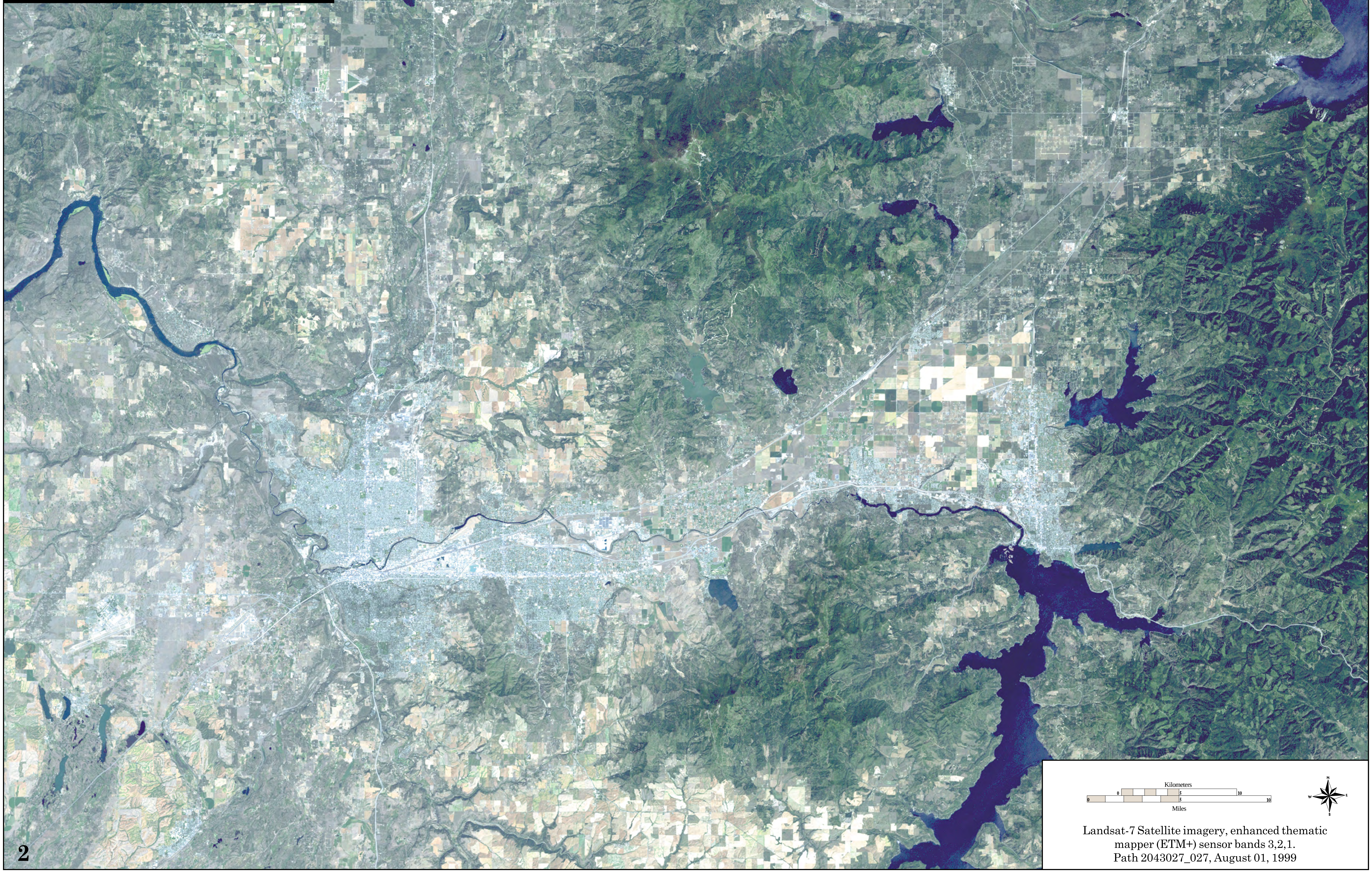
"It can be said that there is no city in the world that has a better water supply than Spokane. Water which shows 100 germs in a cubic centimeter is considered comparatively pure and drinkable. I made from four to eight counts monthly since last October, and the counts in any one month was 17 bacteria, while the tests last month showed 15 bacteria in eight tests, less than two each.

"In April, 1908, I made tests of the river water from which Spokane got its drinking supply at that time. I took water from the place where the Coeur d'Alene sewer emptied into it and another sample from a place about 500 feet below the outlet of the sewer. In both cases the number of bacteria was so great as to be practically uncountable.

"In contrast to this is the practical purity of the water since last October. Special care was taken to make tests for colon bacilli, which show the presence of sewage, and in no case was there a single trace."

The flow model suggests that we are using most of the Aquifer flow, and in high demand times we may be drawing on its reserve capacity. Currently the available supply is adequate to support area growth for some time, but the supply is not inexhaustible.

Aquifer from Space



Above The Aquifer

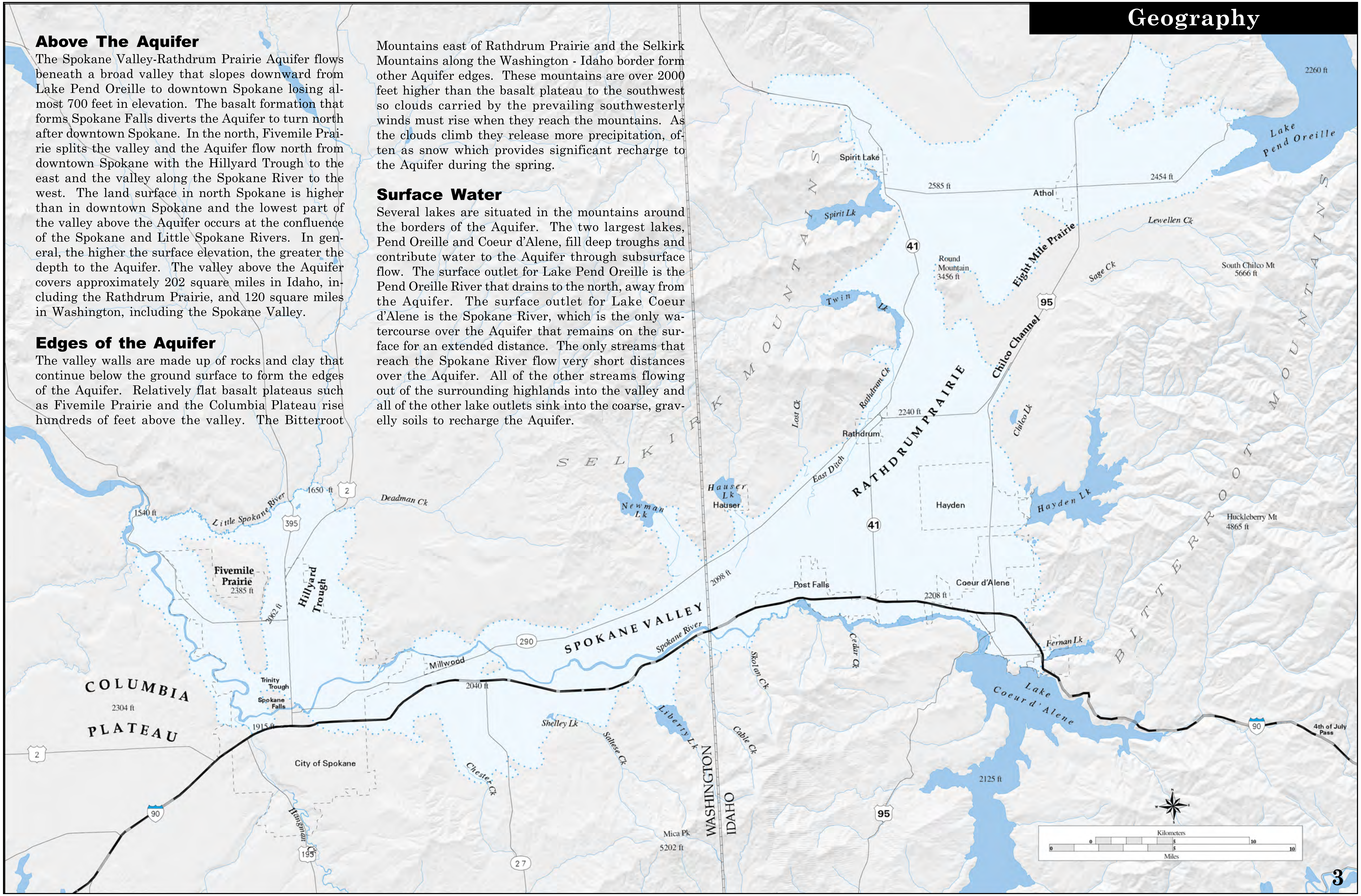
The Spokane Valley-Rathdrum Prairie Aquifer flows beneath a broad valley that slopes downward from Lake Pend Oreille to downtown Spokane losing almost 700 feet in elevation. The basalt formation that forms Spokane Falls diverts the Aquifer to turn north after downtown Spokane. In the north, Fivemile Prairie splits the valley and the Aquifer flow north from downtown Spokane with the Hillyard Trough to the east and the valley along the Spokane River to the west. The land surface in north Spokane is higher than in downtown Spokane and the lowest part of the valley above the Aquifer occurs at the confluence of the Spokane and Little Spokane Rivers. In general, the higher the surface elevation, the greater the depth to the Aquifer. The valley above the Aquifer covers approximately 202 square miles in Idaho, including the Rathdrum Prairie, and 120 square miles in Washington, including the Spokane Valley.

Edges of the Aquifer

The valley walls are made up of rocks and clay that continue below the ground surface to form the edges of the Aquifer. Relatively flat basalt plateaus such as Fivemile Prairie and the Columbia Plateau rise hundreds of feet above the valley. The Bitterroot Mountains east of Rathdrum Prairie and the Selkirk Mountains along the Washington - Idaho border form other Aquifer edges. These mountains are over 2000 feet higher than the basalt plateau to the southwest so clouds carried by the prevailing southwesterly winds must rise when they reach the mountains. As the clouds climb they release more precipitation, often as snow which provides significant recharge to the Aquifer during the spring.

Surface Water

Several lakes are situated in the mountains around the borders of the Aquifer. The two largest lakes, Pend Oreille and Coeur d'Alene, fill deep troughs and contribute water to the Aquifer through subsurface flow. The surface outlet for Lake Pend Oreille is the Pend Oreille River that drains to the north, away from the Aquifer. The surface outlet for Lake Coeur d'Alene is the Spokane River, which is the only watercourse over the Aquifer that remains on the surface for an extended distance. The only streams that reach the Spokane River flow very short distances over the Aquifer. All of the other streams flowing out of the surrounding highlands into the valley and all of the other lake outlets sink into the coarse, gravelly soils to recharge the Aquifer.



Aquifer History

1890

Schemes To Avoid Contamination

The City is seeking a water source not in danger of surface contamination. Among the schemes under consideration are: bringing water from springs near the Little Spokane River; tapping of Hayden Lake for gravity flow with augmentation from Spirit and Twin lakes whenever needed; and a dam east of the City for impounding of the river water from a point above the City's contamination.

October 1, 1905

Water Inflow at Pumping Station

The new pump station at the upriver dam and water extensions will provide water to supply a city of over 120,000 population promises City Engineer Charles McIntyre. The scene of most interest was at the excavation that has been made for the foundation of the pumping station. A large amount of water boils out of the sand and gravel at the bottom of the excavation. When asked as to the amount of water that flowed to the river from the pump station excavation, Engineer Gill made a few calculations and said: "There is twice as much water flowing from this hole as goes through the mains to supply the city of Spokane. The water comes from a vast underground river that percolates many miles through washed gravel and comes to the surface at the excavation. This water is clearly not from the river."

December 13, 1908

City Soap Sales Gain 50 Per Cent

Since the city changed the source of its water supply from the river to the wells, giving the consumer hard instead of soft water, the soap sales have increased 50 per cent according to wholesale grocers. It was found necessary last July on account of the contamination of the river water by the inflow of the Coeur d'Alene sewage to draw the city water supply from wells.

1931

Groundwater Studied

Under contract to the Washington Water Power Company, E. R. Fosdick prepares the first comprehensive study of groundwater in the Spokane Valley and Rathdrum Prairie.

1938

Spokane River Foulest

A survey of all major rivers and waterways found the Spokane River the foulest water body in the state of Washington.

1884

City Purchases Waterworks

The waterworks acquisition is the beginning of a city water system. The plant is located on Havermale Island.

1895

Pump Station Delays

Water In Excavation

(After much debate, City has selected the river dam proposal for Spokane's new water supply.) The contract awarded to R. A. Jones in 1894 to construct the Upriver Dam is proceeding slowly. The pump station at the upriver dam has encountered water during excavation. Pumping 40 million gallons daily out of a hole 24 feet square for a considerable time at a cost of over eight thousand dollars has only lowered the water two feet. *(Although unrecognized at the time, the contractor had discovered the Aquifer.)*

May 30, 1908

Dr. M. B. Grieve Advises Boiling of River Water

It was estimated yesterday by J. T. O'Brien, president of the board of public works, that the new addition to the water system whereby the city is to take its water supply from the gravel near the up-river pumping station will cost about $50,000. City officials are anxious to complete the water extension improvement, traces of colon bacilli having been found in recent tests of river water. Dr. M. B. Grieve, city health officer, has advised everyone to boil all river water before using it for domestic purposes.

1923

Lake Missoula and the Spokane Floods

J. Harlan Bretz publishes an abstract in the Geological Society of America Bulletin stating evidence of large floods across eastern Washington that created the Channeled Scablands. This abstract also states that these enormous floods came through present-day Spokane, Washington.

May 4, 1974

Spokane's EXPO '74 "Preserving the Environment"

EXPO '74 opens in Spokane, Washington, with the theme: "Celebrating Tomorrow's Fresh New Environment". Many visitor's are impressed with EXPO's beautiful river front site and the river falls, and they are amazed to learn that just two years earlier this site contained railroad tracks and dilapidated buildings. EXPO's headquarters are located on Havermale Island, the site of the City's first water system. Local residents hope that the EXPO's environmental theme will lead to an increased awareness of Spokane's water resources.

1881 - Northern Pacific Railroad arrives in region

1885 - Lead & silver discovered near Kellogg, Idaho

1889 - Great Spokane Fire

1914-1918: World War I

1929 - Stock Market Crash, Great Depression hits region

1939-1945: World War II

1960 - Seven month strike at Bunker Hill Mine

1880 1890 1900 1910 1920 1930 1940 1950 1960 1970

1890 - Idaho becomes 43rd state

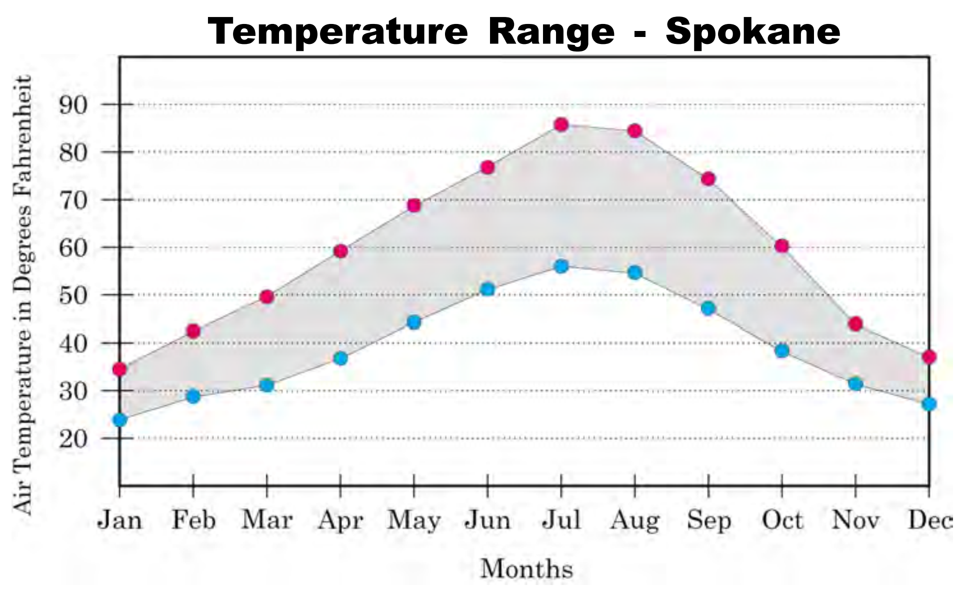
1889 - Washington becomes 42nd state

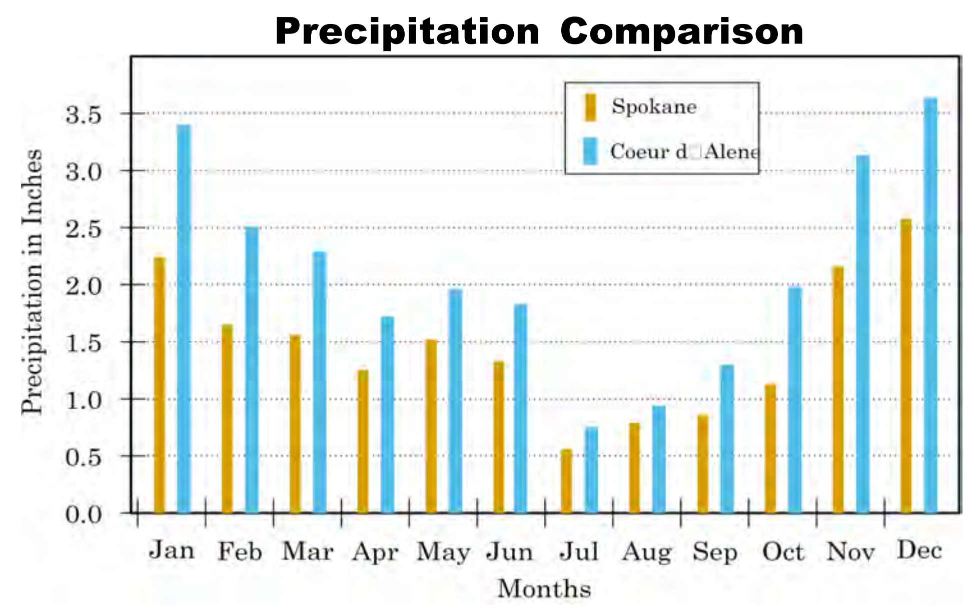
1883 - Gold discovered near Coeur d'Alene

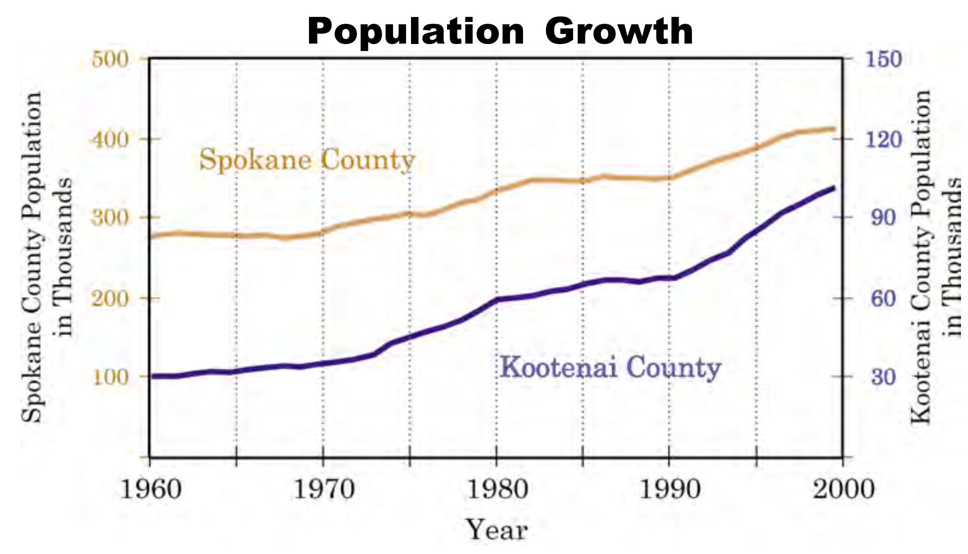
1929-1934: Grand Coulee Dam Project

1967 - Interstate 90 (I-90) is completed

Background is a photograph of the Upriver Dam constructed of timber on the Spokane River in 1895.







Climate

The Spokane-Coeur d'Alene region has warm, dry summers and cool, moist winters. The area's climate ranges from subhumid in the mountains to semiarid in the Spokane Valley and Rathdrum Prairie. Although average annual precipitation varies considerably over the region, average air temperatures across the Aquifer usually vary no more than 2 or 3 degrees Fahrenheit. Seasonal variations in temperature for Spokane are shown in the monthly temperature graph. Temperatures in Coeur d'Alene are usually 1 to 3 degrees cooler.

Precipitation

A few miles west of the Aquifer, at the Spokane International Airport, the average annual precipitation is 16.13 inches. As one moves east across the Aquifer the average annual rainfall increases. In the Spokane Valley, the average annual rainfall is almost 20 inches, and in Coeur d'Alene, it is 25.45 inches. A comparison between the average monthly precipitation in Spokane and Coeur d'Alene is shown on the precipitation graph. In the Bitterroot Mountains east of Coeur d'Alene, part of the Aquifer recharge area, annual precipitation is more than 70 inches. About sixty percent (60%) of the annual precipitation occurs during the five-month period November-March, and much of it falls as snow, especially in the mountains. In the vicinity of Spokane, winter snowfall frequently accumulates to depths of a foot or more, but it usually melts in a few days.

Population

The 1998-1999 population estimate for Spokane County was 414,500 and for Kootenai County was 101, 390, for a total of 515,890 people. While many people in both counties live outside the Aquifer boundary, up to 300,000 live over the Aquifer, and an additional 50,000 to 100,000 people use the Aquifer as a water supply. Between 1970 and 1999 the population in both Counties has increased dramatically as shown in the population graph. In Idaho the population of Kootenai County has almost tripled going from 35,579 in 1970 to over 100,000 in 1999. Spokane County increased in population from 287,487 in 1970 to the 1999 estimate of 414,500, a 44.2 percent increase in 29 years.

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Maximum Temperature in Degrees Fahrenheit													
Spokane Airport	32.9	39.1	48.2	58.3	67.1	74.3	83.9	82.7	72.5	59.3	42.9	34.8	58.0
Spokane	34.5	42.5	49.6	59.2	68.8	76.8	85.8	84.5	74.4	60.3	44.0	37.1	59.8
Coeur d'Alene	34.3	40.5	48.4	58.5	68.3	75.2	85.1	85.0	73.9	60.4	44.2	36.6	59.2
Bayview	34.4	38.8	45.3	54.4	63.8	71.4	79.2	78.6	68.7	55.4	42.9	35.9	55.7
Average Minimum Temperature in Degrees Fahrenheit													
Spokane Airport	21.5	25.1	30.5	36.5	43.7	50.1	55.8	54.5	46.6	37.7	30.0	24.3	38.0
Spokane	23.9	28.8	31.2	36.8	44.3	51.2	56.0	54.7	47.2	38.4	31.5	27.2	39.3
Coeur d'Alene	21.5	24.4	28.4	34.2	41.5	48.1	52.6	51.7	44.5	37.2	29.9	25.2	36.6
Bayview	20.9	23.9	27.0	32.2	38.6	45.0	48.7	47.8	40.8	33.3	28.4	23.2	34.1
Average Precipitation in Inches													
Spokane Airport	1.99	1.57	1.37	1.10	1.39	1.21	0.56	0.63	0.82	1.18	2.11	2.20	16.13
Spokane	2.24	1.65	1.56	1.25	1.52	1.33	0.56	0.79	0.86	1.13	2.16	2.58	17.62
Coeur d'Alene	3.40	2.51	2.29	1.72	1.96	1.83	0.75	0.94	1.30	1.98	3.13	3.64	25.45
Bayview	2.90	2.31	2.06	1.74	2.02	1.83	1.03	1.10	1.23	2.06	2.95	3.22	24.40

Year	Spokane	Kootenai	Year	Spokane	Kootenai	Year	Spokane	Kootenai
1960	278,333	30,000	1973	299,500	42,519	1986	350,348	66,761
1961	278,700	30,555	1974	304,000	44,600	1987	348,703	66,160
1962	279,800	31,110	1975	304,300	47,365	1988	349,415	66,859
1963	278,500	31,665	1976	311,000	48,828	1989	352,715	67,738
1964	277,900	32,220	1977	318,900	51,565	1990	361,333	70,412
1965	277,200	32,775	1978	323,500	55,396	1991	365,969	73,792
1966	276,600	33,330	1979	334,100	58,728	1992	374,569	77,278
1967	274,200	33,885	1980	341,835	59,996	1993	383,600	82,194
1968	276,300	34,440	1981	346,815	60,827	1994	392,000	87,418
1969	280,000	35,005	1982	346,674	62,436	1995	401,200	91,845
1970	287,487	35,579	1983	346,078	62,987	1996	406,500	95,550
1971	292,000	36,644	1984	347,790	65,494	1997	409,900	98,797
1972	296,900	39,195	1985	351,417	66,783	1998	410,900	101,390

Geology

General
The Spokane Valley-Rathdrum Prairie Aquifer area contains richly varied and interesting geology. The geologic history of this area includes ancient mountain building, spectacular basalt lava flows, and some of the largest known glacial outburst floods. The map on the opposite page provides a visual description of the surface geology of the Aquifer area.

Geologic Time
Geologists use the geologic time scale to place events in geologic history. This time scale was developed through age dating and fossil correlation. Geologic time is organized into four “Eras” and numerous “Periods”, as shown on the map key on this page. Three major geologic events define the creation of the Spokane Valley-Rathdrum Prairie Aquifer. The first event was the emplacement, metamorphism, and erosion of the Precambrian basement rock; the second event was the eruption of Tertiary (Miocene) flood basalts that created the Columbia Plateau; and, the third event was the glaciation in the Quaternary Period that first eroded, then filled the Spokane Valley-Rathdrum Prairie area with coarse sediments and gravel to create the Aquifer.

Belt Formations
Throughout the Idaho Panhandle and the mountains around the Spokane Valley of Washington, the Belt Formations of Proterozoic sedimentary rocks, dominate the geologic landscape. These rock formations were named after the Belt Mountains of central Montana, where they were first studied. The Belt Formations of Idaho and Washington consist mostly of mudstones and sandstones in somber shades of gray and brown, along with some pale gray limestone. Ripple marks are preserved in many of the mudstone and sandstone layers of the Belt Formation rocks, indicating these rocks were likely deposited in a shallow marine environment. Throughout northern Idaho the Belt Formations contain intruded layers (or sills) composed of diabase, a black igneous rock with the composition of ordinary basalt. These sills were formed as molten magma squirts between layers of sedimentary Belt rock forming a layer of igneous rock. The Precambrian Belt Formation also contains metal minerals (of silver, lead, and gold) in hydrothermal vein deposits, a valuable resource for the region. The placement of these valuable mineral deposits is associated

A view of a wall in a gravel pit showing the soil and coarse sands and gravels that comprise the Aquifer.

with the mountain building continental plate collisions that created the Rocky Mountains.

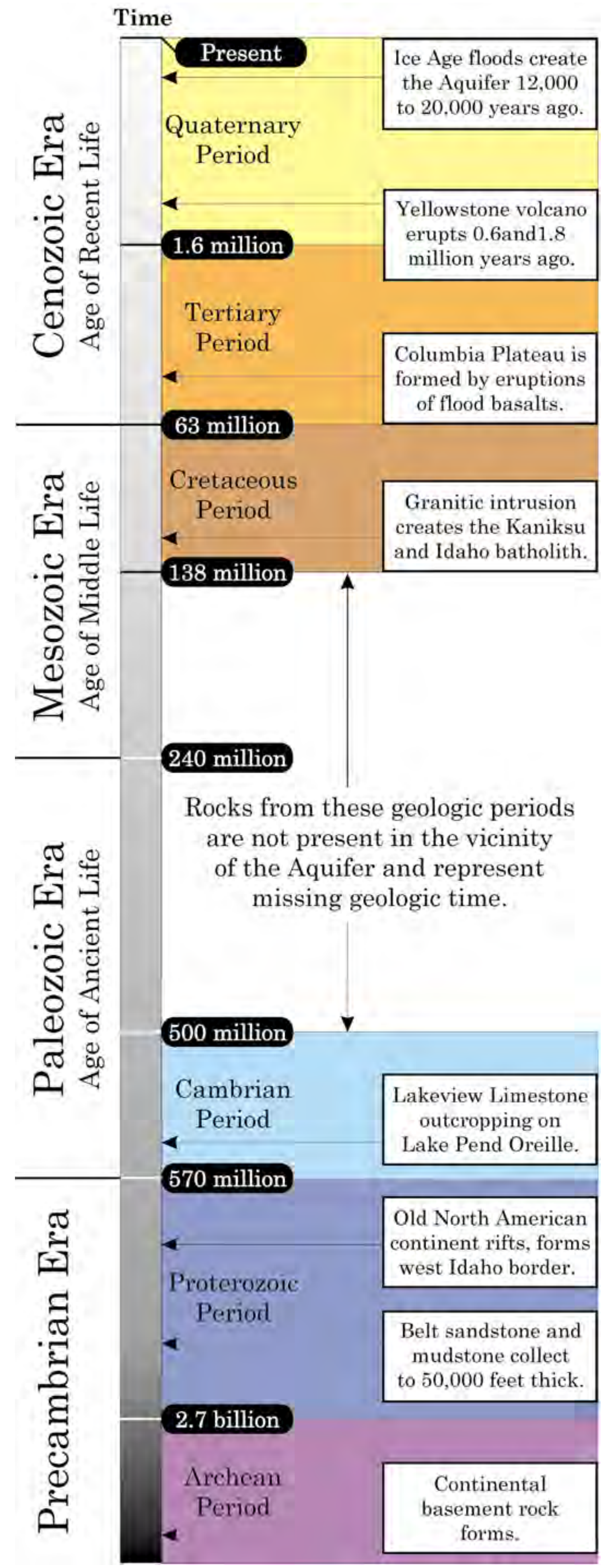
Basalt Flows
Spokane and Coeur d’Alene are situated on the eastern edge of the Columbia Plateau. Many of the largest lava flows in the Columbia Plateau erupted about 135 miles southwest of the Aquifer. Extraordinarily fluid lava flows extended northward past the present location of Spokane and into Idaho. The remnants of these flows are found in and around the Spokane Valley. Basalt is a dense dark rock with very fine crystals, and it sometimes has a unique hexagonal (six-sided) column-like appearance. The Columbia basalts in the Spokane-Rathdrum valley were eroded prior to the formation of the Aquifer, and now only the western portion of the Aquifer lies on Columbia basalts.

Glaciation
Geologic evidence suggests two Ice Ages have left a clear record in the landscape of the northern Rocky Mountains. The exact time of the first Ice Age is unknown, but likely occurred about 100,000 years ago. The most recent Ice Age climaxed about 15,000 years ago and ended approximately 10,000 years ago (see Back Cover). Evidence of other ice ages older than 100,000 years have nearly disappeared from the landscape, but occasional patches of glacial sediment attest to their existence.

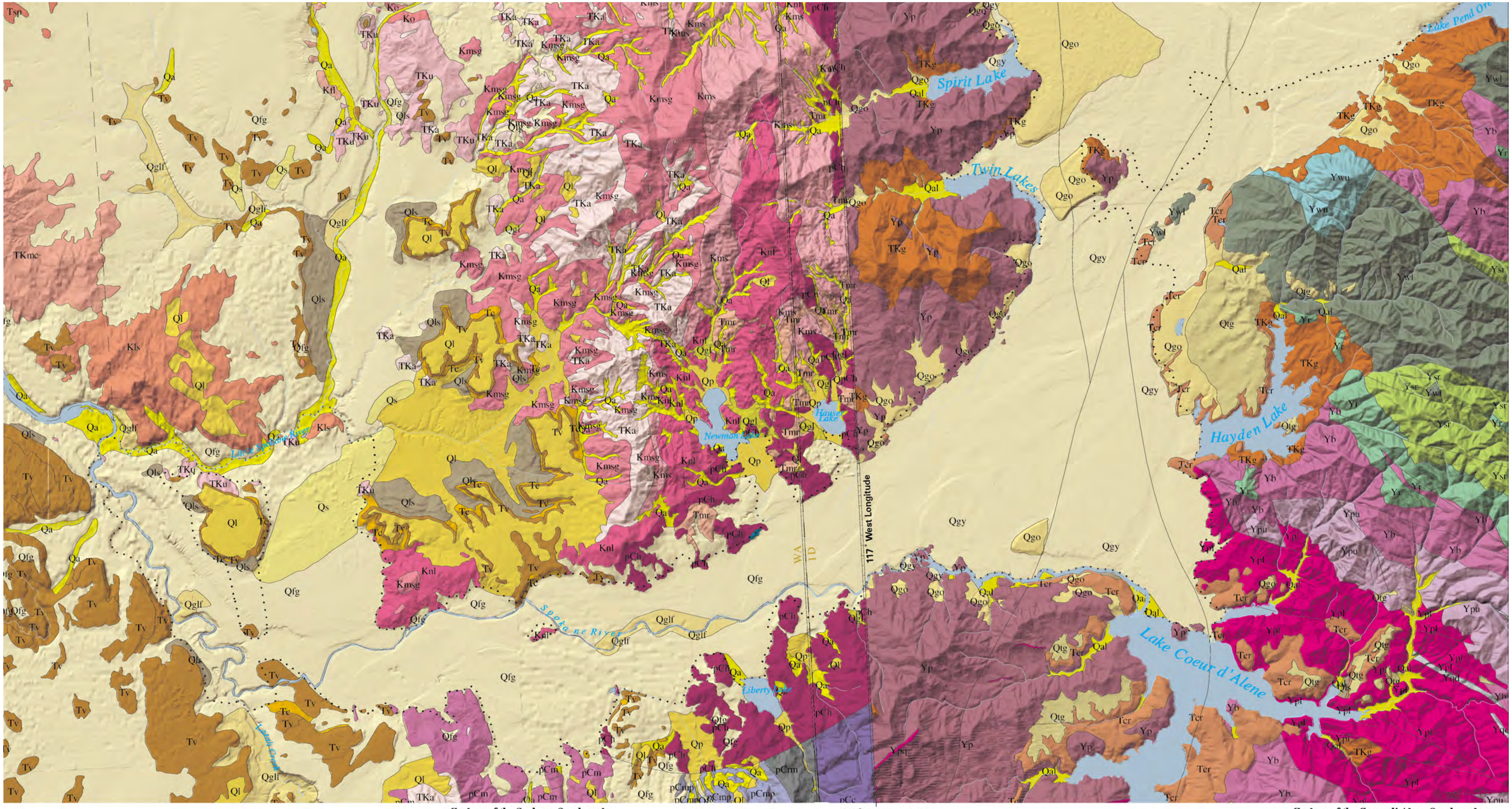
During both Ice Ages, glaciers covered most of British Columbia and moved south into northern Idaho and Washington, filling the valleys and covering all but the higher mountains. Those higher mountains also supported glaciers that flowed down the valleys to join the regional ice. In the broad valleys of northern Idaho, the main evidence of both ice ages is found in widespread deposits of glacial debris: till and outwash. However, more of these materials occur in the Spokane Valley and Rathdrum Prairie.

Glacial Till and Outwash
Glacial till is surface material pushed and carried by glacial ice: an unsorted and unlayered mixture of all sizes of sediment from clay to boulders. A till deposit is called a moraine, and moraines provide geologists with the location of ancient glacial ice. The most conspicuous and informative deposits of till are the morainal ridges that precisely outline the former boundaries of the glacier. Outwash is deposited from glacial meltwater, and it consists of neat layers of clay, sand, and gravel. A smooth blanket of outwash extends down slope from many moraines, evidence of the torrents of muddy meltwater that swept across those slopes during ice age summers. Since the last Ice Age ended, streams have entrenched themselves into most outwash deposits, exposing through erosion remnant benches along the stream course.

Glacial Lake Missoula
During both ice ages, glaciers moved south down the Purcell Valley, and dammed the Clark Fork River at the present site of Pend Oreille Lake, creating a vast impoundment called Glacial Lake Missoula. The events that followed the formation of this lake created the Spokane Valley-Rathdrum Prairie Aquifer. Pages 8 and 9 have additional information on this lake and the related outburst floods.



Geologic Time Scale



Geology of the Spokane Quadrangle

117° West Longitude

Geology of the Coeur d' Alene Quadrangle

Key to Geologic Units

- Qa,Qal alluvium
- Qfg flood gravel
- Qgo, Qglf glacial outwash
- Qgy younger glacial deposits
- Qtg,QTg older glacial deposits
- Qgl glacial lake deposits
- Ql, Qp loess
- Qls landslide deposits
- Qs sand deposits
- Tc Latah formation
- TKg basalt flows
- Tcr Columbia River basalt
- Tv Wanapum, Columbia Riv basalt
- TKmc quartz monzonite, granite
- TKu granite, unassigned
- Tmr granite, Mt Rathdrum
- TKfm FourMound granite
- Kls quartz monzonite, Little Spokane River
- TKa alaskaite, pegmatite,aplite
- Tsp quartz monzonite, Silver Point
- Kfl Fan Lake grandiorite,
- Kmsg granite, Mt. Spokane
- Knl gneiss, Newman Lake
- Ko quartz monzonite, Otter Creek
- Ypq Pritchard quartzite
- Yb, pCm heterogeneous metamorphic rock
- Kms Mt.Spokane, orthogneiss
- Yqd amphibolite, quartzdiorite
- Yp Pritchard formation Belt Super Group
- Ypl lower Pritchard
- Ypu upper Pritchard
- Yr Belt Super Group Revett formation
- Ysr St. Regis formation Belt Super Group
- Ywl lower member, Wallace formation
- Ywu upper member, Wallace formation
- pCa amphibolite
- pCc gneiss, Cable Ck
- pCh gneiss, Hauser Ck
- pCmp gneiss, Mica Pk
- pCrm gneiss Round Mt

Extent of Aquifer

Fault lines

State line

County line

Kilometers 0 5 10

Miles 0 5 10

Digital geologic data : U.S.Geological Survey, Spokane Quad:1997; Coeur d 'Alene Quad: USGS and Idaho Geological Survey (Preliminary Data) 1999

Ice Age

Between about 10,000 and 1.6 million years ago, during the Pleistocene Epoch (or Ice Age), the Earth's climate underwent periods of alternate cooling and warming. During the periods of cooling, with an average annual temperature probably between 5 and 10 degrees Fahrenheit cooler than present, vast continental ice sheets grew in size and extended far beyond the polar regions. In addition, alpine glaciers developed locally in the higher mountains. In southern Canada, the ice sheets periodically thickened and advanced southward, some reaching the northern parts of the United States before retreating and melting back to the north as the climate again became warmer. Evidence indicates that at least four, and perhaps six or more, major glaciations affected the Spokane–Coeur d'Alene area. The last of these occurred between 10,000 and 22,000 years ago and had the most significant effect on the present landscape. The map on the back cover provides a representation of the Pacific Northwest during this most recent Ice Age.

Glacial Lake Missoula Facts

The ice dam that created the lake was about 2,150 feet (0.4 miles) high.

At its greatest extent, the lake covered more than 3,000 square miles, an area greater than the state of Delaware.

The lake contained about 500 cubic miles of water, about one half the volume of present Lake Michigan.

At its full extent, the lake was 950 feet deep at present day Missoula, Montana.

After most flood events, the ice dam was reformed allowing Glacial Lake Missoula to refill.

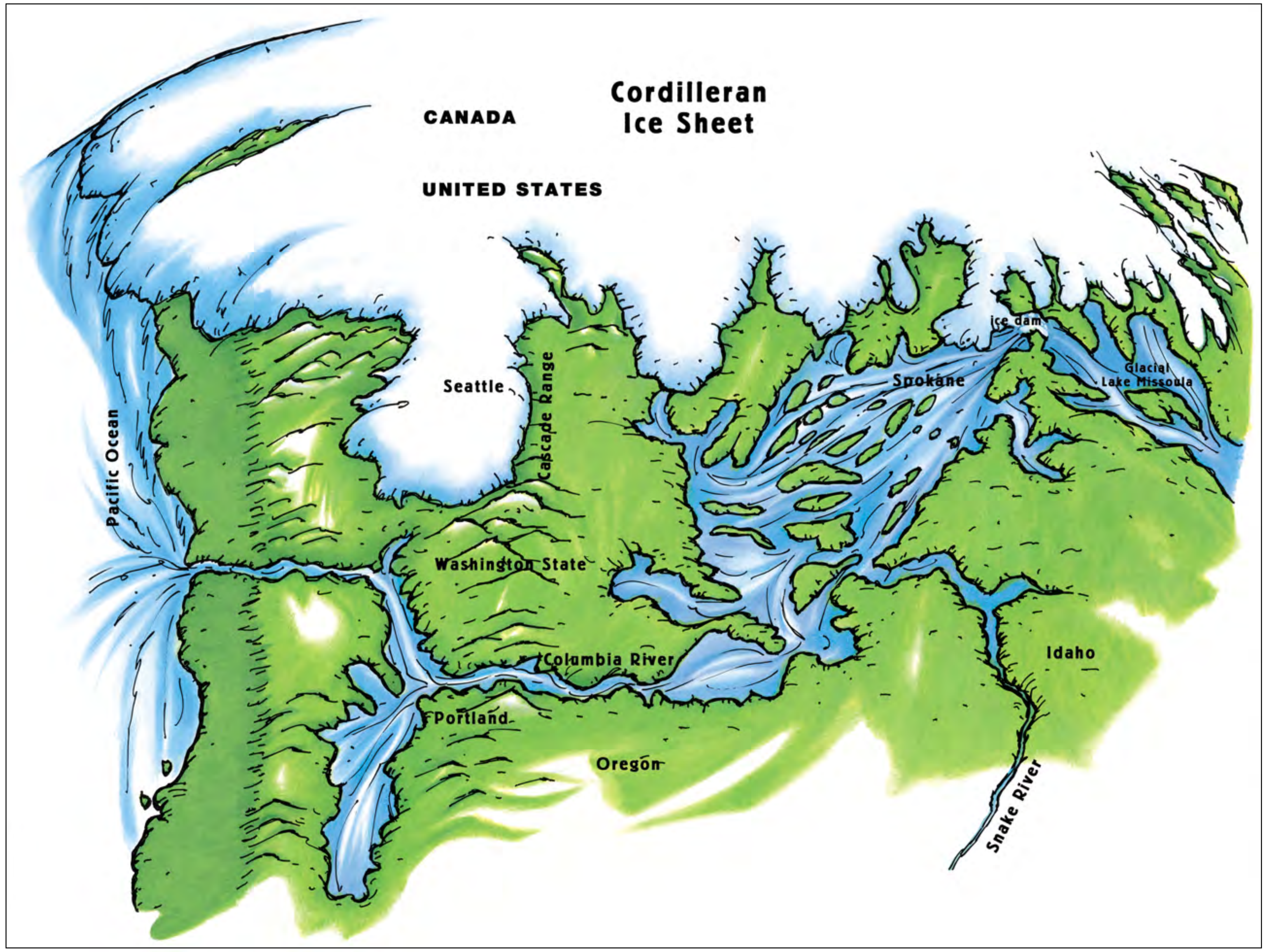
Cordilleran Ice Sheet

The Cordilleran Ice Sheet was that part of the southward-moving continental ice mass that covered much of the Rocky Mountains in Canada and eventually extended into the northern part of the United States. In western Washington State, it covered parts of the northern Cascade Range and the northern margins of the Olympic Mountains. A thick ice lobe (a separate tongue of the glacier mass) extended down the Puget lowland. In eastern Washington, ice lobes extended down the principal valleys and onto the margins of the Columbia Plateau. During the last Ice Age, the advancing glaciers stopped short of the Spokane–Coeur d'Alene area. Meltwater streams draining these lobes carried large quantities of sand, gravel, silt, and clay and deposited them in and along the lower valleys. The deeply entrenched Spokane Valley was partially filled with these glacial materials.

Glacial Lake Missoula

Eventually, the Purcell ice lobe moved into the valley of the north-flowing Clark Fork River near Sandpoint, Idaho and formed a massive ice dam across the valley. At the maximum glacial advance, the dam was nearly 2,150 feet high, about four times the height of Grand Coulee Dam. As a result, melt water from other ice lobes far up the Clark Fork River drainage became ponded behind the ice dam and eventually formed a vast lake, Glacial Lake Missoula, which occupied the intricate system of valleys in western Montana.

At its highest level, the lake covered an area of about 3,000 square miles and contained an estimated 500 cubic miles of water, one-half of the volume of present-day Lake Michigan. Traces of the ancient shorelines of Glacial Lake Missoula in western Montana indicate that, at its maximum elevation, the lake was about 950 feet deep at present-day Missoula and more than 1,100 feet deep at the south end of Flathead Lake. The lake's wave-cut shorelines are faint, however, suggesting that no one level of the lake was of long duration.



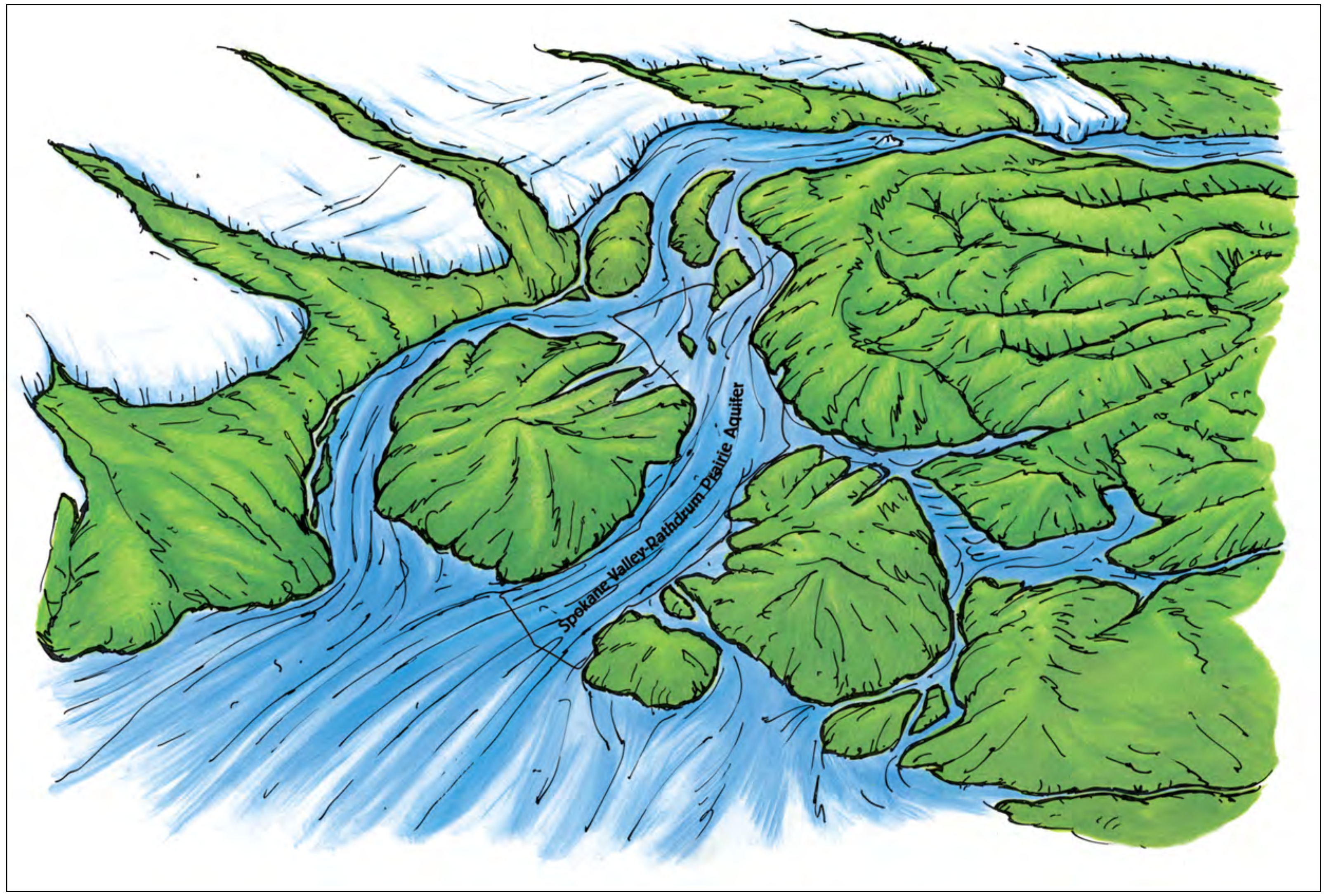
Each time the ice dam failed and Glacial Lake Missoula drained, an enormous flood swept through the Spokane-Coeur d'Alene area and flowed all the way to the Pacific Ocean.

Other Glacial Lakes

At the same time, other lakes were formed by the melt water from local mountain glaciers and snow fields elsewhere in the valleys and basins of the Northwest interior. The back cover depics the Pacific Northwest during the last Ice Age. The location and likely exent of Glacial Lake Missoula and Glacial Lake Columbia are shown on this map.

Breaching the Dam

Ultimately, as the water deepened behind the ice dam, the glacial lobe floated off its foundation, allowing the water in Glacial Lake Missoula to escape in an enormous "outburst" flood. The flood wave swept down the Rathdrum Prairie, through the Spokane Valley and eventually flowed across the Columbia plateau through a braided series of channels as shown on the image on this page. This flood initially eroded then deposited sediments in the Rathdrum Prairie and Spokane Valley. The flood also created the coulees and pothole topography called the "Channeled Scablands" in eastern Washington. In 1923 J. Harlen Bretz was the first scientist to recognize the flood origin of the Channeled Scablands. Geologic evidence suggests that these outburst floods occurred as the ice dam was reformed and failed as many as 40 times during the last Ice Age.



As Glacial Lake Missoula drained, an enormous flood swept through the Spokane-Coeur d'Alene area covering lower elevations with flood waters.

The Spokane Floods

The resulting rapid draining of 500-cubic-mile Glacial Lake Missoula, probably in only a few days, resulted in a maximum discharge across the Columbia Plateau calculated in 1973 to be 750 million cubic feet per second, 20 times the combined flow of all the rivers of the world today. The floodwaters of the lake rapidly shot south-westward down the length of the present sites of Pend Oreille and Coeur d'Alene Lakes and the Rathdrum Prairie - Spokane Valley area and out across the Columbia Plateau beyond. Attaining speeds estimated to be as great as 45 miles per hour, the water swept across the Columbia Plateau, through the Pasco and Umatilla Basins, down the Columbia River Gorge, and eventually into the Pacific Ocean beyond the Coast Range.

Flood Aftermath

The most prominent testimony to the cutting power of the floodwaters is observed clearly today in the numerous coulees carved into the basalt surface of the Columbia Plateau; this forms an area of unique topographic relief known as the Channeled Scablands. Other features that indicate the magnitude of the flood event and the amount of rock debris carried and dumped along the flood's pathway include giant current ripples and gravel bars, some more than 50 feet high and 500 feet between crests. These are found today along much of the flood's course, from the valleys of western Montana to the lowlands along the Columbia River beyond the Cascade Range. Along its journey to the ocean, at various reaches where the river valley narrows, the floodwater was impounded temporarily by restrictions and formed several large temporary lakes.

Rathdrum Prairie–Spokane Valley

In passing through the Rathdrum Prairie-Spokane Valley area, the floodwaters carried large volumes of rock debris in the masses of ice broken from the glacier's terminus, which included large boulders that came from the mountains farther north. The flood carried great quantities of sediment of all sizes, from clay particles to large cobbles and boulders, picked up from the flood channels. The heavier, large materials, such as boulders, cobbles, and coarse gravel, were deposited first. These coarse materials were deposited along the main valley in the line of greatest flow and velocity; much of these materials were deposited on top of the previously deposited normal glacial outwash silts, sands, and gravels. Some of the smaller particles in these earlier outwash materials were separated from and carried in suspension, then eventually either deposited in side eddy valleys, such as the Hillyard Trough, or carried out onto the Columbia Plateau and beyond. Thus were deposited the coarse materials that today underlie the Rathdrum Prairie-Spokane Valley lowland. Some isolated localities contain boulders as much as 8 or 10 feet across.

Glacial Retreat

The subsidence of the floodwaters following the final emptying of Glacial Lake Missoula was followed by a gradual northward retreat of the Cordilleran Ice Sheet, and, eventually, during recent time, the region acquired its present aspect and drainage system. After the disappearance of the ice from the Pend Oreille Valley, the Clark Fork River drained through Pend Oreille Lake and then west and north to the Columbia River. To the east, the Coeur d'Alene, St. Joe, and St. Maries Rivers drained to Coeur d'Alene Lake, the source of the Spokane River. The broad, flat, gravel-filled flood pathway between Pend Oreille Lake and the Spokane Valley became virtually devoid of a surface drainage system, with streams from side valleys flowing only short distances before sinking into the coarse materials. The Spokane River resumed its course westward to Spokane; then, instead of flowing north through the Hillyard Trough, which now had a higher surface created by flood deposits, the river followed a new, lower course along the margin of the Columbia Plateau lava to its confluence with the Columbia River.

Area Lakes

A few small lakes were created in the lower parts of tributary mountain valleys. These lakes are held in their basins by the finer-grained deposits laid down along the edges of the valley where flood velocities were low. They include Spirit, Twin, Hauser, and Newman Lakes on the lower east and south flanks of the Spokane Mountain area, Hayden Lake at the base of the Coeur d'Alene Mountains, and Liberty Lake below Mica Peak. Discharges from the lakes percolated rapidly into the main valley gravels, and only a few short stream channels were formed.

Present Conditions

As the climate became warmer, vegetation began developing over the area; eventually coniferous forests covered parts of the adjacent uplands and mountains, and cottonwoods and other deciduous trees, along with small groups of conifers, lined the river channel. The valley floor and nearby slopes became covered by grasses and other small plants. This was the Spokane Valley–Rathdrum Prairie area as inhabited by Indians when first visited by the early white explorers, fur trappers, and traders.

Spokane Flood Facts

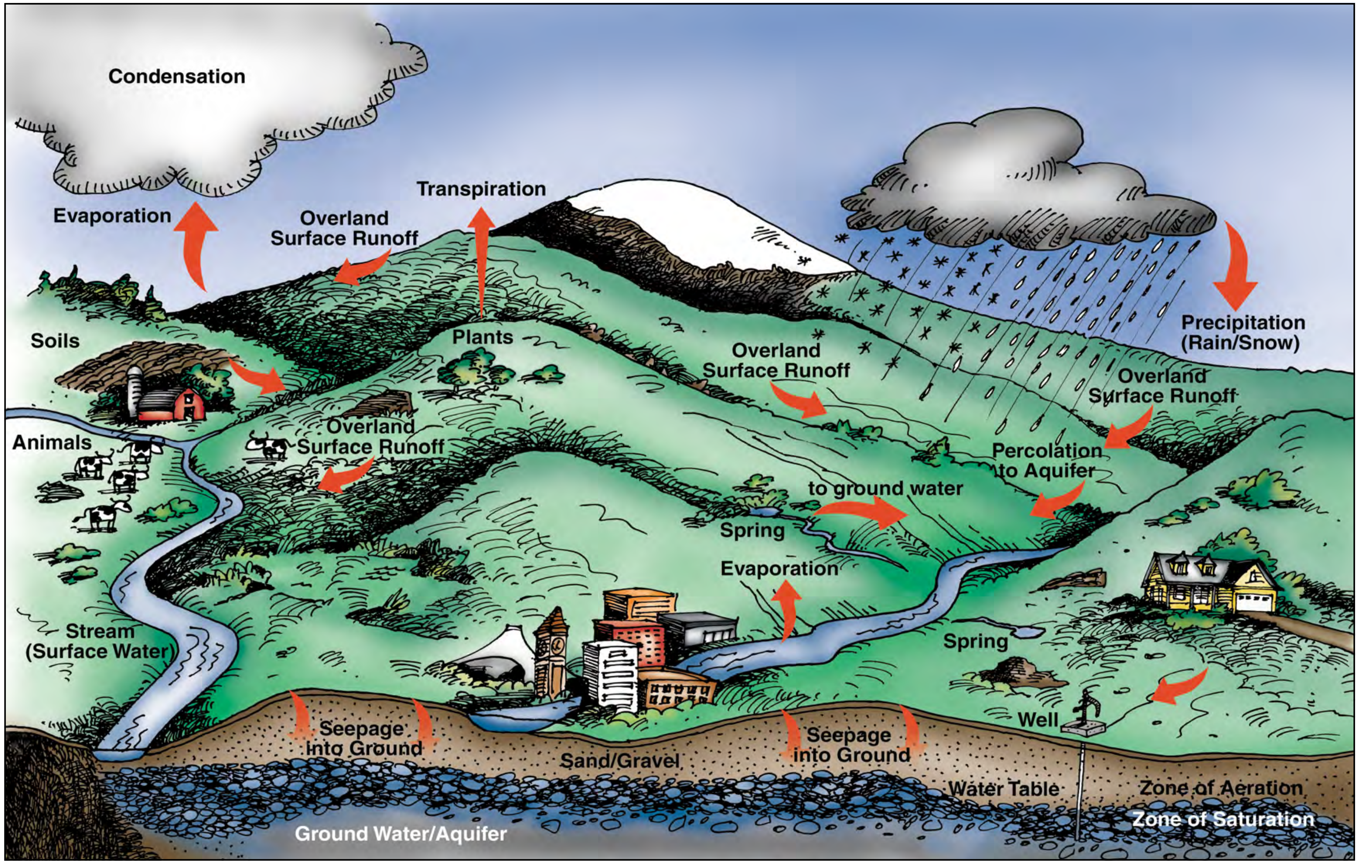
Most of Lake Missoula, about 500 cubic miles, drained in a few days.

The maximum flood discharge was estimated as 750 million cubic feet per second, twenty times the combined flow of all the rivers in the world today.

The floods may have occurred as many as 40 times.

The flood velocity over the Columbia Plateau is estimated at 45 miles per hour.

The flood carried boulders as large as 8 to 10 feet across to the Spokane Valley – Rathdrum Prairie region.



Water on the Earth

In one form or another water occurs practically everywhere on the Earth. It occurs in the atmosphere as water vapor, clouds and precipitation. On the earth's surface it is found in streams, ponds, lakes and oceans. As a solid, water exists as glaciers and as polar ice caps. It is also found underneath the ground surface in aquifers.

Hydrologic Cycle

The hydrologic cycle, sometimes called the water cycle, is the continual movement of water around the earth. In this cycle, water is continually evaporating from the land and sea. The evaporated water vapor condenses to form clouds. These clouds drop their moisture as rain back into the oceans or on the lands surface as precipitation (rain, sleet, snow). Water that falls on the land then flows by gravity into streams, lakes or rivers and eventually back to the ocean where the cycle starts all over. Some of the water that falls on the Earth's surface seeps or percolates into the ground through porous soils, streambeds, the forest floor or your yard to become groundwater. Groundwater is found in a permeable rock layer called an aquifer.

Hydrologic Cycle in our Region

The hydrologic cycle for our region that includes the Aquifer is illustrated in the figure on page 11. Several characteristics of our local water cycle are slightly different than a typical one. Almost no water from the surrounding area flows to the Spokane River by surface streams. Some of the water from the surrounding watersheds does enter the Spokane River eventually, not on the surface but as subsurface flow out of the Aquifer.

Aquifer Discharge and Recharge

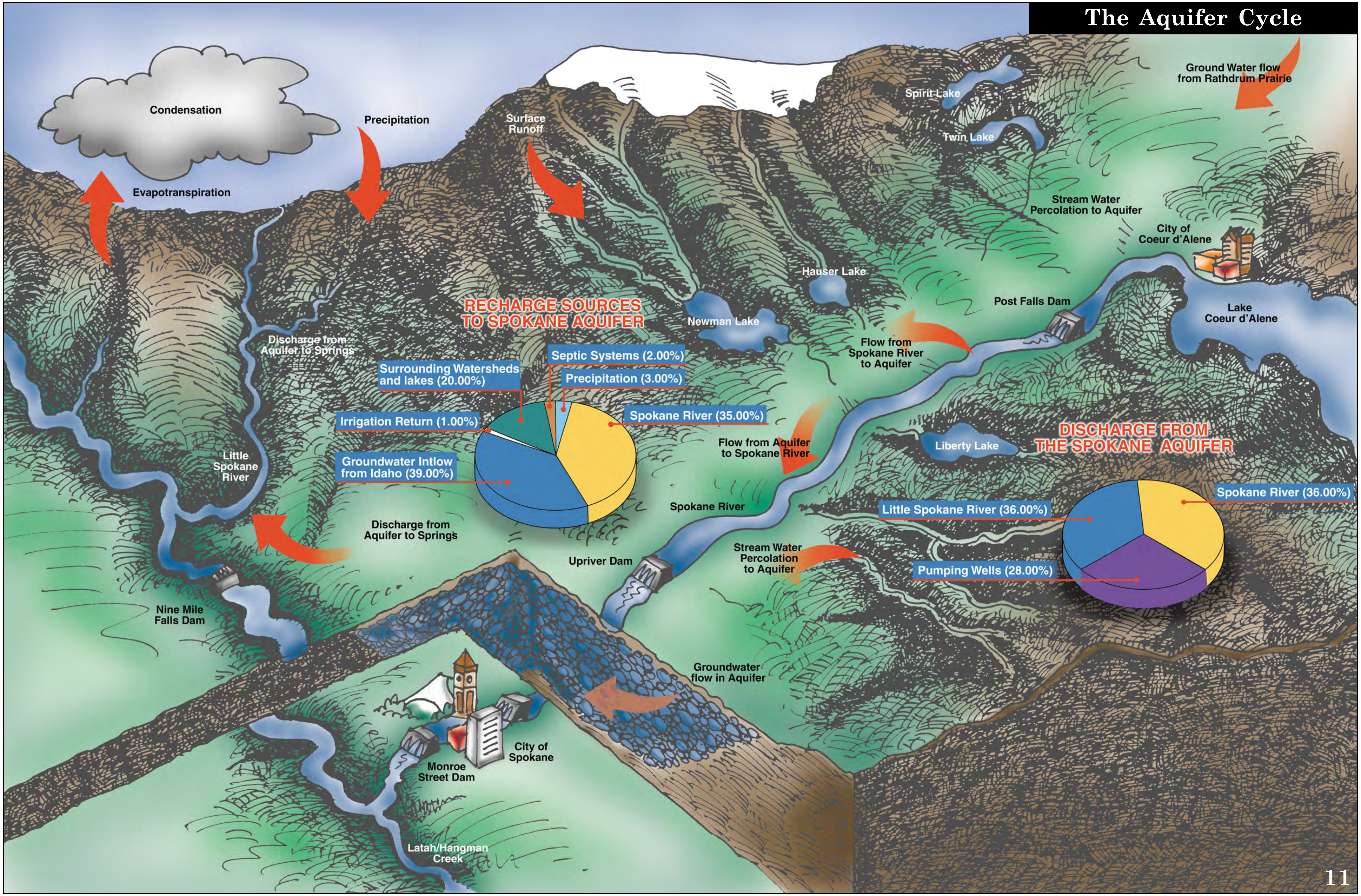
As the Spokane River flows out of Coeur d' Alene Lake there are portions (reaches) of the river that lose water to the Aquifer as water percolates out of the river bottom. The reach from the beginning of the river at Coeur d' Alene Lake loses water to the Aquifer until about Flora road in the Spokane Valley. From Flora road to about Greene street the Aquifer discharges water into the river. During the summer months when the flow out of Coeur d'Alene Lake is low, most of the water in the river below the Flora road through the City of Spokane is water discharged from the Aquifer.

Aquifer Water Path

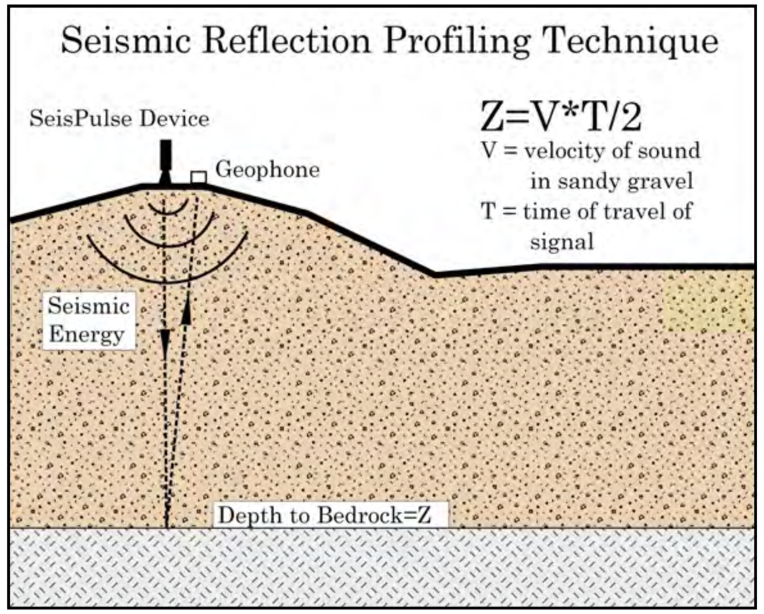
The Aquifer originates in the northern portion of the Rathdrum Prairie. The water flows south, until it reaches the Coeur d' Alene area when it then turns westerly to the Spokane Valley. Flow in the Aquifer is increasing along this portion of its journey, as water from the surrounding watersheds percolates into the ground. At the Idaho/Washington state line, the Aquifer flow has been estimated at 390 cubic feet per second. With the exception of water that discharges from the Aquifer into the river, most of the groundwater continues flowing west towards the City of Spokane. The water then turns to the north and flows under the city until it comes out of the ground (discharges) in the area along the Little Spokane River. During this journey from the state line to the discharge along the Little Spokane River, the Aquifer gains about 350 cubic feet per second of water from local watersheds. But, pumping for water supplies removes about that same amount from the Aquifer!

The Future

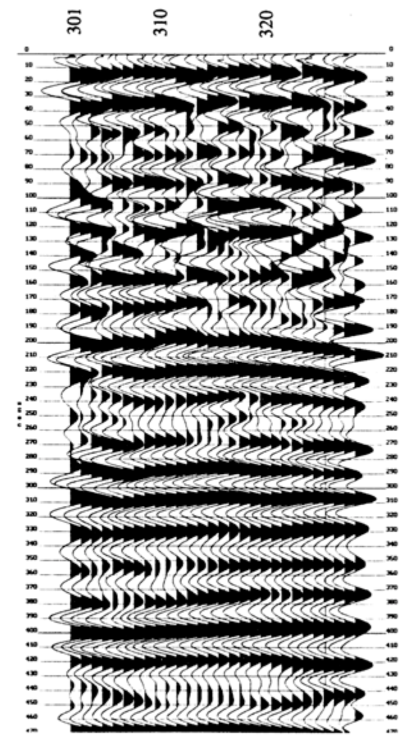
Using the groundwater as a water supply affects not only the amount of water in the Aquifer, but also the flow in the Spokane River. When flow in the river is lowered, fish and wildlife habitat can be affected. Human water use is also part of the water cycle, and all parts of the water cycle are connected. The future quality of life in this region depends on our awareness of the water cycle and on the knowledge that what happens in one part of the cycle may affect another part of the cycle.


Condensation
Precipitation
Evapotranspiration
Surface Runoff
Spirit Lake
Twin Lake
Ground Water flow from Rathdrum Prairie
Stream Water Percolation to Aquifer
City of Coeur d'Alene
Hauser Lake
Post Falls Dam
Lake Coeur d'Alene
Newman Lake
Flow from Spokane River to Aquifer
RECHARGE SOURCES TO SPOKANE AQUIFER
Discharge from Aquifer to Springs
Surrounding Watersheds and lakes (20.00%)
Septic Systems (2.00%)
Precipitation (3.00%)
Irrigation Return (1.00%)
Spokane River (35.00%)
Groundwater Intlow from Idaho (39.00%)
Little Spokane River
Flow from Aquifer to Spokane River
Liberty Lake
DISCHARGE FROM THE SPOKANE AQUIFER
Spokane River (36.00%)
Little Spokane River (36.00%)
Pumping Wells (28.00%)
Spokane River
Discharge from Aquifer to Springs
Upriver Dam
Stream Water Percolation to Aquifer
Nine Mile Falls Dam
Groundwater flow in Aquifer
City of Spokane
Monroe Street Dam
Latah/Hangman Creek

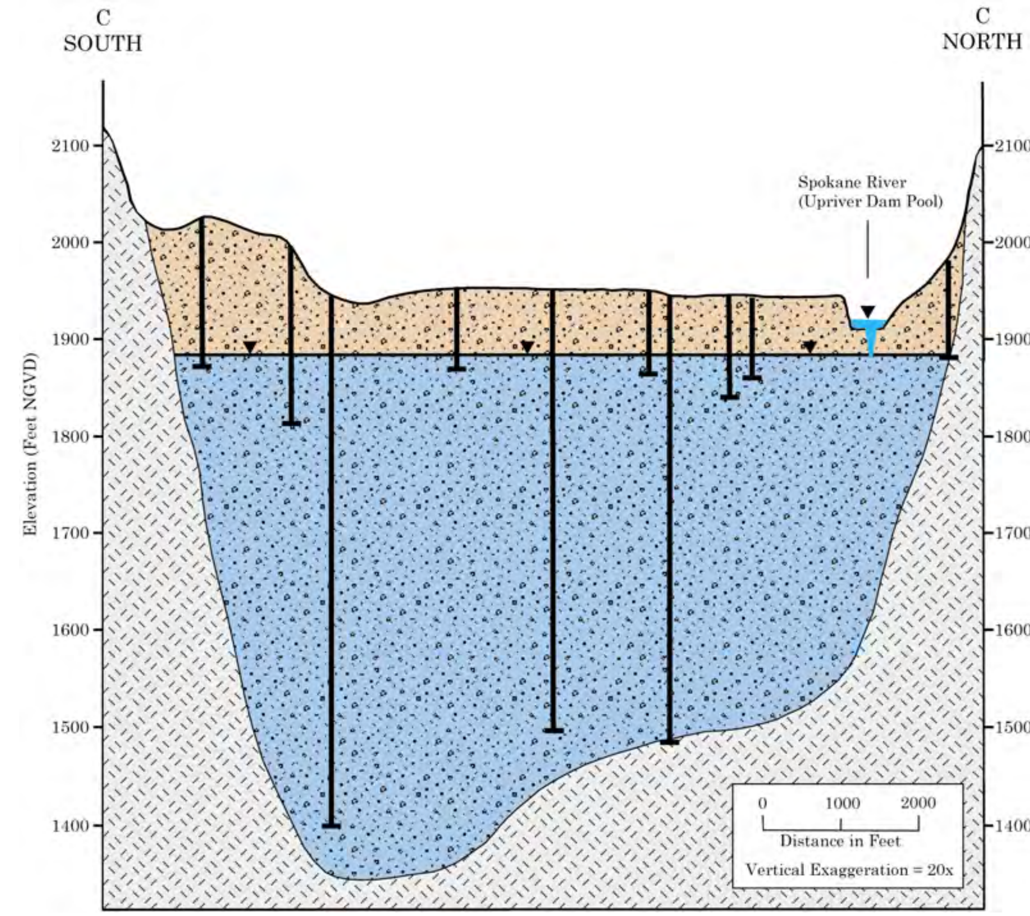
Exploring the Aquifer



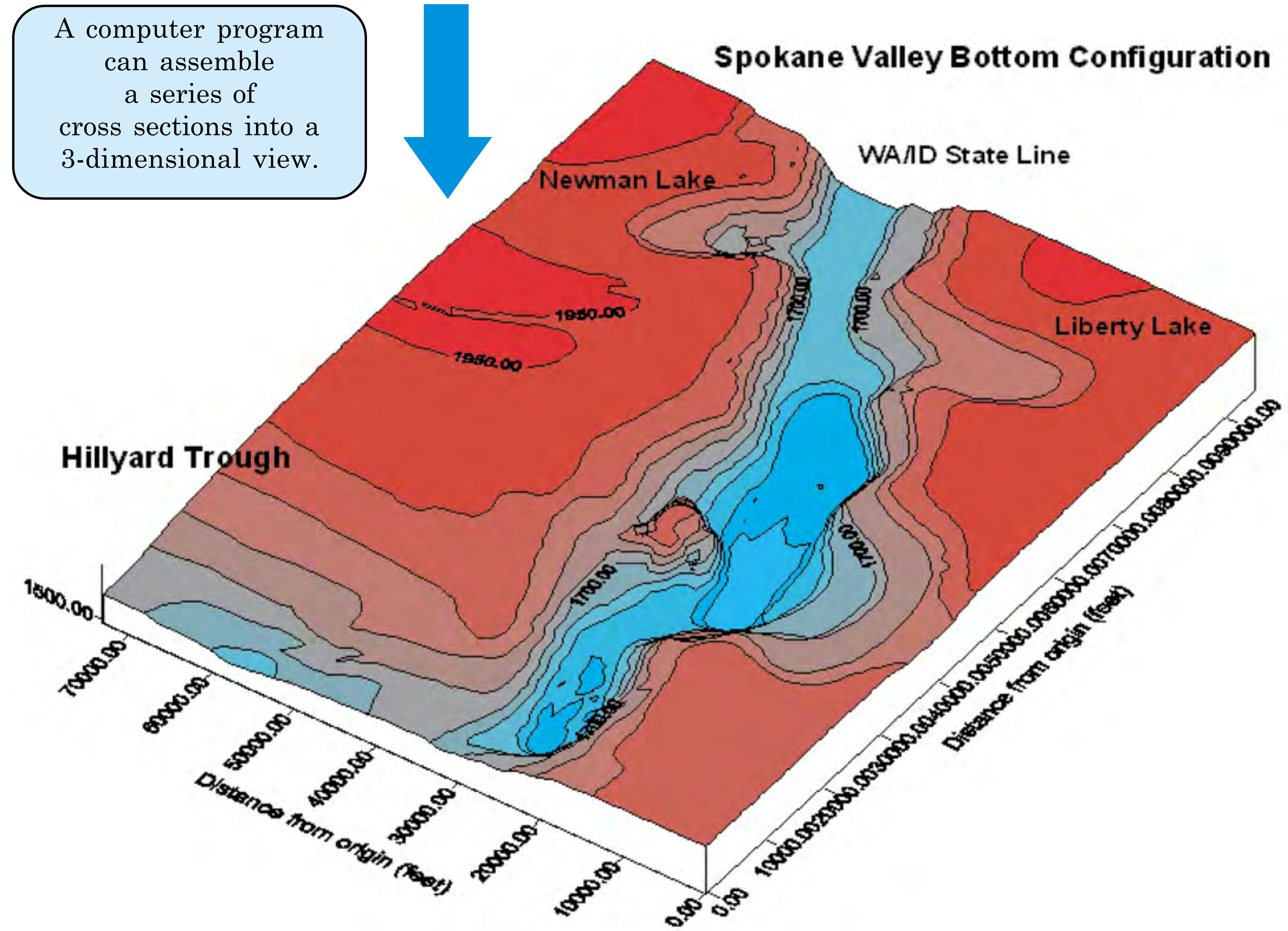
Data from seismic reflection is recorded on a strip chart.



Information from the strip chart and water wells will generate a cross-section.



A computer program can assemble a series of cross sections into a 3-dimensional view.



Underground Water

Unlike a river where you can easily see the water flowing down the channel, it is difficult - if not impossible - to actually see the water moving beneath the ground in an aquifer. Therefore, geologists use a variety of tools to visualize the shape and extent of an aquifer, to map the groundwater table surface, and to better understand the flow of groundwater within this subterranean reservoir. These tools include something as simple as drilling a well into the ground to the high tech use of seismic energy.

Water Wells

Drilling a water well provides information at a single point in the aquifer, such as depth to the water table and maybe the thickness of the aquifer. It is also useful to periodically take water level measurements to see how the water table moves up and down with the seasonal changes in recharge and discharge of the aquifer. Water wells also provide a point where water samples can be taken for purposes of monitoring water quality through time. Wells are very expensive to drill and provide information at only one point in the aquifer - they can't provide much information about the other parts of an aquifer system.

SeisPulse™

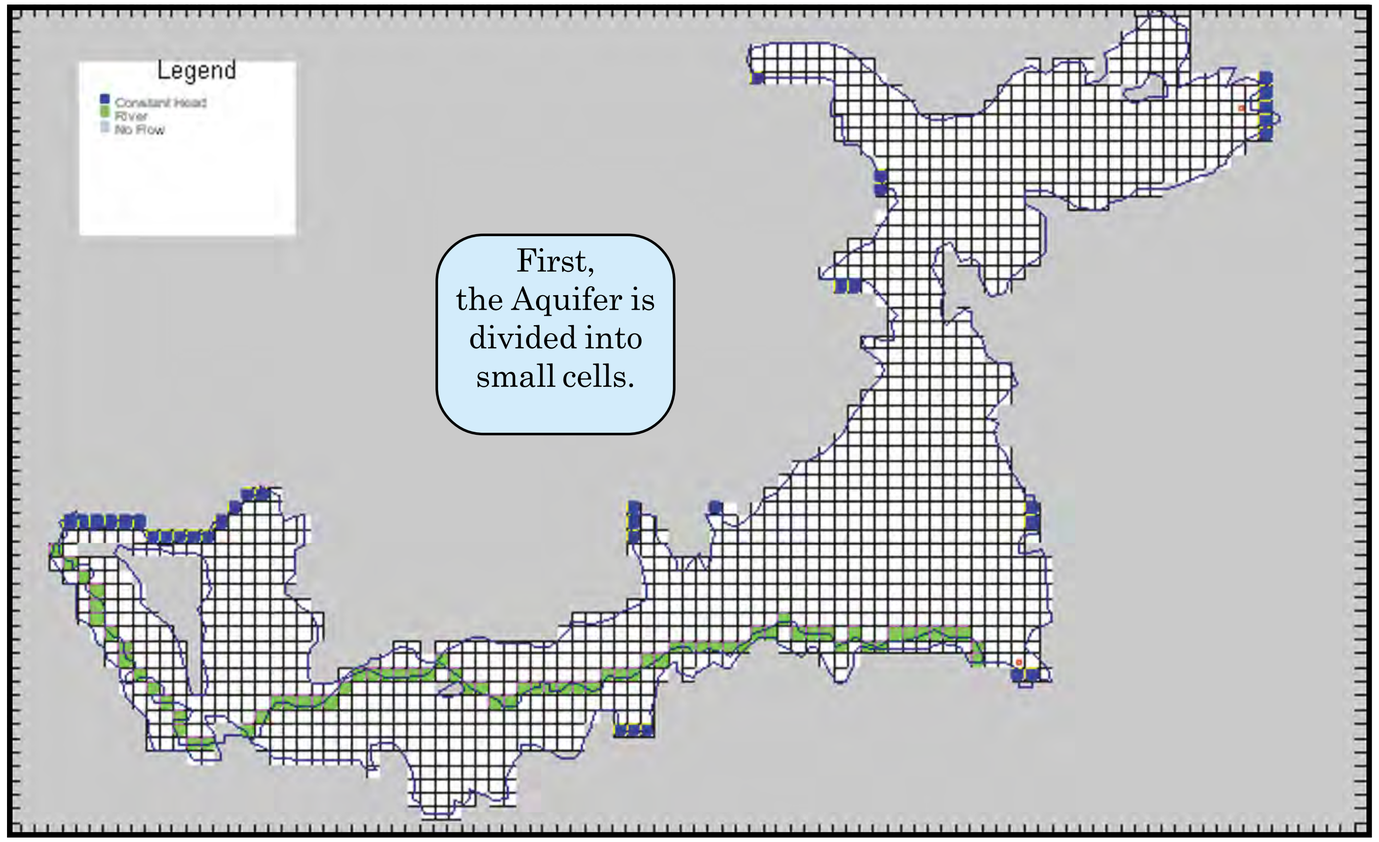
To visualize the shape of the aquifer across a larger area a SeisPulse™ device was used to map out the bottom of the aquifer so that scientists could better determine the volume of water underground. This device uses seismic energy - actually sound waves created by small, contained explosions directed downward at the Earth - much like ultra-sound technology is used to look inside the human body. A geophone set nearby listens for the reflected return vibrations from deep underground. By knowing the velocity of sound in sand and gravel one can estimate the thickness of the aquifer by carefully measuring the time the sound energy takes to travel down and back.

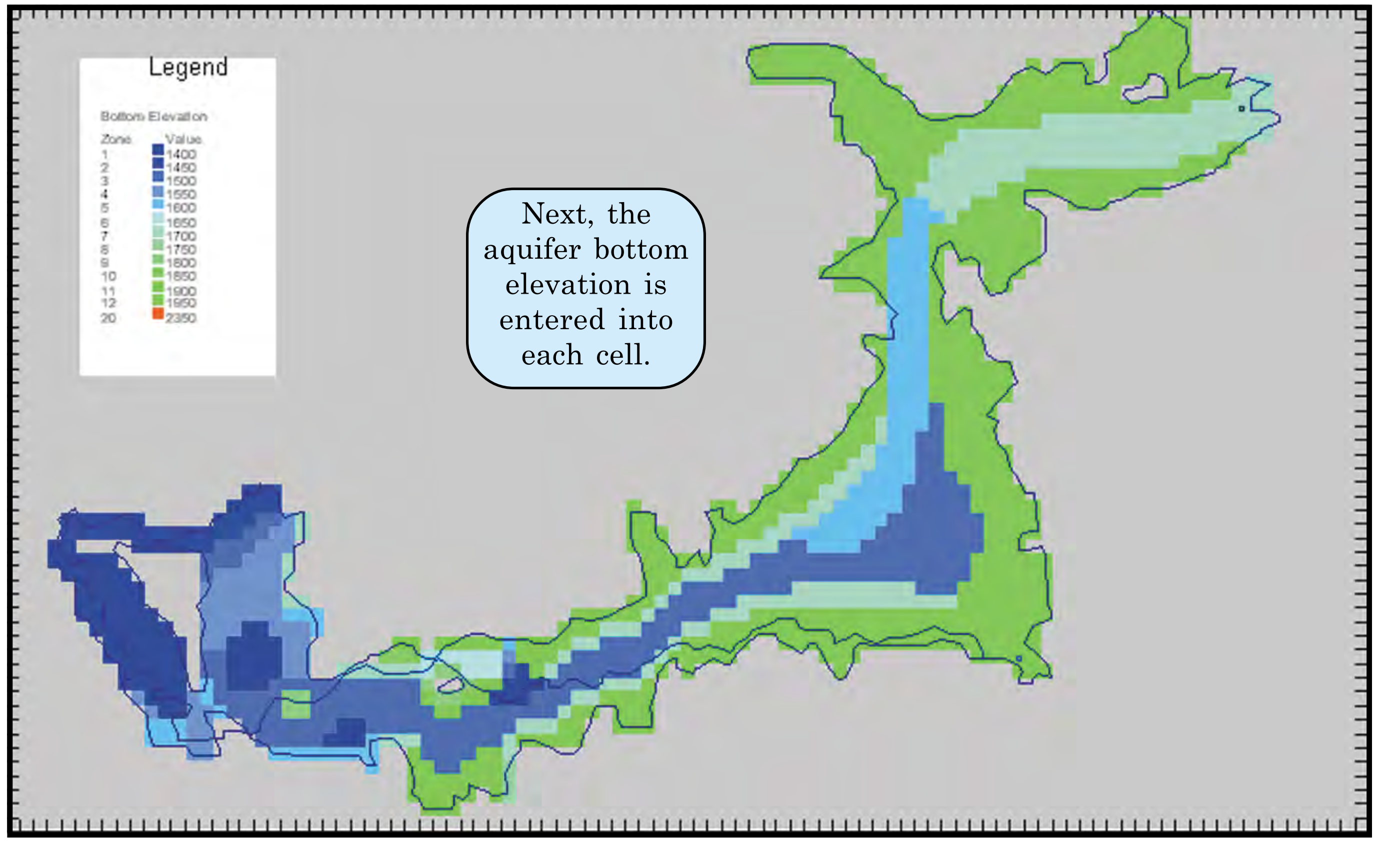
Cross Sections

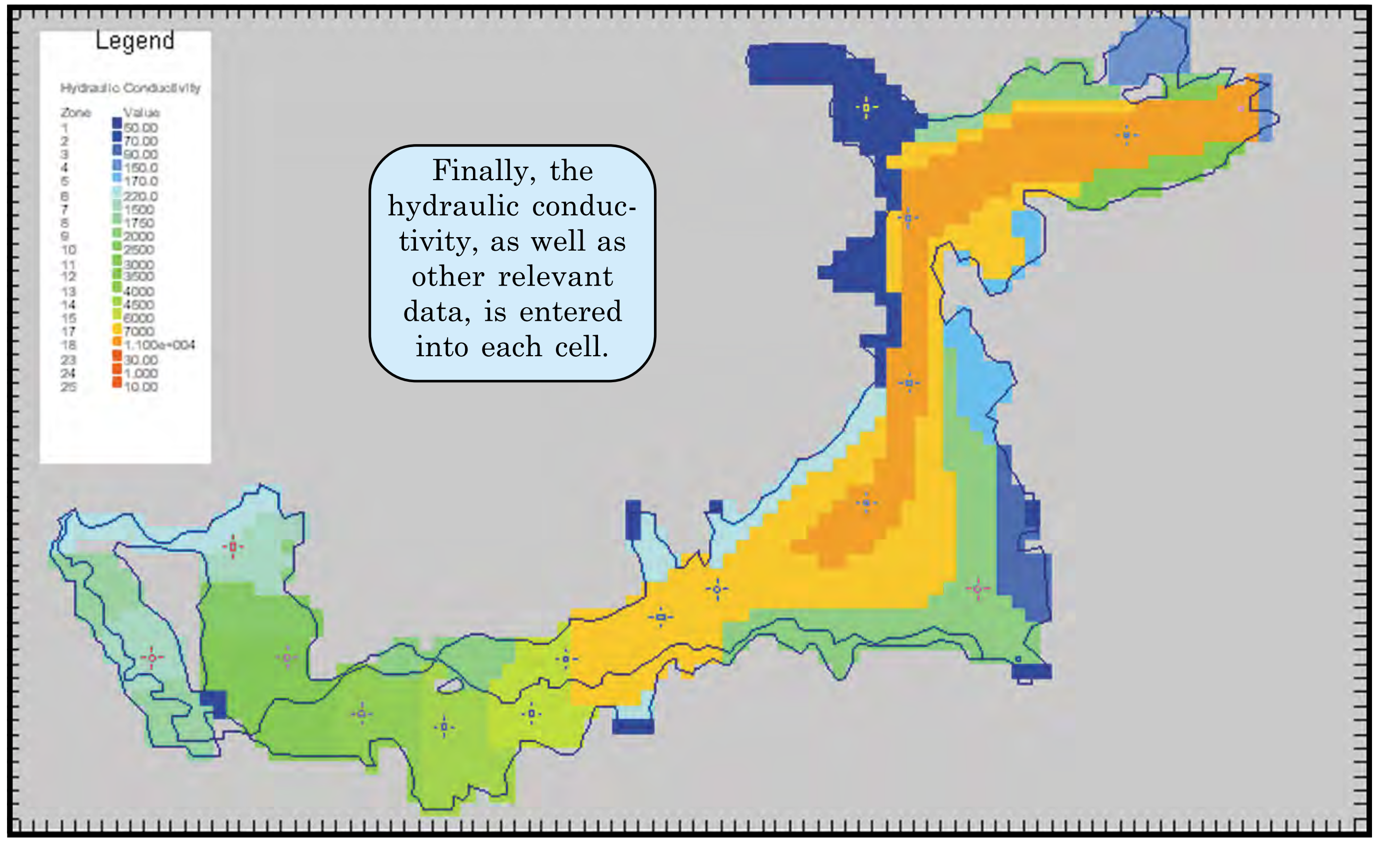
In contrast to the fixed position of a water well, the seismic device can be moved across the surface of the ground, along a roadway for example, and repeatedly "shot" in a series of closely spaced locations. This creates a cross-section of the bottom of the aquifer such as the one shown on this page. The vertical lines on the diagram represent the position of water wells in the line of section.

Three Dimensional View

Once a number of cross-sections are assembled, it is possible to visualize the shape of the aquifer in three dimensions. First a number of cross-sections must be placed in their proper relationship to one another, and then a computer is used to extrapolate, or "fill in," the areas between them. The final result is a picture of the aquifer that resembles a deep trough or valley cut into the underlying bedrock. This of course is hidden from view as it is filled with up to 600 feet of rocks, sand and gravel, the sediments that comprise the aquifer framework and through which the groundwater moves.







Computer Models

Since we can't directly see or measure the direction and rate of groundwater flow underground, hydrogeologists (scientists who study groundwater) use computer models to simulate this process. A computer model is a mathematical representation of the physical aspects of the aquifer, such as its thickness, porosity, hydraulic conductivity (permeability), and other parameters. It is necessary to have good field data on a wide variety of aquifer properties in order to develop a good working model of an aquifer system.

Model Data

In order to construct a computer model, the aquifer region is first divided into small cells or elements and the aquifer boundaries established, that is, the physical edge of the aquifer as well as where water enters and leaves the system. Each cell in the model requires data on the aquifer properties at that location. You can see that a great deal of information is required to build an aquifer model!

An Example

As an example, the first panel shows the Spokane Valley-Rathdrum Prairie Aquifer as represented in a computer model where the grid is superimposed on a map of the aquifer. Additional boundary conditions representing the Spokane River and surrounding lakes are also shown. Additional figures show the model grid with values for the bottom elevation and the hydraulic conductivity for each cell.

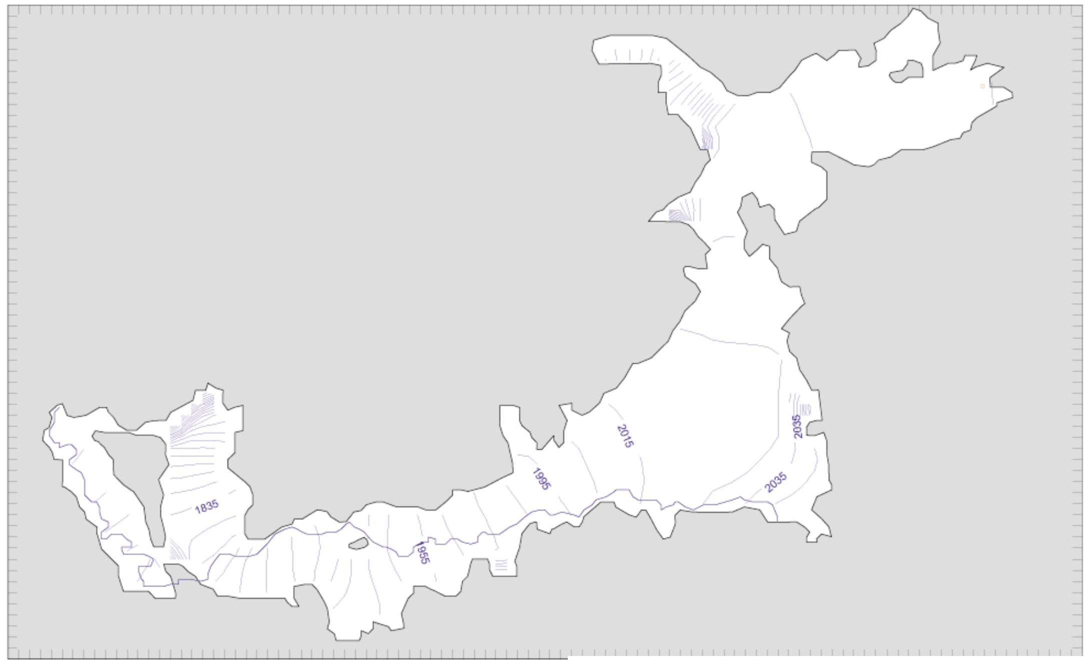
Solving the Model

Once the physical properties are defined for each cell, then the computer solves a set of equations for the flow of groundwater from one cell to another. Imagine an ice-cube tray with its various compartments - begin filling one end and the water cascades from one compartment to another. This is the way computer models operate during the solution process.

Viewing the Model

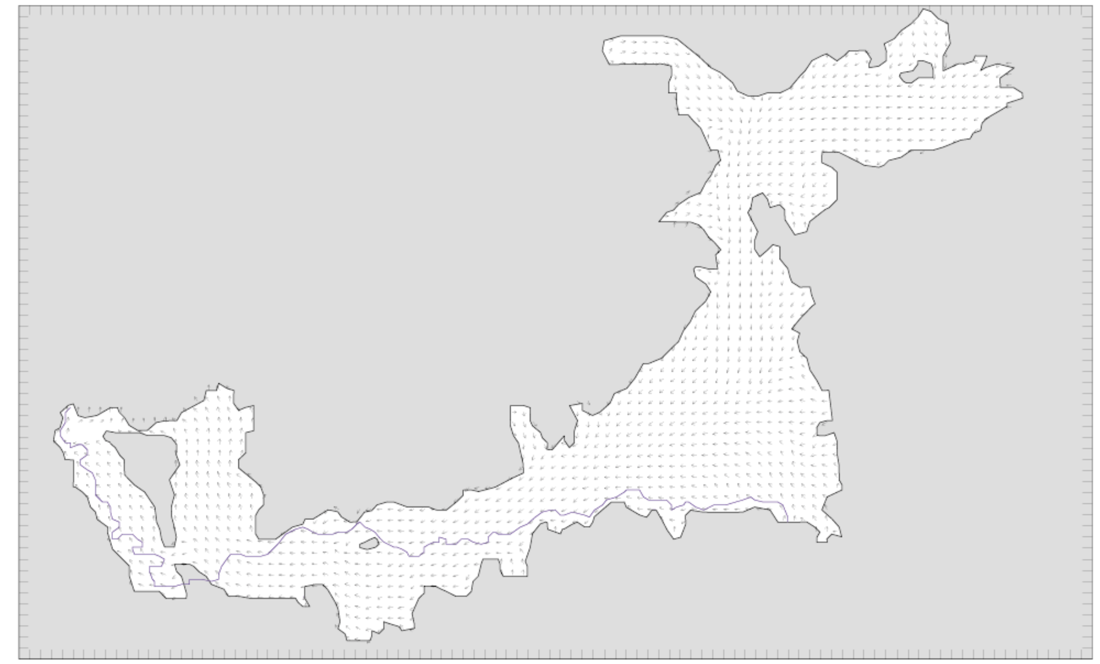
The computer models generate ground water contours.

Groundwater Surface Elevations (feet above mean sea level)

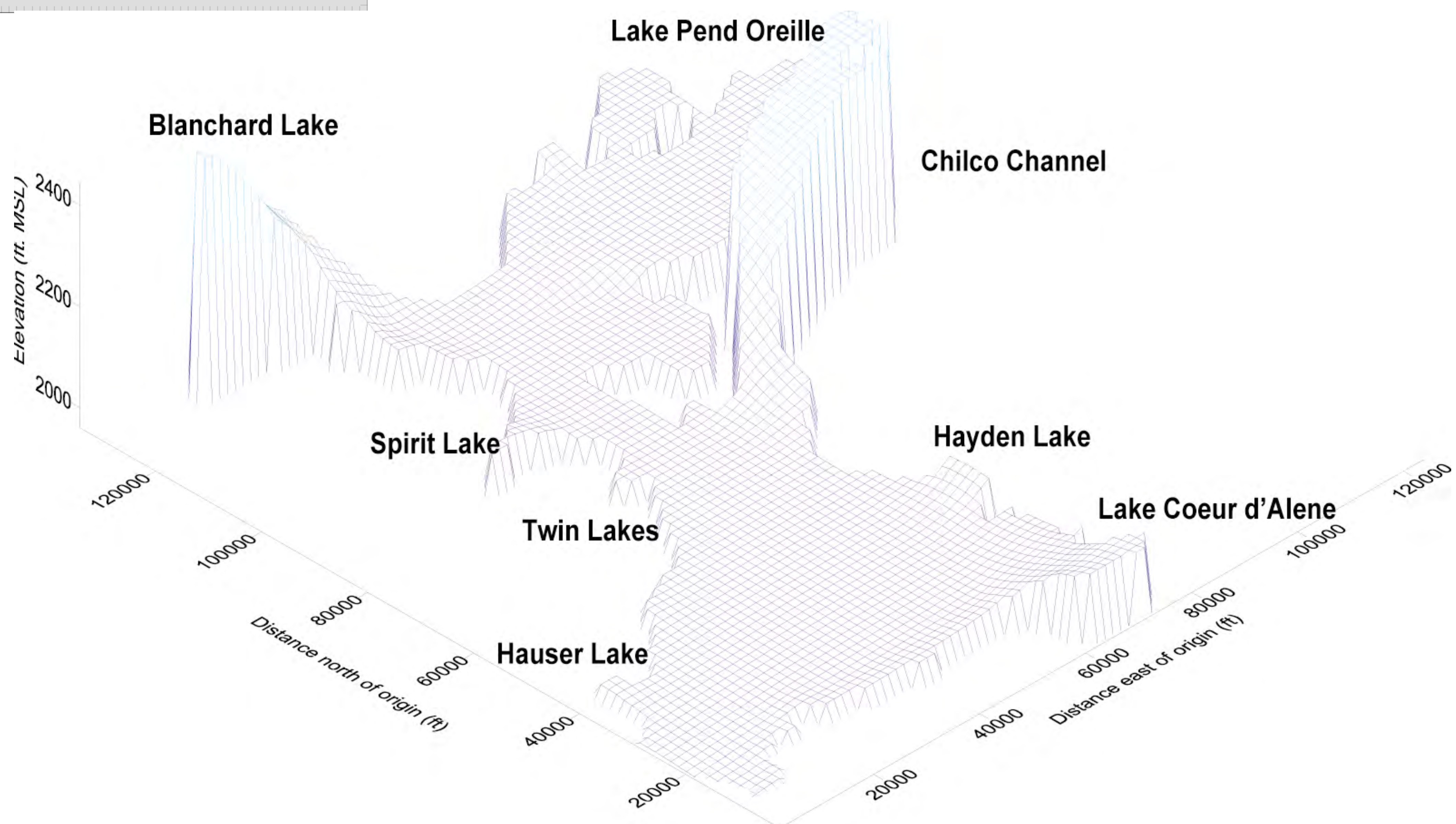


Ground-water flow direction can be computed from the contours.

Groundwater Flow Directions



Groundwater contours from the model can be represented as a 3-dimensional model.



Model Output

The output generated by a computer model is usually the elevation of the groundwater table in each cell, which can also be graphically represented as a map, and contoured like a topographic map that represents the shape of the land surface.

Aquifer Simulation

The output for a computer simulation of the Spokane Valley-Rathdrum Prairie Aquifer in the form of a map showing the elevation of the predicted groundwater table is shown in the first panel. Because groundwater moves in a direction perpendicular to the water table contours, it is possible to represent the flow direction in each cell as a vector (an arrow) as shown in the second panel.

3-D Representation

An alternative view of the output results of the computer model is a three-dimensional representation of the water table surface. This is particularly striking since it clearly shows the change in elevation of the aquifer surface and the direction of groundwater flow.

Aquifer Models

Once an aquifer model has been created, what is it used for? Computer models are essential tools used by groundwater scientists because of the difficulty in directly observing the aquifer system and seeing the movement of groundwater. So models serve an academic purpose in providing a better understanding and in visualizing the groundwater system. But, several computer simulations have also been created for the Aquifer to answer various practical questions.

Model Predictions

First, the model can be used to predict the rate and direction of groundwater flow and to calculate a water budget for the Aquifer; that is, determining the amount of recharge and discharge, much like balancing a checking account. This is important information to know since we depend on the Aquifer as our sole source of water and we can't use more water than exists in the aquifer. The models for the Aquifer clearly show that as more water is pumped out of the Aquifer for human use there is proportionately less groundwater left to flow to the springs and rivers.

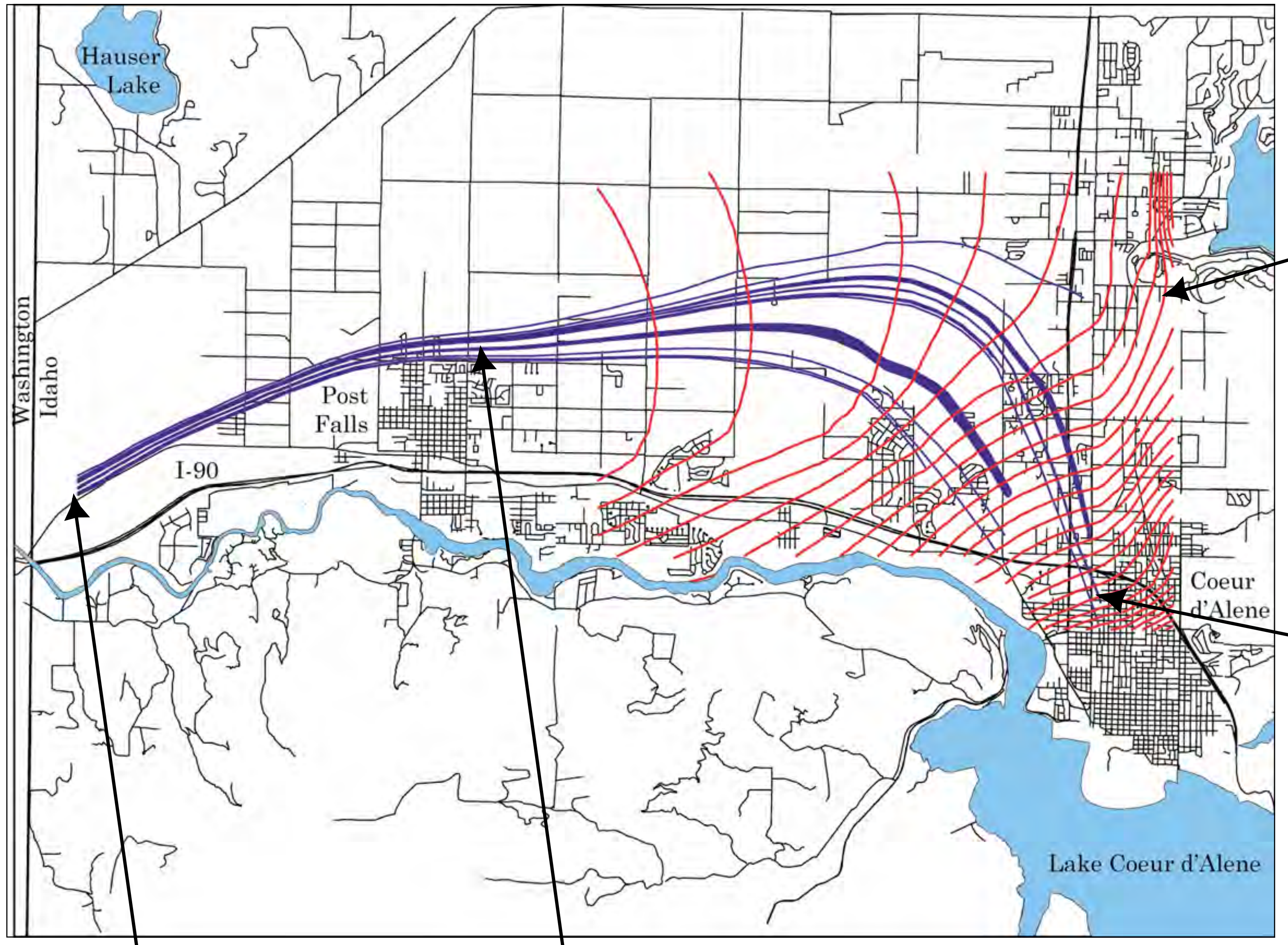
Contamination Predictions

Perhaps more importantly, models can be used to predict movement of contamination in the Aquifer, and alert communities about which wells might be affected. For example, it would be useful to know which wells lay down-gradient (downstream) from an old landfill or from a location where a hazardous substance was spilled. Such was the case in Coeur d'Alene in the early 1990s where a business improperly disposed of a dangerous chemical, trichloroethylene (TCE.) A model constructed for purposes of tracking the contamination plume emanating from this site showed that it traveled to a public well in the northern part of the city. Indeed, TCE was detected in the well and it was taken off-line for a period of time until the problem was addressed.

Capture Zone Delineation

In anticipation of similar contamination events, computer models are used to delineate capture zones around important supply wells, such as a large city well providing water to thousands of citizens. A capture zone is the area of the aquifer up-gradient (upstream) from the well that provides water to the well during a defined period of time. A computer model has delineated capture zones for all of the wells for the city of Spokane. The capture zones described by the computer model extend to the east, up-gradient, toward Idaho. This information could be useful to city planners in defining where appropriate land use activities should be located over the Aquifer. Clearly activities that include handling of hazardous and dangerous substances should not be located in the capture zone for a large well.

Computer Model Simulation of Potential Contaminant Flow Paths in the Idaho part of the Spokane Valley-Rathdrum Prairie Aquifer



The red lines are groundwater contour lines that show the shape of the groundwater table. The groundwater flows from right to left, from high elevation to low elevation.

The beginning of the blue trace lines indicate where the computer model was told the potential contamination enters the groundwater. The blue lines show the potential pathway a contaminant may take through the Aquifer.

The model ends near the state line, but an actual contaminant might continue to travel into Washington depending on its physical and chemical properties.

Water withdrawn from the Aquifer along the blue trace lines may contain a measurable amount of contamination. New wells should be drilled away from this area.

Computer Models Can . . .

. . . predict the rate and direction of ground water flow in the Aquifer.

. . . calculate a water budget (recharge and discharge) for the Aquifer.

. . . predict where contamination may travel in the Aquifer.

. . . define capture zones around important pumping wells.

. . . be a guide to future research needed for the Aquifer.

Depth to Groundwater

Groundwater Map

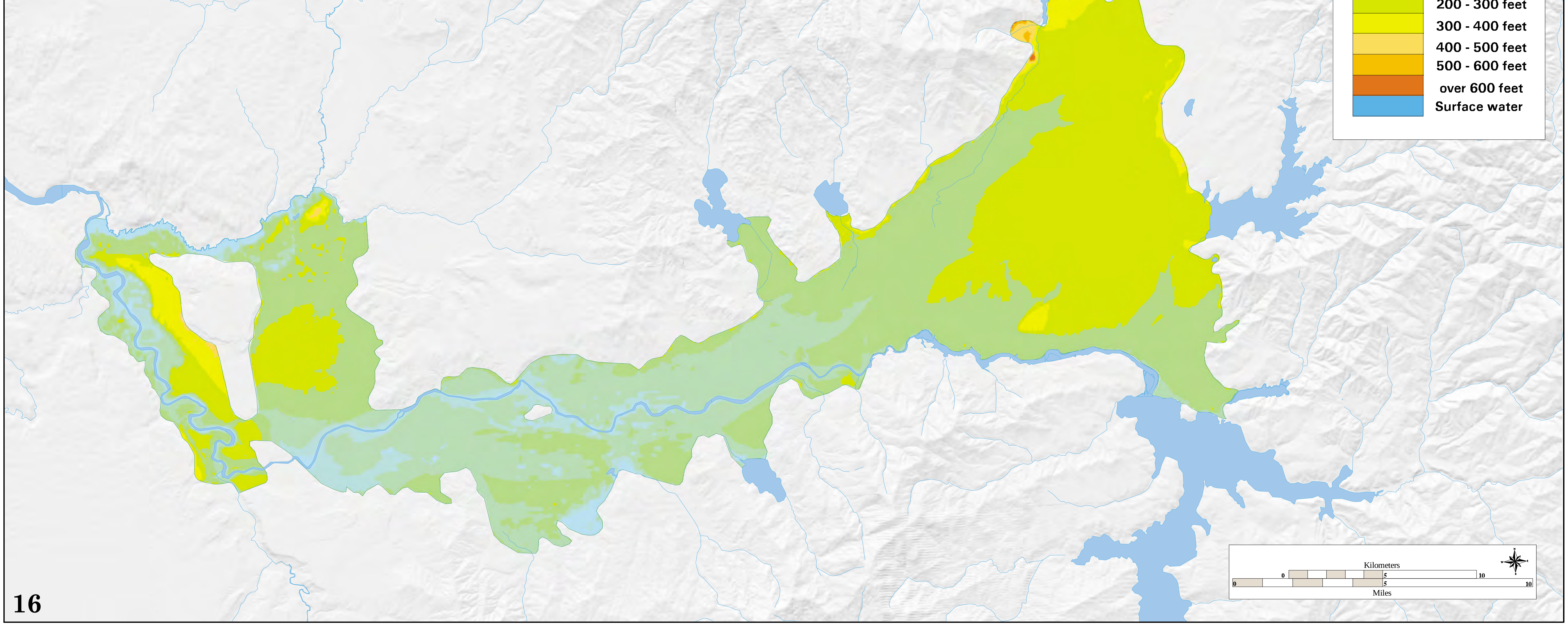
This map shows the depth to groundwater beneath the land surface in the Aquifer. This map can tell you, for example, approximately how deep you would need to drill a well at a given location in order to intercept the groundwater table in the Aquifer. The depth to groundwater in the Aquifer is both dependent upon the elevation of the land surface (described on the Geography Map on page 3) and the elevation of the groundwater table (described on the Aquifer Modeling on page 14).

Groundwater Table

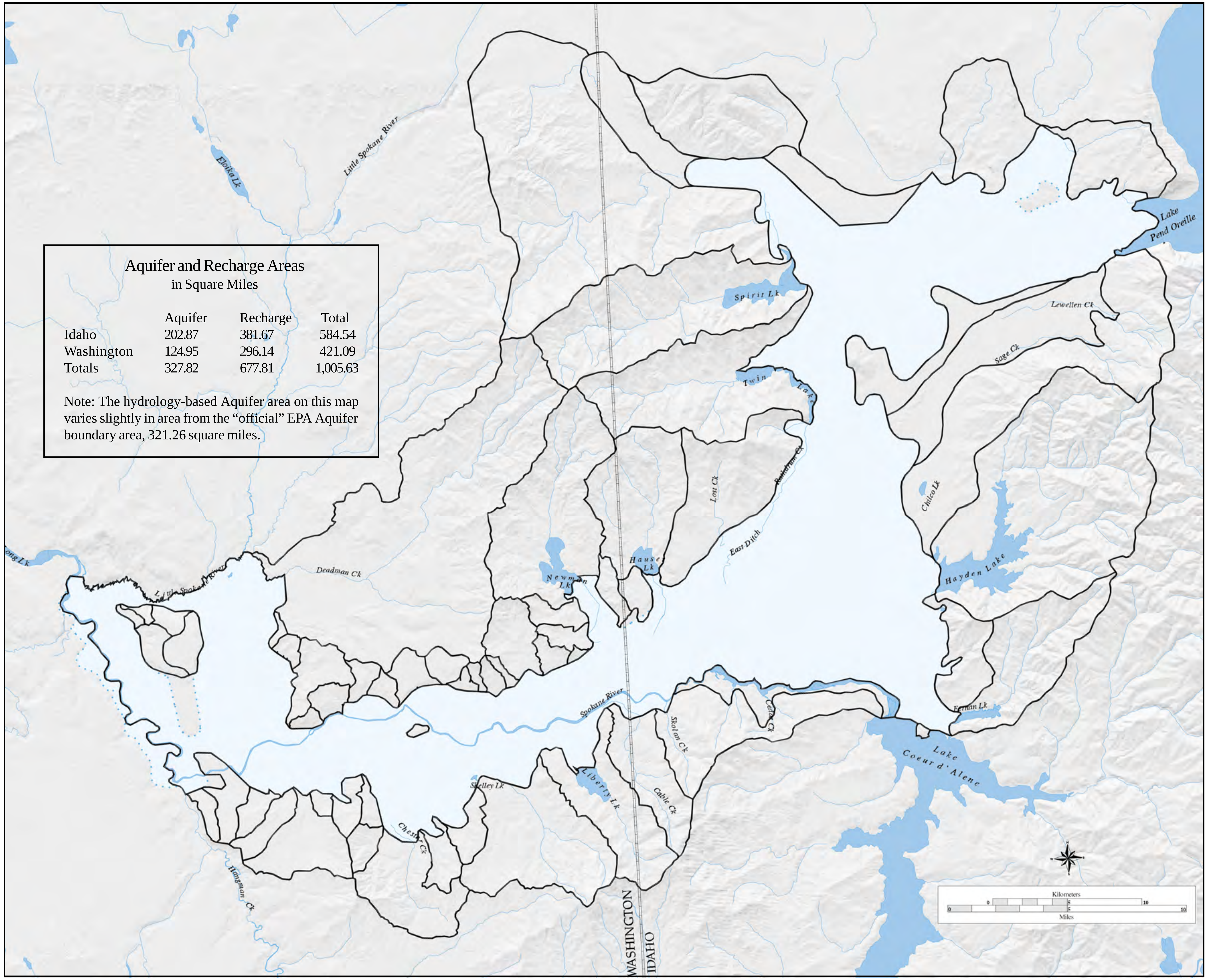
Overall, the groundwater table surface in the Aquifer is pretty flat - much like the land surface over the Aquifer - but it does dip at a gentle slope towards the west. In the northern Rathdrum Prairie the groundwater table lies at about 2,150 feet above mean sea level, while along the Little Spokane it sits at about 1,600 feet above mean sea level. The gentle gradient (slope) between these two points is what drives the groundwater flow in the Aquifer from Idaho and into Washington, and towards the Little Spokane River where it ultimately discharges.

Groundwater Depths

The greatest depths to groundwater in the Aquifer are found in the northern part of the Rathdrum Prairie, and the depths get progressively shallower as one moves into the Spokane Valley and further west. This is due mostly to the fact that the surface of the land in Idaho is higher than in the Spokane Valley, relative to the gently dipping groundwater table surface below the ground.



Recharge Areas of the Spokane Valley-Rathdrum Prairie Aquifer



Aquifer and Recharge Areas
in Square Miles

	Aquifer	Recharge	Total
Idaho	202.87	381.67	584.54
Washington	124.95	296.14	421.09
Totals	327.82	677.81	1,005.63

Note: The hydrology-based Aquifer area on this map varies slightly in area from the "official" EPA Aquifer boundary area, 321.26 square miles.

Aquifer Recharge Areas

The Spokane Valley - Rathdrum Prairie Aquifer receives a large percentage of its water from surface and subsurface flow from the higher regions immediately adjacent to it. These regions, known as "aquifer recharge areas", are shown in the map on this page. Land uses and human activities on the aquifer recharge areas have a significant and measurable affect on the quantity and quality of water in the Aquifer.

Washington Watersheds

In Washington, the aquifer recharge areas are called "watersheds", and these watersheds contribute significantly to the Aquifer. Many of the streams shown on the map originate in the surrounding hillsides but seem to stop before they reach the Spokane River. The water in the streams does not just disappear but it seeps into the ground and then flows underground to the Aquifer. Even the small watersheds with no surface streams contribute water to the Aquifer. The total contribution of water to the Aquifer from the watersheds around the Spokane Valley is about 300 cubic feet per second, equivalent to over 70 billion gallons of water each year. For a comparison, the amount of water crossing the state line from Idaho into Washington is approximately 390 cubic feet per second.

Idaho CARAs

In Idaho, the aquifer recharge areas are called Critical Aquifer Recharge Areas or "CARAs". CARAs were officially recognized by the State of Idaho in 1990 to provide an increased level of protection for the Aquifer. Many CARAs include a lake that acts to moderate the water flow between the CARA and the Aquifer. Note the Hayden Lake CARA on the map. Hayden Lake collects water from its CARA, and this water continually seeps to the Aquifer through the lake bed. Hayden Lake also discharges lake water each spring to a large stream on the ground surface above the Aquifer. This stream completely soaks into porous soils above the Aquifer within one mile of the lake. The Idaho CARAs are beginning to experience development that could affect the water quality of the Aquifer.

Water Quality Table

Contaminant	EPA Maximum (MCL)	Typical Aquifer Level	Potential Health Effects	Sources of Contamination
Nitrate-Nitrogen	10 mg/l	<1 to 8 mg/l	Blue baby syndrome	Fertilizer, septic tanks, sewage, animal waste, natural deposits
Fluoride	4.0 mg/l	<0.12 mg/l	Skeletal and denal fluorosis	Aluminum industry, natural deposits, fertilizer, water additive
Copper	1.3 mg/l	<0.01 mg/l	Gastrointestinal irritation	Natural deposits, industrial uses, wood preservatives, plumbing
Lead	0.015 mg/l	<0.005 mg/l	Kidney, nervous system damage	Industrial uses, plumbing solder, brass alloy plumbing fixtures
Chromium (total)	0.1 mg/l	<0.010 mg/l	Liver, kidney, circulatory disorders	Natural deposits, electroplating, mining, paint pigments
Carbon Tetrachloride	0.005 mg/l	<0.001 mg/l	Cancer	Solvents and their degradation products
Trichloro-ethylene	0.005 mg/l	<0.001 mg/l	Cancer	Textiles, adhesives, metal degreasers
1,1,1-Trichloro-ethane(TCE)	0.2 mg/l	<0.001 mg/l to 0.005 mg/l	Liver, nervous system	Paints, inks, textiles, adhesives, metal degreasers
Tetrachloro-ethylene	0.005 mg/l	not detected	Cancer	Dry cleaning and other solvents
Xylenes	10 mg/l	not detected	Liver, kidney, nervous system	Gasoline, paints, inks, detergents

Groundwater

Groundwater is 30 - 40 times more plentiful than all fresh water on the Earth's surface, excluding water trapped as glacial ice. About half of the United States population obtains domestic water from groundwater sources. In many areas of the country groundwater is the only source of domestic water for communities. If contaminated, groundwater may be very difficult and costly to clean up, and developing a new supply of water may be difficult or nearly impossible. Protecting groundwater from contamination is extremely important.

Sole Source

The Spokane Valley-Rathdrum Prairie Aquifer is an EPA designated Sole Source Aquifer. The Aquifer is the only economically available supply of drinking water for approximately 400,000 people in our region. The quality of the Aquifer water is high, yet water quality trends from the 1970s and 1980s have shown a gradual increase of contaminants reaching the Aquifer. Our Aquifer is highly susceptible to pollution because of the porosity of the glacial gravels, shallow soils, and shallow water table. Pollutants such as coliform bacteria, nitrates, and volatile organic compounds have been detected in Aquifer water samples. These contaminants are seldom in concentrations high enough to exceed water quality standards and only occur in limited areas for short periods of time. The high flow rate of our Aquifer tends to dilute pollution comparatively quickly. The trend of increased contamination indicates that we must protect the Aquifer from further contamination. Local governments in both Spokane County and Idaho have begun to reverse this trend by developing Aquifer protection programs and regulations.

Septic Systems

Past studies have shown that about sixty percent of the pollution reaching the Aquifer originates from septic systems. The most common pollutant from septic systems is nitrogen, usually in the form of nitrate, which can cause health problems in infants (see table above). Household chemicals dumped down the drain are not treated in the septic system and constitute another source of pollution. These chemicals can move through the septic tank and drain field, and then downward eventually reaching the Aquifer. Ongoing efforts in Spokane County and communities in northern Idaho have connected many households and businesses to sewer collection systems, thereby reducing pollutants reaching the Aquifer and improving water quality. However in rural areas, septic systems will continue to be the only method of sewage treatment and disposal. These rural systems must be properly maintained to reduce the pollution threat to the Aquifer.

Stormwater

Another major pollution source, stormwater, accounts for about thirty percent of the pollution reaching the Aquifer. Stormwater can collect a large variety of contaminates as it flows across roads, parking lots, roofs and other impervious surfaces. Some of this water goes into dry wells without treatment. Both Spokane County and Northern Idaho now have regulations that require the use of grassed infiltration basins, also called grassy swales, that use natural processes to clean up the stormwater as it percolates through a grass and soil layer before making its way to the Aquifer.

Contamination Sources

Sources of contamination over the Aquifer are varied and abundant. Almost any activity that generates or stores waste material has the potential to contaminate the aquifer. In the past, human-generated surface contamination has reached the Aquifer including: landfill leachate, industrial process wastewater, vehicle and tanker spills, and contaminated water from industrial and residential activities. These contamination incidents have been costly and technically difficult to cleanup, and local agencies have learned that it is much less costly to prevent contamination from reaching the Aquifer than to clean up contamination after it has occurred.

Common Contaminants

The most common contaminants found in the Aquifer are inorganic chemicals generated by normal everyday activities. Nitrates, chlorides, sulfates and other chemicals associated with human activity mix readily with Aquifer water. Industrial chemicals from poor disposal practices of the past and in landfill leachate have also created plumes in the Aquifer. These chemicals often create greater concern because of their toxicity, which is generally much greater than inorganic chemicals. Industrial solvents, such as trichloroethylene, and gasoline components such as benzene fall into this industrial chemical category.

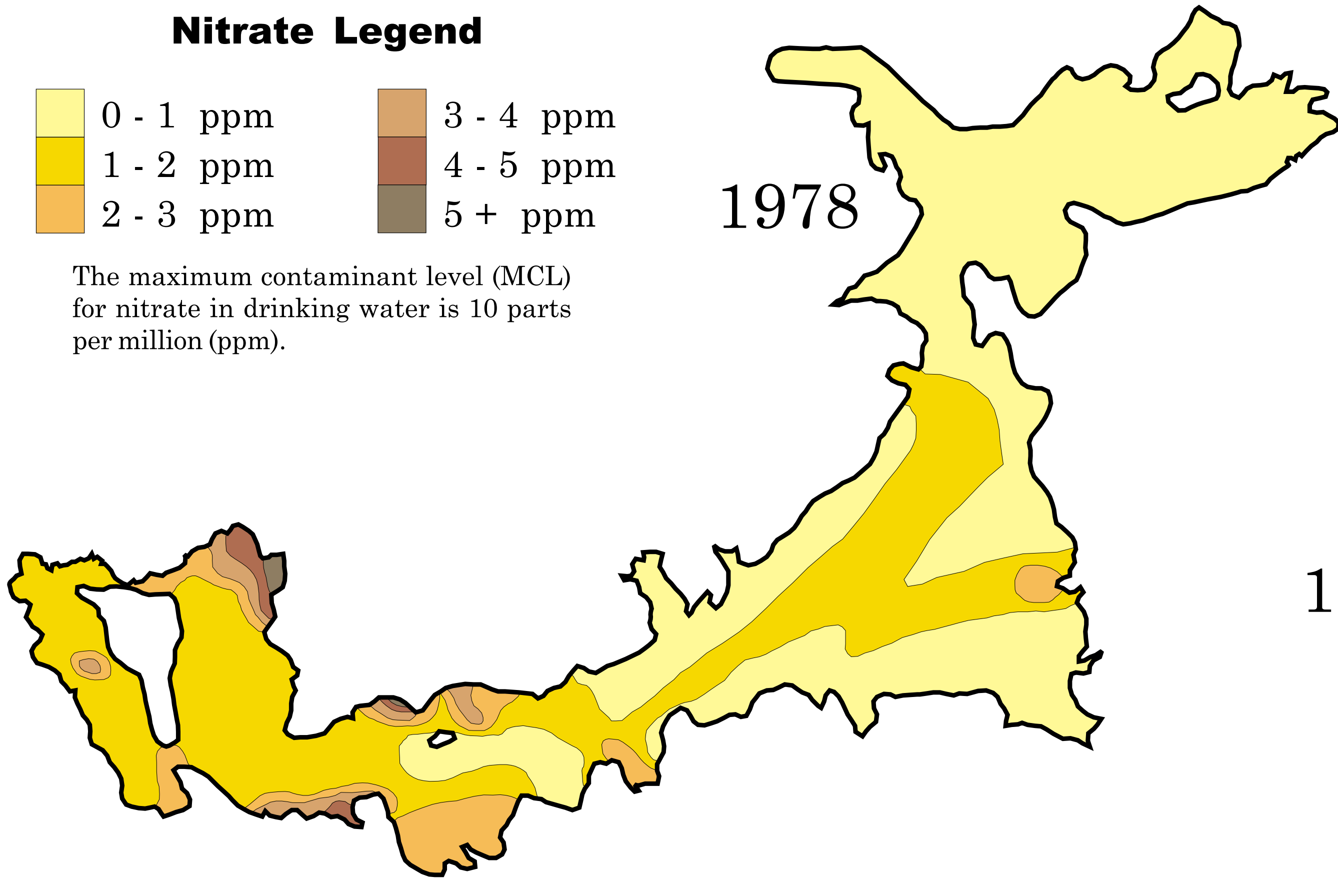
Water Quality Testing

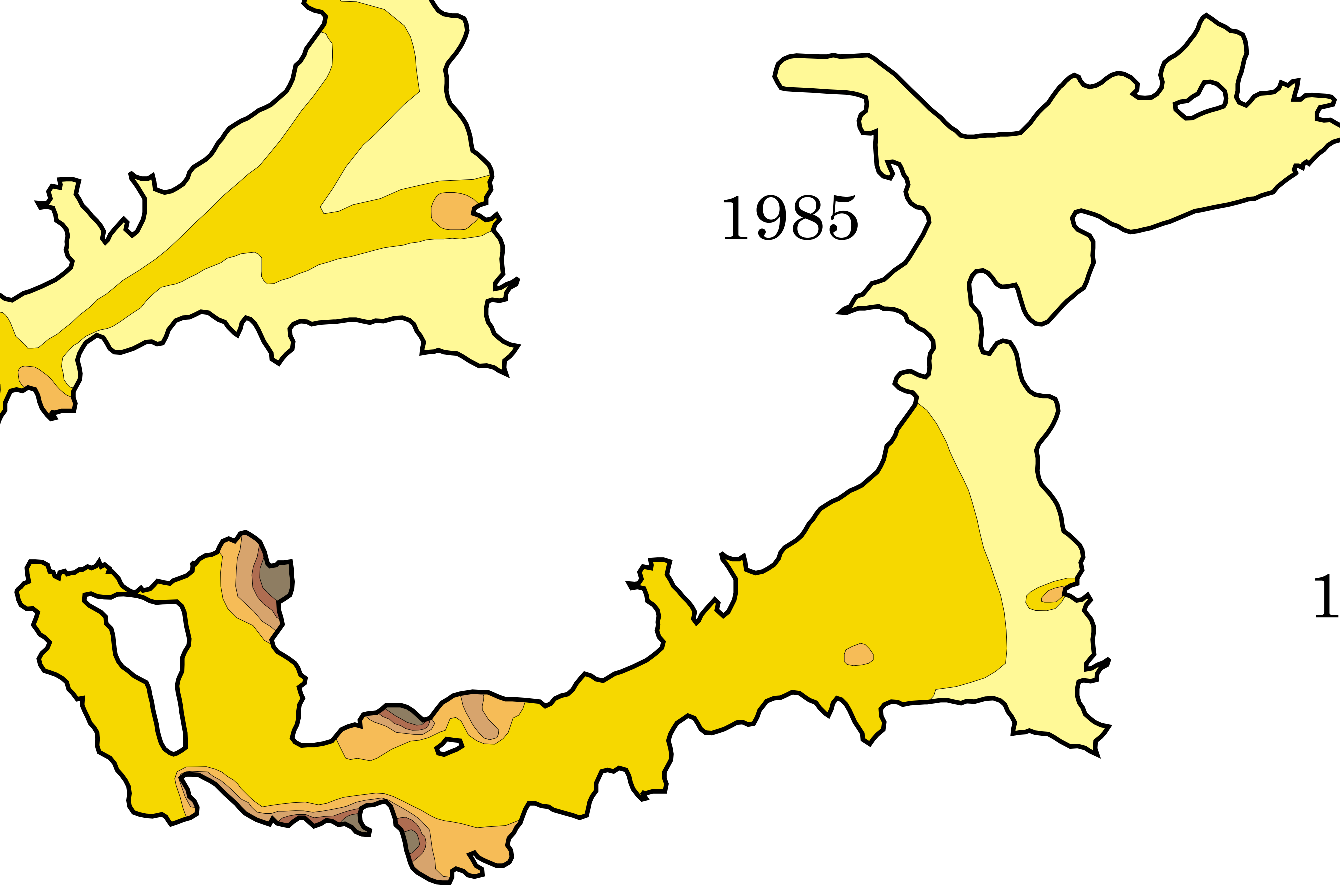
Both Spokane County and Panhandle Health District have ongoing monitoring programs to sample and test the Aquifer for contamination, with about 60-70 wells scattered throughout the Aquifer tested quarterly. The purpose of this testing is to monitor the overall quality of the Aquifer and to examine water quality trends. Results of some of this testing is compiled in the table on this page. You can see that very few contaminants are detected in the water supply and those that are found are usually detected at levels far below drinking water standards. Water suppliers who use the Aquifer are also required to periodically test the water they deliver to homes. Nearly two hundred water supply wells at a hundred locations are tested to insure the water supply meets heath standards established by the federal government and state agencies.

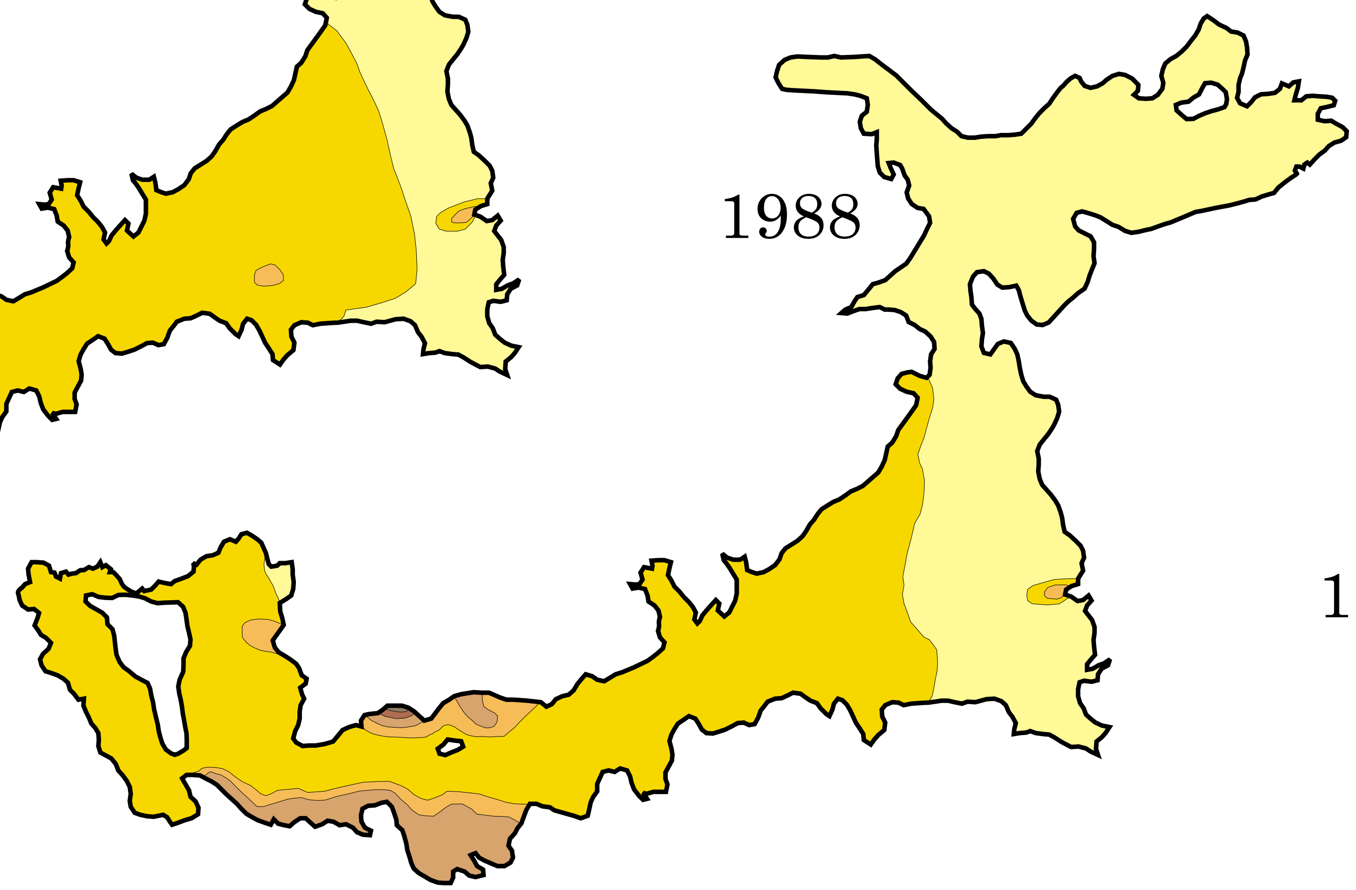
Water Quality Table

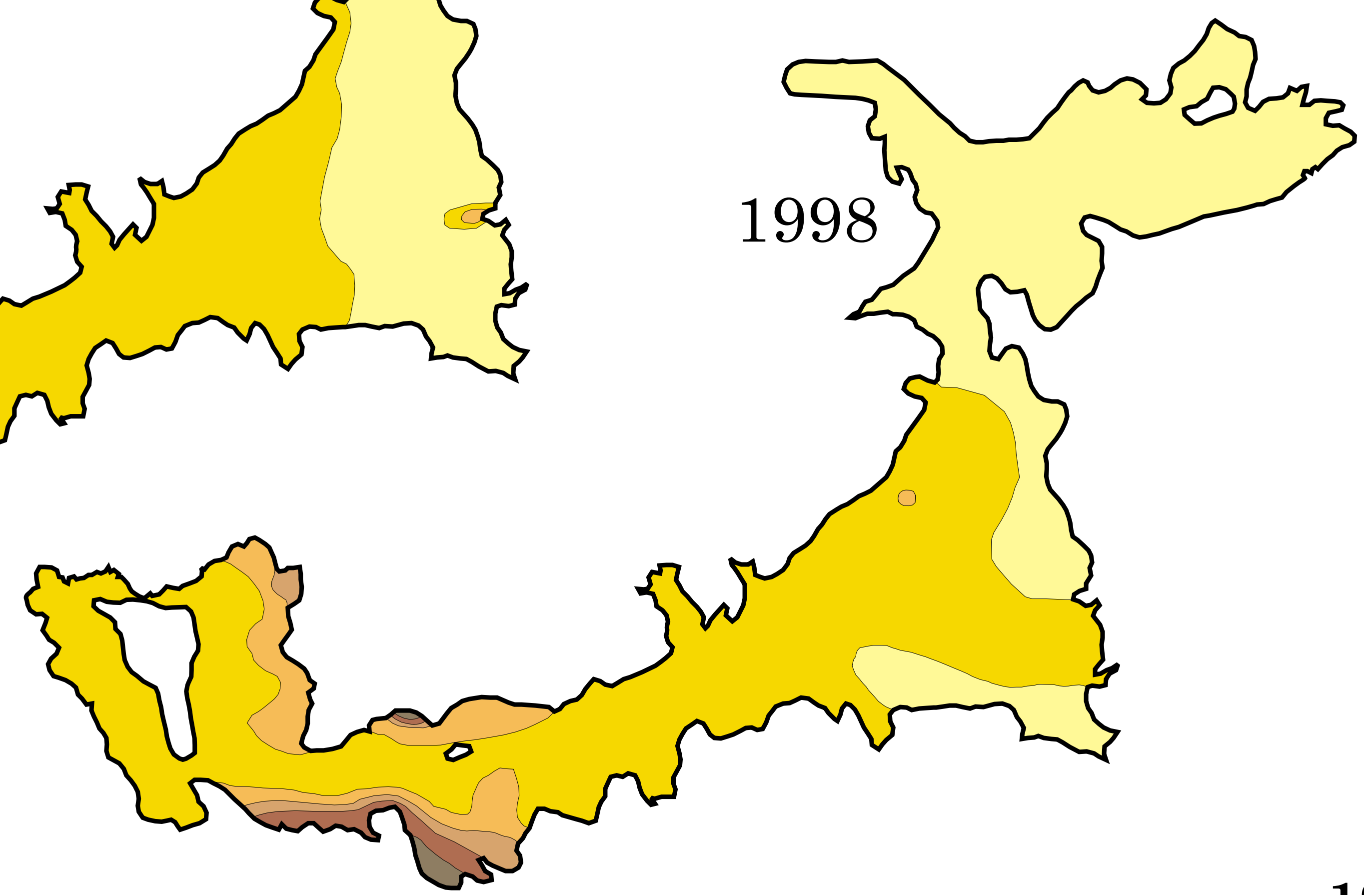
The table on this page provides some information on chemical constituents that are tested for in water supplies. Few of these have been found in Coeur d'Alene and Spokane area water supplies. The information provided gives an indication of the problems associated with some of the materials we hear about on the news. The Maximum Contaminant Levels (MCLs) reported in the table are taken from the levels established by the Environmental Protection Agency in conformance with the provisions of the 1986 Safe Drinking Water Act Amendments. When setting MCLs the EPA establishes a level considered safe for the population most sensitive to exposure. For example, the nitrate—nitrogen level is set for its potential impact on infant children. Similarly, the lead level is set for children during the stage of most rapid neurological development.

Nitrate Contour Maps









Contour Lines

The illustrations in this section show isoconcentration contours of nitrate in the Aquifer through time. The earliest nitrate concentration map is from 1978, which represents the earlier stages of aquifer protection activities in Washington and Idaho. The peak of observed nitrate degradation in the entire Aquifer was 1985. Total contaminant loading to the Aquifer has increased as the population increased over the Aquifer, as shown in the higher concentrations of nitrate through time as illustrated in these maps. On all the maps, certain areas near the edge of the Aquifer show high levels of nitrate. These locations represent "eddy" areas where incoming contaminants from side hill development are not easily or quickly mixed with the better quality water recharging from the east.

Septic Systems

In 1985 a major effort on both sides of the state line was initiated to reduce septic system contamination of the Aquifer through installation of piped sewer collection systems. The Spokane County septic tank elimination project has evolved into an on-going sewer line expansion program. In Kooenai County, wastewater systems, including treatment plants, were constructed in Coeur d'Alene, Post Falls, Bayview, Hayden, Hayden Lake and Rathdrum.

Aquifer Water Quality

The good news about nitrate and other contaminants in the Aquifer is that ongoing protection programs have decreased the rate of contamination. Current trend analysis shows nitrate concentrations are decreasing despite significant population increases. The groundwater in the Aquifer remains some of the best quality water available anywhere.

Nitrate as an Indicator

Nitrate is a form of nitrogen that is highly stable under conditions commonly found in the topsoil and aquifer sediments. Under natural conditions, nitrate occurs in very low concentrations, typically less than 0.1 part per million (ppm). Certain by-products of human activity, such as domestic wastewater and fertilizers, contain high levels of nitrogen which converts into nitrate. When the nitrate level in groundwater is elevated, it indicates that by-products of human activities are reaching the groundwater. While nitrate in drinking water above 10 ppm may cause illness, more importantly, the presence of high levels of nitrate in groundwater is an indicator that other harmful, but less easily detectable, by-products of human activity may be present. As an indicator chemical, nitrate is often used as a measure of overall aquifer water quality.

Aquifer Issues

The Spokane Valley-Rathdrum Prairie Aquifer issues facing the region's residents fall into two broad categories: water quantity and water quality. Issues from both of these categories are presented on this page.

Water Quantity Estimates

From its discovery over 100 years ago through the 1960s, the Aquifer was considered an "inexhaustible supply" of water. In the 1970s, using the best methods and information then available, the first estimate of the aquifer flow at the Washington-Idaho state line was calculated as 1,000 cubic feet per second (cfs) or 645 million gallons per day (mgd). Seven science-based flow estimates have been made from 1970 through 1999, and these estimates are presented in the graph on this page. The most recent effort used the latest computer modeling and with the most current information, and it estimated the flow of water at the state line as 390 cfs, or 252 mgd.

Water Withdrawal

Approximately 219 million gallons were withdrawn from the Aquifer to supply the domestic needs of the area's residents on an average day in 1999. However, on hot summer days the added water use for irrigation increases the daily Aquifer water withdrawal to over 680 million gallons. The national average of water use per household is about 350 gallons per day, but in our region daily household use can be as high as 600 gallons per day. The average daily Aquifer water withdrawal is shown on the flow estimate graph. The region's residents are fortunate that the Aquifer has a large storage capacity estimated to be approximately 10 trillion gallons.

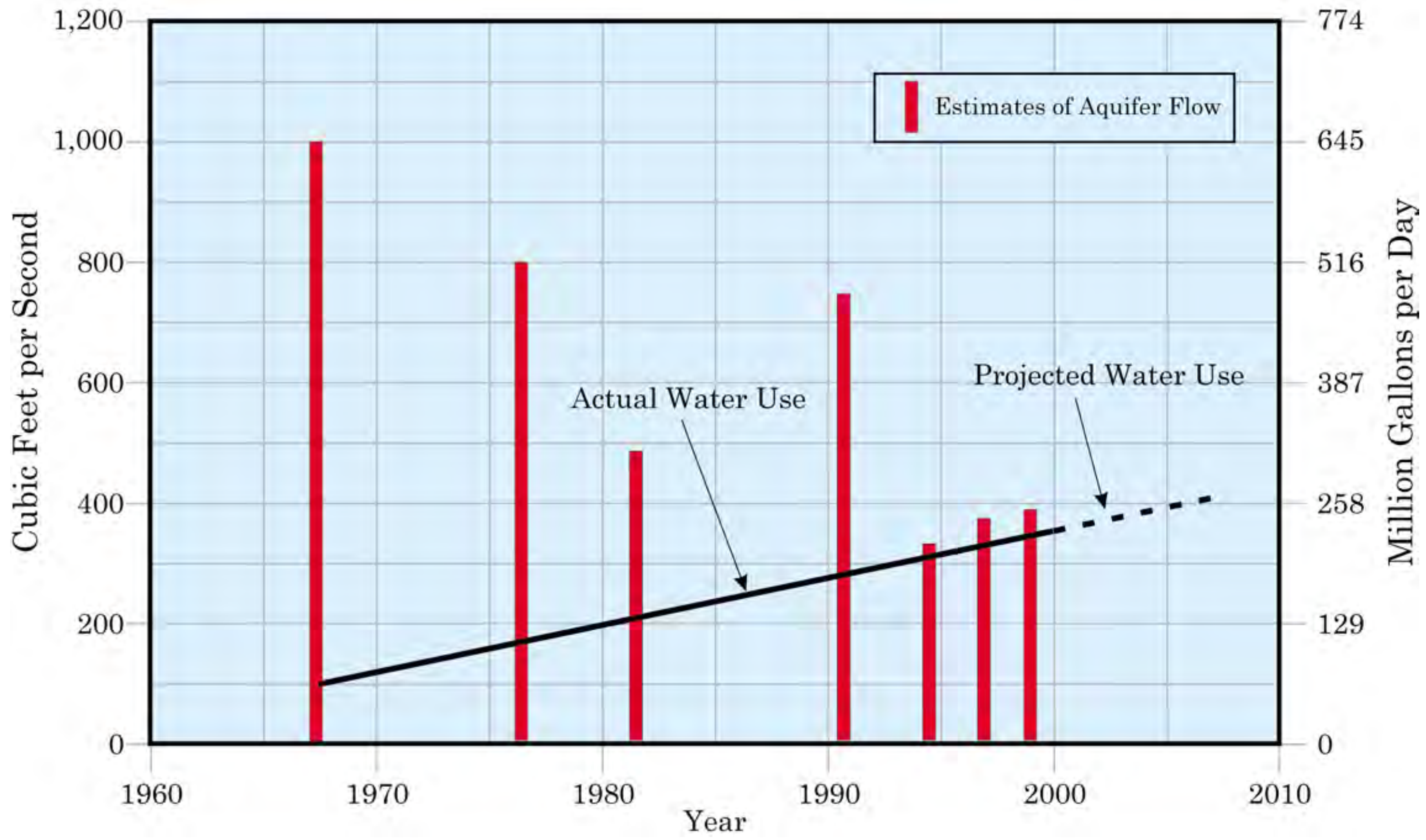
Increased Water Demand

As shown in the graph on this page, the demand for Aquifer water has increased over time. If water demand continues to increase, the average daily water withdrawal from the Aquifer may equal or exceed the Aquifer flow, thereby initiating a depletion of the Aquifer reservoir with a resulting lowering of the water table level.

Spokane River

In certain reaches, the Spokane River discharges to the Aquifer, and in other reaches the Aquifer adds water to the river. The flow in the Spokane River during late summer is very low. During these low flow periods, much of the water in the Spokane River originates from the Aquifer, and this Aquifer water flowing into the river is very important for several reasons. First, the Spokane River supports a diverse plant and wildlife population, and the Aquifer water helps maintain the necessary habitat for these populations. Next, minimum river flows are necessary to dilute the treated effluent discharging from wastewater treatment plants at Coeur d'Alene, Hayden, Post Falls and Liberty Lake. Finally, water from the Aquifer helps the Spokane River meet State and Federal water quality standards.

Estimates of Aquifer Groundwater Flow at the Idaho-Washington State Line



This graph presents both scientific estimates of groundwater flow in the Aquifer and volume of Aquifer water use. The red bars represent the scientific estimates, and it is interesting to note that these estimates have generally been decreasing over time. In contrast, actual Aquifer water use has been increasing over time as the region's population has grown. As the Aquifer is studied with better techniques, scientist are finding it is not the unlimited resource once believed.

Little Spokane River

At the western edge of the Aquifer, groundwater discharges into the Little Spokane River. The flow in the Little Spokane River is frequently below its required minimum flow amount during the summer months, and the recharge from the Aquifer is extremely important in maintaining the minimum flow requirement in this river. Similar to the Spokane River, the Little Spokane River supports a diverse plant and wildlife population, and the Aquifer water is critical to maintaining this population.

Wastewater Issues

Increased water use has consequences not only with possible Aquifer depletion, but also with treating and disposing of the water after it is used. The Spokane River receives treated wastewater from many area treatment plants, and the river has reached its capacity for certain pollutants during the low flow summer months. Not only will increased Aquifer withdrawals create more wastewater, but the subsequent lowering of the Aquifer water table will decrease flow contributions to the Spokane River during the critical summer months. This decreases the river's ability to accept treated wastewater and still meet water quality standards.

Wastewater Land Application

One possible solution to this wastewater issue is currently employed in northern Idaho. During the growing season, a portion of the treated wastewater from the Hayden treatment plant is applied to crops on the Rathdrum Prairie. This method of wastewater treatment and disposal prevents further degradation of the Spokane River, and wastewater, rather than Aquifer water, is used to grow crops.

Contamination Vulnerability

The Spokane Valley-Rathdrum Prairie Aquifer is highly vulnerable to contamination from activities on the ground surface. Unlike many other aquifers, the Aquifer does not have protective layers of clay to deter infiltration of surface contaminants. The soil layer on top of the Aquifer is relatively thin in most areas, and fluids readily infiltrate into the porous sands and gravel that comprise the aquifer soils. Potential contamination is perhaps the most important aquifer issue that must be addressed in order to preserve and maintain the Aquifer as a regional drinking water resource.

Contamination in the Aquifer

Unlike many other aquifers, the travel time for a contaminant on the surface to reach the Aquifer water table is usually a matter of hours or days, particularly for contaminants that are dissolved in water recharging the Aquifer. Once a contaminant enters the Aquifer it spreads into a plume, much like a plume of smoke from a smokestack. A contamination plume moves with the Aquifer flow as it gradually disperses. The process of dispersion causes the plume to spread both horizontally and vertically as it moves along with the aquifer flow. The contaminant concentration in the plume varies and tends to decrease along the edges of the plume as the contamination moves into uncontaminated water and becomes more dilute. As the plume grows and widens more Aquifer area becomes contaminated and the likelihood drinking water wells becoming contaminated increases. Different chemicals mixed with the water in the Aquifer create different plume behavior, and remedial actions must be customized to the specific contaminant. Contamination in the Aquifer may be cleaned-up, or remediated, but the clean-up process is usually costly.

Protecting the Aquifer is a joint effort by agencies and organizations in Washington and Idaho including: Spokane County, the Idaho Department of Environmental Quality (DEQ), Panhandle Health District (PHD), the City of Spokane and the Washington Department of Ecology. The federal Environmental Protection Agency (EPA) has greatly assisted the Aquifer protection efforts by first declaring the Spokane Valley – Rathdrum Prairie Aquifer a "Sole Source Aquifer", then providing annual funding from 1988 through 1995 for aquifer protection projects. This page illustrates recent Aquifer protection activities.

1972

Federal Clean Water Act: Section 208 provided authority and funding for Aquifer protection planning efforts.

1978

EPA designates the Aquifer as a "Sole Source Aquifer" under Section 1424(e) of the Safe Drinking Water Act.

1977

"208" Studies are completed: sources of Aquifer pollution are identified.

"1 to the 5" regulation is adopted by PHD: new development over the Aquifer is limited to one septic system for every five acres.

PHD enters into Sewage Management Agreements with cities to encourage growth near urban centers where sewer lines would eventually be installed.

1979

Spokane County and City of Spokane adopt a Water Quality Management Plan.

1980

Spokane County and Health District initiates a Ground Water Monitoring Program.

DEQ designates the Aquifer as a "special resource water", subject to the highest level of state protection.

Spokane County and Water Purveyors develop a Coordinated Water Supply Plan.

Spokane County adopts a Stormwater Management Drainage Ordinance.

1981

City of Spokane adopts a Stormwater Management Policy.

Spokane County writes a Comprehensive Wastewater Management Plan.

1983

Spokane County creates an Aquifer Sensitive Area Overlay Zone.

1985

Spokane County publishes a Household Toxics Disposal Brochure.

Household Toxics Turn-in Day sponsored by Spokane County and the City of Spokane.

1986

City of Spokane passes a Critical Materials Ordinance.

Spokane County Health District creates a Renewable On-Site Sewage Permit Program.

1988

City of Spokane adopts Hazardous Waste Treatment and Storage Zoning.

U.S. Congress provides Aquifer Protection Funding through the EPA.

Spokane County adopts an Existing Underground Storage Tank Ordinance.

1990

PHD adopts a Critical Materials Regulation.

1991

PHD prohibits new commercial septic tanks over the Aquifer.

1992

PHD publishes a Stormwater Management Handbook and provides free training.

Kootenai County builds a permanent Household Hazardous Waste Collection Facility, partially funded by DEQ.

1993

Spokane County, DEQ, and PHD host a National Conference on Wellhead Protection in Coeur d'Alene, Idaho.

1994

Eastern Washington University publishes a study on the Chilco Channel.

EPA grants Public Water System Waivers for some systems over the Aquifer based on Idaho Aquifer Protection Program.

1995

DEQ adopts guidelines for land applying wastewater over the Aquifer.

1996

Rathdrum Prairie Aquifer Policy Committee evaluates Idaho Aquifer Program and recommends its continuation.

1997

Kootenai County completes an Area Wide Wastewater Plan.

DEQ designates the Aquifer as a "Sensitive Resource Aquifer" in the state Ground Water Quality Rule.

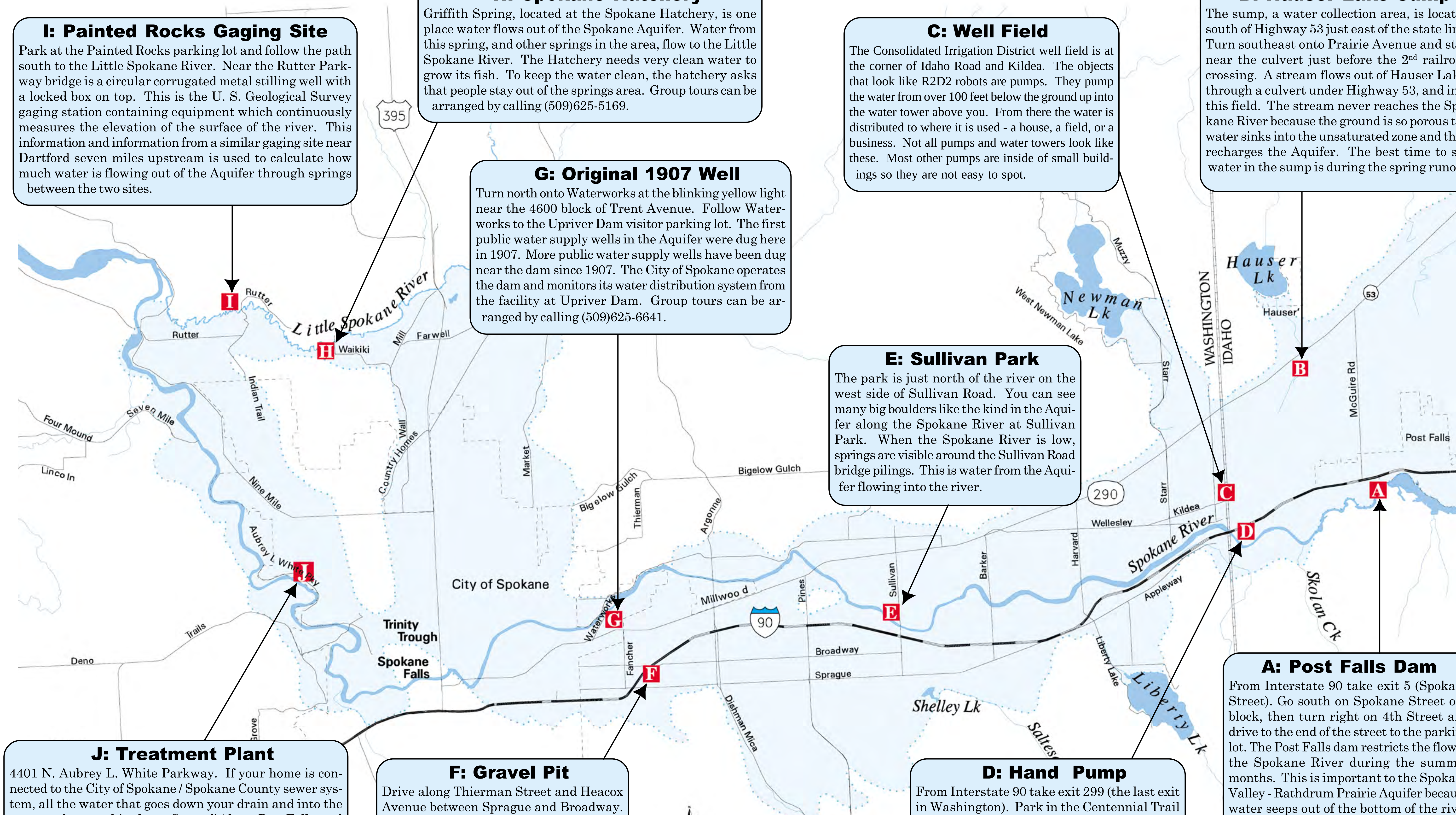
1998

The City of Spokane and the Spokane Aquifer Joint Board publish a wellhead protection plan.

2000

The Aquifer protection funding administered by EPA expires. The funding began in 1988.

Aquifer Tour



I: Painted Rocks Gaging Site

Park at the Painted Rocks parking lot and follow the path south to the Little Spokane River. Near the Rutter Parkway bridge is a circular corrugated metal stilling well with a locked box on top. This is the U. S. Geological Survey gaging station containing equipment which continuously measures the elevation of the surface of the river. This information and information from a similar gaging site near Dartford seven miles upstream is used to calculate how much water is flowing out of the Aquifer through springs between the two sites.

H: Spokane Hatchery

Griffith Spring, located at the Spokane Hatchery, is one place water flows out of the Spokane Aquifer. Water from this spring, and other springs in the area, flow to the Little Spokane River. The Hatchery needs very clean water to grow its fish. To keep the water clean, the hatchery asks that people stay out of the springs area. Group tours can be arranged by calling (509)625-5169.

G: Original 1907 Well

Turn north onto Waterworks at the blinking yellow light near the 4600 block of Trent Avenue. Follow Waterworks to the Upriver Dam visitor parking lot. The first public water supply wells in the Aquifer were dug here in 1907. More public water supply wells have been dug near the dam since 1907. The City of Spokane operates the dam and monitors its water distribution system from the facility at Upriver Dam. Group tours can be arranged by calling (509)625-6641.

C: Well Field

The Consolidated Irrigation District well field is at the corner of Idaho Road and Kildea. The objects that look like R2D2 robots are pumps. They pump the water from over 100 feet below the ground up into the water tower above you. From there the water is distributed to where it is used - a house, a field, or a business. Not all pumps and water towers look like these. Most other pumps are inside of small buildings so they are not easy to spot.

B: Hauser Lake Sump

The sump, a water collection area, is located south of Highway 53 just east of the state line. Turn southeast onto Prairie Avenue and stop near the culvert just before the 2nd railroad crossing. A stream flows out of Hauser Lake, through a culvert under Highway 53, and into this field. The stream never reaches the Spokane River because the ground is so porous the water sinks into the unsaturated zone and then recharges the Aquifer. The best time to see water in the sump is during the spring runoff.

E: Sullivan Park

The park is just north of the river on the west side of Sullivan Road. You can see many big boulders like the kind in the Aquifer along the Spokane River at Sullivan Park. When the Spokane River is low, springs are visible around the Sullivan Road bridge pilings. This is water from the Aquifer flowing into the river.

J: Treatment Plant

4401 N. Aubrey L. White Parkway. If your home is connected to the City of Spokane / Spokane County sewer system, all the water that goes down your drain and into the sewer ends up at this plant. Coeur d' Alene, Post Falls, and Liberty Lake also have wastewater treatment facilities. The water is treated with solids removal, aeration, bacterial activity, and disinfection. Fish can live in the water by the time it is discharged into the Spokane River. Groups tours can be arranged (509)625-4600.

F: Gravel Pit

Drive along Thierman Street and Heacox Avenue between Sprague and Broadway. This gravel pit is another place to see the rock material of the Aquifer in the Spokane Valley. No vegetation hides the rock material because the pit is still being used. The pit extends below the water table and exposes the water of the Aquifer.

D: Hand Pump

From Interstate 90 take exit 299 (the last exit in Washington). Park in the Centennial Trail access parking lot just south of the interchange. Walk east along the Trail and across the river. It's about half a mile to the hand pump and sign. Before electricity many people used hand powered pumps like this to get their water out of the ground.

A: Post Falls Dam

From Interstate 90 take exit 5 (Spokane Street). Go south on Spokane Street one block, then turn right on 4th Street and drive to the end of the street to the parking lot. The Post Falls dam restricts the flow of the Spokane River during the summer months. This is important to the Spokane Valley - Rathdrum Prairie Aquifer because water seeps out of the river and into the aquifer between the Post Falls dam and Barker Road in the Spokane Valley. The lower the flow in the river, the less water gets into the Aquifer. Right at the dam, bedrock prevents leakage out of the bottom of the river.

Alluvium: A general term for all materials deposited by rivers or streams, including the sediments laid down in riverbeds, and flood plains.

Alpine: A mountainous or mountain-like environment or region.

Aquifer: Any underground permeable layer of rock or sediment that holds water and allows water to easily pass through.

Artesian Water: Groundwater that has sufficient pressure to raise above the aquifer containing it when penetrated by a well. It does not necessarily have to rise to the surface.

Basalt: A fine-grained and usually dark-colored igneous rock that originates as surface flow of lava.

Batholith: A body of intrusive rock at least 40 square miles in area.

Capillary Action: A property of soil whereby water is held in the soil by surface tension, as films around individual particles and in the spaces between the soil particles.

Capillary Water: Underground water that is held above the water table by capillary action.

Chlorination: The application of chlorine to water for the purpose of disinfection.

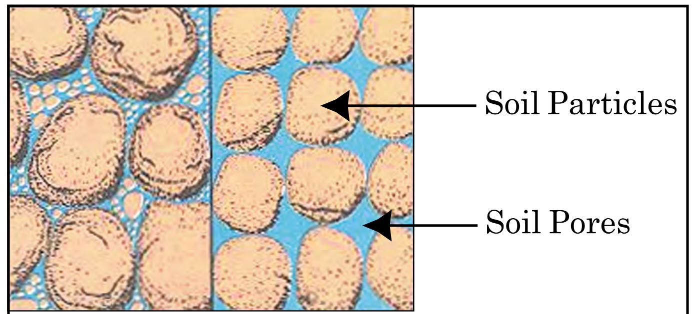
Cobbles: Rocks that are larger than pebbles and smaller than boulders, usually rounded while being carried by water, wind, or glaciers.

Coliform Bacteria: A type of bacteria that live in the digestive tracts of animals and humans but are also found in soils and water. The presence of coliform bacteria in certain quantities in water is used as an indicator of pollution.

Cone of Depression: A cone shaped area in the water table around a pumping well due to the well's influence on the flow of water in the aquifer.

Conifer: An tree that reproduces by means of cones and has needles instead of leaves.

Confined Aquifer: An aquifer with an overlying layer of impermeable or semi-impermeable material.



The sample on the right has higher permeabilitybecause of better interconnections between pores

Consumptive Use (of water): The water used for any purpose that does not return to its source, such as irrigation water lost to the atmosphere by evapotranspiration.

Cordillera: A group of mountain ranges including the valleys, plains, rivers, and lakes between the mountains.

Correlation (geologic): The determination of the equivalence in geologic age and strategraphic position of two formations or other stratigraphic units in separated areas. This can be based on paleontologic or physical evidence.

Coulee: A steep-sided gulch or water channel.

Cubic Feet Per Second: A unit of measurement for expressing the flow rate (discharge) of a moving body of water. One cubic foot per second is equal to a stream one foot deep, one foot wide and flowing at a velocity of one foot per second. One cubic foot of water is equal to 7.48 U.S. gallons.

Discharge: The volume of water that passes through a given cross section of a stream, pipe, or even an entire drainage basin.

Domestic Consumption (use): The quantity of water used for household use including drinking, washing, bathing and cooking.

Effluent: Something that flows out, such as a liquid discharged as a waste; for example, the liquid waste that comes out of a sewage treatment plant.

Effluent Stream: A stream that receives all or part of its water from ground water; also called a "gaining stream".

Emplacement: Development of rocks in a particular place.

Evaporation: The process by which water is changed from a liquid to a vapor. In hydrology, evaporation is vaporization that occurs at a temperature below the boiling point.

Evapotranspiration: Evaporation plus transpiration.

Fluvial: Of or pertaining to rivers; produced by a rivers action, such as a fluvial plain. Also used to denote an organism that grows or lives in streams or ponds.

Gallons Per Minute: A unit for expressing the rate of discharge, typically for the discharge of a well.

Geophone: A detector, placed on or in the ground in seismic work, which responds to the ground motion at its location.

Glacier: A mass of ice that is moving on land in a definite direction, originating from accumulated snow.

Glaciofluvial: Pertaining to streams flowing from glaciers or the deposits made by those streams.

Grass Percolation Area (grassy swale): An area covered with grass or other vegetation used to catch and treat stormwater runoff by allowing the water to slowly percolate through the grass and soils.

Groundwater: Subsurface water found in the zone of saturation.

Hardness: A measure of the amount of calcium, magnesium, and iron dissolved in the water.

Hydraulic Conductivity: A measurement of permeability.

Hydrogeology: The science of the interaction between geologic materials and water, especially groundwater.

Hydrologic Cycle: The endless interchange of water between sea, air, and land: includes evaporation from oceans, movement of water vapor, condensation, precipitation, surface runoff, and groundwater flow.

Hydrology: The science of the behavior of water in the atmosphere, on the earth's surface, and underground.

Hydrothermal vein deposits: A mineral deposit formed in cracks in rocks by the injection and cooling of hot liquid containing dissolved minerals.

Ice Age: A geological period of widespread glacial activity when ice sheets covered large parts of the continents.

Ice Dam: A blockage of a river by ice.

Igneous Rock: A rock formed by the cooling of molten magma; for example, granite or basalt.

Impervious: Incapable of being penetrated by water.

Impermeable Rock: A rock layer made of materials such as clay or shale that does not allow water to pass through it.

Infiltration: In hydrology it is the movement of water into soil or porous rock.

Influent Stream: A stream contributing water to the zone of saturation thereby sustaining or increasing the water table; also called a "losing stream".

Isoconcentration: A line on a chart or map connecting places with the same concentration.

Lava: Molten rock erupted on the surface of the earth by volcanic processes.

Leachate: A solution created by water dissolving chemicals while flowing through the soil or a landfill.

Metamorphism: Transformation in the character of igneous or sedimentary rock, resulting in more compact metamorphic rock.

Moraine: Glacial drift deposited chiefly by direct glacial action, and having constructional topography independent of control by the surface on which the drift lies.

Nonpoint Source Pollution: Pollution discharged over a wide area of land, not from one specific location.

Observation Well: A well used to monitor ground water for water quality and/or changes in water levels.

Glossary & Definitions

Outwash: Neat layers of clay, sand, and gravel deposited by glacial meltwater.

Parts Per Million (ppm): The number of "parts" of a substance by weight per million parts. A commonly used unit used to express a pollutant's concentration in water. Equivalent to milligrams per liter (mg/L).

Perched Water Table: Groundwater separated from the underlying water table by an impermeable rock layer.

Percolation: The downward movement of water through the pores or spaces of a rock or soil.

Permeability: The ability of rock or sediment to permit water to pass through it. It is dependent on the volume of the pores and openings and their interconnectedness.

Point Source Pollution: Pollution discharged from a single source or point such as a pipe, ditch or sewers.

Porosity: In rock or soil, it is the ratio of the volume of openings in the material to the total volume of the material. In hydrology it is used to express the capacity of rock or soil to contain water and is expressed as a percentage.

Precipitation: In hydrology, any form of water that falls to the ground from the atmosphere, including rain, snow, ice, hail, drizzle, etc.

Recharge, groundwater: The addition of water to the zone of saturation. Precipitation and its movement to the water table is an example.

Recharge Area: An area in which an aquifer receives water by the force of gravity moving water down from the surface.

Remedial Action: Actions for the purpose of repairing or remedying a condition or situation.

Runoff: That portion of precipitation or irrigation water that drains from an area as surface flow.

Sanitary Landfill: A method of disposing of solid waste on land by spreading it into thin layers, compacting it and then covering it with soil.

Sanitary Sewers: A sewer system that carries domestic waste water as opposed to a sewer system that carries storm water, or both domestic waste and stormwater.

Saturated: In hydrology, the condition in which all the pore spaces in a rock or soil layer are filled with water.

Saturated Zone: The top of the zone of saturation is the water table. A subsurface zone below which all rock pore space is filled with water.

Sediment: 1) any material carried in suspension by flowing water that ultimately will settle to the bottom of a body of water; 2) waterborne material deposited or accumulated on the bottom of waterways.

Seepage: Water that passes slowly through porous material.

Seismic Energy: Energy similar in character to that produces by an earthquake.

Septic Tank: Underground tanks that receive household wastewater. Bacterial action breaks down the organic matter in the tank. The effluent then flows out of the tank into the ground through drains.

Sewage: The total of organic waste and wastewater generated by residential and commercial establishments.

Sewer, Combined: A sewer that carries both wastewater and stormwater.

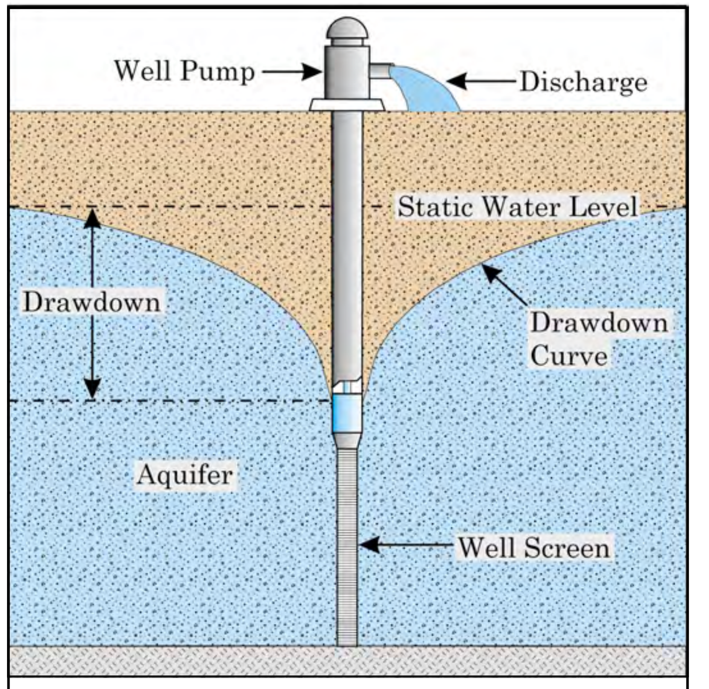
Sole Source Aquifer: An aquifer which is the sole or principal drinking water source for the area and which, if contaminated, would create a significant hazard to public health.

Solid Waste: Unwanted or discarded material produced from agricultural, residential, commercial, municipal, and industrial sources.

Static Water Level: The level of water in a nonpumping or nonflowing well.

Storm Drain (Storm Sewer): A drain (sewer) that carries storm waters and drainage, but excludes domestic and industrial wastewater.

Surface Water: All water on the land surface exposed to the atmosphere, includes oceans, lakes, streams, glaciers and snow.



Well Cross Section

TCE (Trichloroethylene): A solvent used in dry cleaning and metal degreasing that can contaminate groundwater when disposed of improperly.

Till: Unsorted and unlayered mixture of all sizes of sediment carried or deposited by glaciers.

Toxicity: The degree that something is poisonous.

Transmissivity (groundwater): The capacity of an aquifer to transmit water through its entire saturated thickness.

Transpiration: The process by which water from a plant is evaporated to the atmosphere, usually through the leaf surface.

Unconfined Aquifer: An aquifer without an impermeable layer on its upper surface; also called a "water table aquifer".

Underground Storage Tanks: Tanks used to store fuels and other liquids underground. There are usually two or more such tanks at every gas station.

Vadose Zone: The area above the zone of saturation that holds moisture; also called the "unsaturated zone".

Water Budget: A numeric evaluation of all sources of supply to and discharge from an aquifer or a drainage basin.

Water Cycle: The complete cycle of water from its evaporation from bodies of water, movement through the atmosphere, falling back to earth as precipitation, then movement over the earth's surface, and under the earth's surface as ground water, to its eventual discharge and evaporation again from bodies of water.

Water Pollution: The addition of sewage, industrial waste, or other harmful or objectionable material to water in concentrations or in sufficient quantities to result in measurable decline of water quality.

Water Quality: A term used to describe the characteristics of water with respect to its suitability for certain uses. This can include chemical, biological, and physical characteristics.

Water Quality Standards: The lawful limit of a pollutant in water that is established by a governmental authority as part of a program for water pollution prevention.

Watershed: An area of land from which water drains to a single point; in a natural basin, the area contributing flow to a given point on a stream.

Water Table: The upper limit of the part of soil or underlying rock material that is completely saturated with water; the top of the zone of saturation.

Well: A connection to an underground source of water made accessible by drilling or digging to below the water table.

Wetlands: An area of land in which the soils are saturated with water during a portion of the year, and that have vegetation that live in water, or need saturated soils at least for a portion of the year. They include bogs, swamps, marshes, and the shorelines of lakes, rivers and streams.

Zone of Aeration: The unsaturated zone between the land surface and the groundwater table; pores are filled with air and water.

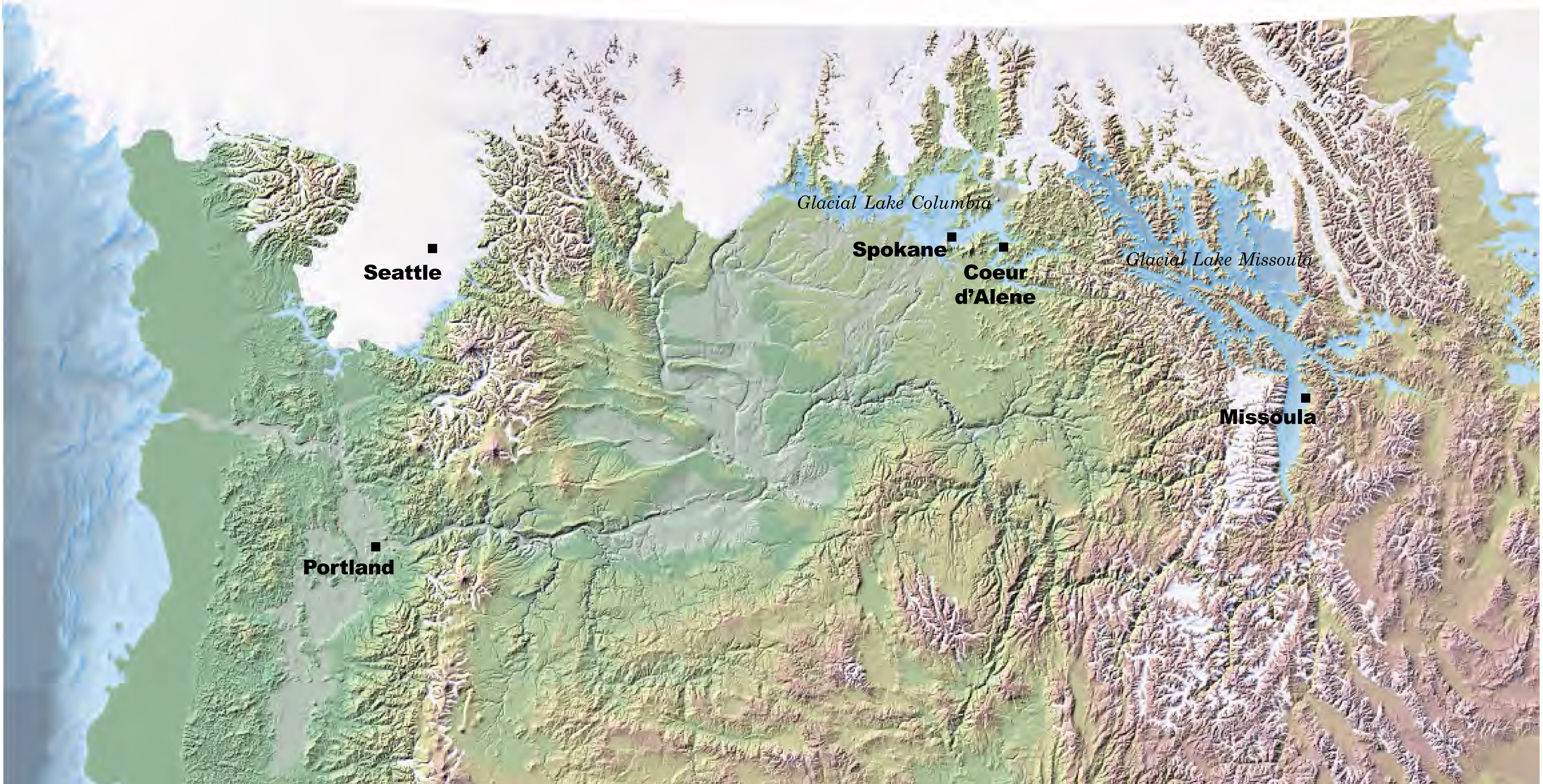
Zone of Saturation: A subsurface zone in which all pore spaces are filed with ground water; below the groundwater table.

Acknowledgements

Creation and publication of this Atlas was the result of faith, hard work and sweat by a small number of people, the Aquifer Atlas Team, whose names appear in the Preface. However, many other people assisted the Team's efforts, and everyone's contribution added measurably to the quality and content of this document. The Aquifer Atlas Team acknowledges the following people for their contributions: Calvin Terada (EPA-Region X), Stan Miller (Spokane County), Connie Grove (Spokane County), Ken Lustig (Panhandle Health District), John Sutherland (Idaho Department of Environmental Quality), and Glen Pettit (Idaho Department of Environmental Quality).

This document was published by the Idaho Department of Environmental Quality under program code 81261, Rathdrum Prairie Aquifer Wellhead Protection Project (other operating expenses). Funds from the United States Environmental Protection Agency grant number X000430-06-0 were used to develop and publish this document. Costs associated with this publication are available from the Idaho Division of Environmental Quality in accordance with Section 60-202, Idaho Code. Publishing cost per unit: $4.07.

Copies of this document may be obtained from Spokane County Utilities Department, (509) 477-3604 or from the Idaho Department of Environmental Quality, (208) 369-1422



The Pacific Northwest During the Last Ice Age: 15,000 to 12,000 Years Ago

This map depicts the Pacific Northwest during the late Pleistocene Epoch based on available scientific evidence. This map presents several interesting conditions relative to modern times. The present city of Missoula, Montana was under Glacial Lake Missoula, the lake responsible for generating the floods that created the Aquifer sediments. Present day Spokane and Coeur d'Alene were also under water from Glacial Lake Columbia that was created when glacial ice blocked the Columbia River. The present location of Seattle, Washington was under a lobe of the glacial ice sheet. The vast amounts of water trapped in the ice sheet caused the Pacific Ocean level to drop about 300 feet, and the ocean shore retreated several miles from its present location. A full-size map developed by Jeff Silkwood, "*Glacial Lake Missoula and the Channeled Scabland*" is available from the United States Forest Service.