HYDROGEOLOGIC ANALYSIS OF
THE SOUTHERN RATHDRUM PRAIRIE AREA, IDAHO

A Thesis

Presented in Partial Fulfillment
of the Requirement for the
DEGREE OF MASTER IN SCIENCE

in the

University of Idaho Graduate School

by

Steven R. Sagstad

April, 1977

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ABSTRACT

Many industrial, municipal and domestic water users on the Rathdrum Prairie depend solely on water from the underlying ground water flow system. The source and character of recharge to the aquifer may be significant constraints on the future development of the Rathdrum Prairie.

The ground water system in the southern portion of the ırum Prairie in Idaho was investigated to determine the cteristics and magnitude of recharge to the glacial er from the Spokane River in the reach between Lake Coeur ıe to Post Falls. Particular emphasis was placed upon curence of zinc in the flow regime, originating from rm mining activities in the Coeur d'Alene-Spokane River . The study, conducted in the summer of 1975, in- easurements of water levels in wells and collection s for quality analysis.

configuration of the water table near the Spokane ıicates recharge through the channel bottom. The logic conditions of the glacial aquifer indicate ıge hydraulic conductivity of 10,000 gallons per day e foot. Results of the study show that fine grained sediments largely control the magnitude of recharge through the channel bottom. The rate of ground water recharge from the Spokane River above Post Falls is estimated to be 230 cubic feet per second (cfs).

Evaluation of the hydrochemical characteristics gives

an important indication of ground water movement and recharge characteristics. Studies of selected cations show that concentrations increase away from the Spokane River into the aquifer system. Comparison of the water quality data reveal that no statistically significant difference exists at the .05 level of significance between the Spokane River and the glacial aquifer adjacent to the river. Concentrations of zinc in the ground water system are found to be generally below 0.01 parts per millon (ppm).

INTRODUCTION

An investigation was initiated in 1975 to analyze the ground water-surface water interrelationship in the vicinity of the Spokane River from Lake Coeur d'Alene to Post Falls in Northern Idaho with particular emphasis on heavy metal concentrations from historic mining activities upstream. Ground water development in the southern Rathdrum Prairie has evolved from primarily domestic and municipal use in the 1950's to an agricultural and enlarged municipal and industrial base at the present time. The southern Rathdrum Prairie area is experiencing one of the fastest population growths in Idaho. This study was conducted to describe the water resources of the area to provide the basis for resource management.

The study area, located in Kootenai County, was limited to the southern portion of the Rathdrum Prairie from the city of Coeur d'Alene on the east to Post Falls on the west. The southern boundary was the edge of the consolidated basement material and the lake. An arbitrary northern boundary lies along the line common to townships 50 and 51 north.

Objectives

The objectives of the study were to:

1. Review and describe the geologic conditions existing in the Coeur d'Alene-Post Falls area.
2. Describe the water resources of the Coeur d'Alene-Post Falls area with specific emphasis on

determining the direction of ground-water movement and the amount of the recharge from the Spokane River into the Rathdrum Prairie aquifer.

3. Determine the control for water movement from the Spokane River into the highly permeable underlying glacial sediments.

4. Measure the concentrations and areal distribution of cations in the ground water and surface water in the Coeur d'Alene-Post Falls area. Particular emphasis was placed on zinc concentrations from historic mining activities in the Spokane River-Coeur d'Alene River drainage.

5. Utilize the quality characteristics of the water resources in the area to identify recharge characteristics to the southern Rathdrum Prairie aquifer.

Description of the Study Area

The Rathdrum Prairie covers an area of approximately 234 square miles in the northern panhandle of Idaho (Figure 1). The Prairie ranges in elevation from 2,450 feet near Pend Oreille Lake in the north, to 2,200 feet near Post Falls, and extends from Lake Coeur d'Alene on the east to the Washington-Idaho border on the west. A thick and extensive fill of very permeable glacial outwash material forms the Rathdrum Prairie.

Granitic and metamorphic (consolidated) rocks form the surrounding mountains and basement complex. The Selkirk Mountains are located northwest of the Prairie, while the

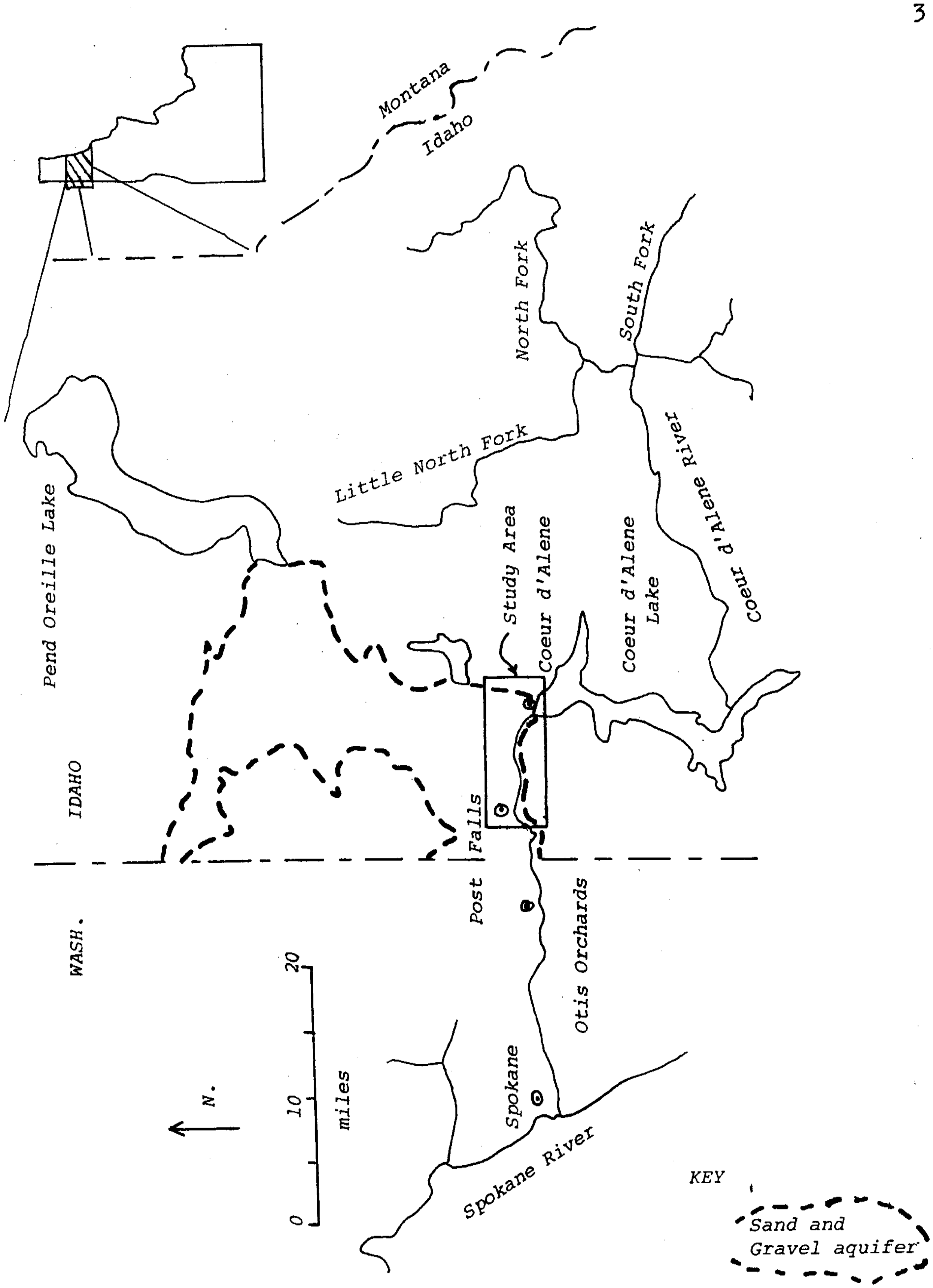


Figure 1 Location of the Coeur d'Alene-Post Falls Study Area

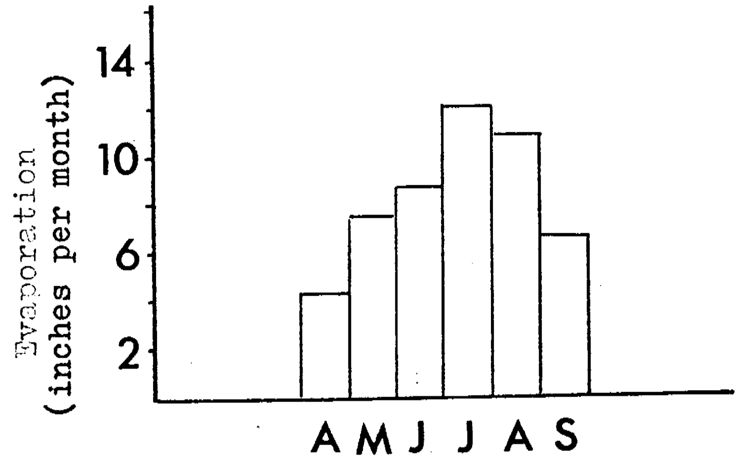
Coeur d'Alene Mountains form the limit of the Prairie to the south and east. The surrounding mountains rise to elevations of 5,000 feet in places.

The climate of the Rathdrum Prairie is influenced by maritime air masses in the winter and semi arid continental air masses during the summer months. Annual climatological data for the Spokane-Coeur d'Alene region are shown in Figure 2. The annual precipitation at Coeur d'Alene, Idaho is 25.03 inches with minimum monthly precipitation occuring in December (U.S. Weather Bureau, 1975). The average daily temperature in July is 70° F. and the average daily temperature in January measures 27° F. The evaporation rates are the highest during July with a maximum pan evaporation rate of 12.14 inches per month.

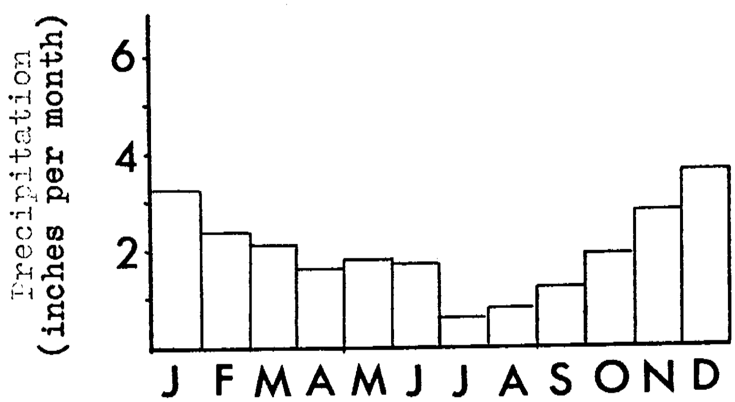
An isohyetal map was constructed using data from 23 climatological stations in the area (Figure 3). The precipitation varies widely with season, elevation and location. Total annual precipitation increases rapidly into the mountains to the east. The change in annual precipitation from south to north varies only slightly. The average precipitation near Mt. Spokane is approximately 40 inches.

The Spokane River is the only major stream crossing the Rathdrum Prairie and is the natural outlet to Lake Coeur d'Alene. It flows westward, eventually discharging into the Columbia River. The Spokane River parallels the southern boundary of the Rathdrum Prairie between Post Falls and Coeur d'Alene.

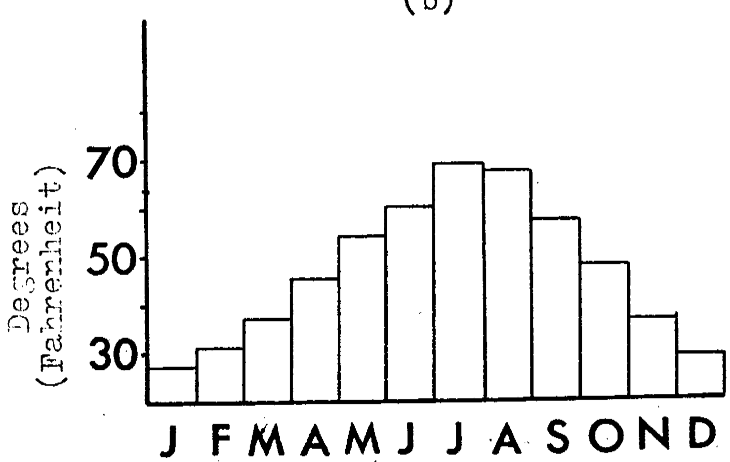
Records of streamflow discharge are available for the gauging station at Post Falls from 1913 to the present (U.S.



Monthly Pan Evaporation
at Spokane
(a)



Monthly Precipitation at
Coeur d'Alene
(b)



Monthly Temperatures
at Coeur d'Alene
(c)

Figure 2 Annual Climatological Data.

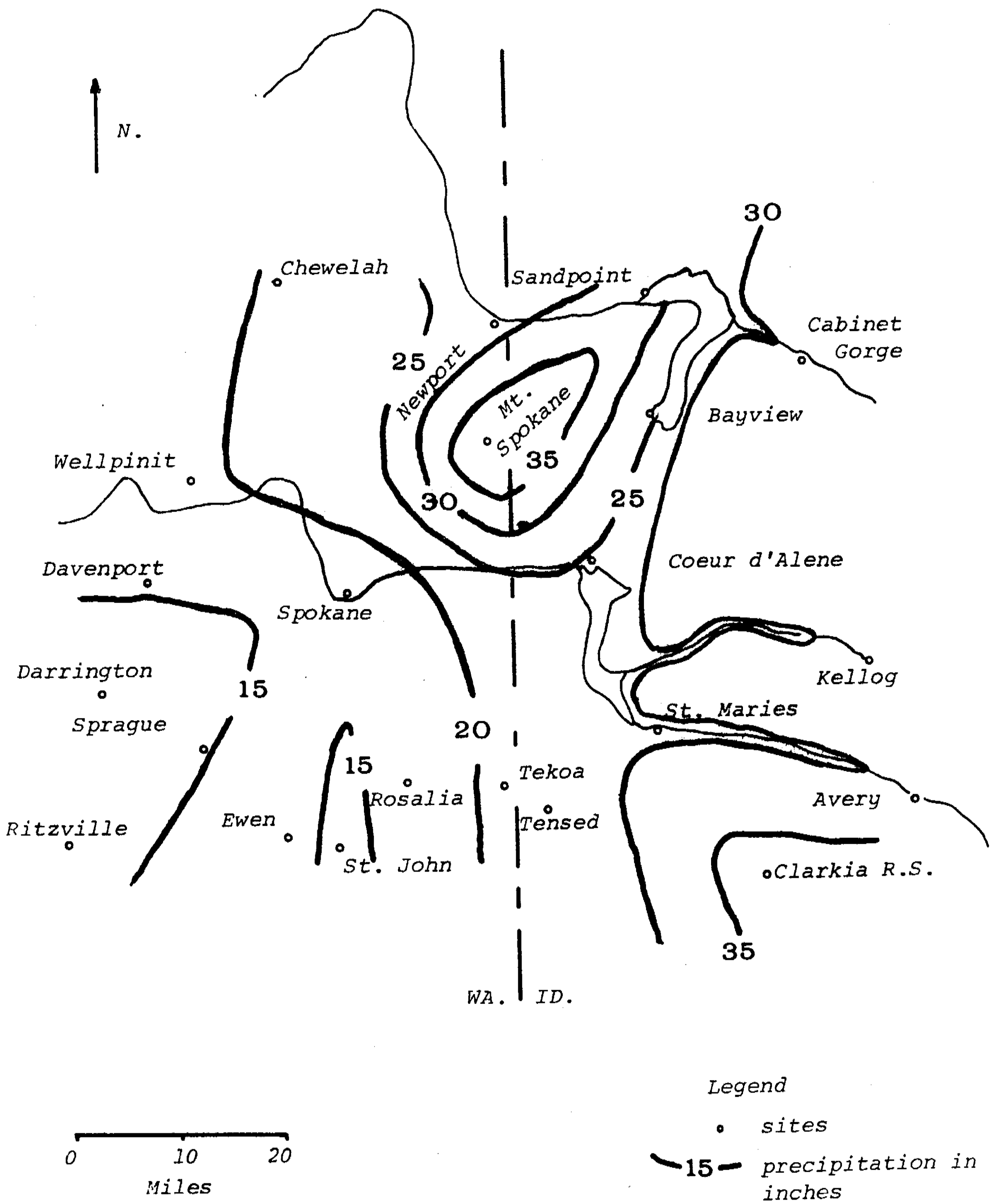


Figure 3 Isohyetal Map of Eastern Wshington and Northern Idaho.

Geologic Survey, 1975). The mean monthly discharge of the Spokane River at Post Falls is illustrated in Figure 4. The peak discharge occurs between April and June, while low flow conditions occur between August and September. The maximum monthly discharge of 575,000 cfs or 1,150,000 acre feet/month occurs in May, while the minimum monthly discharge of 30,000 cfs or 60,000 acre feet/month occurs in August.

The St, Joe and Coeur d'Alene Rivers are the major tributaries flowing into Lake Coeur d'Alene. These rivers comprise a drainage area of over 3,800 square miles above the outlet on Lake Coeur d'Alene. The lake comprises a surface area of 32,000 acres at mean stage and has an active storage capacity of 225,000 acre feet and a total storage capacity of 238,500 acre feet (Pacific Northwest River Basin Commission, 1970).

The relationship between precipitation and runoff in the southern Rathdrum Prairie is influenced by geologic related characteristics. The Prairie is characterized by a gentle slope from the northeast to the southwest underlain by a thick fill of very permeable glacial outwash material. Consolidated rocks form the surrounding mountains. A drainage pattern has not developed on the prairie surface because of the high permeability of glacial outwash. Only a small fraction of the surface runoff is directly tributary to the Spokane River.

Method of Study

Field investigations for the study were conducted during

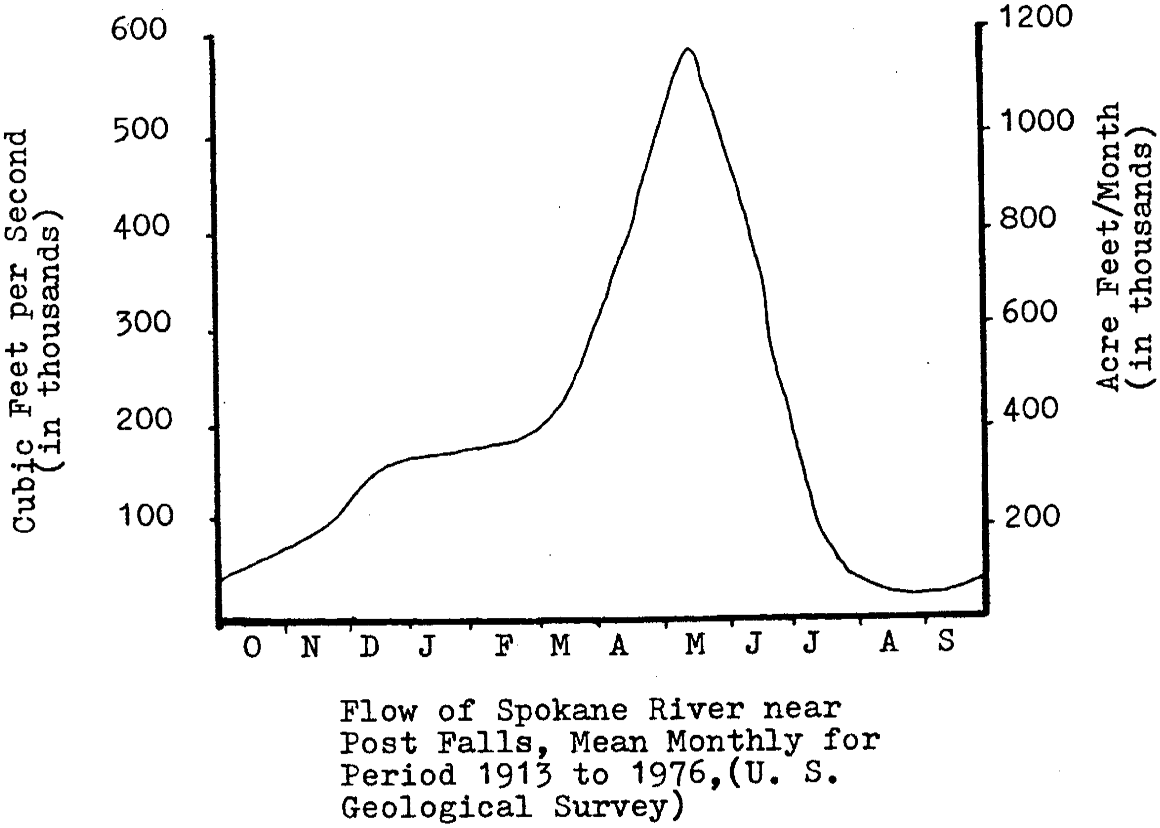


Figure 4 Mean Monthly Discharge of the Spokane River at Post Falls

the months of July thru September, 1975. A data collection program was designed to gather geologic data and information on ground water levels and quality. Geologic data were obtained from published and unpublished reports and well logs. The majority of the wells in the area were visited. Water level measurements were taken to provide information on ground water flow characteristics. Eighty-eight representative water quality samples were collected. These samples were analyzed using the atomic absorption spectrophometer at the University of Idaho and were collected and analyzed in accordance with methods recommended by the U.S. Environmental Protection Agency (1974). Statistical tests were performed on the water quality data to obtain a better idea of the relationship between the aquifer systems and the Spokane River.

Previous Investigations

The interrelationship between the Tertiary basalt flows and the occurrence of micaceous clays in eastern Washington and northern Idaho was first discussed by Russell (1897, 1901). He postulated that the thick accumulations of clays were interbedded between the basalt flows. Pardee and Bryan (1926) described the flora and geology of these clays and named it the Latah formation. They noted that the Latah formation was at least 1500 feet thick in several locations and felt the basalt flows located within the clays were intruded rather than interlayered.

The first geological reconnaissance study of northern Idaho was conducted by Calkins (1909). He described the areal extent of the Belt sediments near Lake Coeur d'Alene and the Spokane River. Anderson (1927) did a study of the drainage changes that have occured in the Rathdrum Prairie as a result of the basalt flows and glacial activity. He felt Pend Oreille Lake was formed by a terminal moraine at least 1,000 feet thick. He postulated that the lake leaks water into the northern Rathdrum Prairie.

An analysis of the Rathdrum Prairie and Spokane Valley fill material was made by Flint (1937). He concluded two periods of aggradation occured in the Rathdrum Prairie, an older deposit of stratified glacial drift and a younger outwash fill. The glacial drift and outwash consist mainly of agrillite and quartzite fragments. Bretz (1923) postulated that several glacial episodes have occured in the Rathdrum Prairie area. He noted that the channel scablands in eastern Washington were formed by glacial fed streams which scoured the area, exposing the underlying basalt. The water originated from the Cordilleran ice sheet which advanced several times into the Rathdrum Prairie.

The first ground water investigation in the Spokane Valley and the Rathdrum Prairie was conducted by Piper and LaRocque (1944). They described the relationship between the Spokane River and glacial outwash aquifer. They noted that the Spokane River from Coeur d'Alene to approximately Otis Orchards was a losing stream while the reach extending west of Otis Orchard was a gaining stream. The U.S. Geological Survey, in conjunction with the U.S. Bureau of Reclamation, initiated a ground water investigation from January, 1949, to December, 1950. In that study, water levels were measured bi-monthly in wells throughout the prairie, and well logs were gathered from most of the wells in the area (Fader, 1951).

A water balance study for the Rathdrum Prairie was conducted by Pluhowski and Thomas (1968). They estimated that the total ground water underflow through the Spokane Valley was approximately 1100 cfs and that recharge from the Spokane River above Post Falls and Lake Coeur d'Alene was about 250 cfs (cubic feet per second).

The ground-water conditions existing in northern Idaho near Athol was described by the U.S. Geological Survey (Hammond, 1974). Gravity geophysical techniques were used to estimate the depth of the glacial outwash in the area. Hammond concluded that the thickness of the glacial outwash near Round Mountain was 1500 feet.

An estimation of the contribution by precipitation to the Rathdrum Prairie aquifer was made by Meneely (1951), He concluded that 6.0 inches of the mean annual precipitation at Coeur d'Alene is consumptively used and the remaining portion of the annual precipitation is direct recharge to the glacial aquifer.

Anderson (1951) conducted a hydrogeological reconnaissance study of the Rathdrum Praire for the U.S. Bureau of Reclamation. He estimated that the quantity of recharge from the Spokane River east of Post Falls to be more than 300 cfs. He noted that coarser gravels and boulders dominated the center of the prairie and graded into finer sands and silts near the margin. The Latah formation may be present below the glacial fill material but could not be determined. A reassessment of Anderson's study by Frink (1962 and 1964) provided a detailed geologic study, a water table contour map and a specific capacity map of the Rathdrum Prairie.

The water resources of Stevens County, Washington was described by Cline (1969). He noted the water bearing geologic units.

Seismic studies at selected sites near the Washington-Idaho border were conducted by Newcomb (1953) and Crosby and others (1971). The depth to consolidated bedrock and the types of fill in the Rathdrum Prairie and the Spokane Valley were examined. Newcomb postualted the presence of basalt and Latah clays beneath the glacial fill materials, but Crosby concluded the valley fill materials are all glacial fill materials. He noted that the glacial outwash three miles west of Post Falls was 500 feet thick. Considering this thickness and the range in depth to ground water of 130 to 270 feet, the saturated thickness of the aquifer may be as great as 350 feet. Crosby also noted that basalt and Latah clay occur as scattered remnants throughout the Prairie.

Rorabaugh and Simmons (1966) proposed that artifical recharge from the Spokane River to the glacial outwash aquifer could be achieved. Water would be recharged into the aquifer during peak runoff periods. Eventually the ground water would be discharged into the Spokane River.

Well Number System

The U.S. Geological Survey has used a well numbering system in the state of Idaho to locate wells with reference to the Boise Baseline and Meridian (Figure 5). The example of well 51/4/21ccb1 will be explained. The first two parts of the number signify the township (51) and range (4). All townships will assume to be north of the Boise Baseline and all ranges west of the Meridian. The third part gives the section number (21) followed by the quarter section (c), the 40 acre tract (c), and the ten acre tract (b). The last number signifies the well number within the ten acre tract (1).

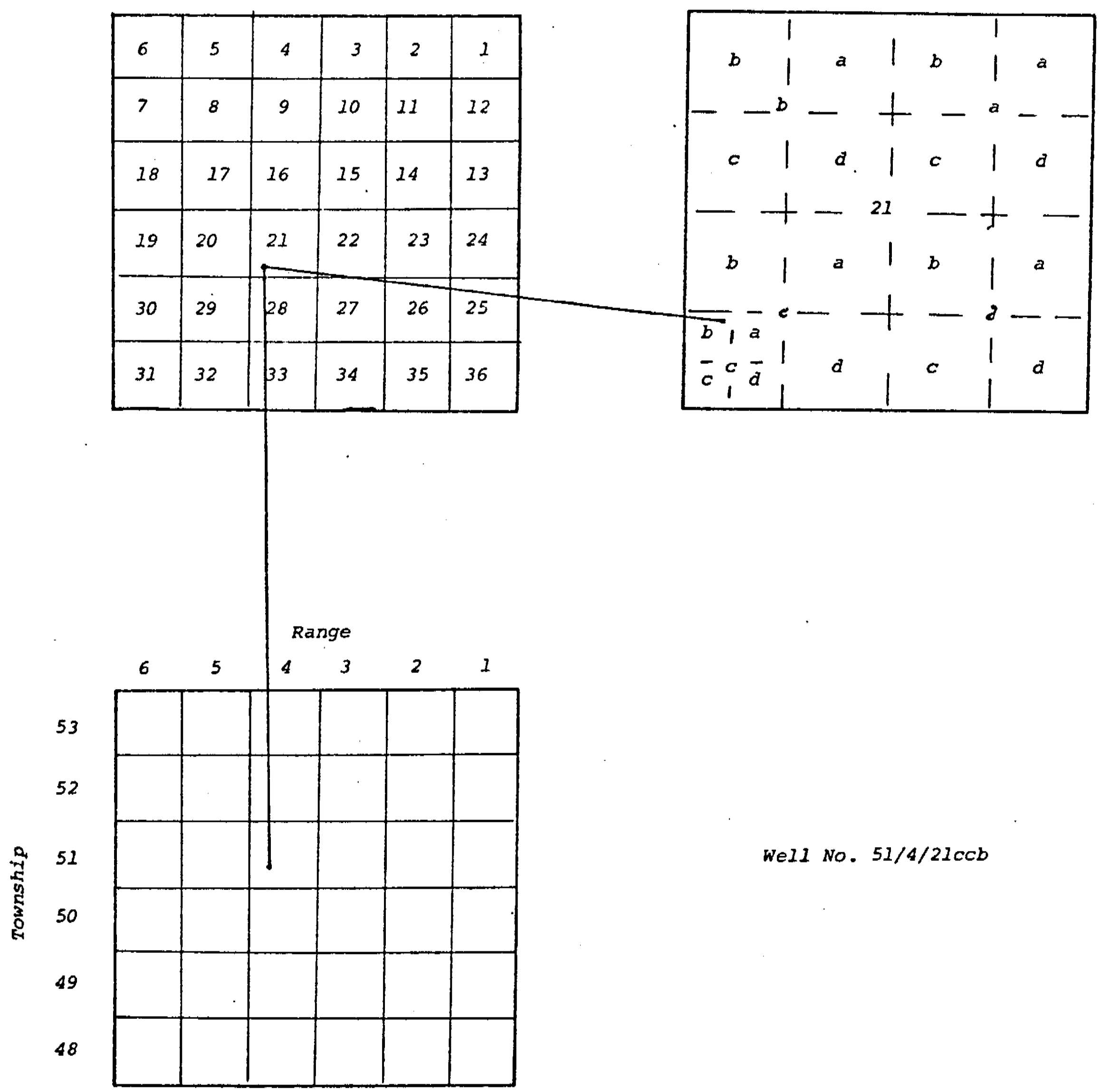


Figure 5 Well Numbering System

HYDROGEOLOGIC CHARACTERISTICS

The hydrogeologic characteristics of the southern Rathdrum Prairie were analyzed to describe the control for water movement from the Spokane River into the glacial aquifer and determine the direction of ground water movement. The major sources of recharge to the glacial aquifer are direct precipitation upon the permeable soils of the Rathdrum Prairie and downward percolation from the Spokane River.

The water bearing rock units in the study area consist of the Pre-Tertiary igneous and metasedimentary rocks, Tertiary basalts and clays, Quaternary glacial deposits and Recent alluvium. Ground water occurs in the glacial aquifer under water table conditions. Ground water levels generally rise during the late winter and spring, and decline through the summer and fall. The configuration of the water table near the Spokane River indicates movement away from the river, between Post Falls and Coeur d'Alene.

Geohydrologic Rock Units

A reconnaissance study of the hydrogeological conditions existing in the Coeur d'Alene-Post Falls area was conducted in the summer of 1975. Most geologic information in this thesis was obtained from publications, reports, well logs, and personal communications with local residents. Feild investigation were conducted to substantiate the basic information and describe local areas of interest. Well logs for the area were supplied by the Idaho Dept. of Water Resources. Data from drilling operations in the Spokane River channel were obtained from the Idaho Dept. of Highways (1975). A general geologic map of the area is provided in Figure 6.

The Rathdrum Prairie is bounded on the south by what is termed the highlands. These mountains and bedrock system rocks underlying the prairie are composed of relatively impermeable Pre-Tertiary igneous and metasedimentary rocks of the Belt Supergroup (Griggs, 1973). Several small basalt terraces and outliers lay just to the south of the Spokane River. The Rathdrum Prairie is underlain by an extensive fill of highly permeable Quaternary glacial deposits of generally unknown depth. Recent alluvium occurs as streambed and floodplain deposits located near the present channel of the Spokane River.

Pre-Tertiary Consolidated Rocks

Pre-Cambrian granitic and metasedimentary rock units, generally considered the Belt Supergroup, form the highlands south of the Spokane River and comprise the basement rocks underlying the Rathdrum Prairie. Calkins (1909) was the first to investigate the Belt sediments. Anderson (1940) divided the Belt sediments in Kootenai County, Idaho, into six formations and identified them as the Pritchard, Burke, Revet, St. Regis, Wallace, and Striped Peak formations. More than 25,000 feet of Pre-Tertiary sediments are estimated to exist in Kootenai County (Anderson, 1940, p. 10). Griggs (1973) delineated the Pre-Tertiary rocks in the study area and des-

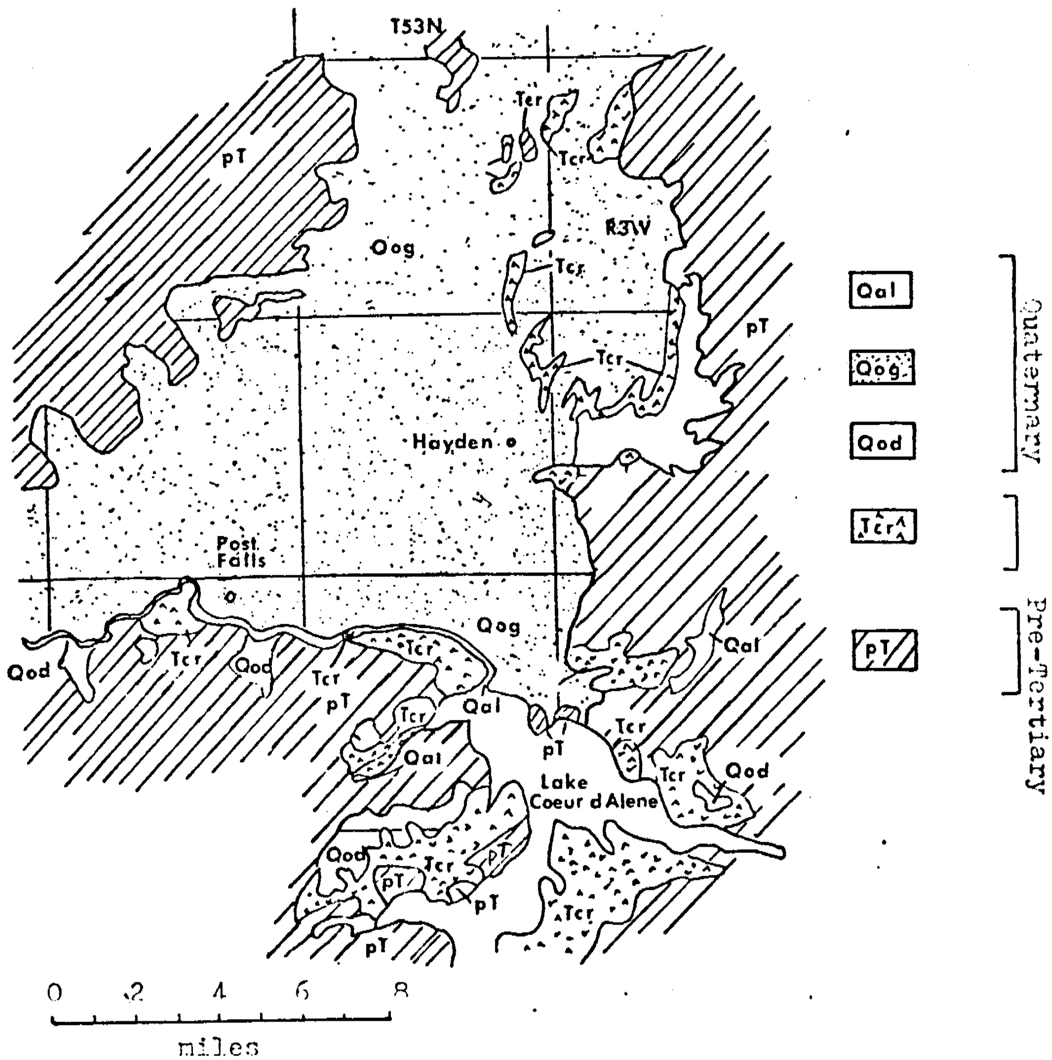


Figure 6 Generalized Geologic Map of the Rathdrum Prairie and Adjacent Area (after Hammond 1974).

cribed the rock units as the Pritchard formation. The metasediments in the study area are extremely fine grained, considered undifferentiated gneisses , quartzites, shales, argillites, and impure limestones. Calkins (1909, p. 28) noted that they were deposited in shallow waters. No conglomerates are observed in the series. Ripple marks and sun cracks occur throughout most of the series (Anderson 1940, p. 10).

The Pre-Tertiary rocks are exposed along road cuts in the Coeur d'Alene mountains. Quartzites, argillites, and metagneisses are exposed along the Green Ferry Road south of Coeur d'Alene. Pre-Tertiary rocks are exposed at two locations on the southern Rathdrum Prairie: Ford Rock near Post Falls and Tubbs Hill on the southern margin in Coeur d'Alene. With the exception of a few wells on Harbor Island which encountered granitic or basalt bedrock, no consolidated rocks were detected underlying the glacial outwash materials at depths less than 400 feet.

Wells drilled in the older consolidated rocks are used for domestic purposes and generally yield only small quantaties of water. Ground water occurs in localized fracture systems and upper weathered zones. Near land surface, where rock units are weathered deeply, local ground water discharge zones occur along steep slopes during the spring runoff period. The depth to ground water varies from ten feet to greater than 100 feet below land surface. Well logs show that subsurface flow is common along the weathered-unweathered contact. Yields generally do not exceed five gallons per minute with many wells yielding less than one gallon per minute.

Latah Formation

A thick sequence of fine grained sediments, largely silts and clays, generally underlie or are interbedded with Tertiary basalt flows throughout eastern Washington and northern Idaho (Russel 1897, 1901). Pardee and Bryan (1926) proposed the name "Latah Formation" to these series of fine grained sedimentary layers. The sediments were probably deposited in a lake or fresh water environment. The Latah sediments in the Washington-Idaho area were deposited directly upon the unconsolidated granitic or basalt rock surface. Whether they exist as scattered remnants beneath the glacial outwash sediments in the Spokane Valley and the Rathdrum Prairie at unknown depths is a major controversy.

The lacustrine sediments were noted by Pardee and Bryan (1926) to be composed of micaceous shale and clay, with sporadic layers of sand and gravel occuring throughout the sequence. They are relatively impermeable. Pardee and Bryan also stated a basalt conglomerate rests directly upon the consolidated rock surface and grades upwards to the clay and shales. This conglomerate bed may provide sufficient quantities of water for domestic use near the consolidated rock margins along the Valley borders.

The thickness of the Latah formation may be as much as 1500 feet in many localities (Pardee and Bryan 1926), but generally are only 100 to 300 feet thick throughout Washingtion and Idaho (Kirkham and Johnson, 1929, p. 501). Savage (1975) noted a thick sequence of Latah sediments along the highlands south of Coeur d'Alene. The thick sequence of sediments are for the most part absent in the southern Rathdrum Prairie area. Several investigators have tried to locate the Latah formation in the Spokane Valley and Rathdrum Prairie using geophysical methods. Newcomb and others (1953), using seismic techniques, postulated that the Latah formation could exist at depths below elevations of 1600 to 1750 feet above mean sea level along the western edge of the Rathdrum Prairie near Post Falls. Crosby and others (1971, p. 103) utilized seismic techniques near the state line area, and felt that the Latah formation is absent beneath the glacial outwash sediments. The presence of the Latah formation can only be confirmed by a drilling program. Scattered remnants may exist throughout the Spokane River-Post Falls area. A well (50/4/3cc1) located on the outskirts of Coeur d'Alene, shows a thickness of 72 feet of green clay which is underlain by two feet of quicksand. This well log illustrates the possiblity of erosional remnants lying beneath the glacial sediments. Four other well logs in 50/4/3 show no similar clay layers. The impermeable clay lense appears to be localized in areal extent and does not form a major barrier to water movement.

Wells in the southern Rathdrum Prairie have not been drilled to Newcomb's postulated upper horizon of 1750 feet. It cannot be concluded that the Latah formation does not exist at these depths, but it is reasonable to assume that the Latah formation does not exist in the upper 200 to 400 feet of the glacial outwash material other than as scattered remnants. The Latah formation is thus not present beneath the Spokane River channel at shallow depths and does not form a barrier for water movement down into the glacial aquifer.

Tertiary Basalt

Tertiary age basalt is very limited in areal extent in the study area. The basalt is located on the highlands to the south of Coeur d'Alene and occurs as an erosional remnant on Harbor Island, situated in the Spokane River (Figure 6). Only a few wells penetrate the basalt within the study area.

Pardee and Bryan (1926) felt two seperate periods of basalt flows occured in the Spokane Valley, noting an earlier "rim rock" flow and a later valley flow. They also noted that rim rock lies approximately above the 2200 foot contour whereas the Valley fill basalt reaches it highest elevation at the 2100 foot contour near the city of Spokane.

At one time, thick basalt flows extended north up through the Rathdrum Prairie and southeast into the Coeur d'Alane River basin (Anderson 1940, p. 26). Since Tertiary time, erosional processes and glacial activity have removed all but scattered rim rock sections adjacent to the Prairie boundaries.

Basalt is found both overlying the Latah formation (Savage 1975) and resting upon the consolidated rock units in the study area. The basalt is composed of horizontally lying layers of dark gray to black, dense basalt. The general features of the basalt are columnar jointing located near the top of the flow. Road cuts that expose the basalt prominently display these characteristics.

Basalt was not found to exist beneath the glacial outwash sediments in the study area. Basalt occurs as an erosional remnant on Harbor Island. This basalt outlier forms a ridge extending one fourth of a mile long in an east-west direction reaching an elevation of 2125 feet. The flow extends to a depth of approximately 1900 feet (well 50/4/8bb1).

Basalt yields only small amounts of water in the study area. Water generally moves downward through joints and fractures and horizontally along flow contact zones. Only one well (50/4/8bd) is known to obtain water from the basalt. Vertical leakage of river water occurs through the basalt. In one instance a well (50/4/8bcd) was drilled through 110 feet of sand and 80 feet of basalt before obtaining sufficient quantity of water for domestic use in a thin zone of sand below the basalt zone.

Older Glacial Sediments

The older Quaternary glacial deposits are observed overlying the Pre-Quaternary rocks in the highlands south of the Spokane River. The deposits are predominantly stratified and well sorted opposed to the poorly sorted younger glacial outwash. The deposits generally overlie basalt and the older consolidated rocks in the study area. These deposits are composed of basaltic fragments, gneissic and argilletic sediments generally derived from the surrounding rocks. A gravel pit, (51/4/15bdd) located just off the Green Ferry Road, exposes about 50 to 70 feet of sand and gravel. The contact between an underlying basalt layer and the glacial sediments shows fine sand in contact with the basalt. Data from well logs and local residents indicate this feature is common in the area.

The thin deposits of sand and gravel serve as shallow aquifers for homes in the area. These deposits overlap the consolidated rocks. The yields are generally small due to the shallow thickness and small areal extent of the sediments.

Younger Glacial Outwash

The younger glacial outwash consists of unconsolidated cobbles, gravels, sands, silts and clays. The deposits are poorly to moderately sorted (Flint, 1936). The glaciofluvial sediments comprise the Rathdrum Prairie and the Spokane Valley fill materials. The material ranges from coarse sands and gravels to sand and silts near the southern margin. Anderson (1915) also stated that coarse gravels and sands occur in the center of the valley while they laterally grade to finer sands, gravels and silts near the Prairie margin.

The thickness of the deposits in the study area is unknown, but extends at least 400 feet below land surface. Wells which penetrate these deposits have not encountered the consolidated rocks. The depths to the consolidated basement rocks increases quickly away from the Prairie margins, as indicated by geophysical profiles (Purves 1966, Newcomb and others, 1953).

The total thickness of the glacial material was estimated by Crosby and others (1971) to be 500 to 600 feet near the state line on the basis of geological and geophysical data.

The depth to the water table ranges from 100 to 300 feet. Newcomb and others (1953) estimated that saturated thickness of the glaical outwash to be 200 to 250 feet at a site northwest of the study area. A reassessment of the thickness of the saturated glacial outwash by Crosby and others (1971) indicated saturated thickness to be approximately 350 feet. The city of Coeur d'Alene well (50/4/4ccd) has a total depth of 350 feet and a saturated thickness of 125 feet, all in the glacial material.

The glacial aquifer produces the largest yields to wells in the Coeur d'Alene-Post Falls study area. Coarse sands, gravels and cobbles comprise the unconfined glaical aquifer. Yields to wells penetrating the glacial material are large, ranging up to several thousand gallons per minute. The saturated thickness in the study area probably is between 150 and 300 feet. Well 50/4/4aa has the largest known yield in the study area. The well was pumped at 6,000 gallons per minute for one hour with twenty-three feet of drawdown (City of Coeur d'Alene Water Dept., 1975).

Alluvium

Deposits of recent alluvium overlie the unconsolidated glacial outwash. The alluvial materials consist of streambed and floodplain sediments located near the present channel of the Spokane River (Griggs, 1973). The alluvium extends beneath the river channel and ranges in thickness from a few feet to thrity feet. The alluvium is composed of clay, silts, sand and some gravels.

Two characteristics of the deposits were noted from well log data provided by the Idaho Dept. of Highways. First, the streambed sediments change vertically from mixtures of silted sands and gravels near the top to cleaner sands and gravels simular to the underlying glacial outwash. Second, the channel sediments exhibit lateral changes in lithologic character. Coarse sands with layers of silt are found in the streambed near the Lake Coeur d'Alene outlet. Downstream near Post Falls, a more fine grained zone of silty sand and gravel occurs throughout the streambed. It is likely the silty sand and gravel layer is continuous over the whole reach of the river channel. The characteristics of the recent alluvial material are important in controlling movement of water from the Spokane River into the ground water system.

Ground Water Flow System

Regional Ground Water Movement

Ground water in the Rathdrum Prairie and Spokane Valley is under water table conditions. Anderson (1951) and Frink (1964) canvassed wells and measured ground water levels in the prairie. The results of Anderson's study are presented in Figure 7. The regional flow of ground water is southwest from

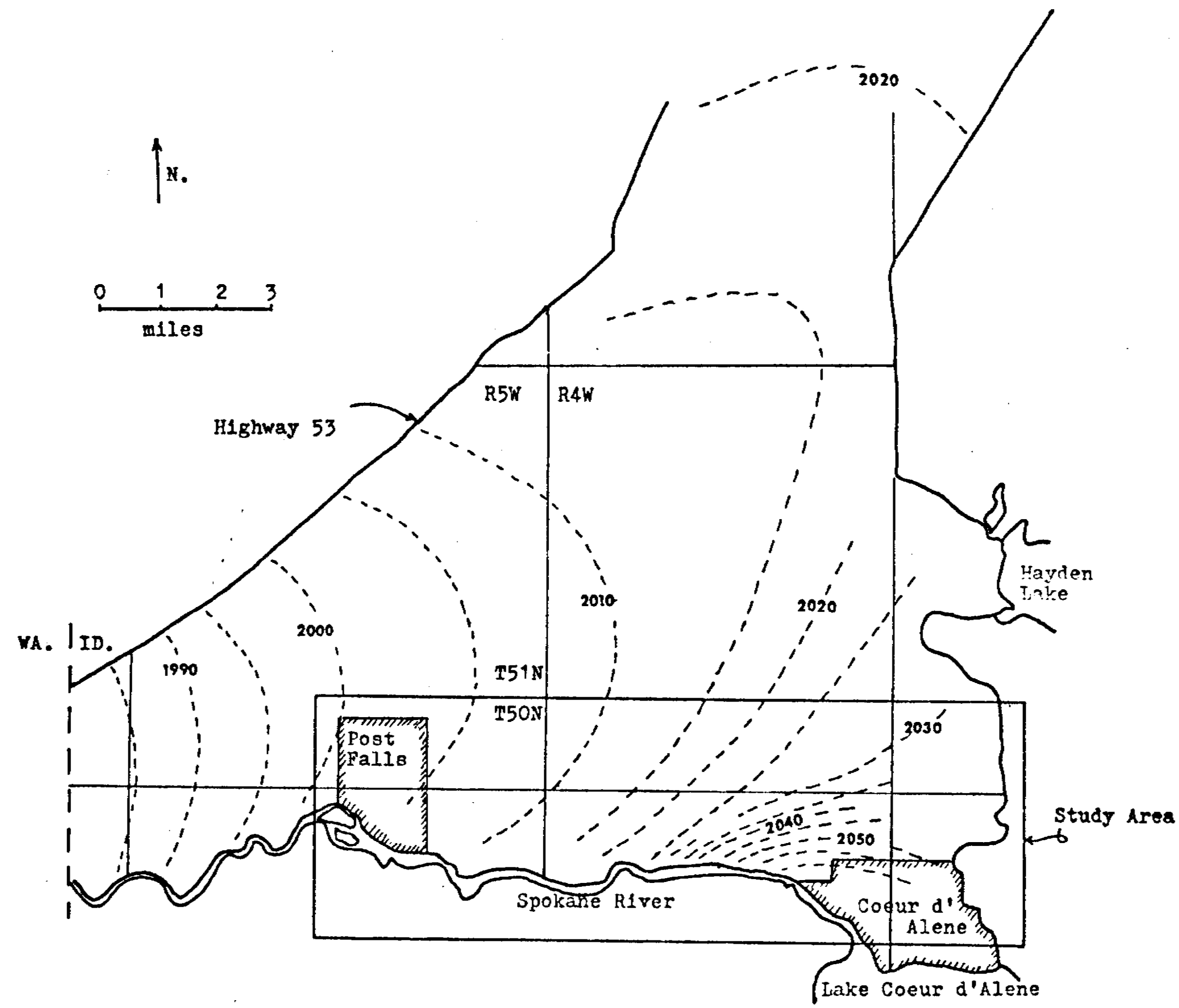


Figure 7 Regional Ground-water Table Map (after Anderson, 1951)

Athol toward Spokane. The principle sources of recharge to the aquifer are runoff from the surrounding mountains, infiltration from precipitation, leakage from Hayden and Pend Oreille Lakes, irrigation seepage, and movement of water from the Spokane River (Pluhowski and Thomas, 1968). The Spokane River is a losing stream above Otis Orchards and a gaining stream below Otis Orchards (Figure 1). Most of the ground water from the Rathdrum Prairie aquifer is discharged into the Spokane River below Dartford.

The water table slopes uniformly from Athol to Spokane. The water table gradient ranges from 30 feet per mile to one foot per mile with an average gradient of three feet per mile. Variations in the gradient are attributed to changes in hydraulic conductivity and local recharge characteristics. Depth to water beneath the Prairie varies from 75 to 375 feet. The depth to water generally increases from west to east.

The regional ground water map illustrates two flow systems in the southern Rathdrum Prairie. The water table contours in the study area indicate ground water movement away from the Spokane River; upstream of Post Falls, ground water to the north of the study area originates from Lake Pend Oreille. A ground water divide is located at the northern boundary of the area of study and extends north of Hayden Lake to Post Falls (Figure 7). The presence of two flow directions are important when considering a water balance for the Rathdrum Prairie glacial aquifer.

Ground Water Movement in the Study Area

The elevation of the ground water surface in selected wells in the unconfined aquifer of the southern Rathdrum Prairie was collected to determine the direction of ground water movement and detect historic water level changes. Measurements of depth to water were obtained from a network of 52 wells in the study area. Water levels were measured using a steel taple or electric tape. The measurements were collected within a five day period (September 15-19, 1975) to minimize the effects of seasonal ground water level fluctuations. All the data are presented in Appendix I.

The configuration of the ground water table in the Coeur d'Alene-Post Falls portion of the Rathdrum Prairie was based upon the 1975 data shown in Figure 8. The data on depth to water was converted to elevation above mean sea level using land surface elevations surveyed by previous investigations (Nace and Fader, 1951) or estimated from a U.S. Geological topographic map.

The water level configuration indicates ground water movement away from the Spokane River. Low permeability consolidated rocks form the southern and eastern boundaries for the glacial outwash aquifer. The contribution of ground water from these rocks to the glacial aquifer is believed negligble. The contours indicate that recharge is occurring from the Spokane River and Lake Coeur d'Alene into the ground water system. Water is believed to percolate downward through the river bottom, entering the ground water flow system with flow

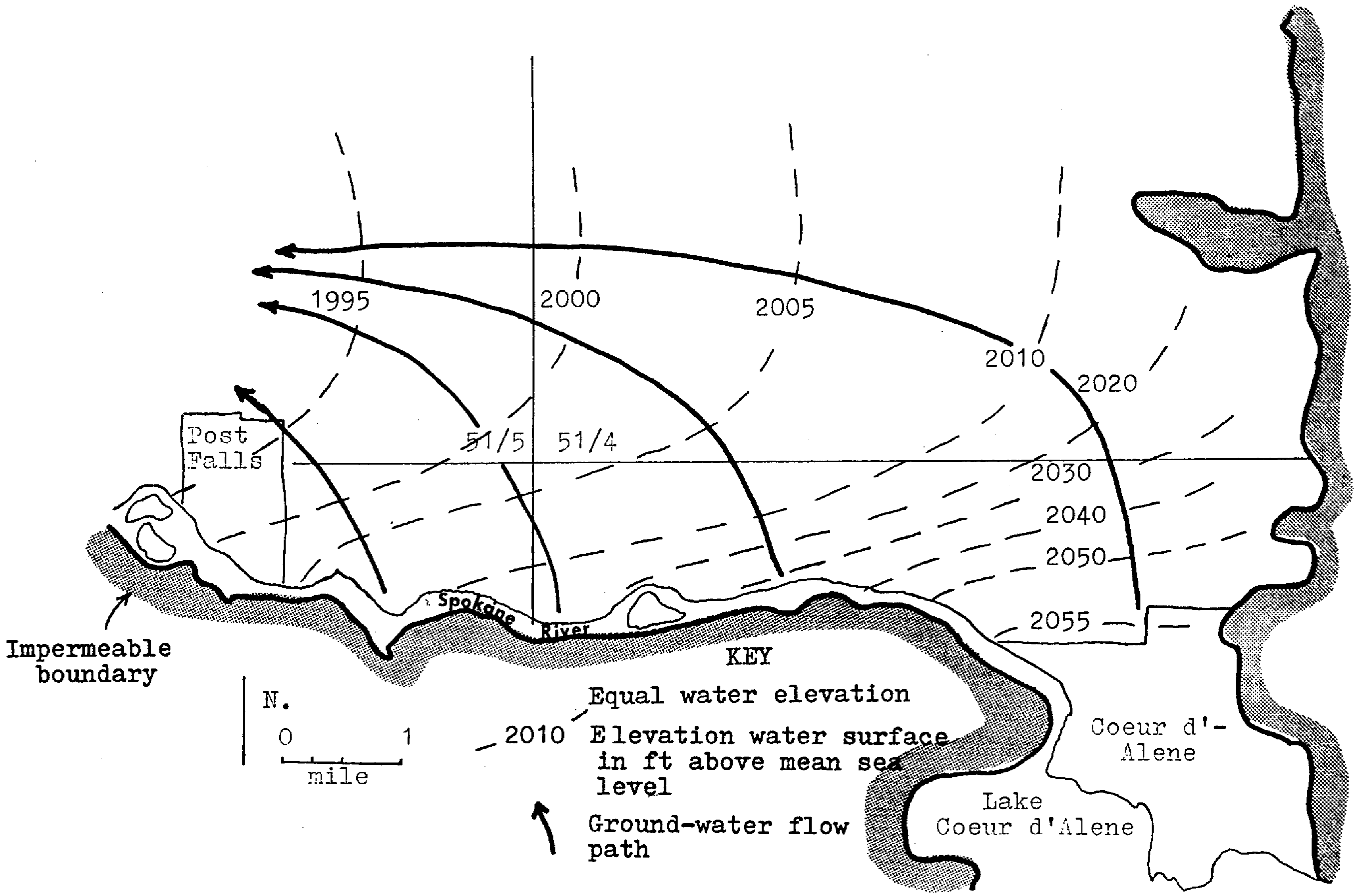


Figure 8 Contours of water level elevation, southern Rathdrum Prairie Study Area

in a general north-northwest direction. The steep gradient of thirty feet per mile in the ground water flow system near the city of Coeur d'Alene indicates either a major recharge area or a local zone of lower hydraulic conductivity. The flatter water table gradient of three feet per mile to the northwest probably indicates higher transmissive characteristics.

The water table contours in the study area resemble the gradients noted in the regional ground water table map. The water table was about ten feet higher in 1949 than that noted in 1975. A ground water divide begins to develop in the northern part of the study area, similar to that of the 1949 study. The ground water divide seperates two distinct flow directions, that of the Rathdrum Prairie and the Coeur d'Alene-Post Falls area.

Ground Water Level Changes

The Rathdrum Prairie aquifer is a dynamic system responding to periods of recharge and no recharge. Direct precipitation upon the Rathdrum Prairie and streamflow infiltration are considered possible sources of recharge to the glacial aquifer east of Post Falls. The cumulative departures of precipitation and streamflow from the mean monthly and mean annual totals are compared to historic ground water levels in the southern Rathdrum Prairie to detect recharge trends.

Seasonal ground water level fluctuations

The only sources of recharge to the Rathdrum Prairie aquifer are direct precipitation and surface water infiltration.

Weekly water level measurements from January, 1973 to August, 1975 are available for two wells being monitored by the U.S. Bureau of Reclamation and four city of Coeur d'Alene wells. The hydrographs for well 51/5/28dd1 and 50/4/22cb are compared with plots of cumulative departures of mean monthly precipitation and stream flow in Figure 9. The mean monthly precipitation, departures and cumulative departures from mean monthly precipitation at Coeur d'Alene for the period of January, 1973 to September, 1975 are presented in Table 1. Mean monthly streamflow, departures and cumulative departures from mean monthly streamflow for the Spokane River at Post Falls for the same period are given in Table 2.

A correlation is observed between mean monthly cumulative departures from precipitation and streamflow and ground water level fluctuations in Figure 9. Between January and October, 1973, cumulative deficiencies are shown for both precipitation and streamflow. The ground water levels responded by declining seven feet for the same period. The below normal precipitation is believed to have caused the water levels to decline. The ground water levels rose sixteen feet from October, 1973, to July, 1974 corresponding to a cumulative precipitation excess of 13.2 inches. The minimum ground water levels of 1974 were more than nine feet higher than levels in 1973. The ground water level trends in 1975 continued to respond to cumulative departures from precipitation. Seasonal water level changes are effected by either precipitation or streamflow patterns.

The Washington Water Power Co. stores water in Lake

Table 1 . . . . Monthly Precipitation at Coeur d'Alene, Idaho

(all values in inches) U.S. Geol. Survey (1975)

Year	Month	Precipitation in Inches	Departures from Normal*	Cumulative Departures
1973	January	2.96	-.38	-.38
	February	.95	-1.50	-1.88
	March	1.69	-.49	-2.37
	April	.95	-.73	-3.10
	May	1.48	-.36	-3.46
	June	.99	-.80	-4.26
	July	.00	-.65	-4.91
	August	.16	-.69	-5.60
	September	2.10	+.79	-4.81
	October	1.14	-.84	-5.65
	November	8.76	5.86	+.21
	December	5.42	1.76	1.97
	Total	26.60		
1974	January	7.54	4.20	6.17
	February	2.84	.39	6.56
	March	3.24	1.06	7.62
	April	1.76	.08	7.70
	May	1.82	-.02	7.68
	June	.76	-1.03	6.65
	July	1.56	.91	7.56
	August	.75	-.10	7.46
	September	.54	-.77	6.69
	October	.06	-1.92	4.47
	November	3.59	.69	5.46
	December	3.21	-.45	5.01
	Total	27.67		
1975	January	4.50	1.16	6.17
	February	3.95	1.50	7.67
	March	2.43	.25	7.92
	Arpil	2.00	.32	8.24
	May	1.31	-.53	7.71
	June	1.77	-.02	7.69
	July	1.78	1.13	8.82
	August	2.14	1.29	10.11
	September	0.00	-1.31	8.80
	Total	19.88		

*Normal is defined as mean monthly precipitation.

Table 2 . . . . Monthly Flow of Spokane River at Post Falls, Idaho (all values in cubic feet per second) U.S. Geol. Survey (1975)

Year	Month	Streamflow in cfs-day (thousands)	Departures from Normal* (thousands)	Cumulative Departures (thousands)
1973	January	158	-7	-7
	February	126	-70	-77
	March	146	-103	-181
	April	166	-283	-464
	May	182	-431	-895
	June	95	-236	-1131
	July	28	36	-1096
	August	18	6	-1090
	September	45	15	-1074
	October	47	-10	-1085
	November	92	-2	-1087
	December	332	178	-909
	Total	1435		
1974	January	630	464	-445
	Februay	384	185	-260
	March	283	33	-227
	April	633	184	-43
	May	780	166	122
	June	801	470	592
	July	163	104	696
	August	41	19	716
	September	45	16	731
	October	53	-47	727
	November	63	-30	969
	December	61	-94	602
	Total	3937		
1975	January	87	-79	522
	February	93	-105	417
	March	202	-48	368
	April	231	-218	150
	May	701	87	237
	June	555	223	462
	July	94	35	497
	August	49	26	524
	September	53	24	548
	Total	2065		

*Normal is defined as mean monthly streamflow.

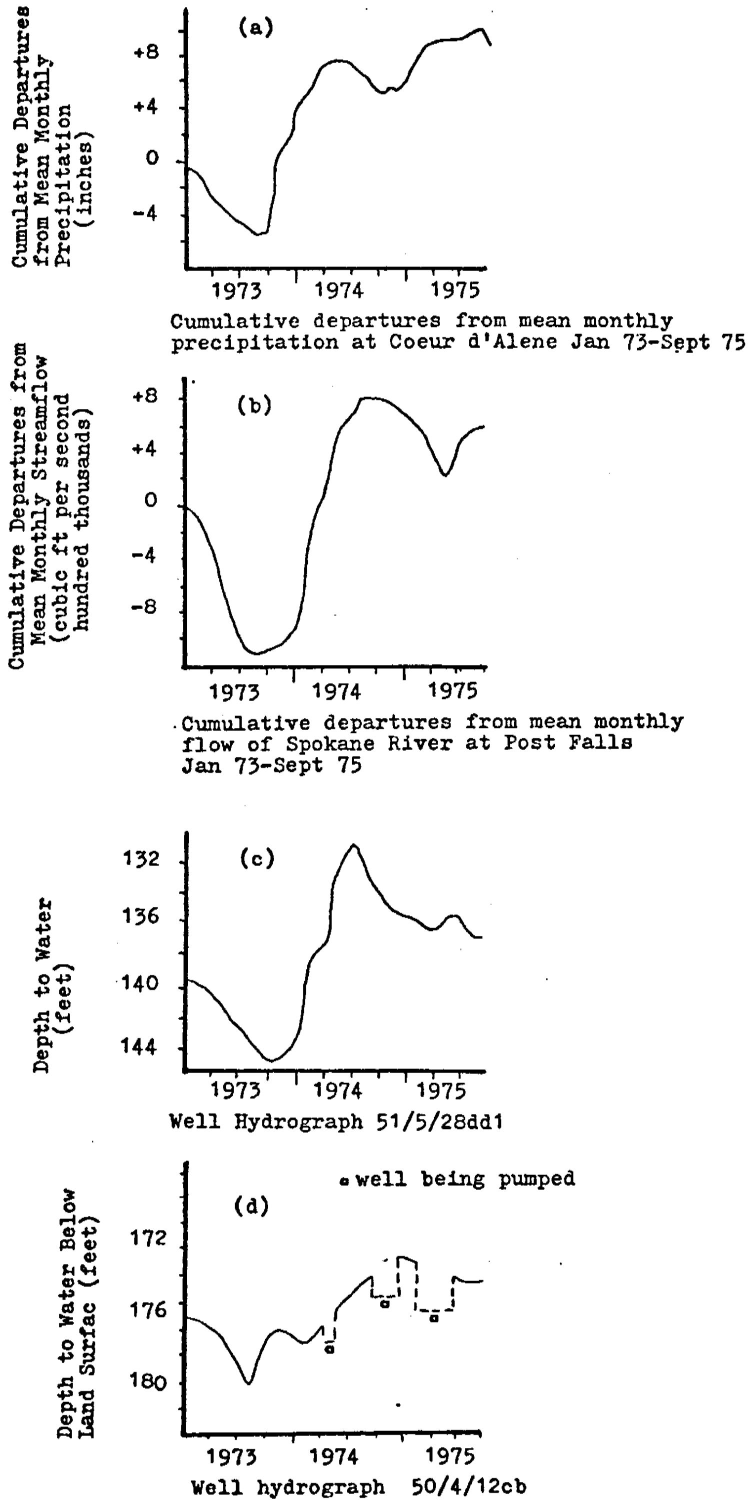


Figure 9 Hydrographs of Wells 51/5/28dd1 and 50/4/12cb and Cumulative Departures from Mean Monthly Precipitation and Flow of the Spokane River at Post Falls.

Coeur d'Alene by regulation at Post Falls Dam for power generation. Storage is within the natural storage area of the lake and river. The lake and river levels provide a variable head source of water available for movement into the underlying glacial aquifer. It is believed that the varying stage levels of the Lake Coeur d'Alene-Spokane River during low and high runoff periods affects recharge rates and timing into the glacial aquifer.

Long term ground water level changes

The long term pattern of ground water level changes in the southern Rathdrum Prairie were compared with long term precipitation and streamflow data for the Coeur d'Alene region. Thirty-three years of continuous water level measurements (1942-1975) were available from a U.S. Geological Survey observation well (51/5/33bba) in the southern Rathdrum Prairie. Cumulative departures from mean annual precipitation and streamflow were compared to the well hydrograph in Figure 10.

A trend is observed between long term ground water level changes and the cumulative departure from the mean annual precipitation. During years of heavy precipitation, the ground water levels rise and during drier periods the water levels decline. No trend was observed between streamflow and ground water levels. No indication of long term water level declines were observed.

Ground water level measurements in 1949 and 1964 were compared with ground water level measurements taken during the

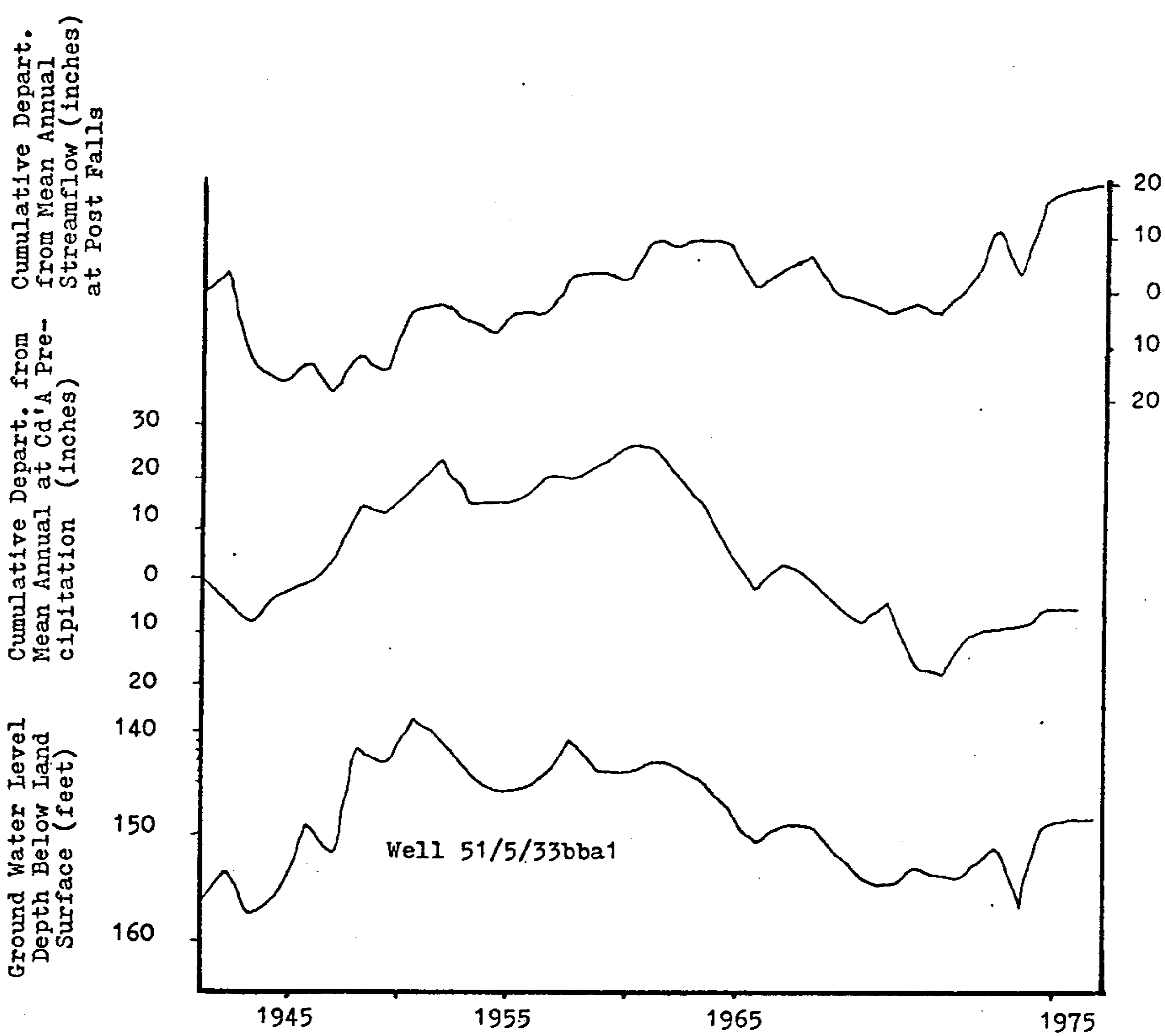


Figure 10 Hydrographs of Well 51/5/33bba1 and Cumulative Departures from Mean Monthly Precipitation and Flow of the Spokane River at Post Falls.

summer of 1975 to determine long term changes in ground water levels in the study area. Of the network of 52 wells chosen for water level measurements in 1975, only seventeen were measured in either 1949 or 1964. Table 3 reveals the water level changes that occured between 1949, 1964 and 1975.

Ground water level declines were observed in the study area between 1949 and 1964. Water levels were relatively unchanged over the past twelve years. No wells showed a ground water rise between 1949 and 1975. The variations in the ground water levels indicate similar recharge characteristics as noted in well 51/5/33bba in Figure 10. Precipitation and surface water infiltration are probably the major contributions to the glacial aquifer system.

Hydraulic Conductivity

Glacial Aquifer Hydrologic Characteristics

The hydrologic characteristics of the glacial aquifer in the study area were evaluated using well log information, data from previous studies, and data on water level elevations and specific capacity. Conventional pump test methods were not utilized. Historic well production tests from four wells near Coeur d'Alene (City of Coeur d'Alene Water Dept., 1975) and twenty wells in the east Greenacres Project, U.S. Bureau of Reclamation near Post Falls, Idaho (U.S. Dept. of Interior, Bureau of Reclamation, 1961) were used to determine the aquifer characteristics.

The productivity of a production well is expressed as the

Table 3 . . . . Ground-water Level Changes 1949, 1964, and 1975

Location	USGS 1948-49 Elevation ft	Frink 1964 Elevation ft	Sagstad 1975 Elevation ft	Difference 1949-64 ft	Difference 1949-75 ft	Difference 1964-75 ft
51/5/34db2	2002.4	1993.0	1993.0	- 9.0	- 9.0	0
51/5/24ab1	2204.8	1989.2	-	-15.6	-	-
51/5/33ab1	1997.0	1986.2	1989.1	-10.8	- 7.9	+2.9
51/4/25cb1	2042.0	2017.3	2018.0	-24.7	-24.0	+1.0
51/4/18dc1	2011.5	2003.2	2003.0	- 8.3	- 8.5	-0.2
51/4/27dd1	2025.0	2010.2	a	-14.8	-	-
51/4/29dd1	2011.0	2010.5	a	- 0.50	-	-
51/4/35cc1	2023.0	-	2020.0	-	- 3.0	-
50/5/1aa1	2011.9	2001.5	2002.0	-10.4	- 9.9	+0.5
50/4/7bc1	2013.8	-	2003.5	-	-10.3	-
50/4/5cd1	2026.1	-	2018.0	-	- 8.1	-
50/4/5ad1	2027.0	2011.7	2010.0	-15.3	-17.0	-1.7
50/4/4dd1	2055.5	2066.6	a	+11.1	-	-
50/4/4dd2	2055.5	-	2052.0	-	- 3.5	-
50/4/3dd1	2035.0	2029.0	a	- 6.0	-	-
50/4/3cc1	2058.0	-	2051.1	-	- 6.9	-
50/4/1cc1	2063.0	2049.7	a	-13.3	-	-

- = no measurement taken

a = well abandoned

specific capacity and is defined as the ratio of pump discharge (Q) to drawdown (s) or Q/s (Walton, 1970). The procedure used in each specific capacity test consisted of pumping the well at a constant rate for twenty-four hours while water levels in the well were measured at repeated intervals.

The specific capacity values were used to estimate the coefficient of transmissibility in the area using the method of Theis (1963). A single drawdown from a constant discharging well after a twenty-four hour period is used in the computation. The specific capacity is not a precise measurement of the actual transmissive properties. Factors such as partial penetration, well losses, type of well construction and hydrogeologic boundaries effect the specific capacity. The coefficient of transmissiblity values were converted to hydraulic conductivity values by dividing the coefficient of transmissibility by the saturated thickness of the glacial aquifer. A saturated thickness of 175 feet was chosen utilizing well log and seismic data. High specific capacity values generally indicate high hydraulic conductivity and lower specific capacity indicates lower hydraulic conductivity values (Walton, 1970).

The estimated hydraulic conductivity values for the glacial aquifer are shown in Table 4. Values for the Post Falls area ranged from about 3300 to 13,000 gallons per day per square foot. The results indicate that transmissive characteristics in the Post Falls area are generally higher than in the Coeur d'Alene area. Well logs show that greater percentages of coarse gravels, pebbles, and sands are present in the Post Falls area

Table 4 . . . . Estimates of Hydraulic Conductivity from Specific Capacity Data in the Rathdrum Area.

Well Location	Pump Discharge (gal per min)	Drawdown (feet)	Specific Capacity (gal per min per ft drawdown)	Hydraulic Conductivity (gal per day per sq ft)
Coeur d'Alene Region				
50/4/1cc	3600	20.1	180	1800
50/4/12cb	3900	5.9	660	6700
50/4/12cc	3100	10.7	290	3000
50/4/4aa	6000	23.2	260	2700
Post Falls Region				
51/5/29cc1	3768	2.36	1596	16,000
51/5/29cc2	4000	2.81	1423	14,700
51/5/29cc3	2400	2.36	1066	10,700
51/5/29cc4	2400	2.71	885	8,700
51/5/29cc5	4000	1.65	1453	14,700
51/5/22bb1	4000	7.52	531	5,500
51/5/22bb2	4000	18.64	214	2,200
51/5/22bb3	4000	11.94	335	3,500
51/5/22bb4	2400	12.96	185	1,900
51/5/28dd1	4000	4.98	803	8,000
51/5/28dd2	4000	2.07	1302	13,000
51/5/28dd3	2400	3.13	766	7,300

than in the Coeur d'Alene area.

Alluvial Hydrologic Characteristics

Recharge of surface water to the aquifer by vertical leakage through the channel bottom deposits can occur when the channel bottom sediments are permeable and the water table is below the surface of the stream. Recharge rates can vary depending upon: surface water temperture, hydraulic conductivity of the stream channel deposits, the position of the water table in the aquifer, and the depth of water in the stream (Walton, 1970). General observations of the alluvial and aquifer sediments revealed differences in sorting and structure which can indicate relative differences in hydraulic conductivity. Conventional hydrologic testing methods were also used to determine the hydraulic conductivty of the alluvial sediments.

Alluvial deposits that were observed in the Spokane River channel during low flow conditions showed a poorly sorted, but very cohesive appearance. The sediments were well compacted and had been severely gullied from stream erosion due to river flow at several localities near the Washington-Idaho border in the stream channel. The deposits often resembled small ridges and valleys, sometimes one to three feet deep and several feet long. The ridges exposed vertical slopes of 60 to 90 degrees signifying a very cohesive material unlike the unconsolidated glacial outwash. The binding qualities of the mixtures of silt, sand and clay is responsible for this phenomenon.

The size distribution of a material is related to its hydraulic conductivity. Todd (1959) lists relative values of hydraulic conductivity for clean sands and gravels and for mixtures of sand, silt and clays. Clean sands and gravels can have hydraulic conductivity values ranging from 50 to 100,000 gallons per day per square foot, whereas values for mixed sand, silt and clay range from .005 to 50 gallons per day per square foot. The magnitude between the extremes of the size classifications is several fold, but it provides a relative comparison that is assumed that the hydraulic conductivity of the glacial aquifer sediments is much greater than that of the finer grained alluvial deposits.

Conventional hydrologic testing methods were used to determine values of hydraulic conductivity for the alluvial sediments. Two seperate testing techniques were used to estimate the hydraulic conductivity of the lower and upper portion of the alluvial sediments.

First method for determination of hydraulic conductivity

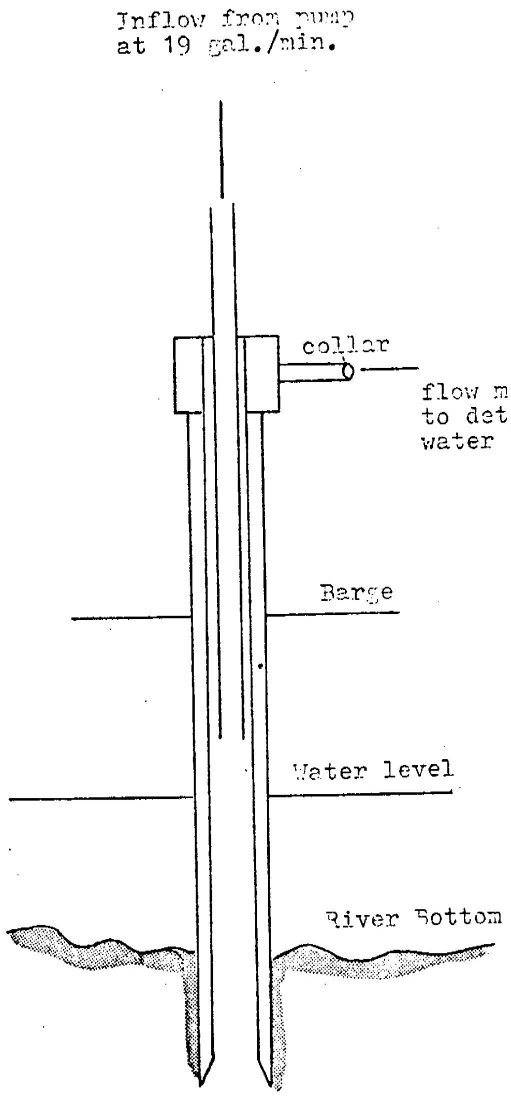
The Idaho Dept. of Highways conducted injection tests in the Spokane River alluvial sediments near the U.S. Highway 95 bridge at Coeur d'Alene, Idaho (Idaho Dept. of Highways, 1975). The constant head injection method was used to measure the hydraulic conductivity of the material (U.S. Dept. of Interior, Bureau of Reclamation, 1960). The lower five to 30 feet of the alluvial sediments were tested.

Investigation holes were drilled to a maximum depth of 30 feet below the bottom of the river channel. The injection tests were performed at five foot intervals, starting with five feet below land surface. A schematic diagram depicting the equipment used in the pumping test is shown in Figure 11a. The testing procedures consisted of the following steps:

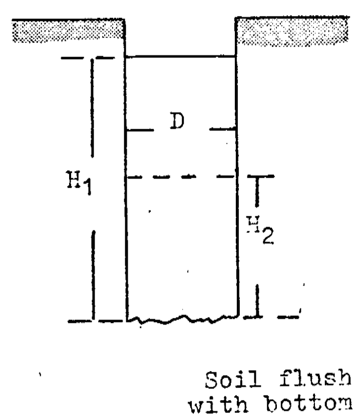
1. A 3.50 inch (NX) casing was driven into the alluvial sediments in five foot sections.
2. The sediments were then drilled out to the bottom of the casing.
3. The drill was removed from within the casing and water was injected into the casing at a constant rate of nineteen gallons per minute maintaining a constant head under atmospheric pressure.
4. A flow meter was used to measure the excess flow of water into a barrel located on the drilling platform to determine the discharge into the bottom of the casing.
5. Each injection test was run for five minutes and the injection rate was measured once at the end of each test.

This procedure can provide reliable estimates of hydraulic conductivity but testing errors are possible (Cedegren, 1967). The most frequent causes of error are silting of the bottom of the hole, leakage along the outside of the casing, and air locking in the sedimentary interstices.

The results of the injection tests are presented in Table 5. The head was measured from the point of water injection to the bottom of the casing. The data were analyzed using an empirical solution to determine hydraulic conductivity



(a) First Method



(b) Second Method

Figure 11 Schematic of Hydraulic Conductivity Testing Procedures

Table 5 . . . . Estimates of Hydraulic Conductivity from Constant Head Injection Tests.

Injection Rate (gal per min)	Head (ft)	Hydraulic Conductivity (gal per day per sq ft)
7	15	900
11	20	1200
7	20	700
8	20	800
9	20	900
10	20	1000
15	20	1500
7	25	600
10	25	800
16	25	1300
8	26	600
10	26	800
11	26	900
12	26	900
8	30	500
12	30	800
15	30	1000
10	35	600
10	40	500
10	45	500

developed by Harza (1935). The hydraulic conductivity can be obtained from

$$K = \frac{Q}{2.75DH}$$

where Q is the injection rate in gallons per minute, D is the diameter of the casing in feet, H is the head in feet, and K is the vertical hydraulic conductivity in gallons per day per square foot. The values of K range from 450 to 1500 gallons per day per square foot. These values indicate the hydraulic conductivities of the lower portion of the alluvail sediments are much lower than that of the glacial deposits.

Second method for determination of hydraulic conductivity

A variable head test was performed in the field to estimate the vertical hydraulic conductivity of the upper five feet of the Spokane River sediments (Figure 11b). Six investigation holes were dug along the river floodplain using a hand auger. The holes, with radii of four inches, were augered to a depth of two feet. An unknown volume of water was injected into the hole. An initial measurement of head was taken at the beginning of the test and a second measurement of head at a later time. The hydraulic conductivity was determined from an empirical method developed by the U.S. Navy, Bureau of Yards and Docks (1961) utilizing the following formula

$$K = \frac{R\,(h_2 - h_1)}{16\,DS\,(t_2 - t_1)}$$

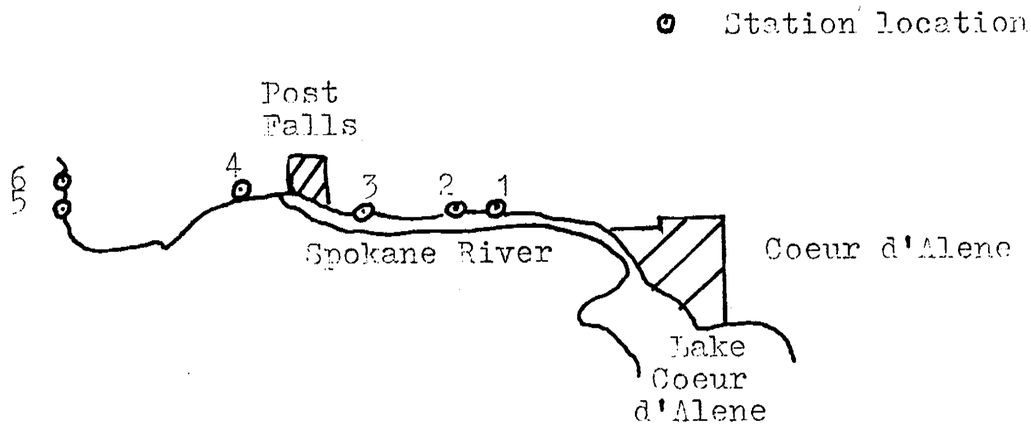
where K is hydraulic conductivity in gallons per day per square foot, R is the radius of the auger hole in feet, D is the head differential between the two measurements in feet, S is a shape factor coefficient and t is time in days. The results of the test are presented in Table 6. The hydraulic conductivity values range from two to 40 gallons per day per square foot. Several factors need mentioning that may affect the validity of the test results. Common errors during field testing include inaccurate measurement of water in the hole, displacement of sediments while augering, and inhomogeneity of the alluvial sediments. The precision and accuracy of the results of this test are questionable.

Discussion of Results

The estimated hydraulic conductivity values for the alluvial sediments and glacial outwash deposits are presented in Figure 12. The top few feet of the alluvial sediments are composed of mixtures of sand, silt and clay. Mixtures of sand, silt and clay generally have values that range between 0.005 to 30 gallons per day per square foot (Tood, 1967). Variable head tests of the top five feet of the alluvial material yielded hydraulic conductivity values ranging from two to ten gallons per day per square foot. Results from the variable head tests seem reasonable but the chance for distorted test results are large. Since only two water level measurements were taken over a short period of time very little quantative data was available for precise analysis. The results should be used with caution.

Table 6 Estimates of Hydraulic Conductivity from Variable Head Tests

Station Index Map



Vairable Head Hydraulic Conductivity

Station	Radius	Time (minute)	H_o (inches)	H_i (inches)	K (gal. per day per ft.^{2})
1	.33	10	22	19.0	3
2	.33	15	22	19.5	2
3	.33	12	22	19.0	3
4	.33	10	22	19.3	2.5
5	.33	10	22	16.5	10
6	.33	10	22	18.0	4

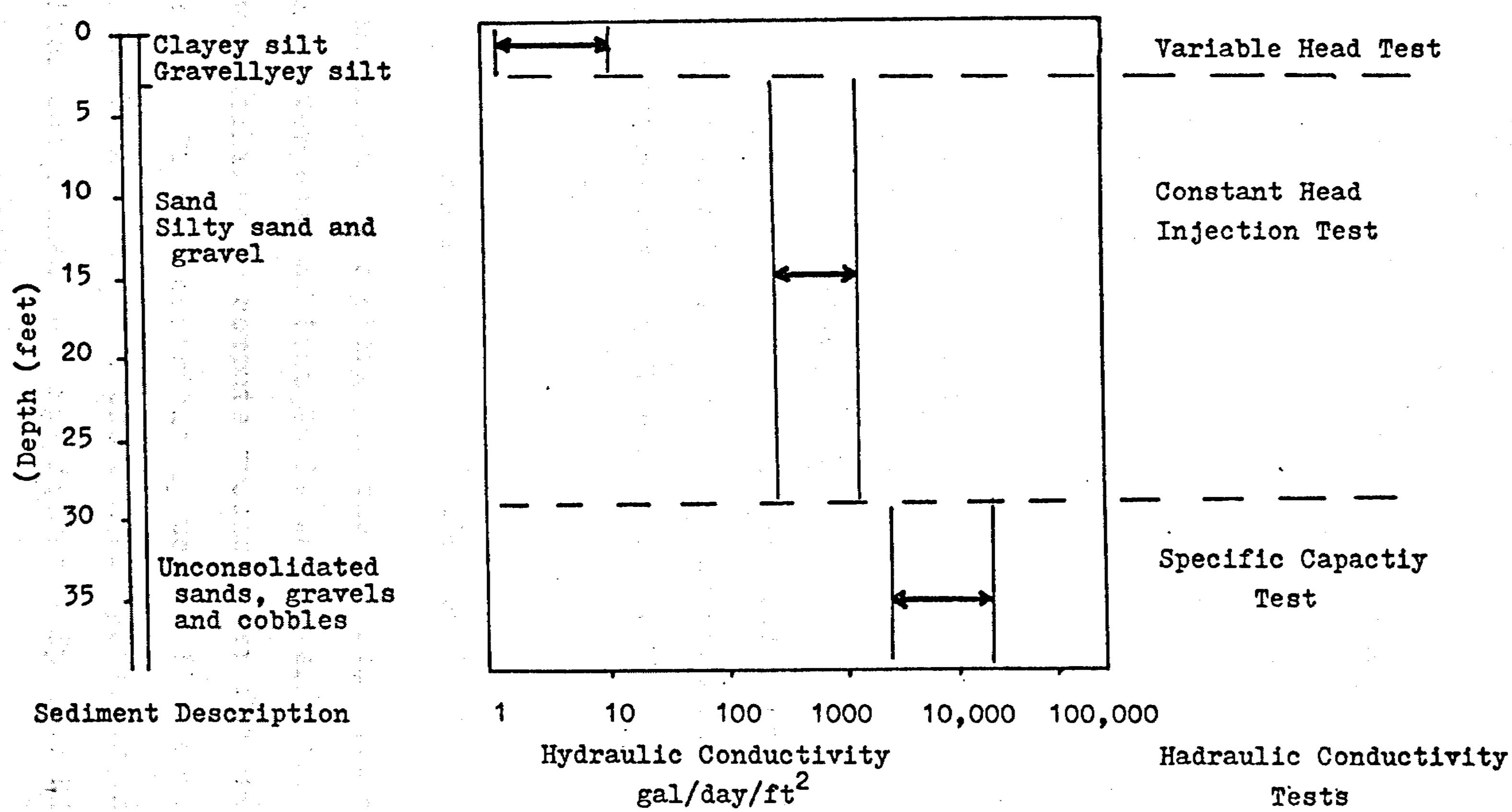


Figure 12 RANGE OF HYDRAULIC CONDUCTIVITIES OF THE ALLUVIUM AND GLACIAL OUTWASH SEDIMENTS NEAR THE SPOKANE RIVER IN THE SOUTHERN RATHDRUM PRAIRIE STUDY AREA.

The hydraulic conductivity values obtained from the constant head injection test ranged from 450 to 1500 gallons per day per square foot for the silty sand and gravel. Todd estimated the hydraulic conductivity of silty sands and clean sands and gravels ranged between 30 and 2800 gallons per day per square foot. Values from specific capacity tests for the glacial outwash ranged between 2700 and 13,000 gallons per day per square foot. Specific capacity is not an exact estimate of the hydraulic conductivity of the aquifer, but the specific capacity ratios obtained from the well production tests are reasonable estimates and generally lower than the actual hydraulic conductivity of the aquifer. The characteristics of the upper portion of the alluvail deposits are thus most important in controlling surface water recharge from the Spokane River into the glacial aquifer.

Recharge to the Glacial Aquifer

The magnitude of recharge to the glacial aquifer from the Spokane River east of Post Falls was determined. The Darcy equation was utilized to compute ground water flow near the Spokane River. Factors contributing to the flow component were estimated. A comparison between all previous investigations which determined recharge from the Spokane River east of Post Falls was outlined.

Recharge to the southern Rathdrum Prairie ground water system from the Spokane River east of Post Falls was estimated using the water table contour map. The water table contour map was divided into three sections to compute the flow component between Coeur d'Alene and Post Falls (Figure 13). Due to the irregular shape of the contours, the three sections were offset for ease in computing the flow values.

The flow of ground water near the Spokane River was calculated using the Darcy equation:

$$Q = KIA$$

where Q is the flow in gallons per day, I is water table gradient in feet per feet, A is cross sectional area in feet, and K is the hydraulic conductivity in gallons per day per square foot. Well log data indicated that wells near the Spokane River in the glacial sediments had a maximum saturated thickness of 130 feet and the wells did not reach bedrock. Since depth to bedrock was unknown, the saturated thickness of the aquifer near the Spokane River was estimated as 150 feet. Average hydraulic conductivity values for the Coeur d'Alene and Post Falls region were used. The results are presented in Table 7.

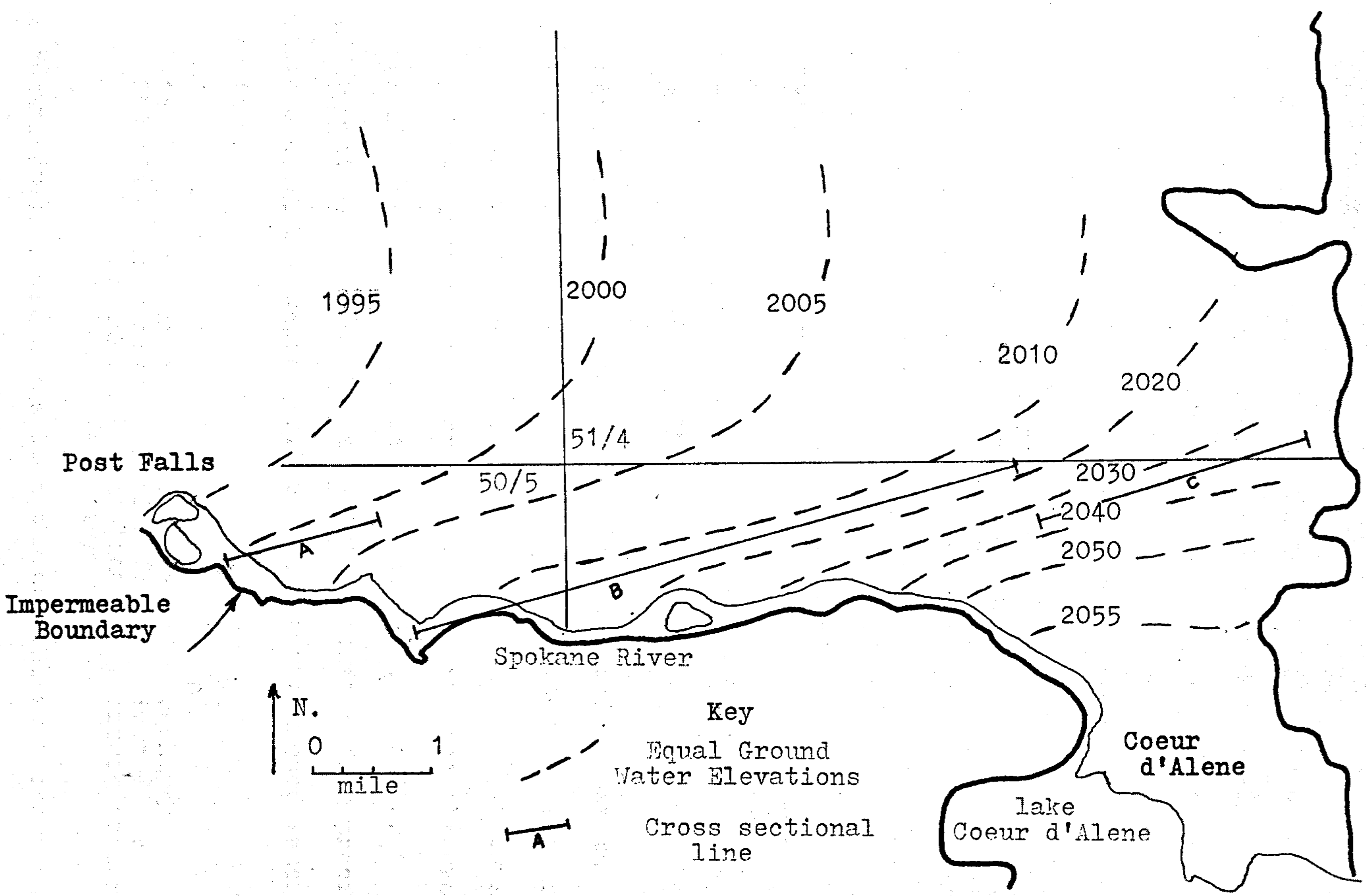


Figure 13 Contour map of ground water surface, showing sectional units used to compute recharge

Table 7 . . . . Recharge to the Glacial Aquifer from the Spokane River in the Coeur d'Alene-Post Falls Reach.

Location	Hydraulic Conductivity (gal per day per sq ft)	Water Table Gradient (ft per ft)	Ground water Flow (cubic ft per second)
Section AA'	10,000	2.525×10^{-3}	41
Section BB'	4,000	6.060×10^{-3}	152
Section CC'	4,000	3.030×10^{-3}	37
		Total	230

Ground Water recharge to the glacial aquifer near the Spokane River was estimated to be 230 cubic feet per second or 170,000 acre feet per year. Large quantities of water must be introduced into the flow system up gradient from the cross-sectional units to sustain this rate of flow. The flow in the aquifer must be equal to the sum of the recharge from precipitation and surface water infiltration and the ground water under flow.

$$Q_{\text{total 240 cfs}} = Q_{\text{recharge from river and lake}} + Q_{\text{ground water inflow from consolidated aquifer}} + Q_{\text{recharge from direct precipitation}}$$

The contribution of recharge from the consolidated rocks south of the Spokane River was considered to be zero considering the low hydraulic conductivity of the rocks and the low water yields to wells. Recharge to the aquifer from direct precipitation is unknown, therefore, 75% of the mean annual precipitation at Coeur d'Alene or 18.5 inches (6.5 cfs) was considered annual recharge to the aquifer. Substracting these two values from the total ground water flow leaves 225 cfs (rounded) of recharge to the glacial aquifer from the Spokane River. There are two major weak points in the estimation. First, the saturated thickness to bedrock was unknown in the area of study; therefore, the saturated thickness of the aquifer is probably underestimated. Second, the hydraulic conductivity used in the calculation is probably lower than the actual hydraulic conductivity of the aquifer because the hydraulic conductivity values were obtained from the specific capacity tests (Walton, 1970). If these variables were actually larger, the amount of ground water flow would substantially change.

The estimated recharge from this study is lower than estimated by previous investigators (Table 8). All authors felt the Spokane River is a major recharge area, and contributes large quantaties of water to the glacial aquifer.

Table 8 . . . . Estimated Recharge to the Glacial Outwash Aquifer from the Spokane River, east of Post Falls.

Investigator	Year	Recharge to the Aquifer from Lake Coeur d'Alene and Spokane River above Post Falls
Sagstad	1975	225
Thomas	1968	250
Frink	1964	300
Anderson	1951	300

WATER QUALITY

The hydro-chemistry of the Rathdrum Prairie aquifer is an important indicator of ground water movement and recharge characteristics. A ground water sampling program was initiated in the Coeur d'Alen-Post Falls study area during the summer of 1975 to define recharge characteristics and illustrate chemical processes taking place in the glacial outwash environment. Particular emphasis was placed on zinc concentations from historic mining activities in the Spokane River-Coeur d'Alene River drainage. Quality samples were collected from a network of 88 wells in the study area.

Regional Water Quality

Surface Water Quality

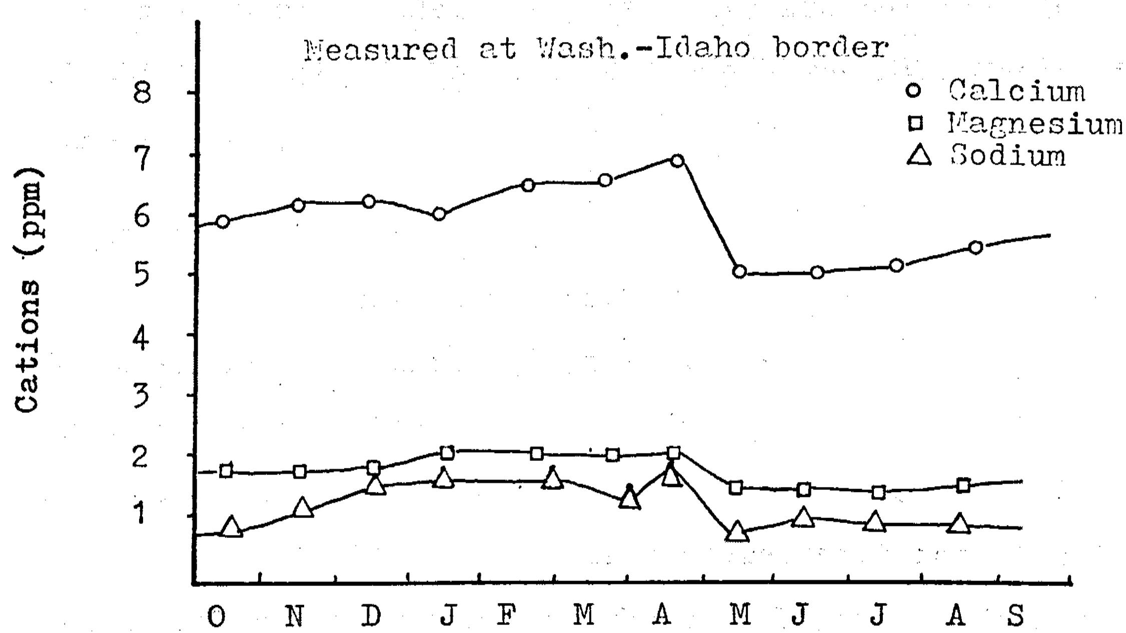
The water quality characteristics in the region are good. Anderson (1951) and the Washington Dept. of Ecology (1969) measured ionic concentrations of magnesium, calcium and sodium in various lakes and streams in northern Idaho and eastern Washington respectively. The concentrations of selected ions for Pend Oreille, Hayden and Coeur d'Alene Lakes are given in Table 9.

Table 9 . . . . Water Quality Characteristics of Lakes in Northern Idaho.

Lake	Calcium (ppm)	Magnesium (ppm)	Sodium (ppm)
Pend Oreille Lake	25.0	6.0	3.0
Hayden Lake	6.2	2.0	1.0
Coeur d'Alene Lake	6.0	2.0	1.0

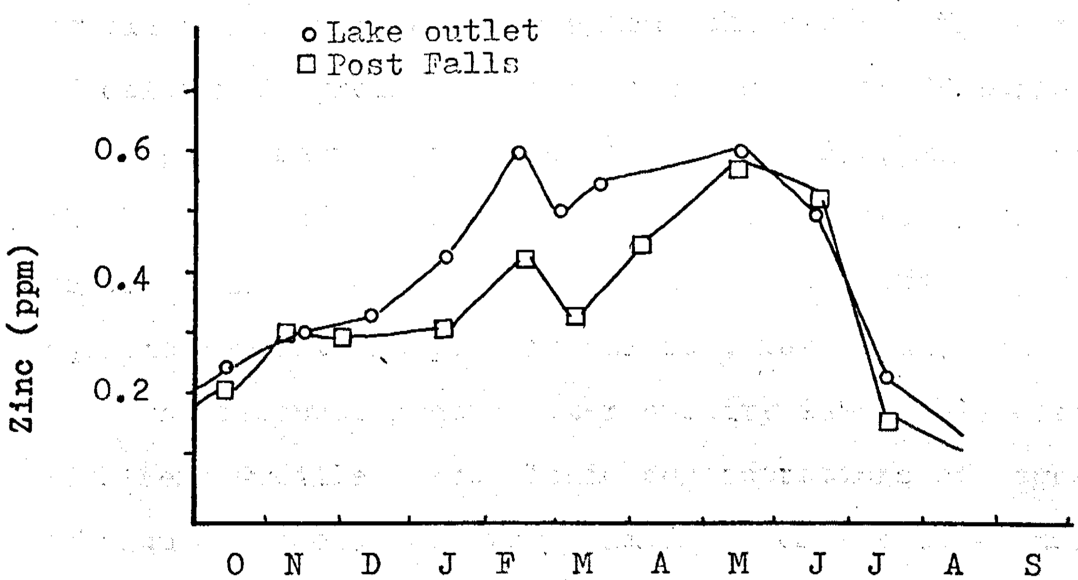
Monthly concentrations of calcium, magnesium and sodium in the Spokane River in 1971-72 are presented in Figure 14. The maximum ionic concentrations occur in the month of April, whereas the minimum values measured are noted in May. These concentrations generally do not fluctuate greatly over the period noted. The mean concentrations for calcium, magnesium and sodium are about five parts per million, two parts per million, and 1.5 parts per million respectively. The abrupt decrease in elemental concentrations between April and May is beilieved to be due to a dilution effect during the high run-off period.

A review of the regional surface water quality characteristics in the Rathdrum Prairie area revealed that the Spokane River is the only available surface water source of zinc. The concentrations of zinc in the Spokane River for the period of 1971-1972 (Funk and others, 1973) are shown in Figure 14. The values range from .10 to .60 parts per million. The higher



Cation monthly measurements, Spokane River, 1971-1972, (Wash. Dept, of Ecology, 1975)

(a)



Monthly Zinc measurements, Spokane River, 1971-1972, (Funk and others, 1973)

(b)

Figure 14 Spokane River water quality (single sample points) zinc measurements during May and July are believed due to a flushing effect of the Coeur d'Alene River-Lake Coeur d'Alene run-off period.

Ground Water Quality

The concentration of dissolved minerals in the Spokane Valley-Rathdrum Prairie ground-water system do not vary greatly from location to location. Generally, the solubility of the minerals control the water quality characteristics of the water (Back, 1965). The quality characteristics of selected wells and surface waters are shown in Figure 15 from reports by Anderson (1951) and Frink (1964). The regional quality characteristics indicated that magnesium, calcium and sodium remain fairly constant throughout the basin. The concentrations of calcium in ground water ranged from 30 to 39 parts per million (ppm), magnesium ranged from 11 to 23 ppm, and sodium varied the least, ranging from 2.3 to 4.8 ppm in the system. This tends to indicate that the regional ground water system is in equilibrium with respect to calcium, magnesium, and sodium.

The regional ground water quality is closely correlated with Pend Oreille Lake. Ionic concentrations of magnesium, calcium and sodium are very similar. On the other hand, the observed concentrations in the Spokane River, Hayden Lake and Lake Coeur d'Alene are lower in magnesium, calcium, and sodium concentrations than the regional flow system.

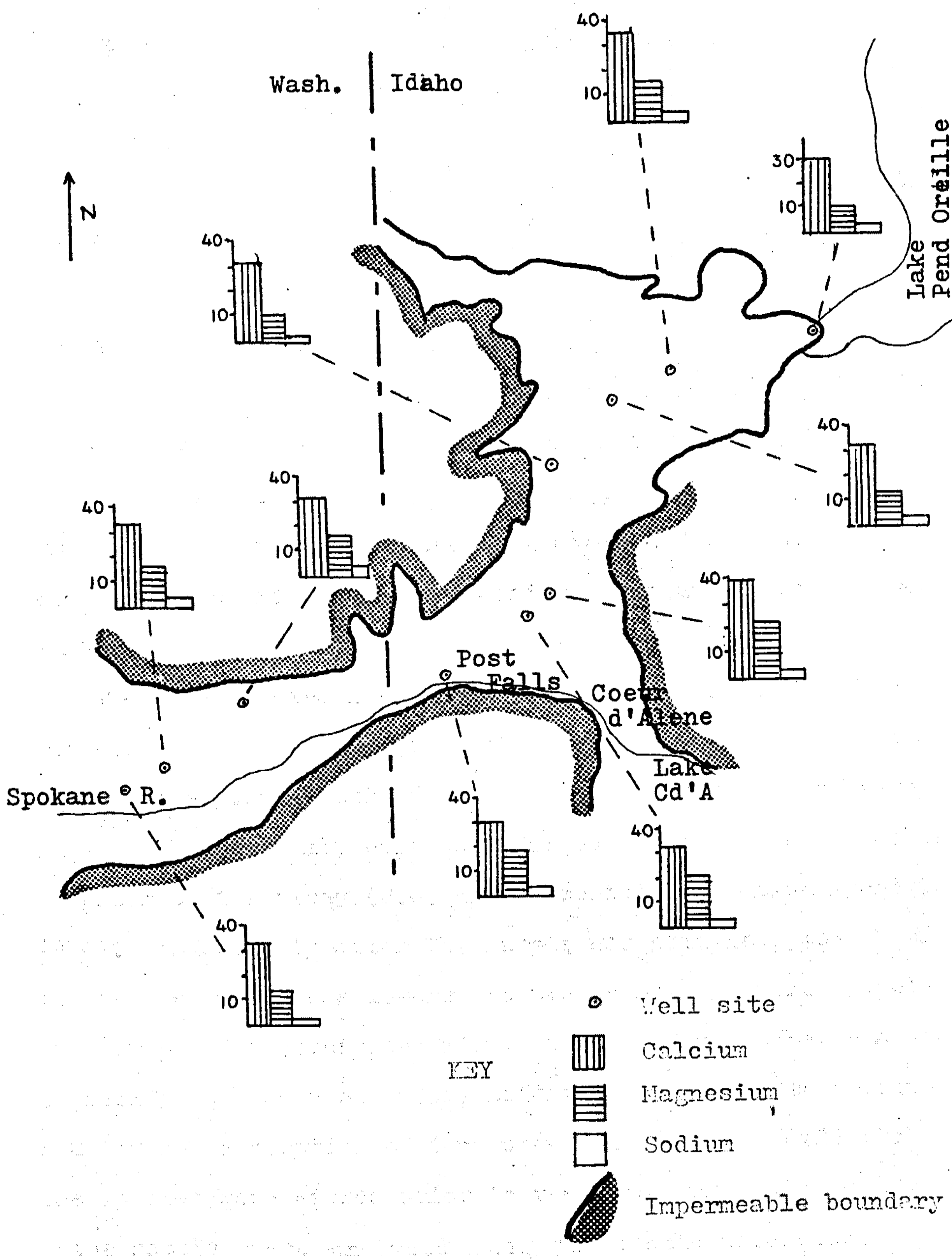


Figure 15 Regional ground water quality (in parts per million)

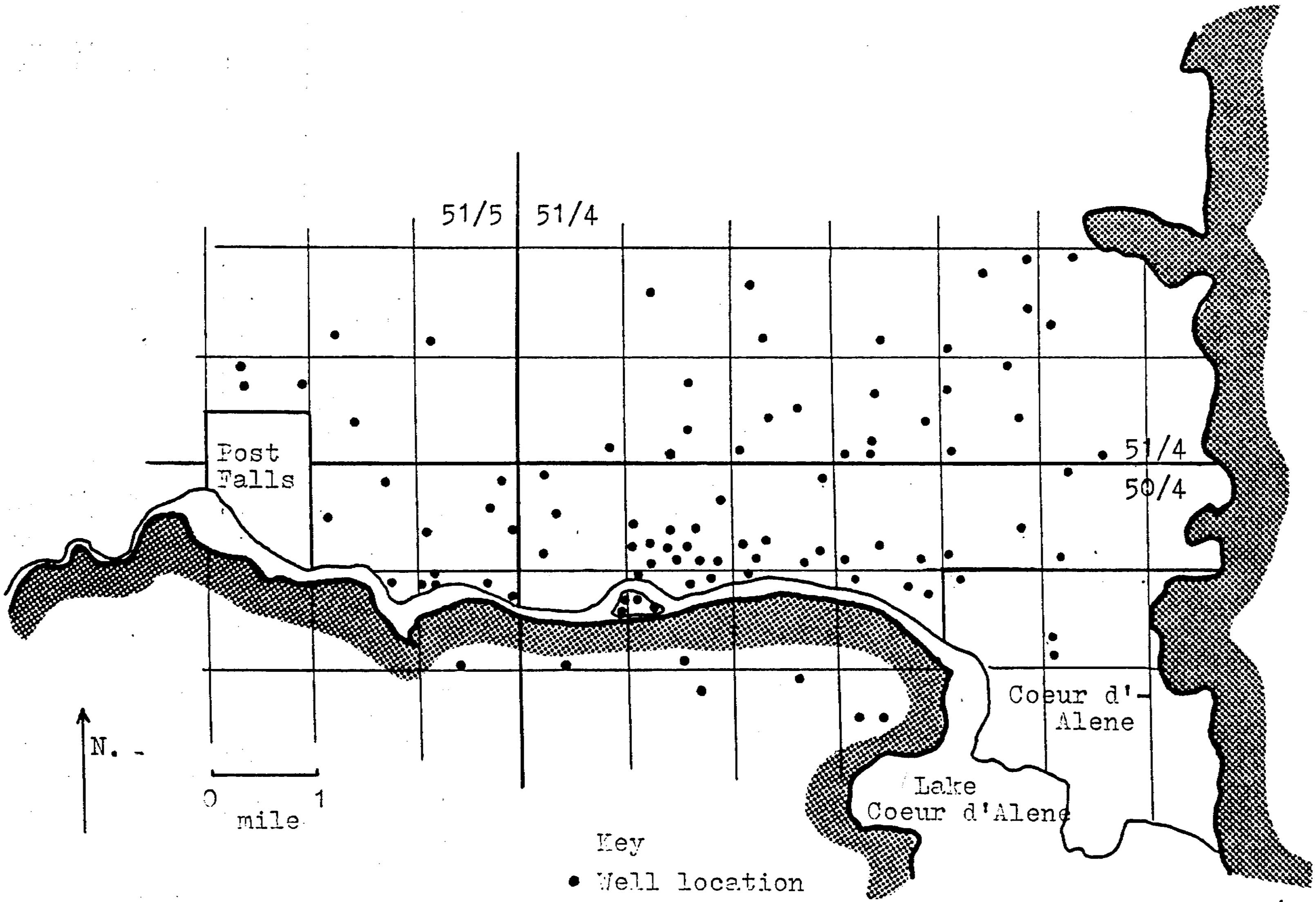


Figure 16 Water Quality Sampling Locations

spectrophometer at the University of Idaho and were collected and analyzed in accordance with methods recommended by the U.S. Environmental Protection Agency (1974).

Highlands

A total of six wells were sampled in the consolidated rock units south of the Spokane River. These samples, (numbers 83-88 in Table 11) were collected from hand dug and drilled domestic wells. The minimum, maximum, and mean concentrations of selected ions for the highlands are presented in Table 10.

The higher content of sodium compared to magnesium and calcium is the result of weathering characteristics of the metamorphic rocks. Also, clay minerals may release large quantaties of exchangeable sodium (Dewiest, 1970, p. 104). The low, but significant concentrations of zinc are attributable to the chemical characteristics of the rock.

Table 10 . . . . Water Quality Data for Highland Area (parts per million).

	Minimum	Maximum	Mean
Mg	1.25	10.30	4.40
Ca	2.20	11.46	7.40
Na	6.14	13.42	8.81
Fe	0.09	2.53	0.96
Zn	0.10	1.73	0.79

Table 11 . . . Elemental Analyses of Water Samples

Well Location	Sample No.	Zinc (ppm)	Iron (ppm)	Magnesium (ppm)	Calcium (ppm)	Sodium (ppm)	pH Lab.	E.C. Field
50/4/1bab1	1	0.05	0.06	12.90	20.01	2.74	7.9	245
51/4/36dcc1	2	0.00	0.06	11.91	29.74	3.18	8.5	225
51/4/35ccc1	3	0.05	0.06	11.60	22.22	2.56	7.9	175
51/4/34cda1	4	0.01	0.06	5.90	19.64	2.86	8.2	158
51/4/33acc1	5	0.00	0.06	14.41	20.06	4.12		
50/4/10bba1	6	0.00	0.06	2.77	5.87	2.86	6.3	39
50/4/12cdc1	7	0.00	0.06	6.26	23.54	2.28	8.0	127
50/4/12cbc1	8	0.00	0.06	8.83	26.17	2.56	8.0	187
50/4/1ccd1	9	0.01	0.06	19.81	40.36	3.91	8.0	250
50/4/3cda1	10	0.01	0.06	6.84	22.45	2.66	7.6	208
50/4/4aad1	11	0.00	0.06	7.44	30.64	2.77	7.4	215
50/4/10aad1	12	0.08	0.06	7.74	32.89	2.23	7.4	197
50/4/4ddd1	13	0.00	0.06	4.80	12.45	2.35	7.3	98
50/4/3ccc1	14	0.00	0.06	4.74	7.46	2.98	7.2	75
50/4/4cac1	15	0.00	0.06	4.84	12.02	2.86	7.3	91
50/4/4cbc1	16	0.00	0.06	5.10	12.87	2.86	7.0	110
50/4/4cca1	17	0.00	0.06	5.14	13.67	2.98	7.6	95
50/4/4aab1	18	0.00	0.13	4.84	14.94	2.56		
51/4/34ccd1	19	0.00	0.06	14.11	38.48	3.18	7.2	109
51/4/25cbb1	20	0.08	0.06	14.26	25.75	3.07	8.1	195
51/4/25bba1	21	0.00	0.06	14.95	38.91	3.79	7.9	240
51/4/34bda1	22	0.00	0.06	12.44	25.75	3.18		
50/4/3ddc1	23	0.00	0.06	2.67	6.67	2.14	7.4	60
50/4/2ccd1	24	0.00	0.06	3.03	7.46	2.35		
50/4/3aad1	25	0.00	0.06	11.87	23.54	2.65	7.5	280
51/4/26add1	26	0.00	0.06	19.81	28.85	3.28	7.8	255
51/4/34cdd1	27	0.00	0.06	14.32	47.56	3.18	7.8	271
50/4/5ddd1	28	0.29	0.06	4.29	13.67	3.28	7.5	87
50/4/5ddc1	29	0.36	0.06	2.37	6.67	3.07	7.4	92
50/4/9bba1	30	0.01	0.06	1.93	5.44	2.03	7.9	55
50/4/8aab1	31	0.45	0.06	2.60	3.75	2.11	7.4	65
50/4/4ddc1	32	0.22	0.27	3.62	11.18	2.14	7.6	116
51/4/35bbc	33	0.08	0.20	10.73	25.75	3.07	8.1	190
50/4/5dca	34	0.00	0.06	3.58	11.18	2.65	7.2	70
50/4/5dcc	35	0.12	0.06	2.63	8.31	2.98	7.5	90
50/4/5cdc	36	0.00	0.06	2.77	7.46	2.03	7.2	90
51/4/26ccc	37	0.05	0.06	13.94	24.43	3.39	8.0	200
50/5/2abd	38	0.01	0.06	9.49	23.96	2.35		
50/5/1cbb	39	0.00	0.06	3.03	7.89	1.82		
51/5/34baa	40	0.00	0.06	12.02	19.21	2.03		
51/5/34ada	41	0.00	0.06	10.06	17.05	1.93		
51/5/34baa	42	0.00	0.06	9.74	21.80	2.03		
50/5/2bcd	43	0.00	0.06	5.26	16.63	2.56		
50/5/1adb	44	0.00	0.06	2.03	8.31	2.56		
50/5/12bbc	45	0.00	0.06	1.93	5.44	1.72		
50/5/11aba	46	0.06	0.06	1.78	4.64	1.61		
51/5/35caa	47	0.00	0.06	10.88	20.48	2.03		
50/5/1daa	48	0.00	0.06	2.42	11.60	2.03		
50/5/1aad	49	0.00	0.06	5.60	14.09	2.14		
50/5/1cdc	50	0.01	0.06	1.51	5.07	1.51		

Table 11 . . . Elemental Analyses of Water Samples (cont'd)

Well Location	Sample No.	Zinc (ppm)	Iron (ppm)	Magnesium (ppm)	Calcium (ppm)	Sodium (ppm)	pH Lab.	E.C. Field
50/4/5cbb	51	0.03	0.06	3.13	16.21	2.03	8.25	105
50/4/6bba	52	0.07	0.06	4.95	14.51	2.44	7.4	60
50/4/8bbb	53	0.00	0.06	1.97	4.64	1.32		
50/4/5dba	54	0.02	0.06	3.43	9.11	2.14	7.4	65
50/4/2dab	55	0.00	0.06	16.67	21.38	3.70		
51/4/35abb	56	0.04	0.06	13.01	20.91	2.86		
51/4/35adc	57	0.01	0.06	12.29	24.43	2.98		
50/4/5cbd	58	0.00	0.06	2.82	8.73	2.03	7.6	83
50/4/5cbc	59	0.00	0.06	2.88	15.36	2.03	7.6	95
50/4/6cdb	60	0.03	0.06	2.27	6.67	1.93		
50/4/7bcb	61	0.00	0.06	2.06	5.07	1.72		
50/5/12aba	62	0.20	0.06	1.47	4.64	1.40		
50/5/12bba	63	0.07	0.06	3.13	9.11	1.93		
50/5/12/bbd	64	0.24	0.06	2.37	5.87	1.82		
50/4/8aba	65	0.00	0.06	2.06	4.64	1.82	7.1	60
50/4/5dbc	66	0.36	0.06	3.49	11.60	2.65	7.5	135
50/4/5add	67	0.01	0.06	4.84	14.51	2.14	8.2	135
51/4/34daa	68	0.07	0.06	8.26	21.80	2.98		
50/4/7add	69	0.80	0.06	2.76	3.24	7.43	7.6	87
50/4/8bbc	70	0.53	0.06	1.97	4.64	2.03	7.3	74
50/4/8bcb	71	0.89	0.06	12.90	4.52	11.52	7.6	123
50/4/7ada1	72	0.44	0.06	1.72	3.85	2.03	7.5	138
51/4/31ddd	73	0.05	0.06	9.28	12.42	2.43	8.2	200
51/4/32cdd	74	0.05	0.06	9.54	15.67	2.51	8.1	250
51/4/32dbc	75	0.00	0.06	11.74	16.35	2.58		
51/4/33ccc	76	1.06	0.06	13.66	24.78	3.05	8.1	275
51/4/32abc	77	0.00	0.06	12.04	20.01	3.82		
51/4/28bbd	78	0.00	0.06	20.80	24.65	2.81		
51/4/33caa	79	0.00	0.06	10.18	14.33	2.43	8.3	215
50/4/7ada2	80	1.47	0.06	1.52	3.00	2.11	7.2	60
51/5/26cca	81	0.01	0.06	15.72	22.03	2.66		
50/4/6bdd	82	0.21	0.06	2.76	4.01	2.11		
50/4/15bcd	83	0.43	0.10	2.82	7.40	6.14		
50/4/15bda	84	1.73	0.09	1.25	2.20	4.85		
50/4/16aba	85	0.54	2.05	10.30	11.24	12.16		
50/4/17abd	86	1.32	0.87	5.69	11.46	13.42		
50/4/7cdc	87	0.61	0.10	4.76	9.89	8.41		
50/5/12cdd	88	0.10	2.53	1.58	2.20	7.90		

Glacial Aquifer

The water quality characteristics (magnesium, calcium and sodium) in the southern Rathdrum Prairie ground water system are shown in Figure 17. The data used in the map construction are noted as water samples one to 82 in Table 11.

Magnesium exhibits an increase in concentration away from the river. Magnesium ranges in concentration from 1.5 ppm, near the Spokane River, to 20 ppm at the northern boundary of the study area. The magnesium gradient is generally uniform throughout the Coeur d'Alene-Post Falls glacial outwash environment. The 20 ppm concentration is typical for the Rathdrum Prairie regional flow system; concentration of 1.5 to 2.0 ppm is similar to the quality of the Spokane River.

Calcium is the predominant cation in the southern Rathdrum Prairie ground water system. Calcium concentration in the samples range from 5 ppm to 38 ppm. Calcium exhibits an increased concentration away from the river, also suggesting a relationship between water movement and ion exchange within the lithologic environment. The 30 ppm concentration is typical for the remainder of the Rathdrum Prairie and Spokane Vally regional flow system. The concentration of 5 ppm is typical of the Spokane River.

The sodium pattern is the same as for calcium and magnesium, but the change is not as great. Sodium changes from two to 4 ppm; again, 4 ppm is typical for the prairie flow system. The small increase in concentration is probably due to the lack of availability of sodium ions in the geologic

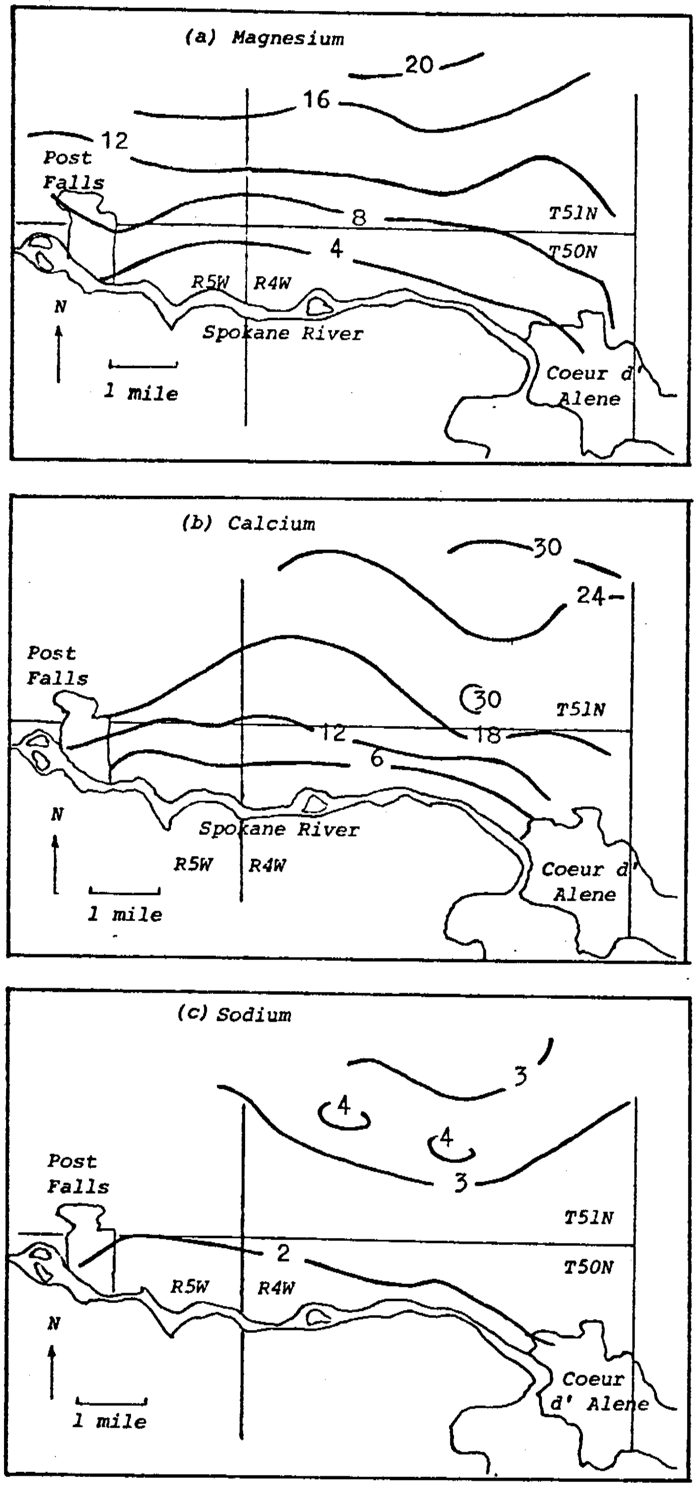


Figure 17 Ion Concentration in Ground Water, Coeur d'Alene-Post Falls Study Area a) magnesium, b) calcium c) sodium (parts per million)

framework. The ratio of sodium to magnesium and calcium is the inverse of that found in consolidated aquifers, where sodium is the dominant ion.

Analysis of Water Quality

The water quality characteristics of the Spokane River, the igneous metasedimentary aquifer and glacial aquifer, were compared to better describe the flow system. The elemental concentrations suggests that the differences in quality are related to the prevailing geologic and hydrologic conditions. The concentrations of calcium, magnesium and sodium from the Spokane River and glacial aquifer adjacent to the Spokane River are lowest in the study area. The chemical gradients as well as the ground water elevation contours indicate flow paths away from the river. This suggests recharge is occurring from the Spokane River. Surface water enters the glacial aquifer by vertical leakage through the river channel bottom. Soluable minerals in the geologic framework react with the ground water while flowing away from the river and increase in concentration, eventually reaching the concentration levels of the regional ground water system in the northern part of the study area.

The trilinear diagram shown in Figure 18 is based on the ratio of each cation (equilvalant per million) to the sample total (epm). For example, sample one in Table 11 has 1.06 epm magnesium, 1.00 epm calcium and 0.12 epm sodium. Each element represents 49, 46 and 6% of the sample total respectively. A

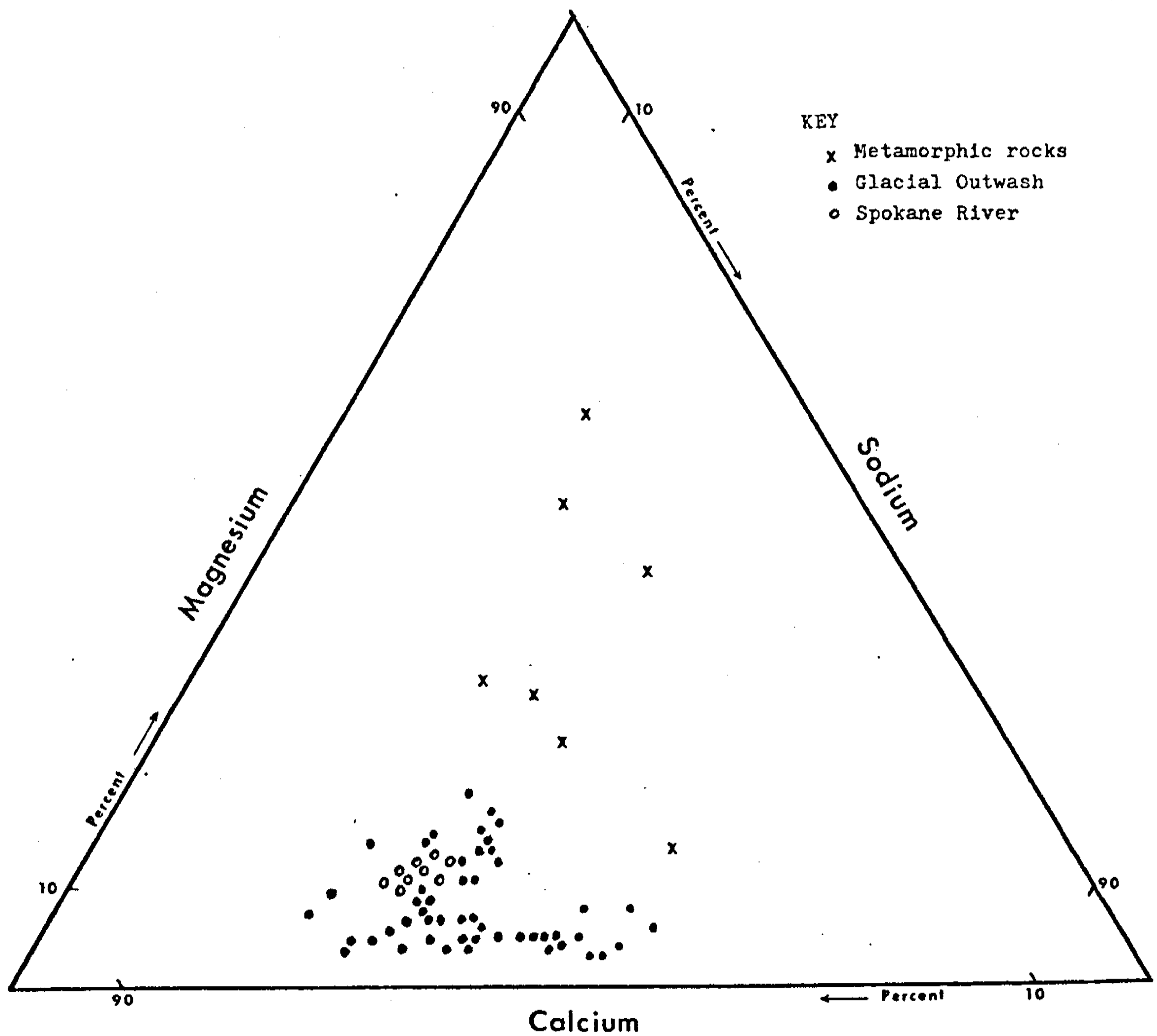


Figure 18 Trilinear Plot of Selected Cations (in equivalents per million)

single point is plotted for that sample on the diagram.

Significant differences are evident between the consolidated rock water quality, the Spokane River, and the glacial aquifer water quality. The ground water and river water are dominantly calcium type waters. The chemical character of water from the igenous--metamorphic units is dominantly sodium. A close correlation can be seen between the quality of the river and ground water quality of the glacial material. The data in this diagram supports the hypothesis that most of the recharge to the glacial aquifer is coming from the Spokane River. If the highlands are a major source of recharge, higher concentrations of sodium and iron should be observed in water quality samples obtained from the glacial aquifer adjacent to the Spokane River.

Zinc concentrations in the glacial aquifer were generally below detection limits of .01 ppm. Sixty-two of the 82 wells sampled showed zinc values less than 0.05 ppm. Of the remaining twenty samples thirteen samples measured concentrations of more than .20 ppm. A localized anomoly occurs in wells located on Harbor Island where the zinc concentrations averaged 0.5 ppm. The anomoly on Harbor Island is believed to be due to vertical leakage of river water either through the basalt or along the basalt alluvial contact. Detectable concentrations of zinc in the remaining samples is probably related to leach-in of zinc from galvanized pipes, well casings or holding tanks.

It is important to determine why zinc is not found in the Rathdrum Prairie aquifer if recharge is occurring from the Spokane River which contains significant zinc concentrations. Funk and others (1973) indicated that high concentrations of zinc were found in the upper few inches of the Coeur d'Alene Lake and River sediments. Illitic clays were noted as the major clay mineral associated with the high concentrations of zinc. This phenomenon is known as ion exchange. It occurs between the fine grain sediments and metal ions. Individaul metal cations are trapped or held in the sedimentary structure of the clay particles by the electrical properties of the clay sediments. Reddy and Perkins (1974) studied fixation of zinc by clay minerals and concluded that zinc was fixed as a result of 1) precipitation, 2) entrapment in clay lattice, and 3) adsorption of exchangeable site. It is believed that much of the zinc from the river water is exchanged and held by the fine grained river sediments.

Statistical Analysis of Water Quality Data

Statistical tests were applied to the water quality data from the study area to test the hypothesis that the water quality characteristics of the Spokane River are significantly different from the glacial aquifer. The tests were divided into two main topics: 1) test the hypothesis that elemental group means are significantly different in the Spokane River and the glacial aquifer and 2) classify the water sample characteristics by location either in the Spokane River or the ground water flow system.

The water quality data are applicable for illustrating recharge characteristics and change in water quality data in the direction of ground water flow. The water quality data in the study area were divided into four territorial groups for data analysis. These groups shown in Figure 19 are designated as the Spokane River, Zone 1, Zone 2, and Zone 3. Zone 1 is an area closest to the Spokane River situated in the glacial aquifer and reflects the lowest ionic concentrations in the glacial aquifer. The boundary between Zone 2 and Zone 3 was arbitrarily drawn between the remaining sample points.

Three statistical methods were applied to the ground water quality data. The Duncan Multiple Range test and the least significant difference test (lsd) were conducted to determine whether there is a significant difference in elemental means exists between the four groups. Each water sample was classified to the four groups by the discriminant analysis method. The water quality characteristics in each group were used to predict individual sample locations using calcium, magnesium and sodium as the combined estimate. The elemental means of calcium, magnesium, and sodium of each group are presented in Table 12.

Least Significant Difference

The least significant difference (lsd) is used to test the hypothesis that elemental means of each group are significantly different from the other groups. The method compares two groups using similar elemental concentrations for each

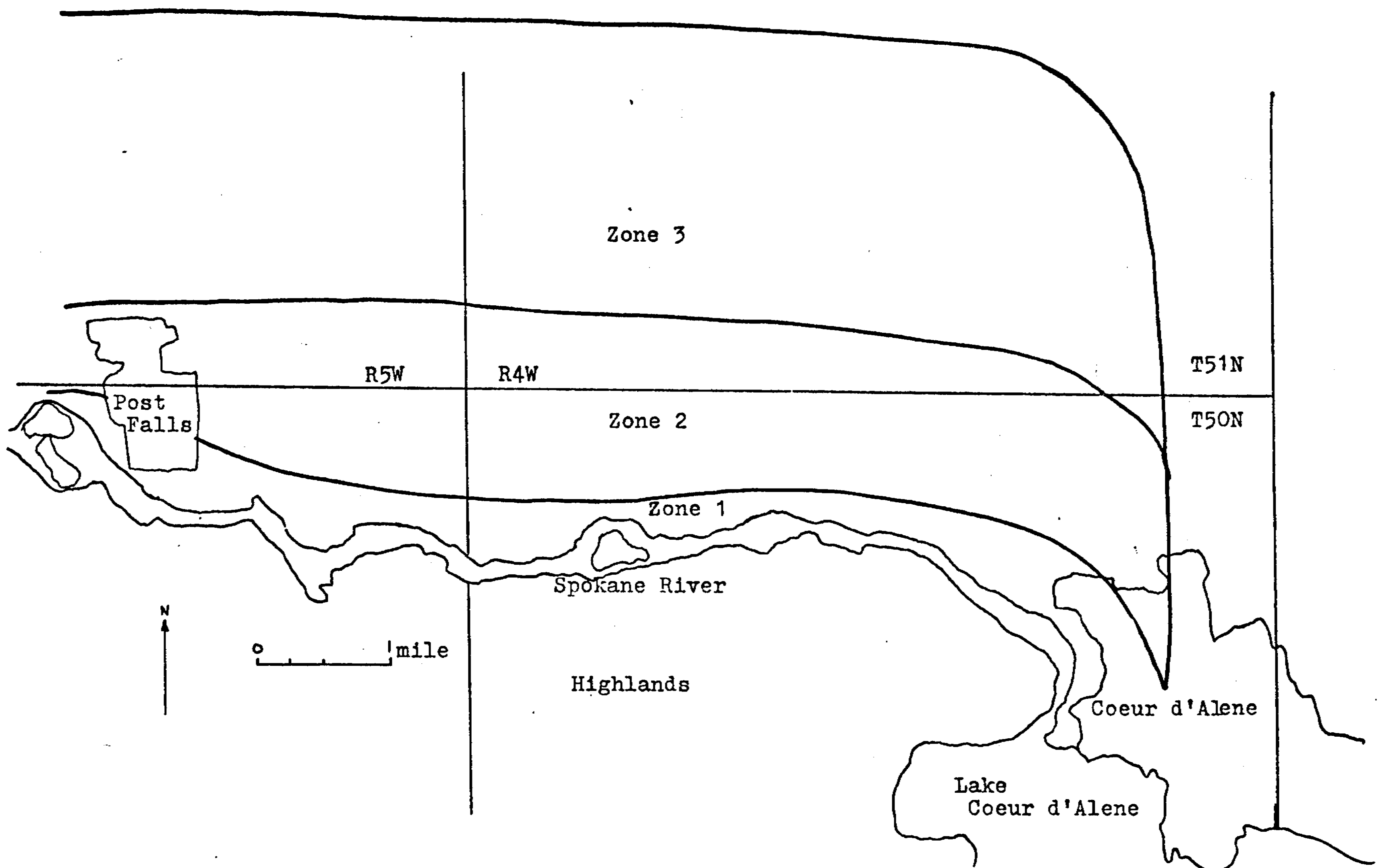


Figure 19 Statistical Boundaries

comparison. The application of this procedure to the water quality data in the study area is subject to large errors. As the number of groups increase over two, so does the experimental error rate (Steel and Torrie, 1969, p. 107). In essence, as the number of groups increase so does the chance that the groups will not be found significantly different.

The least significant difference between two means is given as:

$$\text{lsd}\ (.05) = t\ .05\ s\bar{d}$$

where t .05 is the tabular values of t for error degrees of freedom, $s\bar{d}$ is the pooled error variance and n is the number of observations per mean (Steel and Torrie, 1960, p. 106). This value is calculated only once and the tabular lsd value is found in a statistic table. Each difference between group means being tested is compared to the tabular lsd value. If the difference is greater than the tabular value, then it is declared significant. If the difference is less than the tabualr lsd value, it is found not to be significant. The results of the least significant difference method are presented in Table 12.

No significant differences were found between the Spokane River and Zone 1 elemental mean values of calcium,magnesium, and sodium. This supports the hypothesis that recharge is occurring from the Spokane River into the glacial aquifer. The elemental mean values of sodium did not significantly change through the four groups. The remaining mean differerences are all found to be significantly different. The pattern of elemental concentrations increasing in the direction of ground water flow, as previously discussed, is directly related to the significant difference associated with Zone 1, 2 and 3. The water quality changes significantly as the ground water moves away from the Spokane River.

Table 12 . . . . Elemental Group Means and Statistical Test Results (in parts per million).

	River	Zone 1	Zone 2	Zone 3	Total Mean
Magnesium	1.75	1.98*	4.49	12.29	5.13
Sodium	1.56	1.84*	2.46	2.83	2.17
Calcium	5.58	5.09*	11.42	22.55	11.16

*The New Duncan Multiple Range Test and the least significant difference test found no significant difference between the Spokane River and Zone 1.

New Duncan Multiple Range Test

The Duncan's Multiple Range Test was performed to determine if significant differences exist between elemental means of magnesium, calcium and sodium for each group. The method compares the difference between each treatment mean with every other treatment mean by using a set of significant ranges, dependent on the number of means (Steel and Torrie, 1960, p. 197). The Duncan method attempts to avoid the problem of using a single tabular value as in the least significant difference method by using a set of significant range values for increasing group sizes. As the number of groups increase so does the chance that they will be declared not significant.

The procedure is as follows: similar elemental means from each group are ranked from highest to lowest. A set of significant studentized range values are then obtained for the range of means being tested from a statistic table (Steel and Torrie, 1960). The significant ranges are then multiplied by the error mean square of the analysis of variance to give a set of least significant range values (Steel and Torrie, 1960).

The elemental mean differences between the means are tested in the following order: the largest minus the second largest, the largest minus the third largest, and so on until the second smallest minus the smallest is tested. Each difference is compared to the set of least significant ranges. If the difference is below the least significant range, it is declared not significant. If the difference exceeds the lsd then it is said to be significant.

This method was applied to the ionic concentrations of calcium, magnesium and sodium from the Spokane River and Zone 1, 2 and 3. The elemental mean values of calcium, magnesium and sodium in the four groups showed that no significant difference exist between the Spokane River and Zone 1. A significant difference was shown to exist between Zone 1, Zone 2 and Zone 3. No significant difference was found between the Spokane River, Zone 1, 2 and 3 in sodium concenrations. The results obtained were the same as the least significant difference method.

Discriminant Analysis

Discriminant analysis was used to classify the water samples into four groups. A discriminant function determines the characteristics that are common to each group utilizing the calcium, magnesium and sodium concentrations of each sample and predicts the group to which each sample should belong. This method is useful for classifying changes in water quality in the direction of ground water flow.

The generalized squared distance formula, namely the Mahanobolis D_2 statistic, tests the signifiance of group differences (Koch, 1970). A set of discriminant functions are developed for each group which gives the smallest probability of miss-classification and serves as an index for classifying each observation into one of the four groups (Snedecor, 1968, p. 145). The discriminant functions are computed for each sample and a squared distance identifies the group in which the observation belongs.

A summary of the classification performance using the generalized squared distance formula is shown in Table 13. The results show that 88% of the observations were classified correctly. Four observations from the river were classified into Zone 1, and three observations from Zone 1 were classified into the river group. For Zone 3 and 4, only one observation from Zone 3 was miss-classified into Zone 4. The findings indicate that it is difficult to distinquish between the river and Zone 1 water quality. The water quality characteristics of the glacial aquifer in the area of study were classified by location in the flow system. This lends support to the hypothesis that water is moving from the Spokane River into the underlying glacial aquifer and water quality values can be classified according to its location in the flow system.

Table 13 . . . . Discriminant Analysis Prediction Results for Sample Location Based upon Combined Cation Values of each Sample.

		Predicted Group Membership			
Actual Group	No. of Samples	Group 1 (Spokane R.)	Group 2 (Zone 1)	Group 3 (Zone 2)	Group 4 (Zone 3)
Group 1 (Spokane R.)	17	13 76.5%	4 23.5%	0. 0.0%	0. 0.0%
Group 2 (Zone 1)	17	3 17.6%	14 82.4%	0. 0.0%	0. 0.0%
Group 3 (Zone 2)	17	0. 0.0%	0. 0.0%	16 94.1%	1 5.9%
Group 4 (Zone 3)	17	0. 0.0%	0. 0.0%	0. 0.0%	17 100.0%

SUMMARY AND CONCLUSTIONS

The ground water system in the southern portion of the Rathdrum Prairie was selected for investigation to describe recharge characteristics from the Spokane River above Post Falls into the Rathdrum Prairie aquifer. Wells located in the metasedimentary and glacial aquifers were inventoried. Water levels and quality samples were taken to determine the ground water flow conditions and the areal distribution of selected cation concentrations in the Coeur d'Alene-Post Falls area.

Wells in the southern Rathdrum Prairie aquifer yield up to several thousand gallons per minute. Outliers of basalt and Pre-Tertiary rock units generally yield only sufficient quantaties of water for domestic use.

The water table configuration in the Coeur d'Alene-Post Falls area indicates ground water movement away from Lake Coeur d'Alene and the Spokane River. The regional ground water table map indicates a ground water divide exists at the northern boundary of the study area. It extends west from Hayden Lake to the Washington-Idaho border.

Data was obtained on the geologic and the hydraulic conductivity values of the glacial outwash and alluvial sediments. In situ variable head and constant head permeability tests were conducted to obtain hydraulic conductivity values of the upper portion of the alluvial sediments. Specific capacity data were used to estimate hydraulic conductivity values. Distinct differences in hydraulic conductivity between the alluvial and glacial outwash materials were found. Well logs confirmed the existence of fine grained alluvial sediments overlying the glacial outwash in the Spokane River channel extending from Lake Coeur d'Alene to the Washington-Idaho border.

Temporal fluctuations of ground water levels show that the flow system responds to short term periods of recharge and no recharge. Distinct similarities between long term fluctuations in water levels and long term fluctuations in precipitation were observed.

Samples were collected in August, 1975 from 88 wells in the study area. The samples were analyzed for six cations, pH and E.C. The objectives of the sampling program were to document concentrations in the Spokane River and the ground water system and determine ground water flow conditions and recharge characteristics near the Spokane River. Concentrations of selected cations indicated water movement from the river into the aquifer system.

The following conclusions were drawn from the study:

1. Recharge occurs from the Spokane River into the Rathdrum Prairie aquifer in the reach from Coeur d'Alene to Post Falls. This recharge is shown by water level and quality data. The rate of water contributed by the Spokane River to the ground water system above Post Falls is approximately 225 cfs or 160,000 acre

feet per year.

2. Data obtained from specific capacity tests show no significant differences in hydraulic conductivity throughout the southern Rathdrum Prairie. The hydrologic properties or the recent alluvial material provides the main control for the movement of water from the Spokane River into the ground water system.

3. The long term water level trend indicates ground water levels have declined about ten feet since 1949, but have remained relatively unchanged since 1964. Short term water levels respond to periods of recharge and no recharge.

4. Although zinc is a common constituent of the Spokane River, it is not found in the ground water. The zinc is believed to be held in the sediments along the river bottom because of exchange and absorption properties of the river channel sediments.

RECOMMENDATIONS

A better understanding of the recharge characteristics and ground water flow systems in the Rathdrum Prairie is necessary to help planners and future investigators plan for increased ground water usage. The following recommendations are presented to help achieve the necessary level of understanding:

1. Delineate the recharge zones from Lake Coeur d'Alene to the Washington-Idaho border. More data is needed on

   a. vertical and horizontal hydraulic conductivity data of the alluvial sediments.

   b. ion exchange and absorption characteristics of the fine grained alluvial sediments.

   c. detailed mapping of the alluvial sediments.

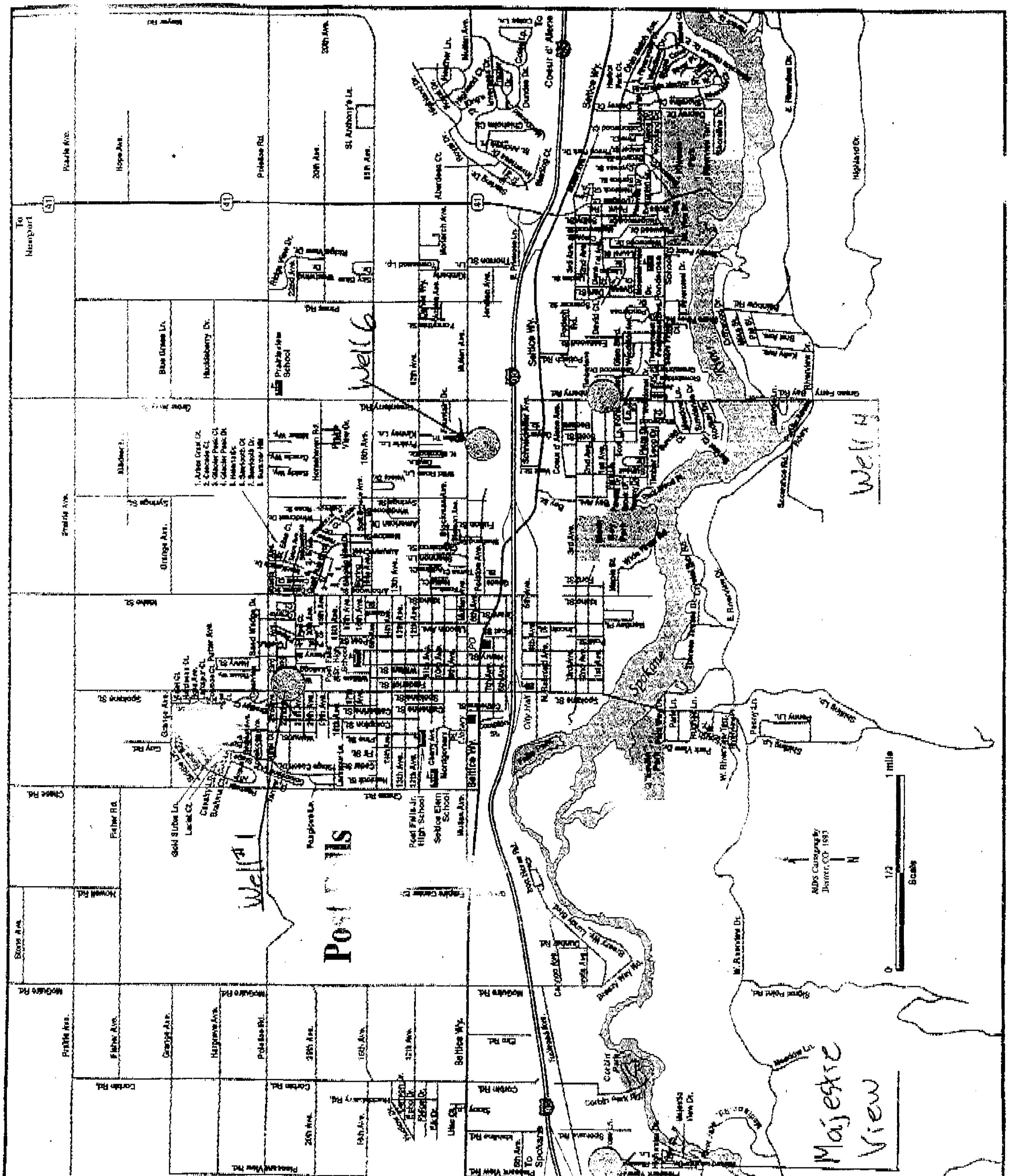
   d. vertical leakage patterns through the channel bottom deposits.

2. Expand the ground water level monitoring sites to include the entire Rathdrum Prairie. More information on ground water movement within the city limits of Coeur d'Alene and along the Spokane River is needed to better define the ground water flow system at the aquifer boundary and document the long term water level changes.

3. Develop a baseline water quality monitoring program to include selected cations, anions and heavy metals. Water quality data help to define the ground water flow patterns and areas that may be impacted by polluting sources.

4. The use of specific capacity tests are limited in

Post Falls Street Map



TD ✓
GH -
PWS file -

Accurate Testing Labs L.L.C.

Date of Report: 9/5/97

Terry Werner
City of Post Falls Water
1720 W. Seltice Way
Post Falls, ID 83854

Re: **Certificate of Analysis**
Results of analysis for samples received 9/2/97, for testing as requested.

Sample ID:	***WELL #6***
Project Name:	CITY OF POST FALLS PWS# 1280147
Matrix:	WATER
Date Sampled:	9/2/97 7:00 AM
Lab ID:	72937

Analyte:	by EPA Method	Concentration	
Cadmium (Cd)	200.7	<1	ppb
Lead (Pb)	200.9	<2	ppb
Zinc (Zn)	200.7	34	ppb
Hardness (as $CaCO_3$)	2340 B	76,800	ppb

Walter Mueller, Lab. Director

QC ________

7950 Meadowlark Way · Coeur d'Alene, ID 83814 · (208) 762-8378 · Fax (208) 762-9082

Accurate Testing Labs L.L.C.

Date of Report: 9/5/97

Terry Werner
City of Post Falls Water
1720 W. Seltice Way
Post Falls, ID 83854

Re: Certificate of Analysis
Results of analysis for samples received 9/2/97, for testing as requested.

Sample ID:	***WELL #1***
Project Name:	CITY OF POST FALLS PWS# 1280147
Matrix:	WATER
Date Sampled:	9/2/97 6:40 AM
Lab ID:	72935

Analyte:	by EPA Method	Concentration	
Cadmium (Cd)	200.7	< 1	ppb
Lead (Pb)	200.9	< 2	ppb
Zinc (Zn)	200.7	28	ppb
Hardness (as $CaCO_3$)	2340 B	64,100	ppb

Walter Mueller, Lab. Director

QC [signature]

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Accurate Testing Labs L.L.C.

Date of Report: 9/5/97

Terry Werner
City of Post Falls Water
1720 W. Seltice Way
Post Falls, ID 83854

Re: **Certificate of Analysis**
Results of analysis for samples received 9/2/97, for testing as requested.

Sample ID:	***WELL #4***
Project Name:	CITY OF POST FALLS PWS# 1280147
Matrix:	WATER
Date Sampled:	9/2/97 7:30 AM
Lab ID:	72938

Analyte:	by EPA Method	Concentration	
Cadmium (Cd)	200.7	<1	ppb
Lead (Pb)	200.9	6	ppb
Zinc (Zn)	200.7	89	ppb
Hardness (as $CaCO_3$)	2340 B	68,600	ppb

Walter Mueller, Lab. Director

QC

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Accurate Testing Labs L.L.C.

Date of Report: 9/5/97

Terry Werner
City of Post Falls Water
1720 W. Seltice Way
Post Falls, ID 83854

Re: **Certificate of Analysis**
Results of analysis for samples received 9/2/97, for testing as requested.

Sample ID:	***MAJESTIC VIEW WELL***
Project Name:	CITY OF POST FALLS PWS# 1280256
Matrix:	WATER
Date Sampled:	9/2/97 6:20 AM
Lab ID:	72938

Analyte:	by EPA Method	Concentration	
Cadmium (Cd)	200.7	< 1	ppb
Lead (Pb)	200.9	5	ppb
Zinc (Zn)	200.7	220	ppb
Hardness (as $CaCO_3$)	2340 B	19,600	ppb

Walter Mueller, Lab. Director

QC [signature]

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Accurate Testing Labs L.L.C.

Date of Report: 9/5/97

RECEIVED SEP - 8 1997 COPY TO Bob Joe Rich Dw

City of Rathdrum
P.O. Box 67
Rathdrum, ID 83858

Re: **Certificate of Analysis**
Results of analysis for samples received 8/29/97, for testing as requested.

Sample ID:	*PINE ST. WELL*
Project Name:	CITY OF RATHDRUM PWS# 1280152
Matrix:	WATER
Date Sampled:	8/29/97 10:30 AM
Lab ID:	72921

Analyte:	by EPA Method	Concentration	
Cadmium (Cd)	200.7	< 1	ppb
Lead (Pb)	200.9	< 2	ppb
Zinc (Zn)	200.7	24	ppb

Walter Mueller, Lab. Director

QC

Accurate Testing Labs L.L.C.

Date of Report: 9/5/97

RECEIVED SEP - 8 1997

COPY TO Bob Joe Mark Ron

City of Rathdrum
P.O. Box 67
Rathdrum, ID 83858

Re: Certificate of Analysis

Results of analysis for samples received 8/29/97, for testing as requested.

Sample ID:	***THAYER WELL***
Project Name:	CITY OF RATHDRUM PWS# 1280152
Matrix:	WATER
Date Sampled:	8/29/97 10:30 AM
Lab ID:	72922

Analyte:	by EPA Method	Concentration		
Cadmium (Cd)	200.7	< 1	ppb	
Lead (Pb):	200.9	< 2	ppb	20
Zinc (Zn)	200.7	23	ppb	37

Walter Mueller, Lab. Director

QC

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their usefulness. Partial penetration, well loss and hydrogeologic boundaries can adversely affect the actual hydraulic conductivity values. Additional hydrologic data on the aquifer system should be gathered using constant discharge pump test techniques.

5. There is a need for hydrologic planning and management of the resource. At present, ground water is a renewable resource. Demands for water will increase in the future as well as potential for water quality degradation. Planners should be aware of the potential problems associated with recharging water that may develop and the pollution hazards to the ground water system. The following considerations provide the means to forecast potential water problems:

a. develop an inventory system which shows water used and water available for a sustained yield.

b. artifical ground water recharge should be considered as a viable alternative when considering conservation and disposal of runoff and supplementing ground water supplies.

c. The ground water divide separating the main prairie ground water system from the Coeur d'Alene-Post Falls system provides site specific boundaries for ground water and land use based decisions. The two flow directions are important in considering sewage disposal areas, artificial recharge sites, and subdivision locations.

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APPENDIX I

RECORDS OF REPRESENTATIVE WELLS IN THE SOUTHERN RATHDRUM PRAIRIE AREA

Appendix A . . . Records of Representative Wells in the Southern Rathdrum Prairie Area.

	Well	Owner	Well Depth (ft)	Casing Diameter (ft)	Land Surface Altitude (ft)	Water Level Below Land Surface	Water Level Date	Water Yielding Material	Pump Type	Use
1	50/4/1bab	Bill Ulrich	235	6	2230	193.7	9-1975	Sand, gravel	S	D
2	50/4/1ccd	City of Coeur d'Alene	309	18	2238	187.3	9-1975	"	T	M
3	50/4/2dab	Heitter	235	12		192.0	1953	"	T	I
4	50/4/2ccd	unknown	202(?)	6		-	-	"	S	D
5	50/4/3aad	Bill Morrow	200	6		-	-	"	S	D
6	50/4/3cda	Coeur d'Alene Golf Course	190	8	2202	155.9	9-1975	"	S	I
7	50/4/3cc	Agte	193	6	2170	136	4-1948	"	S	D
8	50/4/3ddc	H and D Trailer Court	203	5-5/8	2195	146	1962	"	S	D
9	50/4/3ddd	Showboat	176	6	2188	125	9-1949	"	S	D
10	50/4/4aad	City of Coeur d'Alene	350	18	2243	233.8	9-1975	"	T	M
11	50/4/4cbc	Travis	210	6	2205	181.0	9-1975	"	S	D
12	50/4/4cac	Gertch	230	6	2230	205.3	9-1975	"	S	D
13	50/4/4ccd	Diamond International	201	8	2145	C	9-1975	"	S	I
14	50/4/4cca	City of Huetter	185	12		-	-	"	T	M
15	50/4/4ddc	Y and J Foods	175	6		C	9-1975	"	S	D
16	50/4/4ddd1	Johnson	200	6	2181.7	130.5	9-1975	"	S	D
17	50/4/4ddd2	Lundsford	200	6	2184	170.0	1941	"	S	D
18	50/4/4ddd3	Flanagan	215	6	2187	136.6	9-1975	"	S	D
19	50/4/5add	McDonald	360	6	2243	233.75	9-1975	"	S	D
20	50/4/5cbb	Highway Dept. Rest Area	350	8		-	-	"	S	D
21	50/4/5cbc	Highway District Office	325	6	2155	141.0		"		
22	50/4/5cbd	Hunt Brothers	190	8	2175	161.2	9-1975	"	S	D
23	50/4/4dbc	Harry Bright	202	6	2180	160	9-1975	"	S	D
24	50/4/5ccd	W. Shockley	153	6	2146	129.2	9-1975	"	S	D
25	50/4/5cdc	N. Shockley	161	6	2155	136.5	9-1975	"	S	D
26	50/4/5ccc	R. Livingston	145	6	2155	136.3	9-1975	"	S	D
27	50/4/5cdd	Wilbur	170	8	2155	136.0	9-1975	"	S	D
28	50/4/5dcc	Mitson	153	8	2155	140.7	9-1975	"	S	D
29	50/4/5dcb1	Galloway (abandoned)	145	6	2155	137.3	9-1975	"	S	D
30	50/4/5dbd	Koss	214	6	2155	141.3	9-1975	"	S	D
31	50/4/5dca	O. Galloway	155	6	2155	-	-	"	S	D
32	50/4/5dcd1	Osterson	161	6	2155	136.0	6-1975	"	S	D
33	50/4/5ddc	Huetter Speedway	163	6	2155	125.1	9-1975	"	S	D
34	50/4/5ddd	L. Grimm	135	6	2155	113.4	9-1975	"	S	D
35	50/4/5dad	A and K Lab.	180	6	2155	-	-	"	S	D
36	50/4/5cda	Fred Hazel	178	6	2155	-	-	"	S	D

Appendix A . . . Continued

	Well	Owner	Well Depth (ft)	Casing Diameter (ft)	Land Surface Altitude (ft)	Water Level Below Land Surface	Water Level Date	Water Yielding Material	Pump Type	Use
37	50/4/5dcd2	M. Fox	168	6	2155	-	-	"	S	D
38	50/4/5cad	Gookstetter	278	6	2250	247	1968	"	S	D
39	50/4/5dac	J. Peters	216	6	2160	157	1953	"	S	D
40	50/4/5dcd2	D. Drapeau	150	6	2155	127.5	6-1975	"	S	D
41	50/4/6bba	Royal Highlands	375	12	2340			"	T	D
42	50/4/6bdd	Idaho State Fish and Game Dept.	325	6	2227	206.4	9-1949	"	S	D
43	50/4/6cdb	Pine Villa	205	12	2175	160		"	T	D
44	50/4/7bcb	Bubtest Camp	249	6	2157	153.5	9-1975	"	S	D
45	50/4/7add1	Snook	169	6	2140			"	S	D
46	50/4/7add2	Dashiell	229	6	2140	-	-	-	S	D
47	50/4/7add3	Lussier	130	6	2140	-	-	Sand, gravel	S	D
48	50/4/7add4	Moll	437	6	2140	-	-	Granite	S	D
49	50/4/7cdc	S. West	50	6	2400	-	-	"	S	D
50	50/4/7dcc	Chambers	110	6	2400	35	1971	"	S	D
51	50/4/8aab	F. Elkins	163	8	2155	129.5	9-1975	Sand, gravel	S	D
52	50/4/8aba	Galloway	144	7	2142	108.0	9-1949	"	S	D
53	50/4/8bbb	Galloway	171	8	2145	133.0	9-1975	"	S	D
54	50/4/8ada2	J. C. Hampton	135	6	2140	78.6	9-1975	"	S	D
55	50/4/8ada1	C. Johnson	135	6	2140	-	-	"	S	D
56	50/4/8ada1	J. C. Hampton	45	6	2140	8.0	9-1975	Sand, gravel, basalt	S	D
57	50/4/8bcb	B. Johnson	210	6	2140	102.0	9-1975	"	S	D
58	50/4/8bbc	Stockings	165	6	2140	-	-	"	S	D
59	50/4/8ddd	G. Arthur	235	6	-	12	1971	Granite	S	D
60	50/4/8cda	R Tayama	300	6	-	30	1972	"	S	D
61	50/4/9bba	Diamond International	160	7	2138	124	9-1949	Sand, gravel		
62	50/4/10aad	Idaho Forest Industries	unknown	8	2160	88.9	9-1975	"	a	a
63	50/4/10aab	Boulevard Motel	159	6	2190	134.6	9-1975	"	S	D
64	50/4/10abb	Central Pre-Mix	unknown	12		-	-	"	T	D
65	50/4/10bbb	Idaho Forest Industries	125	8		-	-	"	T	D
66	50/4/11bbb	Cement Company	unknown	6	2240	187.5	9-1975	"		I
67	50/4/12cdc	City of Coeur d'Alene	270	18	2220	164.5	9-1975	"	T	M
68	50/4/12cbc	City of Coeur d'Alene	295	18	2221	169.1	9-1975	"	T	M

Appendix A . . . Continued

	Well	Owner	Well Depth (ft)	Casing Diameter (ft)	Land Surface Altitude (ft)	Water Level Below Land Surface	Water Level Date	Water Yielding Material	Pump Type	Use
69	50/4/15abd	Aqua Terrace	111	12	2145	11.2	6-1975	Alluvium		D
70	50/4/15bcb		285			-	-	Granite		D
71	50/4/15bda		180			-	-	Basalt		D
72	50/4/16aba		80			-	-	Granite		D
73	50/4/17abd		200			-	-	"		D
74	50/5/1aad	Washington Water Power	231	30	2192.5	187.0	9-1975	"	T	I
75	50/5/1adb	Interstate-Plastics	243	8	2200	198		"	S	D
76	50/5/1daa	Trailer Park	256	12		-	-	"	S	D
77	50/5/1cbb	City of Post Falls	279	30	2196	193.9	9-1975	"	T	M
78	50/5/1cdc	Symons	202	6				"	S	D
79	50/5/2bcd	Idaho Veneer	210	8	2176	175	1973	"	S	D
80	50/5/2abc	Schneedmiller	200	26				"	T	I
81	50/5/11aba	Presbyterian Bible Camp	175	6				"	S	D
82	50/5/12aba	Johnson	159	6		-	-	"	S	D
83	50/5/12bbc	Satchwell	182	6		-	-	"	S	D
84	50/5/12bbd	Dolf	200	6		-	-	"	S	D
85	50/5/12bba	Dolf	149	6	2135	124.2	9-1975	"	S	D
86	50/5/18dcc1	C. Feely	275	6	2260	257.3	9-1975	"	S	D
87	51/4/25bba	Dalton Gardens	297	20	2245			Sand, gravel	T	M
88	51/4/25cad	Dalton Gardens	281	18	2245			"	T	M
89	51/4/25cbb	Rude	231	6	2233	215.8	9-1975	"	S	D
90	51/4/26baa	Rudolph	283	6	2277			"	S	D
91	51/4/26add	Memorial Cemetary	280	30	2240	220	1974	"	T	I
92	51/4/26aad	Aqua Drilling	330	8	2250	234.0	9-1975	"		No Pump
93	51/4/26abd	Aqua Drilling	390	8	2245	-		"	S	D
94	51/4/26ccc	Boat Works	301	6	2265	252.3	9-1975	"	S	D
95	51/4/27dcc	Schneedmiller	310	30	2260	255		"	T	I
96	51/4/27dda	Schneedmiller	275	6	2270			"	T	I
97	51/4/28bbd	Lyle Jacklin	297	30	2270	260	1972	"	T	I
98	51/4/28cdb	Mica Inc.	348	12	2270	295	1974	"	S	D
99	51/4/29bdd	D. Weiler	285		2250	231	1974	"	S	D
100	51/4/29ddd	T. Brichertt	268	18	2265			"	S	D
101	51/4/31ddd	G. Armstrong	420	20	2340	352	1973	"	S	D
102	51/4/32acc	T. Brichertt	318	18	2260	272	1975	"	S	D
103	51/4/32dbc	G. Armstrong	343	18	2270			"	S	D

	Well	Owner	Well Depth (ft)	Casing Diameter (ft)	Land Surface Altitude (ft)	Water Level Below Land Surface	Water Level Date	Water Yielding Material	Pump Type	Use
104	51/4/32cdd	J. Simmons	315	8	2270			Sand, gravel	S	D
105	51/4/33acc	Idaho Forest Industries-Industrial Park	335	20	2264	261.2	9-1975	"	T	ID
106	51/4/33caa	G. Armstrong	332			264.0	1970	"	S	D
107	51/4/33ccc	G. Armstrong	286	6	2260			"	S	D
108	51/4/34bda	Sceedmiller	247					"		
109	51/4/34add	Abbs	280	6	2255			"	S	D
110	51/4/34daa	Hudson	256	7	2250			"	S	D
111	51/4/34cda	U. S. Forest Service Nursery	280	8	2257			"	T	I
112	51/4/34ccd1	U. S. Forest Service Nursery	270	24	2245	237.0	9-1975	"	T	I
113	51/4/34ccd2	U. S. Forest Service Nursery	320	18	2245			"	T	I
114	51/4/34cdc	U. S. Forest Service Nursery	270	18	2245			"	T	I
115	51/4/35adc	S. West	228	6	2230			"	S	D
116	51/4/35bbc	G. Lamb	279	6	2250	240	1960	"	S	D
117	51/4/35ccc1	R. Fuller	250	6	2220	196.6	9-1975	"	S	D
118	51/4/35ccc2	R. Fuller	218	6	2220			"	S	D
119	51/4/35abb	B. Gordon	296	15				"	S	D
120	51/4/36dcc	T. Hoffman	253	30	2240	208	9-1975	"	T	D
121	51/5/22bbb1	U. S. Bureau of Reclamation	280	19.25	2161	165.0	9-1975	"	T	I
122	51/5/22bbb2	U. S. Bureau of Reclamation	276	15.25	2162	-	-	"	T	I
123	51/5/22bbb3	U. S. Bureau of Reclamation	326	19.25	2163	-	-	"	T	I
124	51/5/22bbb4	U. S. Bureau of Reclamation	290	19.25	2163	-	-	"	T	I
125	51/5/22bbb5	U. S. Bureau of Reclamation	330	15.25	2164	-	-	"	T	I
126	51/5/25bca	P. Bolsei	270	6	-	-	-	"	S	D
127	51/5/26cca	H. Johnson	238	32	-	-	-	"	T	I
128	51/5/27ccc	Unknown	306	12	-	-	-	"	S	D
129	51/5/28ccb1	U. S. Bureau of Reclamation	230	19.25	2146	156.0	9-1975	"	T	I
130	51/5/28ccb2	U. S. Bureau of Reclamation	256	19.25	2146	-	-	"	T	I
131	51/5/28ccb3	U. S. Bureau of Reclamation	257	19.25	2146	-	-	"	T	I
132	51/5/28ccb4	U. S. Bureau of Reclamation	239	15.25	2147	-	-	"	T	I
133	51/5/28ccb5	U. S. Bureau of Reclamation	241	15.25	2146	-	-	"	T	I
134	51/5/28ccb6	U. S. Bureau of Reclamation	256	15.25	2145	-	-	"	T	I
135	51/5/28dda1	U. S. Bureau of Reclamation	273	19.25	2153	161.0	9-1975	"	T	I
136	51/5/28dda2	U. S. Bureau of Reclamation	270	19.25	2151	-	-	"	T	I
137	51/5/28dda3	U. S. Bureau of Reclamation	254	15.25	2153	-	-	"	T	I
138	51/5/33bba1	McGuire (U.S.G.S. observation well)	174	60	2137.6	150.5	9-15-75	"	T	I

Appendix A . . . Continued

	Well	Owner	Well Depth (ft)	Casing Diameter (ft)	Land Surface Altitude (ft)	Water Level: Below Land Surface	Water Level: Date	Water Yielding Material	Pump Type	Use
139	51/5/34ada	City of Post Falls	265	20						
140	51/5/34abb	City of Post Falls	276	20	2218	-	-			
141	51/5/34abd	City of Post Falls	275	24	2215	223.4	9-1975			
142	51/5/35acc	Ross. Pt. Irrigation Dist	230.6	14						

a = Abandoned
S = Submersible
D = Domestic
I = Irrigation
ID = Industrial
M = Municipal