Eastern Columbia Plateau Aquifer System Sole Source Aquifer Investigation

January, 1993

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A Research Report
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ABSTRACT

This report presents hydrogeologic and water-use information necessary for a sole source aquifer (SSA) petition for the Eastern Columbia Plateau Aquifer System. The report has been prepared at the request of Palouse-Clearwater Environmental Institute, Moscow, Idaho, and is based entirely upon existing published information. The aquifers in this report are in the Grande Ronde, Wanapum, and Saddle Mountains basalts, all of which are part of the Yakima Group of the Columbia River Basalts, and in the sedimentary overburden. Significant evidence exists for interconnection between these aquifers. The aquifers are therefore being treated as a system. Boundaries are defined based on the geology (lateral extent) and hydrogeology (major drainage divides) of the aquifer system. Boundaries of the aquifer system are the Clearwater and Snake Rivers to the south, the Columbia River to the southwest, west, and northwest, and the Spokane River to the north. The eastern aquifer system boundary is defined by the lateral margin of the Grande Ronde Basalt. The aquifer area lies within Adams, Douglas, Franklin, Grant, Lincoln, Whitman, and part of Spokane counties in Washington, with small portions of the area extending into the Idaho Panhandle. A water-use budget conducted for the aquifer use area shows that more than 90% of the drinking water for the area is derived from this aquifer system. Also, alternative sources of drinking water are physically limited and do not appear to be economically feasible. Therefore, based on the information presented in this report, we conclude that the aquifer system that we have described meets the criteria established by the U.S. EPA for sole source aquifer designation.

SECTION 1.0: INTRODUCTION

1.1 Background

The Palouse-Clearwater Environmental Institute (PCEI) is interested in petitioning for Sole Source Aquifer Designation for the Eastern Columbia Plateau Aquifer System (ECPAS), which is part of the larger Columbia Plateau aquifer system. PCEI requested that the Mountain Resource Group (MRG) prepare hydrogeologic and water-use information necessary for a sole source aquifer (SSA) petition, and to evaluate this information within the context of U.S. EPA criteria for sole source aquifers. Specific objectives of MRG's research effort included:

1. identifying and evaluating aquifer system boundaries;
2. developing a drinking water budget for the area overlying the aquifer system; and
3. preparing other information required for a SSA petition, including information about local geography, climate, population, land use, surface hydrology, and other water-use information.

This report provides results of the MRG investigation. The SSA Petitioner Guidance Document (1987) provides criteria for defining a sole or principal source aquifer and outlines the petitioning process; this report was prepared under those guidelines. The report includes a brief description of the SSA petitioning process and a physical, geological, and hydrogeological description of the area of interest. Specific aquifer information includes a description of aquifer boundaries, aquifer characteristics, recharge areas, ground water movement, and ground water quality.

1.2 Project Scope

The scope of this project is limited to the Eastern Columbia Plateau Aquifer System, which is located in southcentral and southeastern Washington (Figure 1; a more detailed description of aquifer boundaries is provided in Section 5.0). Much of the drinking water in this area is supplied from aquifers in three basalt units of the Columbia Plateau Basalts and the sedimentary overburden. These units are considered as an aquifer system because aquifers in the units appear to be hydrogeologically connected (see Section 4) and because all three units are significant drinking water sources.

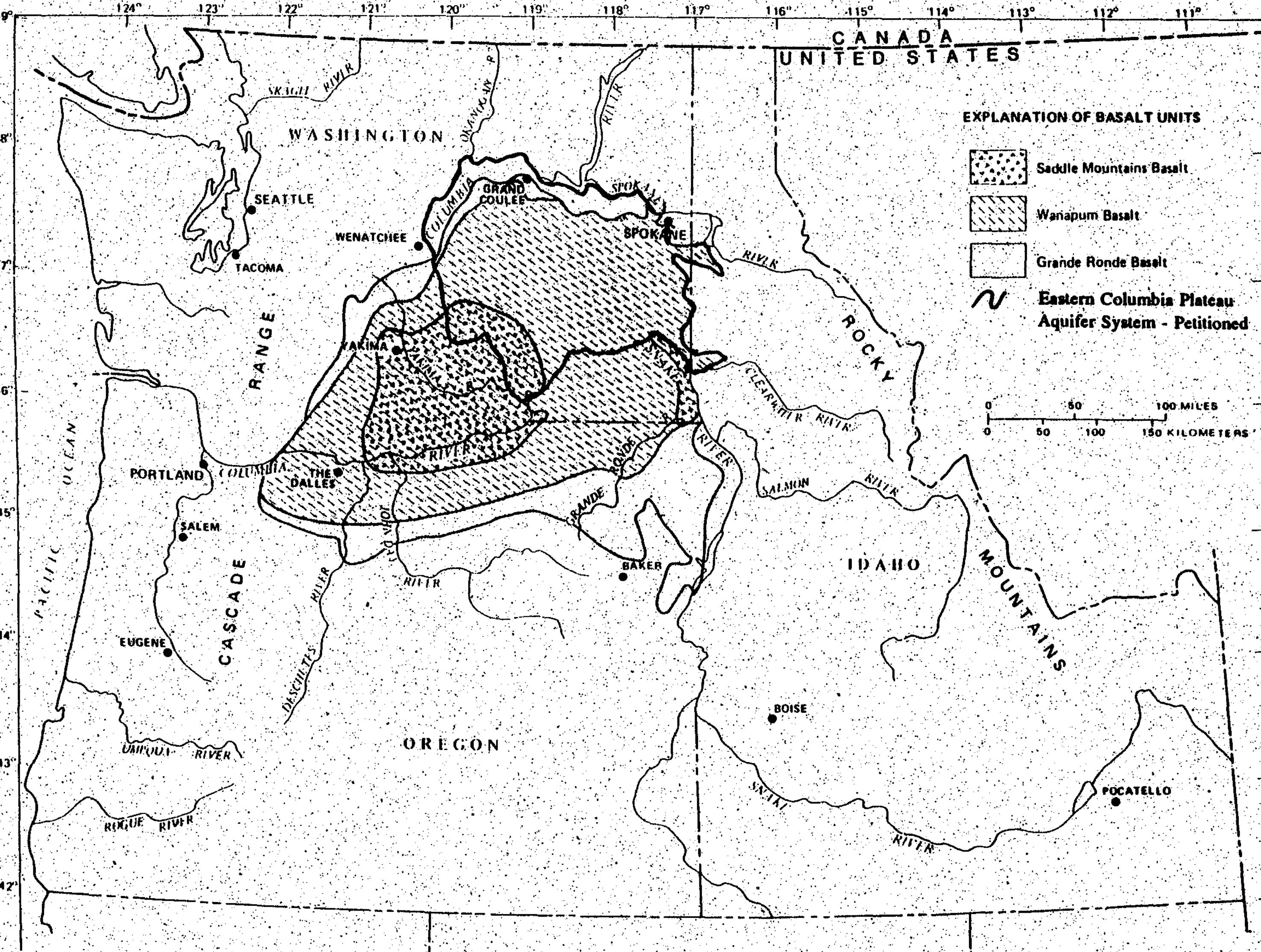


FIGURE 1. Regional Setting of the Columbia River Basalts and Eastern Columbia Plateau Aquifer System (after Whiteman, 1986)

SECTION 2.0: THE SOLE SOURCE AQUIFER PROGRAM

2.1 Sole Source Aquifer Program

The Sole Source Aquifer Program is authorized by the Safe Drinking Water Act of 1974 (Public Law 93-523 42 U.S.C. 300 et. seq.). Section 1424(e) of the Safe Drinking Water Act states:

> "If the Administrator determines, on his own initiative or upon petition that an area has an aquifer which is the sole or principal drinking water source for the area and which, if contaminated, would create a significant hazard to public health, he shall publish notice of that determination in the Federal Register. After the publication of any such notice, no commitment for federal financial assistance (through a grant, contract, loan guarantee, or otherwise) may be entered into for any project which the Administrator determines may contaminate such aquifer through a recharge zone so as to create a significant hazard to public health; but a commitment for federal assistance may, if authorized under another provision of law, be entered into to plan or design the project to assure that it will not so contaminate the aquifer."

EPA defines a sole or principal source aquifer as one that supplies at least fifty percent of the drinking water consumed in the area that overlies the aquifer (U.S. EPA, 1987). Current EPA guidelines also stipulate that designated sole or principal source aquifer areas have no alternative source or combination of sources that could legally, physically, and economically supply all those who depend upon the aquifer for drinking water (U.S. EPA, 1987). For convenience all EPA-designated sole or principal source aquifers are often referred to as "sole source aquifers".

Twelve other aquifers in the Pacific Northwest have received sole source aquifer designation (Figure 2). These include the Spokane-Rathdrum aquifer, which is adjacent to the ECPAS, several aquifers in the Puget Sound area in Washington, and the Eastern Snake River Plain and Lewiston Basin aquifers in Idaho.

It is not the policy of the EPA to initiate petitions for SSA designation; the Agency only responds to petitions. Until 1987 the EPA accepted sole or principal source aquifer petitions which contained a minimum amount of information. The SSA Petitioner Guidance Document, released in 1987, set forth criteria that clarify the definition of a sole or principal source aquifer and describes how to petition the EPA. This document was prepared under those guidelines and with the intention of providing the information necessary to determine whether the proposed aquifer meets the requirements for designation as a sole or principal source aquifer.

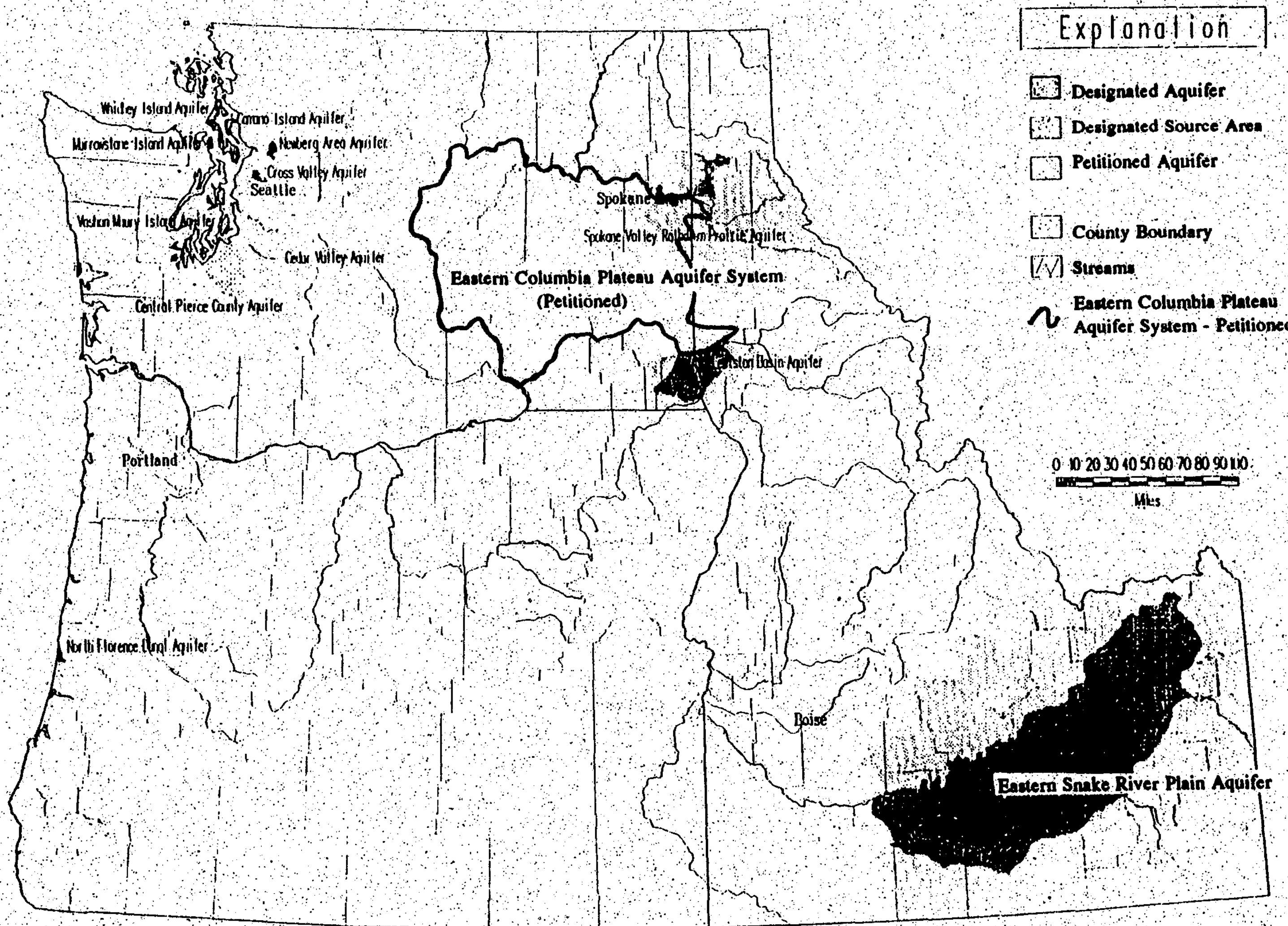


FIGURE 2. Sole Source Aquifers in the Pacific Northwest

SECTION 3.0: DESCRIPTION OF PROJECT AREA

3.1 General Description

The Eastern Columbia Plateau Aquifer System (ECPAS) area covers more than 8.2 million acres and includes Adams, Douglas, Franklin, Grant, Lincoln, Whitman, and part of Spokane counties in southeastern and southcentral Washington state (Figure 3). Some small areas of Idaho along the Washington-Idaho border are also included. Regionally, the ECPAS is located in the Columbia Intermontane physiographic province, which is bounded by the Blue Mountains to the south, the Cascade Range to the west, the Okanogan Highlands to the north, and the Rocky Mountains to the east. Three informal geologic subdivisions have been made for this area - the Yakima Fold Belt subprovince, the Blue Mountain subprovince, and the Palouse subprovince (Myers and Price, 1979). Most of the ECPAS is located in parts of the Palouse Subprovince and the Yakima Fold Belt.

Much of the ECPAS area in the Palouse subprovince is characterized by rolling, loess-covered hills underlain by relatively undeformed, gently dipping basalts. The central part of the area is in the Channeled Scablands, where most of the loess that blanketed the basalt has been scoured away by a series of floods originating from Glacial Lake Missoula. The resulting land surface is characterized by coulees, "scabs" of basalt bedrock, loess islands, and sand and gravel flood deposits. The western part of the ECPAS area lies in the Yakima Fold Belt. The folded basalts in this area are topographically expressed as long, narrow ridges with wide, shallow intervening valleys.

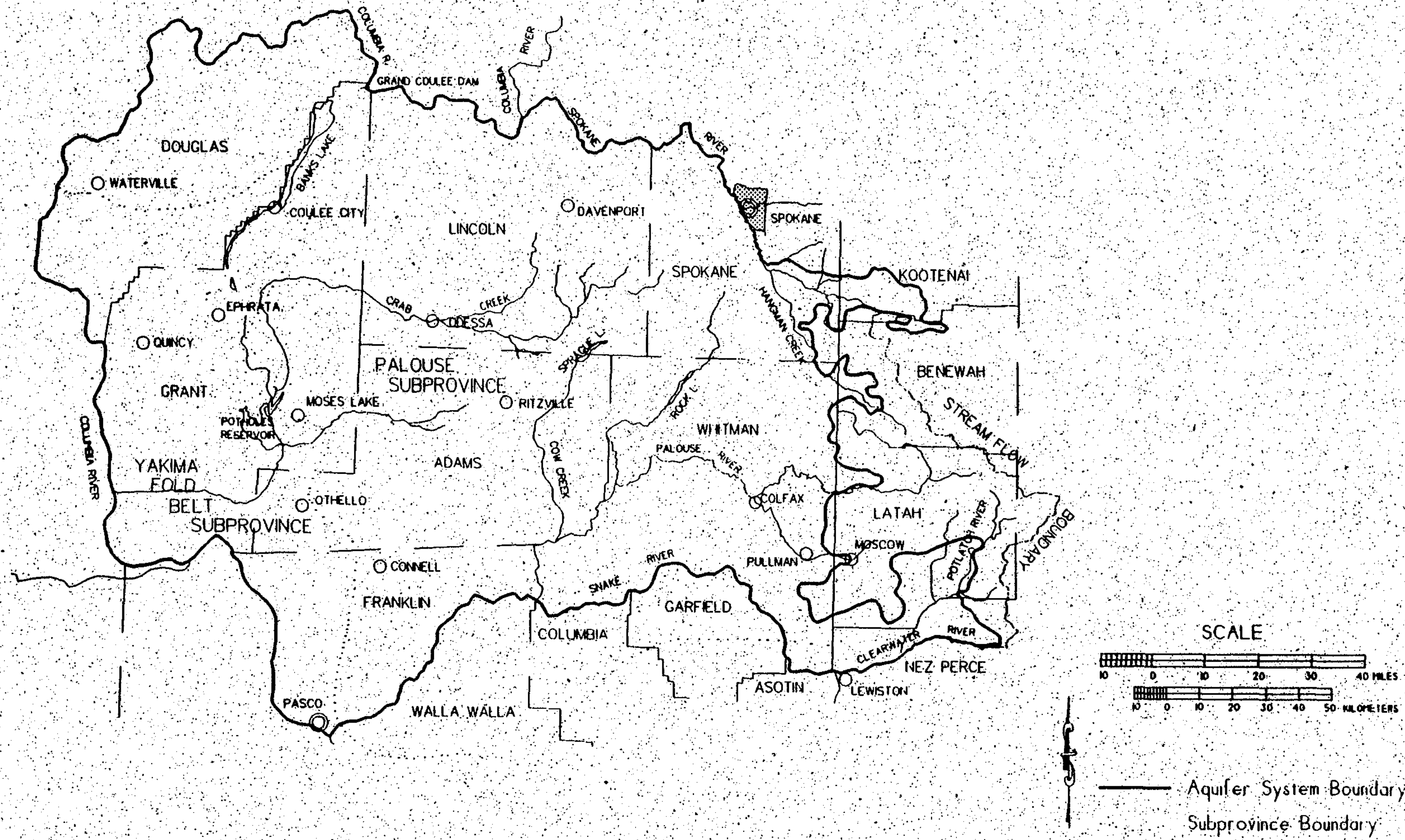


Figure 3. Eastern Columbia Plateau Aquifer System Area

3.2 Climate

The ECPAS is in the rain shadow of the Cascade Mountains. The climate in the ECPAS region is semi-arid, with average annual precipitation of about 13.5 inches (Yates and Yates, 1992). Most of the precipitation occurs during the winter months. Summers are hot and dry, and winters are cool, with occasional cold snaps. Mean January temperature is 26.8 F, and the mean July temperature is 70.4 F. The mean annual temperature for the area is about 48.8 F. A summary of rainfall and temperatures for the area is presented in Table 1.

3.3 Population

Total estimated population for the aquifer use area is 322,320 (Yates and Yates, 1992). With the exception of Spokane County, entire Washington county populations are used in determining total population. Only part of Spokane County lies within the project area, however. Therefore, in calculating the population for Spokane County, the city of Spokane is subtracted from the total county population. Two-thirds of the remaining population in Spokane County, based on aquifer system boundaries, are included in the project area.

Pullman, Pasco, and Moscow, Idaho are the largest cities in the area, with populations greater than 20,000. The populations of Pullman, Whitman County and Moscow, Idaho fluctuate due to the student populations associated with Washington State University and the University of Idaho. Approximately 23% of the people live in cities with populations greater than 10,000. A summary of population by county is presented in Table 2.

3.4 Economy and Land Use

The primary economic activity for the area is agriculture and its associated industries

TABLE 1

CLIMATE SUMMARY BY COUNTY

COUNTY (city)	Elevation (feet)	TEMPERATURE (Fahrenheit) January Mean	July Mean	Annual Mean	PRECIPITATION (inches) January	April	July	October	Annual
Adams (Ritzville)	1,795	27.0	71.1	49.1	1.44	0.74	0.29	1.19	11.67
Douglas (Waterville)	2,605	22.2	66.6	45.1	1.35	0.68	0.22	0.88	11.57
Franklin (Eltopia)	920	29.3	72.8	51.5	0.99	0.51	0.09	0.56	8.31
Grant (Ephrata)	1,272	27.5	76.5	52.5	1.05	0.56	0.20	0.77	8.42
Lincoln (Davenport)	2,450	24.3	67.4	46.2	2.11	1.07	0.53	1.42	16.72
Spokane (Spokane)	1,982	29.9	72.6	50.3	2.03	1.31	0.40	1.17	17.41
Whitman (Pullman)	2,345	27.3	66.0	44.0	2.67	1.49	0.39	1.91	20.49
Average		26.8	70.4	48.4	1.66	0.91	0.30	1.13	13.51

(all data from Yates, R. and Yates, C., editors, 1992, 1992 Washington State Yearbook: A Guide to Government in the Evergreen State, The Information Press, Eugene, Oregon.)

TABLE 2

POPULATION BY COUNTY

COUNTY	COUNTY POPULATION*	PER CAPITA INCOME ** (1988)	LEADING CITIES	POPULATION
Adams	13610	15413	Othello	4640
			Ritzville	1730
Douglas	26210	14289	East Wenatchee	3910
			Waterville	1010
Franklin	37480	13901	Pasco	20660
Grant	54760	13615	Moses Lake	11420
Lincoln	8870	21324	Davenport	1500
Spokane (partial)	122780	14373	Cheney	7840
Whitman	38780	15027	Colfax	2730
			Pullman	23090
Latah (Idaho)	19830		Moscow	19500
			Kendrick	330
Total:	322320	Average 15420		

* data from: Yates, R. and Yates, C., editors, 1992, 1992 Washington State Yearbook: A Guide to Government in the Evergreen State, Information Press, Eugene, Oregon.

** data from: Fox, J.R. and Hodgkin, C., 1990, 1990 Economic and demographic almanac of Washington counties and cities, The Information Press, Eugene, Oregon.

(Cline and Knadle, 1990). Both dryland farming and irrigated farming are practiced in the region. Irrigated farming is more common in the western part of the area, where precipitation is less. Wheat, barley, and beans are the most important crops.

The total land area is about 8.2 million acres, about 90% of which is privately owned (Starr, 1973). More than 50% of the land is cultivated. Of the remaining land, almost 40% is rangeland, and less than 5% is urbanized. Table 3 summarizes land use and ownership.

3.5 Surface Hydrology

The project area lies entirely within the drainage of the Columbia River. Major tributaries to the Columbia in the area include the Spokane, Snake, and Clearwater rivers. Smaller rivers within the area are the Palouse River, Crab Creek, and Cow Creek. Many of the other streams are ephemeral. Two large lakes - Moses Lake and Potholes Reservoir - and several smaller lakes, particularly in southwest Spokane County and northeast Adams County, lie within the project area. Regional aquifer discharge is to the Columbia and Snake Rivers (Whiteman, 1986). In addition, there is hydrologic interaction between the shallower aquifers and some of the lakes and smaller rivers within the area (Whiteman, 1986).

3.6 Geology

The Columbia Plateau is underlain by the Columbia River Basalts, which cover a total of approximately 25,000 square miles in Washington, and 39,500 square miles in Oregon and Idaho. The geologic setting of the Columbia Plateau has been produced by a number of events. Among these are the outpourings of flood basalts, volcanic events that deposited volcaniclastic and fluvial materials in the region, compressional tectonic events, deposition of windblown loess,

TABLE 3

LAND USE AND OWNERSHIP

Total Area (acres)	OWNERSHIP			LAND USE					
	Federal	State	Private	Water Area	Cultivated	Range	Forestry	Municipal	Other
8204689	315701	408860	7480128	149979	4502404	3120684	124745	145059	161818
(% total)	3.8	5.0	91.2	1.8	54.9	38.0	1.5	1.8	2.0

(data from Starr, W.A., 1973, Organization of land area in Washington for water and land use planning, Washington Water Research Center, Report No. 12, Washington State University, Pullman, Washington. – Regions 9 (Columbia Plateau) and 10 (Palouse) used for calculations) and glacial flooding that formed the Channeled Scablands.

The aquifers of the Eastern Columbia Plateau Aquifer System are situated in the Columbia River basalts and, in some areas, an overburden unit that consists of unconsolidated sediments (Figure 4 and Figure 5). The Columbia River Basalts are Miocene age flood basalts that were extruded from vents in northeast Oregon and southeastern Washington from six to sixteen million years ago. The flood basalts flowed into a topographic and structural basin - the Pasco Basin - to the west. The younger flows tend to be thinner than the older flows and in places are separated by sedimentary interbeds, which are an indication of the amount of time that lapsed between flood events.

Exposure of the aquifer units varies within the ECPAS area. Overburden units and outcrops of the Saddle Mountains basalt occur primarily in the southwestern part of the area (Drost and Whiteman, 1986). The Wanapum unit is exposed over most of the surface area in the ECPAS area, and exposure of the Grande Ronde unit occurs in the western part of the ECPAS area and along the deeply incised drainages of Grand Coulee, Crab Creek, and the Palouse, Snake, and Columbia Rivers (Drost and Whiteman, 1986).

The Columbia River Basalts are characterized by both layering and jointing (Whiteman, 1986). Layering results from individual flows from a series of outpourings of lava, and each of the stratigraphic basalt units of the Columbia River Basalts is composed of several individual flows. Individual flows are typically separated from successive flows by interflow zones and/or sedimentary interbeds. Within the individual flows a range of features related to cooling, degassing, and interaction with water exist. These include joints, vesicle sheets, and basalt pillows.

Primary joints that form the entablature and colonnade result from cooling and shrinkage

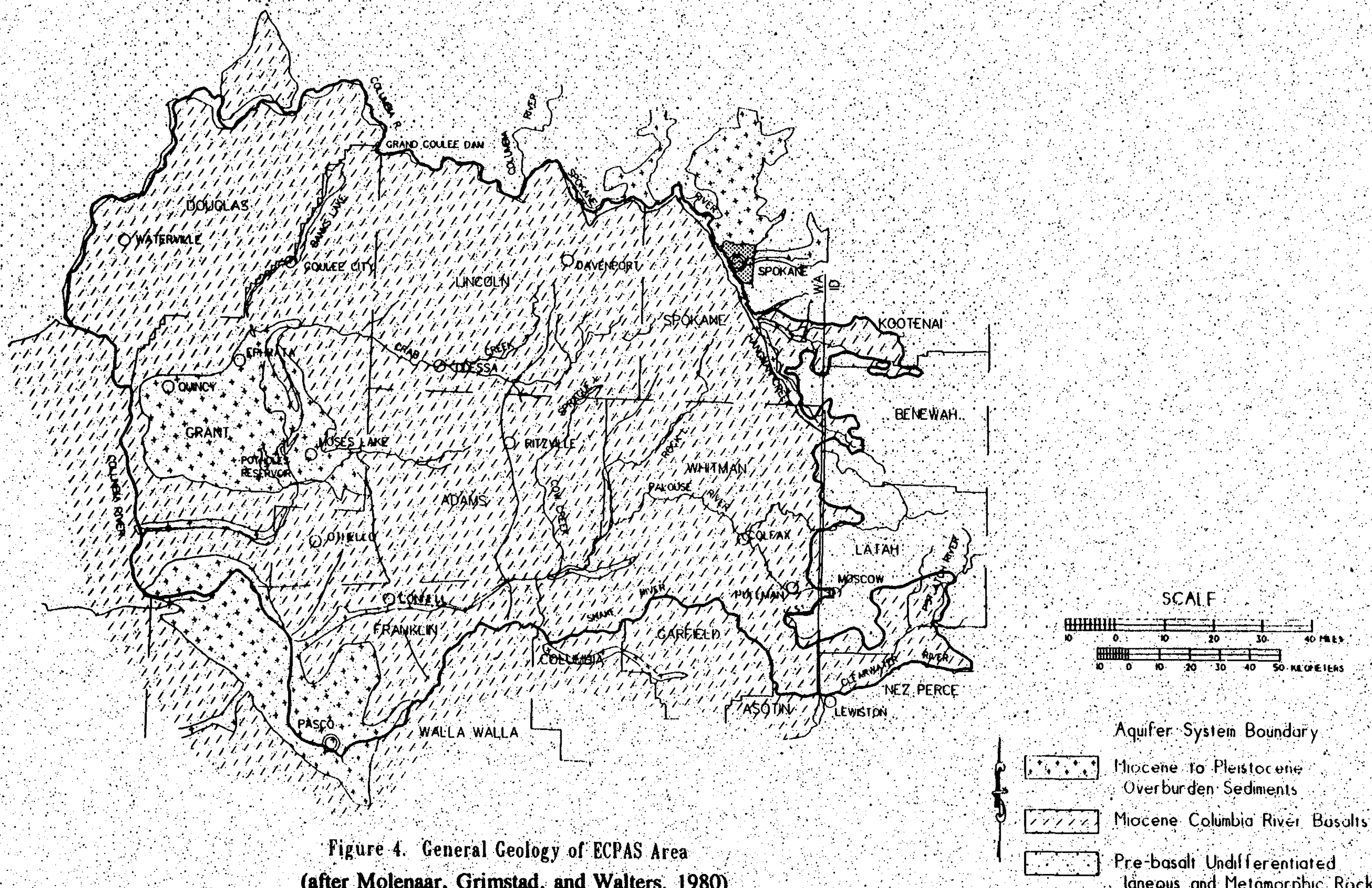


Figure 4. General Geology of ECPAS Area
(after Molenaar, Grimstad, and Walters, 1980)

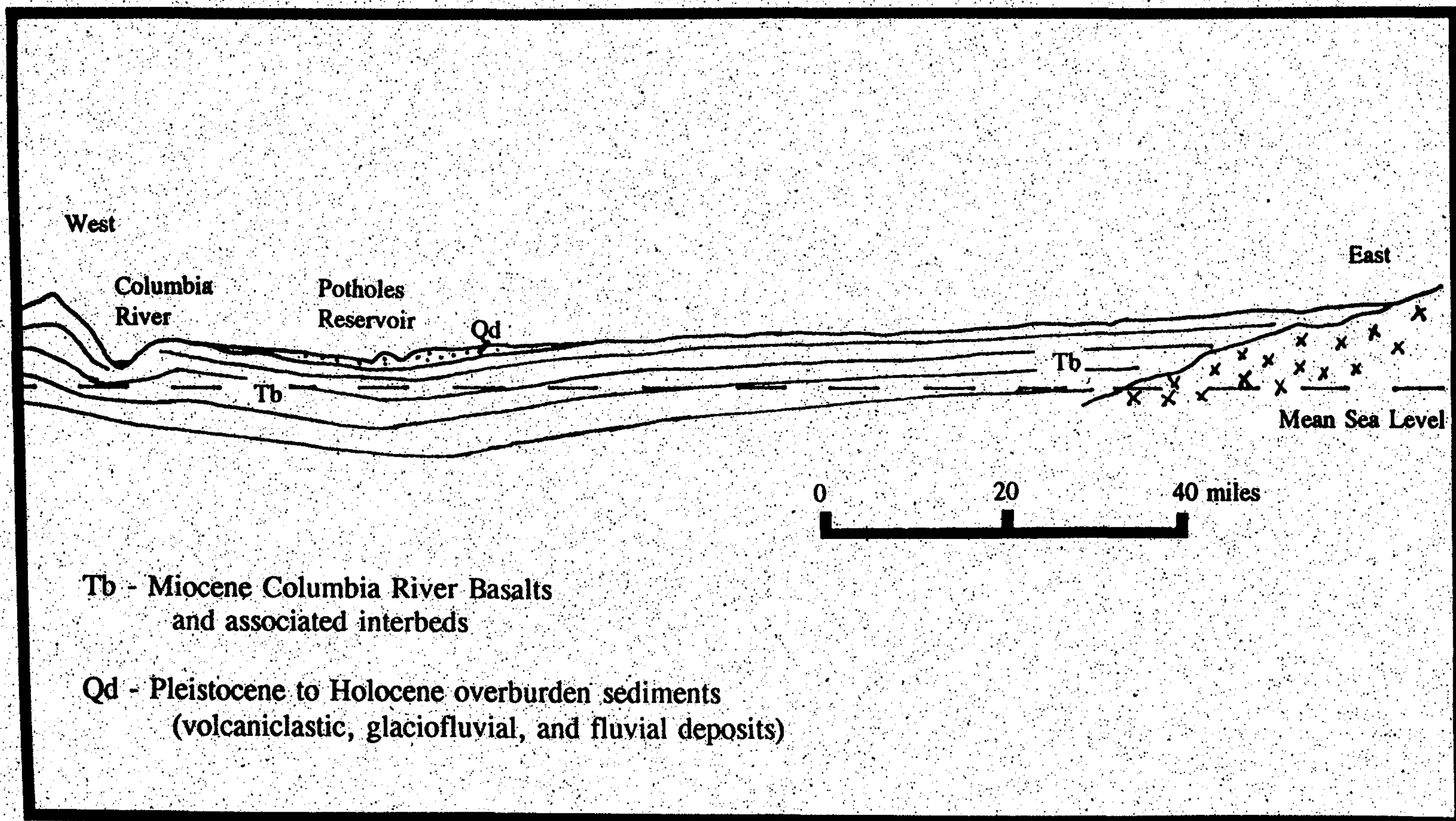


FIGURE 5. Generalized East to West Geologic Cross Section of the ECPAS Area
(after Molenaar, Grimstad, and Walters, 1980)

of the basalt. In addition, secondary joints and fractures form as a result of tectonic stresses and structural deformation. Vesicles and vesicle sheets are cavities or layers of cavities in the basalt created when gas bubbles were trapped in cooling lava. Basalt pillows are rounded masses of basalt that result from the extrusion of lava in an aqueous environment. These features often occur in characteristic zones within basalt flows (Bauer, Vaccaro, and Lane, 1985). The zones, from top to bottom, are the flow top or interflow zone, the entablature, and the colonnade (Figure 6).

The flow top is often highly fractured and is characterized by the presence of vesicular basalt, flow top breccias, and clinker. The zone below the flow top is the entablature, which often consists of small diameter, cross-jointed columns. The entablature may also contain vesicular zones. The flow interior, or colonnade, contains parallel, prismatic columns. The columns themselves are sometimes cut by horizontal joints. Although columns are frequently vertical, horizontal and curvilinear columns occur also. Basalt pillows, flow breccias, and rubble are sometimes found below the colonnade, at the base of the flow.

3.6.1 Stratigraphy

The basalts that are the focus of this investigation are part of the Yakima Basalt Subgroup (Figure 7 - Bauer, Vaccaro, and Lane, 1985). The Grande Ronde Basalt is the oldest of the Yakima Basalt Subgroup and makes up about 85% of the total basalt volume in the Columbia Plateau. It is comprised of at least thirty to as many as several hundred individual flows and ranges in thickness from a few feet at its lateral margins to more than 10,000 feet near Pasco, Washington (Drost and Whiteman, 1986). Sedimentary interbeds are rare in the Grande Ronde (Bauer, Vaccaro, and Lane, 1985). The Grande Ronde unit underlies all of the project area.

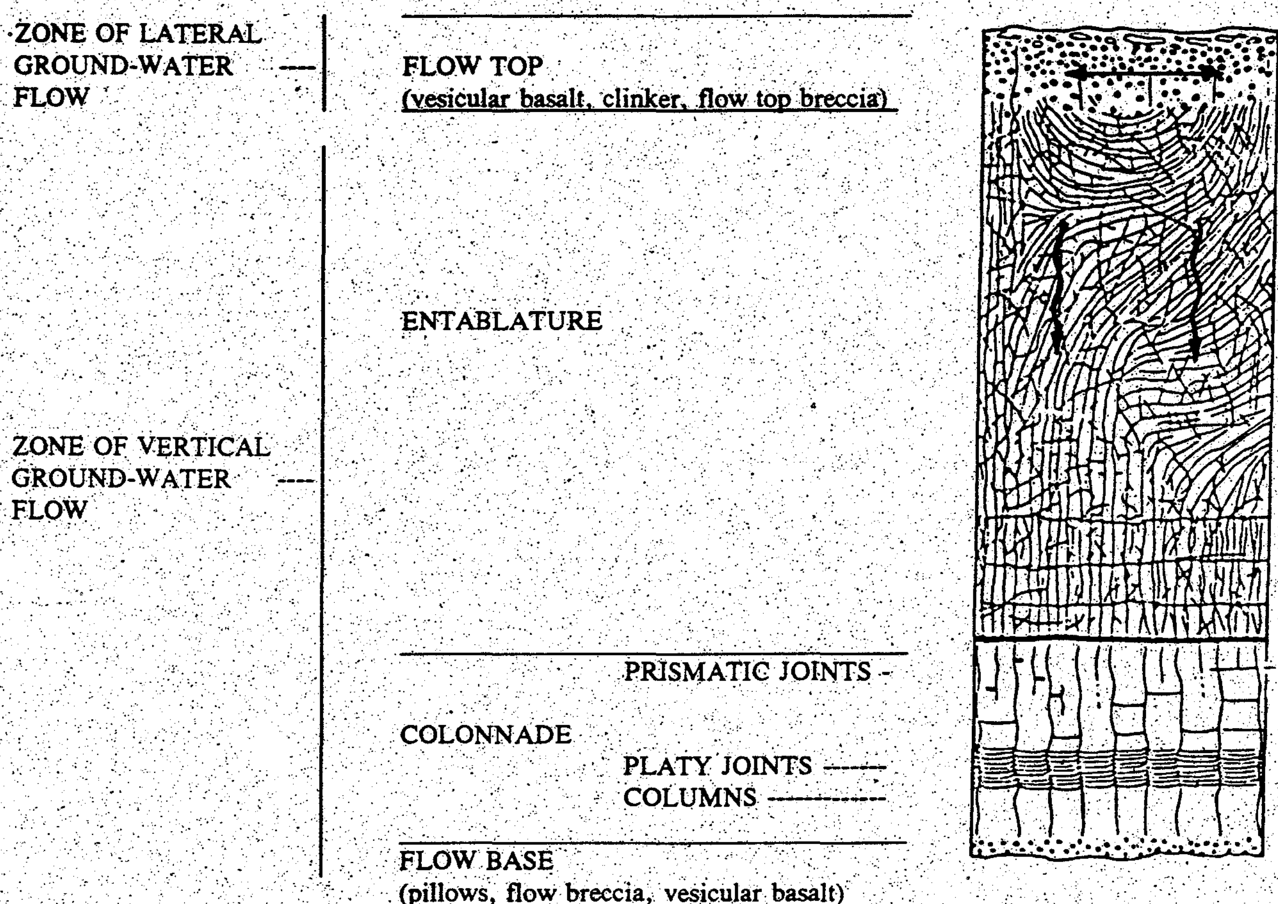


FIGURE 6. Structures, zones, and ground-water flow directions in an idealized basalt flow (after Bauer, Vaccaro, and Lane, 1985)

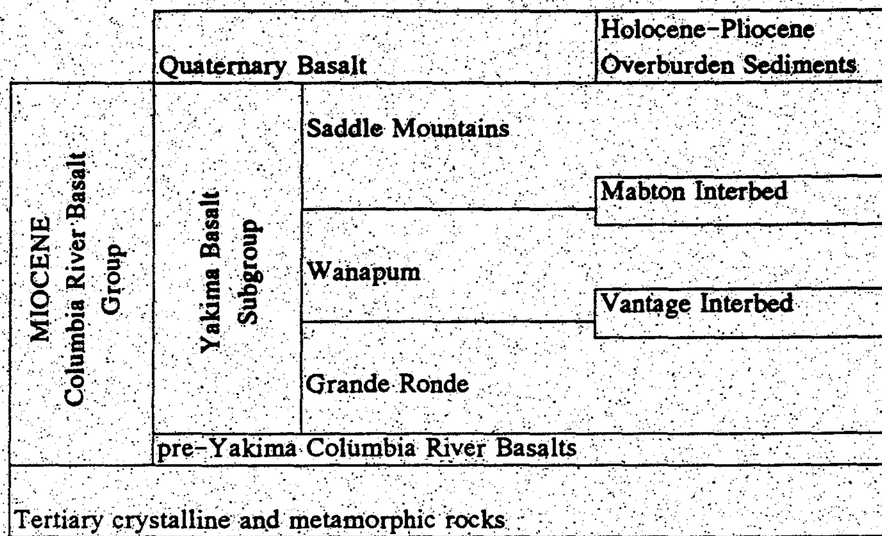


FIGURE 7. General Stratigraphy of the Columbia River Basalts

The Wanapum basalt overlies the Grande Ronde. Although it covers much of the project area, it is much smaller, volumetrically, than the Grande Ronde. The Wanapum is composed of about 10 flows, with a total thickness averaging 400 feet. Its maximum thickness, near Pasco, Washington, is more than 1,200 feet (Drost and Whiteman, 1986). Although sedimentary interbeds within the Wanapum are rare, the Grande Ronde and Wanapum units are separated by the Vantage sedimentary interbed, which ranges in thickness from 0 - 100 feet and is present throughout much of the area (Drost and Whiteman, 1986).

The Saddle Mountains basalt is the third member of the Yakima Basalt Subgroup. It is much less extensive than either the Grande Ronde or Wanapum units, occurring mostly in the southwestern part of the project area. The average thickness of the Saddle Mountains basalt is about 400 feet, but exceeds 800 feet in places. The Saddle Mountains basalt contains several sedimentary interbeds, and is separated from the Wanapum basalt by the Mabton sedimentary interbed.

An overburden unit covers the basalt sequence in some areas. It consists of unconsolidated fluvial, glaciofluvial, and volcaniclastic sediments but does not include the windblown silt that covers much of the Palouse region, which yields very little water (Cline and Knadle, 1990).

3.6.2 Structure

Most of the ECPAS is located in the Palouse subprovince, an area characterized by rolling topography and underlain by basalts that have a shallow regional dip to the southwest. Basalts in this province are relatively undeformed, but there is a fracture zone in southwest

Spokane County and a few folds are located in the western part of the province, near the Yakima Fold Belt.

The western part of the ECPAS area lies in the Yakima Fold Belt, a series of approximately east-west and northwest-southeast trending anticlines and synclines. Some northeast-southwest trending folds are also present in this area. The folds are topographically expressed as long, narrow ridges and with wide intervening valleys. Several faults have also been identified in this area. Fractures related to structural deformation are common, particularly along fold axes and associated with faults.

SECTION 4.0: HYDROGEOLOGY OF EASTERN COLUMBIA PLATEAU AQUIFER SYSTEM

4.1 Aquifer Descriptions

The principal aquifers of the ECPAS are in the Grande Ronde, Wanapum, and Saddle Mountains basalt units, along with their associated interbeds, and in the overburden unit. The aquifers are considered collectively as a system because evidence exists for hydraulic communication among the units (Garrett, 1968; Martin, 1981; Brown, 1983; Bauer, Lane, and Vaccaro, 1985; Steele, et. al., 1989). The aquifers in this system are the primary source of water for municipal, industrial, domestic, and irrigation use in the aquifer-use area (Whiteman, 1986; Steinkampf, 1989).

The layering and internal structure of the basalt flows impart a heterogeneity to the aquifers that significantly affects both vertical and horizontal flow in the system. Groundwater in the basalt units is primarily stored and transmitted in the interflow zones and flow tops, where joints, fractures, and vesicles are common (Figure 6). Groundwater movement within the flow top zones is usually lateral.

Groundwater is also transmitted through the relatively dense flow interiors, which historically were thought to be relatively impermeable (Brown, 1983). More recently it has been suggested that groundwater moves vertically through the basalt flows (Garrett, 1968; Brown, 1979; Martin, 1981; Brown, 1983; Bauer, Vaccaro, and Lane, 1985; Steele, et. al., 1989). Evidence includes marked head similarities between aquifers with significant vertical separation and, in some areas the water-level contours generally mimic topography, suggesting semi-confined or unconfined conditions (Brown, 1983). Results from tracer tests in the Wanapum basalt also indicate vertical movement of groundwater through the interior of a basalt flow (Steele, et. al., 1989).

Permeability of sedimentary interbeds depends on their composition, which ranges from clays to sand and gravel. In some areas sedimentary interbeds are productive aquifers. Some, however, are relatively impermeable, acting as aquitards (Brown, 1983). Evidence for the restriction of vertical conductivity in some areas is that significant head differences between aquifers that are vertically separated are often associated with interbeds or weathered horizons (Brown, 1983). However, even interbeds composed of relatively impermeable clays may permit leakage to overlying or underlying units, as indicated by drawdown responses in some wells (Steele, et. al., 1989). In some areas, water perched on top of sedimentary interbeds is tapped for domestic use (Brown, 1983).

In the overburden unit, groundwater is chiefly contained in the sand and gravel layers. The coarse alluvial gravels and sands of the overburden aquifer are used for domestic water supplies in some areas. Although thin layers of overburden occur in many locations, the thickest and most productive overburden aquifers are located around Moses Lake and in the Pasco area (Molenaar, Grimstad, and Walters, 1980).

4.2 Aquifer characteristics

Aquifer characteristics of the ECPAS, both within the flows and between the flows, are variable because of aquifer heterogeneity. Causes of heterogeneity include stratigraphic pinchouts or overlap of both flows and interbeds; intensity, spacing, width, and orientation of joints and fractures; and structural features such as folds, faults, and dikes.

Aquifers in the basalts are generally productive. Well yields of at least 150 gallons per minute (gal/min) are found throughout most of the region, and wells that penetrate multiple water-bearing zones may yield 1,000 to 3,000 gal/min (Molenaar, Grimstad, and Walters, 1980). Well yields may decrease near the margins of the basalts, where layers begin to thin (Molenaar, Grimstad, and Walters, 1980). Well yields from the overburden unit are 25 to 100 gal/min near Pasco and are as high as 800 gal/min in the lower Crab Creek Valley (Molenaar, Grimstad, and Walters, 1980).

Storage coefficients based on drawdown from a pumping season in the Odessa area were estimated to be approximately 10^{-3}, intermediate between confined and unconfined conditions (Luzier and Burt, 1974). In the Pullman-Moscow area estimates of storage coefficients range from 10^{-3} to 10^{-2} (Barker, 1979; Lum, Smoot, and Ralston, 1990). Storage coefficients of 10^{-5} and 10^{-4} from short term pumping tests increase for longer term pumping tests, suggesting leakage from overlying units (Brown, 1983).

Hydraulic conductivities for the Wanapum and Grande Ronde south of the ECPAS area have been reported by Gephart, et. al. (1979). In the Wanapum conductivity ranges from 10^{-2} to 10^{4} feet/day (ft/day). In the Grande Ronde conductivity ranging from 10^{-4} to 10^{-1} ft/day was measured. Conductivity in columnar basalt ranges from 10^{-8} to 10^{-5} ft/day. Hydraulic conductivity in the Wanapum near Creston in Lincoln County was measured at 10^{-1} to 10^{1} (Steele, et. al., 1989).

Vertical conductivities have been estimated at 10^{-6} and 10^{-5} ft/day (Tanaka, et al, 1974) and 10^{-3} ft/day (MacNish and Barker, 1976). In the Pullman-Moscow area horizontal hydraulic conductivity in the Wanapum and Grande Ronde basalts has been estimated at 10^{-1} to 10^{1} ft/day, respectively (Lum, Smoot, and Ralston, 1990). Vertical conductivity in the Wanapum and Grande Ronde are estimated to range from 10^{-4} to 10^{-3} ft/day (Lum, Smoot, and Ralston, 1990).

4.3 Recharge areas

Recharge to the ECPAS occurs throughout the plateau by percolation of water through the unsaturated zone and into the basalt through vesicles, fractures, and joints. Recharge to the aquifer units is affected by the depth of the unit, the thickness of overburden, land-use practices, and the amount of precipitation. Each of the four aquifer units is exposed at various locations in the ECPAS area (Drost and Whiteman, 1986). Therefore, the possibility of recharge from surface sources exists for each of the units.

For the shallower aquifers, precipitation is the main source of recharge, with additional recharge from seepage from streams and lakes (Molenaar, Grimstad, and Walters, 1980). Recharge from precipitation is generally higher in the eastern part of the area (Gephart, et. al., 1979). Artificial recharge from irrigation in some parts of Grant and Franklin Counties also occurs. Recharge to the deeper aquifers is primarily due to leakage from overlying units (Whiteman, 1986).

Recharge to the ECPAS was calculated from estimates of recharge to the Columbia Plateau Regional Aquifer System for current land-use (Bauer and Vaccaro, 1990). Calculations for recharge were performed using data from zones that were located within the ECPAS boundary. Table 4 shows average recharge for each of the zones within the ECPAS boundary. Recharge rates in individual units range from 0.5 to 18.7 inches per year, with a weighted average recharge for the total area of 4.6 inches/year. In four of the zones, average recharge exceeds average precipitation. This occurs in the western part of the area, where artificial recharge from irrigation contributes to natural recharge from precipitation (Bauer and Vaccaro, 1990).

TABLE 4

ESTIMATED RECHARGE FOR CURRENT LAND USE CONDITIONS

Zone Reference Number	Zone Name	Area (square miles)	Percent of Total Area	Average Precipitation (inches/year)	Area x Precipitation/ total area	Average Recharge (inches/year)	Area x Recharge/ total area
1	BWIP1	729	0.1	7.3	0.6	12.3 *	1.0
24	Bowers Coulee	1020	0.1	9.6	1.1	0.5	0.1
25	Canniwai	347	0.0	10.3	0.4	1.2	0.0
26	Cow Creek	546	0.1	12.6	0.8	2.1	0.1
27	Crab Creek	1019	0.1	12.5	1.5	1.4	0.2
28	Douglas Creek	601	0.1	10.1	0.7	1.0	0.1
30	East Banks	482	0.1	10.1	0.6	1.8	0.1
31	East High Canal	293	0.0	8.7	0.3	1.8	0.1
32	East Low Canal	504	0.1	7.8	0.5	18.7 *	1.1
35	Farrier Coulee	43	0.0	8.9	0.0	1.9	0.0
36	Jameson Lake	293	0.0	10.3	0.4	0.9	0.0
38	Providence Coulee	31	0.0	8.2	0.0	1.2	0.0
39	Pullman-Moscow	130	0.0	22.4	0.3	2.8	0.0
40	Quincy	872	0.1	8.2	0.8	10.1 *	1.0
41	Royal Slope	321	0.0	8.0	0.3	11.9 *	0.4
42	Rye Grass Flat	711	0.1	9.1	0.8	1.3	0.1
48	Union Flat Creek	185	0.0	21.0	0.5	3.7	0.1
52	Wilson Creek	427	0.0	11.3	0.6	1.6	0.1
	Totals:	8554			10.2 inches/year		4.6 inches/year

* average recharge exceeds precipitation, probably due to artificial recharge from irrigation

(data from: Bauer, H.H., and Vaccaro, J.J., 1990, Estimates of ground-water recharge to the Columbia Plateau Regional Aquifer System, Washington, Oregon, and Idaho for predevelopment and current land-use conditions: U.S.G.S. Water-Resources Investigations Report 88-4108.)

4.4 Groundwater movement

Lateral flow of groundwater in the basalt units is through interflow zones and flow tops, while vertical movement takes place along joints, fractures, faults, and uncased wells that penetrate more than one unit. Unconfined conditions usually exist in the shallow aquifers, and the deeper aquifers are considered to be semi-confined (Bauer, Vaccaro, and Lane, 1985). Lateral ground water flow directions in each of the units are shown in Figures 8-11.

The Columbia River Basalts, collectively, are located in a topographic and structural basin. Regional groundwater flow is from areas of higher elevation in the surrounding mountains to areas of low elevation along the Columbia and Snake rivers in the central part of the plateau. For the ECPAS in the Palouse subprovince, the regional ground water movement follows the southwest dip of the basalts, discharging to the Columbia and Snake Rivers in the southern and southwestern part of the area (Bauer, Vaccaro, and Lane, 1985). In the Yakima Fold Belt, ground water flow is generally away from the high anticlinal fold axes, and regional drainage of the aquifer system is west to the Columbia River (Bauer, Vaccaro, and Lane, 1985).

Generally, in the northern part of the area the Columbia River Basalts do not extend as far as the Columbia and Spokane Rivers, except in limited locations (Bauer, Vaccaro, and Lane, 1985; Drost and Whiteman, 1986). Locally, however, the rivers are potential recharge or discharge areas for the aquifer system (Gephart, et. al., 1979).

Local perturbations in the flow regime occur most often in the shallow aquifers and may be influenced by surface hydrology, topography, and geologic structures (Bauer, Vaccaro, and Lane, 1985). This is evident where water levels contours for the Wanapum basalt in the western part of the ECPAS area indicate groundwater flow towards Moses Lake and Potholes Reservoir.

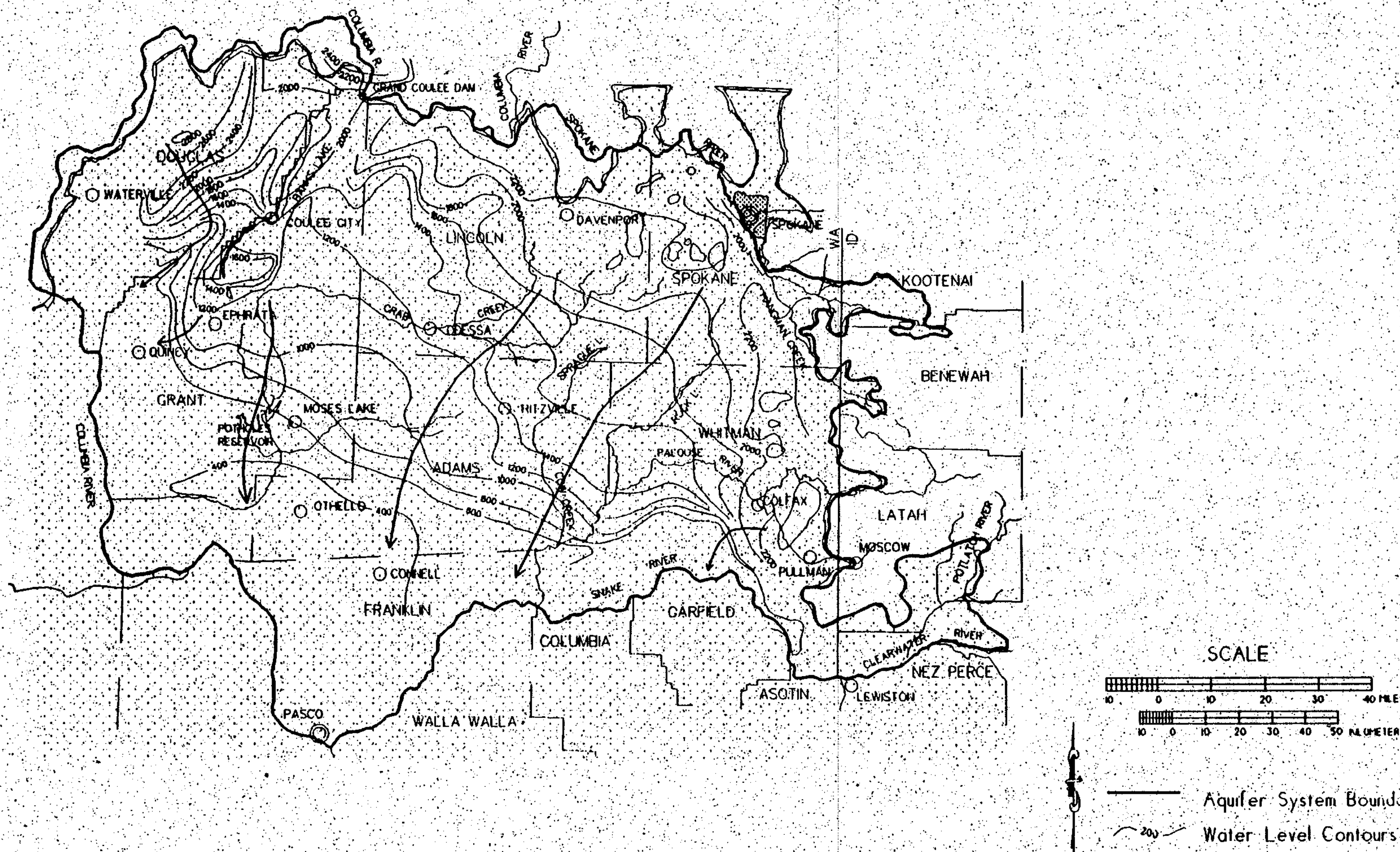
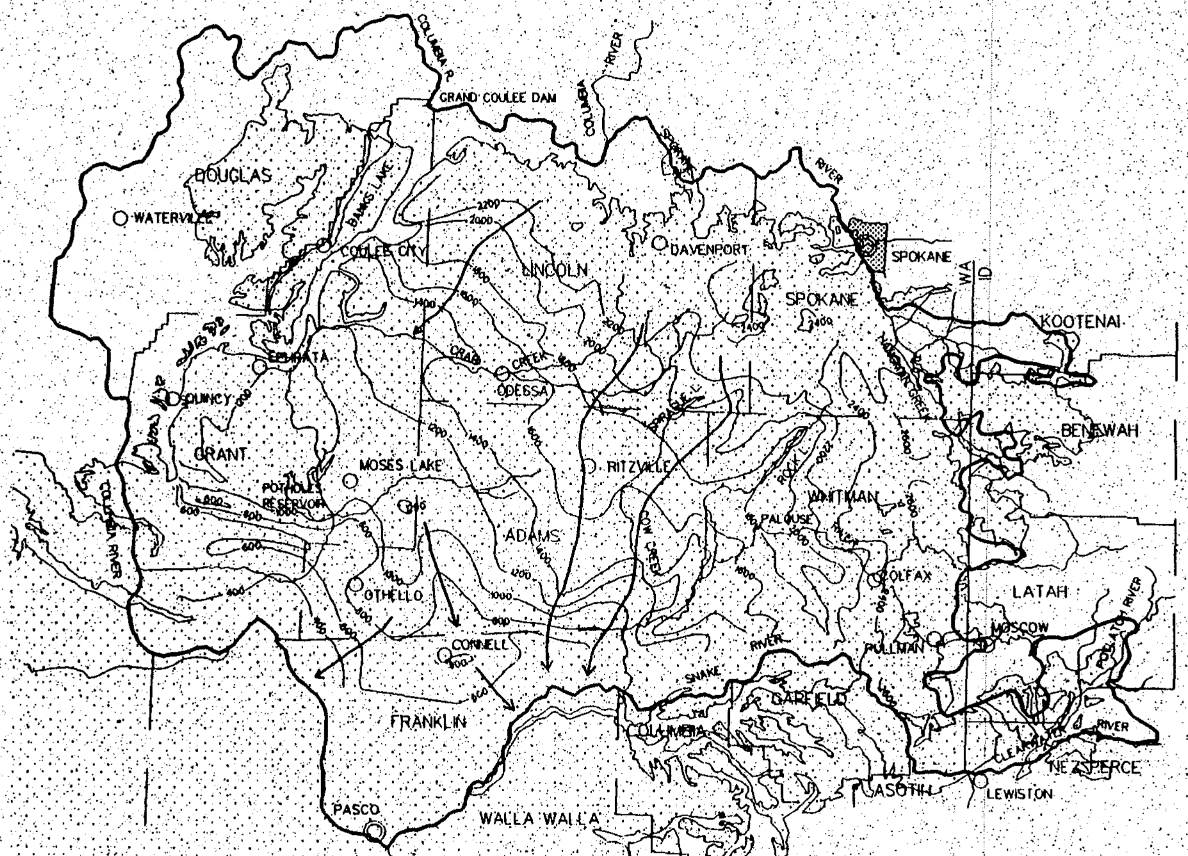


Figure 8. Grande Ronde Unit with Ground Water Flow Directions
(after Whiteman, 1986)



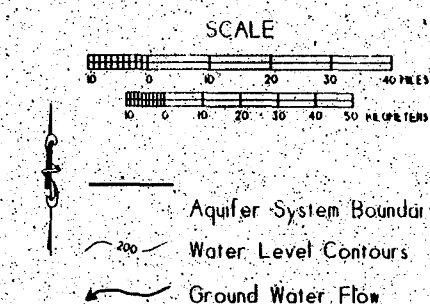


Figure 9. Wanapum Unit with Ground Water flow Directions (after Whiteman, 1986)

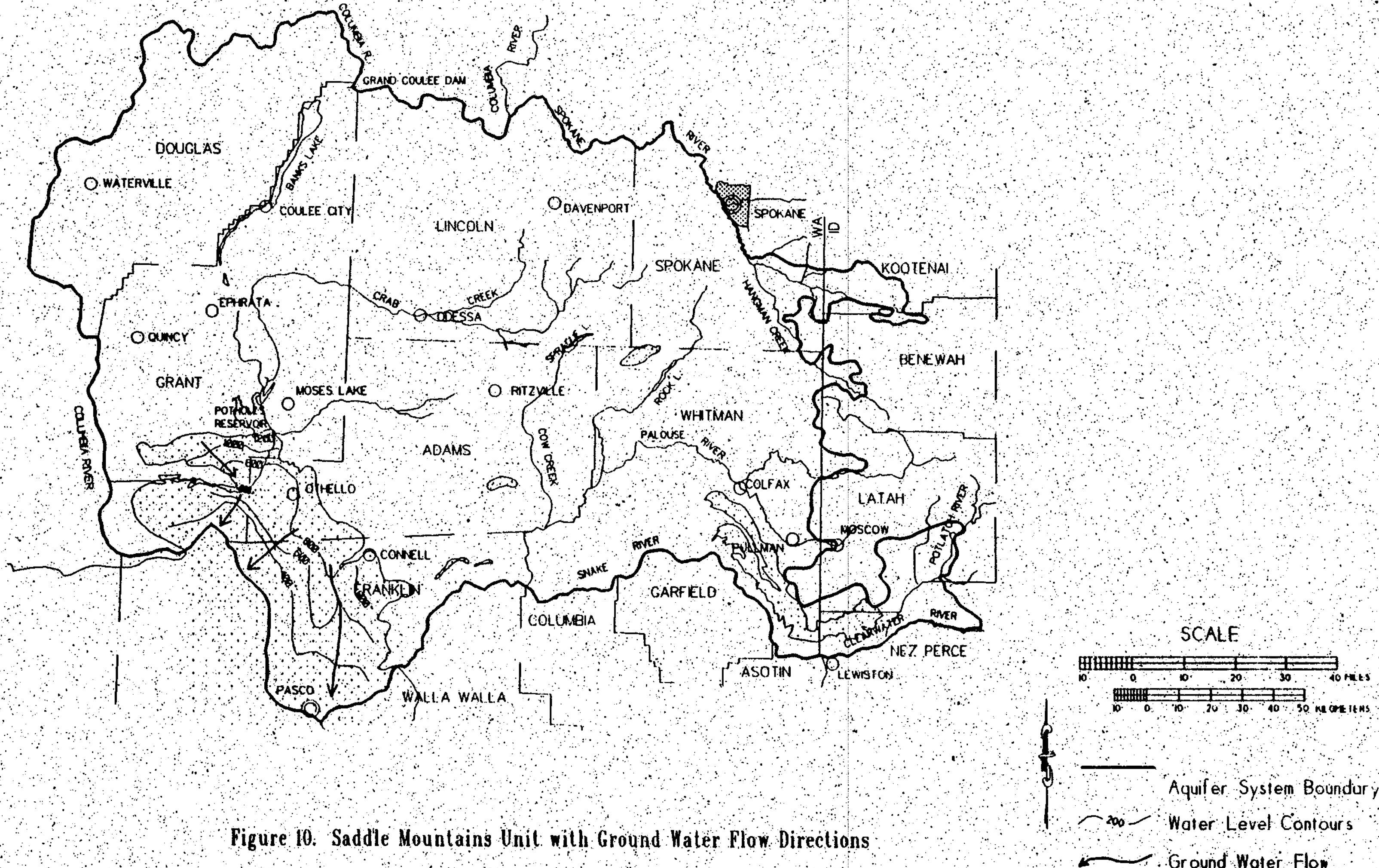


Figure 10. Saddle Mountains Unit with Ground Water Flow Directions
(after Whiteman, 1986)

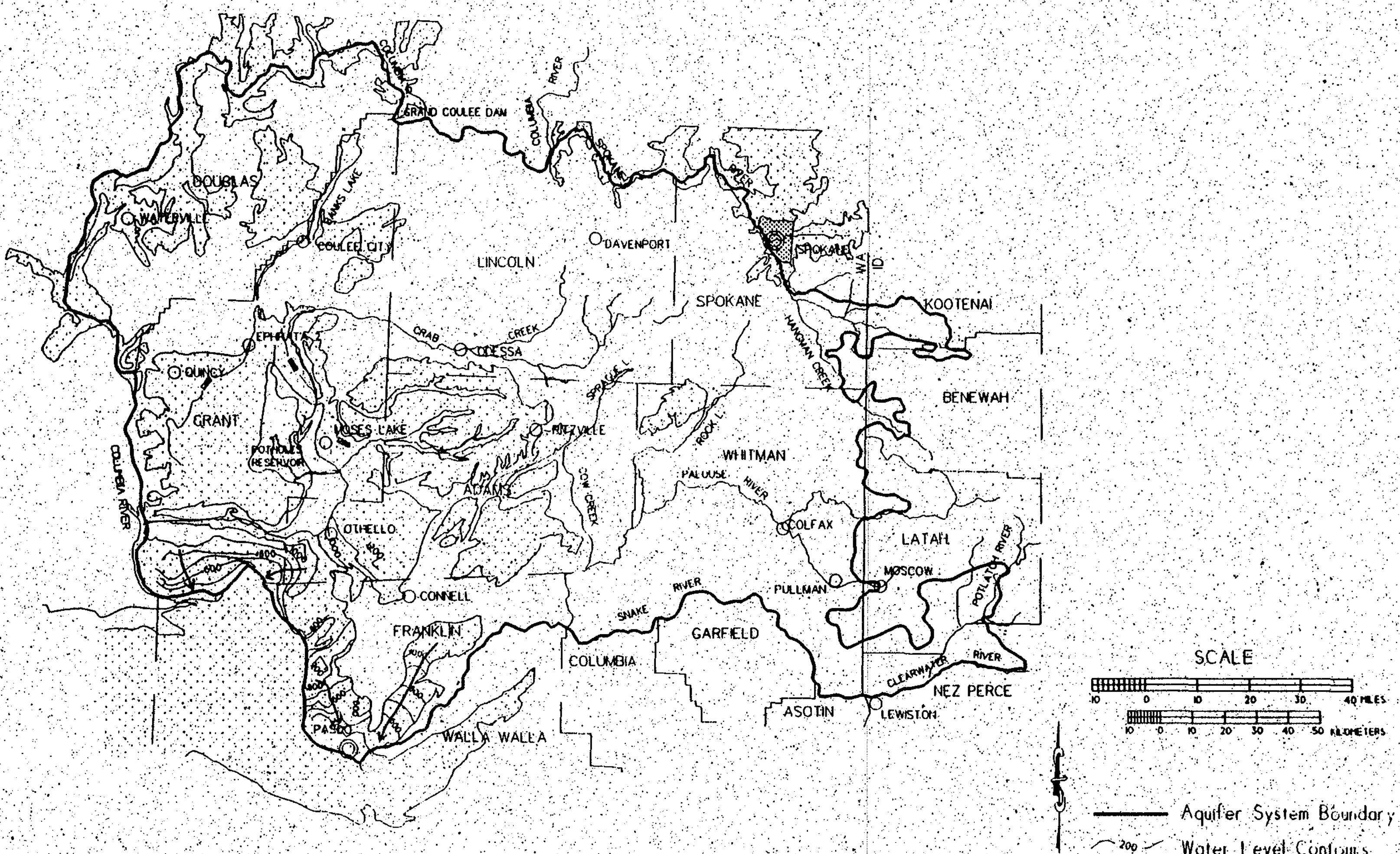


Figure 11. Overburden Unit with Ground Water flow Directions (after Whiteman, 1986)

Also, downgradient flexures of water level contours near several of the smaller lakes in northeast Adams County and southwest Spokane County indicate that these bodies of water are recharging the aquifer (Bauer, Vaccaro, and Lane, 1985; Whiteman, 1986).

Flow in the shallower units may also be intercepted by the creeks and smaller rivers and by deeply incised valleys. In these areas groundwater may discharge as springs or may contribute to stream baseflow, as is evident from water level contours for the Wanapum basalt along Crab Creek, the Palouse River, and Grand Coulee (Bauer, Vaccaro, and Lane, 1985; Whiteman, 1986). Where the basalts are folded, flow is typically away from the anticlinal axes, which are topographically expressed as ridges. Water level contours in deeper aquifers are generally smoother and reflect less influence from surface topography and hydrology (Bauer, Vaccaro, and Lane, 1985).

4.5 Groundwater quality

In general, ground-water chemistry in the basalt aquifers is controlled by chemical processes such as dissolution and precipitation of mineral phases, which in some cases is a function of residence time in the aquifer (Deutsch, et. al., 1982; Hearn, et. al., 1985). In addition, land-use practices such as agriculture or industry can affect ground-water chemistry over the short-term by influencing recharge and flow rates, and therefore residence times, in the shallow subsurface, and by introducing chemical species to the soil.

Unless otherwise noted, information regarding water-quality characteristics in the ECPAS is largely derived from Steinkampf's 1989 contribution to the Regional Aquifer System Analysis of the Columbia Plateau. In Steinkampf's study data from about 350 wells were analyzed. The data indicate that groundwater in the ECPAS is generally of good quality and suitable for most uses.

Groundwater from the ECPAS is usually the calcium-magnesium bicarbonate type. However, sodium bicarbonate type water is found in some of the deeper wells sampled, in downgradient areas of the flow system, and in the central plateau near the Columbia River. Also, calcium-magnesium sodium-sulfate waters occur in irrigated areas where the overburden is thin (less than 100 feet thick) and dissolved oxygen (DO) concentrations are greater than 4 or 5 milligrams per liter (mg/L), consistent with recent recharge.

Total Dissolved Solids (TDS) concentrations are generally less than 500 mg/L, which is the EPA secondary drinking water standard (Embrey, 1986). Dominant dissolved species include sodium, calcium, magnesium, bicarbonate, silica, sulfate, and chlorine. TDS concentrations are usually higher in discharge areas, indicating a longer residence time in the aquifer. Hardness (measured as $CaCO_3$) is usually less than 180 mg/L in the aquifers of the system (Embrey, 1986).

Nitrates have been detected in the groundwater and probably result from agricultural practices (Turney,1986). Nitrate concentrations in the groundwater are usually below the EPA MCL of 10 mg/L. The median nitrate concentration in the Saddle Mountains unit is less than 2.0 mg/L, with a maximum of 54 mg/L (Embrey, 1986). Groundwater from the Wanapum has a median nitrate concentration of 2.1 mg/L (Embrey, 1986). The median nitrate concentration in the Grande Ronde is less than one mg/L, with a maximum of 15 mg/L (Embrey, 1986).

4.6 Potential for Contamination

The primary threats to ground-water quality arise from urbanization, industrialization, and agriculture. Potential contaminants from urbanization include nitrates, chloride, and bacteria from septic systems, wastewater, and urban runoff. Industrial activities and county and municipal landfills may introduce metals and organic and inorganic chemicals and solvents into the groundwater. Finally, nitrates, pesticides and herbicides from agricultural practices may contaminate groundwater.

The susceptibility of an aquifer to contamination is influenced by several natural factors. These include areas of recharge, thickness and hydrogeologic properties of overburden, depth to groundwater, and groundwater movement. Lakes and streams that recharge aquifers may act as contaminant pathways to groundwater. In areas where overburden is thin and groundwater is near the surface, the potential for contamination from spills of hazardous materials, agricultural chemicals, urban runoff and other sources is relatively high compared to areas where the aquifer is deep or capped by a layer of relatively impermeable material.

The potential for contamination from surface sources exists for all of the aquifers in the ECPAS because each of the four aquifer unit is exposed at various locations in the ECPAS area (Drost and Whiteman, 1986). Once part of an aquifer is affected, contaminants can spread to other areas in the aquifer by lateral and/or vertical flow. Contamination of a shallow aquifer may also pose a threat to deeper aquifers, which are recharged by vertical leakage from overlying units. The potential for contamination between different aquifers in the system is compounded by the fact that many of the wells penetrating more than one aquifer are uncased, allowing mixing of waters and possible cross-contamination of aquifers (Steinkampf, 1989).

SECTION 5.0: PROJECT BOUNDARIES

5.1 Boundary Descriptions

The area to be considered for SSA Designation includes the eastern part of the Columbia Plateau Aquifer system and the streamflow source area. As previously described, the four major aquifer units of the Columbia Plateau aquifer system cover thousands of square miles in Washington, Oregon, and Idaho. However, only the part of the system in southcentral and southeastern Washington is included in this petition (Plate 1). Selection of a portion of the entire system is justified if part of the system is hydrogeologically separate from other parts of the system (EPA, 1987). Information used to determine the boundaries is derived from published reports and maps, particularly those produced by Bauer, Vaccaro, and Lane (1985) and Whiteman (1986) as part of the U.S. Geological Survey (USGS) Regional Aquifer System Analysis for the Columbia Plateau.

5.2 Aquifer System Boundaries

Boundaries for the ECPAS have been determined based on published information on the geology and hydrogeology of the Columbia River Basalts. Boundaries are based on major ground water flow divides and the eastern extent of the Grande Ronde basalt. The Columbia and Snake Rivers are the south, west, and northwest boundaries of the ECPAS. The rest of the northern boundary is defined by the Spokane River. The eastern boundary is defined by the lateral margins of the Grande Ronde, which pinches out against the mountains in eastern Washington and parts of Idaho. A detailed explanation of aquifer system boundaries is presented below.

1. Northern and Northwestern Boundary - Columbia and Spokane Rivers

Except in small areas, the Grande Ronde basalt unit does not extend as far north as the Columbia and Spokane Rivers (Bauer, Vaccaro, and Lane, 1984; Drost and Whiteman, 1986). However, the aquifer system boundary is extended to the rivers because, locally, the rivers are potential recharge or discharge areas for the aquifer system (Gephart, et. al., 1979). In the northeast part of the area, the aquifer system boundary follows the Spokane city limits. Spokane's municipal water source is the Spokane-Rathdrum aquifer, which received Sole Source Aquifer Designation from the EPA in 1977, and whose boundaries coincide with the western portion of the Spokane City limits.

2. Eastern Boundary - Foothills

The eastern boundary, which is inferred from existing geologic data, is limited by the termination of the Grande Ronde basalt unit against the hills and mountains in eastern Washington and the Idaho Panhandle (Whiteman, 1986). The lithologic transition along this boundary is from Columbia River Basalts to Tertiary age igneous and metamorphic rocks. Maps published for the RASA indicate that Moscow, Idaho lies beyond the lateral edge of the Grande Ronde. However, the "Pullman-Moscow Basin Aquifer" is included in the ECPAS area because the cities of Moscow and Pullman actually overlie Grande Ronde basalt and derive their drinking water from aquifers in the formation (Lum, Smoot, and Ralston, 1990).

3. Southern Boundary - Clearwater, Snake, and Columbia Rivers

The Snake and Columbia Rivers have been designated as boundaries for this part of the ECPAS because they are areas of regional discharge (Bauer, Vaccaro, and Lane, 1985;

Whiteman, 1986). The hydrogeology along the Clearwater River is not well defined. However, the Grande Ronde basalt pinches out in the area, and it is assumed that the Clearwater River, like the Snake River, is an area of discharge.

4. Western Boundary - Columbia River

As indicated by published reports, the Columbia River is a discharge area for the Grande Ronde and is therefore defined as the western boundary of the ECPAS (Bauer, Vaccaro, and Lane, 1985; Whiteman, 1986). In the northwest part of the area the Grande Ronde does not extend to the Columbia River. However, the aquifer system boundary is extended to the Columbia because the river is a potential recharge or discharge area for the aquifer (Gephart, et. al., 1979).

5.4 Streamflow Source Area

Drainage basins within and adjacent to the ECPAS area and interactions of surface water with the aquifer were considered in defining the streamflow source area. The boundary of the streamflow source area encompasses drainage areas that may contribute to surface and ground-water recharge.

To the south, west, and north the streamflow source area boundary coincides with the Clearwater, Snake, Columbia, and Spokane Rivers. Tributaries to these rivers outside of the aquifer system boundary are not considered as part of the streamflow source area because, although some local recharge and interaction between the aquifer system and these rivers may occur, regional ground water flow is to the southwest and regional discharge is to the Columbia and Snake Rivers in the western and southern parts of the area. Therefore it is assumed that contamination of these tributary streams is unlikely to contaminate the aquifer system.

To the east, streams originate in the mountains of northern Idaho and flow into the ECPAS area. In this area the streamflow source boundary extends to the topographic divide that separates the drainage of Hangman Creek, the Palouse River, and the Potlatch River from the headwaters of rivers to the east. To reduce overlap with the Spokane-Rathdrum Aquifer, the streamflow source boundary does not extent north of Lake Couer d'Alene.

SECTION 6.0: WATER USE

6.1 Water Use

The purpose of this section is to describe water use in the aquifer service area and to determine whether the aquifer system supplies at least 50% of the drinking water in the aquifer service area, which includes all of the area directly overlying the aquifer. In general, water use in the area includes municipal and domestic use, irrigation, and industry. In some areas, particularly the Channeled Scablands, aquifers remain undeveloped because soil is too thin the support agriculture (Molenaar, Grimstad, and Walters, 1980).

6.2 Drinking Water

It was necessary to calculate a drinking water budget for the aquifer use area to determine whether the aquifer meets the definition of sole source aquifer. In calculating the water budget, city halls or public works departments of several cities within the aquifer study area were contacted to determine their source of drinking water, annual usage, approximate population served by the water system, and method of treatment.

A summary of drinking water use, annual volume, population served, and water treatment appear in Table 5. With the exception of the city of Pasco, in Franklin County, all of the city water districts that were contacted obtain their drinking water from groundwater sources in the aquifer service area. Because aquifers of the Columbia Plateau Basalts are the major source of water for domestic use (Cline and Knadle, 1990), it was assumed that the remainder of the population obtains its drinking water from groundwater. Water consumption for these people was estimated by assuming a usage of 150 gallons per capita per

TABLE 5

DRINKING WATER USE BY COUNTY

COUNTY	COUNTY POP.	CITY	POPULATION	GROUNDWATER USE (mgal/yr)	SURFACE WATER USE (mgal/yr)	TREATMENT
Adams	13610	Othello	4640	1260		usually untreated
		Ritzville	1730	240		not currently treated
		Remaining pop.	7240	396		
Douglas	26210	E. Wenatchee Water Dist.	7730	1002		untreated
		Waterville	1050	95		untreated
		Remaining Pop.	17430	954		
Franklin	37480	Pasco Water Dist.	25000		1820	filtered and chlorinated
		Remaining Pop.	12480	683		
Grant	54760	Moses Lake	19200	1940		untreated
		Remaining Pop.	35560	1947		
Lincoln	8870	Davenport	1500	210		untreated
		Remaining Pop.	7370	404		
Spokane (partial)	122780	Cheney	8000	365		chlorinated; fluoride added
		Remaining Pop.	114780	6284		
Whitman	38780	Colfax	2730	249		chlorinated
		Pullman	23480	1411		chlorinated
		Washington State Univ.	17000	750		chlorinated
		Remaining Pop.	12570	688		
Idaho (State)	19830	Moscow	17000	775		chlorinated
		University of Idaho	10000	630		chlorinated; polyphosphate
		Kendrick	330	28		to sequester iron
Totals:	322320	(92.8% served by groundwater)	346820	20312	1820	

day (U.S. EPA, 1987).

Generally, quality of the groundwater is good, and treatment of groundwater before use is minimal. Several of the municipalities contacted use untreated groundwater. These cities include Othello, Ritzville, East Wenatchee, Waterville, Moses Lake, and Waterville. The other water distribution systems chlorinate the groundwater. In the city of Moscow, Idaho, polyphosphate is added to sequester iron, and the water is chlorinated. In the city of Pasco water from the Snake River is treated, filtered and chlorinated before use.

Based on population estimates from municipal contacts and published data, the approximate number of people served by the ECPAS is 346,800, which is more than the population determined by county census data. There may be some overlap between the estimated population served by municipal water districts and the remaining county population. The fluctuating populations associated with the two universities in the cities of Moscow, Idaho and Pullman, Washington may also contribute to the difference between the population based on the county census and the drinking water budget. Also, populations served by the university water systems include non-resident faculty and staff, in addition to the student population, and may also overlap with population served by the city system.

Information calculated in the water use budget indicates that approximately 92% of the population obtains its drinking water from groundwater, and approximately 92% of municipal and domestic water supply is from ground water sources.

6.3 Irrigation and Industrial Water Use

Irrigation of agricultural lands accounts for most of the pumpage from large capacity wells in the aquifer service area (Cline and Knadle, 1990). Irrigation wells are completed in all three of the basalt units and the overburden unit. Well yields range up to 2,000 gal/min (Molenaar, Grimstad, and Walters, 1980). A summary of groundwater pumpage for irrigation is presented in Table 6.

Industry is the other significant consumer of groundwater in the aquifer service area. Water for industry may be either municipally supplied or self-supplied. A summary of water use for industry is presented in Table 7.

TABLE 6

GROUNDWATER PUMPAGE FOR IRRIGATION

(by county, acre-feet)

County	Grande Ronde	Wanapum	Saddle Mountains	Overburden	Total
Adams	81050	51700	100	0	132850
Douglas	2840	0	0	0	2840
Franklin	5810	22940	3800	62950	95500
Grant	50610	100360	0	74940	225910
Lincoln	33470	16230	0	0	49700
Spokane	7200	3030	0	0	10230
Whitman	6550	730	0	0	7280
Totals	187530	194990	3900	137890	524310

(data from Cline, D.R. and Knadle, M.E., 1990, Ground-water pumpage from the Columbia Plateau Regional Aquifer System, Washington, 1984, USGS Water Resources Investigations Report 87-4135.)

TABLE 7

INDUSTRIAL USE BY COUNTY IN 1975 – MUNICIPALLY-SUPPLIED

(millions of gallons)

County	Ground Water	Surface Water	Total	% Use from Ground Water	% Use from Surface Water
Adams	302	0	302	100	0
Douglas	0	0	0	0	0
Franklin	489	16	505	97	3
Grant	369	0	369	100	0
Lincoln	0	0	0	0	0
Spokane*	164	0	164	100	0
Whitman	9	0	9	100	0
Totals	1333	16	1349	99	1

INDUSTRIAL USE BY COUNTY IN 1975 – SELF-SUPPLIED

(millions of gallons)

County	Ground Water	Surface Water	Total	% Use from Ground Water	% Use from Surface Water
Adams	720	0	720	100	0
Douglas	1113	0	1113	100	0
Franklin	390	0	390	100	0
Grant	1954	0	1954	100	0
Lincoln	0	0	0	0	0
Spokane*	9308	0	9308	100	0
Whitman	0	0	0	0	0
Totals	13485	0	13485	100	0

* Spokane water-use estimated

(all data from Dion, N.P. and Lum II, W.E., 1977, Municipal, industrial, and irrigation water use in Washington, 1975, USGS Open-File Report 77-308.)

SECTION 7.0: ALTERNATIVE RESOURCES

According to the Petitioner's Guidance Document an aquifer that serves as a sole or principal source aquifer may not receive designation as such if an alternative source or combination of sources can physically, legally, and economically supply the population within the aquifer service area with drinking water of equal or better quality than that supplied by the aquifer.

Alternative drinking water sources in the area are limited. Cities and towns located along the Clearwater, Snake, Columbia, and Spokane Rivers could conceivably obtain municipal water supplies from these rivers, as does Pasco. However, implementing surface water supply systems would require construction of treatment, storage, transmission, and distribution systems. In addition, whereas water from the ECPAS requires little or no treatment, water from surface water sources would require filtration and treatment before municipal use.

Surface water is limited within the aquifer service area. Many of the existing streams are ephemeral. The perennial streams, such as the Palouse River, Hangman Creek, and Crab Creek, are small and have water quality problems from high sediment loads, wastewater effluent, and coliform bacteria (WaDOE, 1992). Diversion of water from the boundary rivers into the aquifer service area, even if legally possible, would require construction of pipelines, treatment, storage, transmission, and distribution systems.

An estimated cost for a conventional, one million gallon per day water treatment plant is more than 1.7 million dollars (Williams and Culp, 1986, cost adjusted to 1990 dollars using Table 1261, Statistical Abstract of the United States: 1991). A community like Cheney, Washington pumps approximately one million gallons of water a day and has about 8,000 people. Based on per capita income figures for the aquifer service area, the cost of the treatment plant alone would be greater than 1.3 percent of the average per capita income. This cost does not include pipelines from surface bodies of water, such as the Spokane River, intake structures, storage facilities, or distribution systems.

The paucity of surface water in the area and its low quality, relative to water available from the ECPAS, make it an unacceptable alternative drinking water source. In addition, the necessity of building water supply systems would make use of surface water economically infeasible.

SECTION 8.0: CONCLUSIONS

The Eastern Columbia Plateau Aquifer System (ECPAS) area covers more than 8.2 million acres. The area includes Adams, Douglas, Franklin, Grant, Lincoln, Whitman, and part of Spokane counties in southeastern and southcentral Washington state. Some small areas of Idaho along the Washington-Idaho border are also included. The project area lies entirely within the drainage of the Columbia River and its tributaries.

Approximately 346,800 people are served by the ECPAS. The primary economic activity for the area is agriculture and its associated industries (Cline and Knadle, 1990). The climate in the ECPAS region is semi-arid, with average annual precipitation of about 13.5 inches, and the mean annual temperature for the area is about 49 degrees Fahrenheit (Yates and Yates, 1992).

The principal aquifers of the ECPAS are in the Grande Ronde, Wanapum, and Saddle Mountains basalt units, along with their associated interbeds, and a sedimentary overburden unit. The aquifers are considered collectively as a system because evidence exists for hydraulic connection between the units (Garrett, 1968; Brown, 1979; Martin, 1981; Brown, 1983; Bauer, Vaccaro, and Lane, 1985; Steele, et. al., 1989). The aquifers in this system are the primary source of water for municipal, industrial, domestic, and irrigation use in the aquifer-use area (Whiteman, 1986; Steinkampf, 1989).

Recharge to the ECPAS occurs throughout the plateau by percolation of water through the unsaturated zone and into the basalt through vesicles, fractures, and joints. Lateral flow of groundwater in the basalt units is through interflow zones and flow tops, while vertical ground water movement takes place along joints in the more dense basalt flow interiors.

Groundwater in the ECPAS is generally of good quality and suitable for most uses

(Steinkampf, 1989). The primary threats to ground-water quality arise from urbanization, industrialization, and agriculture. The potential for contamination from surface sources exists for all of the aquifers in the ECPAS because each of the four aquifer unit is exposed at various locations in the ECPAS area (Drost and Whiteman, 1986). Once part of an aquifer is affected, contaminants can spread to other areas in the aquifer by lateral and/or vertical flow. Contamination of a shallow aquifer may also pose a threat to deeper aquifers, which are recharged by vertical leakage from overlying units. The potential for contamination between different aquifers in the system is compounded by the fact that many of the wells penetrating more than one aquifer are uncased, allowing mixing of waters and possible cross-contamination of aquifers (Steinkampf, 1989).

Boundaries for the ECPAS have been determined based on published information on the geology and hydrogeology of the Columbia River Basalts. The Columbia and Snake Rivers are the south, west, and northwest boundaries of the ECPAS. The rest of the northern boundary is defined by the Spokane River. The eastern boundary is defined by the lateral margins of the Grande Ronde, which pinches out against the mountains in eastern Washington and parts of Idaho.

EPA defines a sole or principal source aquifer as one that supplies at least fifty percent of the drinking water consumed in the area that overlies the aquifer (U.S. EPA, 1987). Groundwater supplies approximately 92% of the drinking water consumed in the Eastern Columbia Plateau Aquifer System aquifer service area. Further, the availability of alternative drinking water supplies of equal or better quality is physically limited in most of the aquifer service area and seems to be economically infeasible throughout. Therefore, the Eastern Columbia Plateau Aquifer System appears to meet EPA criteria for designation as a sole source aquifer under Section 1424(e) of the Safe Drinking Water Act.

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