STATE OF OREGON

WATER RESOURCES DEPARTMENT

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# GROUND WATER ASSESSMENT

# OF THE

# JOHN DAY BASIN

PREPARED FOR THE

STRATEGIC WATER PLANNING GROUP

by

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Salem, Oregon
November, 1984

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## CONCLUSIONS

1. Yields adequate for domestic and stock use appear to be obtainable in most locations in the John Day Basin, though with difficulty in some areas of Clarno and John Day Formations and pre-Tertiary rocks.

2. The most productive aquifer units in the John Day Basin are the Columbia River Basalt Group and the Quaternary alluvium. The Mascall and Rattlesnake Formations can produce moderate quantities locally.

3. Estimates of recharge to the basin as a whole range from 0.20 to 0.42 inches per year. Recharge estimates to the major Columbia River Basalt areas range from 0.4 to 0.6 inches per year. Recharge estimates are considerably higher in some small areas of high elevation and high precipitation.

4. Estimates of annual recharge to various parts of the basin are as follows:

| Area | Range of estimates (acre-ft) |
|---|---|
| John Day Drainage above Picture Gorge | 14,336 - 51,072 |
| North Fork Drainage above Monument | 63,168 - 95,424 |
| Sherman County area | 11,776 - 17,664 |
| Gilliam County area | 25,898 - 38,848 |
| Entire basin above McDonald Ferry | 80,853 - 169,792 |

The annual recharge does not represent the volume of water which can be pumped each year. If the total recharge were removed from the system by pumping, the natural discharge (streamflow) would be reduced, and water storage would be reduced. There is a balance between recharge, storage, natural discharge and use which must be maintained.

5. Well yields adequate for irrigation purposes are obtainable from the Columbia River Basalt in many locations, however the limited recharge precludes any large scale development.

6. Well yields adequate for irrigation purposes are obtainable from alluvial deposits at some locations in the river valleys, however removal of water from the alluvial aquifer can cause a decrease in streamflow. Because of the hydraulic connection between these two sources of water they should be managed together.

7. This study revealed no areas in the John Day Basin where sufficient groundwater is available for large scale irrigation development.

# INTRODUCTION

## Purpose and Scope

An assessment of the ground water resource is a crucial part of any comprehensive water resource investigation. This ground water resource evaluation, undertaken as part of the Water Resources Department's responsibilities under Senate Bill 523, examines the geology, identifies and characterizes the hydrology of the major aquifer units, and estimates ground water storage and annual recharge within the John Day Basin. The nature of the activity and time constraints imposed by Senate Bill 523 are such that this assessment be generated from available data.

The time and data restrictions limit the conclusiveness of results in this study. The major source of ground water data available for the John Day Basin is the water well reports on file at the Oregon Water Resources Department. Previous studies in the basin are only cursory, or deal with very restricted areas (ie. Robison, 1968; Thayer, 1972). No significant detailed ground water studies have been conducted anywhere in the basin, and no detailed aquifer test data are available. Detailed ground water studies have been conducted in the Umatilla Basin adjacent to the John Day Basin, and the results of these studies have relevance to the northern part of the John Day Basin.

A relatively large amount of climatological and stream flow data is available from the National Oceanic and Atmospheric Administration and the U. S. Geological Survey. While this data does not relate to ground water directly, it is extremely valuable in estimating recharge.

There are several tasks originally scheduled for inclusion as part of the ground water assessment which have proven unattainable due to insufficient data. These include the mapping of water tables and potentiometric surfaces, defining direction and rates of ground water movement, and estimation of annual recharge based on mass discharge calculations. Mapping the water table

or potentiametric surface was prevented by the lack of sufficient resolution of the water level data. This in turn, prevented completing the other tasks. In addition, due to the lack of adequate pump test data, the hydrologic properties of the major units are not known accurately enough to provide meaningful results from flow rate and mass discharge calculations.

## Methodology

Available published and unpublished geologic information was compiled and reviewed, and the major geohydrologic units in the basin were identified. Water well reports were reviewed and those with suitable pump test data were grouped according to geohydrologic unit. The general hydrologic properties of the major units were determined. The area, volume, and saturated thickness of each of the major aquifer units were determined from geologic maps and water well reports where sufficient data were available. Combining this information with the appropriate lithologic information, the amount of ground water in storage in each of the major aquifer units was estimated. Annual ground water recharge to various parts of the basin was estimated by three different methods including analysis of stream hydrographs, analysis of low flow statistics, and analysis of observation well hydrographs. All these methods provide rough estimations which are considered conservative. These methods were determined to be the most appropriate given the time and data limitations.

## GEOGRAPHY

The John Day Basin comprises 8094 square miles of north-central Oregon, or about 8 percent of the state. The basin is bounded on the south and east by the Ochoco and Blue Mountains, on the north by the Blue Mountain Anticline and the low divide separating it from the Umatilla Basin, and on the west by the relatively low divide separating it from the Deschutes Basin.

The basin includes parts of two major physiographic provinces. These are the Deschutes-Umatilla Plateau Province, a broad upland composed primarily of volcanic rock, chiefly basalt; and the Blue Mountains Province, a mountainous terrain composed of a diverse assemblage of older sedimentary, volcanic, and metamorphic rock. Major physiographic features in the basin are presented in Figure 1.

Elevations in the basin range from 147 feet above sea level at the mouth of the John Day River, to 9038 feet at the top of Strawberry Mountain in the southern part of the basin. Most of the basin is between 2000 and 5000 feet above sea level.

Precipitation in the basin ranges from less than 10 to over 40 inches per year, with most stations recording between 10 and 20 inches per year. Mean annual temperature over most of the basin ranges from about 45 to 50 degrees Fahrenheit.

The John Day River is 284 miles long from the headwaters to the mouth. The North Fork and the South Fork are the major tributaries. Other important tributaries to the main stem include Canyon Creek, Bridge Creek, Pine Creek, Butte Creek, Thirtymile Creek, and Rock Creek. Major tributaries to the North Fork include the Middle Fork, Desolation Creek, Camas Creek, and Cottonwood Creek. The only major tributary to the South Fork is Murderers Creek. The stream system in the basin totals about 9500 miles.

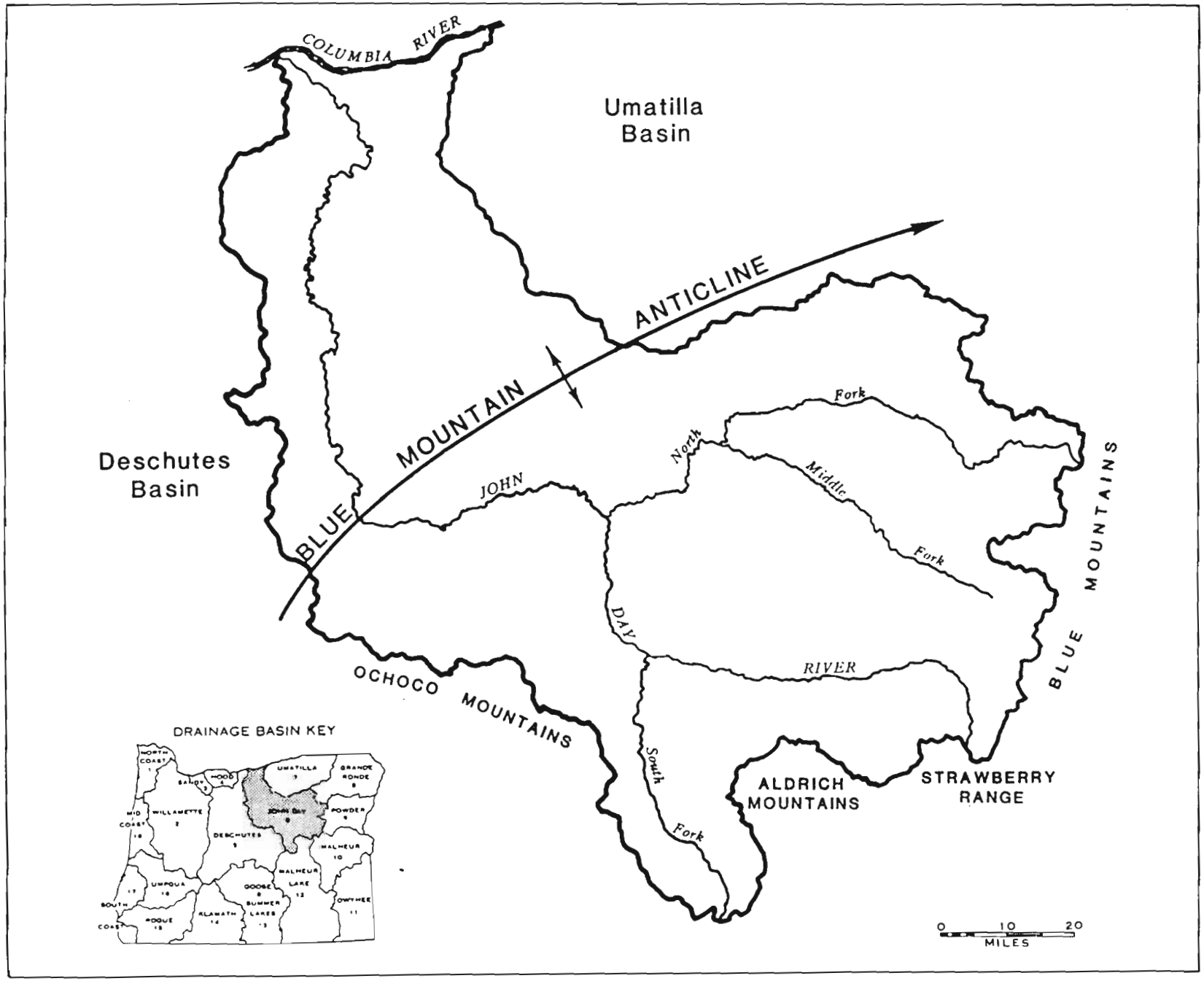



Figure 1. MAJOR PHYSIOGRAPHIC FEATURES OF THE JOHN DAY BASIN

According to the 1978 census data, the population of the basin is about 13,800. The highest concentration of population in the basin is in the upper John Day River Valley upstream of Picture Gorge. This area includes the cities of John Day, Prairie City, Canyon City, and Mount Vernon.

The economy of the basin is based on agriculture and timber. Mining was historically a major source of income, but presently is of relatively little importance. Major agricultural activities include dryland wheat, livestock (mostly beef), and hay production. Timber activity has been decreasing in recent years.

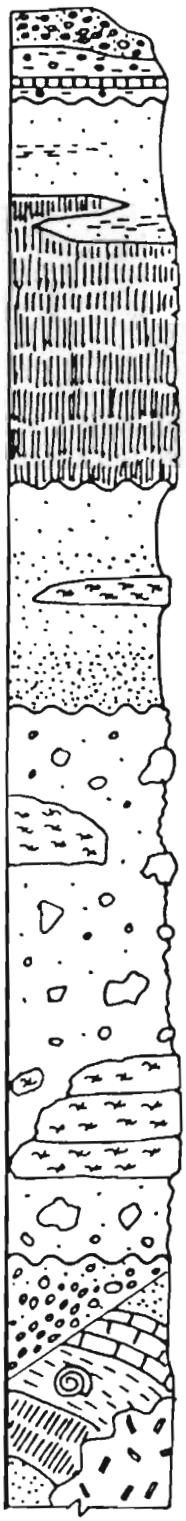
Most of the water wells in the basin are for domestic or stock use. Irrigation use of ground water is limited in the basin except in the very northern part in Gilliam County where several high yield irrigation wells produce water for center pivot systems. The most widely used method of irrigation in the basin is flood irrigation utilizing water diverted from surface streams. Most irrigation occurs on the flood plain along the upper John Day River.

## GEOLOGIC HISTORY

The John Day Basin has a long and complicated geologic history which has resulted in a structurally complex diverse assemblage of rocks exposed at the surface. The rocks exposed in the basin include masses of oceanic crust, shallow and deep marine sediment, intrusive bodies, a wide variety of volcanic materials, ancient river and lake deposits, and recent river and landslide deposits. The distribution of the major geologic units has been controlled largely by the structural evolution of the basin. The stratigraphic sequence of the major units is presented in Figure 2. The geologic evolution of the John Day Basin includes the accretion to the continental margin of marine sediments, associated volcanic rocks, and oceanic crust. This material was contorted, uplifted and eroded prior to the Tertiary Period. The Tertiary Period was a time of volcanic activity starting in the Eocene with the wide spread andesitic eruptions resulting in the Clarno Formation. This activity eventually waned giving way in the Oligocene and the early Miocene to deposition of the largely pyroclastic John Day Formation, which resulted from eruptions in the area of the present day Cascade Range. During the Middle Miocene, the whole area (along with much of northern Oregon, southern Washington and western Idaho) was inundated by a series of flood basalts known collectively as the Columbia River Basalt Group. In the late Miocene, fine-grained volcanic sediments of the Mascall Formation were deposited locally on top of the Columbia River Basalt. The youngest of the major geologic formations in the John Day Basin is a thick sequence of Pliocene sand and gravel, known as the Rattlesnake Formation, deposited in the ancestral John Day Valley.

The distribution of the Tertiary Formations was controlled largely by the presence of major topographic and structural features in the pre-Tertiary sequence. Some of these features persisted throughout the Tertiary to the present.

Major features which have persisted throughout the Tertiary into the present include the Blue Mountains (including the Aldrich and Strawberry Ranges), the



| | |
|---|---|
| Quaternary Alluvium | PREDOMINANTLY UNCONSOLIDATED SILT, SAND AND GRAVEL |
| Rattlesnake Formation (PLIOCENE) | CONGLOMERATE, SANDSTONE, AND MUDSTONE WITH INTERBEDDED ASH FLOW TUFF, ±630 FT. THICK |
| Mascall Formation (LATE MIOCENE) | WATERLAID TUFF, TUFFACEOUS SANDSTONE, AND CONGLOMERATE WITH LOCAL DINTOMITE, ±1,000 FT. THICK |
| Columbia River Basalt (MID-MIOCENE) | MULTIPLE FLOWS OF DARK GRAY, FINE GRAINED CRYSTALLINE BASALT, ±3,000 FT. THICK |
| John Day Formation (OLIGOCENE TO EARLY MIOCENE) | PRIMARY TUFFACEOUS CLAYSTONE, AIR FALL TUFF, AND ASHFLOW TUFF, ±2,300 FT. THICK |
| Clarno Formation (EOCENE) | INHOMOGENEOUS ASSEMBLAGE OF ANDESITIC LAVA FLOWS, VOLCANIC BRECCIA, MUDFLOWS, TUFF, AND TUFFACEOUS SEDIMENT; LOCALLY INTRUDED, ±5,800 FT. THICK |
| Pre-Tertiary Sequence | DIVERSE ASSEMBLAGE OF MARINE SEDIMENTS AND VOLCANICS, THEIR VARIABLY METAMORPHOSED EQUIVALENTS, AND INTRUSIVES, ±45,000 FT. THICK |

Figure 2. GENERALIZED STRATIGRAPHIC SEQUENCE OF MAJOR UNITS IN THE JOHN DAY BASIN

Mitchell Anticline and the Blue Mountain Anticline. It is important here to differentiate between the Blue Mountain Anticline and the Blue Mountains (Figure 1).

The ancestral Blue Mountains, a highland of pre-Tertiary rock, have acted as a topographic barrier and marked the southeast boundary of most of the Tertiary formations in the John Day Basin. The Clarno formation abuts against the Blue Mountains in the southern part of the basin, and occurs only locally in the Blue Mountains in the eastern part. Other highlands of pre-Tertiary rock over which the Clarno formation was thin or nonexistent include the Mitchell Anticline and the Blue Mountain Anticline. A schematic geologic cross section NW-SE through the John Day Basin is presented in Figure 3.

The distribution of the John Day formation was also partly controlled by the Blue Mountain Anticline. It has been demonstrated that while many of the airfall units in the John Day formation can be correlated across the Blue Mountain Anticline, most of the ash flows cannot, indicating that the Blue Mountain Anticline was a major topographic feature during John Day time. On the flanks of the Blue Mountain Anticline, the dips of beds in the lower part of the John Day formation are steeper than in the upper parts, indicating that active uparching of the structure was occurring during deposition of the John Day formation. The eroded surface of the John Day formation was eventually covered by Columbia River Basalt.

The same major structures which affected the distribution of earlier formations controlled distribution of the basalt. The Blue Mountains marked the southern and eastern boundary of the Columbia River Basalt in the John Day Basin. The Blue Mountain Anticline separated various sub-units within the Columbia River Basalt group. The stratigraphy of the basalt is discussed in more detail in later sections. The basalt is thin or nonexistent along the axis of the Blue Mountain Anticline. Post-Columbia River Basalt structural activity is well preserved in the originally flat surface of the basalt. The basalt now dips away from the axis of the Blue Mountain Anticline indicating uparching has occurred since the Columbia River Basalt flowed into the area. The post-Columbia River Basalt structural fabric of the John Day Basin includes a dominant E-W to ESE-WNW direction of faulting and a series of large

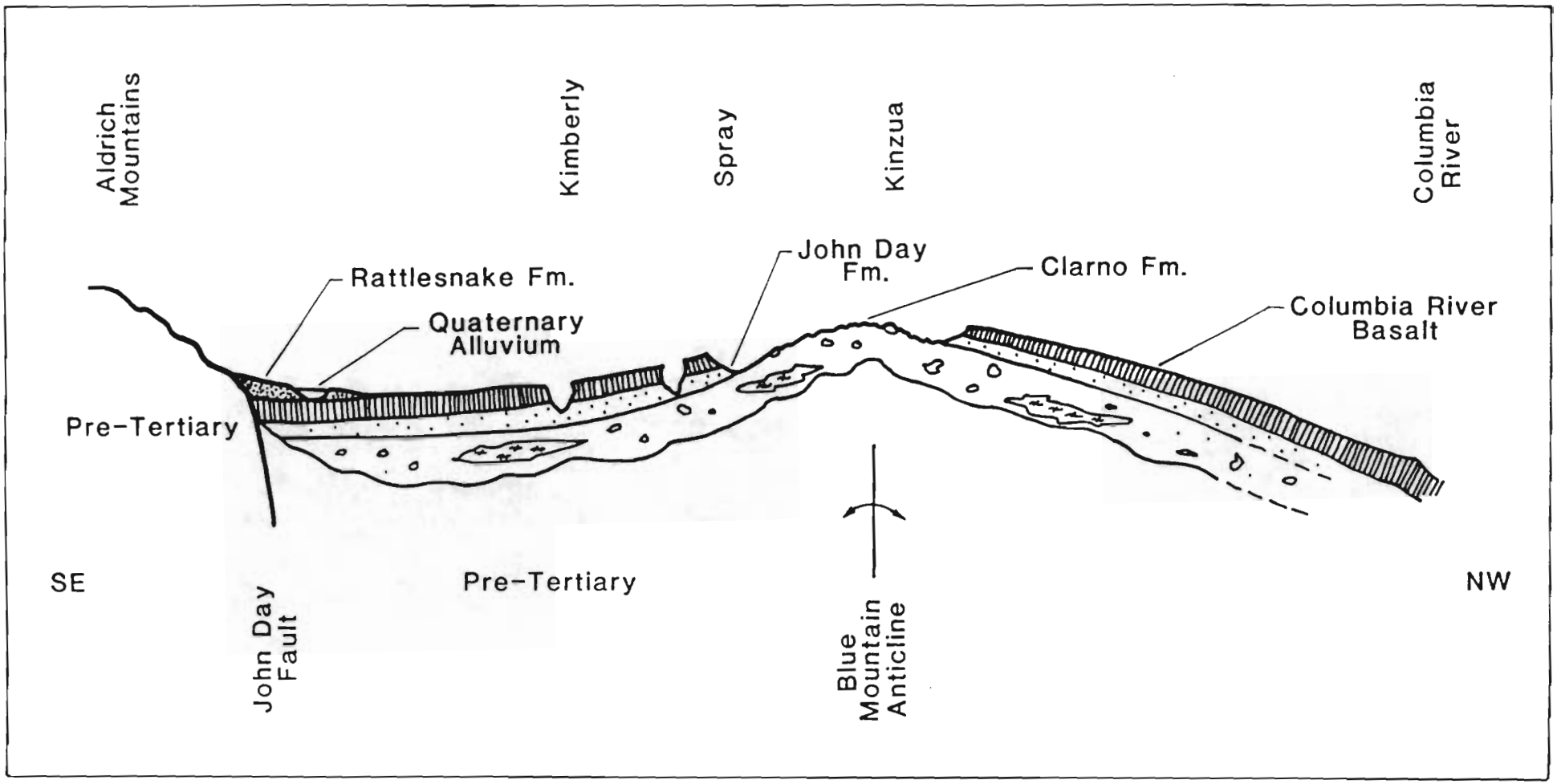



Figure 3. SCHEMATIC GEOLOGIC CROSS SECTION SE-NW THROUGH THE JOHN DAY BASIN

ESE-WNW trending anticlines and synclines. This structurally induced topography tended to localize subsequent accumulations of volcaniclastic material such as the Mascall Formation.

An E-W fault zone occurs along the base of the Aldrich and Strawberry Ranges. This fault zone, which includes the John Day fault, probably controls the location of the John Day River upstream of Picture Gorge. This area has probably been the location of a major valley at least since the Pliocene, as evidenced by the thick accumulation of clastic debris represented by the Pliocene Rattlesnake Formation. The Rattlesnake Formation is largely confined to the long E-W trending structural low now occupied by the upper John Day River and Mountain Creek.

## LITHOLOGY AND HYDROLOGIC CHARACTERISTICS OF MAJOR GEOLOGIC UNITS

### Introduction

In order to assess the ground water potential of any of the major geologic units, it is important to understand their lithology. Lithology is the physical character or mechanics of a rock. It is the lithology which determines the basic hydrologic characteristics of a rock or sediment, and how these characteristics will respond to structural activity and weathering processes. In the following sections the general lithology and lithologic variations of each of the major stratigraphic units in the John Day Basin are discussed, as well as their general hydrologic characteristics as determined from water well report pump test data.

One must use caution when interpreting water well pump test data for hydrologic information, and realize first what the data represent. For example, wells are usually drilled to the depth at which sufficient water is encountered to meet the intended use, at which point drilling is curtailed. In the John Day Basin, most of the wells are of a small diameter drilled for domestic use or stock watering. Therefore, most wells in the basin yield about 20 gallons per minute. This reflects the cost of drilling more than it does aquifer potential. It is also important to remember that well log pump test data does not accurately reflect the number of "dry" wells drilled and abandoned. However, it is possible to assess the general hydrologic characteristics of an aquifer by analyzing the well depth, diameter, and drawdown required to produce a given yield. Specific capacity and transmissivity determinations based on these data will not represent the full hydrologic potential of a given geologic unit, but they will represent the potential relative to other units analyzed similarly. Augmenting the information determined from the water well pump tests with other available hydrologic information can lead to a reasonable understanding of the general ground water potential of a particular geologic unit.

In reviewing water well reports for this study, only pump or bailer tests with yield, drawdown, and time data were used; no airlift tests were used because they lack critical drawdown information. When drillers indicated zero drawdown, it was assumed that no detectable drawdown was observed and a drawdown of one foot was arbitrarily used for specific capacity and transmissivity calculations. In addition, well reports with ambiguous or unassignable geologic descriptions were not used. The transmissivity values presented in the following sections are derived from single well pump tests using a Theis nonequilibrium equation program written by Vorhis (1979). Transmissivity values calculated in this manner cannot be considered absolute, but should be used for comparing the relative hydrologic properties of the various geologic units. Hydrologic data determined from water well reports for each unit is summarized in Table 1. A summary of water well reports, and cumulative curves of the distribution of all pump test data used in this report are presented in Appendix 1.

The storage coefficients and specific yield values used throughout this report have been estimated from published and unpublished sources. For most units, water table conditions are assumed, and the storage coefficient is considered essentially equal to the specific yield (Lohman and others, 1972). Specific yield values were estimated comparing published information on the lithology of the various units as well as field observations with values presented for similar lithologies by Johnson (1967), Todd (1959, 1964), and Fetter (1980). The Columbia River Basalt Group units are treated as confined aquifers. Storage coefficient and specific yields values for basalt aquifers are derived from those presented by Robison (1968), Oberland and Miller (1981) and from personal communications with Donn Miller.

TABLE 1

Hydrologic properties of major units in the John Day Basin as determined from pump tests on water well reports.

| Formation | Number of Wells | Yield (gpm) | | | Specific Capacity (gpm/ft) | | | Transmissivity (ft2/day) | | | Storage Coefficient |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Low | High | Median | Low | High | Median | Low | High | Median | |
| Pre-Tertiary | 19 | 5 | 200 | 15 | .06 | 5.83 | 0.72 | 6 | 1,320 | 93 | 0.02 |
| Clarno | 24 | 1 | 230 | 6 | 0.001 | 88 | 0.2 | 0.7 | 20,000 | 20 | 0.02 |
| John Day | 22 | 0.5 | 100 | 15 | 0.01 | 100 | 0.5 | 0.4 | 20,392 | 60 | 0.05 |
| CRB Sherman Co. | 57 | 4 | 300 | 19 | 0.028 | 65 | 2 | 5 | 21,764 | 600 | $10^{-4}$ |
| CRB Gilliam Co. Wells 12" diam. | 38 | 0.75 | 1,500 | 16 | 0.01 | 130 | 2.5 | 0.2 | 44,769 | 700 | $10^{-4}$ |
| CRB Gilliam Co. Wells 12" diam. | 13 | 50 | 2,000 | 660 | 2.15 | 655 | 15.5 | 549 | 61,421 | 2,000 | $10^{-4}$ |
| CRB South of the Blue Mt. Anticline | 41 | 1.3 | 1,000 | 10 | 0.01 | 40 | 0.17 | 1 | 13,888 | 45 | $10^{-4}$ |
| Mascall (Fox Basin) | 21 | 10 | 230 | 30 | 0.14 | 30 | 1.2 | 12 | 5,226 | 150 | 0.05 |
| Rattlesnake | 21 | 2 | 1,200 | 12.5 | 0.03 | 10 | 0.33 | 2 | 1,695 | 37 | 0.04 |
| Quaternary Alluvium | 69 | 3 | 193 | 15 | 0.027 | 44 | 0.8 | 0.4 | 7,371 | 80 | 0.2 |

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## Pre-Tertiary Units

The pre-Tertiary units in the John Day Drainage Basin comprise a diverse assemblage of variably deformed and metamorphosed late Paleozoic and Mesozoic marine sediments, metasediments, metavolcanics, and plutonic rocks. These rocks crop out over large areas in the southern and eastern parts of the basin, and are described by Lupher (1941), Wallace (1956), Brown and Thayer (1966a, 1966b), Thayer (1977), Brooks (1979), Mullen and Sarewitz (1983), and Mullen (1983). The pre-Tertiary units are treated as a single entity for the purposes of this report because of their limited occurrence in the John Day Basin, their high degree of stratigraphic and structural complexity, the scarcity of hydrologic data and their low probable ground water potential. There are three major areas of pre-Tertiary rock in the basin, and each is discussed separately (Figure 4).

Figure 4 Location of major areas of pre-Tertiary rock in the John Day Basin

The first area comprises the Cretaceous sequence in and around Mitchell including the Hudspeth and Gable Creek Formations (Wilkinson and Oles, 1968), and incorporates parts of at least eight townships. Swanson (1969) describes the pre-Tertiary rocks in this area as consisting largely of graywacke, subgraywacke, conglomerate, and shale. The graywacke occurs in bedded units up to several feet thick with planar surfaces. The conglomerate also occurs in planar beds typically "many feet thick", and ranges from poorly to moderately well sorted. Shales occur in thin beds up to a few inches thick, and are locally fossiliferous. The entire sequence is greater than 9000 feet thick.

Brief reconnaissance indicates that this material is generally quite indurated and has extremely low permeability and porosity. No well data is available for this unit.

The second major area of pre-Tertiary rock occurs to the south of the towns of John Day and Mount Vernon and includes most of the Aldrich Mountains and the area to the southwest, including much of the upper reaches of the South Fork of the John Day River in the Izee area. This is the largest area of pre-Tertiary rocks in the basin and includes parts of at least 30 townships. This area has been described by Lupher (1941), Wallace (1956), Dickinson and Vigrass (1965), Brown and Thayer (1966a, 1966b), and Thayer (1977). The rocks in this area are only slightly deformed and metamorphosed, and have a composite thickness of greater than 45,000 feet (Brooks, 1979).

This pre-Tertiary sequence consists predominantly of Jurassic and Triassic fine grained marine sediments, with lesser Paleozoic sedimentary, volcanic, and metamorphic rocks, and minor Cretaceous marine sediments. Also included is the Triassic Canyon Mountain Ophiolite Complex. The marine sediments include the Vester Formation, the Aldrich Mountains Group (Brown and Thayer, 1966), the Mowich Group (Dickinson and Vigrass, 1965), as well as the Snowshoe, Trowbridge, and Lonesome Formations. These units consist of graywacke, siltstone, shale, and mudstone, with minor lava flows and occasional limestone and conglomerate. The Canyon Mountain Ophiolite Complex consists primarily of peridotite, serpentine, and gabbro, along with a basaltic dike complex and associated silicic rocks. This complex is interpreted to be a slice of oceanic crust and upper mantle tectonically

emplaced along with the sediments.

None of the sedimentary rocks in this second area are considered to have much potential for permeability or storage due to their predominantly fine grained fabric. One exception might be the thick conglomerates of the Vester Formation reported in the upper reaches of the South Fork of the John Day River. These conglomerates may be permeable depending on their degree of sorting and cementation, though no well data is available to substantiate this. The Canyon Mountain Complex is composed of crystalline rocks with probably extremely low permeability.

The third major area of pre-Tertiary rocks occurs in the Blue Mountains in the far eastern parts of the John Day River Basin along the upper reaches of the North Fork, and the Dixie Butte area, and includes parts of at least 25 townships. This area is described as "dismembered oceanic crust" by Brooks (1979), and consists largely of complexly folded and variably metamorphosed fine grained marine sediments and volcanics, including cherts, argillites, greenstones, and schists, as well as ophiolitic ultra-mafic rocks similar to the Canyon Mountain Complex. These rocks range in age from Paleozoic to Triassic, and were intruded during the Cretaceous by numerous dioritic masses ranging from dikes to batholiths.

It is not likely that any of the pre-Tertiary rocks in this third area have any significant permeability due to their fine grained or crystalline lithology. Very little well data is available from this area.

Only 19 water well reports with usable pump test data are available in Oregon Water Resources Department files for areas mapped as pre-Tertiary rock in the John Day Basin. Thirteen of these wells are in a single section (Township 13 South, Range 31 East, Section 33) west of Canyon City. Therefore, these 19 wells cannot be considered a representative sample. Pumpage rates range from 5 to 200 gpm with a median of 15 gpm. Specific capacities range from 0.06 to 5.83 gpm/ft with the median 0.72 gpm/ft. Transmissivities calculated assuming a storage coefficient of 0.02 range from 6 to 1320 $ft^2$/day, with the median 93 $ft^2$/day. Most of these wells appear to be developing water from basalts in the pre-Tertiary sequence.

None of the pre-Tertiary units in the John Day Basin are considered to be hydrologically important. The areas of pre-Tertiary rock are generally very rugged and sparsely settled. The potential for producing ground water in amounts necessary for domestic or stock use exists, but is variable and dependent upon the local geology.

## Clarno Formation

By virtue of its extensive areal distribution, the Clarno Formation is one of the major geologic units in the John Day Basin. Descriptions of the Clarno Formation are provided by Hodge (1941), Waters and others (1951), Taylor (1960), Peck (1964), Enlows and Parker (1972), Robinson (1975), and Noblett (1981). The Clarno Formation consists largely of lava flows and volcanic breccia, mudflows, tuffaceous sediment, ashflow tuff, clay, siltstone and conglomerate. In addition, it has been intruded by many mafic plugs, dikes, and irregular intrusive bodies. The unit is predominantly andesitic, though rocks of basaltic to rhyolitic composition are present in subordinate amounts. Most of the material in the Clarno Formation is locally derived. Units are generally discontinuous, and there is a high degree of lateral and vertical variability. The total composite thickness of the Clarno Formation is greater than 5800 feet (Peck, 1964). Numerous saprolitic horizons occur within the Clarno Formation, and the top of the unit is locally marked by a saprolite 10 to 100 feet thick. The Clarno Formation is considered Eocene (Noblett, 1981), and rests unconformably on pre-Tertiary rocks. The locations of major areas of Clarno Formation are presented in Figure 5.

The high amount of tuffaceous material, clay and fine grained volcanic sediments restrict water movement in the Clarno Formation. As a result, overall permeability is generally quite low. However, local isolated units within the formation, such as flow sequences and domes, can have relatively good permeability and storage potential. One well produces over 200 gpm from Clarno Formation andesites. The discontinous geometry of these units, and their probable confinement by material of low permeability severely limits their recharge, and long term development of these aquifers is unlikely.

Figure 5 Location of major areas of Clarno Formation in the John Day Basin

Water well reports with complete pump test data are available for 29 wells producing from the Clarno Formation in the John Day Basin. Eighteen of these are from an area of a few square miles in the vicinity of Fossil, so the sample may not be representative. Reported pumpage rates from wells producing from the Clarno Formation range from 1 to 230 gpm. The 230 gpm well is anomalous, and the median yield is 6 gpm. Specific capacities range from 0.001 to 88 gpm/ft with the median about 0.2 gpm/ft. Transmissivities calculated assuming a storage coefficient of 0.02, range from 0.7 to 20,000 $ft^2$/day with the median transmissivity 20 $ft^2$/day.

Even though the well data from the Clarno Formation indicate a low ground

water potential, the Clarno is considered somewhat important hydrologically due to the large area in the basin which it covers. The Clarno Formation occurs over approximately 1164 square miles in the John Day Basin, or about 14 percent of the total basin. Regardless of its low ground water potential, many people in the basin rely on the Clarno Formation as their sole source of water. Obtaining adequate well yields for domestic or stock use is extremely difficult in many cases. The best prospects for ground water production are fractured crystalline rock, such as lava flows or domes within the unit. Careful analysis of the detailed geology and careful selection of drill sites can maximize the chances of obtaining usable amounts of ground water from the Clarno Formation.

## John Day Formation

The John Day Formation is a largely tuffaceous unit which occurs beneath the Columbia River Basalt throughout large areas in the northern John Day Basin (Plate 1). This formation has been described by Taylor (1960), Hay (1962), Peck (1964), Fisher (1967), Swanson and Robinson (1968), Robinson (1975), and Robinson and others (1984). It includes primarily devitrified tuffaceous claystone, air fall tuffs, and ash-flow tuffs of andesitic to dacitic composition. Rhyolitic, andesitic, and basaltic flows and basaltic cinder deposits occur and are locally abundant, especially in the lower part of the unit.

Numerous variably welded ash flow tuffs occur within the John Day Formation, some of which are fairly widespread. These include one near the middle of the unit, informally referred to as the Picture Gorge Ignimbrite, and one which crops out intermittently along the bottom of the formation north of the Painted Hills.

The John Day Formation represents the accumulation of material erupted predominantly from the general area of the present day Cascade Range, with some locally erupted material (Robinson and others, 1984), and is considered to be Oligocene to early Miocene in age. The John Day Formation rests unconformably on the Clarno Formation and is reported by Hay (1962) to be 2300

feet thick in a measured section near Mitchell.

Since the bulk of the John Day Formation is composed of fine grained devitrified tuffaceous material, the permeability is generally extremely low. Isolated units within the formation, such as sequences of flows or domes, may have relatively good permeability and storage potential locally, however these are very scarce, and their probable confinement by low permeability material greatly restricts their recharge potential.

Water well reports with complete pump test data are available for 22 wells producing from the John Day Formation in the John Day Basin. Most of these wells are in the valley along the main stem of the John Day River between Picture Gorge and Kimberly, and along the North Fork between Monument and Kimberly. Most of these wells are located near the river and many may be recharging from the river. Yields from these wells range from 0.5 to 100 gpm, most are from 5 to 30 gpm, and the median yield is 15 gpm. Specific capacities range from .01 to 100 gpm per foot with the median 0.5 gpm per foot. Transmissivities, calculated assuming a storage coefficient of .05, range from 0.4 to 20,392 $ft^2$/day with a median 60 $ft^2$/day. Ninety percent of the wells have a transmissivity of less than 3000 $ft^2$/day. Because of the very low potential and somewhat limited exposure, the John Day Formation is not considered an important unit in terms of ground water in the John Day Basin.

## Columbia River Basalt Group

The Columbia River Basalt Group is the most extensive and hydrologically important unit in the John Day Drainage Basin. Columbia River Basalt in the basin is discussed by Hodge (1942), Newcomb (1959, 1967, 1969, 1970), Peck (1964), Thayer (1966), Swanson (1969), Walker (1973), and Bela (1982). Major Columbia River Basalt areas are presented in Figure 6.

The Columbia River Basalt Group comprises a thick sequence of tholeiitic flood basalt covering large areas of northern Oregon, southeastern Washington, and western Idaho. The sequence is greater than 3000 feet thick in the area of

the Columbia River (Newcomb, 1971) and is composed of a series of laterally extensive flows ranging from 10 to 200 feet thick, averaging about 80 feet thick. This series is distinctively layered, with the flows typically exhibiting columnar jointing. The sequence thins near its margins in the John Day Basin, where it laps against Miocene structural highlands.

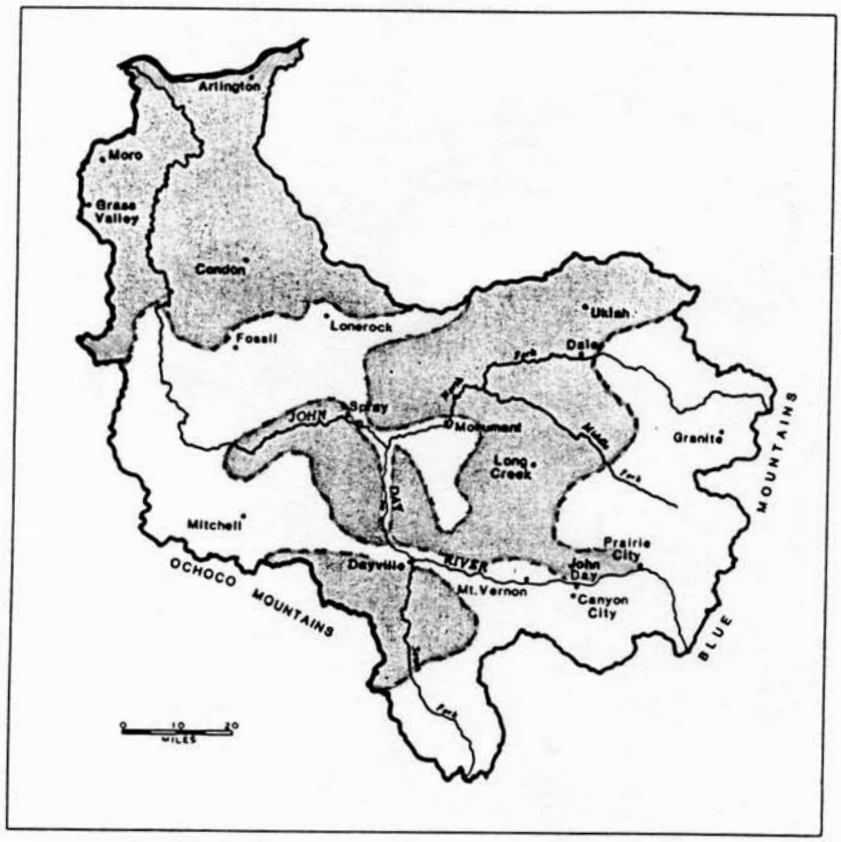


Figure 6 Distribution of Columbia River Basalt in the John Day Basin

The cores of basalt flows are typically composed of uniformly textured, fine grained, non-vesicular to slightly vesicular basalt, with columnar or hackly jointing. The tops of flows are typically highly vesicular and often brecciated and rubbly, while the bottoms are typically glassy. Brecciated zones and flows are reported up to 100 feet thick (Newcomb, 1969). The Columbia River Basalts are generally flat lying or gently warped with very low dips, except near faults, where very high dips can occur.

While interbeds are not common, they do occur in the John Day Basin. Thirty to 350 feet of poorly indurated tuff and fine sediments (the Ellensburg Formation) occur near the top of the basalt sequence in the vicinity of Arlington (Bela, 1982; Newcomb, 1971). Brown and Thayer (1966) report that thin ashy interbeds occur with the lower flows in the Canyon Mountain 1° x 2° quandrangle, and that the upper flows are interbedded with the Mascall Formation in Fox Basin.

The hydrologic characteristics of the Columbia River Basalt are discussed by Piper (1932) and by Newcomb (1959, 1969). Lateral permeability is moderate to high, because water can move easily through the rubbley or brecciated zones between flows and through totally brecciated flows. Vertical permeability is usually quite low because of the massive, dense nature of the central portions of most flows. Water does not move easily through the ubiquitous fractures and joints in the central parts of basalt flows, because they are typically tightly closed at depth (Newcomb, 1969). The basalt interflows have excellent hydraulic conductivity and storage capacity. Recharge is limited by the very low vertical permeability of the flows, but will occur where the ends of the flows are exposed at such an angle as to allow percolation of precipitation or surface water into the interflow zones. The lateral continuity of the basalt interflow zones can be disrupted by such things as faults or flows pinching out. The broad anticlines which occur in the Columbia River Basalts may also act as hydrologic barriers. Ground water commonly flows toward the synclines which often act as ground water reservoirs. According to Newcomb (1969) individual interflow aquifers are "generally identifiable for only a few miles".

A total of 149 water well reports with usable pump test data are available for wells producing from the Columbia River Basalt. The basalt is separated into two major areas in the John Day Basin by the ENE-WSW trending Blue Mountain Anticline. In assessing pump test data for this report, these two major areas are discussed separately.

The basalt terrain northwest of the Blue Mountain Anticline comprises much of

Sherman and Gilliam Counties. Water well reports with usable pump test data are available for 108 wells producing from this area. The majority of these wells are domestic or stock wells with diameters of ten inches or less. In the extreme northeastern part of the area (along and to the northeast of Rock Creek) there are a number of deeper higher yield wells with diameters of 12 inches or more drilled for irrigation. Because these wells are all in a fairly restricted area, and their depth and construction are atypical for the rest of the area, they are considered separately from the rest of the wells to avoid skewing the data. The Sherman and Gilliam County areas, which are separated by the John Day River, are considered separately from each other because of structural differences between them. The Gilliam County area east of the John Day River is more intensely folded and faulted according to a map presented by Bela (1982).

Usable pump test data are available for 57 wells producing from basalt in the John Day Basin in Sherman County. These wells, nearly all of which are less than 12 inches in diameter, produce from 4 to 300 gpm, with the median yield 19 gpm. Specific capacities range from 0.028 to 65 gpm/ft, with the median 2 gpm/ft. Transmissivities calculated using a storage coefficient of $10^{-4}$ range from 5 to 21,764 $ft^2$/day, with the median of 600 $ft^2$/day.

Well logs with usable data are available for 38 wells producing from basalts within the basin in Gilliam County with diameters of 12 inches or less. These wells yield from less than 1 to 1500 gpm, with the median yield 16 gpm. Specific capacities range from 0.01 to 130 gpm/ft, with the median 2.5 gpm/ft. Transmissivities calculated assuming a storage coefficient of $10^{-4}$, range from 0.2 to 44,769 $ft^2$/day, with a median 700 $ft^2$/day.

Pump test data is available for 13 wells with diameters of 12 inches or more producing from basalts within the basin in the northeastern part of Gilliam County. These wells yield from 50 to 2000 gpm with the median yield of 660 gpm. Specific capacities range from 2.15 to 655 gpm per foot, with the median 15.5 gpm per foot. Transmissivities calculated assuming a storage coefficient of $10^{-4}$ range from 549 to 61,421 $ft^2$/day, with the median transmissivity 2000 $ft^2$/day. These deeper larger diameter wells may,

in fact, more accurately represent the hydrologic potential of the basalt. This is not to imply, however, that recharge is adequate to sustain a great number of these high yield wells.

Usable data is available for 41 wells producing from the Columbia River Basalt south of the Blue Mountain Anticline. These wells are scattered throughout the basin and represent a variety of geologic settings. Each of these settings is discussed separately in the later section dealing with storage estimates. A few relatively deep, larger diameter, high yield municipal wells producing from the Columbia River Basalt are included in this group, including the 1000 gallon per minute Canyon City well and the 876 gallon per minute City of John Day well. Well yields in this group range from 1.3 to 1000 gpm, with the median being about 10 gpm. Specific capacities range from 0.01 up to 40 gpm per foot with the median being about 0.2 gpm per foot. Transmissivities calculated assuming a storage coefficient of $10^{-4}$ range from 1 to 13,888 $ft^2$/day with the median approximately 45 $ft^2$/day.

The Columbia River Basalt is the most important and areally extensive aquifer unit in the basin covering over one-half the basin area. The Columbia River Basalt will supply adequate water for domestic and stock watering uses at reasonable depths in most places throughout the basin, and can locally supply large quantities of water suitable for municipal or irrigation use. The confined nature of many basalt aquifers produces artesian, and often flowing artesian, conditions given the proper geologic setting. Development of the basalt aquifers for large scale irrigation use is limited, however, by the very low recharge due to poor vertical permeability. Hydrologic characteristics of the Columbia River Basalt as determined from water well reports are summarized in Table 1.

## Strawberry Volcanics

The Strawberry Volcanics are an important unit in the vicinity of the headwaters of the John Day River. Descriptions of the Strawberry Volcanics are provided by Brown and Thayer (1966, 1973), Robyn (1977), and Wheeler (1982). The location of the Strawberry Volcanics is presented in Figure 7.

Figure 7 Distribution of the Strawberry Volcanics in the John Day Basin

The Strawberry Volcanics consist primarily of basalt and basaltic andesite flows with lesser dacite and rhyolite. Flows are commonly columnar, and exhibit plately jointing parallel to the flow surfaces. In the northern part of their extent in the John Day Basin near Bates, diatomites occur interbedded with the flows (Wheeler, 1982). Dips are generally low in this unit, though Wheeler (1982) reports one dip of 13 degrees. The thickness of the unit is reported to be 560 feet near Bates, though it probably thickens toward the south. The Strawberry Volcanics erupted from numerous vents in the Strawberry Mountain-Lookout Mountain area. They are considered Miocene (10 to 20 million years old) and rest unconformably on older rocks, usually the Clarno Formation.

Layered basalt flows such as the Strawberry Volcanics typically exhibit poor

vertical permeability and relatively good lateral permeability owing to the thin flow breccias and rubble between the individual flows. This lateral permeability can be disrupted by faults or other lateral discontinuities in the sequence. Lateral permeability in the Strawberry Volcanics may also be limited if the sequence consists of numerous fairly small discountinuous flows from scattered vents as opposed to the areally extensive flows of the Columbia River Basalt Group. Permeability and storage potential in the Strawberry Volcanics are considered to be low to moderate. Well data is insufficient to accurately assess the hydrologic characteristics.

Water well reports with usable data are available for only 3 wells in the Strawberry Volcanics. They range from 109 to 193 feet deep, and yield from 15 to 45 gpm. Because of their somewhat limited extent in a sparsely populated area, the Strawberry Volcanics are not considered an important hydrologic unit.

Mascall Formation

The Mascall Formation in the John Day Basin is a unit of rather limited extent occuring along the John Day River in the vicinity of Picture Gorge and Dayville, and in Fox Basin, about 20 miles northeast of Dayville (Figure 8). It is discussed by Hodge (1942), Baldwin (1964), and Brown and Thayer (1966).

The Miocene Mascall Formation consists predominantly of bedded waterlayed tuff and tuffaceous sandstone, with lesser conglomerate and diatomite deposited conformably in gentle structural lows on the Columbia River Basalt Group. Hodge (1942) reports a total thickness of 400 to 1000 feet for the formation. The lithology of the Mascall Formation is variable, especially from one geographic area to another. In the upper John Day River valley around Dayville, the unit is very tuffaceous and clay rich, and probably has very low hydraulic conductivity. Hodge (1942) reports a 400 to 500 foot thick conglomerate in the Mascall Formation east of Dayville. Only one water well report with usable data is available for the Mascall Formation in the John Day

Valley, and it is in a landslide block.

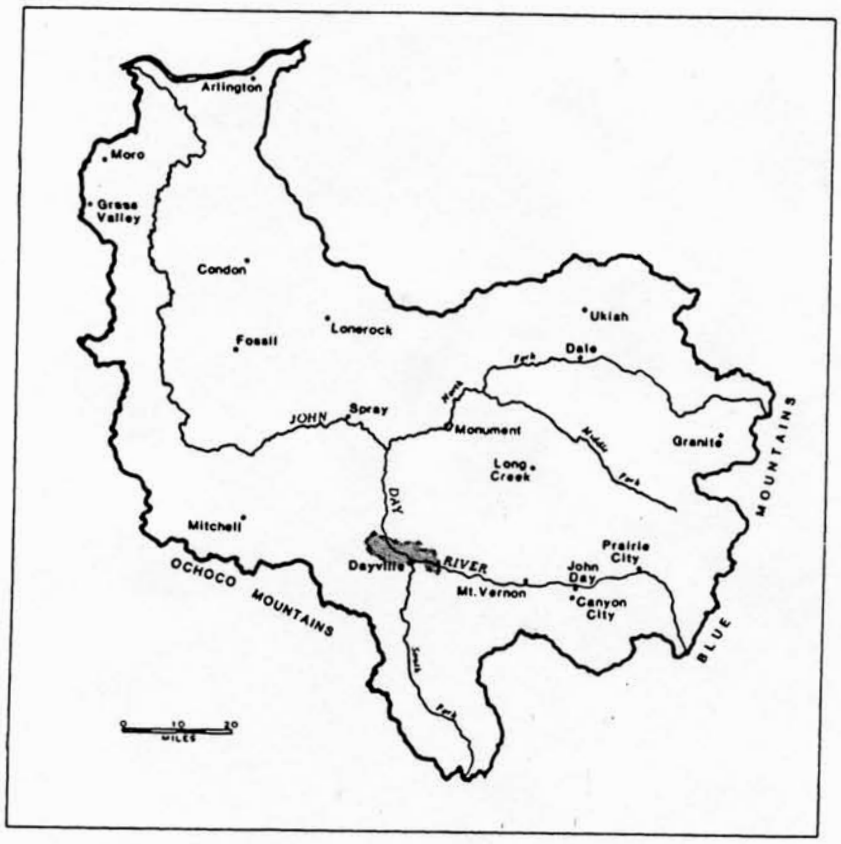


Figure 8 Distribution of the Mascall Formation in the John Day Basin

In the Fox Valley area, the Mascall Formation appears to be much more sandy, with gravel and basalt interbeds. The Mascall has been developed as a source of ground water in this area.

Usable data is available for 21 wells in the Fox Basin area. Some of which are actually located in areas mapped as alluvium by Brown and Thayer (1966). At least some of these probably penetrate through this alluvial cover into the underlying Mascall sediments. There is no clear distinction between lithologic descriptions on logs for wells drilled in alluvium and those drilled in the Mascall Formation in Fox Basin, hence they are lumped together in this report. Yields from these wells range from 10 to 230 gpm, with the median yield of 30 gpm. Specific capacities range from 0.14 to 30 gpm/ft with the median being about 1 gpm/ft. Transmissivities calculated assuming a

storage coefficient of 0.05 range from 12 to 5226 $ft^2$/day with the median at 150 $ft^2$/day.

The ground water potential of the Mascall Formation is variable from place to place. Along the John Day River near Dayville little well data are available and the unit appears to be tuffaceous and clay rich, therefore, it is not considered an important aquifer unit. In the Fox Basin area the unit appears to contain more sand and gravel, and well data indicated it has a good potential for domestic and stock watering purposes. Limited recharge due to low precipitation in the area precludes pumping from the Mascall for extensive large scale irrigation.

Rattlesnake Formation

A potentially important aquifer along the John Day River and Mountain Creek in the southern part of the basin is the Rattlesnake Formation, a thickness of Pliocene sands and gravels (Figure 9). This formation is discussed by Hodge (1942), Baldwin (1964), Davenport (1970), and an excellent description is provided by Enlows (1976).

The Rattlesnake Formation consists of gravels, sands, and mudstones deposited in the ancestral John Day River Valley, along with one widespread welded ash flow tuff. The gravels are derived from the highlands adjacent to the valley. Enlows (1976) divides the Rattlesnake Formation into three members: the lower fanglomerate, the Rattlesnake Ignimbrite, and the upper fanglomerate. The lower fanglomerate consists of poorly consolidated, porous conglomerate, typically with pebble to cobble size clasts in a sandy matrix, along with a high proportion of poorly consolidated volcanic wacke and minor mudstone. The Rattlesnake Ignimbrite consists of a single, variably welded ash flow tuff which entered the basin through the area of the headwaters of the South Fork of the John Day River. The ignimbrite is widespread, and extends beyond the limits of the lower fanglomerate. The maximum thickness is reported to be 120 feet, though it is thinned by erosion in many areas, and locally removed totally by erosion. The upper fanglomerate member is more uniform than the lower member, and is described as a coarse, poorly

consolidated conglomerate with thin lenses of volcanic wacke. The Rattlesnake Formation is considered Pliocene, and rests unconformably on rocks ranging in age from Paleozoic to Miocene.

Figure 9 Distribution of the Rattlesnake Formation in the John Day Basin

While the coarse, poorly consolidated, clastic nature of the Rattlesnake Formation suggests it may have good permeability and storage potential, field reconnaissance and well data indicate otherwise. Examination of outcrops in the John Day River Valley showed most of the fine-grained fraction of the matrix of the sandstone and conglomerate to be weathered to clay. This clay acts to cement the sediments, fill void spaces, and impede water flow. The ubiquitous welded ash flow tuff in the middle of the formation probably has very low permeability, and may act as a hydrologic barrier between the upper and lower fanglomerates.

Twenty-one water well reports with complete pump test data are available for wells producing from the Rattlesnake Formation. The majority of these wells occur in the John Day River Valley from the area around Mount Vernon east to the Prairie City area. The yields from these wells range from 2 to 1200 gpm, with the median yield 12.5 gpm. Most of the wells yield from 5 to 20 gpm, and the 1200 gpm well mentioned is a 1210 foot well and is somewhat anomalous. Specific capacities range from 0.03 to 10 gpm/ft, with the median 0.33 gpm/ft. Transmissivities calculated assuming a storage coefficient of 0.04 range from 2 $ft^2$/day to 1695 $ft^2$/day with the median transmissivity being 37 $ft^2$/day.

The Rattlesnake Formation is a small unit in terms of the total John Day Basin, however, it occurs along the river in the most densely populated part of the basin. Therefore, it is considered an important aquifer unit. Wells drilled into the Rattlesnake Formation will usually yield water in amounts adequate for domestic or stock uses. Because of its low hydraulic conductivity, the Rattlesnake Formation generally will not yield water in sufficient amounts for a large scale irrigation.

Alkali Canyon Formation

The Alkali Canyon Formation occurs in the very north part of the John Day Drainage Basin in the area to the south and west of Arlington (Figure 10). It was defined by Farooqui and others (1981) and has previously been referred to as the Shutler Formation (Hodge, 1942) and as The Dalles Formation (Newcomb, 1969, 1971). The Alkali Canyon Formation is one of five descrete, predominantly epiclastic volcanic deposits resting unconformably on the top of the Columbia River Basalt Group in north-Central Oregon.

The Alkali Canyon Formation consists primarily of basaltic cobble gravel with lesser but variable amounts of fine tuffaceous sediment. The unit is highly variable laterally. The base of the formation is locally marked by a vitric tuff unit about 16 feet thick. The Alkali Canyon Formation ranges in thickness from 32 to 130 feet, and is the uppermost unit where it occurs.

Figure 10 Distribution of the Alkali Canyon Formation in the John Day Basin

The predominance of clast supported gravel in the Alkali Canyon Formation suggests it has moderate to high permeability and storage potential. The basal tuff may tend to perch water. Recharge is limited to percolation of precipitation in the immediate area, as most surface water in the area flows in canyons cut through the gravels into the underlying formations.

Negligable pump test data is available for wells producing from the Alkali Canyon Formation. Nearly all the wells drilled in areas mapped as Alkali Canyon Formation penetrate through it and are producing from Columbia River Basalt. The reasons for this are unclear. It may be that the gravels do not have a sufficient saturated thickness, or that the higher yields obtained by drilling into the basalts outweigh the additional drilling costs. The Alkali Canyon Formation is not considered an important aquifer unit.

Quaternary Alluvium

Quaternary alluvium, specifically as deposited in river and stream channels, is one of the most important aquifer units in the John Day Basin in terms of usage, second only to a Columbia River Basalt. Significant masses of alluvium include the entire stretch of the main stem of the John Day River from Picture Gorge upstream to Deardorff Creek, the stretch of the North Fork of the John Day River from Monument to Kimberly, and the areas around Spray, Twickenham and Clarno (Figure 11). The alluvium in Fox Basin is included with the Mascall Formation for the purposes of this report.

Figure 11 Location of major occurrences of Quaternary Alluvium in river valleys in the John Day Basin

The nature of the alluvium varies from place to place and the exact lithology reflects the stream dynamics, topography, and geology of the adjacent area. A

typical section of alluvium consists of an unconsolidated series of interbedded gravel, sand, and silt, in beds a few inches to several feet thick. The degree of sorting is variable, with most material moderately to well sorted. Alluvial deposits in stream channels vary in thickness and width. In the John Day Basin, alluvium filled valleys over one mile wide are not uncommon, especially upstream of Picture Gorge. Thicknesses vary from a few tens of feet to a few hundred feet. Where the river is deeply incised in the Columbia River Plateau, very minor alluvium is present. The geometry of alluvial deposits is considered in more detail in the later section dealing with storage estimates.

Water well reports with usable pump test data are available for 69 wells producing from alluvium in the John Day Basin. Yields from these wells range from 3 to 193 gpm with a median yield of 15 gpm. Specific capacities range from 0.027 to 44 gpm/ft, with a median specific capacity 0.8 gpm/ft. Transmissivity values calculated using a storage coefficient of 0.2, range from 0.4 to 7371 $ft^2$/day, with a median of 8 $ft^2$/day. These numbers probably underestimate the hydrologic potential of the alluvium, as most of the wells represented are smaller diameter wells drilled for domestic and stock watering purposes. Deeper, higher yield wells designed for efficient production would undoubtedly indicate higher transmissivities.

Alluvial deposits in stream and river channels typically have high porosity and permeability, with specific yields as high as 20 to 25 percent. Stream channel deposits are generally considered good aquifers due to their ability to store and transmit relatively large amounts of water, combined with the high potential for recharge from surface sources.

## GROUND WATER STORAGE ESTIMATES

The volume of water contained in the ground water system at a given time is termed the ground water storage. The ground water storage can be thought of as a reservoir. The level is this reservoir is a function of the balance between recharge and discharge (both natural and appropriated).

It is important to remember that to suggest a certain volume of ground water is present as storage does not imply that the total amount is available for appropriation. The amount of water in storage is one part of a dynamic system which also includes recharge and discharge. If water were removed from the ground water system at a rate which exceeded recharge to the point where storage was depleted, the natural discharge would be disrupted. This would result in decreased stream flow.

The aquifer units used in ground water storage estimates are further a subdivision of the geologic units as defined on the basis of the geologic and hydrologic characteristics in the previous section. Generally, the subdivisions define areas of a particular rock or sediment type within which there are no major structural or stratigraphic hydrologic barriers. For example, the adjacent subdivisions (aquifer units) in the Columbia River Basalt (geologic unit) may be separated by major anticlines and/or faults or by outcroppings of underlying material. Isolated masses of a particular geologic unit are considered separate aquifer units.

The geologic units for which storage was estimated include the Columbia River Basalt, the Mascall Formation in Fox Basin, the Rattlesnake Formation, and Quaternary Alluvium. Ground water storage was not estimated for the pre-Tertiary units, the Clarno Formation, or the John Day Formation, because of their low production potential and lack of available data to constrain volume, specific yield and hydrology. Aquifer units for which storage is estimated were selected on the basis of size and available data on the geometry, lithology, and hydrology. In

the following sections the amount of available ground water is estimated for each of the major aquifer units selected.

The following method was used to calculate storage. The area of the unit in question was determined planimetrically from maps with the smallest land area per unit map area available. Thickness of the unit was estimated from published geologic and topographic maps, and from stratigraphic information from water well reports. Saturated thickness was determined using static water level information from water well reports. Specific yields were estimated using published sources, including Todd (1954, 1964), Fetter (1980) and Johnson (1967). To simplify calculations, the units were considered to be flat and have vertical edges. In the case of very thick units, the amounts of water in storage in the upper 500 feet, and from 500 to 1000 feet were calculated separately. The volume of water in storage was calculated by multiplying the area, the saturated thickness, and the specific yield. For each unit, the questionable parameters were bracketed with a range of values, with the best estimate in the center.

There are obvious sources of error in the method described, particularly in assumptions about the geometry. However, over estimations of thickness near the edges of a unit are compensated for by the conservative estimations of the overall total thickness. Extremely irregular or dissected topography will tend to reduce the amount of ground water in storage. Specific yield values were estimated from published sources only after careful consideration of the lithology, and are considered to be good. Where there was question in assigning a value to some parameter, the approach was always conservative.

## Columbia River Basalt Group

The Columbia River Basalt Group has been subdivided into 9 major aquifer units based on structure, stratigraphy and geographic occurrence (Plate 2). The amount of ground water in storage has been estimated for six of these aquifer units. The remaining 3 units lack sufficient data

for storage estimates. The various basalt units are divided on the basis of their relative hydrologic isolation. This isolation may be stratigraphic and/or structural. Many are surrounded almost entirely by older rock of very low permeability; a stratigraphic isolation. Other of the basalt aquifer units are part of a larger continuous basalt mass and are isolated by zones of intense faulting, often associated with anticlinal folds; these are structurally isolated. Often it is a combination of factors which isolate the aquifer units in the basalts. The boundaries of the aquifer units often correspond approximately to surface drainage divides.

Specific yield and effective porosity values for Columbia River Basalt are discussed by Oberlander and Miller (1981) and by Robison (1968). Robison uses value of one percent, while Oberlander and Miller used 3.2 percent. According to Miller (oral communication, 1984), one percent seems to be the closer value

## Sherman County Basalt Area

### Aquifer Unit Description

The large area of continuous basalt north of the Blue Mountain anticline has been subdivided into two areas separated by the John Day River. This is because the river is incised over 1000 feet into the basalt plateau, and there are slight differences in the structural settings on either side. Nearly all of the basalt area west of the river is in Sherman County, and most of the basalt east of the river is in Gilliam County, hence, these areas are referred to as the Sherman and Gilliam County Basalt Areas.

The Sherman County Basalt Area is bounded on the east by the John Day River, and on the west by the surface drainage divide between the John Day and Deschutes River drainages. This is a rather weak divide and probably does not actually correspond to a ground water divide. The basalt is bounded on the south by underlying John Day Formation exposed

along the Blue Mountain anticline. The area is generally a broad plateau with gently rolling hills. Little faulting has been mapped in the area and the only major structures are the ENE-WSW trending Grass Valley syncline and the E-W trending Dalles-Umatilla syncline, both in the northern part. Surface drainage is chiefly through Grass Valley Canyon (which follows the Grass Valley syncline), Jackknife Creek and Pine Hollow Creek, all of which flow directly into the John Day River.

Figure 12 Location of the Sherman County Basalt Area

Ground Water Storage Estimates

The Sherman County Basalt Area (Figure 12) comprises 552 square miles or

353,280 acres. The thickness of the basalt is probably greater than 2000 feet. Canyon walls along the John Day River commonly expose 1,500 to 1,800 feet of basalt section and a well drilled in the plateau in Gilliam County near Condon penetrated 2440 feet of basalt. Static water levels measured in 58 wells range from 0 to 400 feet below ground level, with the median 150 feet. Using this median static water level as representative of the whole area indicates a saturated thickness of 385 feet in the upper 500 feet of basalt. Storage estimates for the Sherman County Basalt Area are presented in Table 2 for specific yields of 0.5, 1, and 2 percent.

TABLE 2

Estimated acre-feet of ground water storage in the Sherman County Basalt Area. Area = 552 square miles, 353,280 acres.

| Specific Yield | Storage in Acre-feet 0-500 ft. | 500-1000 ft. |
|---|---|---|
| 0.5 % | 680,064 | 883,200 |
| *1.0% | 1,360,128 | 1,766,400 |
| 2.0% | 2,720,256 | 3,532,800 |
| | saturated thickness = 385 ft. | saturated thickness = 500 ft. |

* Most reasonable estimate.

## Gilliam County Basalt Area

### Aquifer Unit Description

The Gilliam County Basalt Area (Figure 13) is bounded on the west by the John Day River, on the north by the Columbia River, on the east by the surface drainage divide between the John Day and Umatilla drainage basins, and on the south by older rocks exposed along the Blue Mountain anticline. Like the Sherman County area, the Gilliam County area is a plateau gently dipping northward, however it has been more intensely folded, faulted, and dissected by surface drainage. The area shows N-S and NW-SE trending normal faults, and NW-SE and NE-SW trending anticlines

and synclines. Major structural features include a series of synclines and anticlines in the Condon area, the Turner Butte anticline and the Dalles-Umatilla syncline in the northern part of the area. Major drainages in the area include Rock Creek, Hay Creek, and Thirtymile Creek. The basalt is covered by a veneer of volcanically derived sediments of the Alkali Canyon Formation in the northern part of the area, however wells drilled in this material nearly always penetrate through it and produce water from the basalts.

Figure 13 Location of the Gilliam County Basalt Aquifer Unit

Storage estimates

The Gilliam County Basalt area includes 1214 square miles or 76,960 acres. The thickness of the basalt is probably greater than 2000 feet

based on the same agruments presented for the Sherman County area, including the 2440 feet of basalt drilled near Condon. Static water levels measured in 50 wells in Gilliam County range from 0 to 684 feet below the surface, with the median being is 125 feet. Extrapolating this over the whole area gives a saturated thickness of 375 feet in the upper 500 feet of basalt. Storage estimates for the Gilliam County Basalt Area are presented in Table 3.

TABLE 3

Estimated acre-feet of ground water storage in the Gilliam County Basalt Area.

Area = 1214 square miles, 776,960 acres.

| Specific Yield | Storage in Acre-feet 0-500 ft. | 500-1000 ft. |
|---|---|---|
| 0.5% | 1,456,800 | 1,942,400 |
| *1.0% | 2,913,600 | 3,884,800 |
| 2.0% | 5,827,200 | 7,769,600 |
| | saturated thickness = 375 ft. | saturated thickness = 500 ft. |

* Most reasonable estimate.

## North Fork-Middle Fork Basalt Area

### Aquifer Unit Description

The North Fork-Middle Fork Basalt area comprises an enormous expanse of basalt extending from the Blue Mountain anticline south to the Long Creek Mountain anticline, and east past Dale to the highlands of pre-basalt rock exposed in the Blue Mountains (Figure 14). This terrain includes approximately 1450 square miles of basalt or approximately 18 percent of the entire John Day Basin. The North Fork-Middle Fork basalt area is hydrologically bounded on the northwest by older rocks exposed along the Blue Mountain anticline and on the east by the divide between the John

Day and the Umatilla drainage basins, and by highlands of older rock exposed in the Blue Mountains. It is hydrologically bounded on the south by the Long Creek anticline on associated faults, and on the southwest by exposures of John Day Formation along the John Day River valley. This large expanse of basalt is considered a single entity because there are no major structural or stratigraphic hydrologic barriers within it, and no major surface drainage divides within it. The northern part of the area is crossed by numerous NW-SE to WNW-ESE trending normal faults. The central portion of the area is traversed by the E-W trending Middle Fork syncline. The area is drained primarily by the North Fork of the John Day River and its tributaries including the Middle Fork. A small portion (approximately 70 square miles) of the western edge of the area is drained by tributaries of the main stem of the John Day River. The north and south portions of the area are fairly flat, while the central portion is quite dissected by the surface drainage.

Figure 14 Locaton of the North Fork - Middle Fork Basalt Aquifer Unit

Storage Estimates

Static water levels measured in 43 wells throughout the area range from 0 to 625 feet below ground level, with the median 39 feet. Static water levels are generally shallower in the northern portion of the area, and deeper in the southern part. Using the 39 foot static water level to represent the whole area, a 461 foot saturated column in the upper 500 feet of basalt is indicated. Estimates of the amount of ground water in storage for this area are presented in Table 4.

TABLE 4

Estimated acre-feet of ground water storage for the North Fork-Middle Fork Basalt Area.

Area = 1450 square miles, 928,000 acres.

| Specific Yield | Storage in Acre-feet 0-500 ft. | 500-1000 ft. |
|---|---|---|
| 0.5% | 2,139,040 | 2,320,000 |
| *1.0% | 4,278,080 | 4,640,000 |
| 2.0% | 8,556,160 | 9,280,000 |
| | saturated thickness = 461 ft. | saturated thickness = 500 ft. |

* Most reasonable estimate.

Fox Basin Basalt Area

Aquifer Unit Description

The Fox Basin Basalt Area comprises 153 square miles including Fox Valley and much of the surrounding highlands (Figure 15). A 36 square mile area in the central part of this basalt mass is occupied by a thickness of Quaternary and Tertiary alluvium and volcanic sediments including tuffs, sandstone and fine gravel. Brown and Thayer (1966) suggest the volcanic

sediments are interbedded with the Columbia River Basalt; and drillers logs substantiate this.

Fox Basin is a synclinal graben-like structure bounded on the northeast by the Long Creek anticline and associated faults, on the south by the Black Butte anticline and associated faults, and on the west by exposures of the underlying John Day Formation. The area is drained primarily by Fox Creek which runs westerly through the central part of the basin and into Cottonwood Creek. A small portion of the basalt area to the northwest is drained to the north by Deer Creek.

Figure 15 Location of the Fox Basin Basalt Aquifer Unit

Storage Estimates

Topographic relief on the basalt in the Fox Basin area is generally less

than 1000 feet. The geologic map by Brown and Thayer (1966) indicates a thickness of approximately 1000 feet of basalt at Hamilton Mountain, and cross sections indicate greater than 2000 feet of basalt toward the center of Fox Valley. Brown and Thayer show the thickness of the sediments in the central part of the valley to vary from a few hundred to over 1000 feet. Well logs indicate that sediments occur to depths of at least 475 feet. For the purposes of this report the sediments are conservatively considered only to be 500 feet thick. Specific yields of 0.5, 1, and 2 percent are used for storage estimates for the basalts. Storage estimates for the sediments are presented in a later section. Static water levels in 35 wells in the western part of Fox Valley range from 0 to 52 feet, with the median about 10 feet. Storage estimates are presented in Table 5.

TABLE 5

Estimated acre-feet of ground water storage in the Fox Basin Basalt Area.

Area = 153 square miles

| Specific Yield | Storage in Acre-Feet 0-500 ft. | 500-1000 ft. |
|---|---|---|
| 0.5% | 183,456 | 244,800 |
| *1.0% | 366,912 | 489,600 |
| 2.0% | 733,824 | 979,200 |
| | saturated thickness = 490 ft. | saturated thickness = 500 ft. |

* Most reasonable estimate.

## Western John Day Valley Basalt Area

### Aquifer Unit Description

The Western John Day Valley Basalt Area comprises the mass of Columbia River Basalt along the John Day River north to the Black Butte Anticline, from the area of Mount Vernon west to Picture Gorge (Figure 16). The unit is hydrologically bounded on the north by the Black Butte Anticline

and associated faults, on the south by the John Day Fault, and the east and west by exposures of low permeability clarno and pre-Tertiary rock. In the John Day Valley, the basalt is locally covered by a veneer of clastic sediments. Many wells penetrate through the sediment cover and produce water from the basalt. The area is drained by numerous small tributaries to the John Day River, most of which have their origins within the area. The area is locally intensely faulted, especially the eastern part, with NW-SE to WNW-ESE trending faults.

Figure 16 Location of the John Day Valley Basalt Aquifer Units

Ground Water Storage Estimate

As least 1200 feet of relief occur in the Columbia River Basalt in the western John Day Valley. Brown and Thayer (1966) indicate up to 3000 feet of basalt in geologic cross sections. Static water levels in

fourteen wells range from 0 to 61 feet with the median 20 feet. Using this figure to represent the static water level throughout the area indicates a saturated thickness of 480 feet in the upper 500 feet of basalt. Estimates of the amount of ground water and storage are presented in Table 6.

TABLE 6

Estimated acre-feet of ground water storage in the Western John Day Valley basalt area.

Area = 170 square miles, 108,800 acres

| Specific Yield | Storage in Acre-feet 0-500 ft. | 500-1000 ft. |
|---|---|---|
| 0.5% | 261,120 | 272,000 |
| *1.0% | 522,240 | 544,000 |
| 2.0% | 1,044,480 | 1,088,000 |
| | saturated thickness = 480 ft. | saturated thickness = 500 ft. |

* Most reasonable estimate.

## Eastern John Day Valley Basalt Area

### Aquifer Unit Description

The Eastern John Day Valley Basalt Area includes the 105 square miles of Columbia River Basalt along the John Day River between Prairie City and John Day, north to the Dixie Anticline (Figure 16). The basalt also probably extends south of the river beneath the Prairie City bench. The aquifer unit is hydrologically bounded on the south by the John Day fault, on the north and east by the Dixie anticline and by exposures of pre-basalt Clarno Formation, and on the west by faulting and exposures of pre-basalt rock. The surface drainage is by small tributaries to the John Day, many of which have their head waters a few miles above the basalt in the Clarno Formation.

Storage Estimates

Geologic maps show 800 to 1200 feet of basalt exposed in canyon walls, in this area. Brown and Thayer (1966) report a thickness of over 3000 feet for structurally and stratigraphically similar basalts west of Mount Vernon. For storage estimates in this report, the basalts are considered to be greater than 1000 feet thick. Insufficient well data is available to assess the saturated thickness, so a value of 400 feet is arbitrarily assigned to the upper 500 feet of basalt. Estimates of ground water and storage are presented in Table 7.

TABLE 7

Estimated acre-feet of ground water in the Eastern John Day Valley basalt area.

Area = 105 square miles, 67,200 acres

| Specific Yield | Storage in Acre-feet 0-500 ft. | 500-1000 ft. |
|---|---|---|
| 0.5% | 134,400 | 168,000 |
| *1.0% | 268,800 | 336,000 |
| 2.0% | 537,600 | 672,000 |
| | saturated thickness = 400 ft. | saturated thickness = 500 ft. |

* Most reasonable estimate.

Additional Basalt Areas

In addition to the six basalt areas already discussed, there are three more large areas of Columbia River Basalt in the John Day Basin (Figure 17). Estimates of ground water and storage are not presented for these areas, however, due either to insufficient well data to determine saturated thickness, or evidence that the ground water present is not readily usable due to depth or terrain.

Rudio Mountain Basalt Area

The Rudio Mountain basalt area is a 94 square mile mass of basalt southeast of Kimberly and north of Dayville. It is an isolated mass surrounded almost entirely by the older John Day Formation. The basalt forms a large plateau which dips gently northward. Over 2000 feet of basalt are shown on the western edge of the mass by Brown and Thayer (1966). The area includes no through going surface streams.

Figure 17 Locations of the (A) Rudio Mountain, (B) Picture Gorge-Sutton Mountain, and (C) South Fork Basalt Aquifer Units

Reports are available for three water wells drilled in the Rudio Mountain basalt mass. Two of the wells (325 and 350 feet deep) are reportedly dry. The third well, which is 466 feet deep, air tested at 6 gpm with

450 feet of drawdown, and a static water level of 110 feet. Ground water estimates are not presented for the Rudio Mountain basalt area because of the depth required to obtain usable water, the very low recharge potentialdue to hydrologic isolation, and the low probability of development due to remoteness of the area.

Picture Gorge-Sutton Mountain Basalt Area

The Picture Gorge-Sutton Mountain basalt mass comprises a 331 square mile arcuate shaped area which includes all of the basalt west of the John Day River from Picture Gorge to Spray, and on both sides of the river from Spray to Service Creek, and from Service Creek west to Sutton Mountain. This mass is largely isolated, and in most places the base and underlying John Day Formation are exposed. The area includes numerous small drainages which flow directly into the John Day River. In most of these drainages the upper reaches are restricted to the basalts, and the streams have dissected the basalts to create a rugged topography.

Water well reports are available for 10 wells producing from the basalt in this area. All of these wells are located lower in the valleys along the river, however, and do not provide any information on the hydrology of most of the basalt area, since most of the basalt occurs as highlands above the river. No ground water storage estimates are presented for this area due to this general lack of ground water data and the very low recharge potential due to the hydrologic isolation of the area.

South Fork Basalt Area

The South Fork basalt area includes 327 square miles drained by the South Fork of the John Day River, Cottonwood Creek and Rock Creek. The basalt in this area is probably quite thick. Greater than 1500 feet of relief occur within the basalt and Brown and Thayer (1966) indicate greater than 3000 feet of basalt in cross sections. No well data is available for the area, hence estimates of ground water storage are not presented. This is not to imply, however, that the area is without ground water potential, as significant amounts of ground water are probably stored in the basalt.

Topographic maps indicate springs are fairly common in the area often 1000 feet or more above the river level.

## Volcanic Sediments in Fox Basin

In the central portion of Fox Basin there is a 36 square mile exposure of Quaternary and Tertiary alluvium and upper-Miocure volcanic sediments. Published reports and lithologic information on water well reports indicate the sediments are primarily tuff, sandstone, and fine gravel with local interbedded then basalt flows.

The geometry of this mass of sediment and static water level information is discussed in detail in the previous section dealing with the basalt in Fox Basin. The thickness of the sediment is conservatively considered to be 500 feet, and the saturated thickness is estimated to be 490 feet. Information presented by Johnson (1967), indicates a probable specific yield of between two and ten percent. Storage estimates are presented in Table 8.

TABLE 8

Estimated acre-feet of ground water storage in volcanic sediments and associated alluvium in Fox Basin.

Area = 36 square miles; 23,040 acres.

| Specific Yield | Acre-feet Storage |
|---|---|
| 2.5% | 282,240 |
| 5% | 564,480 |
| 10% | 1,128,960 |

saturated thickness = 490 feet

## Rattlesnake Formation

The Rattlesnake Formation in the John Day Basin comprises a thickness of

primarily sand and gravel with one major welded tuff unit. It occurs in an E-W trending structural low along the upper John Day River valley from Prairie City to Picture Gorge, and west past Picture Gorge in the area of Mount and Rock Creeks (Figure 9). In addition, a small area of Rattlesnake Formation also occurs in the Murderers Creek area. The Rattlesnake Formation consists of ancient alluvial sand deposits and occurs in the John Day valley adjacent to highlands. Ground water flow is from the highlands to the rivers. The Rattlesnake Formation in the John Day Basin comprises a few major isolated masses which are considered distinct aquifer units and each is discussed separately. The hydrologic boundary conditions between the Rattlesnake Formation and underlying units is variable and complex. The Rattlesnake Formation unconformably overlies the Mascall Formation, the Columbia River Basalt, the Clarno Formation, and pre-Tertiary units. For the purposes of this report it is considered to be hydrologically isolated from the underlying units. Along the river, the Rattlesnake Formation is locally overlain by Quaternary Alluvium. The Quaternary Alluvium occurs along the lowest part of the Rattlesnake surface, and ground water is probably discharging from the Rattlesnake Formation to the Quaternary Alluvium.

The Rattlesnake Formation seems to behave as a series of thin semi-confined aquifers which probably correspond to layers of coarser, more sorted material with less clay which is probably clast supported. Water well reports indicate that the final static water level in wells is usually higher than the level of water first encountered. At least one flowing artesian well is known (T13S, R32E, Section 22). Springs are not uncommon in the Rattlesnake Formation.

Thickness information on the Rattlesnake Formation is available from topographic and geologic maps, and from lithologic descriptions on water well reports. Topographic maps commonly show 300 to 750 feet of relief on the Rattlesnake Formation, and locally as much as 1000 feet. Brown and Thayer (1966) indicate a thickness ranging from 300 to 600 feet in geologic cross sections. Lithologic descriptions by drillers on many water well reports do not clearly differentiate the Rattlesnake Formation

from the largely sedimentary Clarno Formation or pre-Tertiary units which often underlie it, however, numerous water well reports clearly indicate 200 to 300 feet of Rattlesnake Formation sands and gravels. Specific yield values used in storage estimates are those determined by the California Water Resources Board (1956) and presented by Johnson (1967) for material of similar lithology to the Rattlesnake Formation. Storage estimates are presented assuming specific yields of 2, 5, and 7 percent.

Descriptions, saturated thickness determinations, and storage estimates are presented in the following sections for each of the major masses of Rattlesnake Formation in the John Day Basin.

Rattlesnake Formation East of Canyon Creek

The Rattlesnake Formation east of Canyon Creek comprises about 82 square miles, 61 square miles of which are exposed, and 21 square miles which are covered by a veneer of Quaternary Alluvium. This area includes the Prairie City Bench.

The Rattlesnake Formation is probably at least 300 to 400 feet thick throughout much of this area. The deposit thins near the margins. Static water levels in 45 wells range from 3 1/2 to 200 feet, with the median about 46 feet. Static water levels tend to be deeper at the higher elevations and shallower near the river. Storage estimates are presented in Table 9 for this area, assuming saturated thicknesses of 250, 300, and 350 feet.

Rattlesnake Formation between Canyon Creek and Fields Creek

The Rattlesnake Formation between Canyon Creek and Fields Creek comprises a 55 square mile area, including 11 square miles under a veneer of Quaternary Alluvium. In this area, the Rattlesnake Formation extends 2 to 3 miles north and south of either side of the John Day River (Figure 9).

TABLE 9

Estimated acre-feet of ground water storage in the Rattlesnake Formation east of Canyon Creek including the Prairie City Bench.

Area = 82 square miles, 52,480 acres.

| Specific Yield | Saturated thickness 250 ft. | 300 ft. | 350 ft. |
|---|---|---|---|
| 3% | 393,600 | 472,320 | 551,040 |
| 5% | 656,000 | *787,200 | 918,400 |
| 7% | 918,400 | 1,102,080 | 1,285,760 |

* Most reasonable estimate.

Brown and Thayer (1966) indicate thickness of Rattlesnake Formation of 300 to 600 feet in cross sections. The average thickness is probably between 300 and 400 feet. Numerous wells in the area penetrate 200 to 300 feet of Rattlesnake Formation. Static water levels in 39 wells range from 0 to 365 feet, with the median 26 feet. The probable saturated thickness is somewhere between 250 and 350 feet. Storage estimates for the Rattlesnake Formation in this area are presented in Table 10.

TABLE 10

Estimated acre-feet of ground water storage in the Rattlesnake Formation between Canyon Creek and Field Creek.

Area = 55 square miles, 35,200 acres.

| Specific Yield | Saturated thickness 250 ft. | 300 ft. | 350 ft. |
|---|---|---|---|
| 3% | 264,000 | 316,800 | 369,600 |
| 5% | 440,000 | *528,000 | 616,000 |
| 7% | 616,000 | 739,200 | 862,400 |

* Most reasonable estimate.

Additional Areas of Rattlesnake Formation

There are some additional fairly large areas of Rattlesnake Formation for

which no well data are available, yet which bear mentioning (Figure 9). Any storage estimates presented for these areas are highly speculative.

Along Murderers Creek, south of the Aldrich Mountains, there is an 8 square mile occurrence of Rattlesnake Formation. Brown and Thayer (1966) indicate a probable thickness of less than 200 feet. There are a few springs in the area issuing from the Rattlesnake gravels, the location of which may be controlled by the presence of the welded tuff unit. Storage estimates for this mass of Rattlesnake Formation, assuming a saturated thickness of 100 feet, are presented in Table 11.

TABLE 11

Estimated acre-feet of ground water storage in the Rattlesnake Formation along Murderers Creek.

Area = 8.2 square miles, 5,248 acres.

| Specific Yield | Saturated thickness = 100 ft. |
|---|---|
| 3% | 15,744 |
| 5% | *26,240 |
| 7% | 36,736 |

* Most reasonable estimate.

West of Dayville, in the area of Rock Creek, Pine Hollow Creek, and Mountain Creek, there occurs a 36 square mile area of Rattlesnake Formation. This area is close to where Enlows (1976) measured a 628-foot section of Rattlesnake Formation. There is no data available to constrain the saturated thickness, hence storage estimates are not presented.

## Quaternary Alluvium

The Quaternary Alluvium is one of the most intensely used and productive aquifer units in the John Day Basin. This is due to its relatively good hydrologic characteristics combined with the concentration of population

and agriculture along the river valleys. Estimates of ground water storage are presented for the major alluvial deposits along the John Day River and its major tributaries. The areas considered include the entire John Day valley upstream from Picture Gorge, and areas of greater than one-half of a square mile downstream from Picture Gorge (Figure 18).

Figure 18 Location of the Quaternary Alluvium deposits used in storage estimates

The estimates presented account only for the major alluvial deposits where the river valley is wide, and does not consider water stored in alluvium along narrow parts of the channel or in flood plain deposits of minor tributaries. These latter areas may in fact present locally important

aquifers, however, the lack of data and the time limitations present make assessing these areas beyond the scope of this report. Because of the large amount of data available, and differences in the geometry of the alluvium, the area upstream of Picture Gorge is considered separately from the area downstream.

An important consideration when managing the alluvial aquifers is the high degree of hydrologic communication between the ground water and surface water. Alluvial aquifers adjacent to river channels in many cases receive almost instantaneous recharge from channel leakage when water tables fall below stream level. Therefore, the water removed from the subsurface essentially is removed from the surface stream or river. Similarly, when there is a ground water gradient toward the stream, removal of ground water via wells removes water that would otherwise have discharged to become surface water. This indirect interference also reduces surface flows. The management of the ground water and the surface water in these cases cannot be considered separately.

Quaternary Alluvium Upstream of Picture Gorge

There is approximately 45 square miles of alluvium and flood plain deposits in the John Day valley upstream of Picture Gorge. This also includes significant deposits in the valleys of Strawberry Creek, Indian Creek, and Pine Creek near Prairie City. The thickness of the alluvium is quite variable and is generally thicker in the central portions of the valley and thinner on the edges. The thickness of the alluvium upstream of Picture Gorge was determined from 86 water well reports. Fifty-two of these wells were completed in the alluvium, and 34 penetrated through the alluvium into the underlying bedrock. The thickness indicated for wells completed in the alluvium ranges from 40 to 400 feet, and the median is about 99 feet. The thickness indicated for wells which penetrated through the alluvium into bedrock ranges from 22 to 330 feet with a median of 70 feet. One would expect a thicker section of Quaternary Alluvium for the wells which penetrated through it into the bedrock, yet the reverse is indicated. This is because most of the wells which penetrated through the

alluvium were drilled near the edges of the valley. Wells drilled in the more central portions of the valley where the alluvium is thicker apparently encountered adequate water before penetrating into underlying strata.

The median thickness of 99 feet for the alluvium must be considered an absolute minimum, because this is only the thickness encountered and not the total thickness. Well reports indicate thicknesses of alluvium in excess of 200 feet are not uncommon along the main stem of the John Day River. Static water levels reported for 68 wells producing from the alluvium range from 0 to 180 feet, with the median 16 feet.

Storage Estimates

Storage estimates are presented for the alluvium along the main stem of the John Day River upstream of Picture Gorge assuming saturated thicknesses of 83 feet (the 99-foot alluvial thickness minus the 16-foot static water level), 125 feet, and 165 feet. The specific yield values suggested for unconsolidated sand and gravel deposits range from 15 to 25 percent (Johnson, 1967; Cohen, 1963). Estimates of storage are presented using specific yield values of 15, 20, and 25 percent in Table 12.

Quaternary Alluvium Downstream from Picture Gorge

Approximately 21 square miles of flood plain alluvial deposits occur along the John Day River between Picture Gorge and Clarno, and along the North Fork from Monument to Kimberly. These deposits occur intermittently and are separated by areas where the channel is incised into the Columbia River basalts or is otherwise narrow.

All flood plain alluvial deposits with over approximately a one-half square mile area are included in the storage estimates presented. Areas used include the Kimberly area, the stretch along the North Fork from Kimberly to and including the Monument area, the areas around Spray, Twickenham, and intermittent areas from Twickenham to Clarno, and the

Clarno area. Downstream from Clarno, the river is deeply incised into the Columbia River Plateau, and no significant flood plain alluvial deposits are present.

TABLE 12

Estimated acre-feet of ground water storage in Quaternary Alluvium in the John Day River Valley upstream of Picture Gorge.

Area = 45 square miles, 28,800 acres.

| Specific Yield | Saturated thickness 83 ft. | 125 ft. | 165 ft. |
|---|---|---|---|
| 15% | 358,560 | 540,000 | 712,800 |
| 20% | 478,080 | *720,000 | 950,400 |
| 25% | 597,600 | 900,000 | 1,188,000 |

* Most reasonable estimate.

The thickness of the unconsolidated alluvium of these areas is not easily determined from drillers descriptions on water well reports because of the often clastic or sedimentary nature of the underlying Clarno and John Day Formations. The base of the alluvium on top of John Day Formation was determined to be were descriptions of sand, gravel and brown clay gave way to blue clay, green clay or gray clay, and sand and gravel became subordinate. Clarno Formation occurring beneath the Quaternary alluvium is typically described as brown conglomerate or lava. Water well reports to which the base of the Quaternary Alluvium could not be determined with a reasonable degree of certainty, or in which the description on the log was not clear enough to determine if the material was Quaternary alluvium at all, were not used for thickness determinations in this report.

Water well reports for 52 wells producing from alluvium were selected along the river. The thickness of alluvium indicated ranges from 12 to 180 feet with the median about 40 feet. There was no significant difference between the thickness of alluvium in wells which were

completed in the alluvium and wells which penetrated through it to the bedrock. Wells completed in the alluvium had static water levels ranging from 6 to 65 feet with the median approximately 15 feet, and wells which were completed in bedrock below the alluvium had static water levels ranging from 5 to 245 feet, with the median 26 feet. It could be that these deeper wells encountered lower head aquifers in the bedrock.

## Storage Estimates

Storage estimates are presented for the alluvial channel deposits downstream from Picture Gorge based on saturated thicknesses of 25 feet (the 40-foot median thickness of alluvium minus the 15-foot median static water level), 30 feet, and 40 feet. The 25-foot thickness is considered conservative. Specific yield values suggested for unconsolidated sand and gravel deposits range from 15 to 25 percent (Johnson, 1967; Cohen, 1963). Estimates of ground water storage are presented in Table 13.

TABLE 13

Estimated acre-feet of ground water storage in Quaternary Alluvium in the John Day River Valley downstream from Picture Gorge.

Area = 21 square miles, 13,440 acres.

| Specific Yield | Saturated thickness 25 ft. | 30 ft. | 40 ft. |
|---|---|---|---|
| 15% | 50,400 | 60,480 | 80,640 |
| 20% | 67,200 | *80,640 | 107,520 |
| 25% | 84,000 | 100,800 | 134,400 |

* Most reasonable estimate.

## GROUND WATER RECHARGE

Every year a certain amount of water enters and leaves the ground water system. In an undisturbed system at equilibrium the average amounts of water entering and leaving the system anually are the same. The volume of water entering the system annually is the recharge. Areas where water enters the ground water system are called recharge areas, and areas where water returns to the surface are called discharge areas. Recharge areas are typically areas of higher elevation with high precipitation. A precipitation map of the John Day Basin is presented in Figure 19. Discharge areas are typically the lower elevations, often stream or river valleys.

The total volume of water contained in the ground water system at a given time is the storage. When the amount of recharge is not equal to the discharge, the difference is reflected as a change in storage. Changes in storage manifest as changes in the elevation of the water table, or for confined aquifers, changes in the elevation of the potentiometric surface. When water is pumped from an aquifer, that removal either reduces the amount of discharge, removes water from storage, or both. If a large enough amount of water is pumped from an aquifer on a continual basis, it will be reflected in a lowering of the water table or pressure head, and a decrease in natural discharge. Lowering the water table can in some cases increase recharge by a limited amount by allowing normally rejected recharge water into the system. A decrease in natural discharge may manifest as noticeably lower streamflows and lowering of water levels in lakes and marshes. If the amount of water pumped exceeds the recharge rate, water is being continually removed from storage and the static water level will drop. Unless the withdrawals are modified, the aquifer will eventually be depleted. There is a sustainable rate at which ground water can be removed by pumping which an aquifer can sustain without causing significant adverse effect on the static water level and the natural discharge. However, ground water systems are dynamic, and even after moderate initial development there will be declines which level off as they move toward an equilibrium between supply and demand. Estimates

Figure 19. AVERAGE ANNUAL PRECIPITATION IN THE JOHN DAY BASIN

of the annual recharge an area receives can provide information about the upper limit of sustainable yield. However, recharge is one of the most difficult quantities to determine in hydrology. The problem is further complicated in the John Day Basin by the large area, the complexities of the geology, and the diverse elevation, vegetation, and microclimates.

It is important to point out that the amount of recharge an area receives cannot be totally appropriated by ground water users. If the total amount of annual recharge were removed from the ground water system every year, the natural discharge from the system would cease. It is this natural ground water discharge which is the main contributor to streamflow during the dry summer and fall months. Without this ground water discharge, streams would likely dry up during the time when the demand on surface water is the greatest. Clearly, there is a dynamic balance between recharge, ground water use, and surface water requirements which must be maintained.

There are numerous methods which have been used to estimate recharge. Not all of them are suitable for every area, and they all have had variable success rates. Commonly used methods include assessing the water balance or total hydrologic budget, assessing the mass discharge of an aquifer from flow rates calculated using aquifer characteristics and gradient data, calculating the change in storage on an annual basis from minimum and maximum saturated thickness data, and calculating the annual ground water discharge to surface streams by hydrograph analysis and baseflow separation.

The first two methods mentioned are not practical for use in this study for numerous reasons. The water balance method requires precise knowledge of precipitation, runoff, and evapotranspiration. Insufficient data is available to accurately calculate evapotranspiration over such a large area, and the variations of elevation, microclimate, and vegetation limit the usefulness in empirical methods. Mass discharge calculations require accurate knowledge of aquifer characteristics as well as accurate knowledge of the elevation of the contours of the water table or the

potentiometric surface. Unfortunately, well location data is not accurate enough to reliably contour the water table, and knowledge of aquifer characteristics is probably not sufficiently precise to provide reliable results.

Some observation well data are available for the John Day Basin. These data is some cases indicate the annual fluctuation in the static water level which is considered to approximate the annual variation in saturated thickness from which a change in storage can be calculated. This change in storage is taken to be an estimate of minimum recharge.

Stream hydrograph data and other streamflow statistics are available for many gaging stations throughout the John Day Basin from U.S.G.S. records. This information can be used to estimate baseflow, which indicates the ground water discharge. Estimations of ground water recharge for various parts of the John Day Basin are presented in the following sections based on these methods.

Recharge Estimates from Stream Hydrographs

A stream hydrograph is a plot of the discharge of a stream as a function of time. Various components of streamflow can be recognized on a hydrograph, including the contribution from individual storm events, runoff due to snowmelt, and the discharge of ground water. Hydrograph analysis is discussed by Fetter (1980), Chow (1964), Maxie (1964), and Freeze and Cherry (1979).

The ground water contribution to streamflow is called baseflow. It is the baseflow which sustains streamflow during the dry summer and fall months where there is no contribution from precipitation or snowmelt.

During the dry season streamflow gradually declines as the stored ground water discharging to the stream is slowly depleted. This slow decline in stream discharge is known as the baseflow recession. The relationship between baseflow and ground water is discussed by Hall (1968), Riggs

(1963), Meyboom (1961), and Fetter (1980). Ideally, baseflow recessions follow an exponential decay curve which plotted on semi-logarithmic paper defines a straight line. Analyzing the baseflow recession curve can provide information on the nature of the aquifer and the amount of ground water storage, including the total potential discharge to a stream.

Baseflow recession analysis however is not without its caveats. There are various factors which can influence streamflow which are not easily accounted for when separating out the various hydrograph components including the effects of evapotranspiration, interflow, bank storage, and streambed storage. In addition, stream hydrographs do not reflect subflow, or ground water flow discharging outside the basin. Another problem, especially in large basins with geologically complex ground water systems, is non-linearity of basin response. Most base flow recession analysis techniques assume a linear basin response. There are multiple factors which may cause a basin response to be non-linear, including the presence of multiple aquifers contributing to baseflow. The effects of evapotranspiration by riparian vegetation on streamflow (and consequently on baseflow estimates and streamflow statistics) is unclear. It seems logical to assume that streamflow would be reduced by the evapotranspiration, however some research indicates that during dryer months streamflow is augmented by lush riparian vegetation (Winegar 1977, 1982).

When analyzing hydrographs to determine baseflow it is necessary to be aware of these short comings to the method. As long as one considers the limitations and properly qualifies the results, analysis of baseflow recessions can provide valuable information on ground water discharge from a basin.

Method Used for this Report

The method used to estimate ground water recharge from baseflow recession analysis for this study is that presented by Meyboom (1961) and Fetter (1980). The general theory and algorithims used in this method are

presented in Appendix II. The baseflow recession curves were determined from hydrographs for a number of consecutive years for several stations throughout the basin. The total potential ground water discharge at the beginning of each recession was calculated. This is the amount of water which would be released to the stream if the baseflow recession were allowed to continue to the point where a streamflow ceased. Baseflow recessions seldom reach zero flow in major streams in the John Day Basin before the wet season arrives and recharge resumes. The remaining potential discharge at the end of the baseflow recession was then calculated. The difference between the remaining potential discharge at the end of one baseflow recession, and the total potential discharge at the beginning of the following baseflow recession represents the increase in ground water storage which has occured between recessions. This assumes that ground water recharge is occuring before and after the recessions. The increase in ground water storage does not represent the total volume of water moving through the system each year, since a certain amount of water is moving through and discharging from the system even while storage is increasing. The change in storage does however represent a minimum amount of water which must have been recharged to the system. Throughout this section on recharge estimation from hydrograph analysis the reader must be aware that these numbers are estimates of the annual change in storage, which is a minimum estimate of recharge.

For this report, hydrographs were selected from gaging stations which represent major portions of the basin or are representative of a particular geologic terrane. In selecting hydrographs, a span of years was selected where the precipitation was close to the mean. The years 1949 to 1953 were chosen for this study, as this period of record was available for most stations. The following nine stations were selected for analysis:

1. John Day River at McDonald Ferry
2. Rock Creek above Whyte Park near Condon
3. John Day River at Service Creek
4. North Fork of the John Day River at Monument
5. North Fork of the John Day River near Dale
6. Camas Creek near Ukiah

7. John Day River at Picture Gorge
8. Fox Creek at the Gorge near Fox
9. John Day River at John Day

An index map of these gaging stations is presented in Figure 20. Of the nine stations which were selected, four were unusable due to the effects of diversions for irrigation. These four are all along the main stem of the John Day River. This is rather unfortunate because these represent areas of relatively high population and ground water use.

Figure 20 Gaging stations in the John Day Basin used in this report

Hydrograph analysis and recharge estimates based on change in storage are discussed for the remaining five stations in the following sections. The tables for each station in the following sections present upper and lower values for each entry (marked U and L). These values correspond to the upper and lower limits of the probable baseflow recession lines. The range of probable lines was selected for each hydrograph in order to bracket the uncertainty due to the effects of evapotranspiration, and possible minor diversions.

Camas Creek near Ukiah

The gaging station on Camas Creek near Ukiah is at an elevation of 3589 feet and represents a drainage area of 121 square miles. The area is underlain almost entirely by Columbia River Basalt, with minor Quaternary alluvium and volcanic sediment. This area may be representative of much of the area of Columbia River Basalt in the drainage of the North Fork of the John Day River south of the Blue Mountain Anticline. Precipitation averages about 15 to 25 inches annually. Results of the hydrograph analyses are presented in Table 14. Recharge estimates vary from 1169 to 2274 acre-feet, which corresponds to 0.18 to 0.35 inches over the 121 square mile area.

TABLE 14

Hydrograph Analysis, Camas Creek near Ukiah
Drainage Area = 121 square miles.

| Water Year | | Length of Baseflow Recession (days) | Total Potential Discharge (acre-ft) | Remaining Potential Discharge (acre-ft) | Discharge During Recession (acre-ft) | Discharge During Recession (in.) | | Change in Storage (acre-ft) | Change in Storage (in.) |
|---|---|---|---|---|---|---|---|---|---|
| 49/50 | U | 88 | 1888 | 471 | 1417 | .22 | | | |
| | L | 88 | 662 | 12 | 650 | .10 | | | |
| | | | | | | | U | 1154 | 0.18 |
| | | | | | | | L | 688 | 0.11 |
| 50/51 | U | 66 | 1625 | 722 | 903 | .14 | | | |
| | L | 66 | 700 | 106 | 594 | .09 | | | |
| | | | | | | | U | 2881 | 0.45 |
| | | | | | | | L | 1683 | 0.26 |
| 51/52 | U | 118 | 3602 | 267 | 3335 | .52 | | | |
| | L | 118 | 1789 | 10 | 1779 | .28 | | | |
| | | | | | | | U | 2789 | 0.43 |
| | | | | | | | L | 1136 | 0.18 |
| 52/53 | U | 129 | 3056 | 521 | 2535 | .39 | | | |
| | L | 129 | 1145 | 11 | 1134 | .18 | | | |
| | | | | Average Change in Storage (Approximation of Minimum Recharge) | | | U | 2274 | 0.35 |
| | | | | | | | L | 1169 | 0.18 |

North Fork John Day River near Dale

The gaging station on the North Fork of the John Day River near Dale is at an elevation of 2776 feet and represents a drainage area of 525 square miles. The area is almost entirely pre-Tertiary marine rock and intrusives, with very minor John Day and Clarno Formation material. This area is probably representative of much of the pre-Tertiary sequence in the Blue Mountains in the eastern part of the basin. Annual precipitation ranges from 20 to 40 inches in the area. Results of the hydrograph analyses are presented in Table 15. Recharge estimates range from 7262 to 14,011 acre-feet, corresponding to 0.26 to 0.50 inches over the 525 square mile area.

TABLE 15

Hydrograph Analysis, North Fork John Day River near Dale
Drainage Area = 525 square miles.

| Water Year | | Length of Baseflow Recession (days) | Total Potential Discharge (acre-ft) | Remaining Potential Discharge (acre-ft) | Discharge During Recession (acre-ft) | Discharge During Recession (in.) | | Change in Storage (acre-ft) | Change in Storage (in.) |
|---|---|---|---|---|---|---|---|---|---|
| 49/50 | U | 73 | 19,832 | 8434 | 11,398 | 0.41 | | | |
| | L | 73 | 8730 | 1251 | 7480 | 0.27 | | | |
| | | | | | | | U | 9998 | 0.36 |
| | | | | | | | L | 7608 | 0.27 |
| 50/51 | U | 62 | 18,432 | 6501 | 11,931 | 0.43 | | | |
| | L | 62 | 8859 | 2608 | 6251 | 0.22 | | | |
| | | | | | | | U | 13,627 | 0.49 |
| | | | | | | | L | 5282 | 0.19 |
| 51/52 | U | 71 | 20,129 | 8933 | 11,199 | 0.40 | | | |
| | L | 71 | 7890 | 9993 | 6898 | 0.25 | | | |
| | | | | | | | U | 18,409 | 0.66 |
| | | | | | | | L | 8896 | 0.32 |
| 52/53 | U | 105 | 27,342 | 11,295 | 16,047 | 0.57 | | | |
| | L | 105 | 9888 | 857 | 9031 | 0.32 | | | |
| | | | | Average Change in Storage (Approximation of Minimum Recharge) | | | U | 14,011 | 0.50 |
| | | | | | | | L | 7262 | 0.26 |

North Fork John Day River at Monument

The gaging station on the North Fork of the John Day River at Monument is at an elevation of 1960 feet and represents a drainage area of 2520 square miles. This geologically diverse area represents about 31 percent of the total basin, and includes large areas of Columbia River Basalt as well as pre-Tertiary rock in the Blue Mountains. Precipitation ranges from 15 to 25 inches over much of the area, and up to 40 inches in the mountains. Results of the hydrograph analyses are presented in Table 16. Estimates of recharge range from 16,445 to 29,883 acre-feet annually, which corresponds to 0.12 to 0.22 inches over the 2520 square mile area.

TABLE 16

Hydrograph Analysis, North Fork of the John Day River at Monument
Drainage Area = 2520 square miles.

| Water Year | | Length of Baseflow Recession (days) | Total Potential Discharge (acre-ft) | Remaining Potential Discharge (acre-ft) | Discharge During Recession (acre-ft) | Discharge During Recession (in.) | | Change in Storage (acre-ft) | Change in Storage (in.) |
|---|---|---|---|---|---|---|---|---|---|
| 49/50 | U | 83 | 45,225 | 14,610 | 30,615 | .23 | | | |
| | L | 83 | 18,315 | 1126 | 17,189 | .13 | | | |
| | | | | | | | U | 17,392 | 0.13 |
| | | | | | | | L | 19,905 | 0.15 |
| 50/51 | U | 63 | 32,002 | 11,816 | 20,186 | .15 | | | |
| | L | 63 | 21,031 | 4614 | 16,416 | .12 | | | |
| | | | | | | | U | 26,446 | 0.20 |
| | | | | | | | L | 10,239 | 0.08 |
| 51/52 | U | 77 | 38,269 | 15,032 | 23,237 | .17 | | | |
| | L | 77 | 14,853 | 1336 | 13,517 | .10 | | | |
| | | | | | | | U | 45,661 | 0.34 |
| | | | | | | | L | 19,192 | 0.14 |
| 52/53 | U | 109 | 60,698 | 20,826 | 39,871 | .30 | | | |
| | L | 109 | 20,528 | 868 | 19,660 | .15 | | | |
| Average Change in Storage (Approximation of Minimum Recharge) | | | | | | | U | 29,833 | 0.22 |
| | | | | | | | L | 16,445 | 0.12 |

Fox Creek at the Gorge near Fox

The gaging station on Fox Creek at the Gorge is at an elevation of 4240 feet, and represents a drainage area of 90.2 square miles. The Fox Basin area is primarily Columbia River Basalt with a 36 square mile area of Quaternary Alluvium and volcanic sediments in the central portion. Precipitation averages about 10 inches per year. It is probably representative of much of the Columbia River Basalt terrain along John Day River from Dayville to Prairie City, north to the Long Creek area. Results of the hydrograph analyses are presented in Table 17. Recharge estimates range from 479 to 1132 acre-feet, which corresponds to 0.10 to 0.24 inches over the 90.2 square mile area. This seems like a relatively high amount of recharge for the amount of precipitation this area

TABLE 17

Hydrograph Analysis, Fox Creek at Gorge near Fox
Drainage Area = 90.2 square miles.

| Water Year | | Length of Baseflow Recession (days) | Total Potential Discharge (acre-ft) | Remaining Potential Discharge (acre-ft) | Discharge During Recession (acre-ft) | Discharge During Recession (in.) | | Change in Storage (acre-ft) | Change in Storage (in.) |
|---|---|---|---|---|---|---|---|---|---|
| 49/50 | U | 171 | 1901 | 6 | 1894 | 0.39 | | | |
| | L | 171 | 666 | 0 | 666 | 0.14 | | | |
| | | | | | | | U | 515 | 0.11 |
| | | | | | | | L | 220 | 0.05 |
| 50/51 | U | 134 | 521 | 0 | 521 | 0.11 | | | |
| | L | 134 | 220 | 0 | 220 | 0.05 | | | |
| | | | | | | | U | 1709 | 0.36 |
| | | | | | | | L | 737 | 0.15 |
| 51/52 | U | 158 | 1709 | 0 | 1709 | 0.36 | | | |
| | L | 158 | 737 | 0 | 737 | 0.15 | | | |
| | | | | | | | U | 1172 | 0.24 |
| | | | | | | | L | 480 | 0.10 |
| 52/53 | U | 184 | 1173 | 0 | 1173 | 0.24 | | | |
| | L | 184 | 480 | 0 | 480 | 0.10 | | | |
| Average Change in Storage (Approximation of Minimum Recharge) | | | | | | | U | 1132 | 0.24 |
| | | | | | | | L | 479 | 0.10 |

receives. This may be due to favorable recharge characteristics of the volcanic sediments and alluvium in the central part of the basin.

Rock Creek above Whyte Park near Condon

The last hydrograph analysis presented is for the gaging station on Rock Creek above Whyte Park near Condon, which is at an elevation of 1714 feet and represents a drainage of 297 square miles. Records were unavailable for the 1949 to 1953 period used for the rest of the stations, so a period from 1980 to 1982 was used. There is a certain amount of water which is pumped from Rock Creek and diverted into the Umatilla Basin, so results of this analysis are probably low. This drainage is almost entirely basalt terrain, with a very minor amount of the John Day and Clarno Formations in the extreme upper parts. This area is considered to be approximately representative of the basalt areas north of the Blue Mountain Anticline. Precipitation averages about 15 inches per year. The results of the hydrograph analyses are presented in Table 18. Data for only two years were usable, so confidence in the results is less than for the other stations analyzed. The recharge estimate ranges from 1160 to 2092 acre-feet, which corresponds to 0.07 to 0.13 inches over the 297 square mile area.

TABLE 18

Hydrograph Analysis, Rock Creek above Whyte Park
Drainage Area = 297 square miles.

| Water Year | | Length of Baseflow Recession (days) | Total Potential Discharge (acre-ft) | Remaining Potential Discharge (acre-ft) | Discharge During Recession (acre-ft) | Discharge During Recession (in.) | Change in Storage (acre-ft) | Change in Storage (in.) |
|---|---|---|---|---|---|---|---|---|
| 80/81 | U | 161 | 2831 | 293 | 2537 | 0.16 | | |
| | L | 161 | 1395 | 14 | 1381 | 0.09 | | |
| | | | | | | | U 2092 | 0.13 |
| | | | | | | | L 1160 | 0.07 |
| 81/82 | U | 124 | 2385 | 64 | 2321 | .15 | | |
| | L | 124 | 1174 | 1 | 1174 | .07 | | |

## Discussion of Hydrograph Analyses

These estimates of recharge are based on the annual change in storage, so must be considered estimates of minimum recharge. Certain aspects of the hydrograph analyses suggest that the results are reasonable. The estimates are within the expected range. There is a certain consistency to the results both from year to year within a drainage, and from one drainage to another regardless of size. Hydrographs from the higher elevation, forest and drainages indicated higher recharge than the lower elevation sparsely vegetated areas, as would be expected. The implications of the recharge estimates relative to ground water usage are discussed in a later section.

## Baseflow Approximations from Low Flow Statistics

Among the data available from the U.S. Geological Survey, are summaries of streamflow statistics for numerous stations throughout the John Day Basin. Included in the statistical summaries are the magnitude and probability of annual 1, 3, 7, 14, 30, 60, 120, and 183 day low flows for various gaging stations in the basin. The low flow represents the amount of flow which will probably not be exceeded for the specified period of time. For example, the seven day low flow represents the minimum flow rate which would probably not be exceeded during the seven days of lowest flow during a given year; the 120 day low flow is the minimum flow rate which would probably not be exceeded during the 120 days of lowest flow.

Lowest flow usually occurs during the dry summer and fall months when streamflow is largely due to base flow (ground water discharge). An estimation of mean baseflow (discharge) would approximate the recharge, since on the average recharge must equal discharge. The mean baseflow discharge rate will fall somewhere between the lowest flow discharge rates and the mean annual discharge. The longer duration low flows (60-120 day periods) are considered reasonable approximations of the mean baseflow, and if integrated over the entire year approximate annual recharge to that particular drainage area. A very similar method of

estimating recharge was used by Robison (1968). Robison estimated annual recharge by totaling the discharge of the three lowest months and multiplied that volume by four. The low flow discharge can be extrapolated over the entire year to approximate an annual ground water discharge. Since the low flow data represents a mean of several years to several tens of years, the ground water discharge calculated in this manner can be considered to equal the average recharge.

Recharge estimates are presented in Table 19, based on the 30, 60, 90, and 120 day low flows. The recharge in inches was calculated by dividing the volume of recharge by the drainage area. This method does not account for discharge lost to evapotranspiration, and therefore the estimates are considered conservative. However, of all the methods used to estimate recharge for this report, results from this method are considered to be the most reliable.

Recharge Estimates Based on Observation Well Data

Observation wells often exhibit a cyclical annual fluctuation in the static water level. This annual fluctuation represents the annual change in the staturated thickness, which is proportional to the volume of water recharged to the system during a given year. The fluctuation results from water levels declining as water is discharged from the system in the dry season, and rising as ground water is later recharged to the system. The volume of water represented by the increase in saturated thickness is the minimum amount of water which must have been recharged to the system.

There are a number of obvious problems with this method for estimating recharge. The volume defined by the difference in minimum and maximum saturated thickness in an aquifer is a complex three-dimensional geometric shape. To describe that volume from the single data point of one observation well is highly subjective at best. Static water levels can be affected by factors other than changes in the saturated thickness, including seasonal pumping effects, evapotranspiration, variations in the stage of nearby streams or lakes, and changes in atmospheric pressure.

TABLE 19

Estimated Recharge in Inches Based on Low Flow Statistics

| Station | Drainage Area ($mi^2$) | 30 day | 60 day | 90 day | 120 day |
|---|---|---|---|---|---|
| Strawberry Creek | 7 | 4.46 | 4.85 | 5.24 | 5.62 |
| John Day River at Prairie City | 231 | 1.53 | 1.88 | 2.29 | 2.82 |
| John Day River near John Day | 386 | 0.77 | 1.30 | 0.79 | 2.18 |
| John Day River at Picture Gorge | 1680 | 0.16 | 0.23 | 0.34 | 0.57 |
| Camas Creek near Lehman | 60.7 | 0.25 | 0.29 | 0.34 | 0.42 |
| Camas Creek near Ukiah | 121 | 0.40 | 0.48 | 0.55 | 0.65 |
| Mid. Fk. John Day River at Ritter | 515 | 0.53 | 0.63 | 0.76 | 0.90 |
| North Fk. John Day River near Dale | 525 | 1.22 | 1.34 | 1.50 | 1.65 |
| North Fk. John Day River at Monument | 2520 | 0.47 | 0.54 | 0.61 | 0.71 |
| John Day River at Service Creek | 5090 | 0.27 | 0.34 | 0.45 | 0.59 |
| John Day River at McDonald Ferry | 7580 | 0.20 | 0.26 | 0.32 | 0.42 |

It is important to remember that water is moving through and discharging from the system continually during both the increase and decrease in storage. Therefore the annual change in storage does not reflect the total volume of water which enters and leaves the system each year. However the annual increase in storage does represent the minimum amount of water which must have been recharged to the system for a given year.

Useful information can be gained from regression analysis of year-to-year variations in water levels and precipitation data. This method requires

careful selection and manipulation of the data and is beyond the scope of this investigation.

Data from three observation wells in the John Day Basin indicated regular annual cycles in the static water level. The recharge in inches represented by the fluctuations is calculated by multiplying the amount of the fluctuation (in inches) by the specific yield of the probable rock (dimensionless). To calculate the volume of water represented, one would need to determine the area over which the conditions represented by the observation well prevail. The results are presented in Table 20. Estimates of recharge from observation well data are presented in this report only for comparison with other methods. The reader is urged to use caution when interpreting these values.

TABLE 20

Volume of water in inches represented by annual fluctuation of the static water level in observation wells.

| Well location | T1N, R17E, Sec 4ca | T12S, R26E, Sec 34da | T13S, R31E, Sec 26ba |
|---|---|---|---|
| Owner | O'Meara | Dayville Cemetary | City of John Day |
| No. of Cycles | 7 | 12 | 8 |
| Average fluctuations | 2.40 feet | 5.05 feet | 0.36 feet |
| Standard deviation | 0.46 feet | 2.00 feet | 0.17 feet |
| Rock type | Basalt | Mostly clay | Basalt (?) |
| Specific yield | 0.01 | 0.02 | 0.01 |
| Inches of water | 0.29 inches | *1.21 inches | 0.04 inches |

* Possibly affected by river stage.

## Confidence in Recharge Estimates

Confidence in recharge estimates based on stream hydrograph data and low flow statistics is generally good, though the estimates are considered conservative. There are a number of factors which are unquantifiable which affect the results. These include the affects of evapotranspiration and the non-liniarity of the basin response due to the

size and complexity of the ground water system. However, confidence is increased by the consistency of the results from year-to-year within a particular drainage, and from one drainage to another regardless of size and total volume of flow. In addition, confidence in the results is increased by the favorable comparison of recharge estimates with those presented by other workers in and adjacent to the John Day Basin. Robison (1968) estimated recharge using the low flow discharges of major streams in the basin, his results are presented in Table 21. He considers his estimates to be low due to "excessive evapotranspiration". Numerical computer modeling of ground water in the Umatilla Plateau by the U.S. Geological Survey indicated 0.34 inches of average recharge over that entire area (Anne Smith, Personnal Communication). The Umatilla Plateau is a basalt terrane which lies just north of the Blue Mountain Anticline, and can be considered similar to the area in the John Day Basin just south of the Blue Mountain anticline drained by Camas Creek and tributaries to the North Fork. The recharge estimates based on observation well data are much more divergent than estimates by other methods, however, they are within the same order of magnitude. Confidence in the observation well estimates is low mainly because of the lack of restraints on aquifer geometry and pumping effects.

TABLE 21

Estimated Recharge in the John Day Basin
Based on Streamflow Data (from Robison, 1968)

| Area | Square miles | Millions of acres | Million acre-feet Recharge | Inches Recharge |
|---|---|---|---|---|
| N. Fork John Day | 2630 | 1.7 | 0.08 | 0.57 |
| Upper John Day | 2120 | 1.4 | 0.05 | 0.44 |
| Lower John Day | 3260 | 1.7 | 0.01 | 0.06 |
| Entire Basin | 8010 | 5.1 | 0.14 | 0.33 |

## Discussion of Recharge Estimates

In the preceeding sections annual recharge estimates are presented in acre-feet and inches for various drainages in the John Day Basin. These

numbers represent averages, and the distribution and availability of recharge will not be uniform throughout the whole drainage. One reason for this is the variation of precipitation with elevation.

This variation is exemplified in the drainage of the North Fork of the John Day River. Analysis of data from the Monument gaging station indicates an estimated recharge of 0.47 to 0.71 inches per year, however analysis of data from the station near Dale in the upper reaches of the North Fork indicates an estimated recharge of 1.22 to 1.65 inches per year. The data from the station near Dale reflects the high precipitation in the Blue Mountains, and the data from Monument includes that area as well as a large expanse of Columbia River Basalt. The value obtained from the Monument data must be considered an average. Therefore, in assessing the recharge to particular area within an aquifer unit, it first necessary to determine where the area is situated relative to the ground water system it is part of.

Another problem is that these large areas contain multiple aquifers with various degrees of interconnection. In some terranes, for instance the Columbia River Basalt areas, the multiple aquifers can be effectively considered a single unit. In other areas containing multiple geologic units, the hydrologic properties of the major aquifer units as well as their location relative to the distribution of precipitation must be considered.

Estimates indicate recharge in most of the John Day Basin is quite low, generally less than one inch per year. Recharge is higher in the Blue Mountains and Ochoco Mountains, and lower in the northern parts of the Basin in Sherman and Gilliam Counties. Table 22 presents recharge estimates in acre-feet from low flow statistics for some of the major drainages in the basin. Interpreting the recharge estimates to determine the amount of water moving each year through a particular aquifer unit is not a simple task. Not all units are represented by the recharge estimates. Data is not available to estimate recharge to the Rattlesnake Formation or other individual units along the main stem of the John Day.

This is because they are from drainages which include multiple units, and contributions by individual units cannot be determined. There is no data available to estimate recharge to the Clarno or John Day Formations.

TABLE 22

Estimates of annual recharge in acre-feet for selected drainages in the John Day Basin based on low flow statistics

| Station | Drainage Area ($mi^2$) | Range of Estimates in inches | Range of Estimates in acre-feet |
|---|---|---|---|
| Strawberry Creek | 7 | 4.46 - 5.62 | 1665 - 2098 |
| John Day River at Prairie City | 231 | 1.53 - 2.82 | 18,850 - 34,742 |
| John Day River near John Day | 386 | 0.77 - 2.18 | 15,852 - 44,879 |
| John Day River at Picture Gorge | 1680 | 0.16 - 0.57 | 14,336 - 51,072 |
| Camas Creek near Lehman | 60.7 | 0.25 - 0.42 | 809 - 1,360 |
| Camas Creek near Ukiah | 121 | 0.40 - 0.65 | 2,581 - 4,195 |
| Mid. Fk. John Day River at Ritter | 515 | 0.53 - 0.90 | 14,557 - 24,720 |
| North Fk. John Day River near Dale | 525 | 1.22 - 1.65 | 34,160 - 46,200 |
| North Fk. John Day River at Monument | 2520 | 0.47 - 0.71 | 63,168 - 95,424 |
| John Day River at Service Creek | 5090 | 0.27 - 0.59 | 73,296 - 160,165 |
| John Day River at McDonald Ferry | 7580 | 0.20 - 0.42 | 80,853 - 169,792 |

The unit best represented by the recharge estimates presented in this report is the Columbia River Basalt. The basalt is well represented by recharge estimates from data from gaging stations along Camas Creek and on the North Fork of the John Day at Monument. Recharge estimates in acre-feet are presented for the major basalt areas in the basin in Table 23.

TABLE 23

Acre-feet of estimated annual recharge to the major basalt areas in the John Day Basin based on stream flow data using 0.4 to 0.6 inchesof recharge annually. See section on storage estimates for detailed descriptions of the areas.

| | Area (acres) | Estimated Recharge (acre-feet) |
|---|---|---|
| Sherman County Basalt Area | 353,280 | 11,776 - 17,664 |
| Gilliam County Basalt Area | 776,960 | 25,898 - 38,848 |
| North Fork - Middle Fork Area | 928,000 | 30,933 - 46,400 |
| Fox Basin Basalt Area | 97,920 | 3,264 - 4,896 |
| W. John Day Valley Basalt Area | 108,800 | 3,627 - 5,440 |
| E. John Day Valley Basalt Area | 67,200 | 2,240 - 3,360 |
| Rudio Mt. Basalt Area | 60,160 | 2,005 - 3,008 |
| Picture Gorge-Sutton Mtn. Area | 211,840 | 7,061 - 10,592 |
| South Fork Basalt Area | 209,280 | 6,976 - 10,464 |

## DISCUSSION OF GROUND WATER POTENTIAL IN SELECTED AREAS

### Upper John Day River Valley

This area includes the river valley from Picture Gorge east to Prairie City. This is the most populated area in the John Day Basin, and the most well endowed in terms of ground water resources. Ground water usage in this area is primarily for domestic and stock use, with only minor irrigation and industrial use. Most irrigation conducted in the area utilizes surface water diverted from the John Day River and major tributaries by way of a system of ditches.

Ground water is obtained from nearly all the bedrock units in the area as well as modern and ancient alluvial deposits. The most commonly used aquifer units are the Quaternary Alluvium in the river channel, the Rattlesnake Formation gravels, and the Columbia River Basalt. The Columbia River Basalt and Quaternary Alluvium are in many places capable of producing yields of several hundred gallons per minute with properly located and constructed wells. The City of Mt. Vernon has a municipal well which produces from Quaternary Alluvium (T13S, R30E, Section 21cd). Canyon City and John Day municipal wells produce from Columbia River Basalt (T13S, R31E, Sections 23bd, 23db, and 26db). Prairie City has a municipal well which apparently produces from pre-Tertiary volcanics (T12S, R33E, Section 26cd). A number of the wells drilled into the Columbia River Basalt are artesian and flowing.

A major structural feature which affects the ground water along the upper John Day River is the John Day fault. This fault runs from the base of the Strawberry Range above the Prairie City Bench to the town of John Day, and then west along the river valley almost to Dayville where it loses its identity joining with a number of other faults. The effects of the fault on ground water are most noticeable in the bedrock units in the John Day-Canyon City area. According to local sources the wells south of the fault have lower yields and higher total dissolved solids.

The alluvial aquifer receives essentially immediate recharge from the river.

Any extensive pumping from the alluvial aquifer, for instance for large scale irrigation use, will affect the stream flow. The basalt aquifer receives recharge from precipitation in the hills to the north of the John Day Valley. Recharge estimates range from 0.40 to 0.60 inches per year to the basalt in that area, which corresponds to about 5867 to 8800 acre-feet per year. Bearing in mind that these are conservative estimates it is apparent that the basalt aquifer could not sustain any significant development for irrigation.

Fox Basin Area

Fox Basin is a broad structural basin of Columbia River Basalt with an accumulation of volcanic sediments and alluvium in the central portion. The basin is primarily used for grazing and hay production. Ground water is produced primarily from the sediment and alluvium, and less commonly from the basalt. Numerous small scale irrigation wells have been drilled which produce two to three hundred gallons per minute from the volcanic sediments. Most of the wells producing from the basalt are on the periphery of the basin. Fox Basin appears to be hydrologically isolated by folds and faults in the Columbia River Basalt, and recharges primarily from precipitation within the basin. Recharge estimates for Fox Basin range from 0.40 to 0.60 inches per year, which corresponds to 3264 to 4896 acre-feet annually. Even taking into consideration that these recharge estimates may be low, it appears unlikely that the Fox Basin area could sustain any large scale irrigation development.

Lower John Day River Area

The Lower John Day River Area, north of the Blue Mountain Anticline, comprises a broad basalt platform gently dipping toward the north, and dissected by the John Day River and its tributaries. The area is locally faulted and gently folded. This part of the basin includes several broad, relatively undissected areas which are used predominately for dry land farming. Much of the noncultivated parts of the area is used for grazing.

Ground water in this region is produced almost exclusively from the Columbia River Basalt. Ground water is used primarily for domestic, stock, and small

scale irrigation purposes. In addition, in the northeastern part of Gilliam County there are several large diameter high yield irrigation wells (wells with yields in excess of 1,000 gpm).

Ground water movement is generally northward toward the Columbia River, however it is locally structurally controlled. The numerous faults in the eastern part of the area may act as subsurface barriers by truncating permeable interflows of zones. Anticlines can also act as ground water barriers if uparching is sufficient. Synclines can act as ground water reservoirs, or subsurface channels. An awareness of local geological structure is advised when locating new wells.

The high transmissivity of the basalt in this part of the basin and relatively shallow static water levels make yields adequate for domestic and stock use readily obtainable. In addition, yields of two to three hundred gallons per minute, adequate for small scale irrigation, appear to be obtainable in many places. To date, the large diameter high yield wells are restricted to the area along and to the northeast of Rock Creek. Similar high yields may be obtainable elsewhere in the Sherman-Gillam County areas, but higher lifts may make development uneconomic.

Recharge to this area is quite low. Estimates based on stream low flow data range from 0.40 to 0.60 inches per year, which correspond to approximately 37,674 to 56,512 acre-feet annually. It appears unlikely that the area can sustain any large scale irrigation development, even bearing in mind that these are conservative estimates. In fact, long term declines in static water level have been observed in wells in northeastern Gillam County near the area of the high yield wells (Figures 21 and 22). Increased water level monitoring throughout this area would be appropriate.

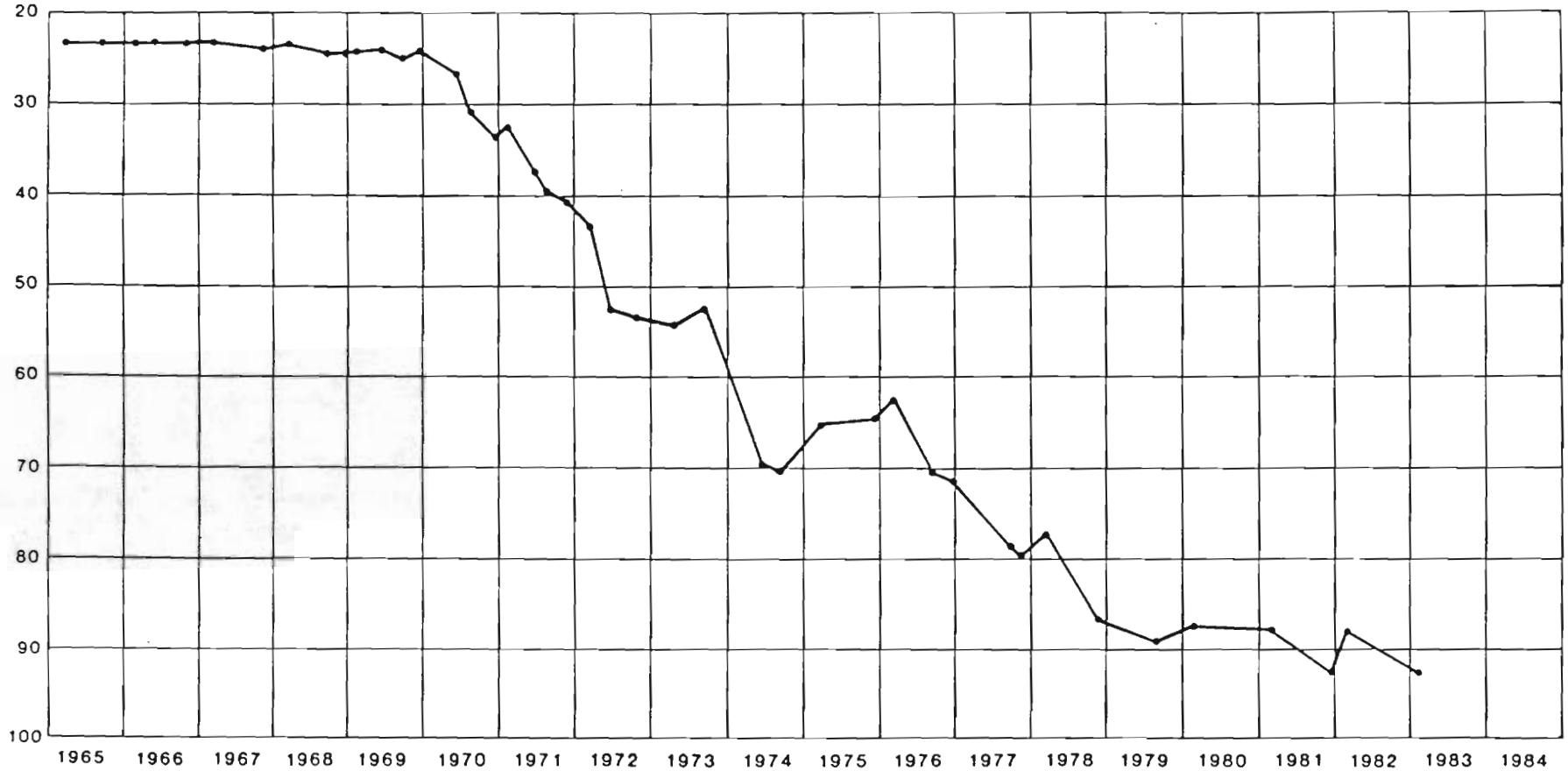


Figure ~~8~~ 21. HYDROGRAPH OF WELL T1N, R22E, SECTION 8ab, GILLIAM COUNTY

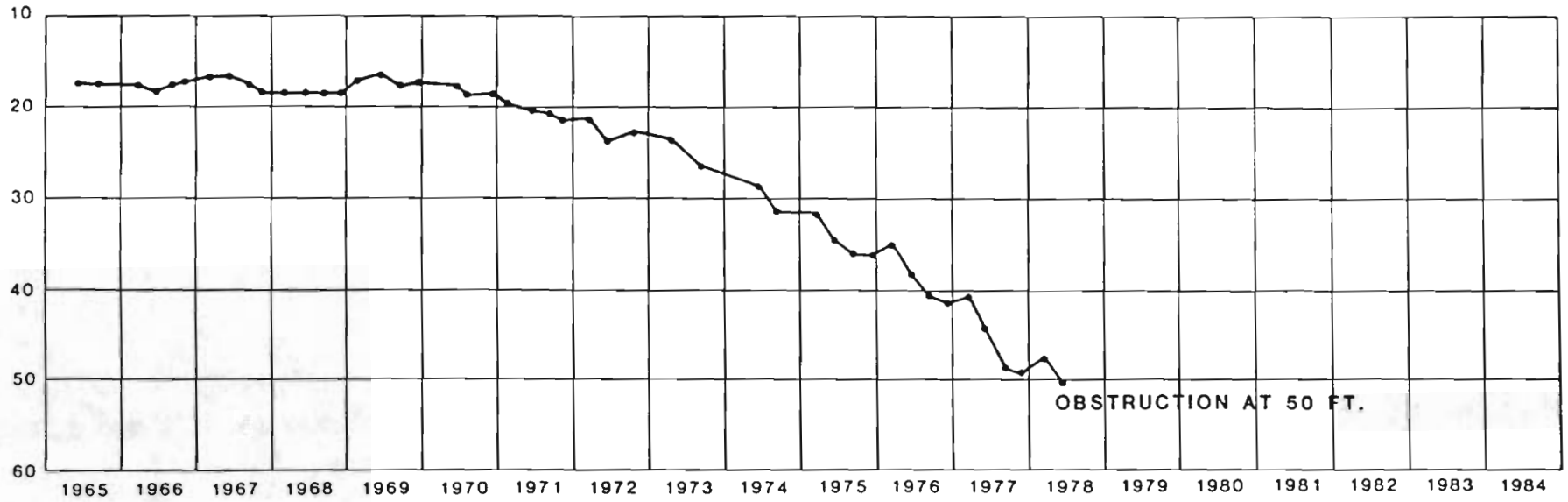


Figure 22. HYDROGRAPH OF WELL T1N, R22E, SECTION 5db, GILLIAM COUNTY

## SUMMARY AND RECOMMENDATIONS

A review of available published and unpublished geologic and hydrologic information including water well reports has indicated that the Columbia River Basalt Group and the Quaternary alluvium are the most productive aquifer units in the John Day Basin. The Rattlesnake and Mascall Formations are locally important aquifer units.

Pump test data from water well reports have been used to determine the hydrologic characteristics of the major aquifer units. The aquifer characteristics determined from these data are useful for comparing the various units in the basin, however these numbers probably do not accurately reflect the total potential of the various units.

The volume of ground water in storage has been estimated for major aquifer units using published lithologic information and geologic and topographic maps. The numbers presented are estimates of the total amount of water contained in the various major aquifer units, and do not represent an amount of water which can be appropriated.

Annual ground water recharge was estimated using stream hydrograph, low flow, and observation well hydrograph data. The estimates based on low flow stream data are considered the most reliable. Annual recharge estimates range from about 0.2 to 0.4 inches for the entire basin, though they are higher in areas of higher elevation and precipitation. Recharge is well below one inch per year over most of the basin. The low recharge appears to preclude any intensive large scale irrigation development using ground water in the basin. In order to maintain the equilibrium between recharge, storage, use and natural discharge, cautious development must be accompanied by scrupulous monitoring.

Knowledge of the ground water potential of the John Day Basin would be refined with increased data collection. Increased data collection needs to proceed along two lines. The first is a basin wide program of long term monitoring of

carefully located observation wells, and the second is a project oriented program of aquifer testing and geological assessment to address specific questions about aquifer characteristics and the potential of certain areas.

The monitoring of carefully located observation wells will provide information as to the long term changes in the ground water system, both natural and induced. This monitoring is of paramount importance in areas where development has occurred or will likely occur.

Certain problems require the gathering of more detailed hydrologic information. These problems include determining the ground water potential of specific areas and the effects of development, assessing areas of ground water decline or significant well interference, or determining precisely the hydrologic characteristics of an aquifer.

The gathering of more detailed information would include increasing the density of observation wells, mapping the water table or potentiometric surface, long term aquifer testing, and geological evaluation to define detailed structure, stratigraphy and lithology. This type of data gathering will provide precise information on transmissivity, storage coefficients and specific yield. As this sort of data is acquired, estimates of recharge and storage could be refined.

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# APPENDIX I

## Presentation of Well Data

Appendix I consists of two parts. In the first part, data from selected water well reports are presented in tabular form, grouped by aquifer unit. In the second part, the hydrologic characteristics of the major aquifer units, as determined from well data, are presented graphically.

Well reports used for this report were selected according to the following criteria:

1. Only well reports with complete pump or bailer tests were selected. No air tests were used. For tests where zero drawdown was indicated, a drawdown of one foot was arbitrarily used for specific capacity and transmissivity calculations.

2. Only well reports in which the producing aquifer could be detemined with reasonable certainty were used.

The casing data presented represents only the smallest diameter casing string installed, or the liner. Transmissivity values were calculated using the program published by Vorhis (1979, and are designated as T (.nn) where .nn is the storage coefficient used in the calculation. Test type is either pump (P) or bailer (B).

WELL PRODUCING FROM QUATERNARY ALLUVIUM (IN MAIN RIVER VALLEYS)

| Location | Owner | Depth (feet) | Yield (gpm) | Draw-down (feet) | Time (hrs.) | Diameter (inches) | Test type | Static water level (ft) | Casing size (inches) | Cased depth (feet) | Perforated interval (feet) | Specific capacity (gpm/ft) | T (0.2) $ft^2$/day |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6S/21E-29cb | Ostrander | 50 | 20 | 26 | 1 | 7 | B | 12 | 8 | 39 | 20-38 | 0.769 | 71 |
| 6S/21E-29cb | Ostrander | 60 | 40 | 40 | 1 | 7 | B | 12 | 8 | 46 | 18-45 | 1.000 | 97 |
| 6S/21E-29cb | Ostrander | 61 | 30 | 49 | 1 | 8 | B | 11.6 | 8 | 44 | 14-43 | 0.612 | 51 |
| 6S/21E-29cb | Ostrander | 61 | 40 | 10 | 1 | 6 | B | 17 | 6 | 46 | 25-45 | 4.000 | 507 |
| 6S/21E-29cb | Ostrander | 60 | 25 | 30 | 1 | 6 | P | 24 | 6 | 62 | 20-60 | 0.833 | 82 |
| 6S/21E-29cb | Ostrander | 38 | 21 | 27 | 2 | 6 | B | 11 | 6 | 24 | 18-24 | 0.778 | 86 |
| 6S/21E-29cb | Ostrander | 51 | 40 | 16 | 1.5 | 6 | B | 16 | 6 | 29 | 20-38 | 2.500 | 314 |
| 6S/21E-29cb | Ostrander | 58 | 44 | 4 | 1.5 | 6 | B | 13 | 6 | 42 | 23-41 | 11.000 | 1660 |
| 6S/21E-29cb | Ostrander | 61 | 44 | 2 | 1.5 | 6 | B | 15 | 6 | 50 | 31-49 | 22.000 | 3578 |
| 6S/21E-29cb | Ostrander | 88 | 10 | 42 | 1 | 6 | B | 18 | 6 | 60 | 24-60 | 0.238 | 18 |
| 6S/21E-29cb | Ostrander | 81 | 10 | 68 | 1 | 7 | B | 13 | 8 | 55 | 20-54 | 0.147 | 9 |
| 6S/21E-32 | Hadley | 40 | 20 | 6 | 0.5 | 6 | B | 20 | 6 | 37 | 12-37 | 3.333 | 371 |
| 6S/21E-32 | Freeman | 31 | 6 | 23 | 1 | 6 | B | 8 | 6 5/8 | 22 | 18-22 | 0.261 | 20 |
| 6S/21E-32 | Taylor | 25 | 10 | 12 | 1 | 6 | B | 7 | 6 | 25 | 18-24 | 0.833 | 82 |
| 6S/21E-32ac | Freeman | 50 | 45 | 20 | 1 | 6 | B | 9 | 6 | 41 | 21-40 | 2.250 | 263 |
| 9S/26E-30dc | Texaco | 42 | 44 | 0 | 1 | 6 | B | 13 | 6 | 39 | 21-38 | 44.0 | 7371 |
| 12S/26E-28ac | Cheney | 52 | 44 | 12 | 1 | 6 | B | 18 | 6 | 40 | 20-39 | 3.667 | 459 |
| 12S/26E-34 | Decker | 263 | 10 | 0 | 2 | 6 | B | 24 | 6 | 145 | 25-145 | 10.0 | 1542 |
| 12S/26E-34da | Dayville | 224 | 5 | 35 | 2 | 6 | B | 185 | 6 | 222 | - | 0.143 | 11 |
| 12S/26E-34da | Dayville | 465 | 10 | 95 | 5 | 6 | P | 67 | 6 | 222 | 177-222 | 0.105 | 10 |
| 13S/26E-1ba | Fisher | 32 | 20 | 11 | 1 | 6 | B | 7 | 6 | 29 | 19-29 | 1.81 | 205 |
| 13S/27E-2 | Rothwell | 110 | 20 | 10 | 1 | 8 | B | 4 | 8 | 110 | 20-110 | 2.0 | 209 |
| 13S/28E-13cd | Moore | 50 | 9 | 38 | 1 | 6 | B | 2 | 6 | 21 | - | 0.24 | 18 |
| 13S/28E-16da | Holthouse | 82 | 30 | 10 | 2 | 8 | B | 29 | 8 | 37 | - | 3.0 | 371 |
| 13S/29E-18cd | Ryan | 42 | 10 | 25 | 1 | 6 | B | 5 | 6 | 21 | - | 0.40 | 34 |
| 13S/29E-20aa | Mid-County | 71 | 30 | 2 | 1 | 6 5/8 | B | 43 | 6 5/8 | 71 | 51-71 | 15.0 | 2189 |
| 13S/29E-21dd | Pierce | 58 | 7 | 14 | 1 | 6 | B | 26 | 6 | 38 | - | 0.50 | 45 |
| 13S/29E-22cc | Page | 30 | 15 | 2 | 4 | 6 5/8 | P | 14 | 6 5/8 | 30 | 20-30 | 7.5 | 1182 |
| 13S/29E-22dc | Holly | 82 | 20 | 26 | 1 | 6 | B | 41 | 6 | 79 | 39-79 | 0.77 | 75 |
| 13S/29E-22dc | Cawrse | 320 | 100 | 100 | 4 | 15 3/4 | P | 9 | - | - | - | 1.0 | 92 |
| 13S/29E-24dc | Nagel | 90 | 30 | 25 | 1 | 8 | B | 25 | 8 | 80 | - | 1.20 | 114 |
| 13S/29E-27ba | Weaver | 54 | 20 | 9 | 1 | 6 | B | 31 | 6 | 55 1/2 | - | 6.67 | 258 |
| 13S/30E-20cd | Sparul | 212 | 20 | 10 | 2 | 6 | B | 60 | 6 | 133 | 40-108 | 2.0 | 253 |
| 13S/30E-21 | Williams | 68 | 16 | 8 | 2 | 6 | B | 21.5 | 6 | 51 | 25-50 | 2.0 | 253 |
| 13S/30E-21cd | Mt. Vernon | 365 | 193 | 107 | 10 | 10 | P | 92 | 10 | 240 | 100-240 | 1.80 | 243 |
| 13S/30E-21cd | deepened | 470 | 60 | 360 | 96 | 8 | P | 90 | 8 | 410 | 210-410 | 0.167 | 23 |
| 13S/30E-21dd | Whale | 32 | 10 | 12 | 0.5 | 6 | B | 3 | 6 | 20 | - | 0.833 | 72 |
| 13S/30E-22 | Dodds | 67 | 20 | 17 | 10 | 6 | B | 23 | 6 | 66 | - | 1.176 | 170 |
| 13S/30E-26 | Oster | 100 | 10 | 50 | 1 | 6 | B | 18 | 6 | 50 | - | 0.20 | 15 |
| 13S/30E-26a | Randall | 125 | 10 | 20 | 1 | 6 | B | 3 | 6 | 40 | - | 0.50 | 45 |
| 13S/30E-26ad | Coarse | 100 | 32 | 25 | 2 | 6 | P | 35 | 6 | 100 | 40-60 | 1.28 | 152 |
| 13S/30E-28aa | Hines Lumber | 250 | 40 | 16 | 2 | 8 | B | 5 | 8 | 187 | 24-160 | 2.50 | 301 |
| 13S/30E-30aa | Carroll | 118 | 40 | 80 | 3 | 8 | B | 1.5 | 8 | 104 | - | 0.50 | 50 |
| 13S/31E-21 | Aasness | 73 | 30 | 6 | 2.5 | 6 | B | 3 | 6 | 70 | 58-70 | 5.0 | 731 |
| 13S/31E-21 | Fergerson | 109 | 15 | 40 | 1 | 6 | B | 20 | 6 | 7 | 26-60 | 0.375 | 32 |
| 13S/31E-21cc | Mt. View | 10 | 1000 | 1.5 | 6 | 36 | P | 4 | 36 | 10 | 0-10 | 666. | UMIT |
| 13S/31E-21cd | Scott | 68.5 | 12 | 20 | 2 | 6 | B | 28 | 6 | 67 | 23-67 | 0.60 | 63 |
| 13S/31E-21dd | Ideal Gas | 225 | 7 | 100 | 2 | 6 | B | 120 | 6 | 153 | - | 0.070 | 4 |
| 13S/31E-21dd | Holland | 100 | 3 | 70 | 3 | 8 | B | 20 | 8 | 40 | - | 0.043 | 2 |
| 13S/31E-22 | Hooe | 232 | 10 | 155 | 1.5 | 6 | B | 26 | 6 | 67 | 30-67 | 0.065 | 4 |

QUATERNARY ALLUVIUM (IN MAIN RIVER VALLEYS)

| Location | Owner | Depth (feet) | Yield (gpm) | Draw-down (feet) | Time (hrs.) | Diameter (inches) | Test type | Static water level (ft) | Casing size (inches) | Cased depth (feet) | Perforated interval (feet) | Specific capacity (gpm/ft) | T (0.2) $ft^2$/day |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 13S/31E-22b | Hines Lumber | 265 | 7 | 150 | 1 | 12 | P | 9 | 12 | 115 | 40-110 | 0.047 | 0.4 |
| 13S/31E-22cc | Hurlburt | 125 | 9 | 20 | 1 | 6 | B | 10.5 | 6 | 21 | - | 0.45 | 40 |
| 13S/31E-22cc | Weldin | 85 | 15 | 30 | 2 | 6 | B | 40 | 6 | 60 | - | 0.50 | 51 |
| 13S/31E-22dc | Wilcox | 180 | 5 | 135 | 1 | 8 | B | 34 | 10 | 19 | - | 0.037 | 0.5 |
| 13S/31E-22dc | Wilcox | 145 | 3 | 110 | 1 | 6 | B | 24 | 6 | 39 | 29-39 | 0.027 | 1 |
| 13S/31E-23 | Smith | 149 | 50 | 2 | 3 | 6 | P | 14 | 6 | 149 | 134-149 | 25.0 | 4411 |
| 13S/31E-35ab | Mosley | 42 | 20 | 3 | 2 | 6 | B | 30 | 6 | 42 | 20-40 | 6.67 | 982 |
| 13S/32E-22db | Kauhn | 50 | 50 | 20 | 2 | 12 | B | 0 | 12 | 39 | 24-38 | 2.50 | 266 |
| 13S/32E-23ca | Milne | 203 | 8 | 10 | 1 | 6 | P | 180 | 5 | 203 | 180-203 | 0.80 | 79 |
| 13S/32E-26aa | Sternman | 106 | 10 | 81 | 1 | 6 | B | 19 | 6 | 105 | 60-105 | 0.123 | 7 |
| 13S/32E-26aa | Stergman | 71 | 25 | 40 | 1 | 6 | B | 7 | 6 | 68 | 38-68 | 0.625 | 59 |
| 13S/32E-26dd | Vanschoiack | 52 | 15 | 40 | 1 | 6 | B | 5 | 6 | 49 | 20-50 | 0.375 | 32 |
| 13S/32E-31 | Robertson | 161 | 7 | 25 | 1 | 6 | P | 110 | 6 | 27 | - | 0.280 | 23 |
| 13S/33E-11 | Wright | 146 | 24 | 6 | 1 | 6 | B | ND | 6 | 138 | - | 4.00 | 507 |
| 13S/33E-11 | Wishard | 205 | 30 | 41 | 0.33 | 6 | B | 24 | 6 | 123 | 37-123 | 0.732 | 56 |
| 13S/33E-18bb | Mitchell | 35 | 10 | 22 | 1 | 6 | B | 7 | 6 | 20 | - | 0.455 | 40 |
| 13S/34E-35ab | Morgan | 157 | 35 | 25 | 1 | 6 | B | 5 | 6 | 57 | - | 1.400 | 152 |
| 13S/34E-35d | Kimberling | 260 | 20 | 208 | 3 | 8 | B | 22 | 8 | 70 | - | 0.096 | 7 |
| 13S/34E-35d | Kimberling | 40 | 15 | 22 | 2 | 6 | B | 4 | 6 | 40 | 30-40 | 0.682 | 73 |
| 14S/34E-6ab | Sokol | 195 | 20 | 18 | 1 | 6 | B | 162 | 6 | 46.5 | - | 1.111 | 116 |

WELLS PRODUCING FROM THE RATTLESNAKE FORMATION

| Location | Owner | Depth (feet) | Yield (gpm) | Draw-down (feet) | Time (hrs.) | Diameter (inches) | Test type | Static water level (ft) | Casing size (inches) | Cased depth (feet) | Perforated interval (feet) | Specific capacity (gpm/ft) | T (0.4) $ft^2$/day |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 13S/27E-1da | Heller | 120 | 15 | 60 | 1 | 6 | P | 12 | 6 | 100 | 60-100 | 0.25 | 26 |
| 13S/29E-13cd | Overton | 155 | 15 | 81 | 1 | 6 | B | 39 | 6 | 56 | - | 0.19 | 18 |
| 13S/29E-22ab | Cawrse | 1210 | 1200 | 130 | 7 | 9 7/8 | P | 270 | 6 | 1210 | 550-1210 | 9.23 | 1695 |
| 13S/29E-22ba | Cawrse | 230 | 540 | 130 | 4 | 15 | P | 22 | 16 | 50 | 20-49 | 4.15 | 609 |
| 13S/29E-22ca | Cawrse | 215 | 520 | 95 | 8 | 15 3/4 | P | 55 | 16 | 107 | 55-107 | 5.47 | 883 |
| 13S/30E-32cc | Dodds | 42 | 12 | 19 | 1 | 6 | B | 23 | 6 | 40 | 20-39 | 0.63 | 77 |
| 13S/30E-33cb | Deming | 139 | 2 | 139 | 1 | 8 | B | 35 | 6 | 139 | 30-139 | 0.014 | - |
| 13S/30E-35ab | Volny | 450 | 65 | 200 | 1 | 6 | P | 0 | 6 | 410 | 380-410 | 0.325 | 35 |
| 13S/30E-36bd | Volny | 500 | 5 | 150 | 1 | 6 | P | 350 | 6 | 20 | - | 0.33 | 3 |
| 13S/31E-28bd | Tolman | 55 | 20 | 1 | 1 | 6 | B | 25 | 6 | 55 | 15-50 | 10.0 | 1691 |
| 13S/31E-36ca | Canyon City | 370 | 65 | 60 | 5 | 11 7/8 | P | 205 | 12 | 358 | 220-310 | 1.08 | 107 |
| 13S/32E-30ac | Gaynor | 135 | 5 | 25 | 1 | 6 | B | 90 | 5 | 125 | 100-125 | 0.20 | 20 |
| 13S/32E-31 | King | 250 | 6 | 200 | 1 | 6 | B | 37 | 6 | 119 | 105-117 | 0.030 | 2 |
| 13S/32E-31ad | Burtis | 125 | 3 | 63 | 0.75 | 6 | B | 62 | 6 | 125 | 70-125 | 0.048 | 3 |
| 13S/32E-31bad | Burtis | 73 | 5 | 20 | 2 | 8 | B | 35 | 8 | 20 | - | 0.25 | 27 |
| 13S/32E-31cab | Craig | 60 | 10 | 5 | 1 | 6 | B | 45 | 6 | 20 | - | 2.0 | 283 |
| 13S/32E-31cb | Morris | 323 | 5 | 158 | 1 | 6 | B | 185 | 5 | 323 | 160-323 | 0.032 | 2 |
| 14S/30E-4bd | Clark | 152 | 18 | 50 | 1.5 | 6 | B | 73 | 6 | 149 | 89-149 | 0.360 | 43 |
| 14S/31E-1aa | Sheedy | 140 | 20 | 40 | 2 | 8 | B | 80 | 8 | 20 | - | 0.50 | 60 |
| 14S/31E-1aa | Bothwell | 118 | 12 | 36 | 1 | 6 | B | 74 | 6 | 20 | - | 0.333 | 36 |

WELL PRODUCING FROM VOLCANIC SEDIMENTS IN THE FOX AREA (INCLUDES Tm, Qa, and Qo of BROWN AND THAYER, 1966)

| Location | Owner | Depth (feet) | Yield (gpm) | Draw-down (feet) | Time (hrs.) | Diameter (inches) | Test type | Static water level (ft) | Casing size (inches) | Cased depth (feet) | Perforated interval (feet) | Specific capacity (gpm/ft) | T (U.S) $ft^2$/day |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10S/30E-31 | MrGirr | 65 | 120 | 45 | 0.5 | 6 | B | 10 | 6 | 141.5 | - | 1.40 | 349 |
| 10S/30E-5 | Allen | 109 | 10 | 43 | 10 | 8 | P | 22 | 8 | 40 | - | 0.233 | 31 |
| 10S/30E-8 | Shaw | 97 | 21 | 15 | 0.5 | 6 | B | 48 | 6 | 100 | 78-100 | 0.233 | 167 |
| 11S/29E-11dd | Simmions | 370 | 200 | 120 | 6 | 6 | P | 10 | 6 | 120 | 40-120 | 2.67 | 275 |
| 11S/29E-13 | Wright | 230 | 200 | 140 | 6 | 6 | P | 0 | 6 | 38 | - | 1.43 | 232 |
| 11S/29E-14dd | Rex | 153 | 66 | 80 | 1 | 8 | B | 2 | 8 | 38 | 28-37 | 0.825 | 93 |
| 11S/29E-14dd | Rex | 152 | 66 | 110 | 1 | 10 | B | 1 | 8 | 39 | 20-38 | 0.600 | 59 |
| 11S/29E-14dd | Rex | 150 | 110 | 5 | 1 | 8 | B | 1 | 8 | 39 | 20-38 | 22.0 | 3717 |
| 11S/29E-14dd | Rex | 189 | 200 | 150 | 4 | 10 | P | 1 | 10 | 19 | - | 1.33 | 183 |
| 11S/29E-14dd | Rex | 207 | 175 | 200 | 4 | 10 | P | 6 | 10 | 18 | - | 0.875 | 133 |
| 11S/29E-34bc | Patterson | 475 | 230 | 113 | 4 | 8 | P | 52 | 9 | 20 | - | 2.03 | 309 |
| 11S/30E-5 | Born | 64.5 | 30 | 29 | 8 | 6 | B | 6 | 6 | 54 | 31-54 | 1.03 | 168 |
| 11S/30E-5aa | Rex | 118 | 15 | 80 | 1 | 8 | B | 35 | 6 | 109 | 90-108 | 0.188 | 16 |
| 11S/30E-5aa | Rex | 87 | 10 | 74 | 1 | 6 | B | 13 | 6 | 40 | 21-39 | 0.135 | 12 |
| 11S/30E-5bb | MrGirr | 53 | 30 | 0 | 1 | 8 | B | 7 | 5 | 53 | 22-53 | 30.0 | 5226 |
| 11S/30E-6aa | McGirr | 71 | 25 | 8 | 1 | 8 | B | 13 | 8 | 40 | 20-40 | 3.12 | 423 |
| 11S/30E-6bb | Reynolds | 80 | 25 | 42 | 1 | 8 | B | 18 | 5 | 80 | 40-75 | 0.595 | 63 |
| 11S/30E-6caa | Geingeb | 66 | 20 | 21 | 0.5 | 5.5 | B | 21 | 6 | 51 | 30-40 | 0.952 | 110 |
| 11S/30E-7 | Simmions | 248 | 20 | 127 | 6 | 6 | P | +1 | 6 | 155 | 55-155 | 0.157 | 20 |
| 11S/30E-7db | Wright | 107 | 12 | 2.5 | 3 | 6 | P | 7.5 | 6 | 40 | 20-40 | 4.8 | 823 |
| 11S/30E-8da | Hewitt | 70 | 40 | 38 | 1 | 6 | B | 32 | 6 | 39 | Yes | 1.05 | 133 |

WELLS PRODUCING FROM COLUMBIA RIVER BASALT IN GILLIAM COUNTY IN THE JOHN DAY BASIN

| Location | Owner | Depth (feet) | Yield (gpm) | Draw-down (feet) | Time (hrs.) | Diameter (inches) | Test type | Static water level (ft) | Casing size (inches) | Cased depth (feet) | Perforated interval (feet) | Specific capacity (gpm/ft) | T ($10^{-4}$) $ft^2$/day |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1N/20E-15ab | UPRR | 303 | 3 | 64 | 3 | 8 | P | 54 | 8 | 42 | - | 0.05 | 9 |
| 1N/21E-12bb | Kerr | 492 | 1965 | 3 | 10 | 15 | P | 386 | 12 | 471 | - | 655.0 | 229,522 |
| 1N/21E-19cb | Marick | 750 | 1500 | 206 | 3 | 10 | P | 51 | 12 | 50 | - | 7.28 | 1925 |
| 1N/21E-21 | Weatherford | 565 | 20 | 95 | 2 | 6 | B | 453 | 6 | 225 | - | 0.21 | 46 |
| 1N/21E-22ba | Childs | 1275 | 900 | 160 | 4 | 12 1/4 | P | 330 | 14 | 875 | - | - | - |
| 1N/21E-22ba | Childs | 1275 | 1500 | 66 | 1 | - | - | 434 | - | - | 620-680 | - | - |
| 1N/21E-23 | Weatherford | 840 | 8 | 0 | 2 | 8 | B | 445 | 10 | 387 | - | 8.0 | 2132 |
| 1N/21E-2ad | Plateau | 400 | 20 | 0 | 1 | 6 | B | 310 | 5 | 400 | 340-400 | 20.0 | 5707 |
| 2N/19E-16J | Wilcox | 236 | 15 | 0 | - | 6 | B | 189 | 6 | 102 | - | 15.0 | 4122 |
| 2N/20E-19dd | Enery | 795 | 1000 | 100 | 8 | 12 | P | 427 | - | - | - | 100.0 | 31,665 |
| 2N/20E-25db | Chem. Nuc. | 620 | 300 | 16 | 4 | 8 | P | 426 | 12 | 200 | - | 18.75 | 5467 |
| 2N/20E-28ad | Big Sky | 1000 | 50 | 0 | 1 | 155 | B | 498 | 16 | 500 | - | 50.0 | 13,176 |
| 2N/21E-11ad | Krebs | 729 | 20 | 7 | 2 | 6 | B | 605 | 6 | 522 | - | 2.86 | 740 |
| 2N/21E-22 | Hickerson | 101 | 15 | 10 | 1 | 8 | P | 46.5 | 8 | 101 | 50-85 | 1.5 | 342 |
| 2N/21E-30bd | Stone | 1325 | 838 | 191 | 8 | 12 1/4 | P | 647 | 10 | | 1300-1325 | 4.34 | 1165 |
| 2N/21E-31ab | Permanente | 185 | 200 | 44 | 4 | 8 | P | 92 | 8 | 185 | 142-184 | 4.55 | 1212 |
| 2N/22E-29ab | West | 590 | 1000 | 200 | 4 | 10 | P | 174 | - | - | - | 5.0 | 1314 |
| 2N/22E-32 | Davison | 200 | 304 | 15 | 4 | 8 | P | 25 | 8 | 104 | - | 20.27 | 5934 |
| 3N/18E-32d | Corps | 273 | 340 | 78 | 48 | 12 | P | 32 | 12 | 106.3 | - | 6.50 | 1286 |
| 3N/19E-23 | Brown | 425 | 3 | 15 | 1 | 6.5 | B | 425 | 6 | 20 | - | 0.20 | 40 |
| 3N/19E-36 | Gibbons | 50 | 15 | 5 | 1 | 8 | B | 30 | 6 | 50 | 30-50 | 3.00 | 718 |
| 3N/21E-21cc | Corps | 250 | 305 | 52 | 36 | 12 | P | 32 | 12 | 51 | - | 5.87 | 1731 |
| 3N/21E-36ab | PGE | 770 | 930 | 5 | 10 | 12 | P | 608 | 12 | 632 | - | 186.0 | 61,421 |
| 3N/21E-36ba | PGE | 787 | 840 | 3 | 12 | 12 | P | 609 | 12 | 590 | - | 280.0 | - |
| 4N/19E-17 | Seale | 866 | 7 | 20 | 2 | 6 | B | 574 | - | - | - | 0.035 | 79 |
| 1S/21E-11 | Olex School | 297 | 15 | 0 | 2 | 8 | B | 185 | 8 | 20 | - | 15.0 | 4151 |
| 2S/19E-20 | Van Rietmann | 830 | 7 | 0 | 1 | 6 | B | 684 1/2 | - | ND | - | 7.0 | 1837 |
| 2S/21E-15ca | Barnett | 610 | 10 | 109 | 1 | 6 | B | 484 | 6 | 23 | - | 0.092 | 18 |
| 2S/21E-21 | Barnett | 650 | 10.5 | 0 | 4 | 6 | B | 650 | - | ND | - | 10.5 | 3060 |
| 2S/21E-21cb | Barnett | 615 | 3 | 50 | 3 | 6 | B | 576 | 6 | 19 | - | 0.060 | 12 |
| 2S/22E-15ca | Warren | 276 | 2000 | 85 | 6 | 18 | P | 2.5 | ND | ND | - | 23.53 | 6483 |
| 2S/22E-15dc | Smith | 300 | 1000 | 35 | 12 | 12 | P | 60 | 12 | 37 | - | 28.57 | 8657 |
| 2S/22E-16aa | Pettejohn | 395 | 1500 | 294 | 1 | 10 | - | 26 | 16 | 70 | - | 5.102 | 1228 |
| 2S/22E-21db | Greib | 856 | 0.75 | 492 | 6 | 6 | B | 364 | 6 | 20 | - | 0.002 | 0.2 |
| 2S/22E-23 | Smith | 370 | 500 | 232 | 8 | 12 | P | 30 | 12 | 30 | - | 2.15 | 549 |
| 2S/22E-26bc | Smith | 558 | 300 | 115 | 6 | 10 | P | 11 | 12 | 65 | - | 2.61 | 675 |
| 2S/22E-26bd | Smith | 700 | 600 | 240 | 60 | 8 | P | 0 | 10 | 30 | - | 2.50 | 757 |
| 2S/22E-36 | Greib | 500 | 5 | 119 | 1 | 6 3/4 | B | 271 | 6 | 20 | - | 0.042 | 7 |
| 3S/20E-20aa | Nelson | 414 | 18 | 119 | 1.5 | 8 | B | 37 | 8 | - | - | 0.151 | 30 |
| 3S/20E-29 | Schott | 205 | 7.5 | 54 | 1 | 6 | B | 145 | 6 | 29 | - | 0.139 | 28 |
| 3S/21E-19 | Condon | 90 | 78 | 28 | 12 | 10 | P | 17 | 8 | 90 | 20-90 | 2.786 | 756 |
| 3S/21E-19 | Condon | 174 | 130 | 0 | 24 | 10 | P | 42 | 10 | 120 | 55-80 | 130.0 | 44,769 |
| 5S/20E-32 | Linnell | 91 | 150 | 20 | 1 | 12 | B | 0 | 10 | 91 | 20-91 | 7.50 | 1807 |
| 5S/21E-28cdb | Dyer | 573 | 180 | 75 | 8 | 6 | P | 225 | 10 | 250 | - | 2.40 | 669 |
| 5S/21E-28cdb | Dyer | 350 | 75 | 0 | 12 | 6 | P | ND | ND | ND | - | 75.0 | 25,562 |
| 5S/23E-20bc | Anderson | 252 | 25 | 99 | 1.5 | 6 | P | 138 | 6 | 20 | - | 0.253 | 54 |
| 5S/23E-36ad | Campbell | 97 | 170 | 67 | 1 | 10 | P | 18 | 10 | 25 | - | 2.53 | 581 |
| 5S/24E-31cb | Rodgers | 90 | 75 | 15 | 2 | 10 | P | 7 | 10 | 20 | - | 5.00 | 241 |
| 6S/21E-3 | Butler | 182 | 42 | 0 | 1 | 8 | B | 45 | 6 | 20 | - | 42.0 | 11,851 |
| 6S/24E-15ba | Edwards | 295 | 3.5 | 105 | 1 | 6 | B | 65 | 6 | 46 | - | 0.033 | 6 |
| 6S/24E-16bd | Edwards | 245 | 1 | 56 | 1 | 6 | B | 90 | 6 | 18 | - | 0.018 | 3 |

WELLS PRODUCING FROM COLUMBIA RIVER BASALT IN SHERMAN COUNTY IN THE JOHN DAY BASIN

| Location | Owner | Depth (feet) | Yield (gpm) | Draw-down (feet) | Time (hrs.) | Diameter (inches) | Test type | Static water level (ft) | Casing size (inches) | Cased depth (feet) | Perforated interval (feet) | Specific capacity (gpm/ft) | T ($10^{-4}$) $ft^2$/day |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1N/17E-28 | McDermid | 392 | 9 | 0.5 | 1 | 6 | B | 352 | 6 | 18 1/2 | - | 18.0 | 5000 |
| 1N/18E-6 | Kaseberg | 475 | 70 | 0 | 2 | 6 | B | 465 | 6 | 23 | - | 70.0 | 21,764 |
| 1N/19E-28 | Drinkard | 485 | 16 | 0 | 2 | 6 | B | 260 | 6 | 19 | - | 16.0 | 4593 |
| 1N/19E-32 | Furnish | 225 | 30 | 1 | 1 | 6.5 | B | 154 | 5 | 160 | - | 30.0 | 8503 |
| 2N/18E-20 | Schare | 675 | 50 | 675 | 2 | 6 | P | 400 | 6 | 128 | - | 0.074 | 15 |
| 2N/8E-26 | Fridley | 523 | 15 | 1 | 2 | 8 | B | 250 | 8 | 12 | - | 15.0 | 4151 |
| 3N/17E-23db | Corps | 158 | 300 | 5 | 72 | 8 | P | 12 | 8 | 143 | - | 60.0 | 21,404 |
| 3N/17E-27bc | Corps | 458 | 264 | 142 | 72 | 12 | P | 5 | 12 | 37 | - | 1.86 | 535 |
| 1S/16E-25 | Moore | 194.5 | 95 | 110 | 4 | 10 | P | 1 | 10 | 22 | - | 0.864 | 202 |
| 1S/16E-25 | Coelsch | 263 | 45 | 6 | 2 | 6 | P | 25 | 6 | 18 | - | 7.50 | 2061 |
| 1S/16E-34da | Powell | 415 | 10 | 360 | 2 | 10 | P | 20 | 10 | 21 | - | 0.028 | 5 |
| 1S/16E-35 | Powell | 420 | 15 | 4 | 2 | 6 | B | 210 | 6 | 100 | - | 3.75 | 988 |
| 1S/16E-35 | Powell | 413 | 25 | 2 | 2 | 6 | B | 300 | 6 | 100 | - | 12.5 | 3539 |
| 1S/16E-36 | Moore | 350 | 10 | 45 | 4 | 6 | B | 295 | ND | - | - | 0.222 | 47 |
| 1S/16E-36 | Olsen | 198 | 15 | 47 | 1 | 6 | B | 38 | 6 | 40 | - | 0.319 | 68 |
| 1S/16E-36d | Coelsch | 370 | 30 | 130 | 1 | 6 | B | 230 | 6 | 54 | - | 0.231 | 48 |
| 1S/17E-16 | Doma | 95 | 65 | 1 | 2 | 6 | B | 28 | 6 | 60 | - | 65.0 | 20,131 |
| 1S/17E-18ac | Moro | 390 | 140 | 8 | 2 | 10 | P | 280 | 10 | 21 | - | 17.5 | 4759 |
| 1S/17E-18ad | Moro | 605 | 220 | 50 | 7 | 8 3/4 | P | 200 | 8 | 28 | - | 4.4 | 1207 |
| 1S/17E-18db | Moro | 197 | 250 | 148 | 3 | 8 | P | 11 | 8 | 33 | - | 1.69 | 419 |
| 1S/17E-19 | Huffman | 180 | 60 | 100 | 1 | 6 | B | 91 | 6 | 18 | - | 0.60 | 133 |
| 1S/17E-19ab | Irzyk | 160 | 60 | 140 | 1 | 6 | B | 0 | 6 | 19 | - | 0.429 | 93 |
| 1S/17E-29 | Miller | 240 | 20 | 3 | 1 | 8 | B | 180 | 5 | 240 | 180-235 | 6.667 | 1682 |
| 1S/17E-29 | Miller | 90 | 60 | 0 | 1 | 6 | B | 22 | 6 | 50 | - | 60.0 | 17,834 |
| 1S/17E-29 | Miller | 97 | 50 | 0 | 1 | 6 | B | 24 | 6 | 40 | - | 50.0 | 10,715 |
| 1S/17E-5 | Coelsch | 170 | 20 | 40 | 1 | 6 | B | 99 | 6 | 33 | - | 0.50 | 110 |
| 1S/18E-14bb | Weedman | 237 | 10 | 40 | 1 | 8 | B | 270 | ND | ND | - | 0.25 | 50 |
| 1S/18E-18 | Thompson | 74 | 35 | 4 | 1 | 6 | B | 35 | 6 | 20 | - | 8.75 | 2328 |
| 1S/18E-18dc | Thompson | 233 | 300 | 123 | 2 | 8 | P | 68 | 8 | 19 | - | 2.44 | 612 |
| 1S/18E-22cb | Hattrup | 289 | 12 | 100 | 6 | 8 | P | 160 | 8 | 39 | - | 0.12 | 26 |
| 1S/18E-3 | Conlee | 208 | 10 | 10 | 1 | 6 | B | 188 | 6 | 18 | - | 1.0 | 231 |
| 1S/18E-3 | Conlee | 208 | 15 | 10 | 2 | 6 | B | 163 | 6 | 24 | - | 1.5 | 373 |
| 1S/18E-31ad | Olsen | 85 | 60 | 63 | 1 | 6 | B | 22 | 6 | 37 | - | 0.95 | 219 |
| 1S/18E-5ba | Boynton | 145 | 10 | 30 | 1 | 6 | B | 7 | 6 | 24 | - | 0.333 | 71 |
| 1S/18E-5bc | Boynton | 360 | 6 | 75 | 1 | 6 | B | 23 | 8 | 23 | - | 0.080 | 15 |
| 1S/18E-7 | Belshe | 240 | 15 | 20 | 1 | 6 | B | 90 | 6 | 20 | - | 0.750 | 169 |
| 1S/18E-7dd | Thompson | 525 | 10 | 0 | 1 | 10 | B | 285 | 10 | 257 | - | 10.0 | 2516 |
| 2S/16E-22 | Barnett | 290 | 30 | 2 | 3 | 6 | B | 239 | 6 | 58 | - | 15.0 | 4389 |
| 2S/16E-35 | Schilling | 100 | 20 | 10 | 1 | 6 | B | 74 | 5 | 100 | 70-100 | 2.0 | 484 |
| 2S/16E-35bc | Alberty | 126 | 20 | 12 | 1 | 6 | B | 79 | 6 | 39 | - | 1.67 | 398 |
| 2S/16E-8cd | Sherman Co. | 44 | 60 | 35 | 2 | 6 | B | 5 | 6 | 44 | - | 1.71 | 430 |
| 2S/17E-12da | Hart | 465 | 10 | 0 | 1.5 | 8 | B | 367 | 8 | 36 | - | 10.0 | 2655 |
| 2S/18E-31 | Smith | 357 | 8 | 7 | 1 | 6 | B | 320 | 6 | 33.5 | - | 1.4 | 266 |
| 2S/18E-3aa | Bull Trust | 339 | 4 | 30 | 1 | 6 | B | 261 | 6 | 38 | - | 1.33 | 26 |
| 2S/18E-5 | Frazen | 250 | 20 | 4 | 1.5 | 6 | B | 210 | 6 | 20 | - | 5.0 | 1318 |
| 2S/18E-5 | Frazen | 250 | 15 | 2 | 1 | 6 | B | 160 | 6 | 20 | - | 7.5 | 1977 |
| 3S/16E-10cc | Hartley | 126 | 135 | 70 | cont. | 8 | P | 51 | 8 | 10 | - | 1.93 | 547 |
| 3S/16E-10cc | Hartley | 106 | 140 | 50 | cont. | 10 | P | 51 | 10 | 10 | - | 2.8 | 791 |
| 3S/16E-12 | Trimble | 300 | 30 | 10 | 1 | 8 | B | 113 | 6 | 20 | - | 3.0 | 718 |
| 3S/17E-1ca | Eakin | 336 | 25 | 1 | 3 | 6 | B | 306 | 6 | 18 | - | 25.0 | 7521 |
| 3S/17E-20 | Alberty | 142 | 15 | 20 | 1 | 6 | B | 80 | 6 | 18 | - | 0.75 | 169 |

COLUMBIA RIVER BASALT GROUP IN SHERMAN COUNTY IN THE JOHN DAY BASIN

| Location | Owner | Depth (feet) | Yield (gpm) | Draw-down (feet) | Time (hrs.) | Diameter (inches) | Test type | Static water level (ft) | Casing size (inches) | Cased depth (feet) | Perforated interval (feet) | Specific capacity (gpm/ft) | T ($10^{-4}$) $ft^2$/day |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3S/17E-20 | Wilcox | 145 | 30 | 0 | 2 | 6 | B | 80 | 6 | 20 | - | 30.0 | 8917 |
| 3S/17E-23 | Eakin | 255 | 20 | 0 | 1 | 6.5 | B | 185 | 6 | 160 | - | 20.0 | 5707 |
| 3S/18E-33 | Brown | 340 | 20 | 0 | 1 | 8 | B | 265 | 6 | 19 | - | 20.0 | 5403 |
| 4S/17E-11 | Martin | 425 | 5 | 15 | 1 | 6 | B | 365 | 6 | 21 | - | 0.33 | 71 |
| 4S/17E-26cd | Justesen | 316 | 10 | 35 | 1 | 6 | P | 225 | 6 | 251 | - | 0.286 | 60 |
| 5S/17E-22 | McKay | 400 | 12 | 70 | 1 | 6 | B | 207 | 8 | 20 | - | 0.171 | 35 |
| 3S/17E-23 | Eakin | 255 | 20 | 0 | 1 | 6.5 | B | 185 | 6 | 160 | - | 20.0 | 5707 |
| 3S/18E-33 | Brown | 340 | 20 | 0 | 1 | 8 | B | 265 | 6 | 19 | - | 20.0 | 5403 |

WELLS PRODUCING FROM COLUMBIA RIVER BASALT IN THE JOHN DAY BASIN EXCLUSIVE OF GILLIAM AND SHERMAN COUNTIES

| Location | Owner | Depth (feet) | Yield (gpm) | Draw-down (feet) | Time (hrs.) | Diameter (inches) | Test type | Static water level (ft) | Casing size (inches) | Cased depth (feet) | Perforated interval (feet) | Specific capacity (gpm/ft) | T ($10^{-4}$) $ft^2$/day |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3S/23E-26 | Zinter | 183 | 1.3 | 183 | 16 | 8 | B | 105 | 8 | 18 | - | 0.007 | 1 |
| 4S/24E-20 | VanSchoiack | 160 | 250 | 80 | 6 | 10 | P | 6 | 10 | 44 | - | 3.125 | 818 |
| 5S/31E-14bd | Ukiah | 580 | 520 | 13 | 26 | 9 | P | 23 | 8 5/8 | 501 | - | 40.0 | 13,205 |
| 5S/31E-21ab | State Hwy. | 108 | 25 | 23 | 2.5 | 8 | P | 0 | 6 | 97.5 | 76.5-TD | 1.09 | 258 |
| 6S/16E-36 | Cunnion | 412.5 | 2.5 | 210 | 2 | 6 | B | 196 | 6 | 10 | - | 0.012 | 2 |
| 6S/16E-36ac | Cunnion | 412.5 | 2.5 | 210 | 2 | 6 | B | 196 | 6 | 10 | - | 0.01 | 2 |
| 6S/17E-21db | Justesen | 185 | 355 | 30 | 336 | 8 | P | 93 | 8 | 30 | - | 11.83 | 4204 |
| 6S/18E-20 | Black Rock | 145 | 7 | 18 | 2 | 6 | B | 96 | 6 | 19 | - | 0.39 | 2 |
| 6S/18E-20 | Black Rock | 145 | 7 | 18 | 2 | 6 | B | 96 | 6 | 19 | - | 0.389 | 88 |
| 6S/31E-33db | Pilot | 275 | 150 | 35 | 24 | 8 | P | 15 | 8 | 61 | - | 4.29 | 1311 |
| 8S/24E-34cc | Griggs | 245 | 25 | 140 | 1 | 6 | B | 26 | 6 | 49 | - | 0.18 | 36 |
| 8S/28E-30a | Kerns | 360 | 12 | 140 | 1 | 8 | B | 220 | 8 | 5 | - | 0.86 | 15 |
| 8S/31E-32 | McGrew | 50 | 12 | 15 | 1 | 6 | B | 15 | 6 | 34 | - | 0.800 | 182 |
| 9S/23E-8cc | McQuinn | 63 | 60 | 5 | 1 | 6 | B | 36 | 6 | 43 | - | 12.0 | 3253 |
| 9S/24E-6 | Hannen | 43 | 10 | 15 | 1 | 6 | B | 28 | 6 | 35 | - | 0.66 | 149 |
| 9S/25E-6ca | Garber | 100 | 5 | 30 | 75 | 6 | P | 30 | 6 | 20 | - | 0.17 | 45 |
| 9S/28E-24 | Kerns | 470 | 9 | 125 | 2 | 8 | B | 345 | - | - | - | 0.07 | 14 |
| 9S/29E-19 | Kerns | 365 | 20 | 3 | 1 | 6 | B | 335 | - | - | - | 6.66 | 1744 |
| 9S/29E-29c | Kerns | 486 | 8 | 289 | 1 | 8 | B | 175 | - | - | - | 0.03 | 5 |
| 9S/29E-30 | Kerns | 253 | 6 | 60 | 1 | 8 | B | 195 | 8 | 4 | - | 0.10 | 18 |
| 9S/30E-26ac | McGirr | 157 | 5 | 150 | 1 | 8 | B | 6.5 | 8 | 157 | - | 0.03 | 5 |
| 9S/31E-20 | Morogios | 60 | 4 | 20 | 2 | 6 | B | 35 | 6 | 18 | - | 0.20 | 43 |
| 11S/29E-25db | Bryant | 215 | 10 | 112 | 4 | 8 | P | 20 | 8 | 26 | - | 0.089 | 18 |
| 11S/29E-25db | Bryant | 215 | 10 | 112 | 4 | 8 | P | 20 | 8 | 26 | - | 0.089 | 18 |
| 11S/30E-20 | Johns | 165 | 10 | 79 | 9.5 | 6 | P | 0 | ND | ND | - | 0.13 | 30 |
| 11S/30E-20 | Johns | 165 | 10 | 79.5 | 9.5 | 6 | P | 0 | 8 | 15.5 | - | 0.126 | 29 |
| 13S/27E-3 | Driscoll | 157 | 150 | - | - | - | - | 0 | - | - | - | - | - |
| 13S/27E-3 | Driscoll | 115 | 42 | 9 | 1 | 6 | B | 0 | 6 | 29.5 | - | 5.25 | 1352 |
| 13S/29E-20bc | Perry | 190 | 6 | 139 | 1 | 6 | B | 60 | 6 | 190 | 90-190 | 0.04 | 8 |
| 13S/30E-27aa | State Hwy. | 155 | 200 | 16 | 4 | 6 | P | 6 | 6 5/8 | 155 | 106-156 | 12.5 | 3677 |
| 13S/31E-23bd | Canyon City | 185 | 1000 | 160 | 2 | 15 1/2 | P | 17 | 12 | 184 | 104-182 | 6.25 | 1506 |
| 13S/31E-23db | John Day | 250 | 876 | 100 | 14 | 11 3/4 | P | 0 | 12 | 59 | - | 8.76 | 2515 |
| 13S/31E-26db | Canyon City | 455 | 50 | 0 | 1 | 10 | P | 10 | 10 | 58 | - | 50.00 | 13,888 |
| 14S/31E-2dc | Sprouffske | 100 | 15 | 26 | 1 | 6 | P | 56 | 6 | 100 | 80-99 | 0.58 | 128 |

WELLS PRODUCING FROM THE STRAWBERRY VOLCANICS

| Location | Owner | Depth (feet) | Yield (gpm) | Draw-down (feet) | Time (hrs.) | Diameter (inches) | Test type | Static water level (ft) | Casing size (inches) | Cased depth (feet) | Perforated interval (feet) | Specific capacity (gpm/ft) | T ($10^{-4}$) $ft^2$/day |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11S/35E-21bc | Dow | 125 | 15 | 77 | 1 | 6 | B | 33 | 6 | 24 | - | 0.195 | - |
| 11S/35E-28ca | Oregon Lumber | 109 | 40-45 gpm artesian flow | | | - | - | 0 | 6 | 50 | - | - | - |
| 11S/35E-33 | Lawrence | 193 | 30 | 15 | 1 | 6 | B | 14 | 6 | 53 | - | 2.00 | - |

WELLS PRODUCING FROM THE JOHN DAY FORMATION

| Location | Owner | Depth (feet) | Yield (gpm) | Draw-down (feet) | Time (hrs.) | Diameter (inches) | Test type | Static water level (ft) | Casing size (inches) | Cased depth (feet) | Perforated interval (feet) | Specific capacity (gpm/ft) | T ($10^{-4}$) $ft^2$/day |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5S/26E-25 | Huey | 80 | 12 | 0 | 2 | 6 | B | 45 | 6 | 68 | - | 12.000 | 2161 |
| 5S/26E-32 | Olsen | 300 | 50 | 30 | 2 | 6 | B | 200 | 6 | 39 | - | 1.667 | 244 |
| 5S/26E-33 | McKinney | 88 | 30 | 0 | 1.5 | 6 | B | 62 | 6 | 88 | - | 30.0 | 5719 |
| 6S/21E-23 | Chambers | 495 | 100 | 0 | 1 | 6 | B | 180 | 6 | 350 | - | 100.0 | 20,392 |
| 6S/21E-31ac | Wilson | 394 | 30 | 150 | 2 | 10 | B | 29 | 6 | 387 | 180-385 | 0.20 | 18 |
| 8S/27E-33dc | Leathers | 27 | 10 | 15 | 1 | 10 | B | 10 | 10 | 27 | 20-27 | 0.677 | 67 |
| 8S/31E-5ab | Domas | 294 | 40 | 90 | 2 | 8 | B | 7 | 6 | 227 | 18-226 | 0.444 | 50 |
| 9S/26E-19db | Thomas | 582 | 25 | 2 | 1 | 6 | P | 22 | 6 | 41 | - | 12.500 | 2114 |
| 9S/26E-11 | Budke | 126 | 1 | 60 | 1 | 8 | B | 67 | 6 | 19 | - | 0.017 | 1 |
| 9S/26E-11 | Budke | 62 | 6 | 38 | 1 | 8 | B | 24 | 6 | 19 | - | 0.158 | 13 |
| 9S/27E-2bc | Wirf | 304 | 0.5 | 60 | 1 | 6 | B | 245 | 6 | 35 | - | 0.008 | - |
| 9S/27E-3ad | Plank | 134 | 2 | 130 | 2 | 6 | B | 30 | 6 | 20 | - | 0.15 | 1 |
| 9S/27E-7dd | Balcom | 176 | 5 | 176 | 1 | 8 | B | 137 | 6 | 176 | 127-176 | 0.028 | 1 |
| 9S/27E-12aa | Carl | 120 | 2 | 120 | 1 | 8 | B | 65 | 6 | 60 | - | 0.017 | 1 |
| 9S/28E-20 | King | 400 | 3 | 400 | 3 | 6 | B | 30 | 6 | 49 | 33-47 | 0.008 | 0.4 |
| 9S/29E-30 | Kerns | 253 | 6 | 60 | 1 | 8 | B | 195 | 8 | 4 | - | 0.100 | 7 |
| 10S/28E-8ac | King | 300 | 20 | 10 | 1 | 6 | B | 14 | 6 | 110 | 20-100 | 2.000 | 275 |
| 11S/26E-8cd | Florian | 90 | 30 | 5 | 1 | 6 | B | 53 | 6 | 86 | 56-86 | 6.000 | 940 |
| 11S/26E-8ca | Florian | 127 | 30 | 11 | 1 | 6 | B | 19 | 6 | 121 | 34-121 | 2.727 | 391 |
| 11S/26E-20bb | Holfman | 180 | 1.5 | 133 | 1 | 6 | B | 47 | 8 | 19 | - | 0.011 | 0.5 |
| 11S/26E-8cd | Florian | 96 | 70 | 40 | 8 | 6 | P | 4 | 6 | 46 | 20-46 | 1.750 | 299 |
| 11S/26E-8cd | Florian | 96 | 35 | 26 | 1 | 6 | B | 4 | 6 | 46 | 20-46 | 1.346 | 177 |

WELLS PRODUCING FROM THE CLARNO FORMATION

| Location | Owner | Depth (feet) | Yield (gpm) | Draw-down (feet) | Time (hrs.) | Diameter (inches) | Test type | Static water level (ft) | Casing size (inches) | Cased depth (feet) | Perforated interval (feet) | Specific capacity (gpm/ft) | T ($10^{-4}$) $ft^2$/day |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6S/21E-32da | Fossil | 800 | 1 | 800 | 4 | 6 | B | 260 | 12 | 40 | - | 0.001 | - |
| 6S/21E-29cb | Ostrander | 236 | 6 | 236 | 2 | 8 | B | 23 | - | - | - | 0.025 | 2 |
| 6S/21E-29ac | Stout | 115 | 30 | 20 | 1 | 6 | B | 30 | 6 | 80 | 6-80 | 1.500 | 223 |
| 6S/21E-30 | Wilson | 275 | 20 | 50 | 20 | 6 | B | 40 | 6 | 20 | - | 0.400 | 71 |
| 6S/21E-32 | Welsh | 110 | 12 | 89 | 1 | 6 | B | 12 | 6 | 63 | 23-43 | 0.135 | 14 |
| 6S/21E-32bd | Zachery | 138 | 4 | 75 | 1 | 6 | B | 63 | 6 5/8 | 98 | - | 0.053 | 5 |
| 6S/21E-32bd | Wilson | 83 | 5 | 83 | 1 | 6 | B | 22 | 6 | 84 | 50-84 | 0.060 | 6 |
| 6S/21E-33 | VanSwoll | 55 | 6 | 48 | 1 | 6 | B | 21 | 6 | 55 | 20-54 | 0.125 | 13 |
| 6S/21E-33 | Brooks | 35 | 2.5 | 33 | 1 | 8 | B | 2 | 6 | 18 | - | 0.076 | 6 |
| 6S/21E-33 | Rector | 100 | 5 | 0 | 2 | 6 | B | 17 | 6 | 35 | 20-35 | 5.0 | 902 |
| 6S/21E-33 | Munjar | 37 | 3.33 | 15 | 1 | 6 | B | 17 | 6 | 37 | 0-22 | 0.222 | 25 |
| 6S/21E-33bd | Dunn | 120 | 4 | 80 | 2 | 8 | B | 15 | 8 | 30 | - | 0.50 | 4 |
| 6S/21E-33ca | Wheeler Co. | 80 | 35 | 40 | 1 | 6 | B | 18 | 6 | 59 | 20-58 | 0.875 | 122 |
| 6S/21E-33cb | Miller | 35 | 5 | 0 | 2 | 6 | B | 12 | 6 | 35 | 20-35 | 5.0 | 902 |
| 6S/21E-33cc | Asher | 28 | 20 | 1 | 1 | 6 | B | 24 | 6 | 28 | 0-15 | 20.0 | 3843 |
| 6S/21E-33aa | Daley | 82 | 1 | 82 | 1 | 6 | B | 51 | 6 | 20 | - | 0.012 | 1 |
| 6S/21E-36cd | Wright | 100 | 88 | 0 | 1 | 6 | B | 12 | 6 | 83 | 20-82 | 88.0 | 19,077 |
| 6S/22E-27ca | Kinzua | 50 | 3 | 43 | 1 | 6 | B | 7 | 6 | 22 | 18-22 | 0.070 | 7 |
| 6S/22E-32cc | Hunt | 240 | 36 | 30 | 1 | 8 | B | 21 | 8 | 24 | 18-245 | 1.200 | 161 |
| 7S/32E-2a | USFS | 344 | 2.3 | 213 | 4 | 8 | P | 9.5 | 8 | 267 | 33-240 | 0.011 | 1 |
| 8S/18E-35cc | Rajneesh | 240 | 30 | 4 | 72 | 8 | P | 8 | 8 | 34 | 18-25 | 7.5 | 1779 |
| 8S/19E-22bd | Rajneesh | 55 | 10 | 22 | 1 | 6 | B | 26 | 6 | 50 | 35-55 | 0.45 | 58 |
| 8S/19E-27db | Rajneesh | 215 | 2.5 | 215 | 1 | 6 | B | 20 | 6 | 33 | - | 0.012 | 0.7 |
| 8S/19E-28aa | Rajneesh | 220 | 230 | 11.6 | 57 | 8 | P | 18.5 | 8 | 75 | 35-75 | 19.8 | 4916 |
| 8S/19E-32 | Rajneesh | 162 | 15 | 25 | 1 | 6 | B | 20 | 6 | 54 | - | 0.60 | 79 |
| 9S/19E-24 | Shrum | 40 | 20 | 3 | 1 | 6 | B | 18 | 6 | 37 | 20-35 | 6.667 | 1158 |
| 11S/19E-35 | Bear Cr. | 34 | 2 | 15 | 1 | 6 | B | 18 | 6 | 34 | 28-34 | 0.133 | 14 |
| 12S/34E-29ab | Ricco | 260 | 20 | 117 | 2 | 12 | B | 2.5 | 12 | 49 | - | 0.171 | 17 |
| 13S/33E-2db | Prairie City | 511 | 18 | 415 | 24 | 8 | P | 16 | 8 & 7 | 470 | 85-470 | 0.43 | 6 |

WELLS PRODUCING FROM PRE-TERTIARY MARINE SEDIMENTS AND VOLCANICS

| Location | Owner | Depth (feet) | Yield (gpm) | Draw-down (feet) | Time (hrs.) | Diameter (inches) | Test type | Static water level (ft) | Casing size (inches) | Cased depth (feet) | Perforated interval (feet) | Specific capacity (gpm/ft) | T ($10^{-4}$) $ft^2$/day |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10S/32E-2 | Brackengury | 44 | 5 | 20 | 4 | 6 | P | 10 | 6 | 28 | - | 0.250 | 36 |
| 10S/32E-11 | Taylor | 67 | 10 | 40 | 1 | 6 | B | 5 | 6 | 27 | - | 0.250 | 29 |
| 12S/33E-26cd | Prairie City | 710 | 200 | 290 | 48 | 8 | P | 0 | 7 | 710 | 680-705 | 0.690 | 131 |
| 13S/31E-33ab | Erickson | 210 | 20 | 30 | 1 | 8 | B | 65 | 8 | 19 | - | 0.667 | 82 |
| 13S/31E-33a | Tate | 48 | 35 | 6 | 48 | 8 | P | 7.5 | 6 | 47 | 25-45 | 5.88 | 1320 |
| 13S/31E-33aa | Robertson | 110 | 5 | 84 | 1 | 6 | B | 21 | 6 | 97 | 30-97 | 4.0 | 6 |
| 13S/31E-33dc | Jensen | 160 | 15 | 40 | 1 | 6 | B | 90 | 5 | 160 | 104-160 | 0.375 | 46 |
| 13S/31E-33aa | Robertson | 67 | 12 | 16 | 0.5 | 6 | B | 15 | 5 | 67 | 28-65 | 0.750 | 93 |
| 13S/31E-33 | Hunter | 107 | 12 | 35 | 1 | 6 | B | 55 | 6 | 107 | 20-106 | 0.303 | 42 |
| 13S/31E-33ab | Erickson | 162 | 25 | 35 | 1 | 6 | B | 32 | 5 | 160 | 40-150 | 0.714 | 97 |
| 13S/31E-33cc | Lyons | 101 | 30 | 25 | 1 | 8 | B | 19 | 5 | 101 | 20-101 | 1.20 | 161 |
| 13S/31E-33bd | Ledford | 107 | 15 | 12 | 1 | 6 | B | 48 | 6 | 20 | 90-107 | 1.25 | 181 |
| 13S/31E-33bd | Ledford | 71 | 20 | 18 | 1 | 6 | B | 36 | 5 | 71 | 48-71 | 1.11 | 159 |
| 13S/31E-33bd | Ledford | 140 | 15 | 40 | 1 | 8 | B | 85 | 6 | 140 | 85-140 | 0.375 | 42 |
| 13S/31E-33ab | Lyons | 60 | 15 | 20 | 1 | 8 | B | 18 | 6 | 60 | 40-60 | 0.750 | 95 |
| 13S/31E-33ab | Lyons | 100 | 20 | 5 | 1 | 8 | B | 20 | 5 | 100 | 30-100 | 4.00 | 621 |
| 13S/31E-34bd | Lyons | 80 | 15 | 20 | 1 | 8 | B | 20 | 5 | 80 | 30-80 | 0.75 | 95 |
| 15S/31E-11ab | Steagall | 188 | 30 | 18 | 2.5 | 6 | B | 5 | 8 | 12 | - | 1.67 | 277 |
| 17S/27E-21dd | Rodgers | 390 | 80 | 138 | 4 | 10 | P | 12 | 10 | 225 | - | 0.580 | 80 |

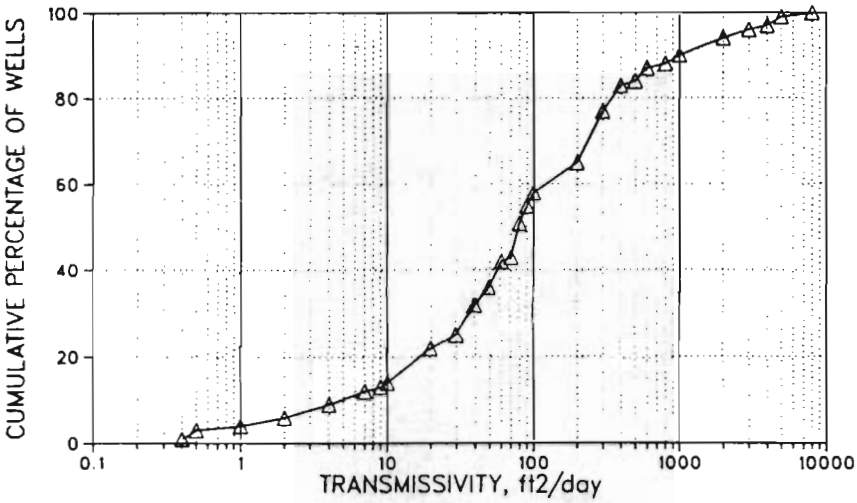
## Graphical Presentation of Well Data

In the following section, the distribution of yield, specific capacity, and transmissivity values are presented for each of the major aquifer units in the John Day Basin. The curves presented show the cumulative percentage of wells at or below a given yield, specific capacity, or transmissivity.

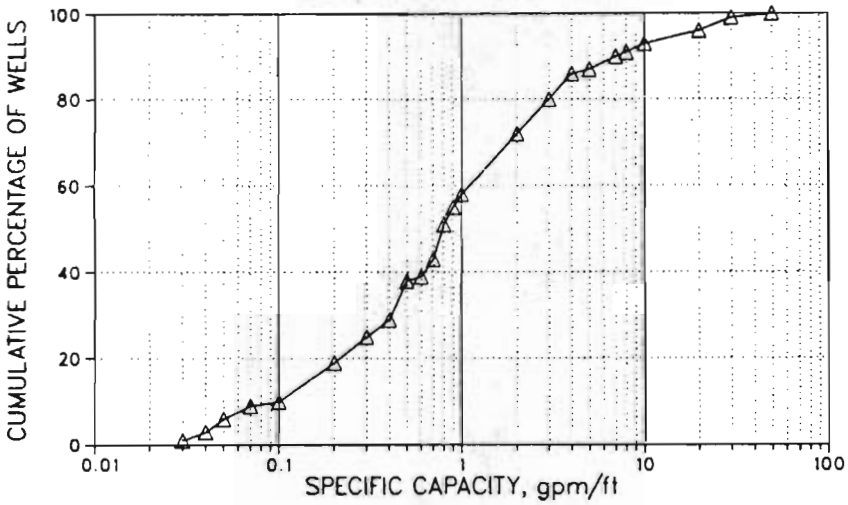
The curves enable the reader to quickly assess the data from many water well reports with one figure. One can, for example, quickly determine the range of values and the median value (the 50th percentile). In addition, the reader can see that 10 percent of the wells fall below a certain value, 10 percent fall above a certain value, and 80 percent of the wells fall between these two values.

The number of wells represented on the graphs for each unit is indicated next to the graphs.

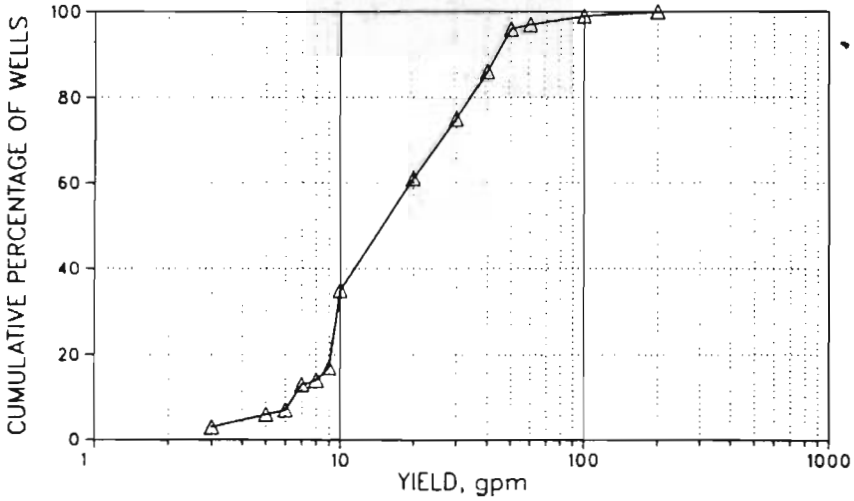
CUMULATIVE DISTRIBUTION, TRANSMISSIVITY
QUATERNARY ALLUVIUM




CUMULATIVE DISTRIBUTION, SPECIFIC CAPACITY
QUATERNARY ALLUVIUM

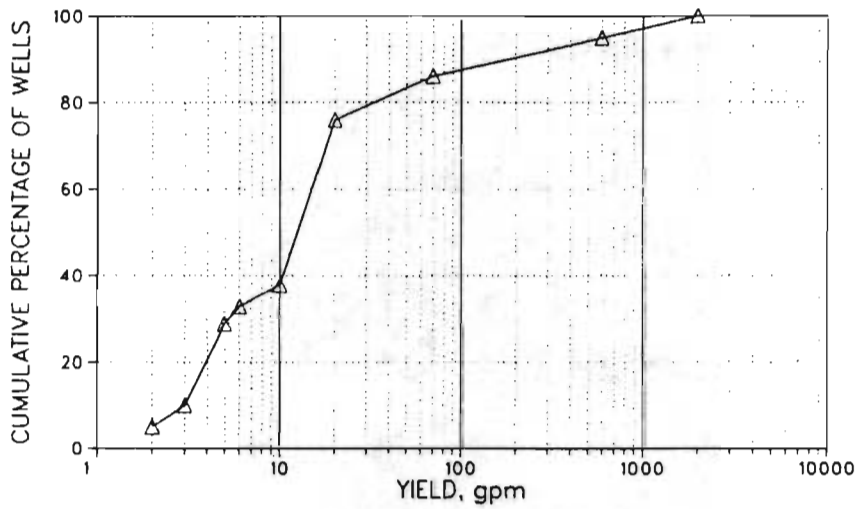



CUMULATIVE DISTRIBUTION, YIELD
QUATERNARY ALLUVIUM

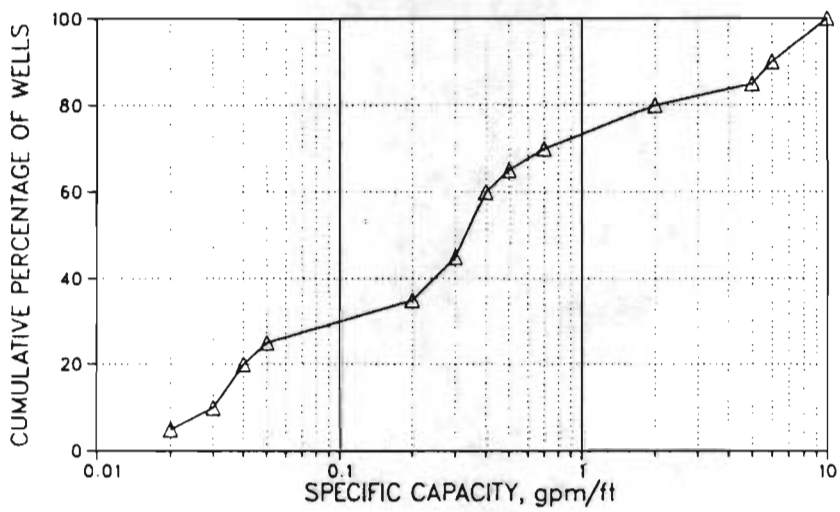



69 WELLS REPRESENTED

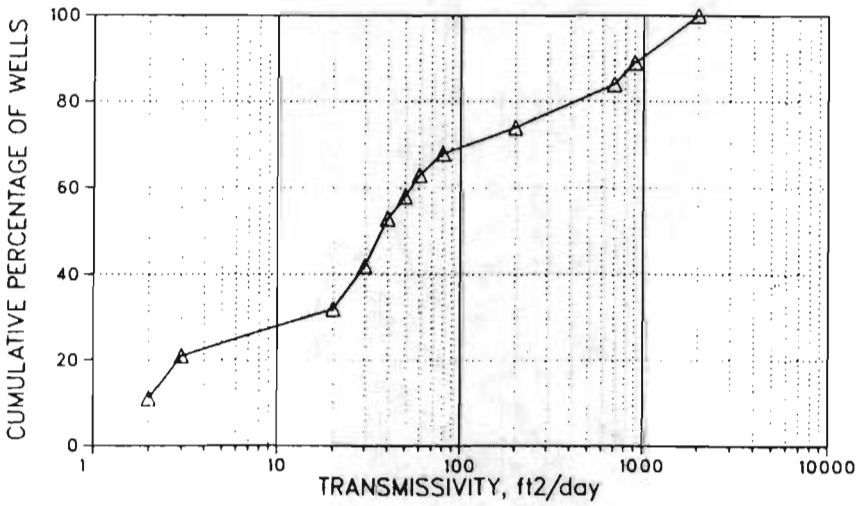
CUMULATIVE DISTRIBUTION, YIELD
RATTLESNAKE FM.




CUMULATIVE DISTRIBUTION, SPECIFIC CAPACITY
RATTLESNAKE FM.

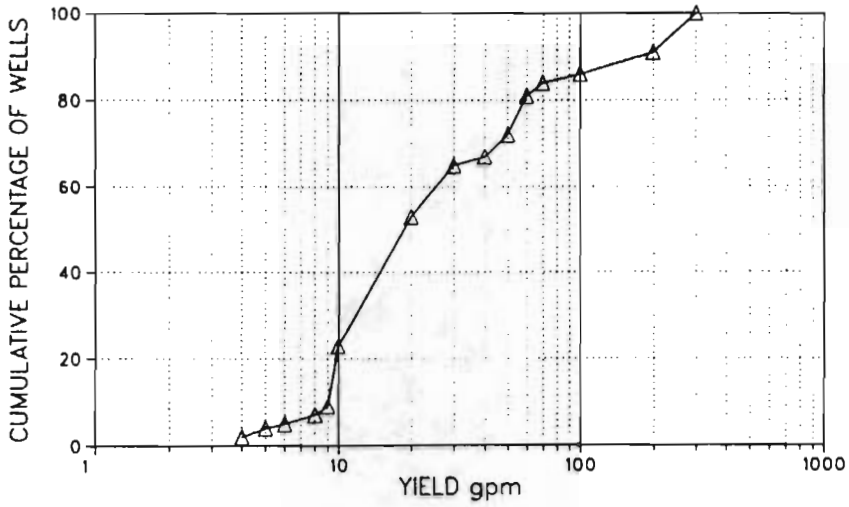



CUMULATIVE DISTRIBUTION, TRANSMISSIVITY
RATTLESNAKE FM.

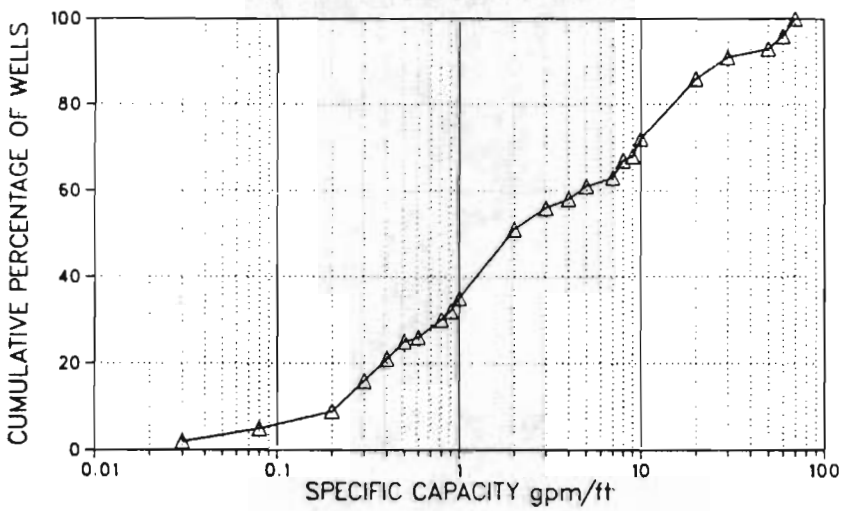



20 WELLS REPRESENTED

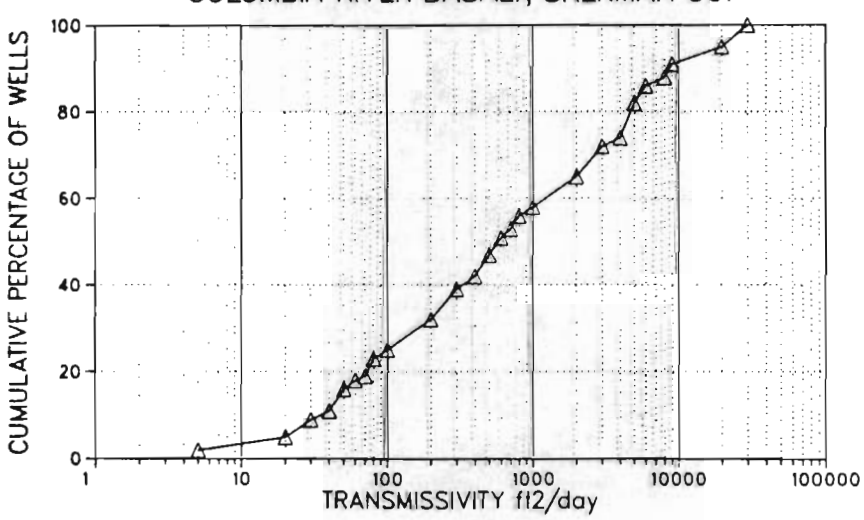
CUMULATIVE DISTRIBUTION, YIELD
COLUMBIA RIVER BASALT, SHERMAN CO.




CUMULATIVE DISTRIBUTION, SPECIFIC CAPACITY
COLUMBIA RIVER BASALT, SHERMAN CO.

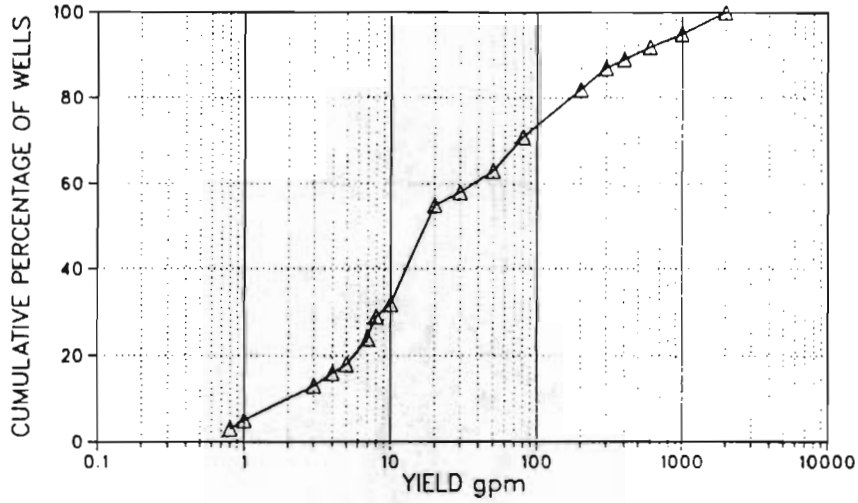



CUMULATIVE DISTRIBUTION, TRANSMISSIVITY
COLUMBIA RIVER BASALT, SHERMAN CO.

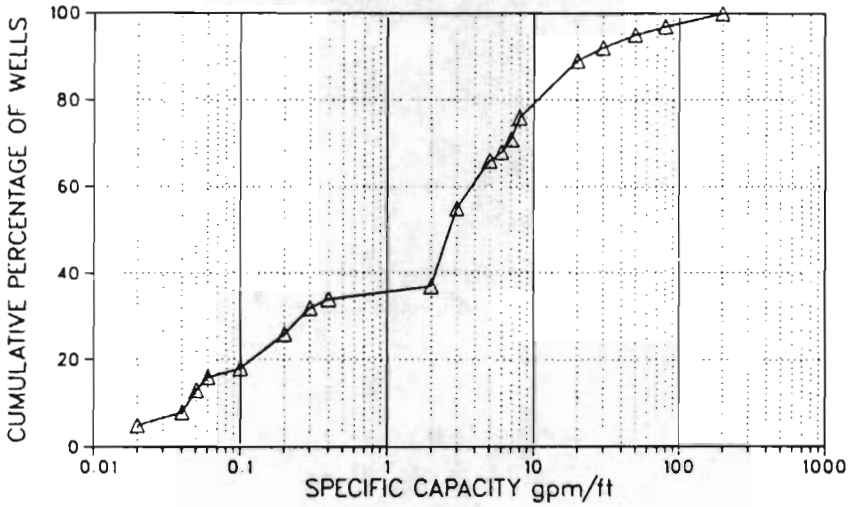



57 WELLS REPRESENTED

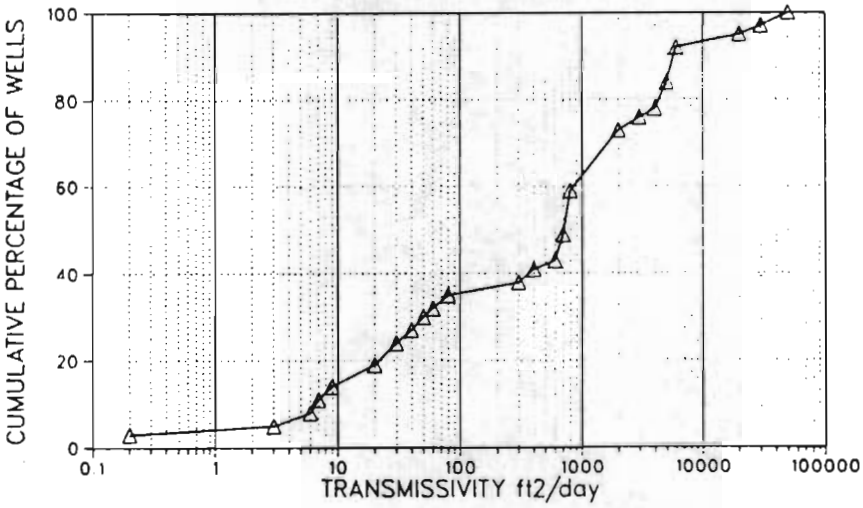
CUMULATIVE DISTRIBUTION, YIELD
WELLS LESS THAN 12 INCHES DIAMETER
COLUMBIA RIVER BASALT, GILLIAM CO.




CUMULATIVE DISTRIBUTION, SPECIFIC CAPACITY
WELLS LESS THAN 12 INCHES DIAMETER
COLUMBIA RIVER BASALT, GILLIAM CO.

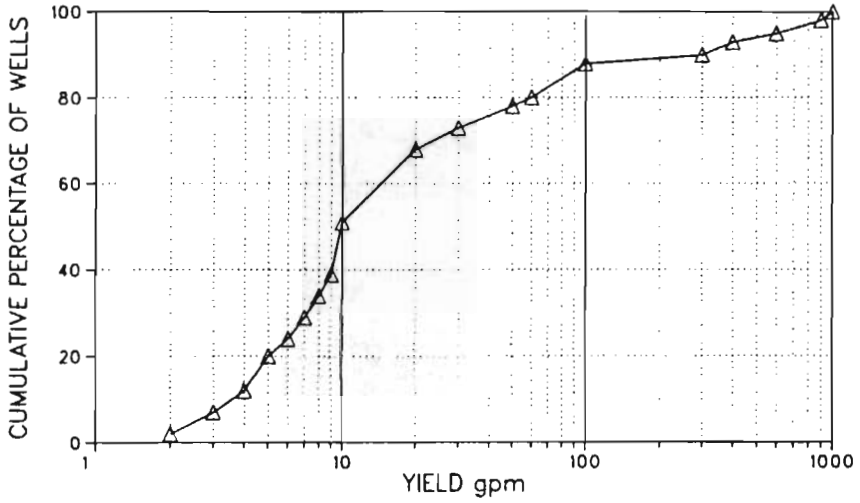



CUMULATIVE DISTRIBUTION, TRANSMISSIVITY
WELLS LESS THAN 12 INCHES DIAMETER
COLUMBIA RIVER BASALT, GILLIAM CO.

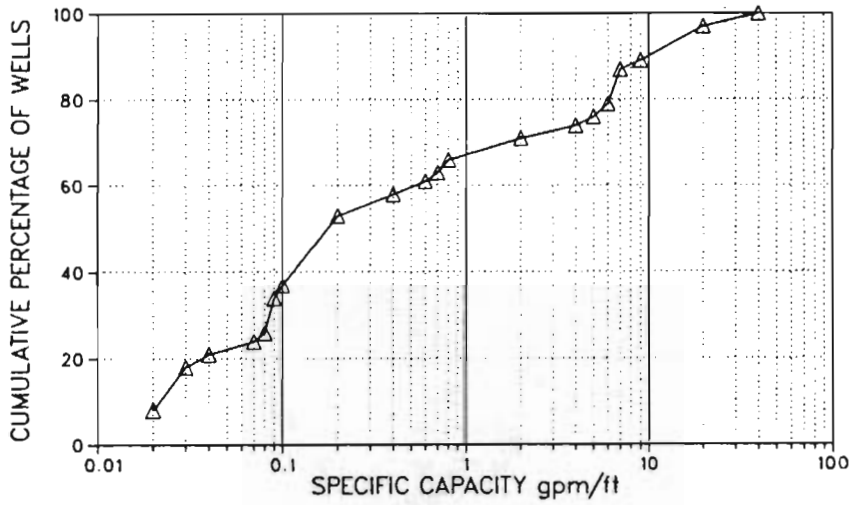



38 WELLS REPRESENTED

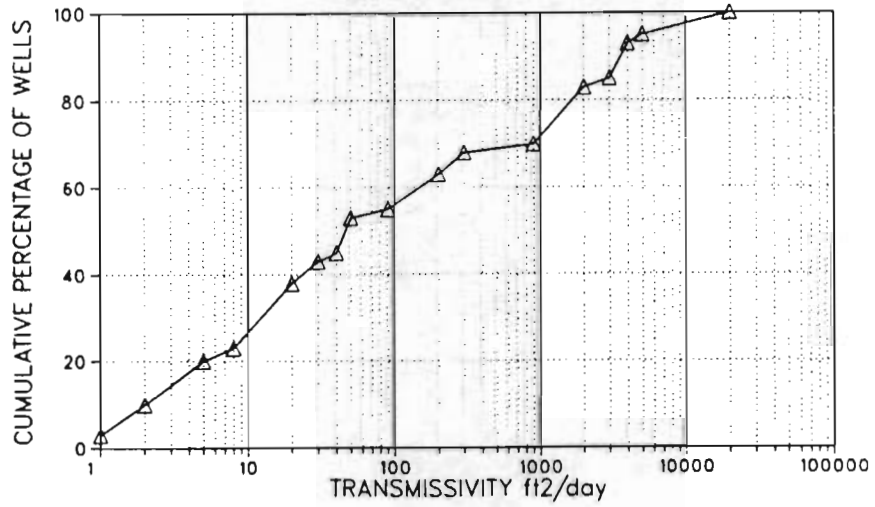
CUMUILATIVE DISTRIBUTION, YIELD
COLUMBIA RIVER BASALT
SOUTH OF THE BLUE MT. ANTICLINE




CUMULATIVE DISTRIBUTION, SPECIFIC CAPACITY
COLUMBIA RIVER BASALT
SOUTH OF THE BLUE MT. ANTICLINE

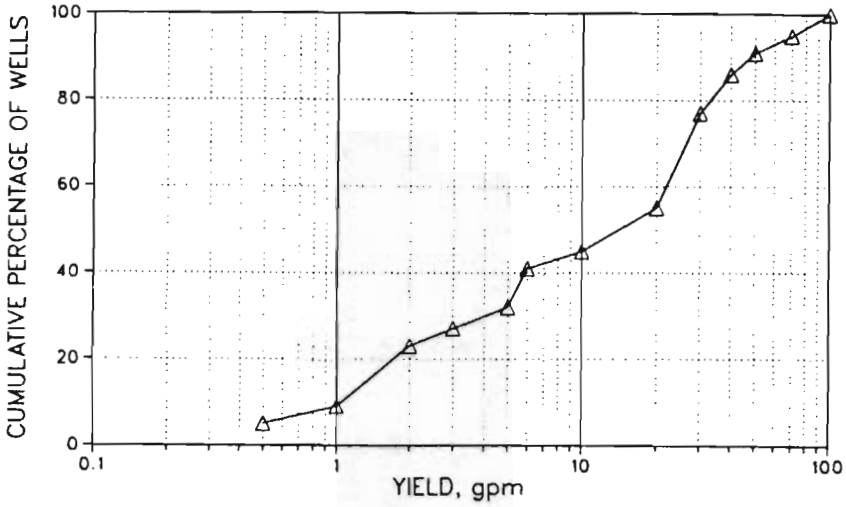



CUMULATIVE DISTRIBUTION, TRANSMISSIVITY
COLUMBIA RIVER BASALT
SOUTH OF THE BLUE MT. ANTICLINE

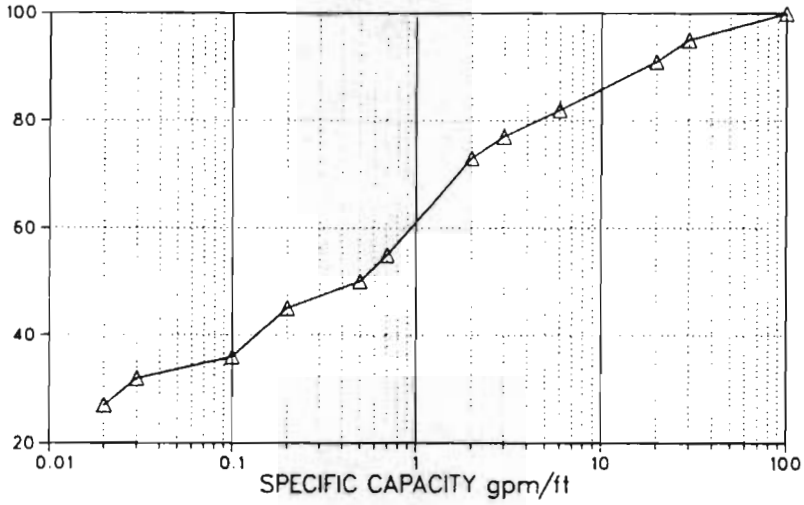



34 WELLS REPRESENTED

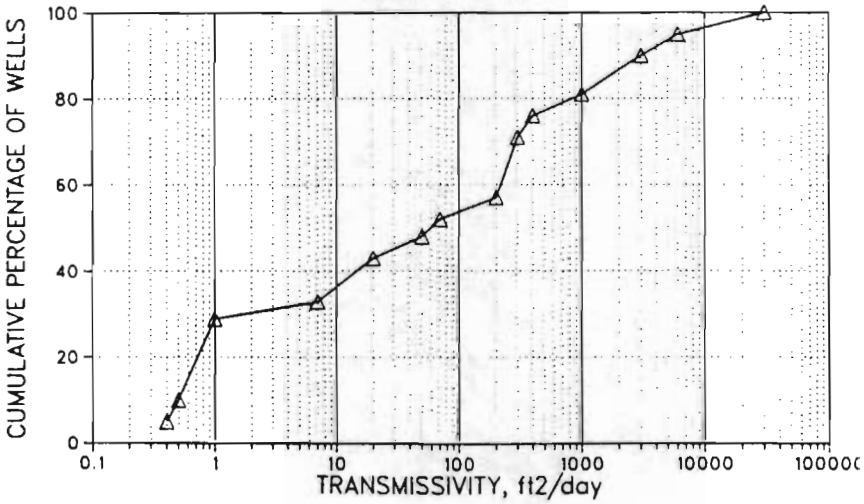
CUMULATIVE DISTRIBUTION, YIELD
JOHN DAY FM.




CUMULATIVE DISTRIBUTION, SPECIFIC CAPACITY
JOHN DAY FM.

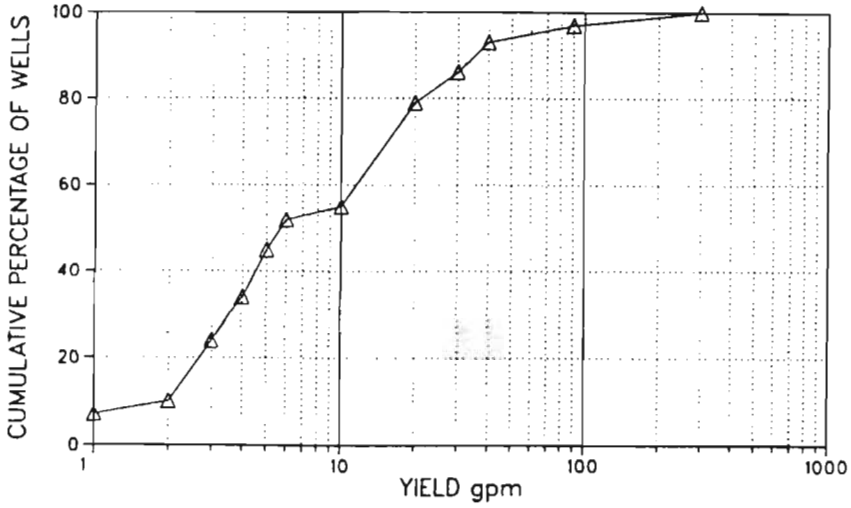



CUMULATIVE DISTRIBUTION, TRANSMISSIVITY
JOHN DAY FM.

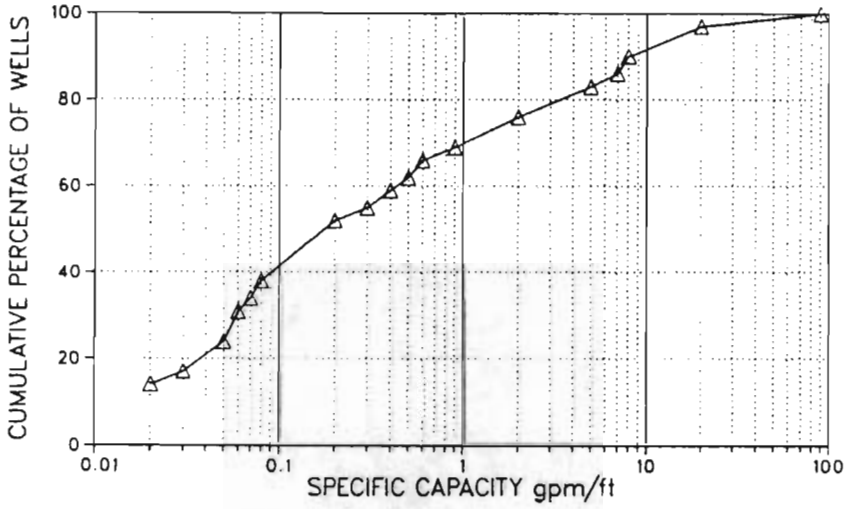



22 WELLS REPRESENTED

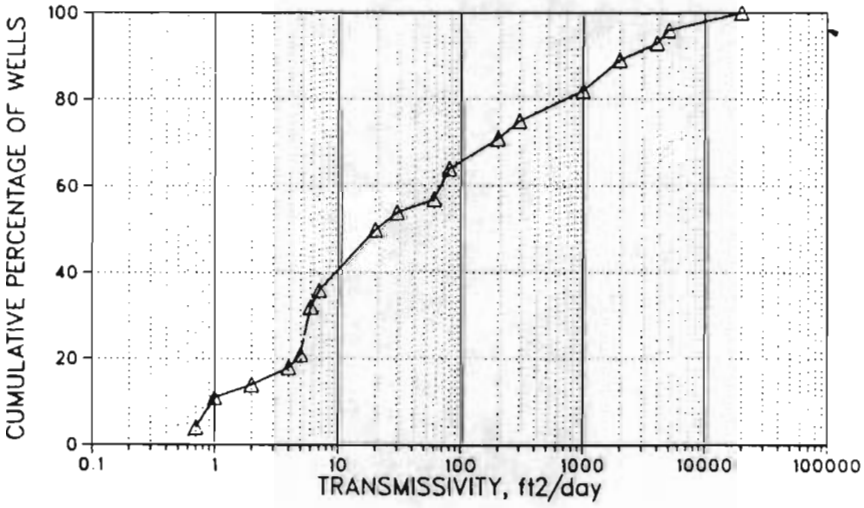
CUMULATIVE DISTRIBUTION, YIELD
CLARNO FM.




CUMULATIVE DISTRIBUTION, SPECIFIC CAPACITY
CLARNO FM.




CUMULATIVE DISTRIBUTION, TRANSMISSIVITY
CLARNO FM.

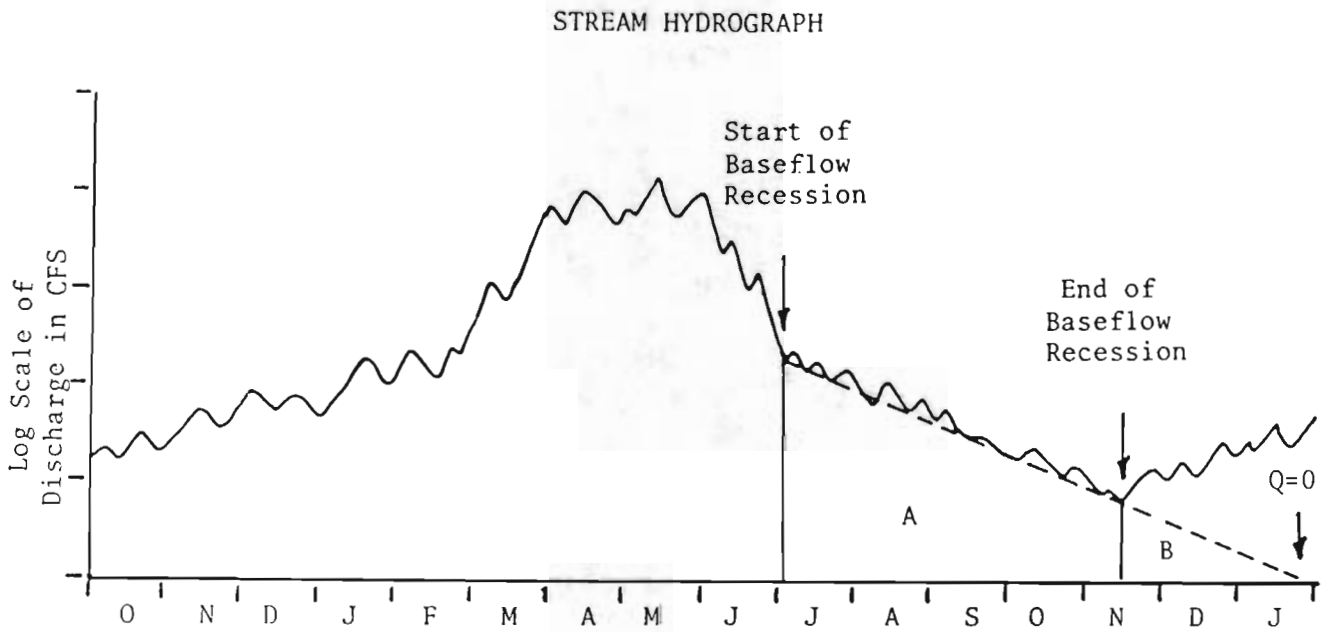



29 WELLS REPRESENTED

APPENDIX II

Recharge Estimates From Baseflow Analysis

The following method of estimating the annual change in storage is adapted from Fetter (1980) and Meyboom (1961).




The total potential discharge (Qtp) is the volume of water that would be discharged if a baseflow recession were allowed to proceed until discharge ceased. Qtp is represented in the figure above by the area A plus B.

$$Qtp = \frac{Qo\ t_1}{2.3}$$

Where Qo = the discharge at the beginning of the recession,
and $t_1$ = the time required for a decrease in discharge of one order of magnitude.

The potential discharge at the end of a baseflow recession (Qt) is represented by area B in the above figure.

$$Qt = \frac{Qtp}{10^{(t/t_1)}}$$

Where $t$ = the duration of the baseflow recession.

Assuming the basin response is linear, and that the ground water system is recharging before and after the baseflow recession, the annual change in storage can be calculated.

The difference between the potential discharge at the end of one baseflow recession (Qt) and the total potential discharge at the beginning of the next baseflow recession (Qtp) equals the change in storage in the ground water system between the two recessions.