Ground Water in the Pullman Area Whitman County, Washington

By B. L. FOXWORTHY *and* R. L. WASHBURN

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 1655

Prepared in cooperation with the State of Washington, Department of Conservation, Division of Water Resources

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1963

UNITED STATES DEPARTMENT OF THE INTERIOR

STEWART L. UDALL, *Secretary*

GEOLOGICAL SURVEY

Thomas B. Nolan, *Director*

The U.S. Geological Survey Library catalog cards for this publication appear after page 71.

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington 25, D.C.

CONTENTS

ILLUSTRATIONS

[Plates are in pocket]

TABLES

GROUND WATER IN THE PULLMAN AREA, WHITMAN COUNTY, WASHINGTON

By B. L. Foxworthy and R. L. Washburn

ABSTRACT

This report presents the results of an investigation of the ground-water resources of the Pullman area, Whitman County, Wash. The investigation was made in cooperation with the State of Washington, Department of Conservation, Division of Water Resources, to determine whether the 1959 rate of ground-water withdrawal exceeded the perennial yield of the developed aquifers, and if so, (1) whether additional aquifers could be developed in the area, and (2) whether the yield of the developed aquifers could be increased by artificial recharge.

The Pullman area includes the agricultural district surrounding the city of Pullman, in southeastern Whitman County, and the western two-thirds of the Moscow-Pullman basin, which extends into Latah County, Idaho. The mapped area comprises about 250 square miles.

The area is in a region of smooth rolling hills formed by erosion of thick deposits of loess, which cover a dissected lava plain. The loess (Palouse formation of Pleistocene age) ranges in thickness from less than 1 foot to more than 150 feet. The underlying lava flows, part of the Columbia River basalt of Tertiary age, are nearly horizontal and form bluffs and low cliffs along the major streams. The total thickness of the basalt sequence in the area is not known, but it may be considerably greater than 1,000 feet beneath the city of Pullman. The basalt sequence is underlain by a basement mass of granite, granite gneiss, and quartzite, of pre-Tertiary age.

The most productive aquifers in the area are in the Columbia River basalt. They consist of the permeable zones, commonly occurring at the tops of individual lava flows, which may contain ground water under either artesian or water-table conditions. Two such permeable zones have produced more than 95 percent of the ground water used in the Pullman area, or as much as 870 million gallons per year (1957). These two zones are hydraulically connected and lie at depths ranging from about 50 to 170 feet below the land surface at Pullman.

The area receives about 21 inches of precipitation annually, about two-thirds of it from October through March. Only a fraction of the precipitation reaches the aquifers; the remainder is returned to the atmosphere by evapotranspiration or leaves the area as surface runoff. The basalt is recharged mainly by infiltration from streams and downward percolation from the overlying loess.

The ground water moves generally westward. However, most water in the artesian aquifers tapped by wells in the vicinity of Pullman may move toward the city of Pullman, which is the center of major pumping. The rate of movement ranges from extremely slow in the loess and the massive basalt to very rapid in the permeable zones of basalt.

The principal modes of discharge from the artesian aquifers are seepage to streams and pumpage from wells. The amount of natural discharge is unknown, but the pumpage ranged from about 340 to 870 million gallons per year, and during 1949–59 it averaged about 800 million gallons (2,500 ac-ft) per year.

For about the last 25 years at least, the piezometric surface of the artesian zones has declined each year, indicating that the annual ground-water discharge from the artesian aquifers (including pumpage and natural discharge) has exceeded the recharge in the Pullman area. An analysis of the relation of pumpage to the decline in artesian level indicates that during 1952–59 an average of about 65 million gallons per year was removed from storage. Although the decline in artesian pressures has resulted in an increase in the recharge to the aquifers, the present rate of pumping may be equal to or even exceed the perennial yield of the artesian aquifer in the report area under natural conditions.

Geologic and hydrologic conditions seem favorable for the existence of potentially good aquifers below those which are now extensively developed. The deep aquifers seem to have only a slight hydraulic connection with the overlying artesian basalt aquifers.

The best possibility for artificially recharging the artesian aquifers seems to be through the injection of water from streams into one or more wells that penetrate the artesian zones. In such an arrangement, the well could be used alternately for recharge and pumping. One perennial and several intermittent streams are possible sources of recharge water. The stream water is similar in chemical quality to that from the artesian aquifers and so would be suitable for recharge, but removal of sediment would be required prior to injection.

INTRODUCTION

The first well drilled into the basalt artesian aquifers in the Pullman area probably was the M. C. True well, drilled in 1884. This well, according to I. C. Russell (1897, p. 80), tapped an artesian aquifer at a depth of about 65 feet and flowed at the surface. The success of this well led to the drilling of 14 more wells by 1896. Eleven of the 15 were flowing wells in the flood plain of the South Fork of the Palouse River, where the water was under pressure sufficient to raise it about 25 feet above the valley floor. The 4 other wells were on the slopes of the valley about 25 to 30 feet higher than the wells in the valley floor and did not flow.

In the Moscow area in Idaho, according to Russell, 14 wells were drilled between 1890 and 1896. The average depth of the wells was reported to be about 100 feet. Ten of the wells were flowing in 1891, but by 1896 the water levels had declined until they stood at depths of 8 to 9 feet below the land surface.

During 1935–37, the U.S. Geological Survey began periodic measurements of 6 artesian wells that penetrated basalt aquifers—4 at Pullman and 2 at Moscow. Measurements on 3 of these wells continued to 1959. Except for seasonal fluctuations, the water levels in all the wells have declined continuously, indicating that the yearly discharge of ground water from the artesian aquifers in both areas has consistently exceeded the yearly rate of replenishment.

PURPOSE AND SCOPE OF THE INVESTIGATION

Because of increasing concern regarding the continuing and accelerating decline of water levels in the Pullman area, the State of Washington, Division of Water Resources, in 1953 curtailed the approval of applications for withdrawal of additional ground water from the artesian zone. Before additional large withdrawals could be permitted, it was considered necessary to determine whether the rate of withdrawal exceeded the long-term yield, and if so, (1) whether there were additional aquifers that might be developed in the area, and (2) whether it might be feasible to increase the yield of the artesian aquifers by artificial recharge.

This investigation is part of a statewide cooperative ground-water program which was largely under the immediate supervision of M. J. Mundorff, of the U.S. Geological Survey until August 1956, and Robert H. Russell, of the Washington Division of Water Resources.

The fieldwork upon which this report is based was done chiefly by R. L. Washburn, under the immediate direction of B. L. Foxworthy, from October 1953 to November 1955. During that period the area was canvassed to obtain information on wells, and land-surface altitudes at the wells were determined by barometric traverses. A network of observation wells was established, and periodic measurements were made to determine water-level fluctuations. Samples of ground water were collected for chemical analysis, and the geology of the area was mapped.

Landforms, climate, and drainage, the geologic and geographic characteristics of the Pullman area are described in this report, because the occurrence of ground water is controlled or influenced by the geology.

LOCATION AND EXTENT OF THE AREA

The city of Pullman is in the southeastern part of Whitman County, in southeastern Washington. (See inset, pl. 1.) The city lies within a shallow physiographic basin (the Moscow-Pullman basin), which extends into Latah County, Idaho.

The Pullman area, as described in this report, is a ground-water subbasin constituting the western two-thirds of the Moscow-Pullman basin. Its total area is about 250 square miles. Apparently the Pullman area is hydraulically separate from the Moscow area or subbasin which occupies the eastern third of the basin. The investigation was carried to the physiographic divides on the north and south sides of the subbasin, westward to the vicinity of the town of Albion, and eastward to include a small part of Idaho surrounding Moscow (pl. 1).

WELL-NUMBERING SYSTEM

Well numbers used by the Geological Survey in the State of Washington are based on locations of wells according to the rectangular system for subdivision of public land, indicating township, range, section, and 40-acre tract within the section. For example, in the well number 14/45–5P1, the part preceding the hyphen indicates successively the township and range (T. 14 N., R. 45 E.) north and east of the Willamette base line and meridian. Because all townships in Washington are north of the Willamette base line, the letter "N.", indicating north, is omitted; and because most of the State is east of the Willamette meridian, the letter "E." is omitted for those ranges east of the Willamette meridian, but "W." is included for wells in Idaho, to indicate that they lie west of the Boise meridian.

The first number after the hyphen indicates the section (sec. 5), and the letter (P) gives the 40-acre subdivision of the section as shown in figure 1. The last number (1) is the serial number of the well in that particular 40-acre tract. Thus, the first well recorded

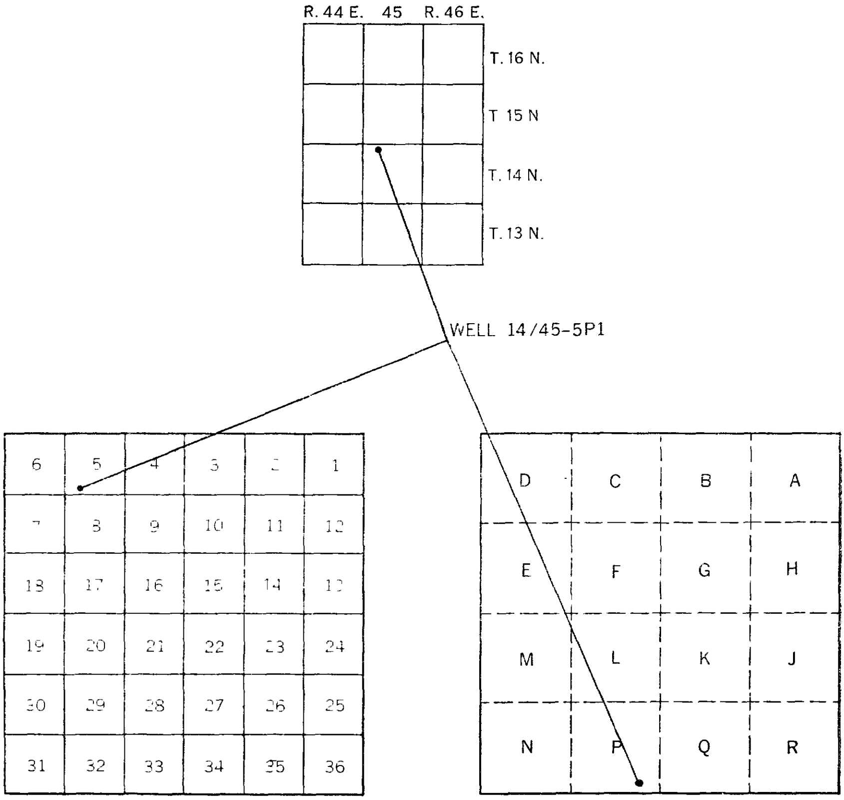


FIGURE 1. Well-numbering system.

in the SE¼SW¼ sec. 5, T. 14 N., R. 45 E., would have the number 14/45–5P1 (see fig. 1), and the second well would have the number 14/45–5P2.

Most of the wells referred to in this report are in Washington; consequently all of them are listed in table 1 according to the Washington system. In tables 1 and 2, where records of Idaho wells also are presented, township and range numbers are based on a different base line and meridian, as described above.

ACKNOWLEDGMENTS

The investigation was facilitated by many persons. Well data were supplied by owners, operators, and drillers in the area. City officials from Pullman and Moscow furnished records of pumpage and chemical analyses. Faculty members and officials of the Washington State University and the University of Idaho supplied similar helpful information. The assistance of all is gratefully acknowledged.

GEOGRAPHY

PHYSIOGRAPHY

The Moscow–Pullman basin is a shallow elliptical basin bordered on the north, east, and south by a broken horseshoe-shaped ring of mountains and hills of granite, gneiss, and quartzite. The physiographic divide on the east side of the basin is the crest of the Moscow Mountains, in Idaho. The northern margin of the basin is a semicircle of prominent hills, including Kamiak Mountain, the Ringo Hills, and Smoot Hill. A series of lower hills, including Bald Butte, marks the southern border. The basin is about 20 miles long from east to west and about 15 miles wide at the widest place.

The basin floor consists of a moderately dissected lava plain forming low rolling hills that have a thick cover of wind-deposited silt, or loess. These irregularly shaped rounded hills rise only 200 to 300 feet above the narrow intervening stream channels. From the air, the hilltops show a marked concordance, and if connected, they would form a fairly even surface having a gentle westward slope.

CULTURE AND INDUSTRY

The Pullman area is in a richly productive agricultural district whose principal product is winter wheat, grown by dry-land farming. The crops ordinarily are grown in alternate years. During the year between crops, the land is left fallow but cultivated for the dual purpose of controlling weeds and holding as much moisture in the soil as possible. Thus, a part of 2 years' precipitation is available to grow a single crop of wheat.

The only significant irrigation in the area in 1959 was done with water from three wells—well 14/44–34C1, owned by N. Hatley; well 14/45–4H1, owned by Washington State University; and well 14/45–8L1, owned by the Pullman cemetery.

Pullman and Moscow, the only incorporated cities in the Moscow-Pullman basin, are remarkably similar in several respects. For example, both are commercial centers in the same agricultural district, and both have universities whose faculty and students make up a considerable percentage of the populations. The two cities are similar in size, and have had roughly parallel population fluctuations during the past 15 years. Census figures for 1950, which include university enrollments, list populations of 12,022 for Pullman and 10,593 for Moscow.

CLIMATE

The climate of the Pullman area is transitional between typical grassland and woodland climates (Klages, 1942, p. 17). Precipitation averages 20.4 inches per year at Pullman but increases slightly toward the east and averages 22.2 inches per year at the University of Idaho, in Moscow (1932–52). Three-fourths of the precipitation falls from October through April and one-fourth from May through September, the growing season. Probably less than 20 percent of the precipitation is snow. The monthly distribution of precipitation at Moscow and Pullman is shown on figure 2.

The average temperature at Pullman during 1934–54 was 48.2°F. A high temperature of 102°F and a low of −29°F were recorded during 1934–59. Normally, July is the warmest month and January is the coldest.

No evaporation data are available from the Pullman weather station, but averages of a 4-year record of evaporation (1939–42) from Moscow are shown in figure 2.

DRAINAGE

The Pullman area is drained by one perennial stream and many intermittent ones. The perennial stream is Paradise Creek; all others are dry in late summer or early autumn.

Surface drainage in the area generally is to the west. The pattern of the smaller streams is dendritic, and there is no apparent control by joints or other structures in the underlying rocks. However, as can be seen on the 15-minute Pullman topographic quadrangle, the South Fork of the Palouse River and Union Flat Creek (southwest corner, pl. 1) have northwestward trending courses that closely parallel the nearby Snake River (south of map area). This parallel pattern suggests that the courses of these streams may be controlled to some extent by gentle flexures in the underlying basalt flows.

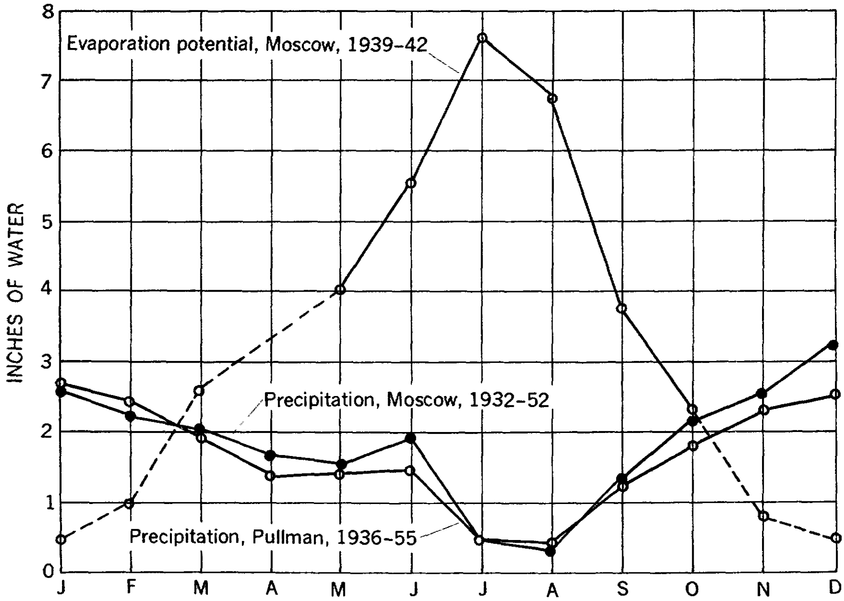


FIGURE 2.—Comparison of mean monthly precipitation at Moscow and Pullman, and monthly evaporation potential at Moscow. Averages for precipitation at Moscow for May through October are from Klages (1942); other values are estimated from records at other stations. Data for line representing evaporation potential are from Klages (written communication, 1954). Data for line representing precipitation at Pullman are from the U.S. Weather Bureau (1953, Climatological Data).

GEOLOGY

The occurrence, availability, and quality of ground water are governed largely by character of the rock materials, geologic structure, and topography as well as climate. Therefore, a knowledge of the geology is important in the study and understanding of ground-water resources.

The generalized surface geology of the Pullman subbasin is shown on plate 1, and the basalt exposures in the vicinity of Pullman are shown on plate 2. Geologic sections shown in plate 3 and figure 3 were constructed from data obtained from well logs and rock outcrops.

ROCK UNITS

PRE-TERTIARY ROCKS

The oldest rocks exposed in the Moscow-Pullman basin are quartzite, granite, and granite gneiss, all of pre-Tertiary age. They form the high hills and buttes encircling the basin on the north, south, and east and are the basement rocks throughout the area. In general, they are dense and nearly impermeable and, hence, are capable of yielding only small quantities of water to wells. However, at places they have been weathered to a considerable depth, forming permeable

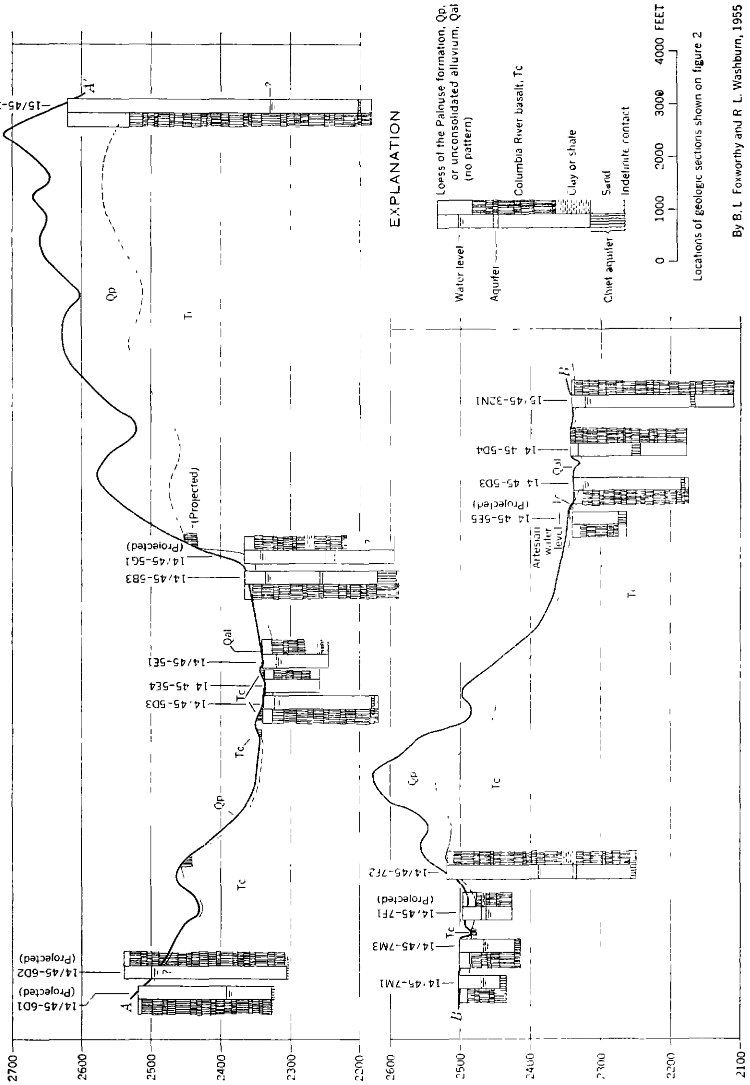


FIGURE 3.—Geologic sections in the vicinity of Pullman showing aquifers and water levels.

sand and grit which have considerable influence on the occurrence of ground water in the basin. The weathered material was the source for the sand, silt, and clay beds that are interbedded with the basalt; it is an important aquifer locally along the margins of the basin, where it underlies the basalt on the lower flanks of the crystalline rock hills; and it may act as a conduit through which precipitation on the high bordering hills migrates to the aquifers in the basalt.

Where the uppermost basalt flows abut the pre-Tertiary hills, the zone of weathering probably is thin, ranging in thickness from about a foot to a few feet. At most places the contact is covered by loess. Also, much of the weathered material contains appreciable amounts of clay and is only slightly or moderately permeable. These factors limit the effectiveness of the weathered zone as an intake area for ground-water recharge.

BASALT SEQUENCE

Basaltic lava overlies the crystalline rocks throughout the Moscow-Pullman basin. The basalt locally interfingers with sedimentary deposits derived from the crystalline rocks, especially along the margins of the basin. The basalt is part of the extensive sequence of lava flows of the Columbia River basalt of Miocene and early Pliocene(?) age, first described and named by I. C. Russell (1893, p. 20–22). The basalt flows are exposed principally along the flanks of valleys and subordinately in draws or gullies in the rolling upland. Basalt is exposed also at many quarries, borrow pits, and road cuts. Outcrops of more than one flow are uncommon; but 8 miles to the southwest, along the Snake River canyon, as many as 15 separate flows have been counted (Treasher, 1926, p. 310).

As usually seen in the Moscow-Pullman basin, the basalt is dense, medium gray to black on fresh surfaces, and light gray to brown where weathered. Locally the basalt is vesicular. Because ordinarily it is covered, zones of specific texture, color, or degree of vesicularity commonly cannot be correlated from place to place.

Nearly all the flows consist of two parts. The lower and thicker part is hard, dense, and usually massive, although the lower parts of some flows exhibit blocky or rough columnar jointing. Occasionally, widely scattered vesicles can be found in the lower zone. The upper part is generally 1 to 10 feet thick and highly vesicular, but the vesicles vary considerably in size and abundance. The upper zones usually are jointed and form small plates or closely spaced blocks and are highly weathered to a depth of several feet. These upper zones commonly are highly permeable, owing in part to the weathering and jointing, and they constitute the principal aquifers in the basalt sequence.

According to W. C. Warren (1941, p. 802), the Columbia River basalt consists principally of small crystalls of calcic labradorite, pyroxene, and olivine in a dense matrix of sodic labradorite, augite, and volcanic glass. Magnetite and apatite are common accessory minerals. Secondary vesicle fillings include zeolites, plagioclase, magnetite, siderite, calcite, limonite, and opal (Shannon, 1923, p. 5–19).

Most flows are 50 to 100 feet thick, but some only 10 to 15 feet thick have been reported in well logs; Fenneman (1931, p. 225) reported that some flows are more than 200 feet thick. Because outcrops are discontinuous and scattered, individual flows in the Moscow-Pullman basin cannot be traced far, but in the Snake River canyon some flows can be traced for several miles.

At a few outcrops, vertical or near-vertical clastic dikes, ranging in thickness from a few inches to several feet, extend down through the basalt. The dikes are fissures in the basalt that have been filled, probably from above, by sedimentary materials. The grain size of the fill material generally ranges from clay to sand, but in some places small pieces—less than 1 inch across—of platy gray or tan weathered basalt are included. The fill material commonly is light tan to gray, but it may be black, yellow brown, or green. The sand in most of the dikes is composed chiefly of quartz, biotite, and muscovite. It is impossible to determine how many flows are penetrated by the fissures or how far down they extend, for their vertical exposure is small. If the fissures extend to a considerable depth, they may be important locally as conduits for the downward percolation of ground water.

Some of the basalt flows are interbedded with sand, silt, or clay, although only two exposures of the sedimentary materials were found. One exposure in a road cut three-quarters of a mile east of Albion on the road to Pullman is about 20 feet thick. The upper 6 or 7 feet is clay, the top 3 or 4 feet of which has been baked by the heat of the overlying lava flow. The clay is underlain by about 14 feet of stratified silt and silty clay, ranging in color from light gray to yellow brown, and the silt and silty clay unit in turn is underlain by 5 or 6 feet of weathered vesicular basalt. The overlying basalt is vesicular and spheroidally weathered.

The second exposure of sedimentary material is at a road cut about three-quarters of a mile southeast of Pullman along the Moscow-Pullman highway. The sediments occur in the shape of a lens about 25 feet thick and 125 feet wide that cuts across at least one basalt flow. The lens consists of an unstratified matrix of clay, silt, and fine sand, interspersed with pebbles and cobbles of basalt. The material probably was deposited as a channel filling on an old basalt surface and was buried by subsequent lava flows.

Although no permeability tests were made on the sedimentary materials from the exposures just described, their general appearance indicates that movement of water through them probably would be slow.

Interbedded sediments ranging in thickness from 1 to 30 feet also have been reported in logs of wells in the area. The zones apparently are thickest and most numerous along the margins of the basin and become thinner and fewer toward the center, Most of these zones probably are irregularly shaped and discontinuous, as the altitudes at which they are penetrated vary widely from well to well, and commonly the logs of closely adjacent wells are greatly different. In many deep wells in the basalt, no interbedded sediments were penetrated. In others, beds of clay and shale reportedly yield little or no water, and beds of sand yield moderate amounts. Where clay and shale were penetrated, they are relatively impervious and reportedly yield little or no water to wells; where sand is penetrated, it yields moderate amounts of water.

Well logs and exposures indicate a marked accordance in the maximum altitude of flows. Generally this seems to be about 2,650 feet in the Pullman area. Several well logs show basalt at altitudes of 2,600 to 2,610 feet, and one questionable log for well 14/46-6R1 showed basalt as high as 2,661 feet. The highest exposure of basalt seen in the area was at a road cut in the SE¼NE¼ sec. 31, T. 14 N., P. 45 E., at an approximate altitude of 2,640 feet.

The upper surface of the basalt has been dissected by erosion and locally has been weathered to a depth of several feet. This zone of weathering may indicate a considerable period of exposure at the surface before the deposition of the overlying loess. On the basis of well logs and outcroppings of basalt in many roadcuts, the writers assume that many of the hills now covered by loess probably have low rounded basalt cores which may have the same general configuration as the land surface, although considerably more subdued. (See pl. 3 and fig. 3.)

In general, the basalt flows appear flat lying or nearly so. However, even though no measurable dip has been observed at outcrops, the flows may be gently warped. Structural control is suggested by the generally parallel, northwestward trends of several major streams (Snake River, Union Flat Creek, and South Fork of the Palouse River). The occurrence of ground water under considerable artesian pressure, not only in the Pullman area, but also at Johnson and at several places along Union Flat Creek, suggests structural troughs or basins. The fissures that contain the clastic dikes in the area probably are the result of earth movements which also would have caused some warping.

The Lewiston monocline, a zone of major faults and strong folding and one of the most impressive structural features in the region, is only about 20 miles south of Pullman. Such major earth movements probably would cause at least minor warping of the rocks for some distance from the main zone of movement. Because flexures in the area may bear strongly on the occurrence and movement of ground water, further detailed geologic mapping would be worthwhile.

The total thickness of the basalt in the center of the basin is unknown. Several wells drilled in and near Moscow, which is near the eastern margin of the lava, are reported to have penetrated the base of the basalt at depths ranging from 200 to 700 feet, where they entered either sedimentary beds or crystalline rock. The deepest penetration of the basalt near the center of the basin was in well 15/45–32N2, drilled by the city of Pullman in 1956, at an altitude of 2,340 feet. That well entered basalt at a depth of 18 feet and was drilled to a depth of 954 feet without reaching its base (table 2). The sequence of flows is thicker farther west, and about 2,000 feet of basalt is exposed in the Snake River canyon. The present slopes of the pre-Tertiary hills and the thickness reported in wells along the margins of the basin indicate that the total thickness of basalt beneath Pullman may be considerably more than 1,000 feet.

PALOUSE FORMATION

The entire basin, except for some stream valleys and the upper parts of the crystalline-rock hills, is mantled by a layer of loess. The loess, named the Palouse formation by R. C. Treasher (1925), is of Pleistocene age. It forms the smooth rolling surface that is typical of the region.

The Palouse formation is composed of tan or brown clayey silt, is very even textured, and at most places has no apparent bedding. It is compact and somewhat indurated, although it is easily cut with a shovel or hand auger.

Quartz is the principal constituent of the loess, but mica and feldspar also are abundant. Montmorillonite is a major constituent of the clay fractions, and Bryan (1927, p. 31 reported hornblende, garnet, apatite, tourmaline, and zircon as accessory minerals. In most samples, more than 90 percent of the grains were smaller than 0.05 mm in diameter.

In general, the loess is thickest on the tops of hills and thinner on the lower slopes and in draws. It ranges in thickness from less than 1 foot to more than 150 feet. Several wells reportedly penetrated 100 to 150 feet of the Palouse formation before reaching basalt, and well 14/44–3P1 was drilled to a depth of 176 feet without reaching basalt.

The loess is 300 feet or more thick in the central part of Whitman County, 10 to 15 miles west of the Moscow–Pullman basin, according Bretz (1928, p. 449).

The porosity of the loess is estimated to range from about 35 to 50 percent of the volume. The permeability of the Palouse formation is low, and water moves through it very slowly. Wells tapping the loess have small yields.

RECENT DEPOSITS

The youngest deposits in the area crop out chiefly in the valleys and consist of a mixture of reworked loess and weathered basaltic material of Recent age. At most places these deposits are difficult to distinguish from the Palouse formation. They are thin, generally less than 10 feet thick, but they yield water to a few shallow domestic wells.

At higher levels sand, silt, and clay, formed by decomposition of crystalline rocks, mantle the flanks of the bedrock hills. These deposits, also of Recent age, are of small extent and are important only as possible conduits for recharge of basalt aquifers from precipitation. However, their appearance indicates that their permeability generally is low.

GEOLOGIC HISTORY

At the beginning of the Miocene epoch, the area now known as the Moscow–Pullman basin was a deep valley eroded into a mountain mass of granitic and quartzose rocks. Drainage was generally to the west between two mountain ridges. This ancient landscape was largely buried during Miocene and early Pliocene(?) time by flows of the Columbia River basalt. The lava probably emanated from fissures west of the Pullman area and spread eastward, filling depressions and damming stream courses, until it was stopped by the mountains. As successive flows accumulated, mountain streams deposited sand, silt, and clay along the edges and out onto the surface of the flows. The lava flood rose to an altitude of about 2,650 feet, leaving several outliers of older granitic and quartzose rocks completely surrounded by basalt.

After the cessation of lava flow, the nearly level basalt surface was eroded to a region of low hills whose summits probably were not reduced appreciably below the level of the uppermost flow.

After this period of erosion, the region was covered by a thick deposit of loess, known as the Palouse formation. The loess probably was derived largely from outwash silt and clay of Pleistocene ice sheets that were north of the area. The mantle of loess gives the hills the unusual smooth rounded appearance that is typical of the topography developed upon the Palouse formation.

656185—62——2

OCCURRENCE OF GROUND WATER

The approximate limits of the Pullman ground-water subbasin are shown on plate 1. The ground-water divides on the north and south, and in part on the east, follow approximately the surface drainage divide. The subbasin probably is more open to the west, although the movement of ground water in that direction may be retarded somewhat by gentle flexures in the basalt.

Prior to this investigation it was generally believed that the confined aquifers in the Pullman area and in the Moscow area, Idaho, were parts of the same hydrologic system. However, the following lines of evidence indicate that the two areas probably are hydrologically separate. The ground-water barrier between Moscow and Pullman is inferred on the basis of significant differences in the altitudes and fluctuations of water levels in the two areas and differences in chemical character of the ground water. Those differences are described more fully in subsequent parts of this report.

In the Pullman subbasin, ground water occurs in the Recent alluvium, the Palouse formation, the Columbia River basalt, and the sedimentary materials derived from the pre-Tertiary rocks. At different places in the area, it occurs under artesian, perched, and water-table conditions (as defined by Meinzer, 1923).

Ground water in the Palouse formation commonly occurs under water-table conditions, but at places the loess contains perched ground water. The confining strata probably are either clay-rich layers in the loess or the top of the underlying basalt. At a few places, perched water occurs at more than one level in the area.

The Palouse formation is an important source of domestic and stock water in the rural areas, but individual well yields are small. Most water is pumped from large-diameter dug wells, although several of the largest springs in the area also are utilized. The sustained-pumping yields of wells in the loess probably range from a small fraction of a gallon to only a few gallons per minute, but the large diameter of the wells allows them to function as cisterns. Several hundred gallons of water may be pumped from these wells, and their levels will recover slowly between periods of pumping. Some wells whose yield is adequate during most of the year can be pumped dry in the late summer or autumn, when the water table is lowest.

Ground water in the basalt sequence, at altitudes above 2,300 feet, generally occurs under water-table conditions; below that level it occurs under artesian pressure. The upper parts of some basalt flows, which are relatively permeable because of vesicularity, fracturing, and weathering, constitute the chief aquifers. Small to moderate amounts of water are obtained also from the scattered sedimentary beds between flows.

Two permeable zones in the basalt apparently constitute the main aquifers in the Pullman area. The earliest artesian wells in Pullman, drilled before 1900, were completed in a water-bearing zone about 50 to 90 feet below the valley floor (alt 2,250–2,290 ft). Later wells penetrated another water-bearing zone 150 to 170 feet below the valley floor (alt 2,170–2,190 ft). Measurements of water levels over a period of many years in wells tapping both zones indicate that they are hydraulically interconnected.

In and around Pullman, water levels in nearly all wells that extend below an altitude of about 2,300 feet reflect the piezometric surface of the two aquifers. Water in the aquifers is confined under pressure sufficient to raise it above the tops of the aquifers but not sufficient to cause it to flow at the surface or even to raise it as high as the water table within most of the subbasin. However, in downtown Pullman the piezometric surface generally is less than 10 feet below the water table.

In the Pullman area the artesian aquifers underlie an area of at least 35 square miles. They extend northward from Pullman 5.5 miles (to well 15/45–10E1), northeast 4 miles (to well 15/45–26K1), south 2.5 miles (to well 14/45–16E1), and west 3.2 miles (to well 15/44–35E1). They undoubtedly are even more extensive in some directions, but no relaible data are available outside the Pullman area.

Ground water in the basalt sequence has been developed almost entirely from drilled wells. A few dug wells penetrate a short distance into the basalt, but the yields are small—probably no greater than a few gallons per minute.

The artesian aquifers are much more productive than the unconfined basalt aquifers in the area. Pumping yields as great as 1,800 gpm (gallons per minute) have been reported for one artesian well (14/45–5D1), and at least 9 other wells in the artesian aquifers have pumping yields of 100 gpm or more. Conversely, none of the wells in the unconfined basalt aquifers are reported to yield as much as 100 gpm, and most of them yield less than 50 gpm.

Along the east, north, and south margins of the area, ground water occurs in the weathered zone of the pre-Tertiary rocks and in the deposits of sand, silt, and clay interfingered with the basalt flows. The weathered mantle is poorly permeable, and the sedimentary strata generally are only moderately permeable. Wells penetrating these pre-Tertiary deposits yield small to moderate amounts of ground water, generally under artesian pressure. The most productive wells are along the southeast side of Smoot Hill, in and around Albion. Well 15/44–15A2, owned by the town of Albion, is reported to have a pumping yield of 90 gpm.

Most of the ground water is derived from precipitation within the Pullman subbasin. In addition, an average of about 17 cfs (cubic feet per second) of streamflow annually enters the Pullman subbasin from the Moscow subbasin; during at least part of the year some of that inflow contributes to the recharge of the basalt aquifers.

The average annual precipitation in the Pullman subbasin is about 21 inches; the surface inflow is approximately equivalent to another inch of precipitation. Surface runoff from the area (outflow minus inflow) is about 2 inches. Of that amount, more than 1 inch probably is direct runoff, and less than 1 inch represents seepage discharge from the aquifers. Evapotranspiration and recharge to ground-water bodies account for the remaining 20 inches; evapotranspiration undoubtedly accounts for the larger part. Of the total recharge, only a part replenishes the artesian aquifers of the Pullman area. The remainder enters the other aquifers—the Palouse formation, the unconfined basalt aquifers and the interbedded sedimentary materials, and any undeveloped artesian aquifers that exist in the basalt below the aquifers developed in the Pullman area.

RECHARGE

Aquifers in the Pullman area are recharged mainly by infiltration from precipitation and by influent seepage from streams.

The Palouse formation is recharged by direct infiltration from precipitation and by influent seepage from intermittent streams on the uplands which result from heavy rainfall or rapid snowmelt. Snowmelt probably contributes more recharge than rainfall and may contribute most of the recharge derived directly from precipitation.

The unconfined basalt aquifers are recharged almost entirely by downward migration of water from the overlying Palouse formation. Direct infiltration of precipitation through the basalt is small because exposures of the basalt are small.

The piezometric surface of the artesian aquifers tapped by wells at Pullman is below the water table (and the stream levels) in nearly all the area discussed in this report, and the artesian aquifers probably are recharged mainly by downward percolation of unconfined ground water from the overlying basalt and the Palouse formation. Water probably migrates through the dense basalt confining layers by widespread slow downward percolation through countless fractures, from one permeable zone to the next. Considerable recharge may infiltrate through larger fissures, such as those occupied by the clastic dikes, but these may be too scattered to transmit a large percentage of the recharge to the artesian aquifers.

The confined basalt aquifers undoubtedly are recharged additionally by infiltration along the many stream courses. However, the amount of this recharge also is unknown.

Most of the wells tapping the artesian aquifers at Pullman have casings extending only a few feet into the basalt. Some of the uncased basalt above the artesian aquifer may be water bearing and may contribute water to the artesian aquifer in the lower part of the well. The amount of downward leakage at each well depends mainly upon the thickness of the uncased saturated section above the artesian level and the permeability of that section. Because the yields of water-table wells in the basalt commonly are rather low indicating low permeabilities, the total downward leakage in the wells probably accounts for only a minute fraction of the total recharge to the artesian aquifers.

Some recharge probably takes place along the edges of the basin, where the basalt abuts the weathered surface of the pre-Tertiary rocks. It was suggested by Laney and others (1923, p. 4, 7) that most of the infiltration to the artesian zone takes place along the flanks of the pre-Tertiary hills, and that the water moves toward the center of the basin through sedimentary interbeds in the basalt. However, this mode of recharge probably is much more important in the Moscow subbasin than in the Pullman subbasin. In the Moscow subbasin, the sedimentary materials interbedded with the basalt are thick and extensive and constitute productive aquifers. Conversely, where the materials derived from weathering of the pre-Tertiary rocks are exposed along the edges of the Pullman subbasin, they are relatively thin and seem to be poorly permeable; where they are not exposed they are generally covered with loess, which is also of poor permeability. (See p. 15.) Thus, the intake capacity of the weathered material probably is small. Also, the records of wells in the Pullman subbasin indicate that the sedimentary interbeds are discontinuous and relatively thin, that they consist largely of clay, and that they generally do not constitute the principal aquifers in wells that penetrate them. (See pl. 3 fig. 3.) Therefore, the sedimentary interbeds are considered incapable of transmitting any large proportion of the water that is pumped from the artesian zone in the Pullman subbasin. This conclusion is supported by a comparison of the analyses of water from several wells in the subbasin that tap the basalt with water from well 15/44–15A2, which taps material derived from weathered pre-Tertiary rocks. As discussed subsequently in this report, those analyses show that the water from the weathered material is of a substantially different chemical character than the water derived from the basalt.

MOVEMENT

Drainage in the area generally is westward, and ground water probably moves in the same direction. Some of the ground water in the Palouse formation moves laterally toward ravines and valleys, in the same general direction as the surface drainage, and the remainder percolates downward to the basalt. Several aquifer tests have shown that movement in the Palouse formation is extremely slow—probably only a few feet per year under gradients of several hundred feet per mile. In general, vertical movement probably is slower than lateral movement, because at places clayey layers of very low permeability impede the downward migration of water in the loess.

Ground water in the basalt moves slowly downward by percolation through fractures in the massive parts of the flows and migrates laterally through the permeable zones toward areas of discharge. In the unconfined basalt aquifers, movement toward the stream channels is virtually continuous. During periods of rising stream levels, water from the stream channels may infiltrate a short distance into the unconfined aquifers. However, the net effect of that infiltration probably is negligible, as most of the water discharges back into the stream as the water level falls.

In most of the area to the east, north, and south of Pullman, ground water confined in the two principal artesian aquifers probably moves generally toward the city, which is the center of the main ground-water pumping. Ground water in aquifers west and northwest of Pullman probably moves predominantly toward the channel of the South Fork of the Palouse River, in the same general direction as the drainage. Water confined in at least the upper of the two principal aquifers probably is prevented from moving westward and southward by gentle flexures in the basalt flows that bring the aquifer above the altitude to which the artesian head will raise the water. In artesian aquifers below those intensively developed at Pullman, and perhaps in the lower of the two principal artesian aquifers at Pullman, ground water probably moves generally southwestward toward the canyon of the Snake River. Movement in deeper aquifers probably is not impeded, because the heads probably are sufficient to raise the water over minor upfolds.

DISCHARGE

Ground water is discharged by flow from springs or seeps, evaporation and transpiration, and withdrawal from wells. Springs or seeps discharge where a water-bearing zone or a joint system intersects the land surface. A seep or spring may discharge either upon the land or into a body of water. Water evaporates directly where the zone of saturation, or the capillary fringe above it, is at or near the surface.

Water is transpired by plants where their roots extend to a shallow zone of saturation or to the capillary fringe. Most wells in the area are pumped wells; only four (14/44–34C1, 14/45–35N1, 15/44–1N1, and 15/44–11F2) are known to have flowed during the period of this investigation.

Ground water is discharged from the Palouse formation mainly by springs and seeps. Hundreds of these seeps and small springs issue from the loess, and, although the individual discharges commonly are small, the sum probably amounts to a considerable fraction of the total ground-water discharge from the area. Most of the springs yield less than 1 gpm, and yields commonly dwindle to slow seeps or cease entirely during the summer. Some springs that issue from the Palouse formation may have their source in the underlying basalt.

Evapotranspiration constitutes a substantial part of the natural discharge from the Palouse formation. It prevails only where the water table is sufficiently close to the land surface that roots of plants can penetrate to the capillary fringe above the zone of saturation, or where water is evaporated directly from free-water surfaces or the capillary fringe.

The other forms of discharge from the loess are pumpage from wells and downward leakage to the underlying basalt. The migration into the basalt probably accounts for a substantial part of the total discharge from the loess; the withdrawal from wells in the loess is comparatively small.

Besides the general downward leakage to the deeper aquifers, ground water is discharged from the unconfined basalt aquifers principally by seeps and springs either at the land surface or in streams. Withdrawals from wells account for an additional, but smaller, fraction of the total discharge from these aquifers. Evapotranspiration from the basalt is negligible because the water table lies at a shallow depth in the basalt in only a small area.

The upper artesian aquifers may discharge to the channel of the South Fork of the Palouse River, where the channel is lower than the general piezometric surface. However, within the Pullman subbasin, the only reach of the South Fork that is lower than the piezometric surface is between Pullman and Albion. (See pl. 1.) The deeper aquifers tapped by well 15/45–32N2 and perhaps the lower of the two principal aquifers probably discharge to the canyon of the Snake River.

In the uppermost part of the principal artesian aquifers, ground-water movement toward and discharge into the Snake River are probably prevented by gentle flexures in the basalt flows.

Natural discharge from the confined basalt aquifers probably does not vary greatly from season to season. Seemingly, the only factors that could appreciably affect the discharge are fluctuations of the artesian head and perhaps fluctuations of the water table and stream levels in the area of discharge. Presumably, fluctuations caused by variations in recharge to and pumping from the artesian zone would cause only slight changes in the hydraulic gradient toward the discharge area. The effects of water-table and stream-level fluctuations in the discharge area probably also are minor. At any rate, the artesian levels are highest when the water table and stream levels are highest; so the effects would be somewhat counterbalanced.

Withdrawals from wells may constitute the largest element of ground-water discharge from the two principal aquifers. Of the estimated total pumpage in the area, more than 95 percent comes from the artesian basalt aquifers.

Pumpage from the artesian aquifers during 1936–44 and 1949–59 is shown in the following table. In addition to the amounts shown, it is estimated that less than 5 million gallons (15 ac-ft) per year was developed from the unconfined basalt aquifers and less than 2 million gallons (6 ac-ft) per year from the Palouse formation. Ground water from the nonartesian aquifers is used almost exclusively for domestic and stock purposes.

Pumping withdrawals, in millions of gallons, from the artesian aquifers of the Pullman area [1]

Calendar year [2]	User			Total
	City of Pullman	Washington State University	Other [3]	
1936	175	176	30	381
1937	156	154	30	340
1938	163	163	30	356
1939	179	179	30	388
1940	208	166	30	404
1941	165	154	30	349
1942	193	176	30	399
1943	175	188	30	393
1944	181	184	30	395
1949	367	341	50	758
1950	348	335	49	732
1951	389	371	48	808
1952	361	414	47	822
1953	351	347	85	783
1954	339	311	45	695
1955	394	346	53	793
1956	405	399	53	857
1957	431	385	54	870
1958	419	393	54	866
1959	383	411	52	846

[1] Figures prior to 1952 are after M. C. Jensen (written communication, 1952).
[2] No record for 1945–48.
[3] Includes domestic, industrial, irrigation, railroad, and stock uses.

As shown in the table, the average ground-water withdrawal during 1949–59 was about 800 million gallons (2,500 acre-feet) per year. About 60 percent of the total is pumped during the 6 warmest months (April through September), and about 40 percent is pumped during the rest of the year. Pumping during the summer varies considerably with the amount of summer precipitation.

WATER-LEVEL FLUCTUATIONS

Fluctuations of the piezometric surface and the water table have been studied by means of periodic measurements of water levels in observation wells. During 1936–37, the Geological Survey began measurements in 6 wells that penetrate basalt aquifers in the Moscow-Pullman basin. Of these, 4 are in or near Pullman and the other 2 are in Moscow. In addition, during that same period, several shallow wells in the Palouse formation were measured (Rockie and others, 1938). At the beginning of the present investigation (1953), measurements were begun on 14 additional observation wells in the Moscow-Pullman basin. Hydrographs of these observation wells are shown in figures 4 to 10.

As far as the Pullman artesian aquifers have been traced, their piezometric surface (as defined by Meinzer, 1923, p. 38) is nearly flat. Altitudes of the water surfaces in the wells, obtained by barometric leveling, indicate that the slope of the piezometric surface probably is nowhere steeper than about 20 feet per mile. Its altitude at the end of 1959 was 2,320 feet at Pullman, although it had been declining at a rate of 0.5 to 1.5 feet per year. When water-level measurements were started by the Geological Survey in 1936, the altitude of the piezometric surface at Pullman was about 2,340 feet. During 1936–45, it declined at an average rate of 5 to 9 inches per year. Beginning about in 1946, the decline accelerated to an average of about 21 to 22 inches per year until the end of 1951. Since 1951 the decline at Pullman has averaged 10 to 13 inches per year.

Apparently the piezometric surface in the Moscow area also is relatively flat, but it is about 158 feet higher than at Pullman, or at about 2,480 feet. The artesian aquifers at Moscow apparently extend westward to well 15/46–20P1; that well, which is about a quarter of a mile west of the Idaho–Washington boundary and 3.3 miles northwest of Moscow, has about the same water level as the Moscow artesian wells. Thus, the easternmost artesian well of the Pullman subbasin (15/45–26K1) is only 3 miles west of the westernmost artesian well of the Moscow subbasin. The position of the ground-water divide shown between the two subbasins on plate 1 was inferred largely on the basis of the water levels in those two wells.

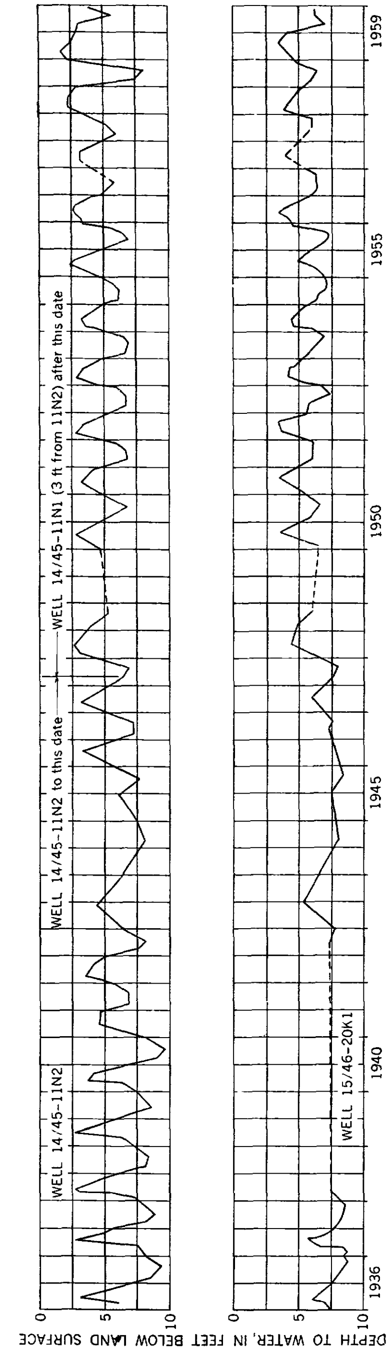


FIGURE 4.—Hydrographs of wells 14/45-11N1, -11N2, and 15/46-20K1, showing fluctuation of water table in the Palouse formation.

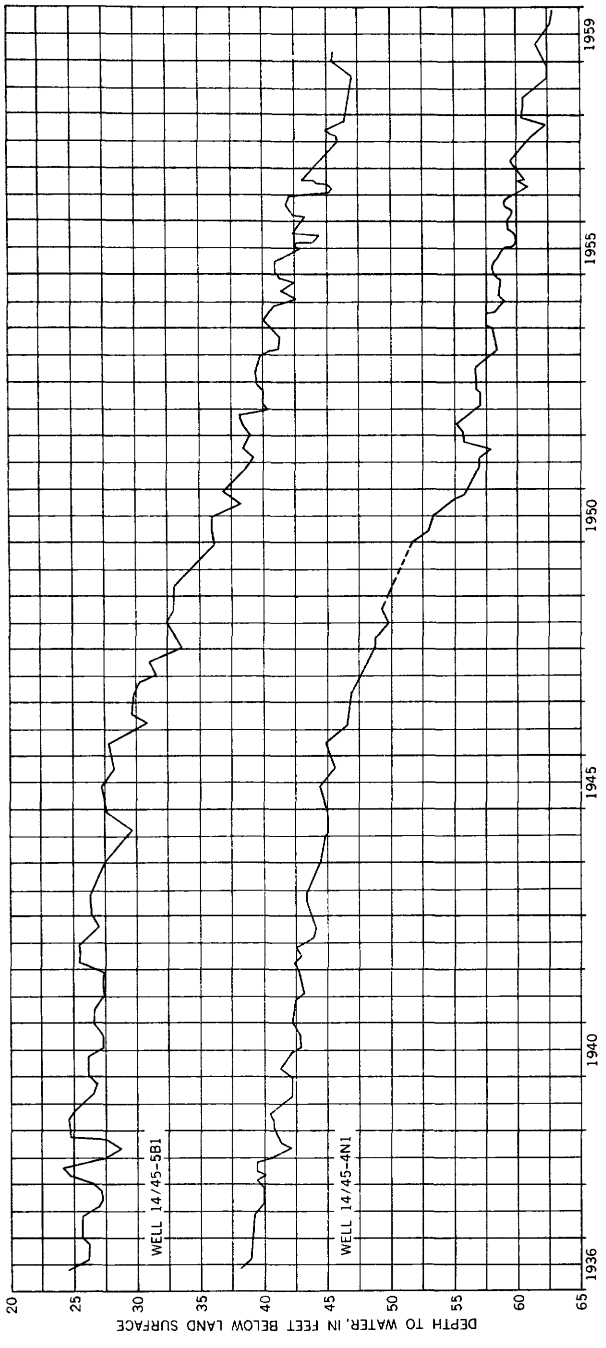


FIGURE 5.—Hydrographs of wells 14/45-4N1 and -5B1, showing fluctuation of water level in the principal artesian aquifers in the Pullman subbasin.

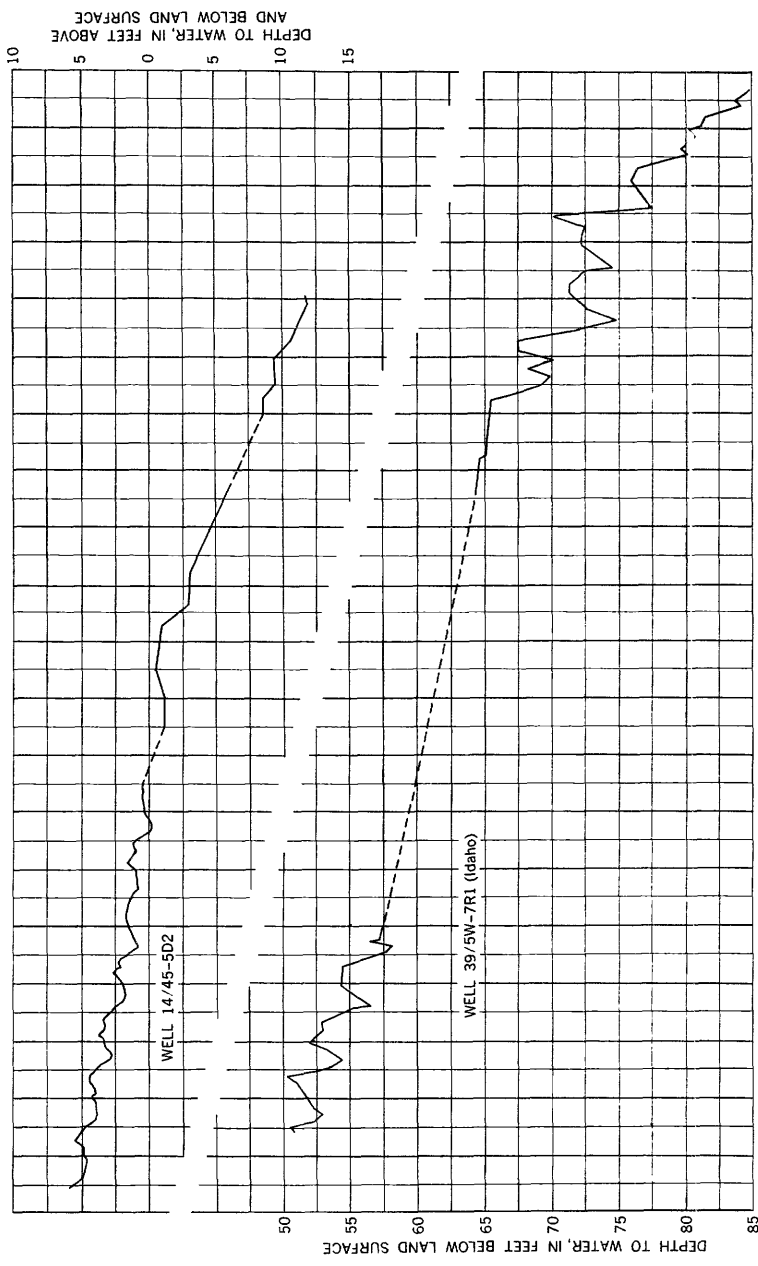


FIGURE 6.—Hydrographs of well 14/45-5D2 in the Pullman subbasin and 39/5W-7R1 in the Moscow subbasin, showing progressive decline in water level.

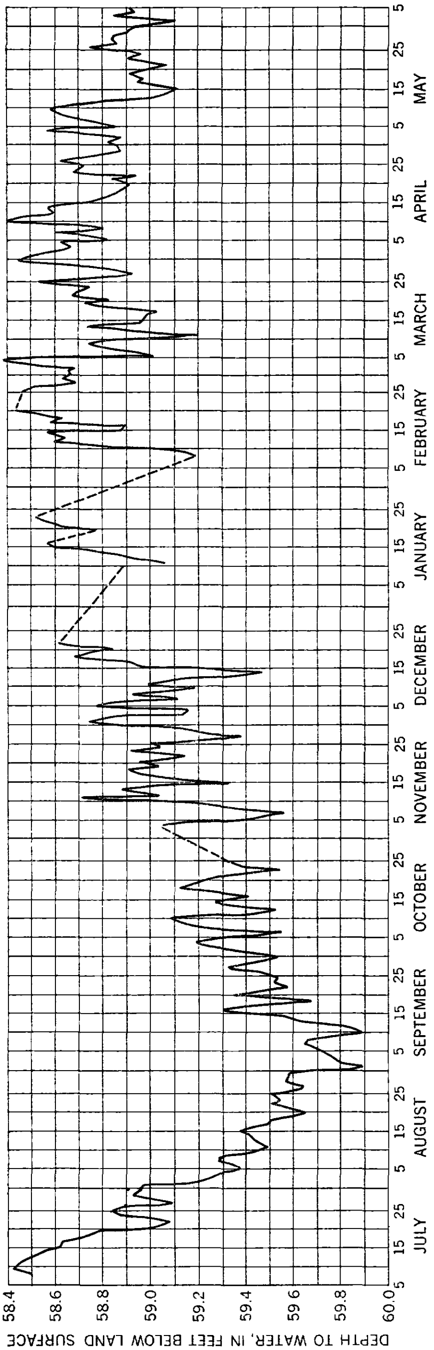


FIGURE 7.—Hydrograph of mean daily water levels in well 14/45-4N1, near Pullman.

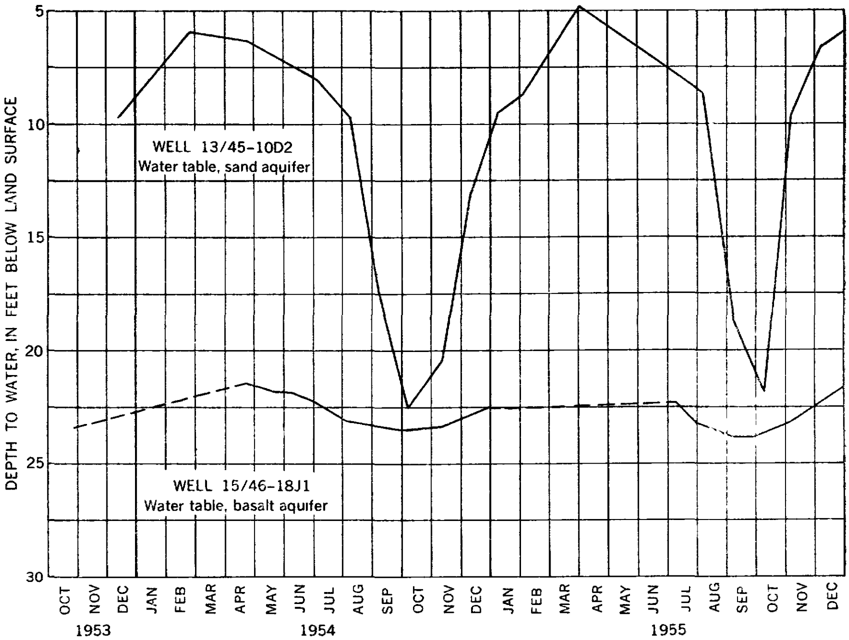


FIGURE 8.—Hydrographs of wells 13/45-10D2 and 15/46-18J1 in the Pullman subbasin.

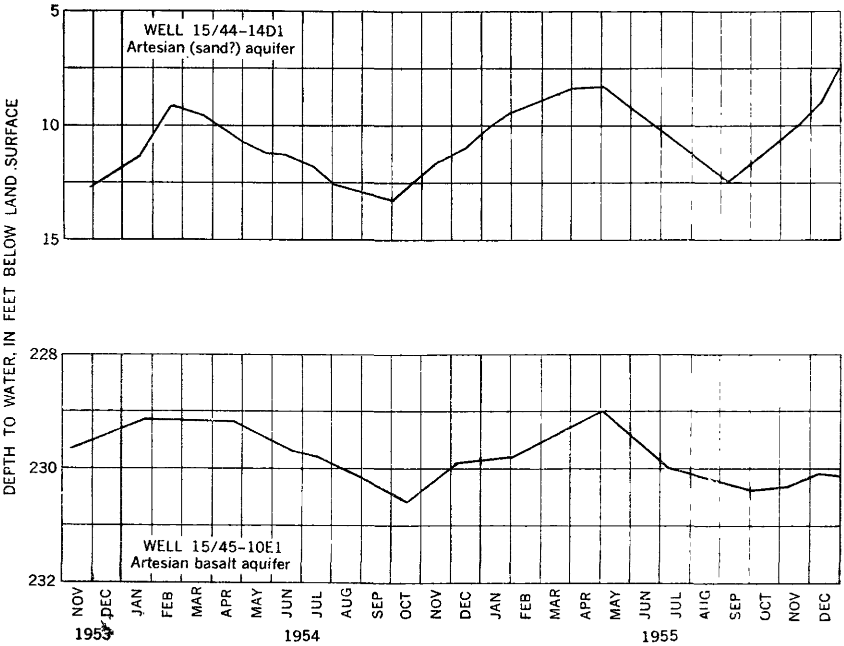


FIGURE 9.—Hydrographs of wells 15/44-14D1 and 15/45-10E1 in the Pullman subbasin.

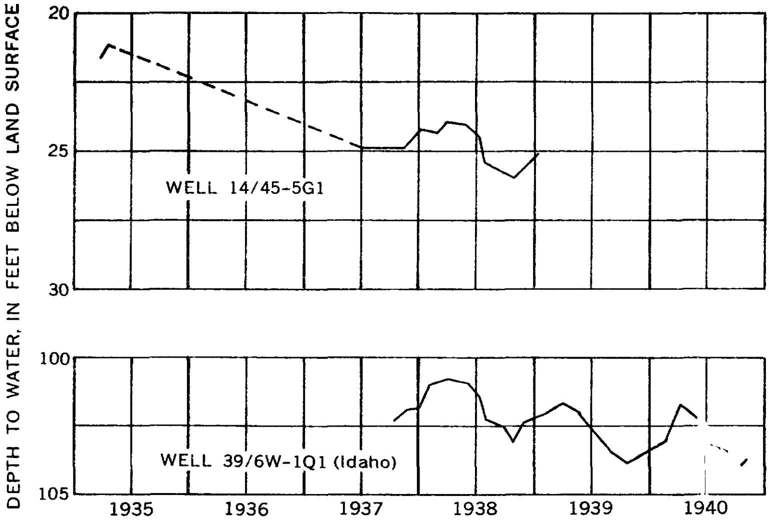


FIGURE 10.—Hydrographs of well 14/45-5G1 in the Pullman subbasin and 39/6W-1Q1 in the Moscow subbasin, showing progressive decline in water level.

Although the piezometric surface of the artesian zone at Moscow has declined in a manner similar to the decline in the Pullman area, recent rates of decline have differed markedly. The hydrograph of well 39/5W-7R1 (fig. 6) indicates an average decline of 21 to 22 inches per year during 1937–40, 11 inches per year during 1941–49, 30 to 35 inches per year during 1950–52, and 50 to 55 inches per year during 1953–55. A comparison of that hydrograph with those of the artesian wells in the Pullman area (14/45–4N1, –5B1, –5D2, and –5G1) shows that the rates of decline in the two areas were roughly equal until about 1952, when the rate of decline in the Pullman area began to decrease. At the same time, the piezometric surface in the Moscow area began to decline at an increased rate. Since 1951, the average decline in the Moscow area has been nearly four times as rapid as the decline at Pullman.

The different rates of water-level decline during the last few years lend minor support to the hypothesis that the Moscow and Pullman subbasins are hydrologically distinct. If the aretsian aquifers in the two areas were freely interconnected, the increased drawdown at Moscow probably would have been reflected in the Pullman area.

In both areas, annual fluctuations are superimposed upon the general declining trend of the piezometric surface. In the vicinity of Pullman, the water levels in wells penetrating the artesian zone normally fluctuate about 1 to 3 feet during the year; the highest level commonly is in March or April and the lowest in late summer or autumn. (See figs. 3–7, 9, 10.) The highest levels in the Moscow area are more likely to occur in winter, and the fluctuations commonly range from about 4 to 7 feet, according to differences in the pumpage from wells (fig. 6).

The smallest fluctuations that have been observed in the artesian levels are the result of variations in atmospheric pressure. In July 1955, a semiautomatic water-stage recorder was installed on well 14/45–4N1, about 1 mile southeast of Pullman. The chart from that recorder shows diurnal barometric fluctuations as small as a few hundredths of a foot and fluctuations as great as 0.7 foot during the passage of major storms. Figure 7, a hydrograph of mean daily water levels recorded at the well, shows the larger barometric fluctuations.

CHEMICAL QUALITY OF GROUND WATER

Chemical analyses were made on 61 samples of water from 53 wells and 2 streams in the Moscow–Pullman basin. These analyses are reported in tables 3 and 4. Field determinations of hardness and concentrations of bicarbonate and chloride in water from 36 wells are given in table 4. Of the analyses in table 3, 17 are comprehensive in that all the common cations and anions have been determined.

The chemical data suggest that the Moscow and Pullman subbasins are hydraulically separate or poorly connected as discussed in detail below.

GENERAL RANGE IN CHEMICAL CONCENTRATION

Moderate ranges in hardness and in concentrations of chloride and bicarbonate were found for the water in the Moscow–Pullman basin. Except for samples of water from wells 14/45–20E1, 15/45–23B1, and 15/46–20P1, whose apparent anomalies in chemical character may result from local contamination, the range in chloride is from 1 to 20 ppm (parts per million) and in hardness from 76 to 184 ppm. The range in bicarbonate is from 79 to 216 ppm.

The range in concentration of all dissolved solids cannot be determined for the area as a whole because of the limitations of the data. Analyses of water from wells in or near Pullman and near Moscow show a small range in concentration of dissolved solids, from 211 ppm for well 14/45–5D1 to 260 ppm for well 39/5W–7P1. The water from well 15/44–15A2 at Albion, about 6 miles northwest of Pullman, contains 272 ppm of dissolved solids.

PULLMAN SUBBASIN

Twelve comprehensive analyses are available for water samples from 11 wells in the Pullman subbasin. Of these wells, 10 tap basalt aquifers, and 1, well 15/44–15A2 at Albion, taps weathered granite.

These analyses, together with 5 for water from the Moscow subbasin, have been plotted on figure 11. In general, the position of each point on the graph is dependent on the chemical character of the water, as represented by the proportions of the three major cations (calcium, magnesium, and sodium) and the three major anions (bicarbonate, sulfate, and chloride) in the water (Piper, 1944, p. 914–923).

The graph can show even more clearly than the analyses whether two or more samples of water are similar. Analyses of samples of nearly identical chemical character plot closely together. Analyses of completely different types of water plot in entirely different places on the graph. The analyses of the water from wells in the Pullman subbasin that tap basalt aquifers are represented by points 1 to 12, inclusive.

All the plotted points, except the one representing the analysis of water from the well at Albion, group very closely. This fact indicates that the water from basalt is uniform and exhibits no perceptible change in chemical quality with depth. The analyses plotted are of water from wells that range in depth from 95 to 954 feet below the land surface. Well 14/45–5E1, 95 feet deep, taps the upper water-bearing zone. Well 15/45–13N2, 954 feet deep, taps deep zones heretofore undeveloped. The other nine tap either the upper or the lower of the two principal artesian aquifers.

Well 15/44–15A2 at Albion, which taps granitic sand, yields water similar in chemical quality to that produced from the Moscow subbasin (fig. 11).

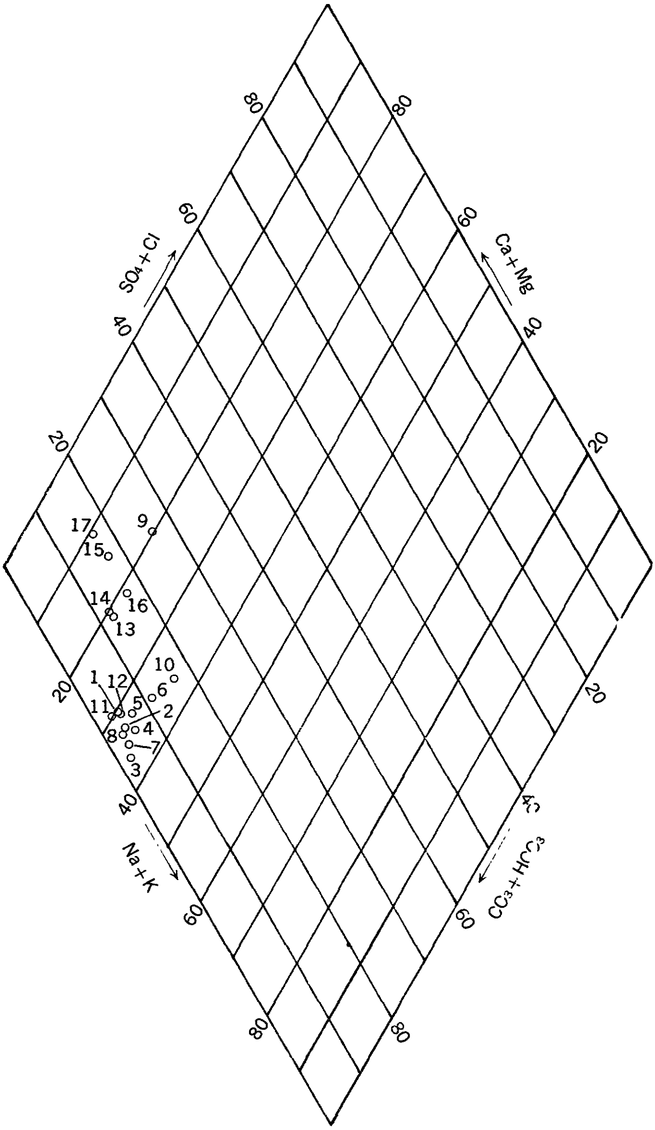
For the Pullman subbasin as a whole, the overall range in hardness of water from wells tapping only basalt is from 80 to 124 ppm. Bicarbonate ranges from 116 to 216 ppm. In general, the few analyses of water from the loess show a greater range in hardness—from 76 ppm (well 14/45–3H2) to 174 ppm (well 15/45–32G1)—than water from the basalt. The range in bicarbonate (92 ppm, well 14/45–3H2, to 213 ppm, well 14/45–13F2) is only slightly greater than that for water from the basalt.

MOSCOW SUBBASIN

On figure 11, plotted points 13–17 represent analyses of water from two sources in the Moscow subbasin. Points 13, 14, and 16 represent water from basalt, and points 15 and 17 represent water from granitic sand or weathered granite.

Points 15 and 17 fall more closely together and in a slightly different area on the grid than points 13, 14, and 16. This fact indicates minor differences in the chemical character of the water from the two sources. The distinction of the two groups results almost entirely from a higher proportion of calcium and magnesium in the water from the weathered

656185—62——3



Well	Plot	Depth (ft)	Principal aquifer
Pullman subbasin:			
14/45-5B1	1	237	Basalt.
5B3	2	223	Do.
5D1	3	164	Do.
5D3	4	167	Do.
5D3	5	167	Do.
5D4	6	166	Do.
5E1	7	95	Do.
5G1	8	213	Do.
15/44-15A2	9	78	Granitic sand.
Pullman subbasin—Continued			
15/45-26K1	10	302	Basalt.
32N1	11	231	Do.
32N2	12	954	Do.
Moscow subbasin:			
39/5W-7J2	13	254	Basalt.
7J3	14	245	Do.
7P1	15	355	Granitic sand.
8B2	16	373	Basalt.
18C1	17	330	Granitic sand.

FIGURE 11.—Chemical character of water from wells in the Moscow and Pullman subbasins.

granite. (See table 3 and fig. 11.) However, too few analyses are available to show whether this difference is significant.

Only one analysis is available for water from loess (well 15/46–20K1) in the Moscow subbasin. It is listed in table 4.

COMPARISON OF WATER FROM BASALT AQUIFERS IN THE PULLMAN AND MOSCOW SUBBASINS

The water from basalt aquifers in the Pullman and Moscow subbasins is similar. Similarity is to be expected in adjacent subbasins within the same geologic setting; however, a small but significant difference in chemical character is apparent from figure 11. Except for point 9, representative analyses of water from the Pullman subbasin form a group entirely separate from those from the Moscow subbasin. Point 9, representing an analysis of water from granitic materials in the Pullman subbasin, plots in the part of the field (fig. 11) occupied by those points representing analyses of water from wells in the Moscow area that tap basalt.

The difference between water in the two areas can be shown also by the use of a classification system introduced by Palmer (1911, p. 11–12), in which the alkaline cations (Na, K) are designated the primary constituents; the alkaline-earth cations (mostly Ca and Mg), the secondary constituents; the strongly acid anions (SO_4, Cl, NO_3) the saline constituents; and the weakly acid anions (CO_3, HCO_3) the alkaline constituents. For normal water, or at least for water that does not contain free hydrogen (H^+) or hydroxyl (OH^-) ions, the following four conbinations are possible: primary salinity, secondary alkalinity, primary alkalinity, and secondary salinity. In terms of balance between anions and cations, these expressions have the following significance.

The water contains primary salinity to the extent that the alkalies are balanced by strong acids; secondary alkalinity to the extent that alkaline earths are balanced by weak acids; primary alkalinity to the extent that the alkalies, in excess of strong acids, can be balanced by weak acids; and secondary salinity to the extent that the alkaline earths, in excess of the weak acids, can be balanced by the strong acids. As the latter two properties, primary alkalinity and secondary salinity, are mutually exclusive, water can have only 3 of the 4 characteristics. The water of the Pullman–Moscow basin can be classified by Palmer's system in the manner indicated above, and this has been done in the following table.

The chief difference in water from the two areas is in the relative amount of primary alkalinity, which is higher for the water from the Pullman subbasin.

Classification of water in the Pullman–Moscow basin, by Palmer's system

Aquifer and plot on figure 11	Primary salinity	Secondary salinity	Primary alkalinity	Secondary alkalinity
Pullman subbasin				
Basalt:				
1	4	0	26	70
2	5	0	28	67
3	3	0	33	64
4	5	0	29	66
5	6	0	25	69
6	11	0	23	66
7	3	0	32	65
8	4	0	30	66
10	18	0	18	64
11	3	0	27	70
12	6	0	27	68
Granitic sand:				
9	20	6	0	74
Moscow subbasin				
Basalt:				
13	12	0	10	78
14	12	0	9	79
16	17	0	4	79
Granitic sand:				
15	14	3	0	83
17	11	6	0	83

Comparison of the two groups shows that the water samples from the two areas have minor differences. The water from the Moscow subbasin contains a slightly larger proportion of calcium and magnesium and a slightly smaller proportion of bicarbonate than the water from the Pullman subbasin.

The water of the Moscow subbasin, because of its higher content of calcium and magnesium, must, in general, have a somewhat greater hardness than the water of the Pullman subbasin.

For the Moscow area, the difference in character between the water from granitic sand and that from basalt is clearly indicated in the preceding table. The similarity in water from granitic sand from both subbasins is also noteworthy. Only three (points 9, 15, and 17 on fig. 11) of the total number of samples analyzed for this report had secondary salinity.

A general conclusion that can be drawn from the preceding data is that the chief reason for the difference in chemical character of water from basalt in the Moscow and in the Pullman subbasins is that the water from the Moscow area may represent a blend with water that has been in contact with granitic material. The water from basalt in the Pullman subbasin apparently has not undergone such blending.

RELATION OF RECHARGE AND DISCHARGE TO WATER-LEVEL CHANGE

For at least the last 21 years—the period during which water levels in the Pullman wells have been measured—the discharge from the artesian aquifers has exceeded the local recharge, and the piezometric surface has declined each year. The excess withdrawal has been supplied from stored water and has resulted in the gradual lowering of the piezometric surface.

Recharge to the artesian aquifers from precipitation and streamflow varies widely from season to season, and the relative proportion of recharge from precipitation and streamflow is not known. However, probably about three-quarters of the total recharge occurs during the first half of the water year (October–March). This is the same period when about 40 percent of the annual pumpage from the artesian wells is withdrawn. On the other hand, the natural discharge from the artesian aquifers is reasonably constant throughout the year.

Variations in the size of the area of influence, though not subject to close estimation, probably have only a minor influence on the present water-level fluctuations at Pullman. Theoretically, in an artesian aquifer of infinite extent, continued pumping in excess of recharge would cause a continued enlargement of the area of influence, causing the removal of water from storage in an ever-larger area. However, in the Pullman subbasin, enclosed as it is on at least three sides by ground-water barriers, the area of influence of pumping at Pullman undoubtedly is small. Further, the piezometric surface has a low gradient in much of the subbasin, and a relatively flat gradient probably extends close to the ground-water boundaries. If the present gradients are low, they cannot have steepened much through the years of continued pumping. Thus, the cone of depression probably has reached ground-water boundaries along much of the periphery of the subbasin, and the area of influence probably has been relatively constant during recent years. If so, the lowering of the piezometric surface probably is more like the gradual lowering of the level in a water tank, rather than the expansion of a cone of depression in an infinite aquifer.

Changes in storage are reflected by changes in water level. In figure 12 the annual overall change of water level is plotted against the annual pumpage during 1937–44 and 1949–59. The relation for each year appears as a point, labeled for the year it represents. Values of changes in water level were interpolated from hydrographs of wells 14/45–4N1 and 14/45–5D2 (figs. 5, 6). Annual declines in water levels in these wells were determined by comparison of successive high-water-level stages, as shown on the hydrographs, and were plotted against pumpage for each preceding calendar year. Values

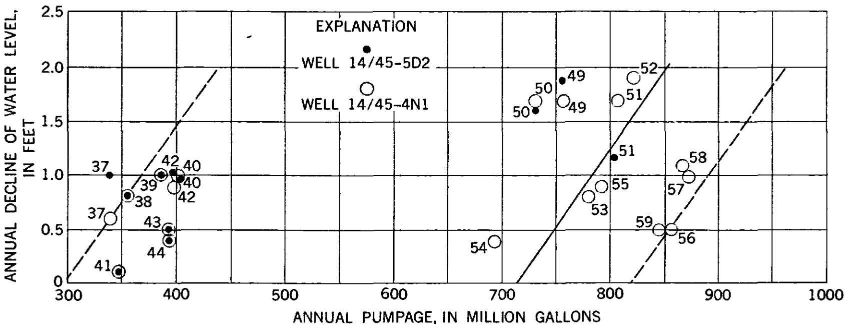


FIGURE 12.—Graph showing relation of annual water-level decline to annual pumpage during 1937–44 and 1949–59.

for pumpage are listed in the table on page 20. Unfortunately, no reliable records of pumpage are available for 1945–48.

The points on the graph (fig. 12) are somewhat scattered, for several reasons: First, because artesian levels are related to the amount of recharge as well as the pumpage, considerable scattering must be expected because of annual variations in recharge. Second, the relation of recharge to natural discharge undoubtedly has changed over the years. Third, discrepancies between the annual changes in the artesian levels interpolated from the hydrographs and the true changes for the subbasin as a whole are unavoidable. Fourth, pumpage, though more accurate than the other data, is partly estimated. (However, pumpage from wells of Washington State University and the city of Pullman constitutes 85 percent or more of the total, and that pumpage is carefully measured.)

The dashed lines on each side of the graph (fig. 12) enclose the points for nearly all years of record; they approximate the limits for all known relations of pumpage and decline of water levels. The limit lines intercept the base line of the graph where the net change in storage is zero and pumpage is about 300 million and 815 million gallons per year. These figures represent approximately the range of the replaced ground water—that is, the part of the pumpage that came from recharge during the years of record.

The points shown on the graph obviously fall into two distinct groups, one represents 1937–44 and the other 1949–59. The limit line on the left side of the graph is adjacent to points for the earliest years of record, and the line on the right passes through or near points representing the latest years. As nearly as can be judged without records for the intervening years, the relation of water levels to pumpage has shifted generally, as indicated by the shift of the points toward the right side of the graph; a large part of the shift must have occurred during 1945–48.

The change in this relation undoubtedly has been caused by a change in some factor (in addition to pumpage) that has affected the amount of water in storage for the period of record. As the piezometric surface gradually declined over the years, the natural discharge from the artesian zone decreased because the deepening cone of depression allowed interception of ground water that formerly was lost as underflow or as effluent seepage to the streams. At the same time, the recharge to the artesian aquifers has increased by the additional intake of potential recharge that formerly was rejected. Thus, recharge has increased from year to year, whereas natural discharge has decreased, so that, for a given rate of pumping, the lowering of the piezometric surface has become less during recent years than it was during the earliest years of record. Also, the maximum pumping rate possible without removal of ground water from storage apparently has just about doubled in the last 18 years.

The solid line on the right side of the graph represents approximately the average relation of artesian levels to pumpage during 1949–59. Its intersection with the base line represents approximately the average amount of replaced pumpage during those years. That value of pumpage is about 715 million gallons (2,150 ac-ft) per year, or about 85 million gallons less than the average pumpage during those years. This means that an average of about 85 million gallons per year was removed from storage during this period.

The accuracy of the above figures depends upon several assumptions, which are based to a considerable extent upon inadequate information. Therefore, the figures should not be considered conclusive, even for the years for which they were compiled. If the area of influence changes significantly with different amounts of withdrawal, the straight lines on the graph should instead be curved and would therefore intercept the line of zero decline at somewhat different points. Also, unusual recharge or natural discharge undoubtedly would cause some deviation. However, the figures do indicate the order of magnitude of the ground water available for withdrawal, without the removal of additional water from storage, during 1949–59.

If pumping in the Pullman subbasin continues to remove ground water from storage, causing a gradual decline in the piezometric surface, recharge to the artesian aquifers may increase somewhat in the future, as it has in the past. However, the subbasin is rather small, and the potential recharge also is small. The 1959 rate of pumping may approach or even exceed the perennial yield of the principal artesian aquifers.

The total recharge to the artesian aquifers undoubtedly is larger than the pumpage, but without an estimate of the natural discharge the total recharge could not be determined. However, the amount of total recharge is not as critical to the management and use of ground water in the Pullman area as the amount that can be pumped each year without causing a serious depletion of ground water in storage. Figure 12 shows that the average annual pumpage of about 800 million gallons in 1949–59 caused only a minor depletion of storage.

ARTIFICIAL RECHARGE

Artificial recharge has been carried out with varying degrees of success throughout many parts of the country. Some of the most notably successful areas are in Louisville, Ky. (Guyton, 1946); Long Island, N.Y. (Brashears, 1941); and Des Moines, Iowa (Moffitt, 1943).

Two methods of artificially recharging a ground-water body are: by application (spreading) of the water on the surface, such as on flat areas or in shallow trenches or basins where conditions are favorable for the water to percolate downward to an aquifer and by introduction of water directly into wells.

The geology of the Pullman area is the main factor which would determine the type of artificial recharge applicable in the area. The chief aquifers in the subbasin occur in the basalt sequence both as interbedded sedimentary material and as porous or fractured zones in the basalt, and the water they contain is under artesian pressure. Therefore, further discussion of artificial recharge in the Pullman area will be directed toward artesian aquifers within the basalt sequence.

The spreading method is attempted only under watertable conditions. Because the most productive aquifers in the Pullman area are confined by overlying relatively impervious zones, the method that seems most applicable is recharge through wells. One other method that might possibly be tried in the Pullman subbasin is recharge through infiltration trenches along the contact zone between the basalt and the underlying granite and quartzite of the hills and buttes surrounding the area. In this way the water might move down the prebasalt surface and percolate into the aquifers in the basalt sequence. However, it is not definitely known whether the weathered material overlying the crystalline rocks actually is in contact with the artesian aquifers that supply Pullman, and water placed in these trenches might never reach the intended area. Additional investigation, including the drilling and testing of several wells, would be required to determine whether the weathered material is hydraulically connected with the aquifers in the basalt sequence and in particular with the aquifers of the Pullman subbasin. Also, because the contact zone generally is higher than the larger creeks, transporting surface water from the source to the infiltration trenches might be difficult and expensive.

Recharge by introduction of the water directly into wells that tap basalt aquifers was accomplished satisfactorily during an experiment at Walla Walla, Wash. (Price, 1960). Also at St. Helens, Oreg., basalt aquifers were recharged artificially by wells each year during 1951–53. Not all details of the operation at St. Helens are known, but it apparently was moderately successful.

The same well could be used alternately for pumping and recharging. This procedure would not only eliminate the cost of drilling an extra well solely for recharge, but periodic pumping would help to remove much of the suspended matter that accumulated during the periods of recharge.

Under ideal conditions, as much water can be injected into a well, per foot of rise in water level as can be removed by pumping per foot of drawdown. Judging from the yield and drawdown data for wells owned by the city of Pullman and Washington State University the writers believed that it should be possible to inject as much as a million gallons per day (about 700 gpm) of filtered water into any one of several wells in the city. (See table 1, wells 14/45–5P2, –5B3, –5D1, and 14/45–32 N1.) That amount of water, injected continuously for 6 months, would exceed the present annual pumpage from storage (estimated to be 85 million gallons per year) by about 115 million gallons.

Whether virtually all water recharged artificially can be recovered depends on how much of the water recharged will move downgradient beyond the cones of depression of all the pumped wells, which are themselves downgradient from the point of recharge. In the Pullman area, conditions are favorable for the recovery of a large part of any water injected into wells. Natural discharge from the principal artesian aquifers is limited by the enclosing bedrock hills and possibly by gentle folds in the basalt. Also, in the vicinity of Pullman, the water in those aquifers undoubtedly moves generally toward the city, which is the center of the main pumping withdrawal. Because any recharge well presumably would be located in the area of influence of the pumped wells, the percentage of recharge that could be recovered would be relatively great. The main loss of the recharge water could be that by leakage to deeper or shallower aquifers, if the head in them is less than that in the recharged aquifer.

Several factors should be considered in the selection of a site for a recharge well: (1) The well must be in an area where the water recharged will move toward the production wells; (2) it should be close to a source of suitable surface water; (3) it must be at an altitude high enough above the piezometric surface to allow the maintenance of a sufficiently high cone of elevation; and (4) the site should be selected with regard to economical drilling.

Three streams that seem to be likely sources of water for artificial recharge are the South Fork of the Palouse River, Paradise Creek, and Missouri Flat Creek. (See pl. 2.) Paradise Creek is perennial; and South Fork above its confluence with Paradise Creek normally carries little or no water in August and September; and Missouri Flat Creek usually is dry from about July to October. Other streams probably would be less suitable because of location or inadequate flow.

The Geological Survey formerly maintained stream-gaging stations on the three streams mentioned above, as well as on Fourmile Creek and the Dry Fork of the South Fork of the Palouse River (pl. 2). The Dry Fork is a short intermittent stream that drains the small area due south of Pullman, and it joins the South Fork in Pullman. Missouri Flat Creek flows southwestward through Whelan and Kitsmiller (pl. 1), and it also enters the South Fork in Pullman.

The available records of streamflow in the area through the 1950 water year have been published in Geological Survey Water-Supply Paper 1317, "Compilation of records of surface waters of the United States through September 1950, Snake River Basin." In that report, streamflow data are summarized in the table below.

All the streams are flashy, and discharge varies widely from month to month. For example, in Paradise Creek, the minimum recorded flow was 0.04 cfs on August 22, 1938, and the July-September average discharge for the period of record was only 0.62 cfs, even though the low flow of Paradise Creek may have been supplemented by effluent from the Moscow sewage-treatment plant.

South Fork Palouse River at Pullman has an average flow about three times that of Paradise Creek. More than three-fourths of the total runoff of South Fork occurs in the first half of the water year,

Summary of streamflow data in the Pullman area

Stream	Period of record	Discharge (cfs)			Highest stage occurred during—	Lowest stage occurred during—
		Maximum of record and date	Minimum of record and date	Average for period		
South Fork Palouse River at Pullman.	1934–42	968, Mar. 21, 1939	0.1, Sept. 23, 1942	28.4	January–April.	January, July–August.
South Fork Palouse River above Paradise Creek.	1934–40	533, Mar. 21, 1939	0	16.6	January–April.	June–October.
Paradise Creek	1934–38	326, Mar. 2, 1936	.04, Aug. 22, 1938	9.4	January, March–April.	January, July–August.
Missouri Flat Creek	1934–40	432, Mar. 19, 1939	0	6.0	January–April.	June–November.
Dry Fork South Fork Palouse River.	1934–38	159, Feb. 27, 1936	0	1.5	February–March.	May–December.
Four Mile Creek	1934–40	786, Jan. 24, 1935	0	14.9	January–March.	June–November.

October through March. The maximum, minimum, and mean discharge of South Fork at Pullman, by months, is shown in figure 13.

It probably would be impractical to divert water for recharge from a stream having a flow of less than 1 cfs. Paradise Creek and South Fork Palouse, flow 1 cfs or more 6 to 8 months of the year, and Missouri Flat Creek flows at comparable rates 3 to 5 months of the year.

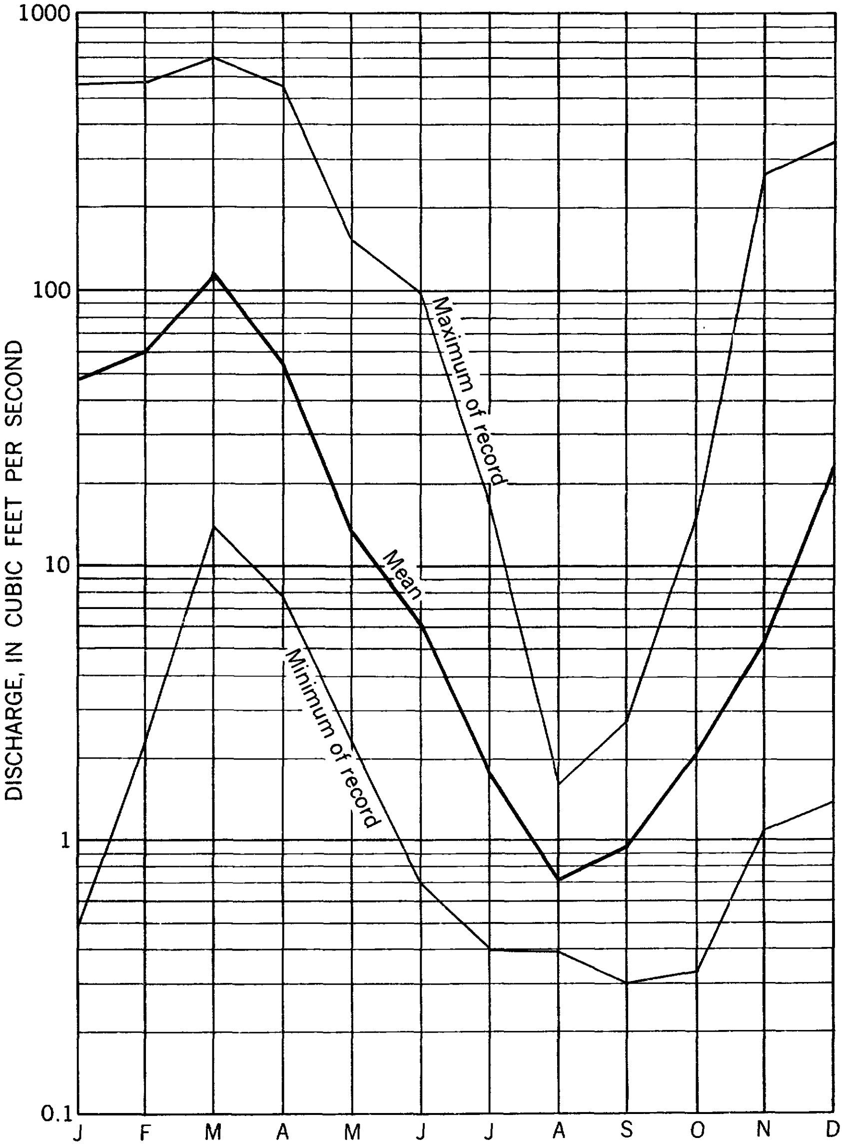


FIGURE 13.—Graph showing monthly maximum, mean, and minimum discharge of South Fork Palouse River at Pullman.

The flow of perennial streams during late spring, summer, and early autumn is maintained largely by ground water. The artesian pressures in some of the basalt aquifers have been declining, thereby progressively decreasing the amount of ground-water discharge to the stream channels. Because the summer streamflow already is meager, the flow of Paradise Creek as well as that of South Fork Palouse River at Pullman could cease entirely during dry seasons if the trend continued.

One of the principal factors in artificial recharge through wells is the quality of the recharge water. The recharge water must be chemically compatible with the native ground water, and the sediment content of the recharge water must be sufficiently low that injection wells will not become clogged. Relatively small amounts of suspended matter in water injected into a well can cause the well to become clogged, greatly reducing its intake capacity and necessitating frequent cleaning and developing. Organic matter, such as algae, should be removed from the water before injection, for it can clog the well even more tightly than sediment.

From 1934 to 1940, daily measurements were made of discharge and suspended-sediment load of South Fork Palouse River above Paradise Creek, Missouri Flat Creek, and Four Mile Creek (Potter and Love, 1942). During that period, the South Fork transported an annual mean sediment load of 24,900 tons. During the same period, Missouri Flat Creek carried an average of 14,200 tons per year and Four Mile Creek carried an average of 40,100 tons per year. The relation of the average monthly sediment load to the average monthly discharge of South Fork above Paradise Creek is shown in figure 14.

A large proportion of the suspended load in the streams is carried during comparatively short periods of time. For example, in South Fork of the Palouse River, nearly 94 percent of the annual load of suspended sediment was carried in about 34 days. However, even under the most sediment-free conditions of record the daily load is great; for example, when the streamflow was 1.1 cfs on December 25, 1935, the daily sediment load was 60 pounds. If water of that quality were used to recharge a well at the rate of 1 million gallons per day, 85 pounds of sediment would be introduced into the well daily. Therefore, the surface water in the area probably is never free enough from sediment to permit direct diversion into wells, and filtering or settling works probably would be essential.

The chemical quality of the surface water available for artificial recharge in the Pullman subbasin is generally good, that is, not markedly different from that of ground water in the principal artesian

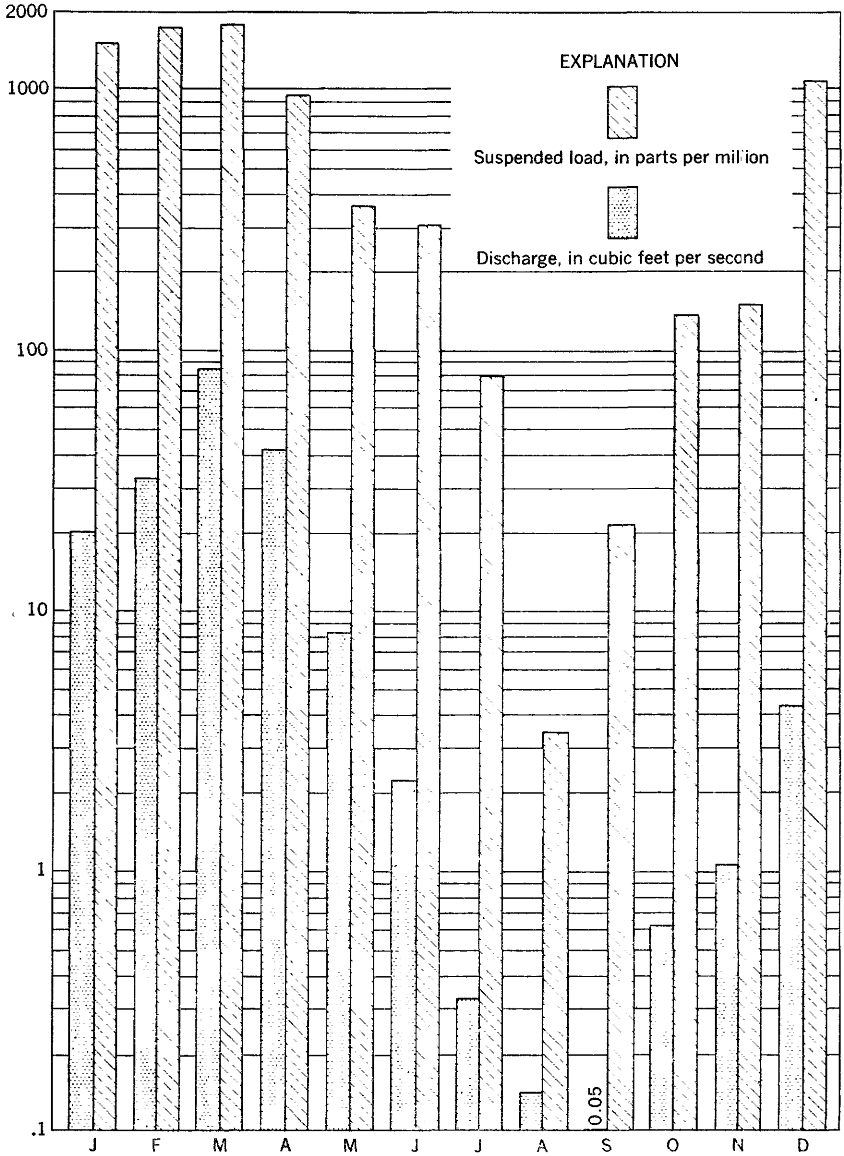


FIGURE 14.—Graph showing relation of average monthly sediment load to average monthly discharge of South Fork of Palouse River above Paradise Creek during 1934–40. (After Potter and Love, 1942.)

aquifers (table 3). Although the mineral content of the surface water probably varies, usually being more concentrated during periods of low flow and less so during times of abundant runoff, apparently it is never too concentrated to be unsuitable for recharge.

POSSIBILITY OF DEVELOPING DEEPER AQUIFERS

Until 1956, no wells in the Pullman area tapped aquifers below an altitude of about 2,170 to 2,190 feet. Well 15/45–32N2 (Pullman city well 4) was completed at a depth of 954 feet in August 1956. The bottom of this well, at an altitude of 1,386 feet, did not reach the bottom of the basalt. All water in basalt aquifers less than 400 feet deep is sealed off. When the well was tested in July 1957, it yielded about 1,000 gpm with 18½ feet of drawdown. The yield of this well has increased to 1,200 gpm, and the drawdown has decreased to 12 feet, according to reports. The deeper aquifers tapped by this well are under almost the same pressure head as the shallower artesian aquifers in the Pullman area. However, head in the shallower artesian aquifers declines only slightly as wells tapping the deeper aquifers are pumped, indicating that hydraulic continuity between the deeper and shallower aquifers is poor. The deeper aquifers tapped by well 15/45–32N2 probably could be tapped by at least a few more deep wells without undue effect on the upper zones.

The chemical quality of water from well 15/45–32N2 is almost identical with that of water from the upper artesian aquifers in the Pullman area, and any deeper basalt aquifer also may contain water of similar quality.

CONCLUSIONS

The major conclusions resulting from this investigation may be summarized as follows:

1. Significant differences in the altitudes and rates of decline of artesian levels and in the chemical composition of the artesian water in the two areas indicate that Moscow and Pullman are in two separate hydrologic subbasins, having a common ground-water boundary near the Idaho–Washington border.

2. Two artesian zones in the basalt sequence at altitudes ranging from about 2,170 to 2,290 feet, are by far the most productive aquifers now extensively developed in the Pullman subbasin. Yields as great as 1,800 gpm have been reported from wells penetrating the artesian aquifers, whereas none of the wells in unconfined aquifers have been reported to yield as much as 100 gpm. The artesian aquifers supply more than 95 percent of the total ground-water pumpage in the subbasin.

3. Ground water from the artesian aquifers is, in general, suitable in chemical quality for domestic and stock use and excellent to good for irrigation. However, it is slightly to moderately hard and at some places contains sufficient iron and manganese to stain plumbing fixtures and laundry.

4. For about the last 25 years, the annual discharge of ground water from the artesian aquifers has exceeded the local recharge,

and the piezometric surface has declined slightly each year. The pumpage derived from recharge, or replaced pumpage, ranged from about 300 to 815 million gallons per year between 1937 and 1959, and the average for 1949–59 was about 715 million gallons per year, or about 85 million gallons per year less than the average annual pumpage during those years.

The gradual decline of the piezometric surface apparently has caused increased recharge to the artesian zone. However, the present rate of pumping may be slightly exceeding the perennial yield of the aquifers as presently developed.

5. The successful operation of well 15/45–32N2 indicates that potentially good artesian aquifers lie below those now extensively developed. Data collected from that well indicate that the hydraulic properties and the pressure head of the aquifers and the chemical quality of the water they contain should be similar to those of the shallower artesian basalt aquifers. That these deeper zones probably are virtually separate hydraulically from the shallower ones is of great advantage in attempting to develop more water in the Pullman area without aggravating the present incipient overdraft.

6. The most feasible method for artificially recharging the Pullman artesian zone would be by direct injection of water into wells during part of the year and pumping from those wells during the remaining time. The alternate recharging and pumping would decrease the time and cost involved in cleaning and maintaining the wells and would prolong their life. Recharge water is available from several streams, but even under the most favorable conditions it would require treatment for removal of sediment and algae before being injected into a well.

REFERENCES CITED

Brashears, M. L., Jr., 1941, Ground-water temperatures on Long Island, New York, as affected by recharge of warm water: Econ. Geology, v. 36, p. 811–828.

Bretz, J. H., 1928, The channeled scabland of eastern Washington: Geol. Rev., v. 18, no. 3, p. 446–477.

Bryan, Kirk, 1927, The "Palouse soil" problem, with an account of elephant remains in wind-borne soil on the Columbia Plateau of Washington: U.S. Geol. Survey Bull. 790–B, p. 21–45.

Fenneman, N. M., 1931, Physiography of western United States: New York, McGraw-Hill Book Co., 534 p.

Guyton, W. F., 1946, Artificial recharge of glacial sand and gravel with filtered river water at Louisville, Kentucky: Econ. Geology, v. 41, no. 6, p 644–658.

Klages, K. H. W., 1942, Climate of the Palouse area of Idaho as indicated by fifty years of climatological data on the University farm: Idaho Univ. Bull. 245, 19 p.

Laney, F. B., Kirkham, V. R. D., and Piper, A. M., 1923, Ground-water supply at Moscow, Idaho: Idaho Bur. Mines and Geology Pamph. no. 8, 13 p.

Maffitt, D. L., 1943, Artificial flooding builds up ground-water yield: Water Works Eng., v. 96 p. 1230–1232.

Meinzer, O. E., 1923, The occurrence of ground water in the United States, with a discussion of principles: U.S. Geol. Survey Water-Supply Paper 489, 321 p.

Palmer, Chase, 1911, The geochemical interpretation of water analyses: U.S. Geol. Survey Bull. 479, 31 p.

Piper, A. M., 1944, A graphic procedure in the geochemical interpretation of water analyses: Am. Geophys. Union Trans., p. 914–923.

Potter, W. D., and Love, S. K., 1942, Hydrologic studies at the South Fork Palouse River Demonstration Project: U.S. Dept. Agriculture, Soil Conserv. Service, 5 p.

Price, C. E., 1960, Artificial recharge of a well tapping basalt aquifers, Walla Walla area, Washington: Washington Dept. Conserv., Water-Supply Bull. 7, 50 p.

Rockie, W. A., Mark, F. A., Parker, G. L., and Bonner, J. P., 1938, Water levels in observation wells, South Palouse soil conservation project, Whitman County, Washington: U.S. Dept. Argiculture, Soil Conserv. Service, 14 p.

Russell, I. C., 1893, A geological reconnaissance in southeastern Washington: U.S. Geol. Survey Bull. 108, 108 p.

——— 1897, A reconnaissance of southeastern Washington: U.S. Geol. Survey Water-Supply Paper 4, 96 p.

Shannon, E. V., 1923, On siderite and associated minerals from the Columbia River basalt at Spokane, Washington: U.S. Natl. Mus. Proc., v. 62, art. 12, p. 1–19.

Treasher, R. C., 1925, Origin of the loess of the Palouse region, Washington: Science, new ser., v. 61, p. 469.

——— 1926, Stratigraphic aspects of loess of Palouse origin: Pan-Am. Geologist, v. 46, no. 4, p. 305–314.

Warren, W. C., 1941, Relation of the Yakima basalt to the Keechelus andesitic series: Jour. Geology, v. 49, no. 8, p. 795–814.

BASIC DATA

656185--62 — 4

TABLE 1.—*Records of wells in the Pullman*

[Location of wells are shown on pl. 1]

Topography and approximate altitude: H, hill; U, rolling upland; V, valley. Altitude of land-surface datum at well from barometric traverses or interpolated from topographic maps.
Type of well: B, bored; Dg, dug; Dr, drilled.
Water level: Measurements made by the Geological Survey expressed in feet and decimal fractions; depths reported by owner, tenant, or driller expressed in feet. In flowing wells, a plus preceding the water-level measurement indicates static head, in feet above land-surface datum. "Flows" indicates unmeasured static head.
Type of pump: C, centrifugal; J, jet; N, none; P, deep-well piston; S, suction (including small-capacity centrifugal, gear, and shallow-well piston pumps); Sb, submersible; T, turbine.

Well	Owner or tenant	Topography and approximate altitude	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Water-bearing	
							Depth to top (feet)	Thickness (feet)
								T. 13N.,
3E1	Earl Harper	U, 2,640	Dr	86	6			
3E2	do	U, 2,640	Dr	60	6			
3L1	B. F. Druffel	V, 2,625	Dr	90	6	60		
3M2	Franz Druffel	V, 2,625	Dr	100	6		90	10
5G1	do	H, 2,620	Dr	61	6			
7Q1	Martin Druffel	U, 2 640	Dr	78	6			
8C1	J. W. Mawxell	U, 2,640	Dr	304	6	40	125	
10C1	Tony J. Frei	H. 2,650	Dr	125	6			
10C2	Alfred Hoffman	U, 2,640	Dr	133	6	44	120	13
10C3	John Ellerson	V, 2,630	Dr	145	6			
10D1	Alfred Druffel	U, 2,660	Dr	175	6	60	173	2
10D2	do	V, 2,630	Dr	100	6	60		
10E1	Frank Busch	V, 2,635	Dr	65	6	30		
10P1	do	V, 2,640	Dr	137	6	50		
10R1	John Druffel	U, 2,670	Dr	273	6	200		
								T. 13 N.,
5N1	August Kopf	U, 2,980	Dr	125	6	80–100		
7A1	Frank Becker	U, 2,940	Dr	75	8	40	72	
8K1	Frank Niehenke	U, 2,830	Dr	155	6	60	75	80
								T. 14 N.,
1J1	Ellen Barclay	U, 2,532	Dr	210	6		210	
1J2	George Faler	U, 2,545	Dg	30	42			
1L1	Rexford Daubenmire	U, 2,580	Dr	275	6–4 (?)		270	5
1M1	Ray Harlow	H, 2,600	Dr	241	6 (?)			
1M2	Jay Snyder	U, 2,531	Dr	87	6		85 (?)	2
2A1	Shiro Okozaki	U, 2,495	Dr	47–50	6			
2K1	Max Hinrichs	U, 2,525	Dr	79	6			
2M1	Floyd Bloomfield	U, 2,508	Dr	93	8			
3P1	Gana Jones	H, 2,664	Dr	176	6			
9J1	Forrest Olson	V, 2,482	Dr	100	6	100		
10E1	Allen Manring	U, 2,555	Dr	143	6			
12P1	Pullman Country Club.	U, 2,600	Dr	100	6			
13H1	Arnold Greenwell	H, 2,555	Dr	90	6	42	90	
14J1	- Greenwell	U, 2,544	Dr	62	6	39	61	1
21F1	Neal Klemgard	U, 2,435	Dr	90	6			

area, Whitman County, Wash.

[Location of wells are shown on pl. 1]

Use of water: C, commercial (restaurants, gas stations, and other small businesses); D, domestic; S, stock; De, destroyed; Ind, industrial; Inst, institutional: Irr, irrigation; NU, not in use; O, observation well; PS, public supply; RR, railroad.
Remarks: C, comprehensive chemical analysis in table 3; Cp, partial chemical analysis in table 3 or 4; dd, drawdown; est, estimated; L, log in table 2; LSD, land-surface datum. Remarks on the adequacy and dependability of water supply, general quality of water, and materials penetrated are reported by owners, tenants, drillers, and others.

zone	Water level		Type of pump and horse-power	Use of water	Remarks
Character of material	Feet below land-surface datum	Date			
R. 45 E.					
Porous material	40–50		C, 2	D, S	Rock at 38 ft. Has never gone dry.
	35.1	June 9, 1954	P	NU	Reported that pumping 75–100 gal will pump well dry.
	12			D, S	Penetrated decomposed granite; dd 8 ft after bailing 20 gpm.
Basalt, clay and sand.	4.8	June 9, 1954	C, 1	D, S	Yields 20 gpm. L.
	31.6	do	P	NU	
	18.4	Dec. 9, 1953	J, ½	D	Rock from 30 ft to bottom. L.
Basalt	60	1948(?)	P, 1	D, S	Adequate supply. L.
	60	Fall 1953	J	D, S	Depth to water 55 ft below LSD when drilled.
Granite, decomposed.	20	1945	P, 1?	D	Yield 1 gpm. L.
		Sept. 7, 1955	J, ¾		L.
Sand	100		J, 2	D	Pumped 10 gpm dd 10 ft. L.
	9.8	Dec. 9, 1953	N	O	L.
Basalt, black	22.2	Sept. 7, 1955	J, 1	D	Bailed more than 15 gpm. L.
	65–70		J, 1½	D, S	Water is hard. L.
	100(?)		P, 1½	D, S	Rock at about 200 ft.
R. 46 E.					
Sand	19.5	June 11, 1954	J, ½	D	Pump breaks suction after pumping 1 hr; recovers quickly.
	8–10	1944	J, ½(?)	D, S	Rock from 40 ft to bottom. Yield 7 gpm.
"Quicksand"		June 11, 1954	N	NU	Well originally cased to 140 ft, but 80 ft of casing was pulled and well capped. L.
R. 44 E.					
Clay, blue, and sand	120(?)	1932	P	D, S	Water is hard.
	23.0	Aug. 13, 1954	S	D	Supply inadequate in summer.
Sand white, quartz, coarse.	205		P, 3 or 5.	D	Slight dd by bailing. Well deepened from 205 ft in 1946.
	91		P, 2	D, S	L.
Basalt	17		J, 1	D, S	Well flowed for a short time during drilling. L.
	13.2	July 14, 1954	J, ½	D	Basalt at 47 ft.
Basalt	15		J, ½	D, S	Pumped more than 30 gpm. L.
	48	1950(?)	J, ¾	D, S	Dd 10 or 17 ft after 1 hr pumping 7 gpm.
	110	Aug. 5, 1954	P, ¾	NU	L.
	69.2	Nov. 11, 1954	P, ¾	D	Well pumping prior to water-level measurement; dd about 61 ft after pumping 1 hr.
	62	August 1949	J, 1	D, S	
			J, 1–3	D	Penetrated no solid rock; can be pumped dry rapidly.
Sand	46	Oct. 12, 1954	J, 1	D, S	Basalt at 50 ft. Water level reported to have declined about 10 ft since drilled. L.
Basalt, soft, porous	12–14	October 1954	N	NU	Can lower water level considerably by bailing ½ hr. L.
	17.6	Aug. 4, 1954	J, ½	D	Yield 6 to 7 gpm. L.

TABLE 1.—*Records of wells in the Pullman*

Well	Owner or tenant	Topography and approximate altitude	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Water-bearing: Depth to top (feet)	Water-bearing: Thickness (feet)
								T. 14 N.,
21H1	Ben Henson	V, 2,335	Dr	68	8-6			
23B1	Paul Lederman	U, 2,555	Dg	20	72-54	20		
24J1	Bob Barbee	U, 2,627	Dr	162	6		161	1
34C1	Nora Hatley	V, 2,457	Dr	200	8-6	18	180	20
36J1	Ada R. Swofford	U, 2,643	Dr	60	6			
								T. 14 N.,
2F1	Larry Thonney	U, 2,520	Dr	35	6			
2F2	do	U, 2,493	Dr	125	6	6		
3H1	R. L. Thonney	U, 2,491	Dr	238	6	6	238	
3H2	do	U, 2,510	Dg	40	48	4		
3K1	William Halpin	U, 2,449	Dr	230	6	16		
3P1	Sig Jorstad	V, 2,450	Dr	60	6			
4H1	Washington State University Experimental Farm.	V, 2,438	Dr	265	6	175	250	10
4N1	Washington State University.	V, 2,382	Dr	100	6		95	5
4Q1	King Evers	U, 2,561	Dr	205	6		205	
4Q2	Washington State University	V, 2,410	Dr	65	6		60	5
5B1	do	V, 2,364	Dr	144	4			
5B2	do	V, 2,364	Dr	237	9	40½		
5B3	do	V, 2,365	Dr	223	16-12	27	195	25
5D1	City of Pullman	V, 2,339	Dr	164	10	34		
5D2	Standard Lumber Co.	V 2,336	Dr	162	6			
5D3	City of Pullman	V, 2 341	Dr	167	16	40	159	3
5D4	Northern Pacific R.R.	V, 2,342	Dr	166	6		89	10
5E1	City Ice Co.	V, 2,341	Dr	95	6	19		
5E3	Audian Theatre	V, 2,340	Dr	73	6		73 (?)	
5E4	Palace Hotel	V, 2,340	Dr	77	6		65	12
5E5	City of Pullman	V, 2,340	Dr	84	6		73	11
5G1	Washington State University	V, 2,364	Dr	213	12 or 10			
6D1	J. C. Hodge	U, 2,519	Dr	190	6	10	190	
6D2	do	U, 2,539	Dr	236	6	12	235	1
6D3	George Utzman	U, 2,501	Dr	190	6			
6D4	James Anderson	H, 2,512	Dr	220	6	40	220	
6E1	Big Sky Drive-In	U, 2,495	Dr	180	6	8-10		
6F1	A. A. Samuelson	U, 2,469	Dr	142	6		140	2
7E1	Harvey Cole	U, 2,515	Dr	82	6	8	70	12
7F1	G. R. Spencer	U, 2,497	Dr	70	6	27		
7F2	Evergreen Builders	U, 2,520	Dr	270	8-6	0-30 145-225	265	5
7F3	Mrs. Baldwin	U, 2,488	Dr	65	6	20	65	
7K1	do	V, 2,470	Dr	29	6			
7M1	Don Adams	U, 2,504	Dr	67	6	30	60	8

area, Whitman County, Wash—Continued

zone	Water level		Type of pump and horse-power	Use of water	Remarks
Character of material	Feet below land-surface datum	Date			
R. 44 E—Continued					
----------	22	1943(?)	J	NU	Alternating zones of basalt and gravel from 11 to 68 ft.
----------	11.2	Aug. 3, 1954	J	D	Complete recovery in a few days.
Rock----------	60	Fall 1951	J, 3	D, S	Rock at 87 ft.
Basalt----------	1	1954	C, 7½	D, S Irr	Pumped 50-60 gpm for days; dd 10-11 ft. Cp. L.
----------	23.7	Aug. 12, 1954	J, ½	D	Well never pumped dry.
R. 45 E.					
Loess(?)----------	6.3	Oct. 21, 1953	----------	D	Temp 52° F. Cp.
----------	53.8	Oct. 22, 1953	N	NU	L.
Sand, black----------	155	1940	P, 1	D, S	Basalt 6-238 ft except for a layer of clay a few feet above 238 ft.
Loess----------	9.8	Oct. 21, 1953	N	NU	Cp. L.
----------	108	1940	P, ¾	D, S	Basalt at 16 ft.
----------	22.3	Oct. 20, 1953	J, ½	Irr	Used for lawn and garden.
Basalt, black, porous.	116.7	Feb. 1, 1955	T, 15	D, S, Irr	Pumped 100 gpm, dd 6 ft. Irrigates 15 acres. L.
Basalt----------	58.3	Oct. 20. 1953	J, 1½	O	Pumped 20 gpm. L.
-----do----------	95.6	----------	S, ¾	D	Bailed 10 gpm, slight dd. L.
Basalt, soft, and sand.	11.2	----------	N	NU	Formerly pumped more than 30 gpm. Destroyed. L.
Basalt----------	40.8	Feb. 1, 1955	N	O	Formerly flowed. Water level declined about 20 ft since 1935. L.
-----do----------	41.2	Oct. 14, 1953	T, 20	Inst	Water level declined about 21 ft since 1933. Pumped 500 gpm with small dd. C.
Basalt, soft, porous, black.	31	August 1946	T	Inst	Pumped 1,500 gpm with 3 ft dd. C, L.
Basalt----------	+4.6	March 1933	T, 60	PS	Pumped 600 gpm with 0.5 ft dd in 1933. Yield, 1,800 gpm in 1933. C, L.
-----do----------	11.7	Feb. 15, 1952	N	NU	Flowed at 7.0 ft above LSD in April 1933. Well sealed at 17 ft.
-----do----------	17.3	Oct. 20, 1953	T, 100	PS	Pumped 24 hr at 1,000 gpm, dd 62 ft. C, L.
Basalt, vesicular----	7.6	Oct. 16, 1953	T, 5	RR	Pumps dry at 30 gpm. C, L.
Basalt(?)----------	18.9	-----do-------	J, 3	Ind	Some water at 60 ft. Flow estimated at 240 gpm when drilled. C, L.
Sand, micaceous----	20 +	1900	N	NU	Probably destroyed. L.
Sand----------	20 +	-----do-------	N	NU	Pumped 30,000 gpd when used Well now capped and probably destroyed. L.
-----do----------	20 +	Mar. 22, 1906	N	NU	Pumped 400 gpm with 30 ft dd. Pumped very fine white quartz sand continuously. L.
Basalt----------	24.3	Oct. 14, 1938	T, 50	PS	C, L.
Sand----------	126.2	Oct. 14, 1954	P, ½	D	Bailed 15 gpm with slight dd. L.
-----do----------	40?	July 14, 1954	P, 1	D	Bailed 15 gpm with slight dd. Supplies three families. L.
----------	130.7+	July 15, 1954	P, ¾	D	Adequate supply.
Sand, white--------	147.0	Mar. 7, 1956	S, 1	D	Pumped 11 gpm for 1 hr with 21 ft dd. L.
----------	6	June 1993	S, ½	D, C	Basalt at about 6 ft first water at 40 ft.
Sand----------	62	-----do-------	J, 1	D	L.
Basalt, soft, black--	36.3	May 18, 1954	N	NU	Bailed 10 gpm. L.
Basalt----------	32.9	Dec. 9, 1953	J, ½	D	L.
Basalt, soft--------	129.8	Oct. 13, 1954	T, 20	PS	Water level dropped from 14 ft to 130 ft when main aquifer was struck. Cp, L.
Contact between soft and hard lenses.	20-25	1940(?)	----------	D	Bailed 15 gpm. L.
----------	2.8	May 25, 1954	N	NU	
Basalt, porous------	33.6	May 24, 1954	N	NU	Bailed 30 gpm with slight dd. L.

TABLE 1.—*Records of wells in the Pullman*

Well	Owner or tenant	Topography and approximate altitude	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Water-bearing	
							Depth to top (feet)	Thickness (feet)
								T. 14 N.,
7M2	Blosser & Loughrey	U, 2,523	Dr	90	6	62	85	5
7M3	Dr. Tomlinson and Baldwin.	U, 2,502	Dr	87	6		80	7
7N1	Max Hinrichs	V, 2,497	Dr	50	6			
8A1	James Cook	V, 2,358	Dr	85	6		80	5
8A2	Marion Wise	V, 2,360	Dr	105	6	36		
8G2	Ben Wooliscrift	U, 2,398	Dr	110	8	60	104	8
8H1	Herbert Neil	U, 2,414	Dr	136	6	22	130	6
8H2	H. C. Weller	U, 2,446	Dr	140	6			
8J1	James Askins	V, 2,381	Dr	85	6	30	85	
8L1	Pullman Cemetery	H, 2,583	Dr	355	6		294(?)	21
8R1	Vern Hickman	V, 2,384	Dr	145	6			
9E1	C. H. Hinchcliff	V, 2,408	Dr	67	6	20	65	2
10Q1	H. G. Stratton	U, 2,540	Dr	200	6			
11K1	Ray Shaw	U, 2,558	Dr	2	6			
11N1	U.S. Geological Survey.	V, 2,523	Bd	15	1½	15		
13F2	Howard Brown	V, 2,540	Dg	20	72	2		
15B1	George Leonard	U, 2,607	Dr	213	6			
16E1	C. A. Stratton	V, 2,378	Dr	80	6	40	60	
17A1	H. M. Jacobson	U, 2,408	Dr	175	6	50	150	10
19D1	A. W. Kienholz	U, 2,558	Dr	74	6		65	9
19P1	Sig Jorstad	U, 2,600	Dg	38	48			
20E1	Claude Kirkendall	U, 2,650	Dg	17	60–36			
21H1	L. C. Staley	V, 2,435	Dr	206	8–6			
22P1	John Staley	U, 2,464	Dr	100	6	20		
22Q1	F. A. Jennings	V, 2,466	Dr	37	6		31	
25D1	Robert H. Lyon	U, 2,521	Dr	54	6			
25Q1	Don Whitman	U, 2,647	Dr	140	6			
26C1	Stanton Bursch	U, 2,529	Dr	60	6			
28H1	L. C. Staley	V, 2,513	Dr		8–6	20	150	15
28H2	Harold Boyd	U, 2,519	Dr	100	8–6	20		
28K2	L. C. Staley	U, 2,511	Dr	80	8	20	15	65
29H1	Howard Gimlen	U, 2,574	Dr	2	6			
31J1	F. A. Jennings	V, 2,555	Dr	37	6			
31R1	Herman Larson	V, 2,565	Dg	19	36	19		
35E1	Gray Brothers	U, 2,558	Dr	148	6			
35N1	G. O. Swales	U, 2,654	Dr	117	6	78		
36Q1	Harry Johnson	U, 2,753	Dr	180–190	6	20		
								T. 14 N.,
5Q1	Edgar Anderson	H, 2,765	Dr	123	6			
6R1	do	H, 2,751	Dr	212	7	90	202	10
6R2	do	U, 2,665	Dr	350	6	50	340	
7G1	Harlan Reid	U, 2,640	Dr	180	6		180	
7N1	C. J. Bowers	V, 2,567	Dr	100+	6			
7N2	Lloyd Shriver	U, 2,567	Dr	242	6		90	
7P2	Edgar Anderson	U, 2,612	Dr	140	6			
8K1	Arnold Anderson	H, 2,680	Dr	125	6	125		
8K2	do	U, 2,630	Dr	240	6	200		
17B1	Henry M. Peterson	U, 2,557	Dr	120	6	20	110	10

area, Whitman County, Wash—Continued

zone	Water level		Type of pump and horsepower	Use of water	Remarks
Character of material	Feet below land-surface datum	Date			
R. 45 E.—Continued					
Basalt, soft	43.2	June 9, 1954	N	NU	Bailed 30 gpm. L.
do	36.0	Nov. 10, 1954		D	L.
	12		J, ½	D, S	Supplies 50 head of stock.
Crevice in basalt	43.6	May 19, 1954	S, ½	D	Basalt at about 20 ft. Cp.
	46.5	do	J, 1	D	L.
	72.4	Apr. 25, 1955	J	D, S	Basalt at 10 to 12 ft.
Basalt	86	1948	J, 1½	D	Basalt from 18 or 20 ft to bottom.
	119.4	Oct. 15, 1954	J, 2	D, S	A few feet of soil overlies basalt.
Opening in basalt	55		J, 3	D, S	Unable to bail dry. L.
Basalt, porous	235	1928	T, 10	Irr	Tested 240 gpm when drilled. L.
	55	1947		D, S	Bedrock at less than 20 ft.
Opening in basalt	5		J, 1	D	First water at 40 ft. L.
	40		P, 1(?)	D, S	Pumped 6 gpm.
	9.7	May 19, 1954	J, ¼	D	Hard water.
Loess	4.1	May 18, 1954	N	O	
do	2.2	May 20, 1954	S, ⅓	D, S	Well entirely in hard clay. Cp.
	140.4	May 19, 1954	P, ¾	D, S	Present yield 400 gpd. In 1932 pumped dry in 3 hr at 6 gpm. Cp, L.
	65.7	May 21, 1954	J, 1	S	Dd 5 to 6 ft by bailing. L.
	90	1950	J, 2	D	Basalt at 50 ft. Bailed 20 gpm with slight dd.
Basalt	2	1943	J	D, S	Basalt at 12–15 ft. Bailed 24 gpm with 10 ft dd. Cp.
	13.0	May 25, 1954	P	NU	
	10.1	do	S	D	Well used occasionally. Cp.
	120–130	June 1956	T, 5	D, S	Basalt at less than 20 ft. Supplies 4 homes and 100 head of stock.
Basalt	15–20	1950	J	D, S	Basalt from 15 ft to bottom.
do	1		P		Adequate supply.
do	13.6	May 21, 1954	J, ½	D	Basalt from 14 or 15 ft to bottom. Cp.
	112.3	do	P	NU	
	22.0	May 20, 1954	J, ¾	D, S	Supplies 20 head of stock.
Sand, white, fine	10	1941(?)	P, 1	D, S	Originally drilled to 165 ft. Bailed for 20–30 min with 10 ft dd. L.
	15		J, 2	D	Basalt at 10 ft. Bailed 30–35 gpm with 25 ft dd.
Basalt	7.9	July 14, 1954	P, ¼	D	Basalt from 5–10 ft to bottom.
	33.1	May 25, 1954	J, ¾	D, S	Soft water.
	8.1	do	J, ½	D	Adequate supply.
	9.4	do	J	D	Do.
	18.6	May 24, 1954	J, 1	D	Well in rock below 100 ft. Water level was at land surface when drilled. Cp.
	Flowing		J, 1	D, S	Water level originally 6 ft above LSD.
	14.4	May 24, 1954	N	NU	Granite from 20 ft to bottom contained a little water.
R. 46 E.					
	106.2	May 19, 1954	P	NU	Good yield.
Basalt, porous	90	1945	P, ¾	D, S	Yield, 16 gpm. L.
	61	1938(?)	N	NU	Sand sealed off chief aquifer. Well capped and covered. L.
Crevice(?) in basalt	40		J, 2	D, S	Supplies 2 homes and 60 head of stock. L.
	9.0	May 20, 1954	J, 1	NU	
Basalt, soft	40		P, 1	D	Well pumps dry in 2½ hr, recovers in 4 hr. L.
	101.6	May 19, 1954	P, ½	D	Inadequate supply.
Granite, decomposed.	35	1947	P, 1	D, S	Granite at 125 ft.
Quicksand			N	NU	Sand heaved up 35 ft in casing. Destroyed. L.
Sand, granite, decomposed.	60–65	1945	J, 1	D, S	Bedrock at 20 ft. Bailed 15–18 gpm with slight dd.

TABLE 1.—*Records of wells in the Pullman*

Well	Owner or tenant	Topography and approximate altitude	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Water-bearing	
							Depth to top (feet)	Thickness (feet)
								T. 14 N.,
19M1	Elmer Haynes	V, 2,481	Dr	80	6	30	79	1
29L1	C. V. Strohm	U, 2,575	Dg-Dr	278	60-6	278	275	3
30A1	Stanford Jester	U, 2,612	Dr	58	6			
31F1	- Steiner	U, 2,690	Dg	33	48(?)			
								T. 15 N.,
1G1	A. V. Clark, Jr.	V, 2,392	Dr	157	6	40	155	2
1N1	Girard Clark	V, 2,481	Dr	73	6	35	70	3
2R1	Boyd Kelso	U, 2,524	Dr	142	6	30		
4A1	Union Pacific R.R.	V, 2,198	Dr	200	4 or 5			
10Q1	City of Albion	V, 2,256	Dr	83	6			
11A1	Joe Bryan	U, 2,552	Dr	150	6	90	135	15
11F1	Clarence Johnson	UV, 2,461	Dr	140	7			
11F2	do	V, 2,445	Dr	225	6-4			
13J1	do	U, 2,525	Dr	178	8(?)			
14D1	City of Albion	V, 2,281	Dr	235	10-6	20		
15A1	Pete Christopher	V, 2,242	Dr	63	6			
15A2	City of Albion	V, 2,244	Dr	78	10-8	78		
15H1	George M. Martin	U, 2,267	Dr	150	6	120		
16K1	Frank Dober	U, 2,345	Dr		6			
16L1	Ed Jones	U, 2,380	Dr	78	6			
16L2	do	U, 2,400	Dr	363	5	72		
21C1	John Fulfs	U, 2,400	Dr	130	6	130	120	
21D1	O. V. McCroskey	V, 2,350	Dr	177	8	20	177	
21D2	do	V, 2,340	Dr	165	8	20		
26L1	Merle Harlow	U, 2,394	Dr	160-165	8	20 0	155	5
28B1	Tom Bush	V, 2,400	Dr	50	6	5	40	
33B1	Leonard Small	U, 2,415	Dr	175	9			
35B1	John Fulfs	U, 2,443	Dr	75	6			
35E1	V. L. Michaelson	V, 2,417	Dr	300	12-10	39	292	8
35R1	John Fulfs	U, 2,506	Dr	56	5			
								T. 15 N.
1H1	Paul Mader	U, 2,600	Dg	26	36(?)	26(?)		
3J1	U.S. Geological Survey.	U, 2,650	Bd	17	1½	17.1		
6H2	Roy Parvin	U, 2,406	Dr	146	6	8	145	1
7D1		U, 2,500	Dg	26	48			
7Q1	W. E. Lawson	U, 2,611	Dr	150	6			
7R1	Oscar Anderson	U, 2,575	Dg	33	42	33.5		
8L1	Helmer Rossebo	U, 2,484	Dr	123	6	40	104	19
8M2	Ross Howell	U, 2,510	Dr	290	6	55	290	
9C1	Paul E. Vernier	U, 2,540	Dr	260	6			
9H1	Kenneth Knight	U, 2,595	Dg	25	36	25		
9R1	Paul Vernier	U, 2,509	Dr	116	8	54	80	
10E1	A. H. Nelson	U, 2,566	Dr	263	6			
10F1	do	U, 2,569	Dr	72	10	38	58	5
11K1	Roy Held	U, 2,562	Dg	30	24	30		
11N1	Kimzey Estate	H, 2,607	Dr	150	6			
13N1	E. Cunningham Estate.	U, 2,550	Dr	153	6	20		

area, Whitman County, Wash—Continued

zone: Character of material	Water level: Feet below land-surface datum	Water level: Date	Type of pump and horsepower	Use of water	Remarks
R. 46 E—Continued					
Sand	9.6	May 20, 1954	J	D	Basalt at 20 to 25 ft. Unable to lower water perceptibly by bailing. L.
do		May 24, 1954	P	D, S	Well dug 0–30 ft, drilled 30–278 ft. Bailed 30 gpm with ½ ft dd. L.
	Dry	May 20, 1954	N	NU	Originally drilled to more than 100 ft. Plugged at present depth.
	3.9	do	P	NU	
R. 44 E.					
Rock	19.4	Nov. 24, 1953	J, 1½	D	Bailed 15 min, 20 ft dd. L.
Basalt	Flowing		J, 1	D, S	Occasionally stops flowing July–Sept. Cp. L.
	30	1946	P, 1	D, S	Rock at about 30 ft. Bailed 36–37 gpm.
	5–6		P	RR	Adequate supply.
	28.6±	Oct. 1, 1954	J, 1	PS	C.
Crevice in basalt	132		P, ¾	D, S	Yield, 30 gpm. Supplies two homes. L.
	3.8	Nov. 24, 1953	N	NU	Quicksand overlies bedrock.
Sand, granitic	0.5+	do	J, ½	D	Quicksand overlies granite. Cp.
	56.6	Nov. 23, 1953	J, ½(?)	NU	
	12.8	do	N	NU	Bailed 12 gpm. L.
	30		J, 1	D	Adequate supply.
Granite, decomposed.	16	January 1954	T, 3	PS	Dd 20 ft after pumping 75 gpm for 14 hr. Cp, L.
	45.6	Dec. 3, 1953	J, 1	D, S	Adequate supply.
	29.2	Aug. 18, 1954	J, ½	D, S	Do.
	76.2	July 15, 1954	J, ½	D, S	Pumping prior to measurement; can be pumped dry rapidly. L.
	72	1944(?)	N	NU	Small yield. L.
Rock, soft	30	1948	J, 1	D	Yield, 15 gpm. L.
	100		P, ¾	D	L.
	90		P	D	Continuous yield, 60 gpm.
Basalt, soft	73.6	July 8, 1955	J, 1 or 1½	D, S	Bailed 10 gpm without noticeable dd. Yield, 10–12 gpm. L.
	19.4	Dec. 11, 1953	J	D	Basalt at 35–40 ft.
Sand(?), black	60	1944(?)	J, ¾	D	L.
	7	July 15, 1954	J, ½	D	Yield, 25 gpm.
Basalt, red, soft	88.9	June 8, 1954	T, 50	Irr	Pumped 490 gpm, dd 34 ft, recovered in 5 min. L.
	11.6	July 15, 1954	J, ¾	D, S	Adequate supply.
R. 45 E.					
	17.6	Nov. 9, 1953	J, ⅓	D	Adequate for domestic supply.
	4.7	Nov. 12, 1953	N	O	
Sand, white	60.0	do	J, 1½	D, S	L.
	9.9	Nov. 24, 1953	P	NU	Temp, 48° F. Cp.
	51.6	Nov. 13, 1953	J, 1	D, S	Adequate supply. Cp.
	18.3	do	J	D	Supply inadequate during summer.
Basalt, soft, porous	30		J, ½	D	Bailed 5 gpm at 65 ft, no noticeable dd. Cp, L.
Basalt	60		P	D, S	Bailed ±20 gpm, dd 20 ft. Cp, L.
	150–160	1938 or 1939	P, 1	D, S	Adequate yield.
	14.7	Nov. 23, 1953	S, ¼	D, S	
Basalt	17.7	Nov. 5, 1953	J, ½	D	L.
	229.6	Nov. 6, 1953	N	NU	
Basalt, porous	42.8	do	Sb, 1	D, S	Yield, 30 gpm. Cp L.
	19.5	Nov. 10, 1953	N	NU	Bottom 10 ft in basalt. Quick recovery.
	79.8	Nov. 6, 1953	P, ¾	NU	Basalt at 20 ft. Yield, 6 gpm.
	19.8	Oct. 29, 1953	P	NU	Originally 165 ft deep.

TABLE 1.—*Records of wells in the Pullman*

Well	Owner or tenant	Topography and approximate altitude	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Water-bearing	
							Depth to top (feet)	Thickness (feet)
T. 15 N.,								
14Q1	Mary Stirewalt	V, 2, 518	Dr	285	6			
15H1	Roy Held	U, 2, 525	Dr	85	6	85		
15R1	Old Whelan Grange	U, 2, 510	Dr	50	6			
17E1	Ross Howell	U, 2, 554	Dr	90	6	35		
17M1	Carl Reid	U, 2, 517	Dr	259	6	25		
19F1	Milton Johnson	V, 2, 437	Dr	134	6			
20H1	Wendell Gwinn	U, 2, 526	Dr	74	6			
20K2	Don Sodorff	U, 2, 517	Dr	172	6			
21H1	Carl Boyd	H, 2, 515	Dr	248	6	31	235	13
23B1	Mary Stirewalt	U, 2, 540	Dr	51	6	51		
24C1	Jesse Grey	U, 2, 590	Dg	20	36	20		
25A1	Merrill Boyd	U, 2, 651	Dr	137	6			
25Q1	W. M. Boyd	U, 2, 620	Dr	264	6	65	264	
26K1	Orval Boyd	U, 2, 608	Dr	302	6	74		
26K2	do	U, 2, 608	Dr	120	6			
27M1	Frank Boyd	U, 2, 530	Dr	150	8	100(?)		
28J1	D. R. Burnham	U, 2, 565	Dg	44	48	43.8		
28J2	do	U, 2, 530	Dr	162	6			
29P1	Kenneth W. Hall	U, 2, 437	Dr	140	6	16		
29P2	do	U, 2, 421	Dr	125	5	10	120	
30G4	Soil Conservation Service Experimental Farm.	U, 2, 530	Dr	371	6		335	25
31G1	Mrs. Beuche	U, 2, 527	Dr	224	6			
32C1	O. O. Turner	V, 2, 384	Dr	105	8 or 9	105(?)		
32G1	D. R. Berry	V, 2, 390	Dg	26	30			
32N1	City of Pullman	V, 2, 340	Dr	231	16	24		
32N2	do	V, 2, 340	Dr	954	20–16–12	399		
33J1	Washington State University	U, 2, 619	Dr	438	6		420	
34L1	Ted Taylor	U, 2, 534	Dr	45	6			
34N1	Earl Whitlow	V, 2, 463	Dr	52	6	52		
35F1	Pullman-Moscow Airport.	V, 2, 532	Dr	172	8			
T. 15 N.,								
6G1	Theodore Quist	U, 2, 636	Dr	65	6	65		
6P1	Paul Mader	V, 2, 633	Dr	78	6			
7C1	Sam Fleener	U, 2, 651	Dg	72	42	72.0		
7J1	Percy Doyle	U, 2, 678	Dr	150	7	150		
8Q1	Marvin Dahl	H, 2, 801	Dr	135	8			
17B1	James Williams	U, 2, 800	Dr	106	6			
18J1	Carl Boyd	U, 2, 685	Dr	214	6			
19J1	John O'Donnell	V, 2, 585	Dr	59	8			
19R1	W. M. O'Donnell	V, 2, 575	Dr	41	6	12		
20K1	N. T. Carson	V, 2, 579	Dg	15	48	14.9		
20P1	do	V, 2, 590	Dr	250	6	180		
29N1	Charles Paul	U, 2, 620	Dr	120	5¼	65	118	2
30N1	John Goughnour	U, 2, 630	Dg	23	48	23.2(?)		

area, Whitman County, Wash—Continued

zone	Water level		Type of pump and horse-power	Use of water	Remarks
Character of material	Feet below land-surface datum	Date			
R. 45 E—Continued					
	146	Fall 1949	P, 1	D, S	Probably deepened from 212 to 285 ft in 1937 or 1938. Prior to deepening, water level declined continuously, and well pumped dry at 4 gpm. L.
Basalt, porous	27.2	Nov. 10, 1953	J, ⅓	D, S	Basalt at 25 ft, test 40 gpm when drilled. Water level ±21 ft April 1933.
	20.9	Nov. 5, 1953	S, ⅓	NU	
Basalt	27.0	Nov. 13, 1953	S, ½	D	Basalt at about 30 ft. Cp.
Rock	18.8	Oct. 1, 1954	J	D, S	Basalt from 24 ft to bottom.
	57.0	May 27, 1954	J, ¾	D, S	Adequate supply.
Basalt(?)	10.7	Nov. 5, 1953	J, ¾	D	Cp.
	±12 8.8	1932 May 27, 1954	N	NU	Basalt at 16 ft. Penetrated pre-basalt rock at 120 ft.
Basalt	193.3	Aug. 3, 1955	P	D	Soil to 31 ft, basalt from 31 ft to bottom. Bailed 40 gpm without noticeable dd. Report hardness ±120 ppm.
	31.4	Oct. 29, 1953	J, ½	D	Cp.
	17.1	do	J, ½(?)	D, S	Adequate supply.
	112.2	Oct. 22, 1953	J, 1½	D, S	Bedrock at 96 ft.
Basalt(?)	59.5	do	P, 1½	D, S	Basalt at ±65 ft. Cp.
Basalt	281.0	Oct. 27, 1953	S, 3	D, S	Some water at 60–74 ft. Tested 50 gpm for several hours. L, C.
do	50–60	October 1953	P	D	Quick recovery. Cp
	30		P, 1	D, S	Adequate supply.
	34.9	Nov. 4, 1953	P	NU	Basalt at 42–43 ft.
	76.7	do	P	D	L.
Shale rock, black	120.4	Apr. 29, 1955	P, 1	D, S	Pumping when measured. Water at 110 ft. L.
	65	1932	N	NU	
Basalt, black, soft, porous.	190 204.4	1938 Oct. 18, 1954	P, ¾	D, S	L.
	30	1932	N	NU	Basalt at 4 ft. Pumps dry at 10 gpm.
	50–60		J, 1	D, S	Hard water.
Loess	11.5	Nov. 9, 1953	N	NU	Cp.
Basalt	9 23	Mar. 12, 1945 October 1953	T, 75	PS	Pumped 800 gpm for 4 hr with 43 ft dd. C, L.
do	21.48	June 5, 1956	T, 150	PS	Pumped 1,000 gpm for 24½ hr with 18.6 ft dd. L.
do	280+ 271	Oct. 28, 1953 September 1933	N	NU	L.
	23.0	Oct. 28, 1953	P	S	Cp.
	6		1¾	D	Rapid dd, quick recovery. Basalt at 8–10 ft.
	15	Sept. 28, 1936	Screw, 2	D	Supplies two apartments and an airport. L.
R. 46 E.					
Basalt, porous	24	October 1952	J, ¾	D, S	Basalt from 30 ft to bottom.
	24.9	Nov. 9, 1953	J, ½	D	Hard water.
	47.1	do	J, ½	D, S	Well bottoms in bedrock.
	20	Fall 1942	J, ½		Yield, 4 gpm. Quick recovery.
	90–95	1947	S, ½	D	Cp.
	36.4	Nov. 10, 1953	P	D	Small yield.
	23.4	Oct. 29, 1953	P	NU	
	16.3	do	S, ½	D	Basalt 4–5 ft below LSD.
	6		J, 1	D	Basalt from 10 ft to bottom; quick recovery.
Loess	6.3	Oct. 28, 1953	N	O	Cp.
Sand, granitic(?)	101.6	do	P, ¾	S	Deepened from 160 to 325 ft in 1938; has since filled to 250 ft. C. L.
Basalt	65	1923	P	D, S	L, Cp.
Loess	7.9	Oct. 23, 1953	J, ½	D, S	Cp.

TABLE 1.—*Records of wells in the Pullman*

Well	Owner or tenant	Topography and approximate altitude	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Water-bearing	
							Depth to top (feet)	Thickness (feet)
								T. 15 N.,
31H1	Gerry Hagedorn	U, 2, 611	Dr	100(?)	6			
31J1	Auto-Vue Theatre	V, 2, 518	Dr	117	6		100	17
31K1	Carrie Yarborough	V, 2, 540	Dg	18	36–20	5+		
								T. 16 N.,
25D1	W. M. Stipe	U, 2, 560	Dr	200	6	25	200	40
25R1	John Tate	U, 2, 600	Dg	24	48	24		
27Q1	Jack Leonard	V, 2, 490	Dr	135	6		±130	5
27R1	Jacob Greenwalt	U, 2, 500	Dr	147	6	3	144	3
32N1	Roy Parvin	U, 2, 550	Dr	140	6	12	140	
36B1	Lloyd Knapp	U, 2, 600	Dg-Dr	100	6			
								T. 16 N.,
29Q2	R. E. Shafer	V, 2,600	Dg	29	48	28.6		
30Q1	E. V. Parker	U, 2,575	Dg	32	42–36	31.9		
31R1	- Koster	U, 2,675	Dg	34	28	33.8(?)		
								T. 39 N.,
4N1	Herb Carlton	H, 2,650	Dr	220	6		216	4
5F1	William Jones, Jr	U, 2,650	Dr	265	6		265	
7J1	City of Moscow	V, 2,570	Dr	245	15 or 18			
7J2	do	V, 2,567	Dr	254	15		224	30
7J3	do	V, 2,568	Dr	245	12			
7P1	University of Idaho	V, 2,548	Dr	355	20	355		
7R1	Inland Motor Freight	V, 2,561	Dr	231	8			
8B1	City of Moscow	U, 2,667	Dr	341	6	141	340	1
8B2	do	U, 2,667	Dr	373	24–18	144		
8R1	do	V, 2,596	Dr	790	15–6⅝			
15C1	J. C. Parker	V, 2,622	Dg-Dr	192	6			
15G1	Moscow Golf Course	V, 2, 610	Dr	203				
17J1	Sunset Memorial Gardens.	V, 2, 610	Dr		12–10–8	461	447	66
18C1	University of Idaho	V, 2, 601	Dr	330	8	98		
21A1	Ed Jutte	V, 2, 635	Dr	316			310	5

area, Whitman County, Wash—Continued

zone	Water level		Type of pump and horsepower	Use of water	Remarks
Character of material	Feet below land-surface datum	Date			
R. 46 E—Continued					
	76.9	Oct. 22, 1953	P, ½	D, S	Pumping prior to measurement. Cp.
Porous or soft formation.	8.2	do	J, 2½	C	Some water between 65 and 70 ft. L.
	11.0	do	P	NU	
R. 45 E.					
Gravel	20–30	Spring 1951	J, 2	D	Originally 240 ft, but since filled to 200 ft with gravel. Water level declining. L.
Clay	10.5	Nov. 11, 1953		D	Well in hardpan or hard clay for entire depth. Cp.
Sand, granitic	20	July 1950	S, ½	D, S	Basalt at 10–15 ft overlying sand. Cp.
Crevice in basalt	40		P	D, S	L.
	40–50	1940	P	NU	
		Nov. 11, 1953	P	NU	Drilled inside 25-ft dug well.
R. 46 E.					
	10.2	Nov. 12, 1953	P	D, S	Used occasionally.
Sand	21.8	Nov. 11, 1953	P	D	Adequate supply.
	16.3	Nov. 10, 1953	P	NU	Cp.
R. 5 W.					
Basalt, brown, porous.	170	1953–54	P, ¾	D, S	Pumped 32 hr with slight dd. L.
Basalt, hard	130	November 1953	P, ¾	D, S	Pumped ¾ hr at 15 gpm with negligible dd. L.
	76 or 92	January 1955	T, 150	PS	Pumped 22 hr at 1,200 gpm with 7–9 ft dd. Temp, 54° F.
Basalt(?)	54 78	December 1932 March 1955	T, 100	PS	Well drilled to 560 ft, plugged with grout below 254 ft. Pumped 22 hr at 900 gpm with 6–7 ft dd. Cp, L.
	Flowing 91–93	1882(?) January 1955	T, 75	PS	Pumped 1 hr at 1,000 gpm with 6 ft dd. C.
Sand, granitic	55	1951	T	PS	Cp, L.
	56.1 85.6	Sept. 18, 1940 Oct. 10, 1955	N	O	
Sand and shale	158	Mar. 15, 1947	N	NU	Test well for 8B2. Pumped 7 hr at 212 gpm with no appreciable dd.
	163	1948	T, 100	PS	Pumped 330 gpm for ½ hr with 137 ft dd. Cp, L.
			N	NU	Some water below first basalt. No other appreciable amount of water; well abandoned. L.
	33.0	Oct. 6, 1954	N	NU	Drilled 446 ft, filled with sand to 192 ft. L.
				Irr	L.
Sand	124	August 1955	N		Will be used to irrigate. Pumped 24 hr at 650 gpm with 64 ft dd. L.
Sand, granitic	84 110	January 1940 Mar. 29, 1955	T	Inst	Pumped 524 gpm, 4 ft dd in 1949. C, L.
Granite formation					Pumped 20 gpm, 80 ft dd. L.

TABLE 1.—*Records of wells in the Pullman*

Well	Owner or tenant	Topography and approximate altitude	Type of well	Depth of well (feet)	Diameter of well (inches)	Depth of casing (feet)	Water-bearing	
							Depth to top (feet)	Thickness (feet)
								T. 39 N.,
13K1	H. E. Hattrup........	H, 2, 762	Dr	141	6	138	138	3
13L1	Hubert Dohmen......	H, 2, 764	Dr	149	6	149	....	....
								T. 40 N.,
30L1	R. T. Moser..........	U, 2, 646	Dr	309	6	94	310	46
								T. 40 N.,
36G1	W. M .O'Donnell.....	U, 2, 608	Dr	204	6	100(?)	200	4

area, Whitman County, Wash—Continued

zone	Water level		Type of pump and horsepower	Use of water	Remarks
Character of material	Feet below land-surface datum	Date			
R. 6 W.					
Loess	100.8	May 19, 1954	P	D	L.
	109		P, 1	D, S	Pumped 5 gpm. Bottom few feet in basalt.
R. 5 W.					
Granite, decomposed.	91.9	Oct. 29, 1955	N	NU	Drilled 356 ft, has filled in to present depth with sand. Pumped 10 gpm with slight dd. Cp, L.
R. 6 W.					
Crevice	80	1948	J, 1	D, S	L.

TABLE 2.—*Logs of representative wells in the Pullman area*

13/45-3M2. Franz Druffel

[Altitude about 2,625 ft. Drilled by Mike Braden, 1946(?). Casing: 6 in.]

Material	Thickness (feet)	Depth (feet)
Clay and sand	30	30
Basalt	60	90
Clay, basalt, and sand (water-bearing)	10	100

13/45-7Q1. Martin Druffel

[Altitude about 2,640 ft. Casing: 6 in.]

Material	Thickness (feet)	Depth (feet)
Loess	30	30
Basalt	48	78

13/45-8C1. J. W. Maxwell

Altitude about 2,640 ft. Drilled by A. R. McInroy, 1948. Casing: 6 in. to 40 ft]

Material	Thickness (feet)	Depth (feet)
Topsoil	2	2
Loess	38	40
Basalt	264	304

13/45-10C2. Alfred Hoffman

[Altitude about 2,640 ft. Drilled by Spray Bros., 1945. Casing: 6 in. to 44 ft]

Material	Thickness (feet)	Depth (feet)
Loess	44	44
Basalt	76	120
Granite, decomposed	13	133

13/45-10C3. John Ellerson

[Altitude about 2,630 ft. Drilled by Spray Bros., 1955. Casing: 6 in., 0-45 ft; 5 in., 85-125 ft]

Material	Thickness (feet)	Depth (feet)
Loess	45	45
Basalt (water 2 gpm at 85 ft)	40	85
Clay	40	125
Basalt (water at 125 ft)	20	145

13/45-10D1. Alfred Druffel

[Altitude about 2,660 ft. Drilled by Spray Bros., 1952. Casing: 6 in. to 60 ft]

Material	Thickness (feet)	Depth (feet)
Topsoil	2	2
Loess	58	60
Basalt	113	173
Sand	2	175

13/45-10D2. Alfred Druffel

[Altitude about 2,630 ft. Drilled by Spray Bros., 1948. Casing: 6 in. to 60 ft; perforated from 25 to 60 ft]

Material	Thickness (feet)	Depth (feet)
Topsoil	2	2
Loess	58	60
Basalt	40	100
Sand (?)	-------	-------

13/45-10E1. Frank Busch

[Altitude about 2,635 ft. Drilled by Spray Bros., 1955. Casing: 6 in. to 30 ft]

Material	Thickness (feet)	Depth (feet)
Loess	27	27
Basalt, black	38	65

13/45-10P1. Frank Busch

[Altitude about 2,640 ft. Casing: 6 in. to 50 ft]

Material	Thickness (feet)	Depth (feet)
Loess	50	50
Basalt	87	137

13/46-8K1. Frank Niehenke

[Altitude about 2,830 ft. Drilled by Spray Bros., 1950]

Material	Thickness (feet)	Depth (feet)
Soil, black	4	4
Clay, red	76	80
Sand (water-bearing)	75	155

14/44-1M1. Ray Harlow

[Altitude about 2,600 ft. Drilled by J. W. Queen, 1938(?). Casing: 6 in.(?)]

Material	Thickness (feet)	Depth (feet)
Loes	90	90
Basalt	151	241

14/44-1M2. Jay Snyder

[Altitude about 2,531 ft. Casing: 6 in.]

Material	Thickness (feet)	Depth (feet)
Loess	30	30
Basalt		(?)
Basalt, porous		(?)
Basalt, hard		87

14/44-2K1. Max Hinrichs

[Altitude about 2,525 ft. Drilled by J. W. Queen, 1940-45. Casing: 6-in.]

Material	Thickness (feet)	Depth (feet)
Loess	13	13
Basalt, hard, blue	12	25
Basalt, soft, gray	15	40
Clay, blue	4	44
Basalt, black, porous	35	79

14/44-3P1. Gana Jones

[Altitude about 2,664 ft. Drilled in 1926. Casing: 6-in.]

Material	Thickness (feet)	Depth (feet)
Loess	176	176

14/44-13H1. Arnold Greenwell

[Altitude about 2,555 ft. Drilled by Spray Bros., 1945]

Material	Thickness (feet)	Depth (feet)
Loess	50	50±
Basalt	40±	90
Sand	-------	-------

TABLE 2.—*Logs of representative wells in the Pullman area*—Continued

Material	Thickness (feet)	Depth (feet)
14/44-14J1. - Greenwell		
[Altitude about 2,544 ft. Drilled by Spray Bros., 1954. Casing: 6-in. to 39 ft]		
Loess	31	31
Basalt, soft (some water)	10	41
Basalt, hard	14	55
Basalt, soft (some water)	3	58
Basalt, hard	3	61
Basalt, soft, porous (water-bearing)	1	62
14/44-21F1. Neal Klemgard		
[Altitude about 2,435 ft. Casing: 6-in.]		
Soil	3	3
Basalt	87	90
14/44-34C1. Nora A. Hatley		
[Altitude about 2,457 ft. Casing: 8-in. to 19 ft]		
Loess	19	19
Basalt	160	179
Sand, soft (water-bearing)	21	200
14/45-2F2. Larry Thonney		
[Altitude about 2,493 ft. Drilled by Nelson(?), 1947. Casing: 6-in. to 72 ft]		
Soil	2	2
Basalt	123	125
14/45-3H2. R. L. Thonney		
[Altitude about 2,510 ft. Dug by owner]		
Loess	40	40
Basalt	--------	--------
14/45-4H1. Washington State University		
[Altitude about 2,438 ft. Drilled by J. W. Queen, 1935. Casing: 6-in. to 175 ft]		
Soil	7	7
Boulders	8	15
Basalt, very hard, black	36	51
Basalt, hard, gray	25	76
Basalt, blue	1	77
Basalt, soft, black	5	82
Basalt, soft, gray	10	92
Basalt, porous, black (water rose from 115 ft to 72 ft; yield of 5 gpm)	23	115
Basalt, soft, black (water level dropped 37 ft)	55	170
Basalt (water level dropped 16 ft; yield of 20 gpm)	50	220
Basalt, porous, black, at 250 to 260 ft	45	265
14/45-4N1. Washington State University		
[Altitude about 2,382 ft. Casing: 6-in.]		
Topsoil	6	6
Basalt	89	95
Basalt (water-bearing)	5	100
14/45-4Q1. King Evers and C. A. Cole		
[Altitude about 2,561 ft. Drilled by Spray Bros., 1953. Casing: 6-in.]		
Topsoil	2	2
Loess	48	50
Basalt	155	205
14/45-4Q2. Washington State University		
[Altitude about 2,410 ft. Drilled by J. W. Queen, 1937-38. Casing: 6-in.]		
Soil	8	8
Boulders	14	22
Basalt, hard, black	12	34
Basalt, soft, gray, few inches of blue clay	11	45
Basalt, hard, black	15	60
Basalt, soft, and sand	5	65
14/45-5B1. Washington State University		
[Altitude about 2,366 ft. Drilled, 1910(?). Casing: 4-in.]		
Basalt	65	65
Clay	30	95
Basalt	49	144
14/45-5B3. Washington State University		
[Altitude about 2,365 ft. Drilled by Strasser & Son, 1946. Casing: 16-in., to 27 ft]		
Topsoil	3	3
Clay, yellow, with rock	10	13
Basalt, hard, gray	25	38
Basalt, softer, yellow	9	47
Basalt, hard, gray	21	68
Basalt, soft, black	4	72
Conglomerate, blue, gray	13	85
Basalt, soft, black	2	87
Basalt, soft, gray	21	108
Basalt, porous, black (water-bearing)	4	112
Basalt, harder, black	11	123
Basalt, softer, black	17(?)	140(?)
Basalt, hard, gray	10(?)	150(?)
Basalt, fairly hard, black	17	167
Basalt, soft, black	3	170
Basalt, hard, gray	8	178
Basalt, softer, black	2(?)	180(?)
Basalt, very hard, gray	12(?)	192
Basalt, hard, black	3	195
Basalt, soft, porous, black (water-bearing)	25	220
Basalt, hard, gray	3	223

TABLE 2.—*Logs of representative wells in the Pullman area*—Continued

14/45-5D1. City of Pullman

[Altitude about 2,339 ft. Drilled in 1913]

Material	Thickness (feet)	Depth (feet)
Soil	6	6
Hardpan, blue, contains rock fragments	15	21
Basalt, hard	35	56
Basalt, porous	91	147
No record	17	164

14/45-5D3. City of Pullman

[Altitude about 2,341 ft. Drilled by Strasser & Sons, 1946. Casing: 16-in. to 40 ft]

Material	Thickness (feet)	Depth (feet)
Soil	7	7
Silt, gray	9	16
Basalt, decomposed, yellow	6	22
Basalt, hard, gray	2	24
Basalt, soft, yellow	25	49
Basalt, harder, yellow	14	63
Basalt, soft, gray	16	79
Basalt, harder, gray	13	92
Basalt, not so hard, gray	6	98
Basalt, soft, green	8	106
Basalt, fairly hard, black	6	112
Basalt, hard, gray	10	122
Basalt, soft, black	29	151
Basalt, soft, red	8	159
Basalt, gray, crevices (water-bearing)	3	162
Basalt, soft, red	5	167

14/45-5D4. Northern Pacific Railway Co.

[Altitude about 2,342 ft. Casing: 6-in.]

Material	Thickness (feet)	Depth (feet)
Overburden	10	10
Basalt	27	37
Basalt, hard, gray	23	60
Basalt, soft	29	89
Basalt, porous	10	99
Basalt, black	67	166

14/45-5E1. City Ice Co.

[Altitude about 2,341 ft. Casing: 6-in. to 19 ft]

Material	Thickness (feet)	Depth (feet)
Soil	10	10
Clay	5	15
Basalt	45	60
Sand, granitic; some lignite	20	80
Clay	--------	--------
Basalt, porous	--------	--------
Sand, fine	--------	95

14/45-5E3. J. R. Ruply (former owner)

[Altitude about 2,340 ft. Casing: 6-in]

Material	Thickness (feet)	Depth (feet)
Soil and loose rock	10	10
Basalt	63	73
Sand, micaceous (water-bearing)	--------	--------

14/45-5E4. M. C. True (former owner)

[Altitude about 2,340 ft. Casing: 6-in.]

Material	Thickness (feet)	Depth (feet)
Soil and cobblestones	12	12
Basalt	53	65
Sand (water-bearing)	12	77

14/45-5E5. City of Pullman

[Altitude about 2,340 ft. Casing: 6-in.]

Material	Thickness (feet)	Depth (feet)
Soil	3	3
Clay	10	13
Basalt	60	73
Gravel and sand; lignite, (water-bearing)	11	84

14/45-5G1. Washington State University

[Altitude about 2,364 ft. Casing: 12-in.]

Material	Thickness (feet)	Depth (feet)
Loess	15	15
Basalt, hard	71	86
Clay, blue	14	100
Basalt, dense	16	116
Basalt, vesicular (aquifer)	14	130
Basalt, dense	15	145
Not known	68	213

14/45-6D1. J. C. Hodge

[Altitude about 2,519 ft. Drilled by Spray Bros., 1951. Casing: 6-in. to 10 ft]

Material	Thickness (feet)	Depth (feet)
Soil	5	5
Basalt	185	190
Sand	--------	--------

14/45-6D2. J. C. Hodge

[Altitude about 2,539 ft. Drilled by Spray Bros., 1949. Casing: 6-in. to 12 ft]

Material	Thickness (feet)	Depth (feet)
Loess	10	10
Basalt	225	235
Sand	1	236

14/45-6D4. James E. Anderson

[Altitude about 2,512 ft. Drilled by Spray Bros., 1955. Casing: 6-in. to 40 ft]

Material	Thickness (feet)	Depth (feet)
Loess	28	28
Basalt, hard	15	43
Basalt, soft	2	45
Basalt, hard	30	75
Basalt, soft	30	105
Basalt, hard	68	173
Clay	37	210
Basalt	10	220
Sand, white (water-bearing)	--------	--------

TABLE 2.—*Logs of representative wells in the Pullman area*—Continued

14/45-6F1. A. A. Samuelson

[Altitude about 2,469 ft. Drilled by Spray Bros., 1948. Casing: 6-in.]

Material	Thickness (feet)	Depth (feet)
Soil	6	6
Basalt, soft	34	40
Basalt, hard	65	105
Basalt, very hard	35	140
Sand (water-bearing)	2	142

14/45-7E1. Harvey Cole

[Altitude about 2,515 ft. Drilled by Spray Bros., 1954. Casing: 6-in. to 8 ft]

Material	Thickness (feet)	Depth (feet)
Loess	7	7
Basalt, hard, gray	63	70
Basalt, soft, black	12	82

14/45-7F1. G. R. Spencer

[Altitude about 2,497 ft. Drilled by Spray Bros.]

Material	Thickness (feet)	Depth (feet)
Loess	20	20
Basalt	6	26
Gravel and clay (some water)	6	32
Basalt	38	70

14/45-7F2. Evergreen Builders

[Altitude about 2,520 ft. Drilled by Spray Bros., 1954. Casing: 8 in. from 0 to 30 ft; 6-in. from 145 to 225 ft]

Material	Thickness (feet)	Depth (feet)
Loess	11	11
Basalt	17	28
Basalt, porous (water-bearing)	2	30
Basalt, hard	110	140
Seams, boulders	25	165
Clay, blue	15	180
Sand, much quartz and mica (water-bearing)	5	185
Basalt, hard and soft layers	80	265
Basalt, soft, broken (water-bearing)	5	270

14/45-7F3. Mrs. Baldwin

[Altitude about 2,488 ft. Drilled by Spray Bros., 1940(?). Casing: 6-in. to 20 ft]

Material	Thickness (feet)	Depth (feet)
Loess	15	15
Basalt, soft	50	65
Basalt, hard	--------	--------

14/45-7M1. Don Adams

[Altitude about 2,504 ft. Drilled by Spray Bros., 1954. Casing: 6-in. to 30 ft]

Material	Thickness (feet)	Depth (feet)
Soil	5	5
Loess	9	14
Basalt, hard, black	46	60
Basalt, porous	8	68

14/45-7M2. Blosser & Loughrey

[Altitude about 2,523 ft. Drilled by Spray Bros., 1954. Casing: 6-in. to 62 ft]

Material	Thickness (feet)	Depth (feet)
Soil	4	4
Loess	26	30
Basalt, hard, black	22	52
Clay	8	60
Basalt, hard, black	25	85
Basalt, soft	5	90

14/45-7M3. Dr. Tomlinson and — Baldwin

[Altitude about 2,502 ft. Drilled by Spray Bros., 1954. Casing: 6-in.]

Material	Thickness (feet)	Depth (feet)
Loess	17	17
Basalt, hard, black	63	80
Basalt, soft (water-bearing)	7	87

14/45-8A2. Marion Wise

[Altitude about 2,360 ft. Drilled by A. R. McInroy, 1948. Casing: 6-in. to 36 ft]

Material	Thickness (feet)	Depth (feet)
Loess	20	20
Basalt, hard (2 soft zones)	85	105

14/45-8J1. James Askins

[Altitude about 2,381 ft. Drilled by Spray Bros., 1945]

Material	Thickness (feet)	Depth (feet)
Loess	20	20
Basalt	65	85

14/45-8L1. Pullman Cemetery

[Altitude about 2,583 ft. Drilled in 1932. Casing: 6-in.]

Material	Thickness (feet)	Depth (feet)
Topsoil and loess	44	44
Basalt, hard	148	192
Basalt, soft, black	7	199
Clay, mixed, and basalt, with sand and clay (some water)	29	228
Basalt, medium-hard	66	294
Basalt, soft, porous (much water)	21	315
Basalt, hard	40	355

14/45-9E1. C. H. Hinchliff

[Altitude about 2,408 Drilled by J. W. Queen, 1930. Casing: 6-in. to 20 ft]

Material	Thickness (feet)	Depth (feet)
Loess	14	14
Basalt	53	67

14/45-15B1. George Leonard

[Altitude about 2,607 ft. Casing: 6-in.]

Material	Thickness (feet)	Depth (feet)
Loess	90	90
Basalt	123	213

TABLE 2.—*Logs of representative wells in the Pullman area*—Continued

14/45-16E1. C. A. Stratton

[Altitude about 2,378 ft. Drilled by Spray Bros., 1945. Casing: 6-in. to 40 ft]

Material	Thickness (feet)	Depth (feet)
Loess	20	20
Basalt		
Clay		35(?)
Basalt	45?	80

14/45-28H1. L. C. Staley

[Altitude about 2,513 ft. Drilled by J. W. Queen, 1941. Casing: 8-in. to 20 ft]

Material	Thickness (feet)	Depth (feet)
Soil	5	5
Basalt	145	150
Sand, fine, white	15	165

14/46-6R1. Edgar Anderson

[Altitude about 2,751 ft. Drilled by J. W. Queen, 1940. Casing: 7-in. to 90 ft]

Material	Thickness (feet)	Depth (feet)
Loess	90	90
Basalt		
Clay	6	
Basalt		202
Basalt, porous (water-bearing)	10	212

14/46-6R2. Edgar Anderson

[Altitude about 2,665 ft. Drilled by J. W. Queen. Casing: 6-in. to 50 ft]

Material	Thickness (feet)	Depth (feet)
Loess	50	50
Basalt	201	251
Clay, blue	30	281
Sand	20	301
(Deepened later)	49	350

14/46-7G1. Harlan Reid

[Altitude about 2,640 ft. Drilled by Spray Bros., 1944. Casing: 6-in.]

Material	Thickness (feet)	Depth (feet)
Loess	160	160
Basalt	20	180
Crevice (water-bearing)		

14/46-7N2. Howard Shriver Estate

[Altitude about 2,567 ft. Drilled by Spray Bros., 1937. Casing: 6-in.]

Material	Thickness (feet)	Depth (feet)
Loess	14	14
Basalt, very soft	50	64
Basalt, hard	2	66
Basalt, soft	24	90
Basalt, hard	55	145
Clay, blue, and sand, black at bottom	20	165
Basalt, soft, and hard	77	242

14/46-8K2. Arnold Anderson

[Altitude about 2,630 ft. Drilled by Spray Bros., 1947. Casing: 6-in. to 200 ft]

Material	Thickness (feet)	Depth (feet)
Soil and loess	60	60
Granite		
Rock, hard		
Sand (water-bearing)		240

14/46-19M1. Elmer Haynes

[Altitude about 2,481 ft. Drilled by Spray Bros., 1951. Casing: 6-in. to 30 ft]

Material	Thickness (feet)	Depth (feet)
Clay, blue	25	25
Basalt	54	79
Sand	1	80

14/46-29L1. C. V. Strohm

[Altitude about 2,575 ft. Drilled and dug by George Woodard. Casing: 60-in.-6-in. to 278 ft]

Material	Thickness (feet)	Depth (feet)
Loess	15	15
Basalt	260	275
Sand	3	278

15/44-1G1. A. V. Clark, Jr.

[Altitude about 2,392 ft. Drilled by Spray Bros., 1951. Casing: 6-in. to 40 ft]

Material	Thickness (feet)	Depth (feet)
Loess	15	15
Basalt, soft, decomposed	25	40
Basalt, hard	117	157

15/44-1N1. A. V. Clark, Sr.

[Altitude about 2,481 ft. Drilled by J. W. Queen, 1940. Casing: 6-in. to 35 ft]

Material	Thickness (feet)	Depth (feet)
Loess	35	35
Basalt	38	73

15/44-11A1. Joe Bryan

[Altitude about 2,552 ft. Drilled in 1934. Casing: 6-in. to 90 ft]

Material	Thickness (feet)	Depth (feet)
Soil	4	4
Clay	66	70
Clay and boulders	20	90
Basalt	30	120
Basalt, vesicular	15	135
Basalt, crevice	15	150

15/44-14D1. City of Albion

[Altitude about 2,281 ft. Drilled by Spray Bros., 1952]

Material	Thickness (feet)	Depth (feet)
Soil and loess	20	20
Granite	215	235

TABLE 2.—*Logs of representative wells in the Pullman area*—Continued

15/44-15A2. City of Albion

[Altitude about 2,244 ft. Drilled by Elmer Ray, 1954]

Material	Thickness (feet)	Depth (feet)
Topsoil	3	3
Loess	21	24
Gravel (water-bearing)	1	25
Loess	5	30
Granite, decomposed	12	42
Shale, brown	3	45
Granite, decomposed	2	47
Granite, decomposed (water-bearing)	23	70
Granite, decomposed, coarse (water, 70 gpm)	2	72
Granite, extra-hard	2	74
Granite, decomposed, crevice at 78 ft (water, 90 gpm)	4	78

15/44-16L1. Ed Jones

[Altitude about 2,380 ft. Drilled by John Woodruff, 1946. Casing: 6-in.]

Material	Thickness (feet)	Depth (feet)
Clay, blue and shell rock	73	73
Basalt, hard	5	78

15/44-16L2. Ed Jones

[Altitude about 2,400 ft. Drilled in 1924. Casing: 5-in. to 72 ft]

Material	Thickness (feet)	Depth (feet)
Clay and shell rock	72	72
Basalt, hard, blue	240	312
Basalt	51	363

15/44-21C1. John Fulfs

[Altitude about 2,400 ft. Casing: 6-in. to 130 ft]

Material	Thickness (feet)	Depth (feet)
Loess	113	113
Basalt	17	130

15/44-21D1. O. V. McCroskey

[Altitude about 2,350 ft. Drilled by Hickam & Wright, 1945]

Material	Thickness (feet)	Depth (feet)
Loess	10	10
Basalt, hard, blue	167	177

15/44-26L1. Merle Harlow

[Altitude about 2,394 ft. Drilled by Davisson, 1950. Casing: 8-in. to 20 ft]

Material	Thickness (feet)	Depth (feet)
Soil	5	5
Basalt	150	155
Basalt, soft	5	160

15/44-33B1. Leonard Small

[Altitude about 2,415 ft]

Material	Thickness (feet)	Depth (feet)
Soil	6	6
Basalt	169	175
Sand, black (?)	-------	-------

15/44-35E1. V. L. Michaelson

[Altitude about 2,417 ft. Drilled by Art Yaeger, 1951. Casing: 12-in. to 39 ft]

Material	Thickness (feet)	Depth (feet)
Loess	16	16
Basalt, broken, brown	22	38
Basalt, hard, gray	103	141
Shale, soft, black	24	165
Basalt, soft, black	80	245
Basalt, soft, brown	47	292
Basalt, soft, red (water-bearing)	8	300

15/45-6H2. Ray Parvin

[Altitude about 2,406 ft. Drilled by J. W. Queen, 1940. Casing: 6-in. to 8 ft]

Material	Thickness (feet)	Depth (feet)
Loess	8	8
Basalt	137	145
Sand	1	146

15/45-8L1. Helmer Rossebo

[Altitude about 2,484 ft. Drilled by J. W. Queen about 1938. Casing: 6-in. to 40 ft]

Material	Thickness (feet)	Depth (feet)
Loess	25	25
Basalt, soft, gray (water, 5 gpm at 65 ft)	50	75
Basalt, hard, black	29	104
Basalt, soft, porous (water-bearing)	19	123

15/45-8M2. Ross Howell

[Altitude 2,510 ft. Drilled by J. W. Queen & Woodard, 1933. Casing: 6-in. to 55 ft]

Material	Thickness (feet)	Depth (feet)
Loess	45	45
Basalt, hard, black	245	290

15/45-9R1. Everett Lyon

[Altitude about 2,509 ft. Drilled in 1951. Casing: 8-in. to 54 ft]

Material	Thickness (feet)	Depth (feet)
Loess	54	54
Basalt	62	116

15/45-10F1. A. H. Nelson

[Altitude about 2,569 ft. Drilled by Robert Bloyed, 1953. Casing: 10-in. to 38 ft]

Material	Thickness (feet)	Depth (feet)
Loess	38	38
Basalt, porous	34	72

15/45-14Q1. Mary Stirewalt

[Altitude about 2,518 ft. Drilled about 1937. Casing: 6-in.]

Material	Thickness (feet)	Depth (feet)
Basalt, dense	240	240
Basalt, porous	26	266
Quartzite(?)	19(?)	285

TABLE 2.—*Logs of representativ wells in the Pullman area*—Co^tinued

15/45-26K1 Orval Boyd

[Altitude about 2,608 ft. Drilled by Town and Boyd. Casing: 6-in. to 74 ft]

Material	Thickness (feet)	Depth (feet)
Dirt, black	2½	2½
Clay (water below 60 ft)	61½	64
Shale (water-bearing)	10	74
Basalt	124	198
Rock, porous, brown	6	204
Soapstone(?)	12	216
Basalt	14	230
Soapstone(?)	25	255
Basalt	37	292
Rock, porous, brown	10	302

15/45-28J2. D. R. Burnham

[Altitude 2,530 ft. Drilled by Noel, 1926. Casing: 6-in. to 162 ft]

Material	Thickness (feet)	Depth (feet)
Loess	41	41
Basalt	97	138
Clay	24	162

15/45-29P1. Kenneth W. Hall

[Altitude about 2,437 ft. Drilled by A. R. McInroy. Casing: 6-in. to 16 ft]

Material	Thickness (feet)	Depth (feet)
Loess	16	16
Basalt	50	66
Basalt(?)	74	140
Basalt	--------	--------

15/45-30G4. Soil Conservation Service Experimental Farm

[Altitude about 2,530 ft. Drilled about 1937. Casing: 6-in.]

Material	Thickness (feet)	Depth (feet)
Soil	60	60
Basalt, hard, black and blue-gray; crevices at 124 and 129 ft	107	167
Basalt, hard, black	11	178
Basalt, soft, gray	11	189
Basalt, hard, black	21	210
Basalt, very hard, black	20	230
Sand (water, 3 gpm)	10	240
Basalt, broken, black	9	249
Basalt, black, and green shale	1	250
Basalt, broken, black	17	267
Basalt, hard, black	19	286
Basalt, very hard, black; crevices at 286 and 297 ft	49	335
Basalt, soft, porous, black (water, large flow; not able to lower level perceptibly with bailer; no change in water level)	25	360
Basalt, hard, black	11	371

15/45-32N1. City of Pullman

[Altitude about 2,340 ft. Drilled by R. J. Strasser, 1946. Casing: 16-in. to 24 ft]

Material	Thickness (feet)	Depth (feet)
Topsoil	3	3
Basalt, broken, gray	10	13
Basalt, soft, black	6	19
Basalt, hard, gray	8	27
Basalt, fairly hard, black	4	31
Basalt, hard, gray	4	35

15/45-32N1. City of Pullman—Continued

Material	Thickness (feet)	Depth (feet)
Basalt, soft, gray	6	41
Basalt, hard, gray	4	45
Basalt, soft, black	4	49
Basalt, hard, gray	2	51
Basalt, soft, black	2	53
Basalt, soft, blue	15	68
Basalt, hard, gray	1	69
Basalt, gray	4	73
Basalt, soft, gray	7	80
Basalt, hard, black	16	96
Basalt, seams, hard, gray	13	109
Basalt, softer, gray	15	124
Basalt, hard, gray	4	128
Basalt, soft, black	1	129
Basalt, hard, gray	(?)	134(?)
Basalt, gray; crevices	(?)	146
Basalt, hard, gray	5	151
Basalt, very hard, gray	19	170
Basalt, soft, black (water-bearing)	6	176
Basalt, soft, brown	11	187
Basalt, soft, black	19	206
Basalt, soft, brown	6	212
Basalt, soft, black	3	215
Basalt, soft, red	11	226
Basalt, hard, gray	5	231

15/45-32N2. City of Pullman well 4

[Altitude about 2,340 ft. Drilled by A. A. Durand, 1956]

Material	Thickness (feet)	Depth (feet)
Topsoil	3	3
Clay and gravel	5	8
Gravel	2	10
Clay and gravel	5	15
Gravel, cemented	3	18
Basalt, hard, dark	2	20
Sand, dark (water-bearing)	1	21
Basalt, hard, dark	6	27
Basalt, hard, gray	23	50
Shale, soft, black	25	75
Clay, soft, gray	5	80
Basalt, broken	20	100
Basalt, hard, gray	5	105
Basalt, medium-hard, dark	44	149
Shale sandy, soft, gray	4	153
Basalt, medium-hard, gray	18	171
Basalt, medium-hard, dark	27	198
Basalt, hard, dark	2	200
Basalt, hard, gray	3	203
Basalt, medium-hard, variegated	11	214
Basalt, hard, gray	12	226
Basalt, medium-hard, gray	40	266
Basalt, soft (casing), gray	2	268
Basalt, medium-hard, gray	6	274
Basalt, hard, gray	6	280
Basalt, medium-hard, broken, dark	10	290
Basalt, hard, gray	15	305
Basalt, very hard, gray	3	308
Basalt, hard, gray	5	313
Basalt, medium-hard, gray	7	320
Basalt, medium-hard, gray	15	335
Basalt, hard, gray	13	348
Basalt, medium-hard, dark	11	359
Basalt, medium-hard, gray	44	403
Basalt, medium-hard, dark	49	452
Basalt, soft, broken, dark	2	454
Basalt, medium-hard, gray	10	464
Basalt, soft, dark	3	467
Basalt, medium-hard, dark	64	531
Basalt, soft, broken, dark	9	540
Basalt, medium-hard, dark	32	572

TABLE 2.—*Logs of representative wells in the Pullman area*—Continued

Material	Thickness (feet)	Depth (feet)
15/45-32N2. City of Pullman well 4—Continued		
Shale, medium-hard, sticky, gray	13	585
Basalt, medium-hard, dark, mixed with shale	21	606
Basalt, medium-hard, dark, and shale	4	610
Basalt, medium-hard, dark	10	620
Basalt, soft, dark	3	623
Basalt, medium-hard, dark	19	642
Shale, soft, sticky, brown	5	647
Basalt, medium-hard, dark	23	670
Basalt, medium-hard, brown, and shale, brown	14	684
Basalt, medium-hard, gray	4	688
Basalt, hard, gray	22	710
Basalt, medium-hard, dark	13	723
Basalt, hard, dark	15	738
Basalt, medium-hard, dark	11	749
Basalt, medium-soft, brown	26	775
Basalt, medium-hard, gray	10	785
Basalt, hard, gray	4	789
Basalt, medium-hard, gray	87	876
Basalt, hard, gray	8	884
Basalt crevice, hard, gray	2	886
Basalt, hard, gray	3	889
Basalt, medium-hard, gray, and shale	4	893
Basalt, medium-hard, gray	11	904
Basalt, hard, gray	2	906
Basalt, medium-hard, gray	48	954
15/45-33J1		
[Altitude about 2,619 ft. Drilled by H. W. Fredricks. Casing: 6-in.]		
Soil and loess	91	91
Basalt, solid	180	271
Basalt, in flows no more than 10 ft thick, variable hardness	149	420
Basalt (water at 420 ft)	18	438
15/45-35F1. Pullman-Moscow Airport		
[Altitude about 2,532 ft. Drilled by Spray Bros. Casing: 8-in.]		
Loess	12	12
Basalt	28	40
Basalt, firm, fresh	20	60
Basalt, firm	8	68
Basalt, soft	3	71
Basalt, firm, fresh	4	75
Basalt, firm, fresh; slow drilling	33	108
Basalt, platy	5	113
Basalt, fresh, firm	15	128
Clay, siltstone	2	130
Basalt, firm	42	172
15/46-20P1. N. T. Carson		
[Altitude about 2,590 ft]		
Old well, mostly basalt	196	196
Basalt(?)	3	199
Clay, blue	51	250
Sand, hard, granitic	30	280
Clay, brown	120	400
15/46-29N1. Charles Paul		
[Altitude about 2,620 ft. Drilled in 1923. Casing 5¼-in. to 65 ft]		
Loess	55	55
Basalt	65	120
15/46-31J1. Ed Metzgar		
[Altitude about 2,518 ft. Drilled by Spray Bros., 1950. Casing: 6-in.]		
Loess	18	18
Basalt	82	100
Basalt, porous	17	117
16/45-25D1. W. M. Stipe		
[Altitude about 2,560 ft. Drilled by Spray Bros., 1951. Casing: 6-in. to 25 ft.]		
Soil	20-25	20-25
Basalt(?)	175-180	200
Gravel	40	240
16/45-27R1. Jacob Greenwalt		
[Altitude about 2,500 ft. Drilled by J. W. Queen, 1942-44]		
Basalt	144	144
Opening in basalt	3	147
39/5W-4N1. Herb Carlton		
[Altitude about 2,650 ft. Drilled by Spray Bros., 1953-54. Casing: 6-in.]		
Dirt, black	2	2
Clay	75	77
Sand (containing wood)	15	92
Clay	48	140
Basalt	6	146
Clay	10	156
Basalt	60	216
Basalt, porous, brown	4	220
39/5W-5F1. William Jones Jr.		
[Altitude about 2,650 ft. Drilled by Spray Bros., 1953. Casing: 6-in.]		
Clay	20	20
Granite, decomposed; 2 logs at 95 ft	80	100
Basalt, black	165	265
39/5W-7J2. City of Moscow		
[Altitude about 2, 567 ft. Drilled by A. A. Durand, 1926-29. Casing: 15-in.]		
Topsoil	36	36
Basalt	36	72
Gravel	5	77
Basalt	82	159
Shale seam (stringer)	0±	159

TABLE 2.—*Logs of representative wells in the Pullman area*—Continued

39/5W-7J2. City of Moscow—Continued

Material	Thickness (feet)	Depth (feet)
Basalt	65	224
Clay, blue-gray	30	254
Sand, granitic	19	273
Shale, sandy	6	279
Sand and pebbles	26	305
Sand, cemented	7	312
Slate	2	314
Soil, brown	11	325
Soil and pebbles	30	355
Shale, micaceous	40	395
Shale, sandy	49	444
Sand, cemented	18	462
Shale, brown	38	500
Shale, micaceous, pebbles	25	525
Shale, brown	28	553
Quartzite	7	560

39/5W-7P1. University of Idaho

[Altitude about 2,548 ft. Drilled by A. A. Durand, 1951. Casing: 20-in. to 355 ft; perforated from 210 to 275 ft; gravel-packed]

Material	Thickness (feet)	Depth (feet)
Clay, yellow	17	17
Clay, blue, and gravel	12	29
Basalt, vesicular	36	65
Basalt, vesicular, and basalt glass	45	110
No record	8	118
Basalt, vesicular, and basalt glass	7	125
Basalt	17	142
Basalt, vesicular	3	145
Basalt	29	174
Basalt, vesicular	9	183
Clay, gray and silt	12	195
Clay, gray and silt; some small quartzite pebbles	12	207
Sand, quartz, coarse	7	214
Quartz, sand and gravel; some argillite pebbles	8	222
Sand, quartz	8	230
Sand, gray, granitic; silt	15	245
Silt, gray; some sand grains	13	258
Sand, gray, granitic, and silt	12	270
Clay, carbonaceous, chocolate to dark-blue	40	310
Clay, greenish-gray	25	335
Claystone, gray, partly cemented	5	340
Clay, brown and greenish-gray	8	348
Sand, granitic, and silt; some clay and pebbles of argillite	3	351
Sand, granitic, and silt; some green clay and basalt pebbles	2	353
Sand, granitic; silt and clay (equal amounts)	1	354

39/5W-8B2. City of Moscow

[Altitude about 2,667 ft. Drilled by A. A. Durand, 1948. Casing: 24 in. to 144 ft]

Material	Thickness (feet)	Depth (feet)
Clay, yellow	80	80
Clay and gravel	5	85
Clay, yellow	10	95
Clay, sticky, light-gray	45	140
Basalt, broken, and black clay	6	146
Basalt, porous, black (lost water, material sticking badly at about 197 ft)	51	197
Basalt, broken, black	8	205
Sand and gravel	6	211
Basalt, black	35	246
Basalt, and large boulders	2	248
Boulders, large	2	250
Basalt, black	27	277

39/5W-8B2. City of Moscow—Continued

Material	Thickness (feet)	Depth (feet)
Basalt, dense, very hard, black	62	339
Basalt, dense, fractured (some water at 354-359 ft)	19	358
Clay	1	359
Basalt (some water)	13	372
Granite	1	373

39/5W-8R1. City of Moscow

[Altitude about 2,596 ft. Drilled by A. A. Durand, 1941]

Material	Thickness (feet)	Depth (feet)
Dirt	4	4
Clay	6	10
Clay and gravel	10	20
Gravel	1	21
Clay, yellow	34	55
Clay, brown	5	60
Clay, black	15	75
Basalt, black	33	108
Basalt, gray	129	237
Basalt, porous, black	9	246
Basalt, solid, black	4	250
Basalt, porous, and clay	8	258
Clay, black and brown, and wood	2	260
Clay, yellow	5	265
Clay, blue	22	287
Clay, blue-gray	9	296
Shale, blue	4	300
Clay, gray	30	330
Clay, brown	2	332
Clay, gray	8	340
Clay, brown	20	360
Clay, mixed colors	6	366
Basalt, black (boulder?)	4	370
Clay, blue	10	380
Clay, brown	40	420
Clay, blue	5	425
Clay, sandy	10	435
Clay, brown	15	450
Clay, blue	18	468
Clay and sand	127	595
Basalt, gray; contains pyrite	5	600
Basalt, gray	95	695
Clay, brown	25	720
Clay, mixed with granitic sand	15	735
Clay, gray, mixed with green shale	20	755
Clay, brown	10	765
Clay, gray	3	768
Clay, mixed	22	790

39/5W-15C1. J. C. Parker

[Altitude about 2,622 ft. Drilled by Woodward, 1936]

Material	Thickness (feet)	Depth (feet)
Dug well	45	45
Basalt	147(?)	192(?)
Sand, white	(?)	(?)
Granite, hard, red	(?)	446

39/5W-15G1. Moscow Golf Course

[Altitude about 2,610 ft]

Material	Thickness (feet)	Depth (feet)
Soil	61	61
Basalt	139	200
Sand, quartz, partly consolidated, red	3	203

TABLE 2.—*Logs of representative wells in the Pullman area*—Continued

39/5W-17J1. Sunset Memorial Gardens

[Altitude about 2,610 ft. Drilled by A. A. Durand, 1955. Casing: 12-in. to 85 ft; 8-in. from 454 to 461 ft; backfilled with gravel from 552 to 508 ft; screened from 456 to 508 ft]

Material	Thickness (feet)	Depth (feet)
Topsoil, soft, black	5	5
Clay, sticky, light-gray	16	21
Clay, light-brown; some small washed gravel	8	29
Clay, fine, yellow, and small washed gravel (water at 34 ft)	10	39
Gravel, coarse, washed, yellow	14	53
Clay, light-brown, and wood	16	69
Clay, dark-brown	13	82
Clay, blue	5	87
Basalt, dark-brown, decomposed	4	91
Basalt, hard, dense, black	163	254
Basalt, broken, and blue clay	18	272
Clay, sticky, light-green	6	278
Clay, light-yellow; broken basalt chips	3	281
Clay, green	73	354
Clay, light-brown, and sand	17	371
Clay, sticky, light-brown	38	409
Clay, sticky, blue	5	414
Clay, chocolate-brown	33	447
Sand, decomposed granitic, light-gray; wood from 480 to 513 ft	66	513
Clay, sticky, chocolate-brown	37	550
Basalt, black	2	552

39/5W-18C1. University of Idaho

[Altitude about 2,601 ft. Drilled in 1920. Casing: 8-in.]

Material	Thickness (feet)	Depth (feet)
Soil	36	36
Sand (some water)	4	40
Clay; some wood	58	98
Basalt, dense	207	305
Sand (some water)	15	320
Clay, blue	10	330

39/5W-21A1. Ed Julte

[Altitude about 2,635 ft]

Material	Thickness (feet)	Depth (feet)
Soil	22	22
Granite, decomposed	42	64
Sand, quartz, semiconsolidated	233	297
Shale	13	310
Granite formation, soft	5	315
Argillite	1	316

39/6W-13K1. H. E. Hattrup

[Altitude about 2,762 ft. Drilled by Spray Bros., 1947. Casing: 6-in. to 138 ft: perforated from 120 to 122(?) ft]

Material	Thickness (feet)	Depth (feet)
Loess	141	141

40/5W-30L1. R. T. Moser

[Altitude about 2,646 ft. Drilled by Spray Bros., 1953. Casing: 6-in. to 94 ft]

Material	Thickness (feet)	Depth (feet)
Sand; log about 60 ft	90	90
Basalt, hard	190	280
Clay, blue	30	310
Granite, decomposed (water-bearing)	46	356

40/6W-36G1. W. M. O'Donnell

[Altitude about 2,608 ft. Drilled by Spray Bros., 1948. Casing: 6-in. to ±100 ft]

Material	Thickness (feet)	Depth (feet)
No log	120	120
Rock, hard	80	200
Crevice (water-bearing)	4	204
Rock, hard	--------	--------

TABLE 3.—*Chemical analyses of water from the Moscow-Pullman basin*

[Analyses by U.S. Geol. Survey except as noted]

Well	Depth (feet)	Principal aquifer	Date of collection	Temperature (°F)	Constituents (ppm) Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Dissolved solids	Hardness as $CaCO_3$	Specific conductance (micromhos at 25°C)	pH
14/45-5B2	237	Basalt	Dec. 2, 1938		65	[1]0.24	22	16	22	4.2	203	0	1.8	3.3	0.2	0.21	224	121		
5B3	223	do	Mar. 28, 1955			.03	25	15	[2]28		216		2.9	4				124	323	7.8
5D1 [3]	147	do	Aug. 16, 1946		58	.5	22	14	28	2.4	209		1.8	2.0	.4		211	113		
5D3	167	do	Mar. 30, 1955			.19	24	13	[2]27		194	4	3.7	4				113	304	8.4
5D3	167	do	Nov. 17, 1959		69	.39	22	15	22	4.2	196		3.1	4.2	.5		[2]238	118	346	2.7
5D4	166	do	Mar. 30, 1955			.02	22	14	[2]27		185		12	5				112	305	8.2
5E1	95	do	do			.22	22	13	[2]28		198		2.1	3				108	299	8.2
5G1	213	do	Nov. 4, 1952		55		19	10			199	0		3				88		7.5
5G1	213	do	Mar. 30, 1955	55		.21	21	15	[2]27		203		2.9	3				114	305	8.3
15/44-15A2	83	Sand, granitic	Nov. 17, 1959		46	.81	42	15	18	1.7	192	0	18	12	.5	23	[2]272	166	406	7.0
15/45-26K1	302	Basalt	Mar. 30, 1955			.67	24	9.4	[2]26		154		23	3				99	287	8.3
32N1	231	do	do	57		.32	21	14	[2]22		184	6	.8	4				110	291	8.5
32N2	954	do	1959		60	.36	24	13	22	4.1	194	0	.7	3.2	1.4		[2]224	114	307	7.8
15/46-20P1	250	Sand, granitic	Mar. 29, 1955			.25	58	24			168		21	29				243	597	7.4
39/5W-7J2 [3]	254	do	May 22, 1946	54		6.5	30	11	[2]15		163	0	17	1	.4		256	120		6.6
7J2 [3]	254	do	Mar. 29, 1955			1.3					166		12	3				116	276	7.8
7J3 [3]	245	Basalt	May 22, 1946	54		2	30	11	[2]14		161	0	15	2	.3		232	120		7.2
7P1 [3]	355	Sand, granitic	Nov. 20, 1953		62	2.2	33	13.6	[2]11		166	0	18	7	.35	.4	260	138		6.7
7P1 [3]	355	do	Mar. 29, 1955			1.4					165		3.7	2				108	254	8.1
8B2 [3]	373	Basalt	Jan. 4, 1952				33	12	[2]17		171		22	4	.35		239	132		6.9
8B2 [3]	373	do	Mar. 29, 1955								153		17	4				116	270	7.6
18C1 [3]	330	Sand, granitic	Nov. 20, 1953		59	3.6	31	12.7	[2]7		149	0	20	3	.35	.2	250	130		6.9
18C1 [3]	330	do	Mar. 29, 1955			1.9					166		78	8				184	422	8.1
South Fork of Palouse River [4]			Dec. 3, 1924		36	.12	29	10	34	5.9	131		15	38	.1	16	254	114		
Paradise Creek near Pullman [5]			Mar. 13, 1953		26	.07	12	3.8	6.0	4.8	55		9.3	3.6		3.8	116	46		

[1] 0.06 ppm Fe in sediment included.
[2] Calculated.
[3] Analyses by Idaho Dept. Health.
[4] Discharge 5.3 cfs.
[5] Discharge 7.4 cfs.

TABLE 4.—*Field analyses of water from wells in the Moscow-Pullman basin*

[Analyses approximate only, not made under laboratory control]

Well	Depth (feet)	Principal aquifer	Constituents (ppm)		
			Chloride (Cl) (HCO_3)	Bicarbonate	Hardness as $CaCO_3$
Pullman subbasin					
14/44-1J2	30.4		10	146	122
34C1	200	Basalt	6	165	120
14/45-2F1	35	Loess(?)	4		94
3H2	40	Loess	4	92	76
7F2	274	Basalt	6	146	102
8A1	85	do	6	207	118
13F2	19.6	Loess	8	213	130
15B1	213		4	213	134
19D1	74	Basalt	8	146	80
20E1	16.5		156	116	260
25D1	53.6	Basalt	8	174	108
35E1	148		6	171	102
15/44-1N1	73	Basalt	6	171	114
11F2	225	Granitic sand	8	207	134
15A2	78	Decomposed granite	20	183	162
15/45-7D1	26.4				170
7Q1	150		5	159	112
8L1	124	Basalt	4	183	108
8M2	290	do	6	171	116
10F1	72.2	do	10	104	78
17E1	90	do	4	171	102
20H1	74	Basalt (?)	4	177	114
23B1	51		60	146	178
25Q1	264	Basalt (?	4	189	116
26K2	120	Basalt	6	116	82
32G1	25.8	Loess	20	146	174
34L1	45.3				84
15/46-8Q1	135			140	82
30N1	23.2	Loess	10	189	126
16/45-25R1	24	Clay	4	98	106
27Q1	135	Granitic sand	4	183	116
16/46-31R1	33.8		14	79	148
Moscow subbasin					
15/46-20K1	14.9	Loess	8	122	122
29N1	120	Basalt	10	189	108
31H1	100(?)		10	189	134
40/5W-30L1	308.9	Decomposed granite	10	195	138

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

WATER-SUPPLY PAPER 1655
PLATE 1

Base from U. S. Geological Survey Pullman
topographic quadrangle, scale 1:125 000

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D. C.—61350

By B. L. Foxworthy and R. L. Washburn, 1955

EXPLANATION

Palouse formation and Columbia River basalt, undifferentiated

Loess of the Palouse formation of Pleistocene age, as much as 200 feet thick, underlain by flows of Columbia River basalt, largely Miocene in age. Columbia River basalt yields moderate to large quantities of water. Loess yields only small quantities of water

TERTIARY AND QUATERNARY

Crystaline rocks

Gneiss, granite, and quartzite. Yields only small quantities of water

PRE-TERTIARY

Contact

Dashed where approximately located

P2

Well

Numbers referred to in text

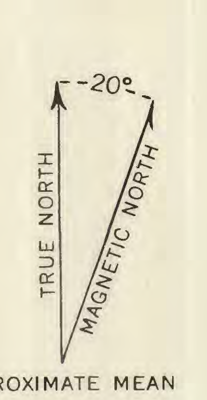
A A'

Geologic section line

Shown on plate 2

Drainage divide

Ground-water divide



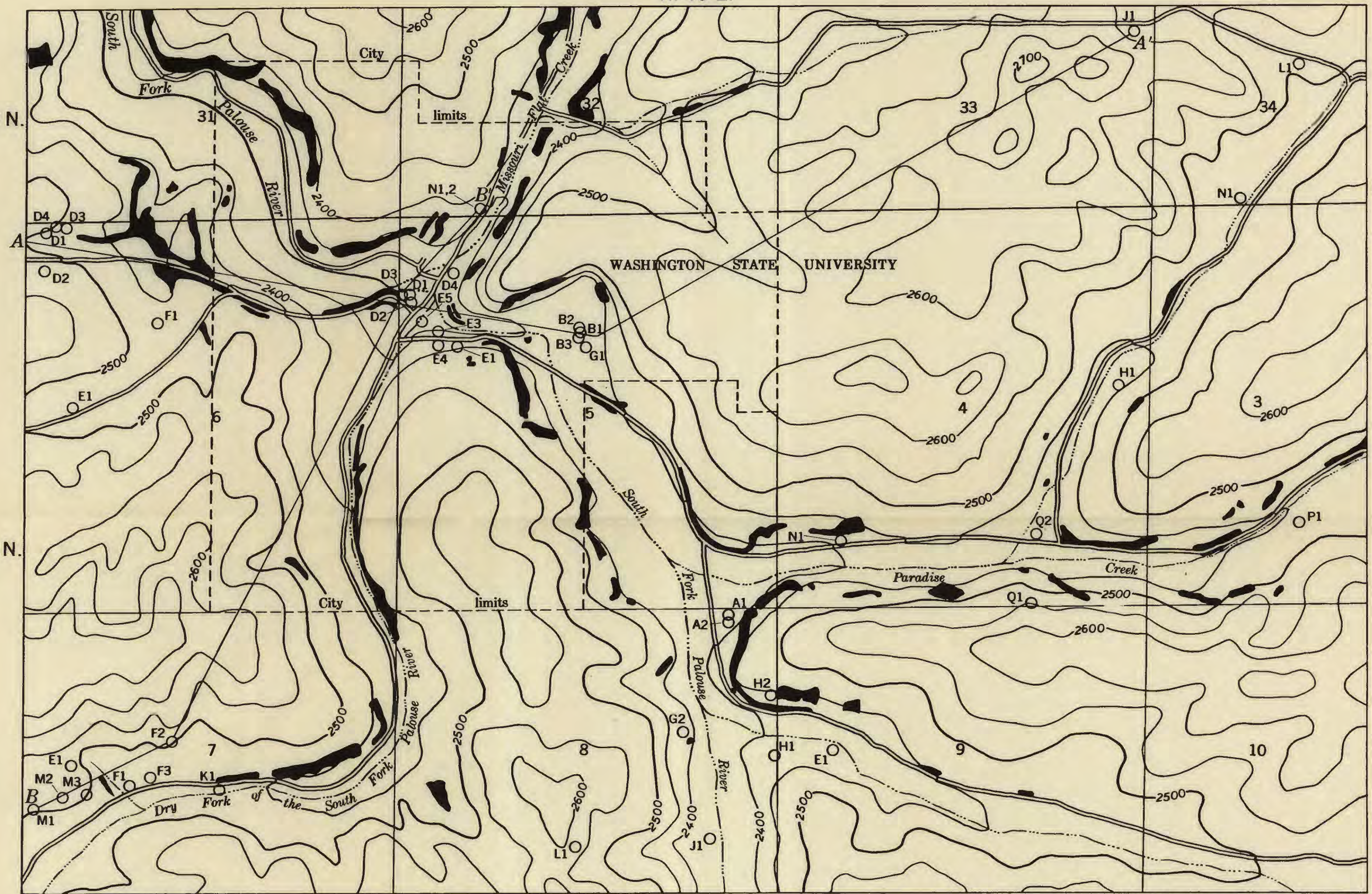
APPROXIMATE MEAN DECLINATION, 1961

MAP OF PULLMAN AREA, WASHINGTON, SHOWING HYDROLOGIC AND GEOLOGIC FEATURES

SCALE 1:63 360

1 ½ 0 1 2 3 MILES

CONTOUR INTERVAL 50 FEET
DATUM IS MEAN SEA LEVEL



Base from U. S. Geological Survey Pullman topographic quadrangle, scale 1:125 000

By B. L. Foxworthy and R. L. Washburn, 1955

EXPLANATION

Well

Outcrop of Columbia River basalt

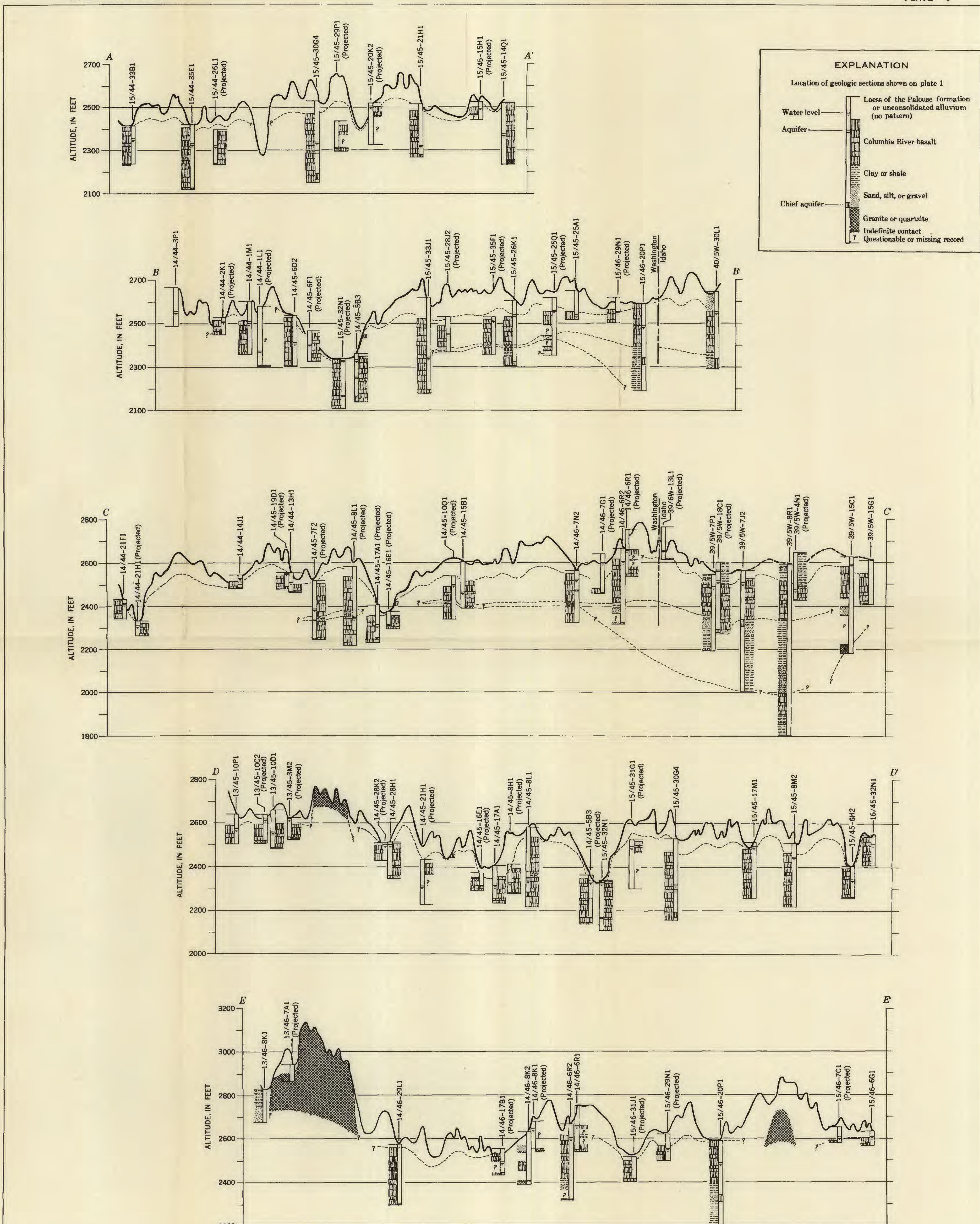
A——A' Line of geologic section shown on figure 3

MAP OF PULLMAN AND VICINITY, WASHINGTON SHOWING WELLS AND BASALT EXPOSURES

1000 0 1000 2000 3000 4000 5000 FEET

CONTOUR INTERVAL 50 FEET
DATUM IS MEAN SEA LEVEL

656185 O - 63 (In pocket) No. 2



By B. L. Foxworthy and R. L. Washburn, 1955

GEOLOGIC SECTIONS IN THE MOSCOW-PULLMAN BASIN

1 0 1 2 3 4 5 MILES
Vertical exaggeration ×26

656185 O - 63 (In pocket) No. 3