THE RELATION BETWEEN STREAMS
AND
GROUND-WATER FLOW SYSTEMS
WITHIN THE PULLMAN-MOSCOW AREA
OF WASHINGTON AND IDAHO

A Thesis

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AUTHORIZATION TO SUBMIT

THESIS

This thesis of Ronald Heinemann, submitted for the degree of Master of Science with a major in Hydrology and titled "The Relation Between Streams and Ground-Water Flow Systems within the Pullman-Moscow Area of Washington and Idaho" has been reviewed in final form, as indicated by the signatures and dates given below. Permission in now granted to submit final copies to the College of Graduate Studies for approval.

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ABSTRACT

A three-dimensional computer model of ground-water flow in the Pullman-Moscow area of Washington and Idaho was constructed in 1987 to address concerns over increasing pumpage rates and declining ground-water levels in the Grande Ronde Formation of the Columbia River Basalts. An integral part of the model is the interconnection of ground water and surface water. Streamflow measurements from a 1984 USGS survey suggest that a significant amount of ground water may be discharging from basalt aquifers and associated interbeds to streams within the area.

Six Pullman-Moscow area streams which are incised into the basalt stratigraphy were investigated to locate zones where ground-water discharge/recharge is occurring. Stream temperature surveys and geologic cross sections were used to identify and describe possible ground-water discharge areas.

Results of the study suggest that sedimentary deposits located along the eastern terminus of the Roza Member of the Wanapum Formation are a source for ground-water discharge along Union Flat Creek, the North Fork of the Palouse River, and Four Mile Creek. Knowledge of the spatial and areal extent of the ground-water discharge zones will increase the accuracy of the Pullman-Moscow ground-water-flow model.

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CHAPTER I

INTRODUCTION

Statement of the Problem

The mathematical model developed by Lum and others (1990) to describe ground-water flow in the Pullman-Moscow basin of Washington and Idaho is an important tool for ground-water management. The model was designed to predict future water level changes within the basin under various pumping conditions. A key facet of the model is the interconnection between surface water and ground water.

Recharge to the basalt aquifers in the Pullman-Moscow basin is believed to occur primarily via infiltration of precipitation through the overlying loess. The principal avenues for water to exit the basin are through ground-water discharge to the network of streams within the basin, and through ground-water outflow to the west. Streamflow measurements from a 1984 study (Blazs, personal communication, 1984) plus the results of the modeling study (Lum and others, 1990) suggest that a significant amount of ground water may be discharging to streams within the area. Union Flat Creek, Paradise Creek, and the South Fork of the Palouse River probably receive discharge where streams have cut into basalt aquifers and/or associated sedimentary interbeds (Figure 1).

Streams within the area generally flow on the surficial loess layer in the upper reaches, and gradually incise into

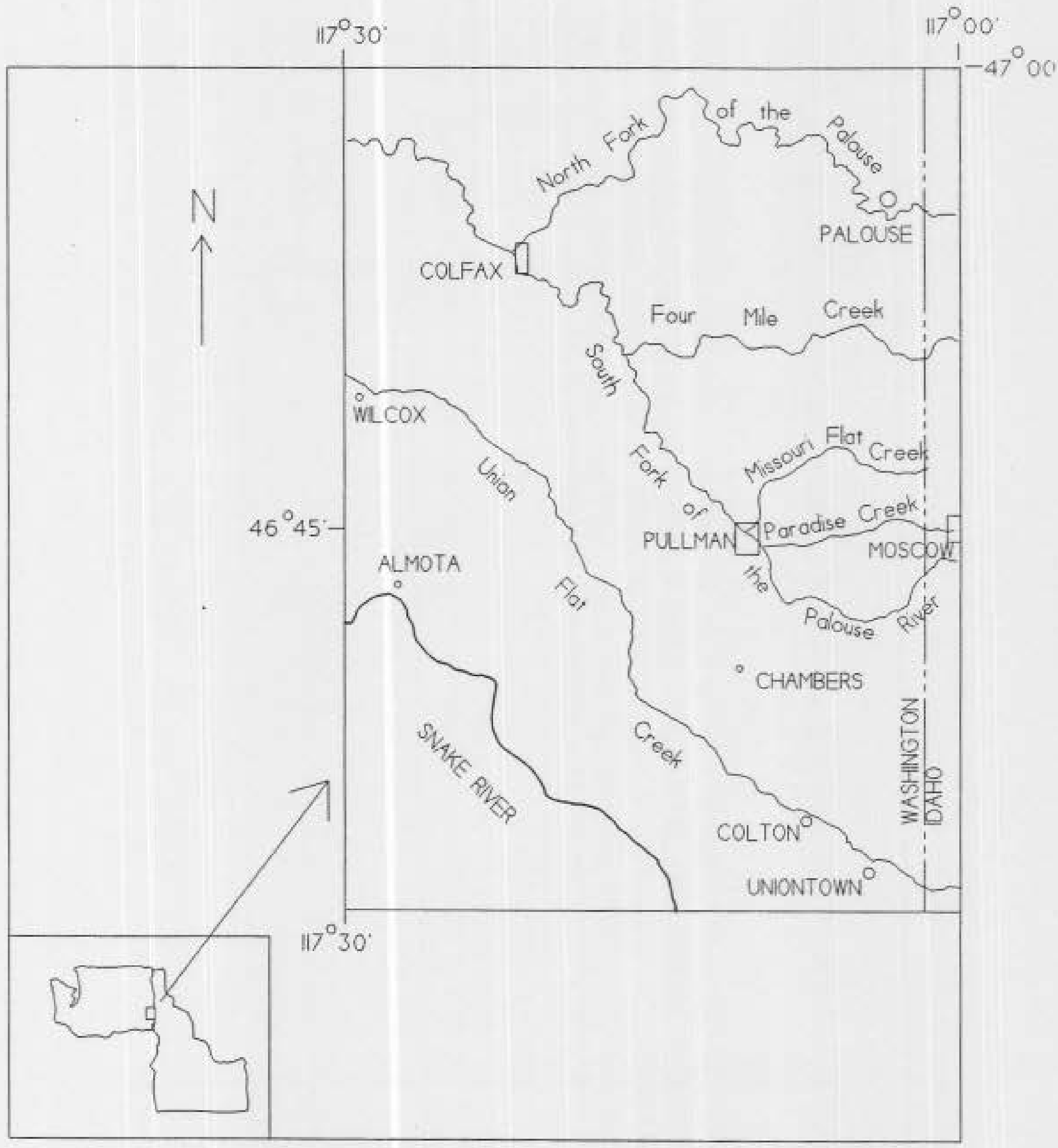


Figure 1. Location map of the Pullman-Moscow region and stream network.

the basalts as they flow westward across the basin. Streams that are incised into the basalts either gain or lose flow depending on water table elevations adjacent to the stream.

Prior to this study, no detailed investigations of the relationship of area streams to the hydrogeology have been made. This study is being conducted in-part to provide ground truth data for the surface water-ground water interrelationships built into the model.

Purpose and Objectives

The purpose of this study is to increase the understanding of the relationship between streams and basalt aquifer systems in the Pullman-Moscow area. The general objective is to identify and describe stream reaches within the area where ground-water recharge or discharge is believed to occur based on the basalt stratigraphy. Specific objectives include the following:

(1) Review regional and local hydrogeology.

(2) Assemble a base of data from near-stream wells and construct stratigraphic cross sections.

(3) Analyze data from six selected stream reaches to correlate the geology to the ground water/surface water interconnection.

(4) State conclusions and recommendations with respect to the interconnection of surface water and ground water within the region.

Method of Study

A data base of approximately 200 wells within the study area was established from previously recorded well data (Walters and Glancy, 1969), and water well reports for Whitman County, Washington and Latah County, Idaho. Topographic maps and aerial photographs were used to locate area wells. A field investigation of well locations (+/- 200 feet) and elevations (+/- 10 feet) was conducted for wells with unknown elevations or inaccurate locations. The data base was used to construct stratigraphic cross-sections showing the geology of near-stream wells relative to the elevation of the adjacent stream. The cross sections were constructed to indicate areas along stream reaches where water-bearing zones within the basalts may be exposed in the stream channel.

A limited field investigation consisting of streamflow measurements and temperature surveys was conducted to verify the existence of ground-water discharge areas in selected reaches. The discharge data were compared with the streamflow measurements and locations recorded by the U.S. Geological Survey (Blazs, 1984). Streamflow velocities were obtained using a pygmy gauge. When applicable, Stevens stream stage recorders were used to gain data on temporal streamflow fluctuations. Temperature measurements, using a digital temperature gauge, were recorded along selected reaches. The temperature data were evaluated, based on the assumption that significant ground-water discharge to the stream would raise stream temperatures during the winter months and lower stream temperatures during the summer months. Ground-water temperatures generally range from 50 to 60 degrees Fahrenheit throughout the year.

Geographic Setting

The study area (Figure 1) occupies approximately 800 mi^2 within the Palouse Basin, and extends from the Snake River Canyon in the south to the North Fork of the Palouse River in the north, and eastward from 117 degrees 30 minutes west longitude to 117 degrees west longitude. The Pullman-Moscow Basin, a sub-basin of the Palouse Basin, occupies approximately 256 mi^2 with 83mi^2 within Latah County, Idaho, and 173mi^2 within Whitman County, Washington.

Streams within the study area include the South Fork of the Palouse River and three tributary streams: Fourmile Creek, Missouri Flat Creek, and Paradise Creek. The North Fork of the Palouse River joins the South Fork of the Palouse River in the northwest section of the study area near Colfax, Washington. Union Flat Creek flows northwesterly along the southern portion of the study area.

CHAPTER II

HYDROGEOLOGY

Introduction

Ground-water flow within the Pullman-Moscow region is controlled by the physical characteristics of the basalts and the associated interbeds. Ground water moves vertically and horizontally through fractures and joints in the basalt with the greatest flow occurring approximately horizontal along flow contacts. Low-permeability layers, such as clays and the interior of flows, act as confining zones. The stratigraphic and areal locations of water-bearing zones are integral parts of the formulation of an accurate model of ground-water flow within the basin.

Regional and Basin Geology

The geology of the Pullman-Moscow area consists of Pre-Tertiary crystalline basement rocks, primarily granites, overlain by a series of Miocene basalt flows, commonly referred to as the Columbia River Basalts. Loess covers the basalt throughout the area.

The Columbia River Basalt Group comprises approximately 55,000 mi^2 in Oregon, Washington, and Idaho, an area known as the Columbia Plateau. During the Miocene Epoch (between 17 million and 6 million years ago) basalt erupted from fissures (feeder dikes) located in southeast Washington, northeast

Oregon, and west central Idaho. Long regarded as a "monotonous sequence of indistinguishable basalt flows" (Hooper, 1982 p. 1464), subsequent investigations employing chemical analyses and fluxgate magnetometer surveys have allowed identification of individual flows.

Basalts in the Palouse Region of the Columbia Plateau are comprised of four Miocene Epoch formations: the Imnaha Formation (17.0 my), the Grande Ronde Formation (16.5 my), the Wanapum Formation (14.5 my), and the Saddle Mountain Formation (13.5 my) (Hooper, 1982). Based on the volume of material erupted, the Grande Ronde Formation constitutes more than 85% by volume of the entire Columbia River Basalt Group. The Imnaha Formation is not hydrologically important in the basin and is not discussed. The other three basalt units are present within the Pullman-Moscow area and are discussed in the following sections.

Grande Ronde Formation

The basalts of the Grande Ronde Formation reach a thickness of approximately 2500 feet (Klein and others, 1987) in the Pullman, Washington area. Individual flows range in thickness from less than 3 feet to more than 150 feet (Swanson and others, 1980). Sedimentary interbeds are occasionally present between flow contacts and generally decrease in thickness from east to west across the basin.

As part of this study, a structural contour map of the top of the Grande Ronde Formation (Figure 2) was constructed from a field reconnaissance of geologic contacts, and geology

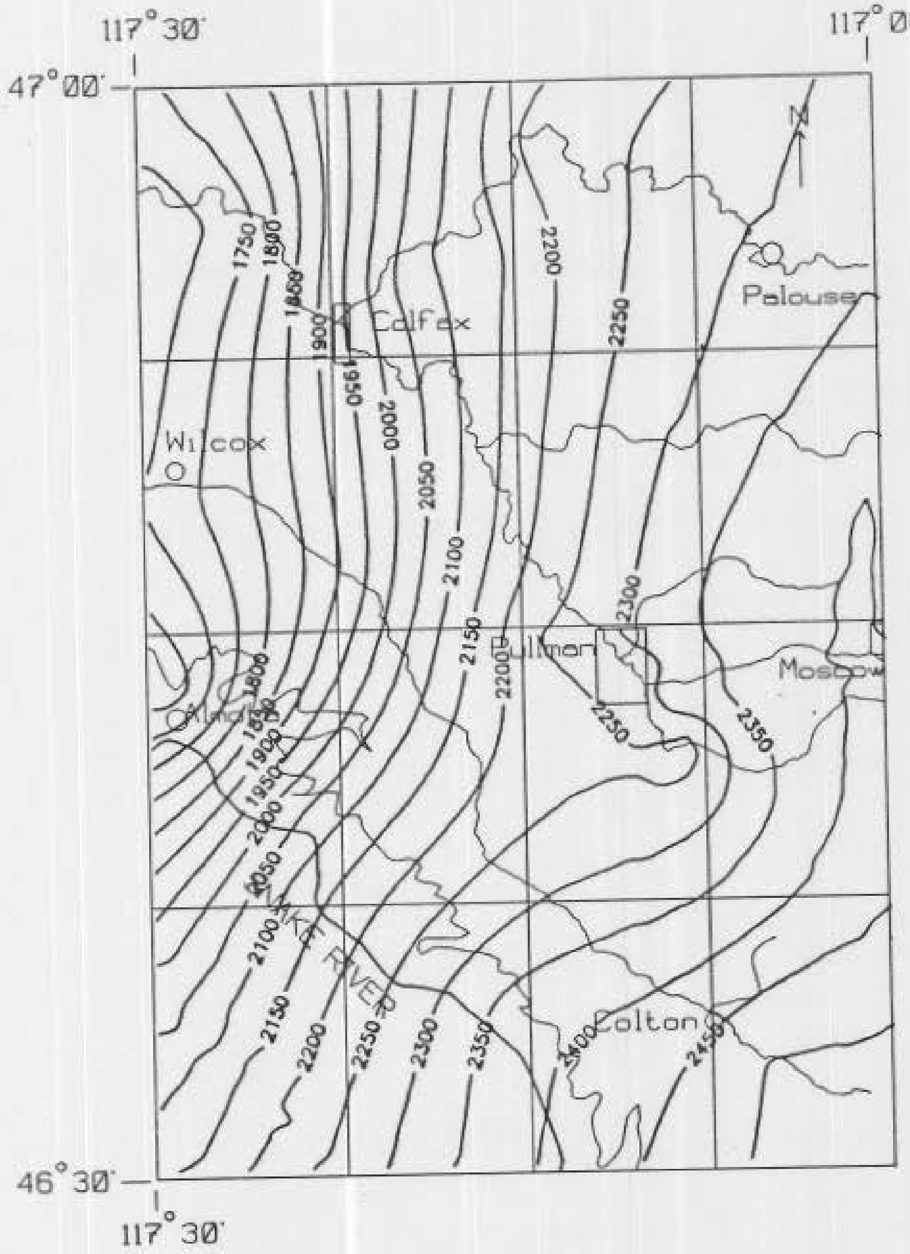


Figure 2. Structural contour map of the top of the Grande Ronde Formation.

interpreted from drill logs of wells completed within the Grande Ronde Formation. Coordinates for most of the geologic contacts along the Snake River Canyon were estimated from the structural contour map by Swanson and others (1980). The structural contour map illustrates the westward dip of the basalts, and generally agrees with previous structural contour maps (Klein and others, 1987, and Swanson and others, 1980).

The Vantage Unit, a layer of siltstone, claystone, and unconsolidated sediments, separates the Priest Rapids Member of the Wanapum Formation from the Grande Ronde Formation. This unit generally ranges in thickness from 0 to 30 feet; along the eastern margin of the Roza flow, Vantage sediments can exceed 100 feet in thickness.

Wanapum Formation

The basalts of the Wanapum Formation overlie the Grande Ronde basalts. This formation has a thickness ranging from 0 to 250 feet, with individual flows averaging 90 to 120 feet in thickness (Swanson and others, 1980). The Wanapum Formation is comprised of four geologically separate flow-sequences (members). They are, in order of increasing age: the Priest Rapids Member, Roza Member, Frenchman Springs Member, and Eckler Mountain Member. The Priest Rapids Member is the only flow of the Wanapum Formation exposed in the Pullman-Moscow basin. The Roza Member of the Wanapum Formation is exposed along the North Fork of the Palouse

River near Colfax, Washington, and along Union Flat Creek west of Union Center.

Saddle Mountain Formation

Intercanyon flows of the Saddle Mountain Formation are present in the southeastern portion of the study area near Colton. Although relatively minor flows in areal extent, the Umatilla Member (Tu) and the Asotin Member (Ta) may be important with respect to ground water discharge to Union Flat Creek, and recharge to the underlying aquifers.

Loess

Aeolian loess covers the basalts in most areas and ranges in thickness from 0 to 300 feet. The loess forms dune-like topography which is important with respect to ground water recharge.

Regional and Basin Hydrogeology

Aquifers within the Wanapum and Grande Ronde Formations are the chief source of water for the Pullman-Moscow region. Based on the correlation of hydrogeologic properties with mappable geologic units, authors Lum and others (1990) and Smoot and Ralston (1987) suggest that three geohydrologic units are present within the study area. These hydrostratigraphic layers consist of: (1) the surficial loess unit which extends from land surface to the top of the Wanapum Formation, (2) the Wanapum Basalt unit which extends from the top of the Wanapum Formation to the top of the

Grande Ronde Formation, and (3) the Grande Ronde Basalt unit which extends from the top of the Grande Ronde Formation to the crystalline basement rocks.

Precipitation is believed to be the major source of recharge within the Pullman-Moscow area. The areal distribution of average annual recharge is estimated to be as much as four inches near Moscow, decreasing to less than two inches along the western margin of the model area (Smoot and Ralston, 1987). Based on model simulation, average annual recharge to the ground-water system is less than three inches per year, with approximately 70 percent of this amount reaching the Grande Ronde Formation (Lum and others, 1990).

The Snake River Canyon is believed to be a major ground-water discharge area (Brown, 1991; Lum and others, 1990). A large percentage of the Grande Ronde Formation is exposed along the canyon walls; ground-water discharge to the Snake River and the Snake River Canyon face is estimated to be approximately 27% of the total outflow from the study area (Lum and others, 1990).

Data from a deep well completed in 1975, and located approximately 1.5 miles north of Lower Granite Dam, refutes the contention that significant discharge is taking place along the canyon walls, at least in this area. The 1150 feet deep Copp well (14/43-21M1) has a static water level 930 feet below land surface (770 feet in elevation). This is approximately 30 feet above the normal pool (normal pool = 738 feet elevation) behind the dam. No water-bearing strata were noted in the upper 900 feet of the drillers log. Data from the Copp well suggest that a significant portion of the Grande Ronde basalts is unsaturated in this area.

Lum and others (1990) estimate that streams within the Pullman-Moscow area account for approximately 26% of the ground-water discharge from the study area. Streamflow measurements from the 1984 USGS study (Figure 3) were used to estimate the amount of streamflow attributable to a direct connection with the ground-water flow system (Table 1). Quantifying the amount of ground water entering the stream network from natural discharge is difficult, as fluctuating discharge rates from city waste-water treatment plants bias streamflow measurements on the larger streams.

Measurements from the 1984 USGS study (Figure 3) suggest a streamflow gain of approximately 1.3 cfs along the central portion of Union Flat Creek. This agrees with earlier USGS measurements recorded during August of 1972 (Nassar & Walters, 1975) which indicates an increase in streamflow of approximately 1.5 cfs along Union Flat Creek between Colton and Wilcox. Wilbur Creek was dry during this period and did not bias the measurements. Measurements along the North Fork of the Palouse River (August, 1972) showed a net loss of 0.1 cfs between two sites: 1/2 mile northwest of Palouse (14.6 cfs), and 100 feet above Elberton (14.5 cfs). This suggests that the ground-water table is near or below stream elevation along this reach. Data obtained during this study from near-stream wells and stream temperature measurements suggest that

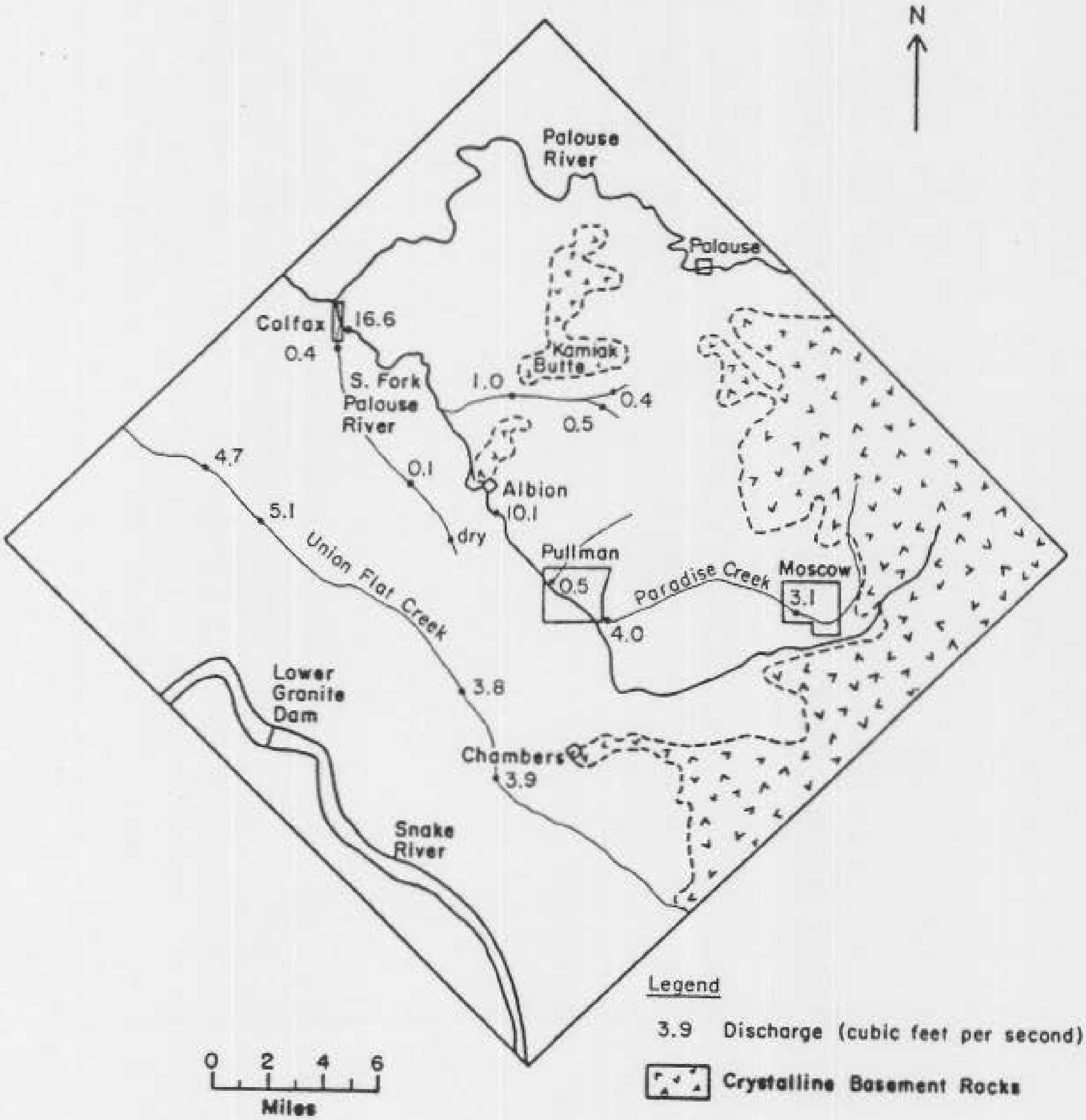


Figure 3. Streamflow measurements, October, 1984 (Blazs, 1984).

ground-water discharge is occurring along the lower portion of this reach.

River reach	Discharge (cfs)
Snake River	---
S. Fork Palouse above Albion	[1]5.6
S. Fork Palouse Albion to Colfax	[1]5.5
Palouse River	---
Union Flat Creek	0.8
Paradise Creek	0.9
Fourmile Creek	1.0
Missouri Flat Creek	0.5
Spring Flat Creek	0.4

[1] Ungaged sewage treatment plant effluent included.

Table 1. Net stream gains attributable to a direct connection with ground-water flow systems derived from the October, 1984 USGS measurements (Lum and others, 1990).

Grande Ronde Aquifer System

The Grande Ronde Formation currently is the principal source for municipal water within the Pullman-Moscow basin. Pumpage from the Wanapum Formation in Moscow has been reduced since the 1960's because of water level declines and water quality issues. Wells completed in the Grande Ronde Formation continue to have water level declines at the rate of approximately 1.25 feet per year (Brown, 1991).

Water level elevations recorded during deep drilling within the Grande Ronde Formation (Pullman Test Well - Brown, 1976; WSU well # 7 - Ralston, 1987) showed little water level change with depth. This suggests that aquifers within the

Grande Ronde Formation are hydraulically connected and that the dominant direction of flow is horizontal.

Producing zones within the Grande Ronde Formation have been identified from well logs and geophysical logs from the Pullman test well, and wells for the two cities and the two universities. Ralston labeled the aquifers from shallow to deep as A, B, C, and D based on data from WSU well #7. These aquifers are located within a range of elevation from 2180 to 1425 feet. Aquifer A is the principal aquifer in the Pullman-Moscow area, and is located between 2180 feet and 2150 feet in Pullman. This correlates with the uppermost Grande Ronde aquifer zone recorded in the Pullman test well (elevation 2220-2180 feet). The A-zone is located at the base of the uppermost Grande Ronde flow, approximately 100 feet below the base of the Wanapum, and 130 feet below where the base of the Wanapum Formation outcrops in the valley of the South Fork of the Palouse River in Pullman.

A contour map showing ground-water flow directions across the region (Figure 4) was constructed as part of this study using static water-level elevations recorded from 25 wells completed within the Grande Ronde Formation. Wells that are completed between 100 to 900 feet below the top of the Grande Ronde Formation were used in generating the contour map. Some wells which are completed within the Grande Ronde Formation were not used in construction of the water-level elevation contour map; these wells are also open to the overlying strata and exhibit substantially higher

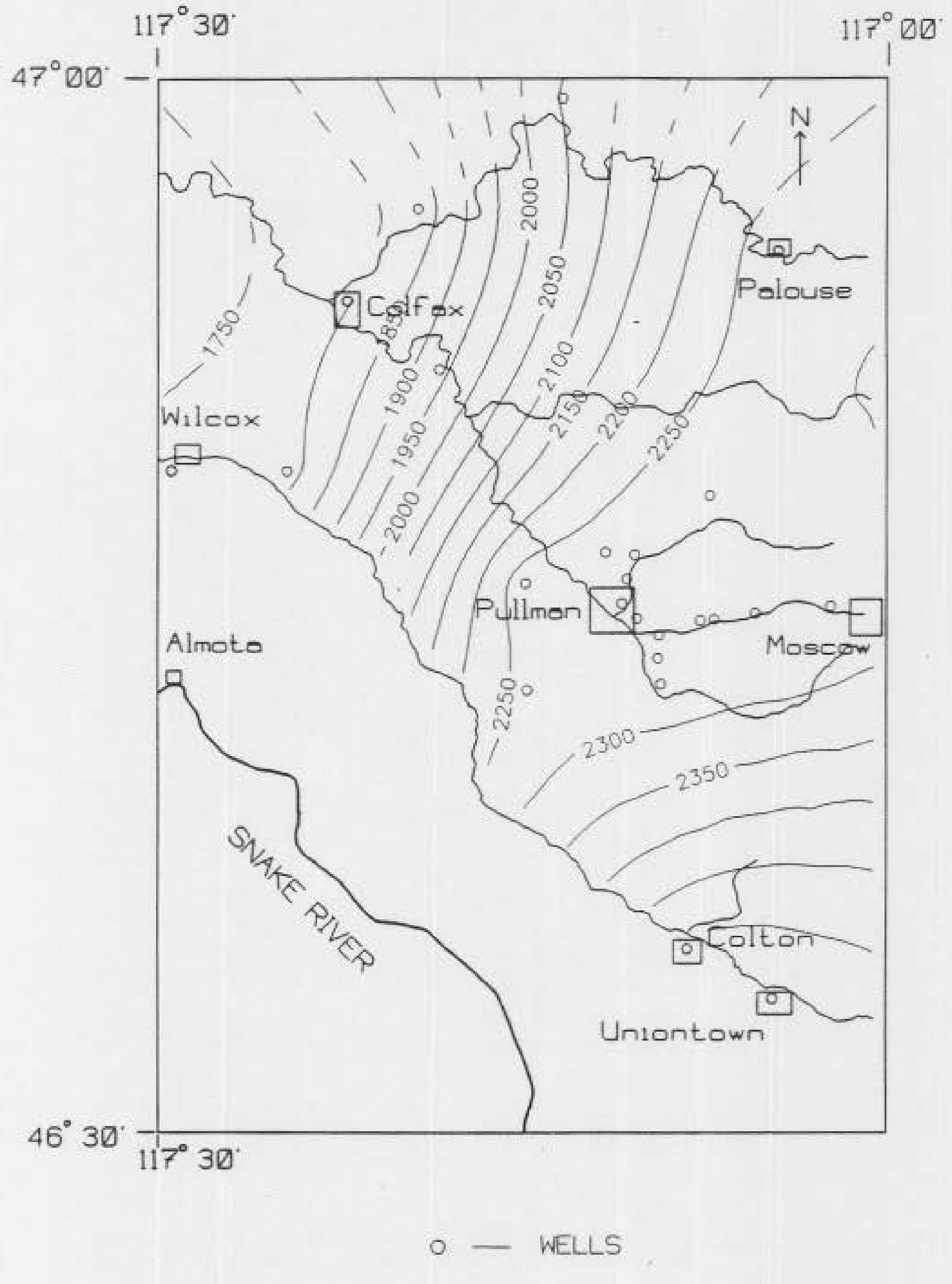


Figure 4. Contour map of static water level elevations of wells completed within the Grande Ronde

water levels. The contour map indicates the principal direction of ground-water flow is toward the northwest, roughly parallel to Union Flat Creek and the South Fork of the Palouse River. This generally agrees with previous work (Bauer and others, 1985), which suggests a more westwardly flow.

Static water levels of near-stream wells completed within the Grande Ronde Formation are generally below stream elevations. The static water levels of wells in the southeastern portion of the study area are approximately 50 feet below Union Flat Creek. The static water levels of wells in the northwestern portion of the study area are approximately 175 feet below the North Fork of the Palouse River.

The stratigraphic contact between the Wanapum Formation and the Grande Ronde Formation does not physically correspond to the transition from upper aquifer to lower aquifer. The transition is believed to occur approximately 100 to 200 feet below the surface of the Grande Ronde Formation. This has been documented during the drilling of WSU well #7 and the Pullman Test Well; data from deep wells drilled near Colfax and Genesee also suggest the transition occurs below the uppermost flow of the Grande Ronde Formation.

Several aquifers with different water level elevations may be present in the Grande Ronde Formation in the northern portion of the study area near Colfax. Wells located in the Colfax area have significantly higher static water levels if their open interval is limited to the uppermost flow contact zone within the Grande Ronde Formation. Wells open below the dense central portion of the first flow have lower static water levels. This suggests that there are two separate aquifers within the Grande Ronde Formation in this area. Water levels of wells along Union Flat Creek near the town of Wilcox, and wells located along the South Fork of the Palouse River between Pullman and Albion exhibit comparable static water-level elevations regardless of depth within the formation.

Wanapum Aquifer

The Wanapum Formation was the principal source of water within the Pullman-Moscow area until the mid 1960's but now is used primarily for domestic wells. Water levels of some wells in Moscow which are completed in the Wanapum Formation have recovered by as much as 20 feet as the result of the switch to the Grande Ronde system for municipal wells. Ground-water occurrence within the Wanapum Formation generally is associated with flow contact zones or sedimentary deposits. Static water levels for most wells completed in the Wanapum Formation generally reflect a potential surface several hundred feet above the Grande Ronde Formation water levels.

The majority of recorded wells which are completed within the Wanapum Formation are located in the southern portion of the study area near Union Flat Creek. Near-stream wells generally have static water levels near stream elevation; wells farther removed from the stream generally have static water levels higher than stream elevations.

Aquifer Model

Water balance data are a key product of the Pullman-Moscow basin ground-water-flow model. Water that enters the model from recharge and constant-head boundaries is balanced by water exiting the model through wells, drains, rivers, and constant-head boundaries. Ground-water flow through constant-head boundaries located along the northeast, southeast, and western boundaries of both the Wanapum and Grande Ronde model layers is estimated to account for approximately 9% of the total inflow and 13% of the total outflow for the basin model. A water budget for the entire model is presented in Table 2 (Lum and others, 1990).

	Quantity of water, in cubic feet per second		
	In	Out	Sum
Constant-head boundaries	12.8	-19.3	-6.5
Wells, pumpage	0	-9.4	-9.4
Snake River and seepage faces	0	-40.5	-40.5
Drains	0	-41.6	-41.6
Rivers	.3	-38.4	-38.1
Recharge	136	0	+136
Sum	+149	-149	0

Table 2. Summary of water budget for time-averaged simulation (Lum and others, 1990).

River and stream reaches are simulated in the model by either a flux into or out of the stream depending on the head gradient from the adjacent layer to the stream. These simulated fluxes can be summed and compared to the USGS streamflow measurements (Figure 3). The water budget for the time-averaged simulation (Table 2) allocates approximately one-third of the total recharge within the study area to stream outflow.

CHAPTER III

RELATIONSHIP BETWEEN AREA STREAMS AND GEOLOGY

Introduction

One of the objectives of this study is to relate stream gain or loss to the underlying geologic conditions. Geologic cross sections along six Pullman-Moscow area streams were constructed using drill logs of near-stream wells and data from exposed geologic contacts. The cross sections were used to interpret the hydrogeology of the area, and to compare the static water levels of wells to stream elevations. Areas where there appeared to be a potential for ground-water discharge to the stream were investigated to verify if ground-water discharge was occurring.

The majority of the streams in the Pullman-Moscow area flow in a westerly to northwesterly direction (Figure 5). Approximately 78 percent of the total stream length is located on the Wanapum Formation, 18 percent on the Grande Ronde Formation, and 4 percent on the loess. In most cases, stream sediments are present over the basalts.

Three area streams are classified as intermittent: Four Mile Creek, Missouri Flat Creek, and the southeastern portion of the South Fork of the Palouse River. Paradise Creek flows the entire year; west of Moscow during low flow conditions, most of the flow is discharge from the City of Moscow waste-water treatment plant. The South Fork of the Palouse River receives water from Paradise Creek, and from waste-water

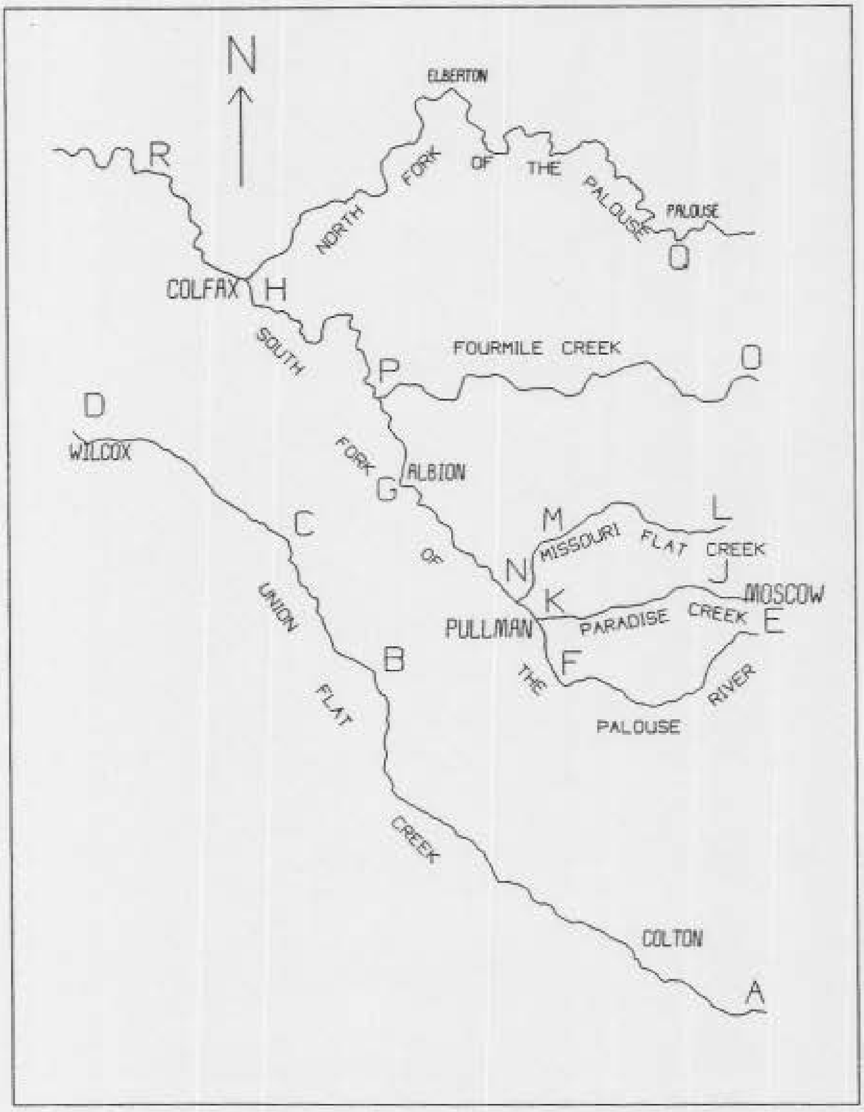


Figure 5. Location map for area stream cross sections.

treatment plants located in the City of Pullman, and the City of Albion.

Investigation of Area Streams

The following sections pertain to the relationship between the Pullman-Moscow area streams and the underlying geology. Stream reaches discussed in the following sections can be referenced using the map presented as Figure 5.

Union Flat Creek

Union Flat Creek (Sections A-B-C-D, Figures 6,7,8) enters the study area near Uniontown, Washington, and initially flows on the upper portion of the Priest Rapids Member. Over the next 30 miles, Union Flat Creek cuts through the entire Priest Rapids Member and the upper portion of the Roza Member. Subsequent to exiting the study area west of Wilcox, the stream gradient decreases, and Union Flat Creek flows stratigraphically higher within the Roza Member (Figure 8), as the dip of the basalts exceeds the stream gradient.

Ground Water Levels

Wells located near Union Flat Creek generally have static water levels near stream elevations regardless of the depth to which the wells penetrate the basalts. Three exceptions to this observation include: (1) deeper wells located in Uniontown have static water levels approximately 50 feet below stream elevation (Figure 6), (2) wells

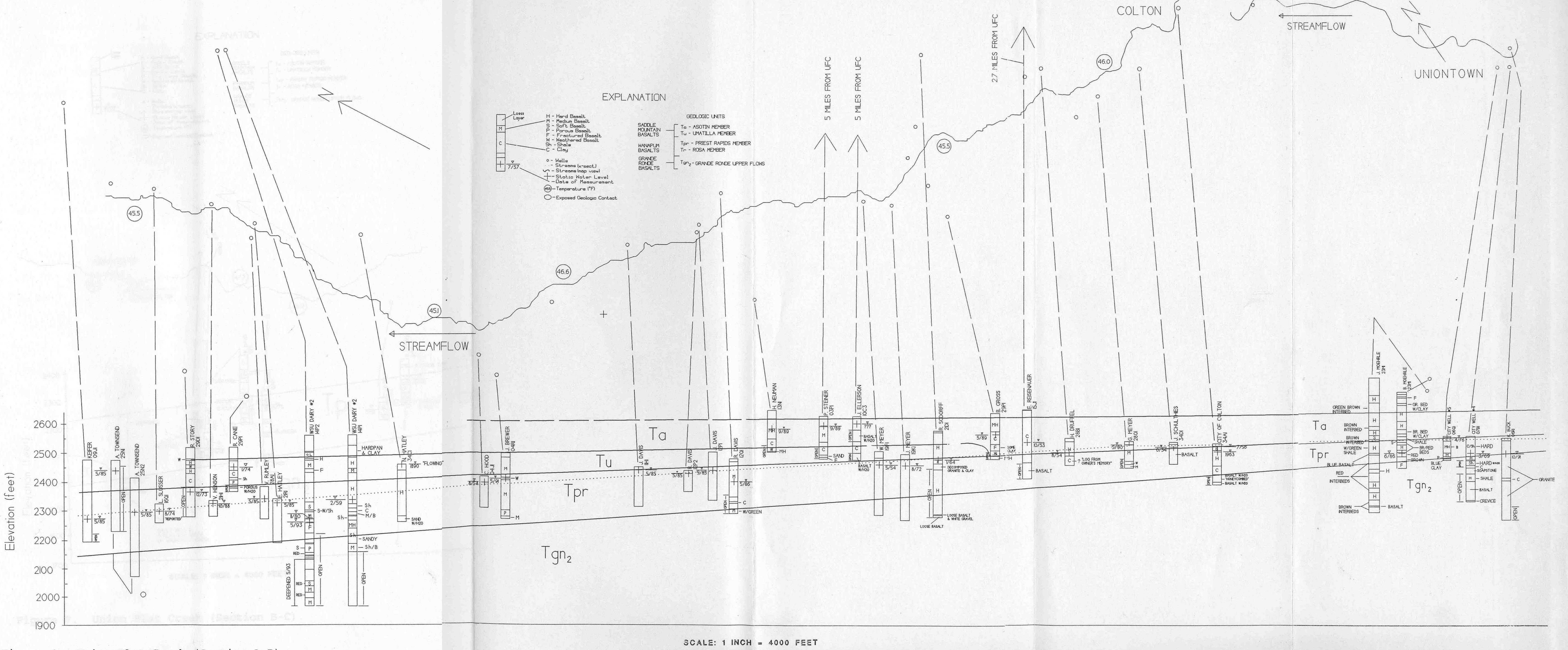


Figure 6. Union Flat Creek (Section A-B).

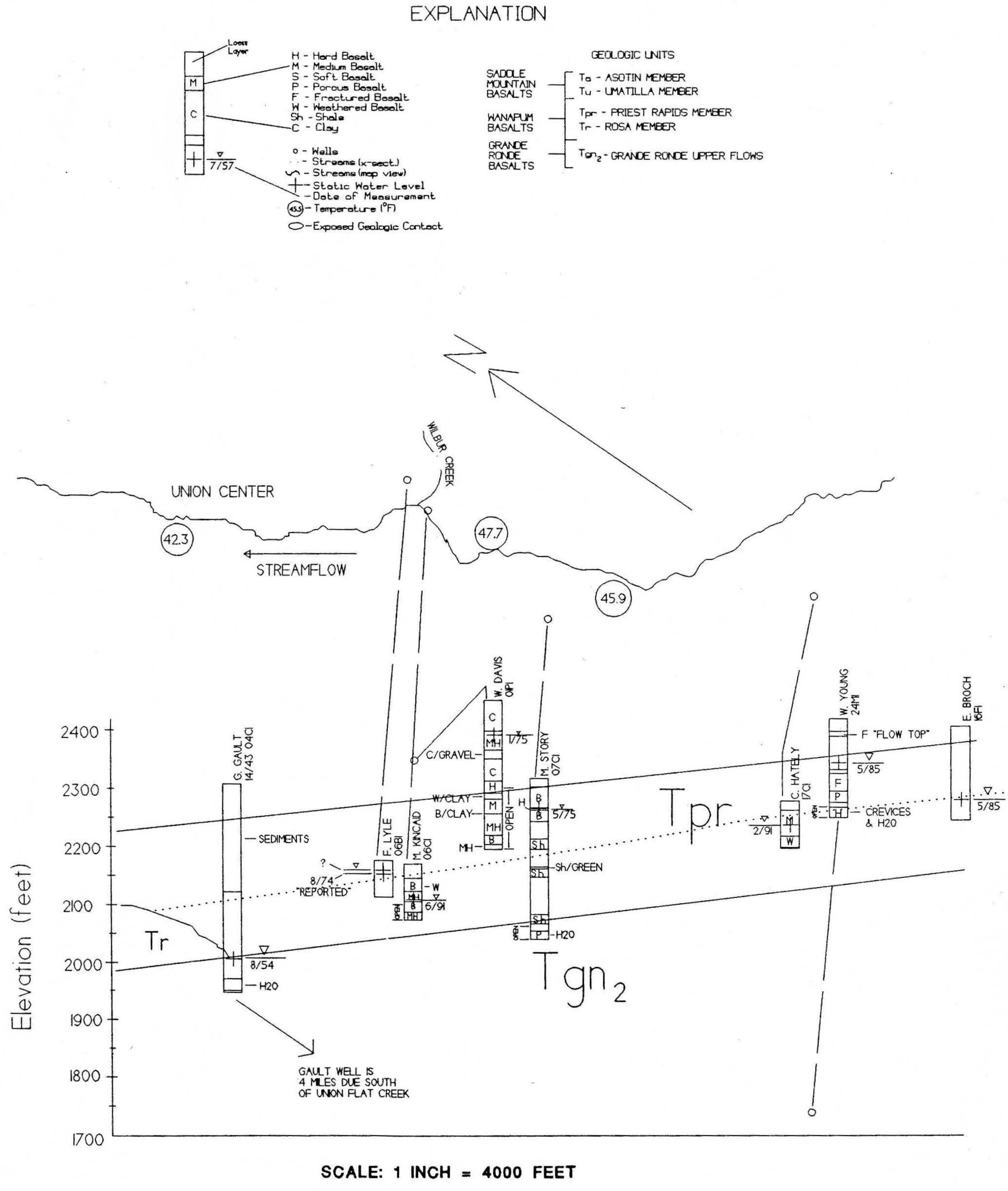


Figure 7. Union Flat Creek (Section B-C).

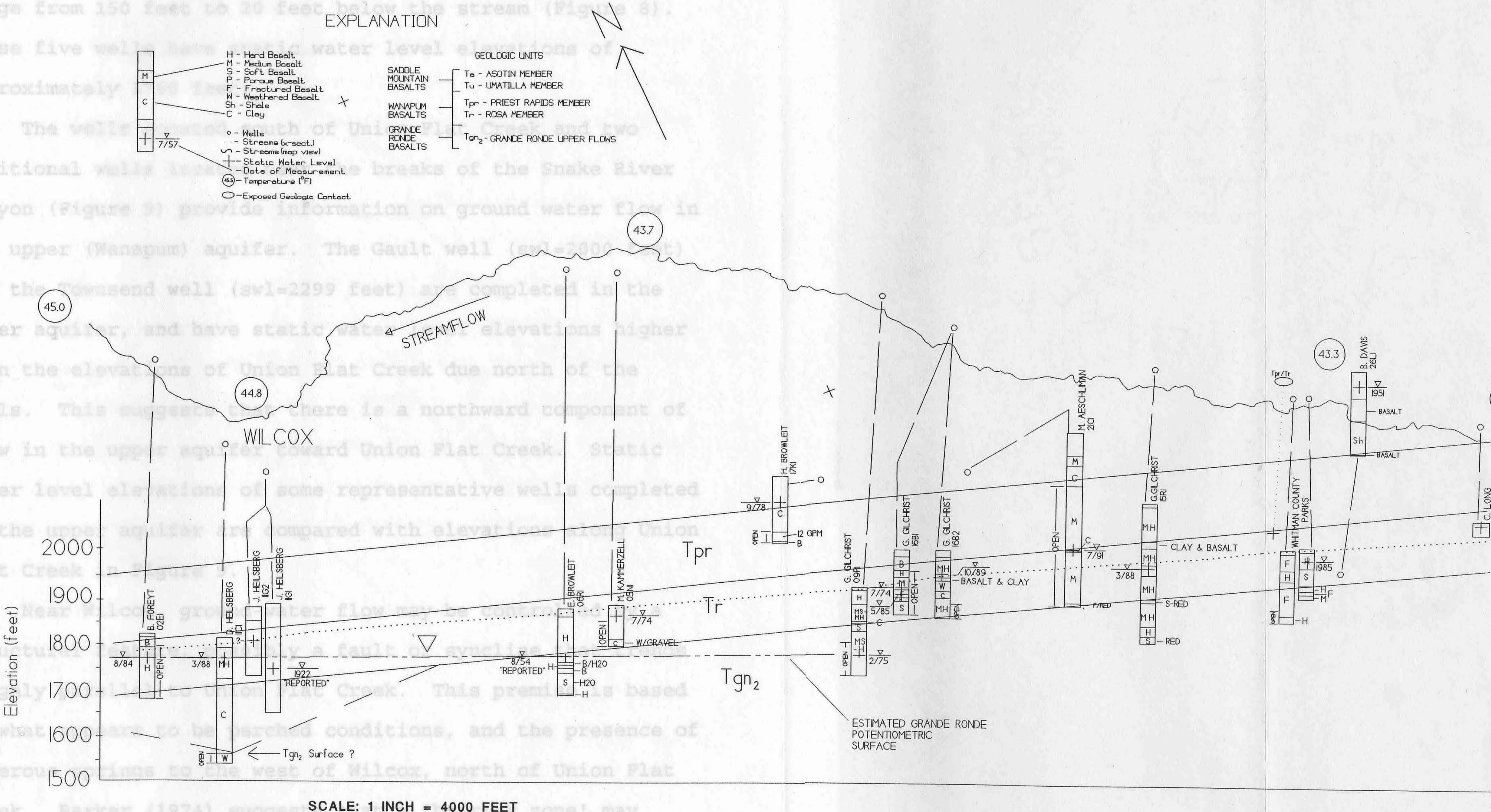


Figure 8. Union Flat Creek (Section C-D).

completed within the Wanapum Formation and located south of Union Flat Creek generally have static water levels 100 to 200 feet above stream elevations (Figures 6,7,8), and (3) five wells located near Wilcox have static water levels which range from 150 feet to 20 feet below the stream (Figure 8). These five wells have static water level elevations of approximately 1760 feet.

The wells located south of Union Flat Creek and two additional wells located near the breaks of the Snake River Canyon (Figure 9) provide information on ground water flow in the upper (Wanapum) aquifer. The Gault well (swl=2000 feet) and the Townsend well (swl=2299 feet) are completed in the upper aquifer, and have static water level elevations higher than the elevations of Union Flat Creek due north of the wells. This suggests that there is a northward component of flow in the upper aquifer toward Union Flat Creek. Static water level elevations of some representative wells completed in the upper aquifer are compared with elevations along Union Flat Creek in Figure 9.

Near Wilcox, ground-water flow may be controlled by a structural feature, possibly a fault or syncline that trends roughly parallel to Union Flat Creek. This premise is based on what appears to be perched conditions, and the presence of numerous springs to the west of Wilcox, north of Union Flat Creek. Barker (1974) suggests that a 'barrier zone' may exist between Pullman and Union Flat Creek that restricts ground-water flow in the lower aquifer. Barker further

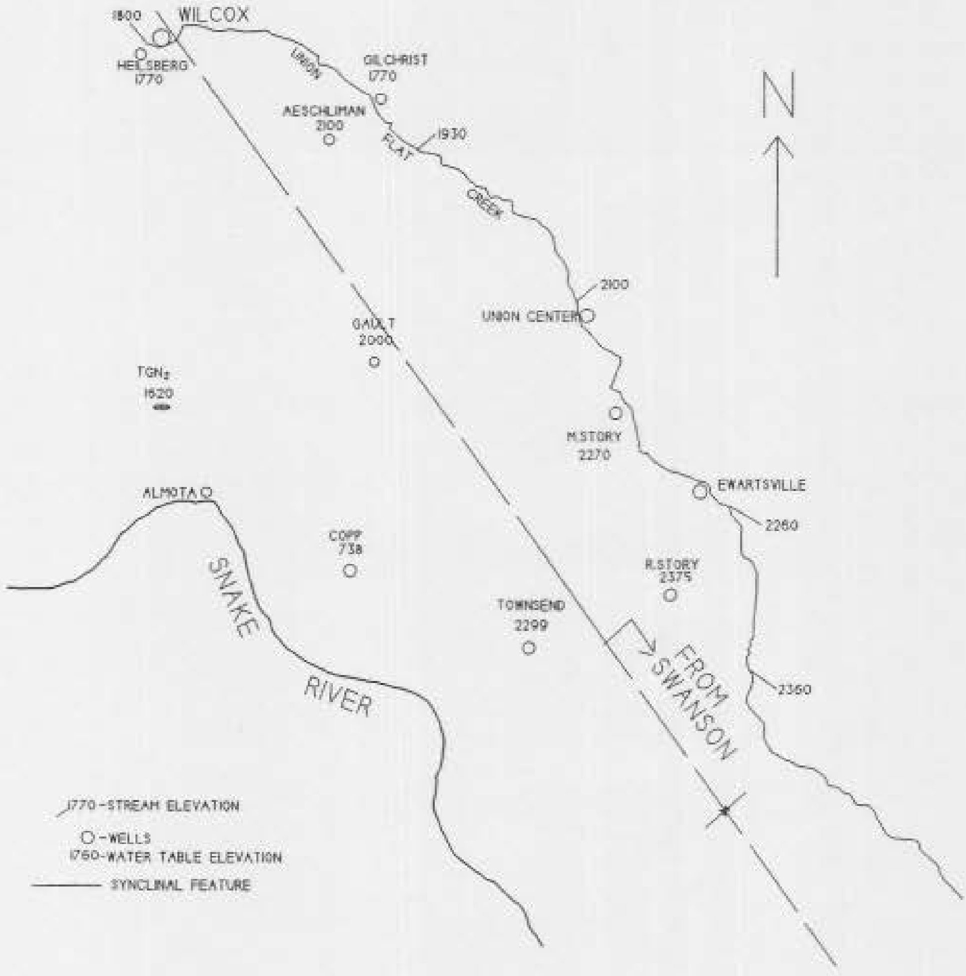


Figure 9. Synclinal feature (From Swanson, 1980) shown relative to Union Flat Creek and nearby wells.

suggests that the upper and lower aquifers merge near the channel of Union Flat Creek, due in part, to an increase in the vertical permeability of the basalts near the channel.

Swanson and others (1980) suggest that a northwest-trending concealed syncline may exist near the Snake River Canyon based on the structural relationship between the Roza and Grande Ronde basalts (Figure 9). The synclinal axis, if projected further to the northwest, would pass near the town of Wilcox. Approximately 200 feet of "blue clay" was encountered between basalt flows in the Heilsberg well. The basalt beneath the 200 feet thick clay layer may represent the top of the Grande Ronde Formation. This would locate the Grande Ronde surface at the well, at approximately 1560 feet in elevation. This is about 60 feet below the exposed contact (elevation 1620 feet) located in Stine Gulch, approximately 5.7 miles due south of the well. The syncline or a fault in the area could account for the difference in elevation of the Grande Ronde Formation. The postulated structural feature appears to control ground-water flow in the Wilcox area.

Ground-Water Discharge

Union Flat Creek receives ground-water discharge along various stream sections from the city of Colton through the town of Wilcox. Ground-water discharge generally occurs along stream sections where near-stream wells have static water levels significantly higher than stream elevation. This conclusion is based on the annual average baseflow estimations (Blazs, 1984) and water level data. Stream temperature measurements (shown relative to the geology in Figures 6,7, and 8), also support this conclusion.

Ground-water discharge near Colton (Figure 6) appears to be associated with the contact between the Priest Rapids Member (Tpr) of the Wanapum Formation, and the overlying Umatilla (Tu) and Asotin (Ta) Members of the Saddle Mountain Formation. A relatively significant ground-water discharge area (Figure 7) is located near the eastern terminus of the Roza Member, approximately two miles upstream from Union Center. A stream temperature increase of 1.8 degrees was recorded in this area during February, 1994. Downstream from the ground-water discharge zone, colder water from Wilbur Creek entering Union Flat Creek caused a stream temperature drop of 5 degrees. Ground-water discharge west of Wilcox is believed to be associated with an area where the water table is above Union Flat Creek.

South Fork of the Palouse River

The South Fork of the Palouse River (Sections E-F-G-H, Figures 10,11,12) enters the study area near Moscow, Idaho. The stream flows on the central portion of the Priest Rapids Member, and becomes incised in the columnar structure of the lower Priest Rapids Member in Pullman, Washington. The Vantage unit is exposed near the channel of the South Fork of the Palouse River west of Pullman (Bush, personal communication, 1992) and is believed to be exposed in the

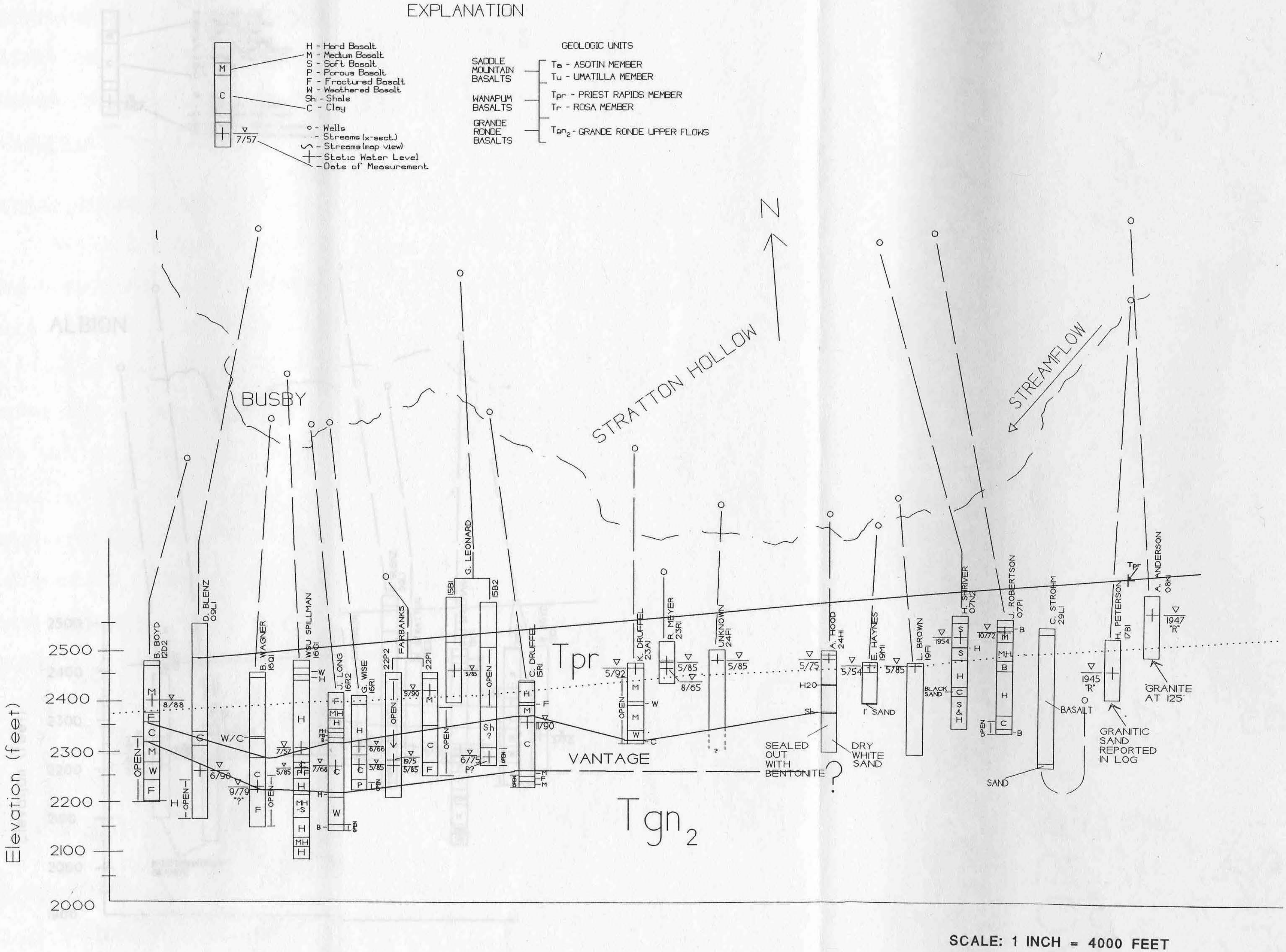


Figure 10. South Fork of the Palouse River (Section E-F).

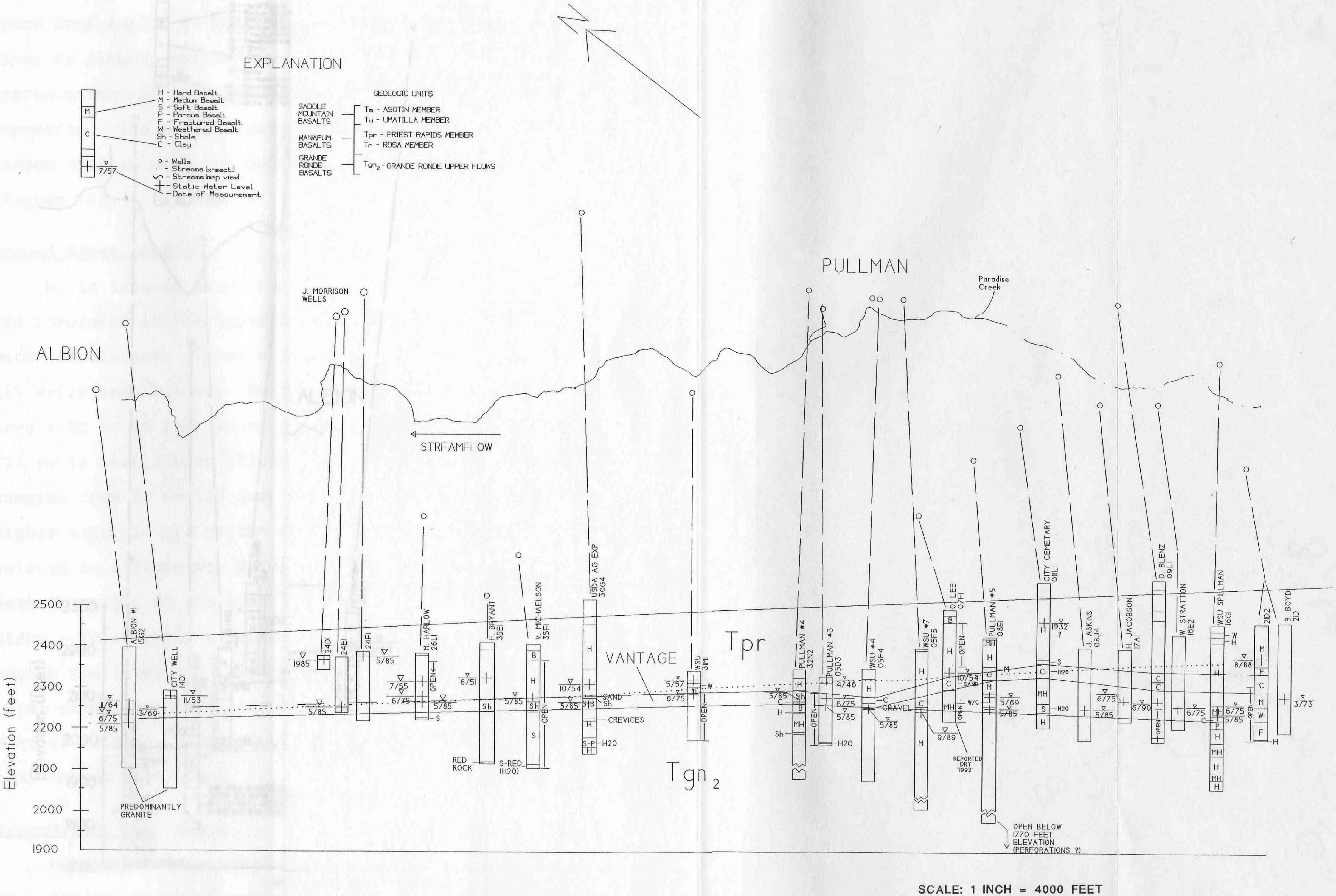


Figure 11. South Fork of the Palouse River (Section F-G).

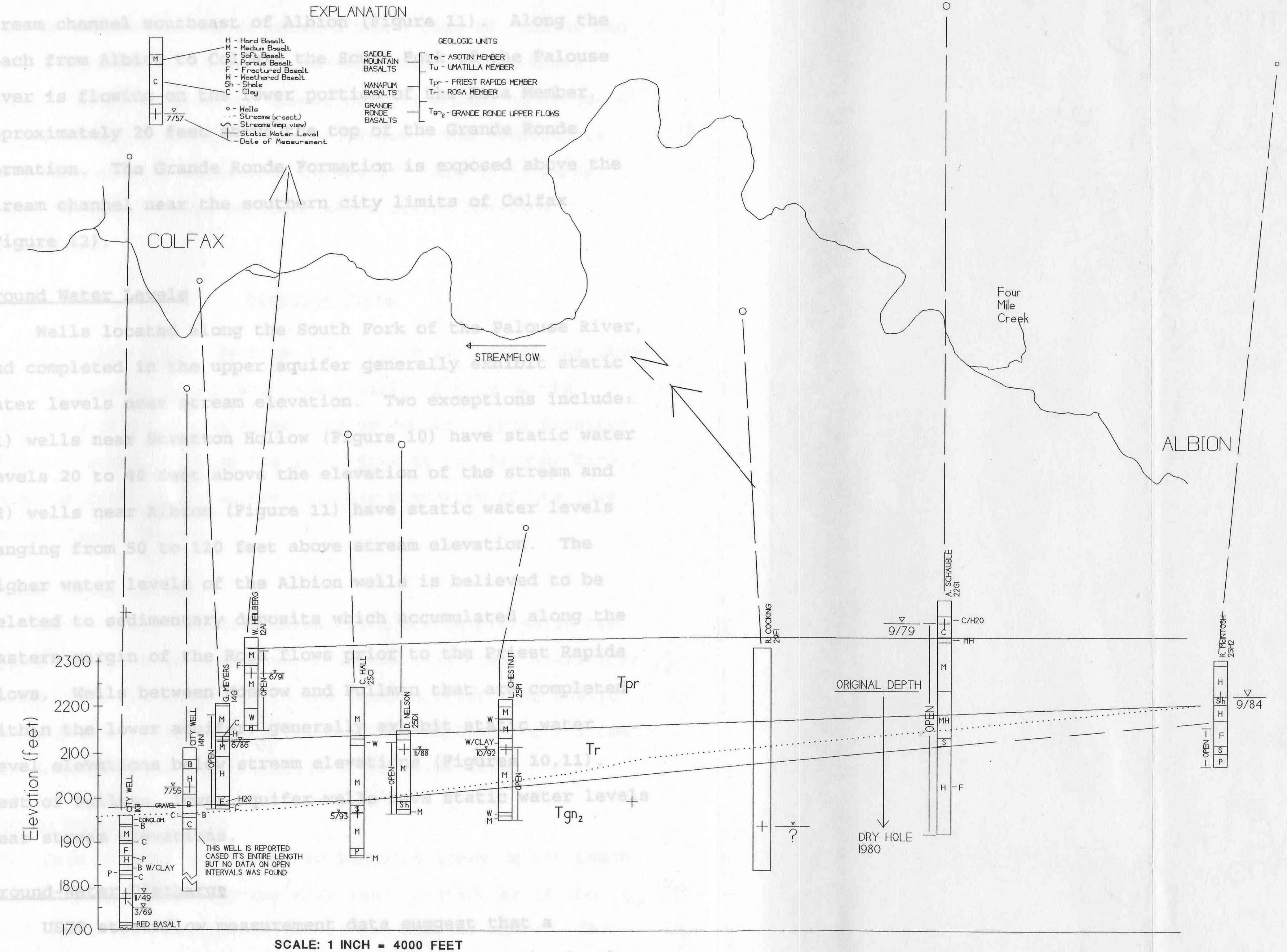


Figure 12. South Fork of the Palouse River (Section G-H).

stream channel southeast of Albion (Figure 11). Along the reach from Albion to Colfax, the South Fork of the Palouse River is flowing on the lower portion of the Roza Member, approximately 20 feet above the top of the Grande Ronde Formation. The Grande Ronde Formation is exposed above the stream channel near the southern city limits of Colfax (Figure 12).

Ground Water Levels

Wells located along the South Fork of the Palouse River, and completed in the upper aquifer generally exhibit static water levels near stream elevation. Two exceptions include: (1) wells near Stratton Hollow (Figure 10) have static water levels 20 to 40 feet above the elevation of the stream and (2) wells near Albion (Figure 11) have static water levels ranging from 50 to 120 feet above stream elevation. The higher water levels of the Albion wells is believed to be related to sedimentary deposits which accumulated along the eastern margin of the Roza flows prior to the Priest Rapids flows. Wells between Moscow and Pullman that are completed within the lower aquifer, generally exhibit static water level elevations below stream elevations (Figures 10,11). West of Pullman, lower aquifer wells have static water levels near stream elevations.

Ground-Water Discharge

USGS streamflow measurement data suggest that a significant amount of ground-water discharges to the South

Fork of the Palouse River between the cities of Pullman and Colfax (Figure 3). However, several stream temperature surveys taken in the late summer of 1993 showed no evidence of ground-water discharge to the stream. The temperature data suggest that streamflow consists primarily of waste-water treatment plant effluent water during low-flow conditions.

Paradise Creek

Paradise Creek (Section J-K, Figure 13) enters the study area in Moscow, Idaho, and is initially flowing on the central portion of the Priest Rapids Member. Upon entering Pullman, where it joins the South Fork of the Palouse River, Paradise Creek flows on the columnar structure of the lower Priest Rapids Member.

Ground Water Levels

Wells along Paradise Creek which are completed in the upper aquifer have static water levels near creek elevations. Wells which are completed in the lower aquifer have static water levels approximately 100 feet (in Pullman) to 275 feet (in Moscow) below the elevation of Paradise Creek.

Ground Water Discharge

Ground-water discharges to Paradise Creek in the reach beginning approximately one mile east (Station 4) of the confluence with the South Fork of the Palouse River. The discharge is believed to be from the lower portion of the

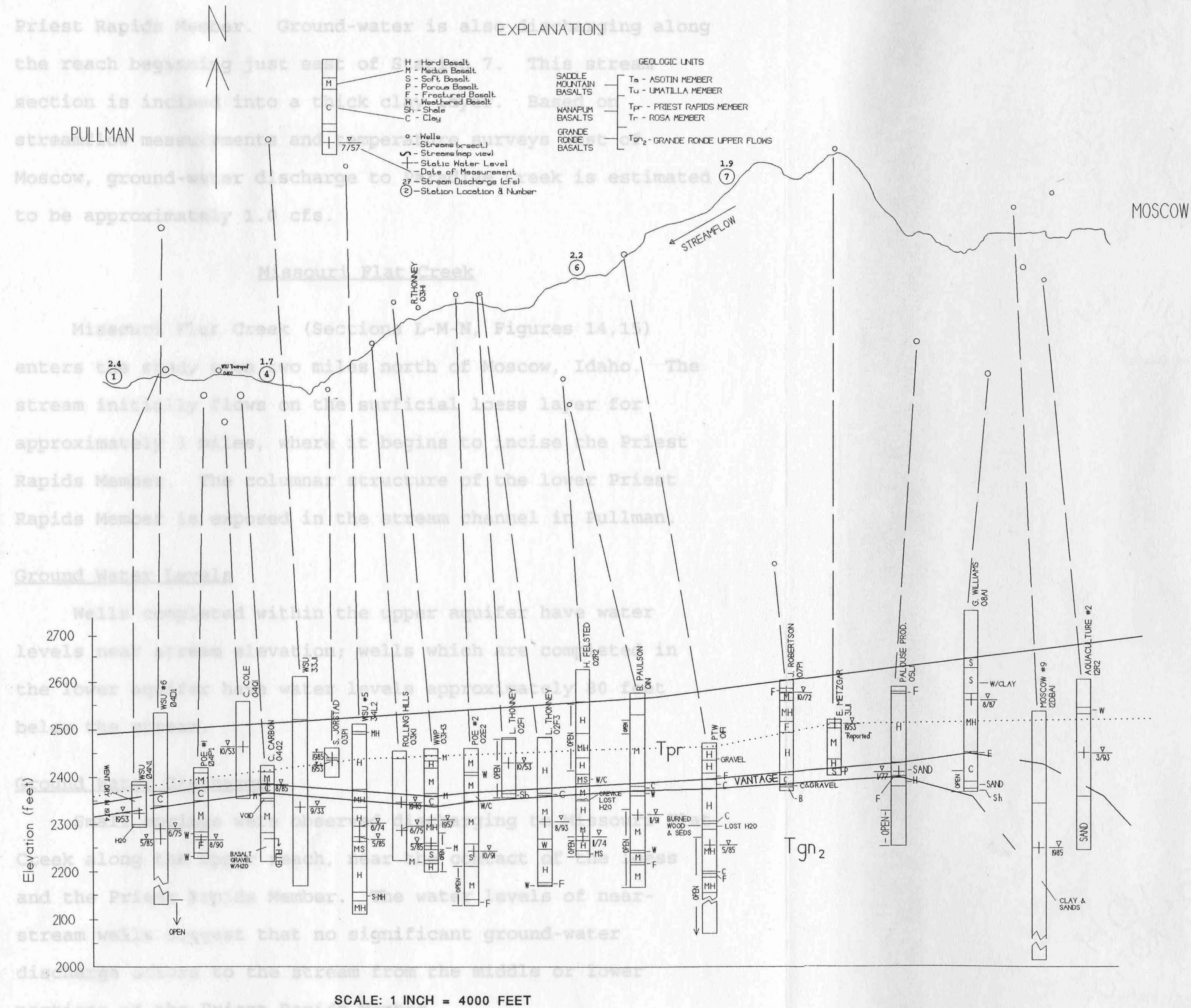


Figure 13. Paradise Creek (Section J-K).

Priest Rapids Member. Ground-water is also discharging along the reach beginning just east of Station 7. This stream section is incised into a thick clay layer. Based on streamflow measurements and temperature surveys west of Moscow, ground-water discharge to Paradise Creek is estimated to be approximately 1.0 cfs.

Missouri Flat Creek

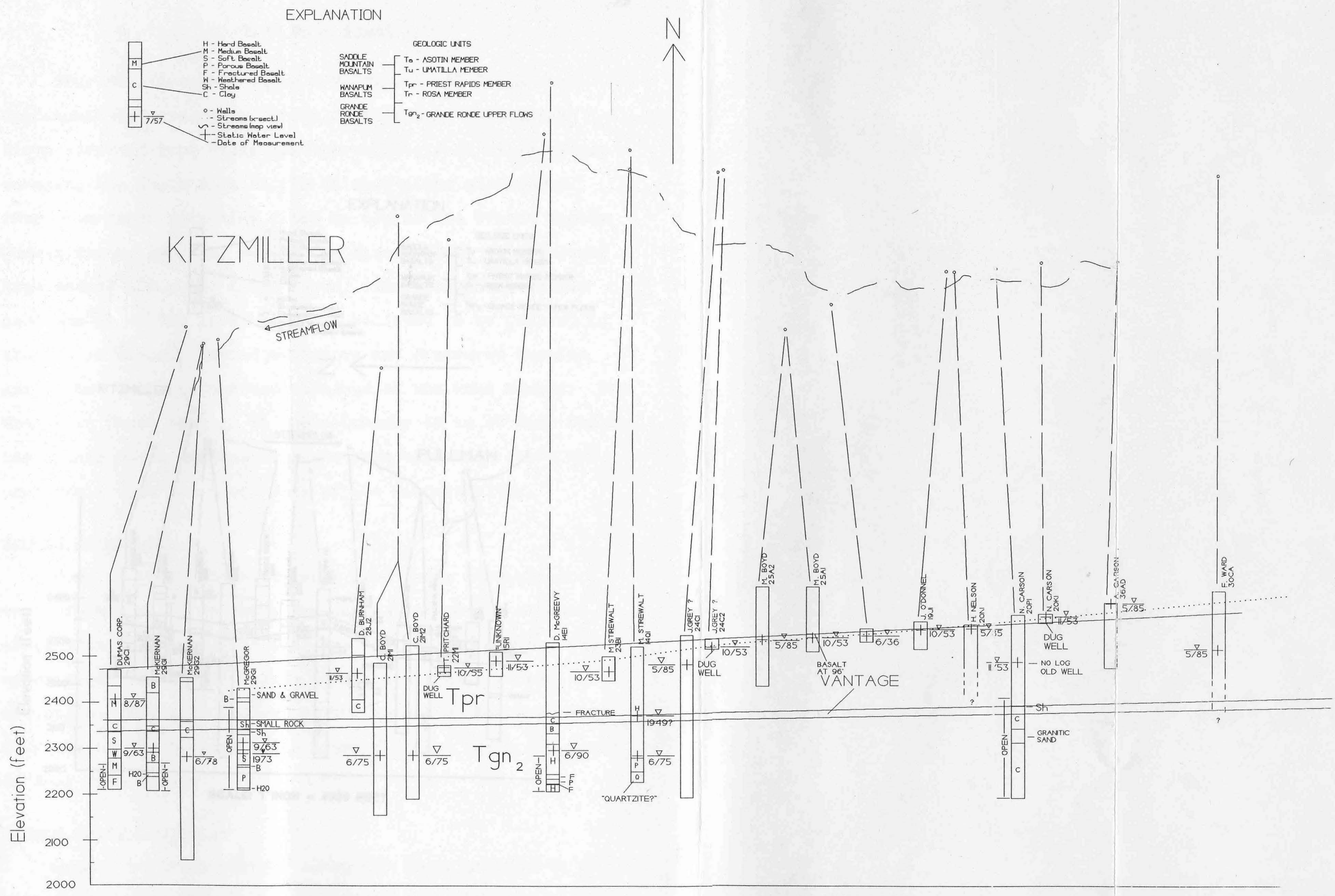
Missouri Flat Creek (Sections L-M-N, Figures 14,15) enters the study area two miles north of Moscow, Idaho. The stream initially flows on the surficial loess layer for approximately 3 miles, where it begins to incise the Priest Rapids Member. The columnar structure of the lower Priest Rapids Member is exposed in the stream channel in Pullman.

Ground Water Levels

Wells completed within the upper aquifer have water levels near stream elevation; wells which are completed in the lower aquifer have water levels approximately 80 feet below the stream.

Ground Water Discharge

Small springs were observed discharging to Missouri Flat Creek along the upper reach, near the contact of the loess and the Priest Rapids Member. The water levels of near-stream wells suggest that no significant ground-water discharge occurs to the stream from the middle or lower portions of the Priest Rapids Member.



SCALE: 1 INCH = 4000 FEET

Figure 14. Missouri Flat Creek (Section L-M).

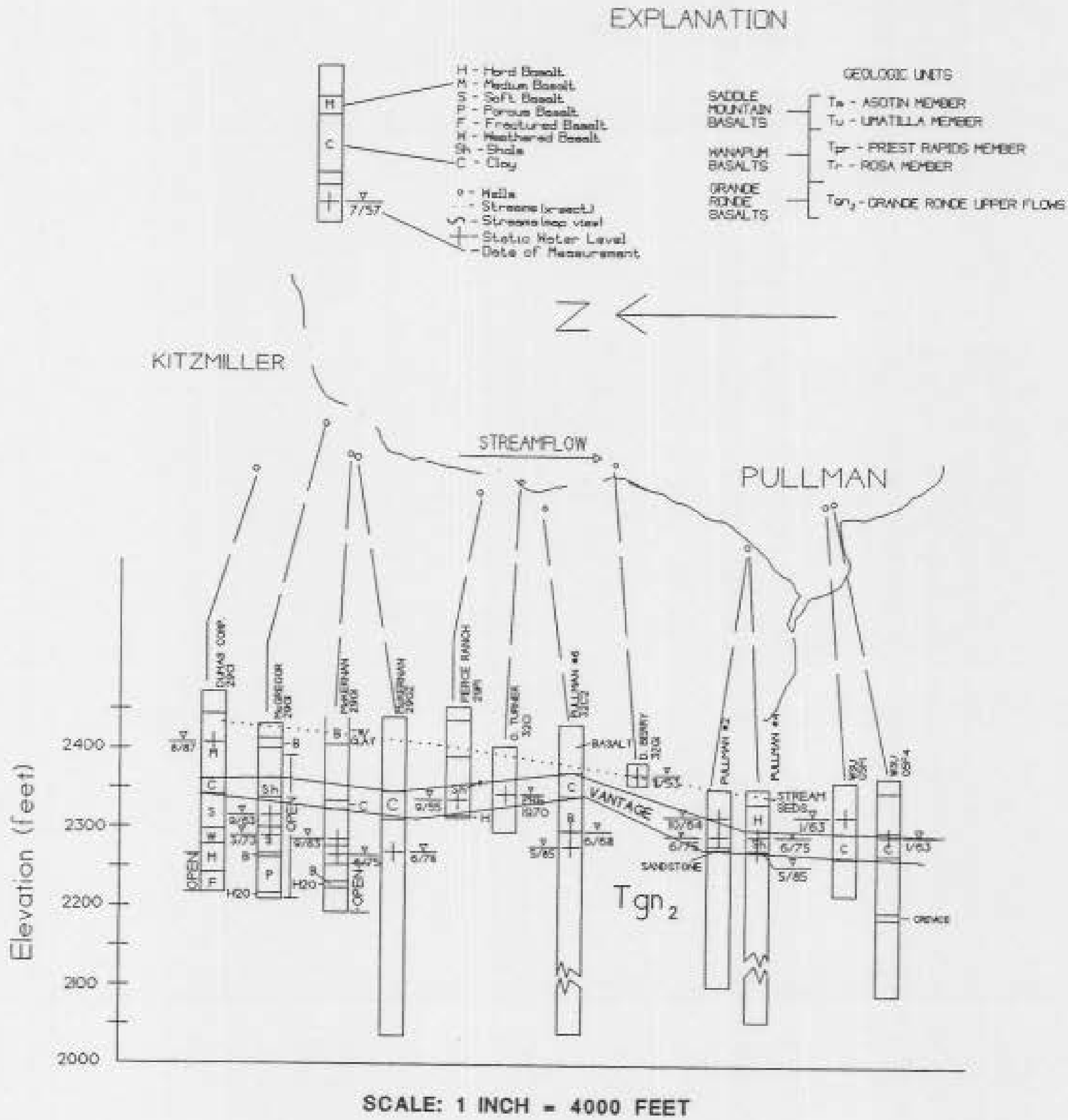


Figure 15. Missouri Flat Creek (Section M-N).

Four Mile Creek

Four Mile Creek (Section O-P, Figure 16) is located approximately seven miles north of Pullman. This stream flows westward from Viola for approximately 16 miles before entering the South Fork of the Palouse River at Shawnee. Four Mile Creek initially flows on top of the Priest Rapids Member along the upper reach; the stream flows on the lower Roza Member along the lower reach. The steepening stream gradient along the lower reach is believed to be related to erosion of unconsolidated sediments and fractured basalts associated with the eastern terminus of the Roza Member. The Four Mile Creek channel is approximately 10 to 20 feet above the Grande Ronde surface over the last half-mile above the confluence with the South Fork of the Palouse River.

Ground Water Levels

Most of the wells along Four Mile Creek have static water levels which do not appear to be related to stream elevations; the exception includes wells located along the upper reach which have static water levels near stream elevation. Water levels may be influenced by the proximity of wells to the granite hills located to the north and south of Four Mile Creek.

Ground Water Discharge

Ground-water discharges along the lower portion of Four Mile Creek where the stream is incised into the base of the Rosa flow. Temperature measurements recorded during August,

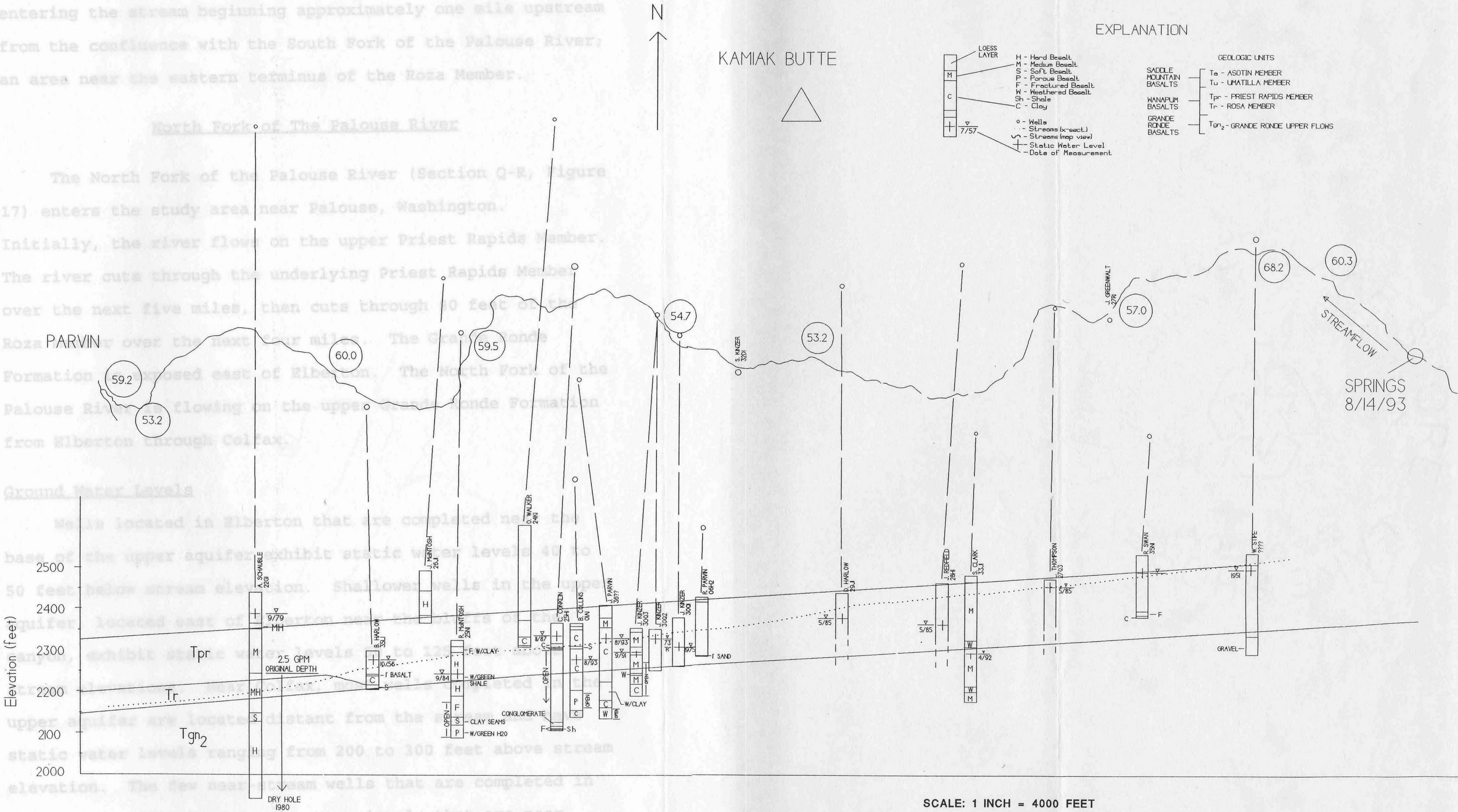


Figure 16. Four Mile Creek (Section O-P).

1993 (Figure 16), indicate that colder ground water is entering the stream beginning approximately one mile upstream from the confluence with the South Fork of the Palouse River; an area near the eastern terminus of the Roza Member.

North Fork of The Palouse River

The North Fork of the Palouse River (Section Q-R, Figure 17) enters the study area near Palouse, Washington. Initially, the river flows on the upper Priest Rapids Member. The river cuts through the underlying Priest Rapids Member over the next five miles, then cuts through 80 feet of the Roza Member over the next four miles. The Grande Ronde Formation is exposed east of Elberton. The North Fork of the Palouse River is flowing on the upper Grande Ronde Formation from Elberton through Colfax.

Ground Water Levels

Wells located in Elberton that are completed near the base of the upper aquifer exhibit static water levels 40 to 50 feet below stream elevation. Shallower wells in the upper aquifer, located east of Elberton near the bluffs of the canyon, exhibit static water levels 50 to 125 feet above stream elevations. Near Colfax, most wells completed in the upper aquifer are located distant from the stream and have static water levels ranging from 200 to 300 feet above stream elevation. The few near-stream wells that are completed in the upper aquifer have static water levels that are near stream elevation. Wells that are completed in the lower

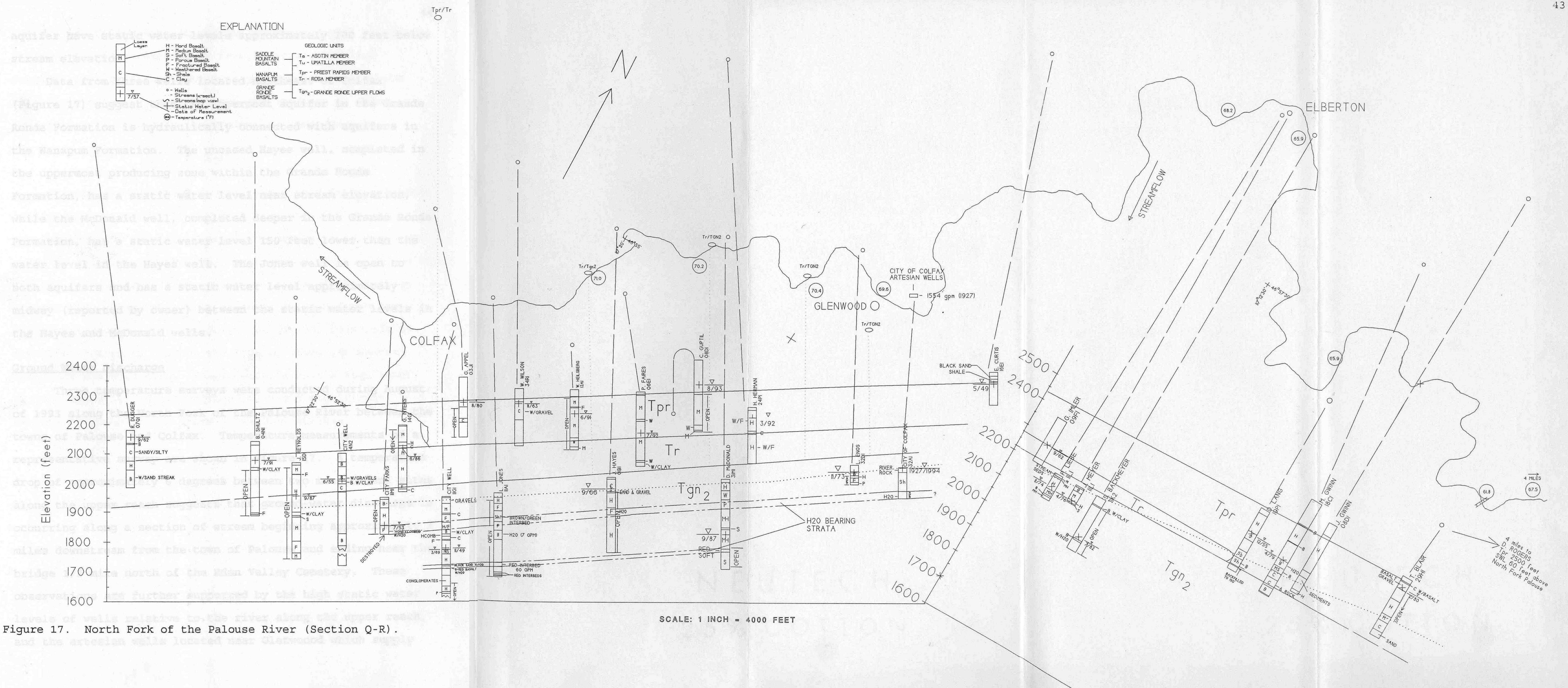


Figure 17. North Fork of the Palouse River (Section Q-R).

aquifer have static water levels approximately 200 feet below stream elevation.

Data from three wells located northeast of Colfax (Figure 17) suggest that the uppermost aquifer in the Grande Ronde Formation is hydraulically connected with aquifers in the Wanapum Formation. The uncased Hayes well, completed in the uppermost producing zone within the Grande Ronde Formation, has a static water level near stream elevation, while the McDonald well, completed deeper in the Grande Ronde Formation, has a static water level 150 feet lower than the water level in the Hayes well. The Jones well is open to both aquifers and has a static water level approximately midway (reported by owner) between the static water levels in the Hayes and McDonald wells.

Ground Water Discharge

Three temperature surveys were conducted during August of 1993 along the North Fork of the Palouse River between the towns of Palouse and Colfax. Temperature measurements of a representative survey are shown in Figure 17. A temperature drop of approximately 6 degrees between two measurement sites along the upper reach suggests that ground-water discharge is occurring along a section of stream beginning approximately 3 miles downstream from the town of Palouse and ending near the bridge 1/2 mile north of the Eden Valley Cemetery. These observations are further supported by the high static water levels of wells relative to the river along the upper reach, and the artesian wells located near Glenwoood which supply the city of Colfax with 80 percent of their water. A steady increase in water temperature from Elberton to Colfax suggests no significant amount of ground water enters the stream along the lower reach, and the increase in water temperature is caused by the ambient air temperature.

Summary

Streams reaches where significant ground-water discharge is occurring appear to be situated near the eastern margin of the Roza Member. Figure 18 shows the ground-water discharge zones in relation to the Roza/Priest Rapids contact mapped by Swanson and others in 1980. Cross-sections of the geology suggest that relatively thick unconsolidated sedimentary deposits (clays, sands, and gravels) and semi-consolidated deposits (fractured shales) are located along the eastern margin of the Roza flow. These deposits have a high water storage capacity and are believed to yield significant amounts of ground water where incised by streams.

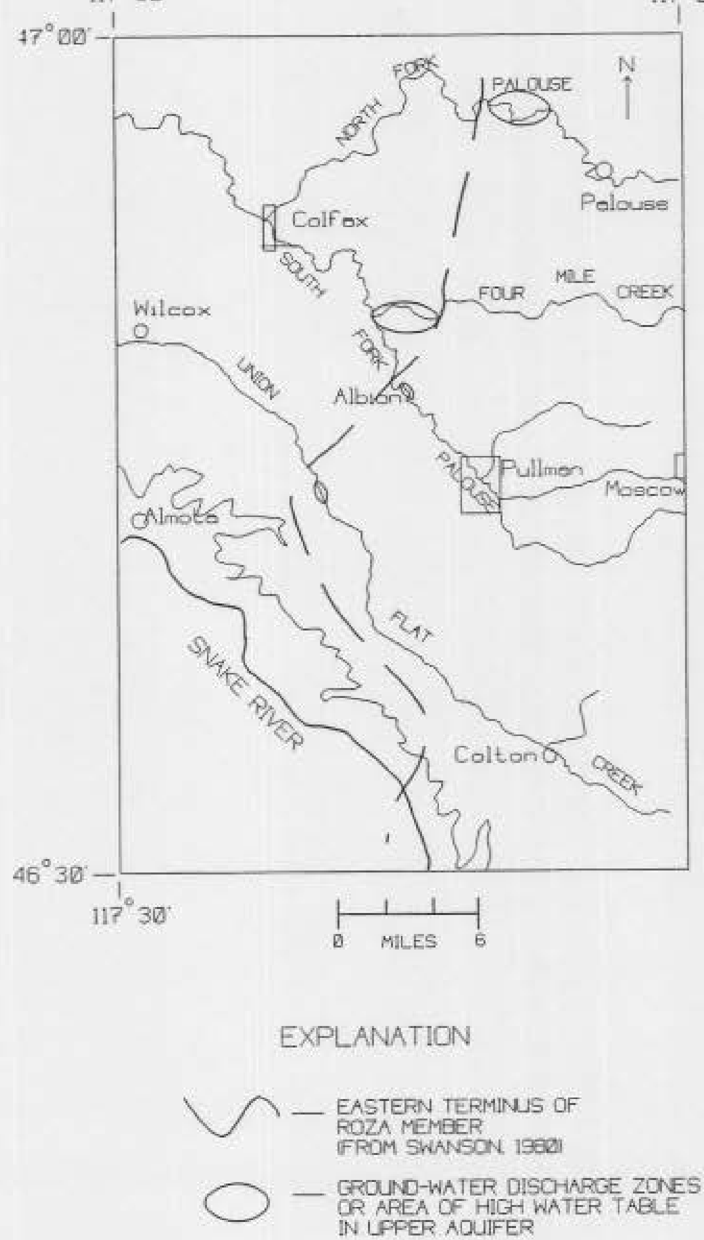


Figure 18. Roza/Priest Rapids contact (From Swanson, 1980) relative to ground-water discharge zones.

CHAPTER IV

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Results of the Pullman-Moscow area streamflow investigation suggest that several ground-water discharge areas are located within the Wanapum Formation. Significant discharge along streams are limited to the central portion of Union Flat Creek and the upper reach of the North Fork of the Palouse River. A lesser amount of ground water discharges along the lower reaches of Four Mile Creek and Paradise Creek. The South Fork of the Palouse River does not appear to be receiving significant ground water as the majority of near-stream wells have static water levels near or below stream elevations.

Specific conclusions:

(1) Streams flow primarily on the Wanapum Formation.

(2) The upper reach of the North Fork of the Palouse River and the central portion of Union Flat Creek receive significant ground-water discharge from aquifers within the Wanapum Formation. Four Mile Creek and Paradise Creek receive a lesser amount of ground-water from the Wanapum Formation.

(3) Sedimentary deposits of the Vantage unit, located along the eastern margin of the Roza flows, are a source of ground-water discharge to streams. These deposits accumulated during the hiatus between the Roza and Priest Rapid flows.

(4) Seepage along the Snake River Canyon walls is believed to be less than previously estimated, based on data obtained from The Copp well and from the static water level elevation contour map. Ground-water flow within the Grande Ronde Formation is believed to be toward the northwest away from the canyon.

(5) A structural barrier controlling ground-water flow within the Grande Ronde Formation may exist south of Union Flat Creek near Wilcox.

(6) The area west of Wilcox is believed to be a ground-water discharge area.

Recommendations

(1) Establish stream gauging stations upstream and downstream from ground-water discharge areas along Union Flat Creek and the North Fork of the Palouse River to obtain average annual increases in streamflow due to a direct connection with ground-water discharge areas.

(2) Further investigation near Union Flat Creek is needed in order to better understand the nature of the structural feature that may be restricting ground-water flow in the lower aquifer.

(3) Continue to obtain well data for the Pullman-Moscow area in order to better understand the hydrogeologic conditions within the basalts.

(4) Reassess the basin model flow boundaries and data inputs to address:

   (a) Location of ground-water discharge areas along streams.

   (b) Ground-water discharge along the Snake River Canyon.

   (c) Vantage unit sedimentary deposits along the eastern margin of the Roza flow.

   (d) An increase in ground-water outflow to the west.

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APPENDIX A

PARADISE CREEK STREAMFLOW MEASUREMENTS

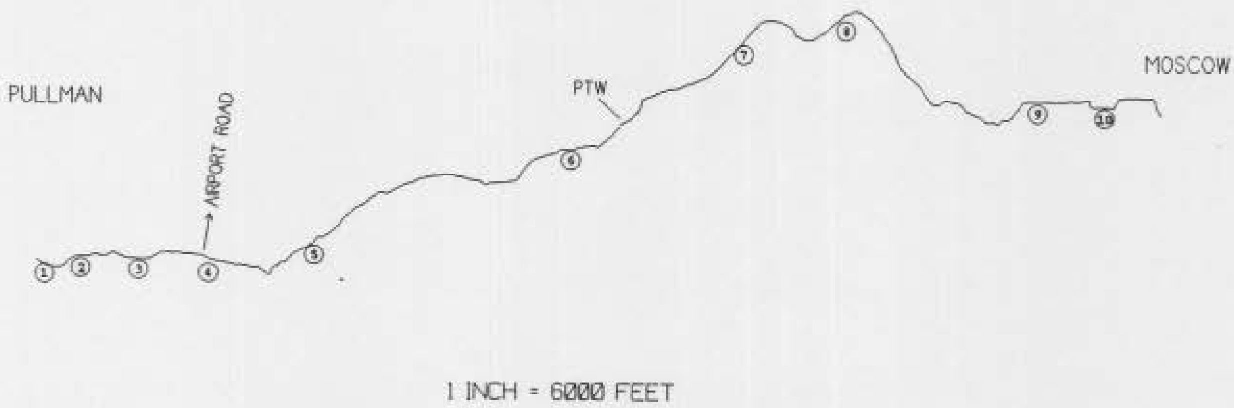

Figure 19. Paradise Creek stream measurement site locations.

	CFS	GPM	Date	Location
Station 1	3.1	1376	9/4/92	100' East of
	3.1	1397	9/18/92	S.F.Palouse
	2.8	1269	9/29/92	River
	[2.4]	1058	10/23/92	
Station 2	4.3*	1948	9/17/92	1200 feet East
	2.9	1285	9/18/92	of Sta.1
	[2.3]	1039	9/29/92	
Station 3	1.8	785	9/4/92	3400 feet East
	1.5*	660	9/22/92	of Sta.1
	2.7*	1224	10/5/92	
	[1.9]	864	10/15/92	
Station 4	2.6*	1167	9/17/92	5600 feet East
	1.7*	758	9/22/92	of Sta.1
	2.2*	980	10/5/92	
	[1.7]	752	10/14/92	
Station 5	2.0	893	10/18/92	10000 feet East
	[1.9]	845	10/18/92	of Sta.1
	2.4*	1062	10/19/92	
	4.1	1847	10/21/92	
	2.4	1057	10/22/92	
Station 6	3.7*	1680	10/11/92	18000 feet East
	5.1	2279	10/13/92	of Sta.1
	5.1	2287	10/19/82	
	[2.2]	1006	10/22/92	
Station 7	3.7	1649	10/16/92	26000 feet East
	5.1	2277	10/17/92	of Sta.1
	[1.9]	856	10/23/92	
Station 8	3.5	1581	10/10/92	29000 feet East
	4.1	1832	10/12/92	of Sta.1
	5.5	2453	10/21/92	
Station 9	[0.25]	112	10/17/92	36500 feet East
	0.22	100	10/18/92	of Sta.1
	0.31	141	10/22/92	
Station 10	[0.34]	151	9/3/92	400 feet East of Perim. Drive

[ ].. Low-flow measurements
*.... Measurements biased due to rising stream conditions.
..... Station 8 measurements were not taken during low-flow.

Table 3. Paradise Creek stream discharge measurements.

APPENDIX B

WELL DATA

Local well number: Numbered by township, range, section, and 40-acre subdivision.

Well owner: Name of owner.

Altitude of land surface (ft): Altitude of land-surface datum, in feet, with reference to sea level (National Geodetic Vertical Datum 1929).

Well depth (ft): As measured, in feet below land-surface datum, by U.S. Geological Survey personnel or other agencies or as reported by well drillers or owners.

Water-level altitude: Altitude of static water level in feet above sea level.

Depth to water below LSD: Measured or reported depth to water surface below land surface datum.

Formation Yld Water: Geohydrologic unit yielding water to well, W means Wanapum Formation, GR means Grande Ronde Formation, SM means Saddle Mountain Formation, U means unconsolidated sediments.

-- : Data not available.

Table 4. Explanation for well records.

<u>WELL RECORDS</u>

LOCATION OF WELL	WELL OWNER	LAND SURFACE ELEV. (feet)	WELL DEPTH (feet)	WATER LEVEL ALTITUDE (feet)	DEPTH TO WATER BELOW LSD (feet)	DATE OF MEAS.	FORMATION YIELDING WATER
12/45 23M1	B. MOEHRLE	2710	260	2500	210	6/86	W
12/45 23M1	J. MOEHRLE	2760	460	----		8/86	GR
12/46 06Q1	UNIONTOWN #5	2560	80	2547	13	3/76	W
12/46 06R1	K. BUCK	2560	279	2490	70	10/91	GRANITE
12/46 07G1	UNIONTOWN #4	2580	227	2548	32	3/69	GR
13/44 04J1	C. HOOD	2450	111	2430	20	8/54	W
13/44 04R1	J. BREWER	2500	225	2413	87	5/91	W
13/44 11H1	J. DAVIS	2455	--130	2444	11	5/85	W
13/44 12P1	J. DAVIS	2440	70	2433	7	5/85	W
13/44 12P2	J. DAVIS	2505	165	2443	62	5/85	W
13/44 12R1	R. DAVIS	2480	185	2402	78	5/86	W
13/44 13N1	H. NEWMAN	2650	140	2589	61	9/89	SM
13/45 03P1	P. STIENER	2620	141	2586	34	9/89	SM
13/45 10C3	J. ELLERSON	2630	145	2605	25	----	SM
13/45 15J1	E. REISENAUER	2655	242	2542	113	12/53	W
13/45 19F1	W. MEYER	2510	219	2465	45	5/54	W
13/45 19K1	J. MEYER	2500	225	2463	37	8/72	W
13/45 21D1	R. SODORFF	2600	294	2504	96	1/64	W
13/45 28B1	H. DRUFFEL	2555	93	2508	47	8/54	W
13/45 28Q1	G. MEYER	2540	90	2529	11	5/90	W
13/45 29P1	B. GROSS	2645	154	2571	74	5/89	W
13/45 34A1	TOWN OF COLTON	2530	143	2505	25	1963	GR
13/45 34D1	J. SCHULTHIES	2539	73	2524	15	6/54	W
14/43 01P1	W. DAVIS	2446	257	2386	60	1/75	W
14/43 04C1	G. GAULT	2310	370	2010	300	8/54	W
14/43 21M1	E. COPP	1700	1150	770	930	1975	GR
14/43 24M1	W. YOUNG	2430	165	2351	79	5/85	W
14/43 25N1	A. TOWNSEND	2480	250	2442	38	5/85	W
14/43 25N2	A. TOWNSEND	2420	350	2299	121	5/85	W
14/44 06B1	F. LYLE	2180	60	2160	20	3/74	W
14/44 06F1	M. KINCAID	2150	84	2098	52	6/91	W
14/44 07C1	M. STORY	2320	280	2270	50	5/75	W
14/44 09J2	KIEFER	2485	286	2275	210	5/85	W
14/44 14P1	WSU DAIRY #1	2550	600	2314	236	2/59	GR
14/44 14P2	WSU DAIRY #2	2550	432	2264	286	9/80	GR
14/44 16F1	E. BROCH	2405	160	2285	120	5/85	W

14/44 16Q1	L. SLUSSER	2325	65	2300	25	1949 (R)	W
14/44 17C1	C. HATLEY	2275	78	2236	39	2/91	W
14/44 21H1	V. HENSON	2335	54	2325	10	10/88	W
14/44 21R1	E. HATLEY	2340	150	2327	13	5/85	W
14/44 28A1	V. RUMLEY	2385	111	2341	44	5/85	W
14/44 29D1	R. STORY	2520	240	2365	155	12/73	W
14/44 29P1	R. CANE	2540	150	2470	70	1/74	SM
14/44 34C1	N. HATLEY	2455	200	2454	1	1890	W
14/45 01F1	PULL.TEST WELL	2470	982	2256	214	5/85	GR
14/45 01N1	B. PAULSON	2584	405	2327	257	11/91	GR
14/45 02E1	POE #2	2460	330	2243	217	10/91	GR
14/45 02F1	L. THONNEY	2530	35	2524	6	1953	W
14/45 02F2	L. THONNEY	2485	125	2431	54	1953	W
14/45 02R1	H. FELSTED	2620	394	2266	354	11/74	GR
14/45 03H1	R. THONNEY	2460	238	2305	155	1940	GR
14/45 03H3	WWP	2460	259	2261	199	5/85	GR
14/45 03K1	ROLLING HILLS	2455	230	2288	167	6/75	GR
14/45 03P1	S. JORSTAD	2460	---	2440	20	5/85	W
14/45 04D1	WSU #6	2535	702	2268	267	5/85	GR
14/45 04N1	WSU	2390	95	DRY		1974	W
14/45 04P1	POE #1	2420	191	2268	152	8/90	GR
14/45 04Q1	C. CARBON	2425	155	2385	40	5/85	W
14/45 04Q1	C. COLE	2560	205	2464	96	1953	W
14/45 04Q2	WSU	2410	65	2399	11	1932	W
14/45 05D3	PULLMAN #3	2340	167	2271	69	5/85	GR
14/45 05F1	WSU OBS.1	2365	144	2271	94	5/85	GR
14/45 05F4	WSU #4	2364	275	2269	95	5/85	GR
14/45 05F5	WSU #7	2415	1824	2261	154	8/87	GR
14/45 07G1	O. LEE	2508	270	2358	150	10/54	W
14/45 08A2	M. WISE	2385	105	2300	85	6/75	W
14/45 08E1	PULLMAN #5	2447	712	2271	176	5/85	GR
14/45 08J1	J. ASKINS	2420	85	2365	55	1953	W
14/45 08J2	J. ASKINS	2445	164	2311	134	6/75	GR
14/45 08J4	J. ASKINS	2420	223	2272	148	5/85	GR
14/45 08L1	CITY CEMETARY	2580	355	2480	100	1932?	GR
14/45 09E1	M. WISE	2415	67	2406	9	5/85	W
14/45 09L2	D. BLENZ	2560	367	2265	295	6/90	GR
14/45 15B1	G. LEONARD	2610	213	2462	148	5/85	W
14/45 15B2	G. LEONARD	2605	330	2296	309	6/75	W
14/45 15R1	C. DRUFFEL	2440	208	2360	80	11/90	W
14/45 16D1	B. BOYD	2410	122	2370	40	7/86	W
14/45 16E1	W. STRATTON	2400	110	DRY		3/73	W
14/45 16E2	W. STRATTON	2455	230	2281	174	6/75	GR
14/45 16G1	WSU SPILLMAN	2480	400	2265	215	5/85	GR
14/45 16Q1	B. WAGNER	2460	308	2230	230	9/79	GR
14/45 16R1	G. WISE	2418	195	2275	143	5/85	W
14/45 16R2	J. LONG	2420	273	2275	145	7/68	GR
14/45 17A1	H. JACOBSON	2420	175	2293	127	6/75	GR
14/45 20B1	M. JACOBSON	2544	63	2534	10	8/84	W
14/45 21D1	W. BOYD	2480	265	2300	180	3/73	GR
14/45 21D2	W. BOYD	2480	280	2402	78	8/88	GR
14/45 22P1	A. FAIRBANKS	2460	200	2425	35	5/90	W
14/45 22P2	A. FAIRBANKS	2464	250	2278	186	5/85	GR
14/45 23A1	K. DRUFFEL	2480	SPRING				W
14/45 23A2	K. DRUFFEL	2490	159	2479	11	5/92	W
14/45 23R1	R. MEYER	2520	80	2481	39	5/85	W
14/45 24F1	---	2505	---	2491	14	5/85	W
14/45 24H1	A. HOOD	2500	202	2482	18	5/75	W
14/46 05K1	PALOUSE PROD.	2600	338	2418	182	1/77	GR
14/46 05L1	PALOUSE PROD.	2600	338	2418	182	1/77	W,GR
14/46 07N2	H. SHRIVER	2575	242	2535	40	1954	W
14/46 07Q1	J. ROBERTSON	2600	228	2574	26	10/72	W
14/46 08A1	G. WILLIAMS	2750	380	2564	186	8/87	W
14/46 08K1	A. ANDERSON	2620	125	2585	35	1947 (R)	W
14/46 17B1	H. PETERSON	2530	120	2465	65	1945 (R)	W
14/46 19F1	L. BROWN	2485	180	2473	12	5/85	W
14/46 19M1	E. HAYNES	2480	80	2470	10	1953	W
14/46 29L1	C. STROHM	2555	278	----			W
15/42 02F1	B. FOREYT	1820	136	1770	50	8/84	W
15/42 11C1	D. HEILSBERG	1820	275	1778	42	3/88	GR
15/42 11G1	J. HEILSBERG	1875	146	1802	73	? (R)	W
15/42 11G2	J. HEILSBERG	1880	236	1744	136	1922 (R)	GR
15/42 27H1	A. STEIGER	1900	310	1695	205	10/86	W,GR?
15/43 05N1	M. KAMMERZELL	1890	90	1858	32	7/74	W
15/43 06R1	E. BROWLEIT	1870	186	1765	105	8/54 (R)	W,GR
15/43 09P1	G. GILCHRIST	1935	207	1769	166	1975	GR
15/43 15R1	G. GILCHRIST	2100	305	1881	219	3/88	W

15/43 16B1	G. GILCHRIST	2000	138	1919	81	1975	W
15/43 16B2	G. GILCHRIST	2000	155	1946	54	10/89	W
15/43 17K1	H. BROWLEIT	2160	144	2103	57	9/78	W
15/43 21C1	M. AESCHLIMAN	2350	380	2100	250	7/91	W
15/43 23F1	WHITMAN COUNTY	2010	106	1980	30	6/86	W
15/43 23K1	WHITMAN COUNTY	2015	150	----		1/76	W
15/43 25C1	C. LONG	2080	30	2070	10	9/89	W
15/43 26L1	B. DAVIS	2395	189	2363	32	1951	SM
15/44 01A1	B. COLLINS	2360	230	2273	87	8/93	GR
15/44 14D1	TOWN OF ALBION	2290	235	2277	13	11/53	GRANITE
15/44 15G2	ALBION #1	2390	290	2210	180	5/85	GRANITE
15/44 24D1	J. MORRISON	2380	35	2372	8	5/85	W
15/44 24E1	J. MORRISON	2375	135	2255	120	5/85	W
15/44 24F1	J. MORRISON	2390	165	2378	12	5/85	W
15/44 26L1	M. HARLOW	2395	160	2269	126	5/85	W
15/44 35E1	F. BRYANT	2410	300	2324	86	6/51	W,GR
15/44 35E1	V. MICHAELSON	2412	300	2282	130	5/85	W,GR
15/45 06H1	R. PARVIN	2425	146	2365	60	11/53	W
15/45 14E1	D. McGREEVY	2530	324	2295	235	6/90	GR
15/45 14Q1	J. McCONAGHY	2518	285	2285	233	6/75	GR
15/45 15R1	---	2510	51	2480	30	1953	W
15/45 20P1	WHELAN GRANGE	2490	14	2485	5	1953	L
15/45 21H1	C. BOYD	2520	326	2290	230	6/75	GR
15/45 21H2	C. BOYD	2485	324	2285	200	6/75	GR
15/45 22M1	T. PRITCHARD	2480	20	2473	7	1953	W
15/45 23B1	M. STIREWALT	2518	50	2487	31	1953	W
15/45 24C1	M. STIREWALT	2540	350	2480	60	5/85	W,GR
15/45 24C1	J. GREY	2535	20	2518	17	10/53	W
15/45 24C1	J. GRAY	2535	20	2518	17	1953	W
15/45 25A1	M. BOYD	2645	137	2533	112	10/53	W
15/45 25A2	M. BOYD	2650	215	2536	114	5/85	W
15/45 28J1	D. BURNHAM	2540	162	2463	77	11/53	W
15/45 28J1	N. CARSON	2540	162	2463	77	11/53	W
15/45 29C1	DUMAS CORP.	2470	255	2407	63	8/87	GR
15/45 29G1	McKIERNAN	2458	400	2287	171	1979 (R)	GR
15/45 29G1	McGREGOR	2430	220	2313	117	5/63	GR
15/45 29G2	McKIERNAN	2458	247	2288	170	6/75	GR
15/45 29P1	PIERCE RANCH	2445	140	2287	158	6/75	GR
15/45 30G4	USDA AG. EXP.	2520	371	2271	249	5/85	GR
15/45 31J1	E. METZGAR	2520	117	2512	8	1953 (R)	W,U
15/45 31M1	WSU	2350	172	2291	59	6/75	GR
15/45 32C1	O. TURNER	2400	105	2340	60	1953	W
15/45 32C2	PULLMAN #6	2430	518	2278	152	5/85	GR
15/45 32G1	D. BERRY	2380	26	2369	11	1953	W
15/45 32N1	PULLMAN #2	2350	231	2288	62	6/75	GR
15/45 32N2	PULLMAN #4	2356	954	2283	73	5/85	GR
15/45 33J1	WSU	2615	438	2344	271	1933	W
15/45 34L2	WSU #5	2510	396	2272	238	5/85	GR
15/46 19J1	J. O'DONNELL	2575	59	2559	16	10/53	W
15/46 20K1	N. CARSON	2590	15	2583	7	1953	W
15/46 20N1	H. NELSON	2570	?	2563	7	5/85	U?
15/46 20P1	N. CARSON	2590	250	2488	102	1953	W
15/46 30D1	W. BOYD	2561	32	2541	20	6/36	W
16/43 01B1	J. HAYES	2038	257	1995	43	9/66	W
16/43 03J1	G. APPEL	2370	102	2308	62	----	W
16/43 08A1	B. SHULTZ	2150	255	2083	67	7/91	W
16/43 11G1	COLFAX	1960	600	1780	180	11/49	GR
16/43 11M1	COLFAX	1975	125	1875	100	1953	GR
16/43 11M1	L. JONES	1975	285	----			GR
16/43 12H1	W. HEILBERG	2350	205	2268	82	6/91	W
16/43 12N1	C. CLAYPOOL						
16/43 14G1	G. MYERS	2215	228	2135	80	6/86	W
16/43 14N2	COLFAX	2110	723	2020	90	7/55	GR
16/43 15D1	J. REYNOLDS	2090	330	1972	118	9/87	GR
16/43 25D1	D. NELSON	2130	180	2094	36	11/88	W
16/43 25P1	L. CHESTNUT	2220	259	2111	109	10/92	W
16/43 25??	C. HALL		380		0	5/93	W?,GR?
16/44 06??	P. FAIRES		255				
16/44 08D1	C. GUPTILL	2430	239	2346	84	8/93	W
16/44 18D1	M. BROOKS		255				
16/44 22G1	A. SCHAUBLE	2430	500	DRY		8/80	W,GR
16/44 25H1	G. CONKLIN	2360	263	2350	10	5/87	W
16/44 25H2	R. McINTOSH	2320	235	2238	82	9/84	GR?
16/44 26J1	J. McINTOSH	2480					W?
16/44 29F1	R. COCKING	2335	500	1935	400	----	GR
16/44 36G1?	J. PARVIN	2400?	280	2316	84	8/93	GR
16/45 27Q3	L. THOMPSON	2460	?	2447	13	5/85	W

16/45 28H1	J. REDFIELD	2373	?	2355	18	5/85	W
16/45 29J1	D. HARLOW	2430	?	2373	57	5/85	W
16/45 30Q1	J. KINZER	2342	99	2320	22	1973 ?	W
16/45 30Q2	J. KINZER	2342	161	2288	54	9/91	GR?
16/45 30R2	J. KINZER	2370	120	2300	70	1973 ?	W?
16/45 33J1	S. CLARK	2470	305	2287	183	3/92	GR
17/43 24N1	H. HERMAN	2280	188	2245	35	3/92	W
17/43 30F1	J. HENENCAMP	1870	207	1705	165	3/79	
17/43 30G1	D. MORGAN	1875	90	1800	75	5/79	
17/43 34R1	W. WILSON				0		
17/44 11K1	J. MEYER	2200	68	2149	51	4/76	W
17/44 11K2	S. BACKMEYER	2205	200	2055	150	7/82	GR
17/44 11L1	P. LIEBE	2200	88	2158	42	11/74	W
17/44 29P1	L. ENOS	2075	70	2048	27	11/73	W
17/44 31M1	D. McDONALD	2010	305	1820	190	9/87	GR
17/44 32A1	COLFAX	2070	105	2070	0	1927	W
17/45 08D1	J. GWINN	2530	290				W
17/45 18C1	M. GWINN	2570	370	2335	235	4/79	W
17/45 19P1	D. LANGE	2460	237	2362	98	12/55	W
17/45 29H1	T. BLAIR	2500	220	2470	30	2/80	W
39/06 12DBA1	MOSCOW #9	2538	1252	2251	287	5/85	GR
40/05 30CA	F. WARD	2638	?	2513	125	5/85	W
40/06 36AD	A. CARSON	2610	135	2610	0	5/85	W