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Hydrogeologic Framework and Selected Components of the Groundwater Budget for the Upper Umatilla River Basin, Oregon

Scientific Investigations Report 2017–5020

U.S. Department of the Interior
U.S. Geological Survey

Cover: View of upper Umatilla River Basin looking north into Buckaroo Canyon, Oregon.
Photograph by Terrence Conlon, U.S. Geological Survey, October 15, 2004.

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By Nora B. Herrera, Kate Ely, Smita Mehta, Adam J. Stonewall, John C. Risley, Stephen R. Hinkle, and Terrence D. Conlon

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RYAN K. ZINKE, Secretary

U.S. Geological Survey
William H. Werkheiser, Acting Director

U.S. Geological Survey, Reston, Virginia: 2017

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Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	4,047	square meter (m^2)
square foot (ft^2)	0.09290	square meter (m^2)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
gallon (gal)	0.003785	cubic meter (m^3)
cubic foot (ft^3)	0.02832	cubic meter (m^3)
acre-foot (acre-ft)	1,233	cubic meter (m^3)
acre-foot per year (acre-ft/yr)	1,233	cubic meter per year (m^3/yr)
foot per second (ft/s)	0.3048	meter per second (m/s)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
gallon per day (gal/d)	0.003785	cubic meter per day (m^3/d)
	Flow Rate	
inch per year (in/yr)	25.4	millimeter per year (mm/yr)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
	Hydraulic conductivity	
foot per second (ft/s)	0.3048	meter per second (m/s)
foot per day (ft/d)	0.3048	meter per day (m/d)
	Hydraulic gradient	
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
	Transmissivity	
foot squared per day (ft^2/d)	0.09290	meter squared per day (m^2/d)

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$°C = (°F - 32)/1.8$$

Datums

Vertical coordinate information is referenced to North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced North American Datum of 1983 (NAD 83).

Elevation, as used in this report, refers to distance above the vertical datum.

Supplemental Information

Hydraulic conductivity: Hydraulic conductivity can be expressed as cubic foot per second per square foot [(ft^3/s)/ft^2]. In this report, foot per second (ft/s), is used for convenience.

Transmissivity: The standard unit for transmissivity is cubic foot per day per square foot times foot of aquifer thickness [(ft^3/d)/ft^2]ft. In this report, the mathematically reduced form, foot squared per day (ft^2/d), is used for convenience.

Hydrogeologic Framework and Selected Components of the Groundwater Budget for the Upper Umatilla River Basin, Oregon

By Nora B. Herrera[1], Kate Ely[2], Smita Mehta[2], Adam J. Stonewall[1], John C. Risley[1], Stephen R. Hinkle[1], and Terrence D. Conlon[1]

Executive Summary

This report presents a summary of the hydrogeology of the upper Umatilla River Basin, Oregon, based on characterization of the hydrogeologic framework, horizontal and vertical directions of groundwater flow, trends in groundwater levels, and components of the groundwater budget. The conceptual model of the groundwater flow system integrates available data and information on the groundwater resources of the upper Umatilla River Basin and provides insights regarding key hydrologic processes, such as the interaction between the groundwater and surface water systems and the hydrologic budget.

The conceptual groundwater model developed for the study area divides the groundwater flow system into five hydrogeologic units: a sedimentary unit, three Columbia River basalt units, and a basement rock unit. The sedimentary unit, which is not widely used as a source of groundwater in the upper basin, is present primarily in the lowlands and consists of conglomerate, loess, silt and sand deposits, and recent alluvium. The Columbia River Basalt Group is a series of Miocene flood basalts that are present throughout the study area. The basalt is uplifted in the southeastern half of the study area, and either underlies the sedimentary unit, or is exposed at the surface. The interflow zones of the flood basalts are the primary aquifers in the study area. Beneath the flood basalts are basement rocks composed of Paleogene to Pre-Tertiary sedimentary, volcanic, igneous, and metamorphic rocks that are not used as a source of groundwater in the upper Umatilla River Basin.

The major components of the groundwater budget in the upper Umatilla River Basin are (1) groundwater recharge, (2) groundwater discharge to surface water and wells, (3) subsurface flow into and out of the basin, and (4) changes in groundwater storage.

Recharge from precipitation occurs primarily in the upland areas of the Blue Mountains. Mean annual recharge from infiltration of precipitation for the upper Umatilla River Basin during 1951–2010 is about 9.6 inches per year (in/yr). Annual recharge from precipitation for water year 2010 ranged from 3 in. in the lowland area to about 30 in. in the Blue Mountains. Using Kahle and others (2011) data and methods from the Columbia Plateau regional model, average annual recharge from irrigation is estimated to be about 2.2 in/yr for the 13 square miles of irrigated land in the upper Umatilla River Basin.

Groundwater discharges to streams throughout the year and is a large component of annual streamflow in the upper Umatilla River Basin. Upward vertical hydraulic gradients near the Umatilla River indicate the potential for groundwater discharge. Groundwater discharge to the Umatilla River generally occurs in the upper part of the basin, upstream from the main stem.

Groundwater development in the upper Umatilla River Basin began sometime after 1950 (Davies-Smith and others, 1988; Gonthier and Bolke, 1991). By water year 2010, groundwater use in the upper Umatilla River Basin was approximately 11,214 acre-feet (acre-ft). Total groundwater withdrawals for the study area were estimated at 7,575 acre-ft for irrigation, 3,173 acre-ft for municipal use, and 466 acre-ft for domestic use.

Total groundwater flow into or from the study area depends locally on geology and hydraulic head distribution. Estimates of subsurface flow were calculated using the U.S. Geological Survey Columbia Plateau regional groundwater flow model. Net flux values range from 25,000 to 27,700 acre-ft per year and indicate that groundwater is moving out of the upper Umatilla River Basin into the lower Umatilla River Basin.

Water level changes depend on storage changes within an aquifer, and storage changes depend on the storage properties of the aquifer, as well as recharge to or discharge from the aquifer. Groundwater level data in the upper Umatilla River Basin are mostly available from wells in Columbia River basalt units, which indicate areas of long-term water level

[1]U.S. Geological Survey.

[2]Confederated Tribes of the Umatilla Indian Reservation.

declines in the Grande Ronde basalt unit near Pendleton and Athena, Oregon. Groundwater levels in the Wanapum basalt unit do not show long-term declines in the upper Umatilla River Basin. Because of pumping, some areas in the upper Umatilla River Basin have shown a decrease, or reversal, in the upward vertical head gradient.

Key data needs are improvement of the spatial and temporal distribution of water-level data collection and continued monitoring of streamflow gaging sites. Additionally, refinement of recharge estimates would enhance understanding of the processes that provide the groundwater resources in the upper Umatilla River Basin.

Introduction

The Confederated Tribes of the Umatilla Indian Reservation (CTUIR) rely on sustainable supplies of fresh water for the development and sustenance of their economy and the preservation of their cultural heritage. Groundwater is an important component of CTUIR water resources. Groundwater resource development in and around the Umatilla Indian Reservation (fig. 1) has resulted in groundwater-level declines near the reservation (Burns and others, 2012), and there is concern that groundwater pumping may be affecting nearby streams. Effective management of groundwater resources in the Umatilla Indian Reservation and the upper Umatilla River Basin requires the development of a conceptual understanding of the hydrologic system.

Study Objective and Report Purpose and Scope

The objective of this study was to synthesize available geologic, hydrologic, and land- and water-use data to develop a conceptual groundwater model of the upper Umatilla River Basin. This report describes results of a collaborative effort of the U.S. Geological Survey (USGS) and the CTUIR to compile and interpret existing data, characterize the hydrogeologic framework, characterize the hydraulic head distribution, and estimate the groundwater budget. This effort relies largely on data and information that the CTUIR have collected from wells, seepage runs, spring surveys, and assessments of water use on or near the reservation. Additional data from USGS studies in the Columbia Plateau help define aquifer geometries and hydraulic characteristics, and quantify recharge, evapotranspiration, and water use. Evaluated information includes geologic maps and stratigraphic sections, groundwater level data, borehole geophysical logs, stream seepage data, baseflow estimates, and aquifer tests. Information from published and unpublished sources that describe the hydrology of the area in and around the reservation is also evaluated. Analysis focused on the period between 1950 and 2012, using either mean annual estimated values for part or all of this period or analyzing data from 2010. Water year 2010 was selected because it was a time of intensive data collection and analysis of water use.

Location and General Features

The 913 mi^2 study area encompasses the upper Umatilla River Basin upstream of Birch Creek, which joins the Umatilla River about 5 mi west of Pendleton. The study area lies on the northwestern flank of the Blue Mountains and the southeastern part of the Yakima Fold Belt in eastern Oregon. The western half of the study area is a gently northwest-sloping, slightly dissected plateau of semi-arid land between 1,000 and 1,500 ft elevation. Dryland and irrigated farming as well as ranching occur in this area. The eastern half of the study area lies in the Blue Mountains, where streams deeply dissect the northwest and west sloping land at elevations ranging between 1,500 and 5,000 ft. In the high-elevation areas, the land is covered in a mix of forest and grasslands (fig. 1).

Major tributaries to the upper Umatilla River include Wildhorse, McKay, and Meacham Creeks. McKay and Meacham Creeks are incised and have narrow floodplains. McKay Reservoir, impounded in 1926, lies west of the Umatilla Indian Reservation and south of Pendleton. Water releases from the reservoir augment flow in the Umatilla River for irrigation and fish habitat.

In Pendleton (elevation 1,490 ft), mean monthly temperatures for 1928–2013 ranged from a minimum of 33 °F for January to a maximum of 73 °F for July (Oregon Climate Service, 2014). In Meacham (elevation 4,060 ft), mean monthly temperatures for 1948–2013 ranged from a minimum of 26 °F for January to a maximum of 63 °F for July. Annual water year precipitation ranges from 12.3 in. near Pendleton to about 33.4 in. near Meacham (fig. 2) to 55 in. in the eastern, upland part of the study area (1951–2010 mean, PRISM Climate Group, 2014). Annual precipitation varies considerably over time. Mean water year precipitation and the cumulative departure from mean water year precipitation for Pendleton for 1928–2014 are shown in figure 2. Several prolonged periods of less than average precipitation occurred from 1928 to 1939, 1960 to 1968, and 1987 to 1992.

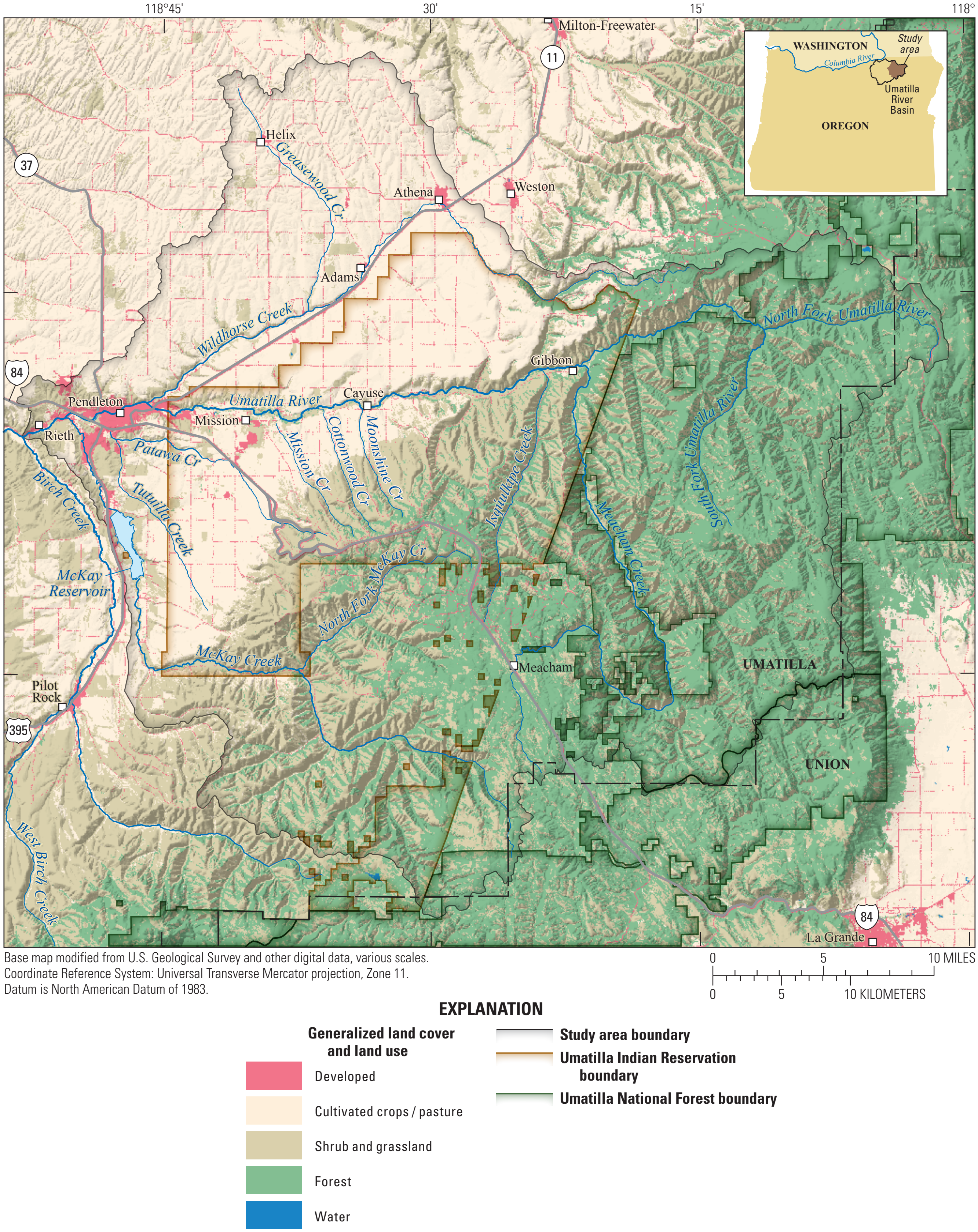


Figure 1. Location of the study area, generalized land cover or land use, and major geographic and cultural features, upper Umatilla River Basin, Oregon.

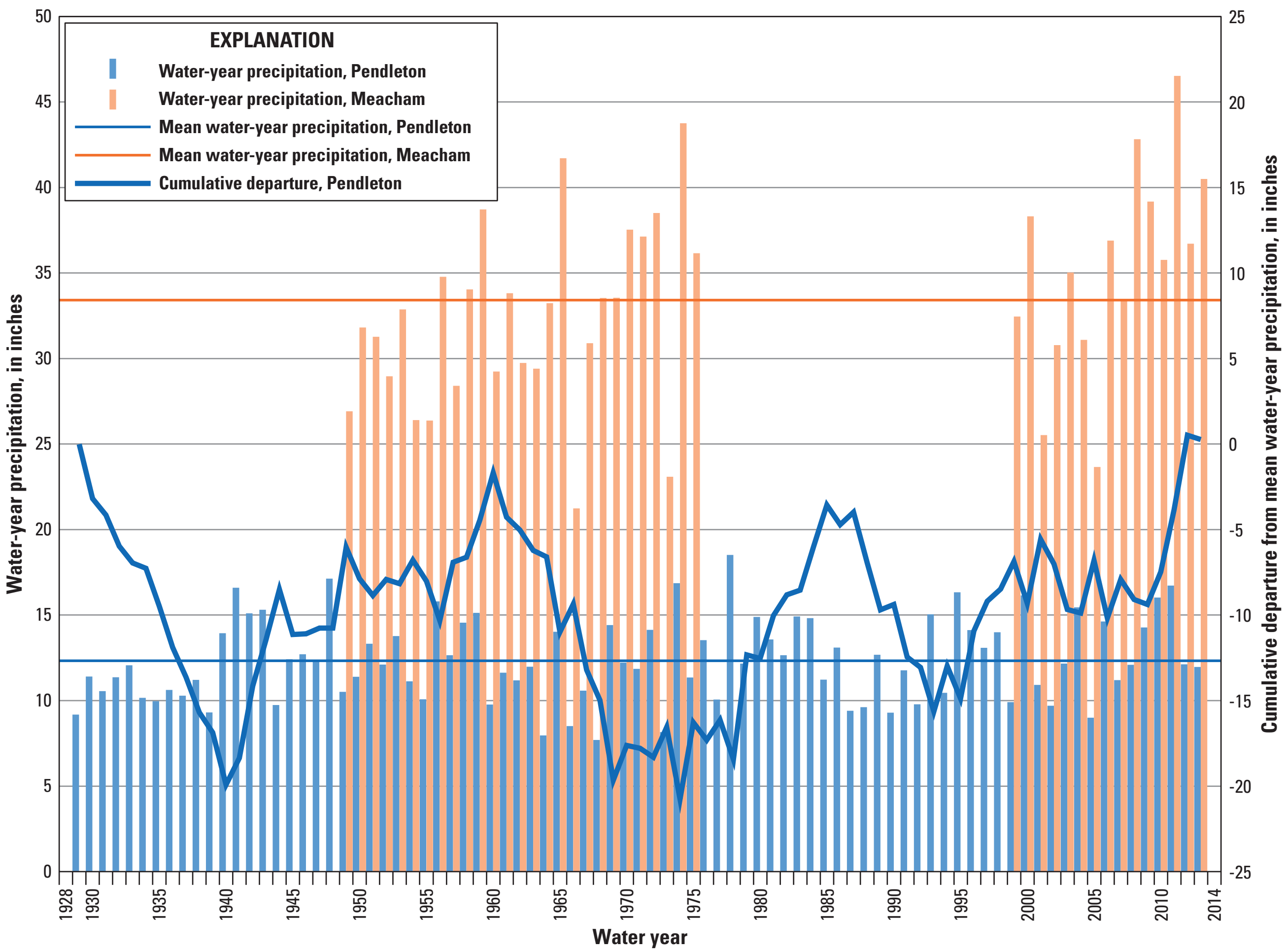


Figure 2. Mean water year precipitation for Pendleton (1928–2014) and Meacham (1949–1975, and 1998–2014), in the upper Umatilla River Basin, Oregon. (Data from Oregon Climate Service, 2014.)

Approach

This study is based largely on existing information. The hydrogeologic framework defined in this study was based on analyses of geologic maps, geochemical data, and geophysical logs. The regional framework developed for the Columbia Plateau Regional Aquifer System (Burns and others, 2011; Kahle and others, 2011) provided the elevation of the basement rock for most areas in the study area and additional geologic information. Exposed basement rock and well data from one well allowed refinement of basement rock elevation in the McKay Creek drainage basin. The CTUIR created a database of wells containing information on lithology, which was used to define the extent and thickness of hydrologic units and flow boundaries.

The groundwater budget was developed using published recharge estimation techniques, streamflow analysis, seepage runs, water-rights information, pumping data, and regional groundwater model results. Analysis of groundwater levels, flow directions, and water-level trends was conducted using water-level measurements collected by the CTUIR; the Oregon Water Resources Department (OWRD); Adams, Athena, Pendleton, and Pilot Rock municipalities; and one homeowner (appendix A). Time-series data from 56 wells measured by CTUIR were also used.

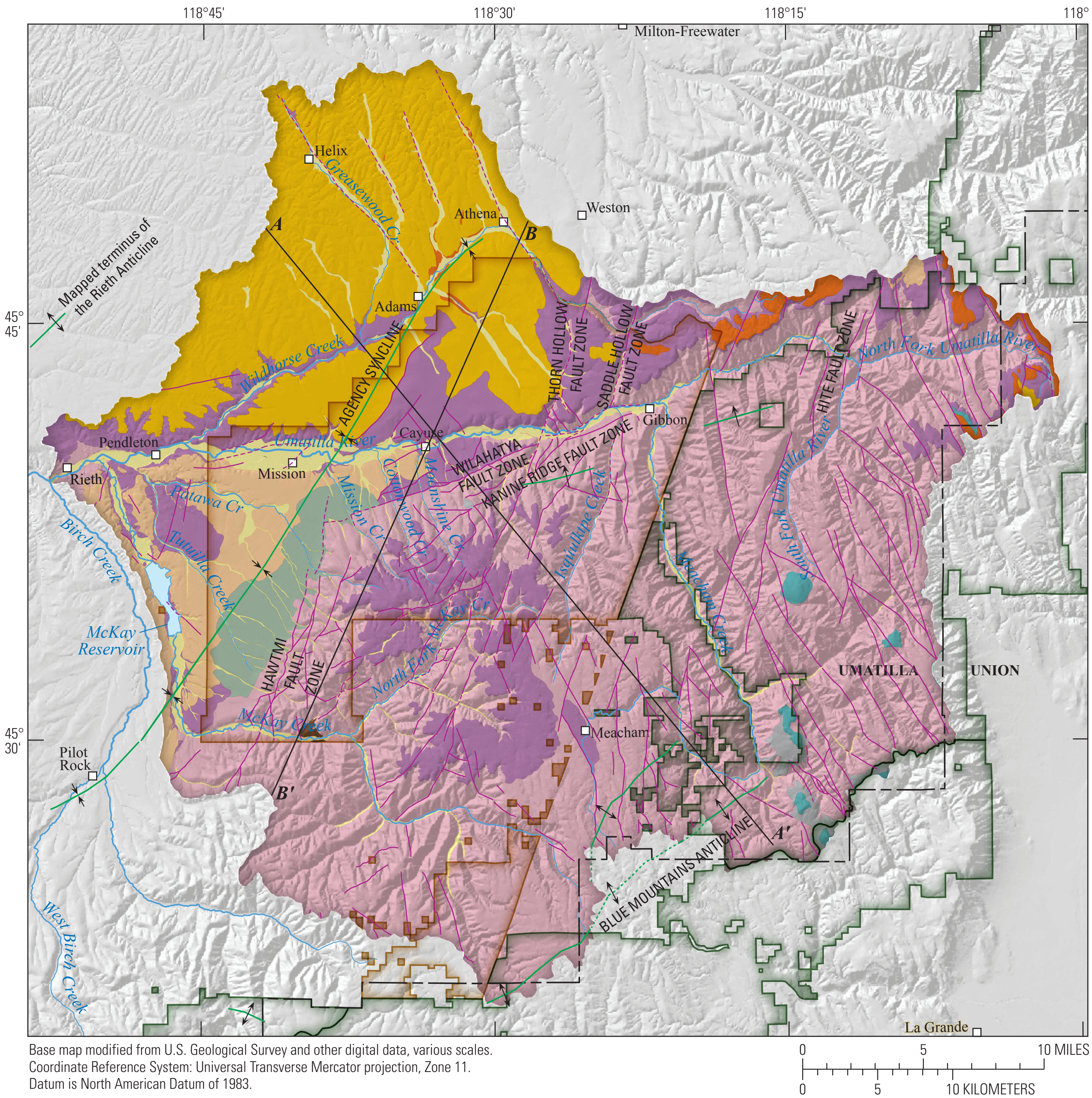
Hydrogeologic Framework

The upper Umatilla River Basin lies within the Columbia River flood-basalt province and is underlain by a thick sequence of Miocene-age volcanic flood basalts that collectively make up the Columbia River Basalt Group (CRBG) (figs. 3 and 4*A*–*B*). In parts of the upper Umatilla River Basin, the CRBG lava flows are overlain by Miocene to Holocene sedimentary deposits of conglomerate, loess, silt, sand, and recent alluvium. The CRBG lava flows are underlain by Eocene to Oligocene volcanic rocks, and Paleocene to Eocene arkosic sandstones assigned to the Herren Formation (generally included as part of the Clarno Formation), and pre-Tertiary amphibolite schist and gneiss, intrusive norite and quartz diorite (Hogenson, 1964; Newcomb, 1970; Walker, 1973; Gonthier, 1999; Ferns and others, 2001; Ferns, 2006a, 2006b, 2006c, 2006d, 2006e).

Folds and faults are common in the upper Umatilla River Basin and can result in flow boundaries and compartmentalization of aquifers in the CRBG (Newcomb, 1959; Porcello and others, 2009; Snyder and Haynes, 2010). The CRBG was considerably deformed by late-Miocene or early-Pliocene fault movement, which continued until middle to late Pleistocene (Hogenson, 1964). Major structural features in the study area are the northeastward-trending Blue Mountains anticline, Agency syncline, and Rieth anticline. The northwestern limb of the Blue Mountain anticline forms a gently dipping slope from the Blue Mountain uplands to the lowland areas. Further uplift of the Blue Mountain anticline increased basalt deformation (Hogenson, 1964). Other notable structures pertaining to this study include the Kanine Ridge, Thorn Hollow, Wilahatya, and Hawtmi fault zones at the foot of the Blue Mountain slope (Ferns, 2006a, 2006b, 2006c, 2006d, 2006e) (fig. 3). Post-Miocene sedimentary materials in the upper basin show minor evidence of secondary structure (Kienle and others, 1979; Personius and Lidke, 2003).

The conceptual groundwater model developed for the study area divides the groundwater flow system into five hydrogeologic units: the sedimentary unit, three Columbia River basalt units, and the basement rock unit. Because the basement rocks are not considered a primary source of groundwater in the study area, they will not be discussed further in this report.

Hydrogeologic sections and maps of extent, thickness, and elevation of the upper surface of the sedimentary unit and Saddle Mountains basalt unit, Wanapum basalt unit, and Grande Ronde basalt unit (figs. 4–6) are based on analysis of well data, previous geologic framework mapping by Kahle and others (2011), and on geologic maps of the study area (Jenks and others, 2005; Ferns, 2006a, 2006b, 2006c, 2006d, 2006e; Madin and Geitgey, 2007; and Mark Ferns and others, Oregon Department of Geology and Mineral Industries, written commun., 2008). The thicknesses of the sedimentary and basalt units are constrained by lithologic descriptions from OWRD water-well reports and from Hogenson (1964) (table 1). Geochemistry of cuttings from nine wells (Ferns and others, 2006; Madin and Geitgey, 2007; and CTUIR, unpub. data, 2010) (table 2), surface-rock samples from nine field-mapped stratigraphic sections defined by Ferns (2006a, 2006b, 2006c, 2006d, 2006e) and Ferns and Ely (2006) (table 3), and geophysical logs from five wells (CTUIR [2007] and this study) (table 4) (fig. 7**)** were analyzed to refine and correlate subsurface geometry in the upper Umatilla River Basin (figs.4–7). Hydrogeologic sections developed from the data were used to generate structure contours and isopachs of the sediment, Saddle Mountain, Wanapum, and Grande Ronde basalt units. The data were interpolated using trend and deterministic approaches to produce contours that represent the range in value and local and regional variability observed in the units. Computer generated contours were compared against hydrogeologic unit elevation points and simplified manually to remove irregularities and retain the character of the contours where possible. Simplified contours were then converted to rasters for each hydrogeologic unit. Limited well data in the upland region of the study area resulted in greater uncertainty in unit thicknesses and elevations in Blue Mountains area (fig. 7).



Base map modified from U.S. Geological Survey and other digital data, various scales.
Coordinate Reference System: Universal Transverse Mercator projection, Zone 11.
Datum is North American Datum of 1983.

Figure 3. Surficial distribution of generalized geologic units in the upper Umatilla River Basin, Oregon.

EXPLANATION

Generalized geologic units—shown in figure 3*A*	Generalized hydrogeologic units—shown in figure 4	Period	Epoch	Upper Umatilla River Basin simplified geologic map unit
Qal	Sediment	Quaternary	Pleistocene to Holocene	Alluvium and terrace deposits
Qf				Alluvial fan deposits
Qls				Landslide deposits
QTs		Quaternary-Tertiary	Late Miocene to Pleistocene	Loess, silt, and sand deposits
Tms		Tertiary	Middle Miocene to Pliocene	Sedimentary rocks, McKay Formation
Tpv	Grande Ronde basalt			Volcanic rocks, Powder River Volcanic Field
Tsu	Saddle Mountains basalt		Middle to Late Miocene	Basalt, Saddle Mountains Basalt Formation
Twu	Wanapum basalt		Middle Miocene	Basalt, Wanapum Basalt Formation
Tgu	Grande Ronde basalt		Early to Middle Miocene	Basalt, Grande Ronde Formation
Tjda	Igneous and metamorphic rocks (basement)	Tertiary and Pre-Tertiary	Oligocene and older	Undifferentiated sedimentary, volcanic, igneous, and metamorphic rocks

- *A* — *A′* **Trace of hydrogeologic section line**
- **Fault, accurately located**
- **Fault, concealed**
- **Anticline, accurately located**
- **Anticline, approximately located**
- **Monocline, accurately located**
- **Syncline, accurately located**
- **Study area boundary**
- **Umatilla Indian Reservation boundary**
- **Umatilla National Forest boundary**

Figure 3.—Continued

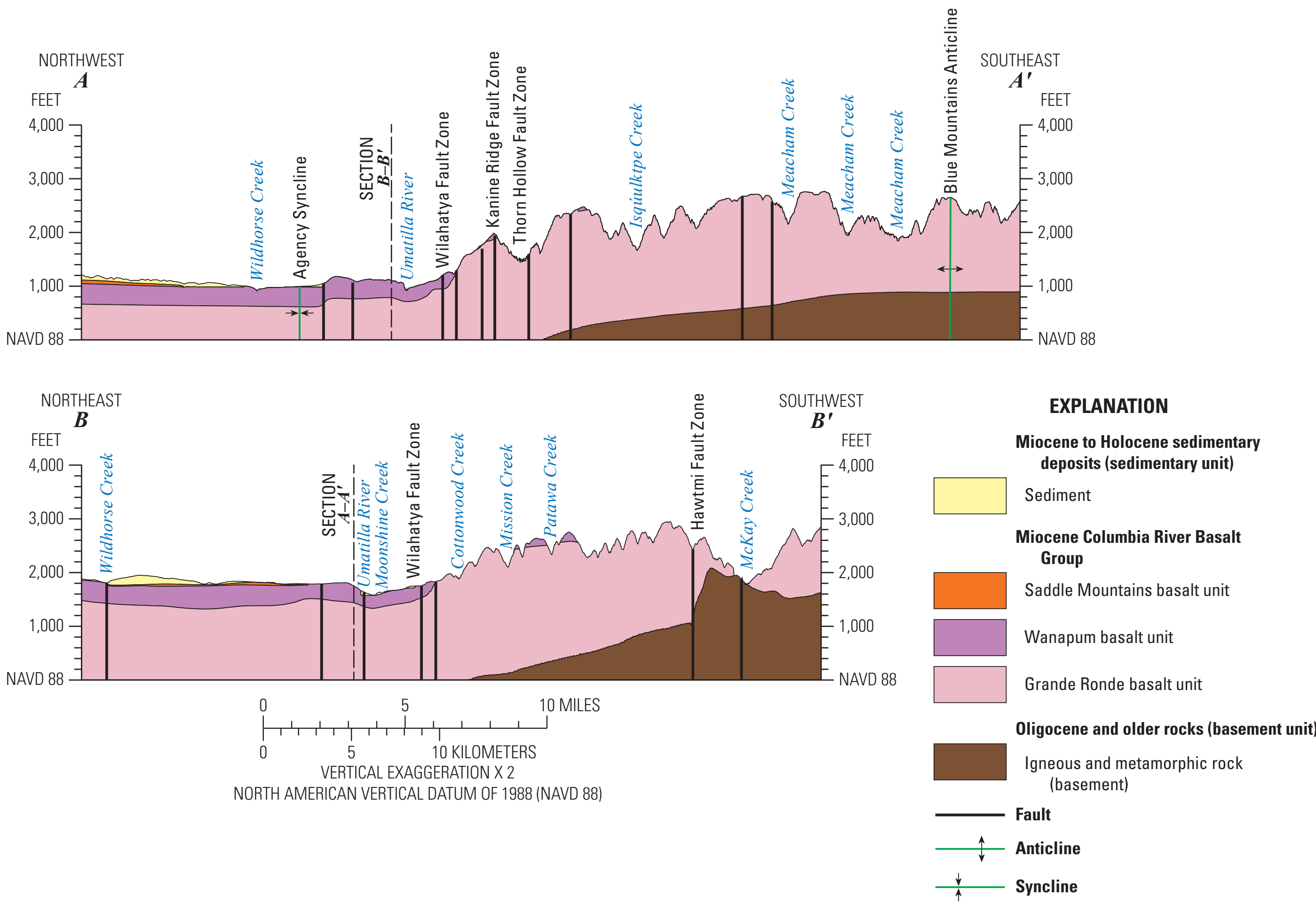


Figure 4. Generalized hydrogeologic sections of units trending (*A*) northwest to southeast, and (*B*) northeast to southwest in the upper Umatilla River Basin, Oregon.

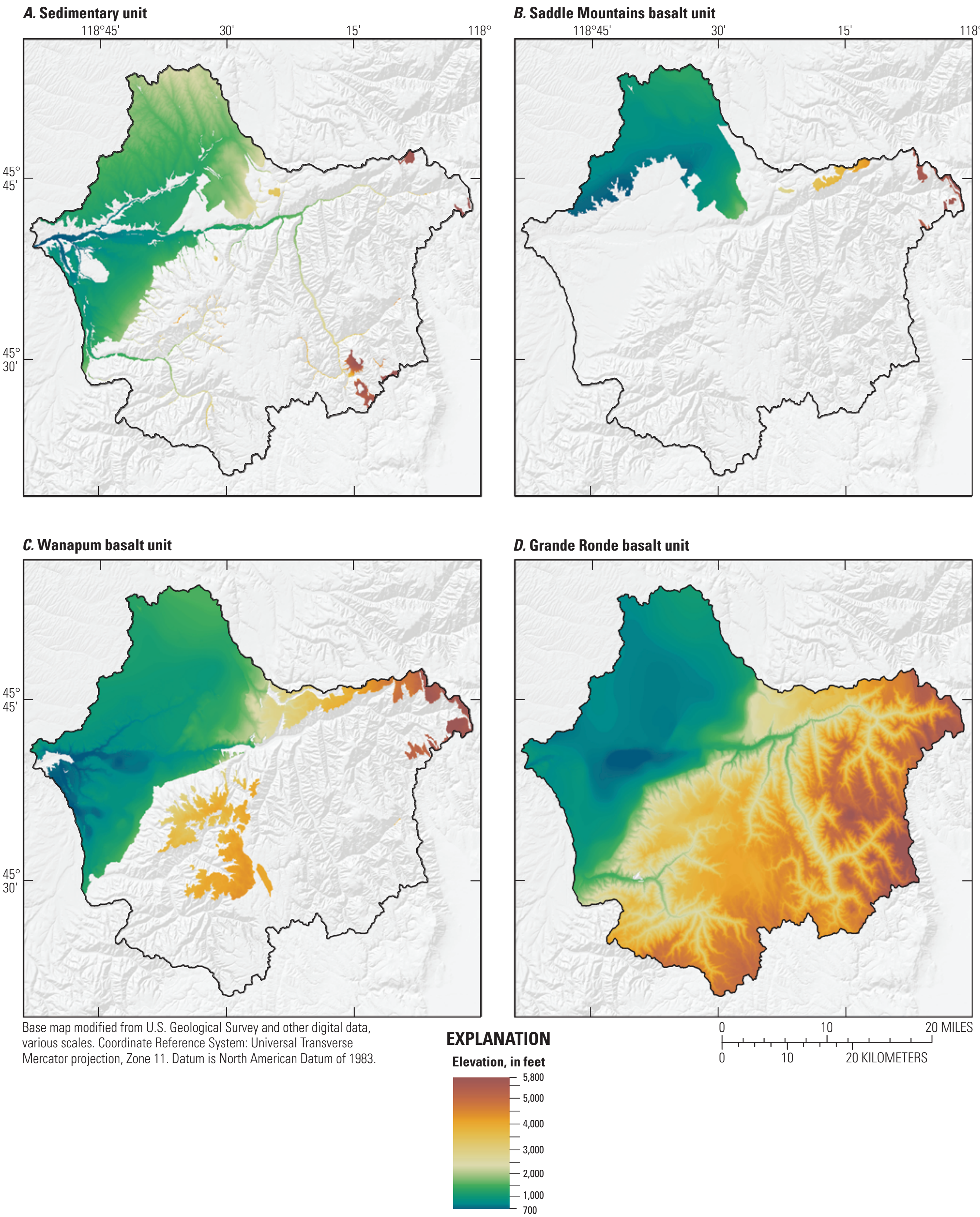


Figure 5. Extent and top elevation of the (*A*) sedimentary unit and Columbia River Basalt Group: (*B*) Saddle Mountains basalt unit, (*C*) Wanapum basalt unit, and (*D*) Grande Ronde basalt unit; upper Umatilla River Basin, Oregon.

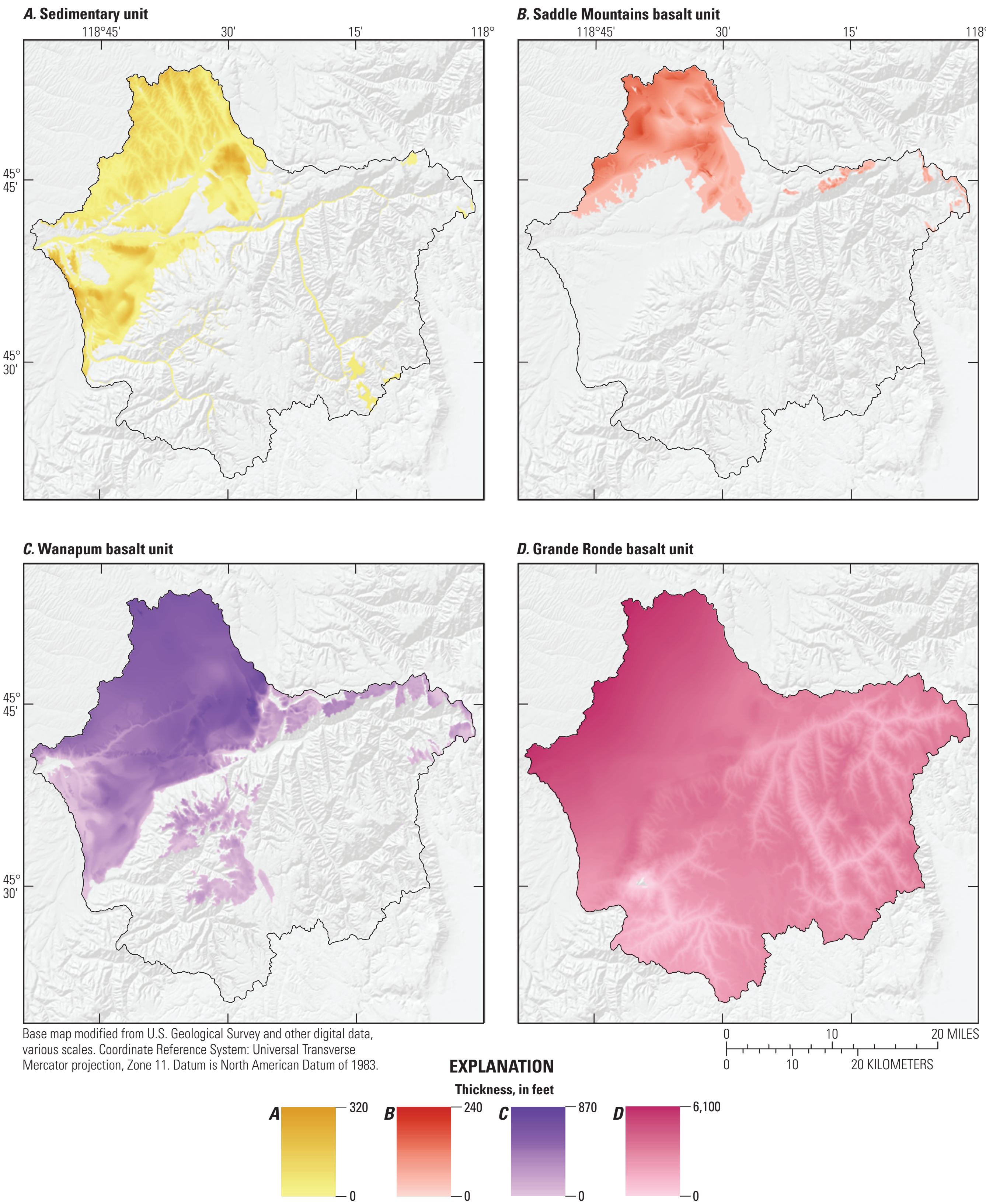


Figure 6. Extent and thickness of the (*A*) sedimentary unit and Columbia River Basalt Group: (*B*) Saddle Mountains basalt unit, (*C*) Wanapum basalt unit, and (*D*) Grande Ronde basalt unit; upper Umatilla River Basin, Oregon.

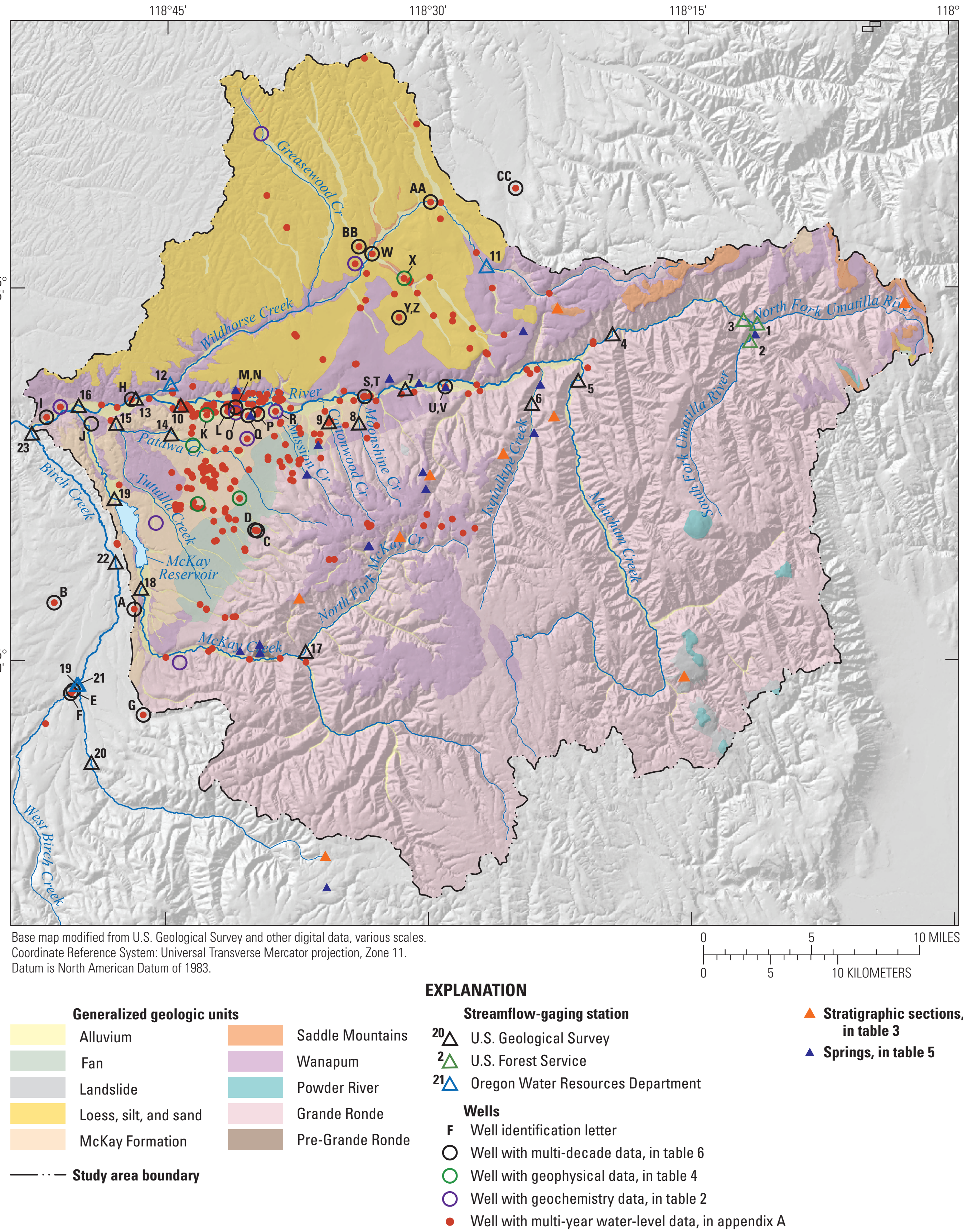


Figure 7. Surficial distribution of selected observation wells, stratigraphic sections, springs, and streamflow-gaging stations throughout the upper Umatilla River Basin, Oregon.

Table 1. Summary of well data used to generate the extent, thickness, and top elevations of the sedimentary unit, Saddle Mountains basalt unit, Wanapum basalt unit, Grande Ronde basalt unit, and basement rock, upper Umatilla River Basin, Oregon.

[The Confederated Tribes of the Umatilla Indian Reservation (CTUIR) is the agency determining and retaining the hydrogeologic elevation data shown in this table. All elevations are in feet above North American Vertical Datum of 1988. **USGS site identification No.**: Site identification number permanently assigned to the well by the U.S. Geological Survey (USGS) and recorded in National Water Information System, a national computer database maintained by USGS. **Well log identifier**: Unique identifier combining a four-letter county code and a well-log number with as many as five digits, which is assigned to the well when a water well report is filed by the well driller with the Oregon Water Resources Deparment (OWRD) and recorded in Ground Water Resource Information Distribution, a statewide computer database maintained by OWRD. **CTUIR well identification No.**: Unique number assigned to the well by the CTUIR when a well report is filed by the driller with CTUIR and recorded in the CTUIR database. **Abbreviations**: *, unit not present at location; ft, foot; NA, not available]

USGS site identification No.	Well log identifier	CTUIR well identification No.	Land surface elevation	Well depth (ft)	Elevation of top of unit			
					Sediment	Saddle Mountains basalt	Wanapum basalt	Grande Ronde basalt
453519118395201	UMAT 341	2	1,817	1,150	1,817	*	1,800	1,362
454033118465801	UMAT 530	153	1,070	700	1,070	*	1,060	1,017
454014118474701	UMAT 53635	154	1,053	761	1,053	*	*	1,036
454019118421601	UMAT 855	310	1,177	655	1,177	*	1,117	707
453956118424001	UMAT 55262	381	1,204	968	1,204	*	1,072	746
454013118412401	UMAT 911	390	1,203	300	1,203	*	1,182	NA
454001118405901	UMAT 5929	422	1,215	1,057	1,215	*	1,204	779
453950118394401	UMAT 945	472	1,245	315	1,245	*	1,182	NA
454005118384301	UMAT 5930	482	1,283	1,100	1,283	*	1,261	781
NONE	UMAT 973	507	1,266	135	1,266	*	1,191	NA
453859118401901	UMAT 53456	539	1,438	975	1,438	*	1,227	885
453842118432501	UMAT 1015	548	1,281	608	1,281	*	1,219	901
NONE	UMAT 1013	551	1,290	635	1,290	*	1,276	920
453620118430901	UMAT 1061	685	1,465	965	1,465	*	1,345	1,030
454542118321901	UMAT 1428	829	1,710	980	1,710	1,699	1,620	962
454526118311901	UMAT 1444	831	1,657	1,030	1,657	1,628	1,567	952
454409118302901	UMAT 1446	843	1,810	1,910	1,810	1,800	1,731	1,107
NONE	UMAT 1449	849	1,455	785	1,455	*	1,437	974
NONE	UMAT 5362	852	1,655	860	1,655	*	1,643	1,090
454353118313901	UMAT 1453	854	1,780	936	1,780	1,762	1,666	1,127
NONE	UMAT 6425	860	1,718	598	*	*	1,509	1,120
NONE	UMAT 1462	875	2,054	1,103	2,054	*	2,044	1,417
NONE	UMAT 1468	889	2,014	380	2,014	2,004	1,959	1,324
NONE	UMAT 1469	891	1,815	700	1,815	1,799	1,757	1,160
454237118273401	UMAT 1474	902	2,295	145	2,295	2,291	2,240	1,740
454751118291301	UMAT 6151	964	1,885	746	1,885	1,880	1,780	1,177
454713118242201	UMAT 3103	967	2,053	1,125	2,053	NA	NA	NA
454625118330901	UMAT 1432	970	1,544	1,263	1,544	1,535	1,440	964
454014118510301	UMAT 53890	1020	1,053	433	1,053	*	*	1,051
454014118510302	UMAT 54072	1021	1,048	826	1,048	*	*	1,044
454038118485601	UMAT 533	1056	1,202	600	*	*	1,202	1,072
NONE	UMAT 663	1078	1,123	46	1,123	*	*	1,119
454328118444201	UMAT 1403	1091	1,485	185	1,485	1,482	1,432	1,032
NONE	UMAT 1416	1094	1,432	800	1,432	*	1,404	995
NONE	UMAT 1417	1095	1,330	742	1,330	*	1,315	998
NONE	UMAT 1425	1096	1195	88	1,195	*	1,180	NA
NONE	UMAT 1438	1100	1570	515	1,570	*	1,556	940

Table 1. Summary of well data used to generate the extent, thickness, and top elevations of the sedimentary unit, Saddle Mountains basalt unit, Wanapum basalt unit, Grande Ronde basalt unit, and basement rock, upper Umatilla River Basin, Oregon.—Continued

USGS site identification No.	Well log identifier	CTUIR well identification No.	Land surface elevation	Well depth (ft)	Elevation of top of unit			
					Sediment	Saddle Mountains basalt	Wanapum basalt	Grande Ronde basalt
454643118335501	UMAT 6433	1102	1554	1,270	1,554	1,543	1,444	939
454856118313801	UMAT 2977	1103	1773	1,000	1,773	1,756	1,641	1,108
455101118364001	UMAT 3039	1104	1850	650	1,850	1,816	1,739	1,143
454841118363401	UMAT 3047	1106	1692	1,035	1,692	1,622	1,582	989
454755118343401	UMAT 2579	1109	1674	979	1,674	1,618	1,539	974
454648118355201	UMAT 3060	1111	1570	1,120	1,570	*	1,559	919
454646118315901	UMAT 3063	1113	1620	1,640	1,620	1,579	1,471	1,010
454602118340801	UMAT 5331	1116	1,580	1,725	1,580	1,557	1,455	940
455115118393201	UMAT 5351	1117	1,817	1,296	1,817	1,738	1,607	997
NONE	UMAT 5361	1118	1,532	1,000	1,532	1,524	1,515	982
NONE	UMAT 6095	1125	1,165	608	1,165	*	1,142	990
NONE	UMAT 51779	1134	1,665	78	1,665	1,595	1,555	955
452957118441001	UMAT 54259	1140	1,690	230	1,690	*	*	1,688
453520118452501	UMAT 54546	1143	1,395	385	1,395	*	*	1,143
NONE	UMAT 54920	1144	2,150	220	2,150	*	*	2,090
NONE	UMAT 55441	1152	1,760	1,195	1,760	1,688	NA	NA
454018118484001	UMAT 55619	1156	1,045	852	1,045	*	*	1,021
NONE	UMAT 56037	1160	1,845	420	1,845	1,820	1,765	1,175
NONE	UMAT 57015	1172	1,573	1,068	1,573	*	1,518	1,237
NONE	UMAT 54447	1739	1,343	650	1,343	*	1,183	1,074
453642118492601	UMAT 683	1743	1,140	620	1,140	*	*	1,123
454844118273101	UMAT 3088	1746	1,935	1,012	1,935	*	1,890	1,330
454750118252302	UMAT 3096	1747	2,000	1,455	2,000	*	1,986	1,435
455024118245001	UMAT 3074	1750	1,836	551	1,836	*	1,828	1,285
455120118240701	UMAT 3067	1751	1,510	300	1,510	*	1,498	1,098
NONE	UMAT 1378	1753	1,208	605	1,208	*	1,187	823
NONE	UMAT 504	1754	898	185	898	*	*	888
NONE	UMAT 287	1765	1,468	720	1,468	*	1,308	1,210
NONE	UMAT 5403	1776	2,063	1,435	2,063	*	*	2,007
NONE	UMAT 55510	1780	5,010	180	5,010	*	5,004	NA
NONE	UMAT 55495	1781	3,145	695	3,145	*	3,140	2,755
NONE	UMAT 1400	1787	1,598	429	1,598	1,588	1,488	888
NONE	UMAT 53934	1788	1,709	425	1,709	1,679	1,579	1,079
NONE	UMAT 3019	1789	1,648	1,500	1,648	1,638	1,598	728
455248118455801	UMAT 3865	1790	1,650	120	1,650	1,634	1,559	750
452959118494001	UMAT 67	1793	1,560	1,500	1,560	*	1,513	1,392
453443118474501	UMAT 292	1796	1,460	700	1,460	*	1,290	1,215
NONE	UMAT 3035	1799	1,957	405	1,957	1,923	1,823	1,200
NONE	UMAT 5710	1815	1,758	620	1,758	*	*	1,742
NONE	UMAT 6001	1816	1,829	410	1,829	*	*	1,822
NONE	UMAT 56683	1822	1,586	912	1,586	*	1,448	1,310
NONE	NA	1865	1,487	825	1,487	*	1,407	976

Table 2. List of selected wells with geochemistry data, upper Umatilla River Basin, Oregon.

[The Confederated Tribes of the Umatilla Indian Reservation (CTUIR) is the agency retaining the hydrogeologic elevation data shown in this table. All elevations are in feet above North American Vertical Datum of 1988. **USGS site identification No.**: Site identification number permanently assigned to the well by the U.S. Geological Survey (USGS) and recorded in National Water Information System, a national computer database maintained by USGS. **CTUIR well identification No.**: Unique number assigned to the well by the CTUIR when a well report is filed by the driller with CTUIR and recorded in the CTUIR database. **Well log identifier**: Unique identifier combining a four-letter county code and a well-log number with as many as five digits, which is assigned to the well when a water well report is filed by the well driller with the Oregon Water Resources Deparment (ORWD) and recorded in Ground Water Resource Information Distribution, a statewide computer database maintained by OWRD. **Abbreviations**: ft, foot]

USGS site identification No.	USGS sitename	Well log identifier	CTUIR well identification No.	Land surface elevation (ft)	Well depth (ft)
[1]454001118405901	02N/33E-09DAA3	UMAT 5929	582	1,215	1,057
[2]454005118384301	02N/33E-11ADC4	UMAT 5930	789	1,280	1,100
453859118401901	02N/33E-15DBC1	UMAT 53456	898	1,435	975
454014118510301	02N/32E-07ADB1	UMAT 53890	965	1,150	433
454014118510302	02N/32E-07ADB2	UMAT 54072	966	1,050	1,086
454602118340801	03N/34E-04DBB	UMAT 5331	1066	1,580	1,725
455115118393201	04N/33E-02CBD	UMAT 5351/5449	1067	1,810	1,296
452957118441001	01S/33E-07BBB	UMAT 54259	1090	1,770	230
453520118452501	01N/32E-01CAC	UMAT 54546	1093	1,400	385

[1] Indicates well with multi-decade data; see table 6. For well location, see map identifier “O” in figure 7.

[2] Indicates well with multi-decade data; see table 6. For well location, see map identifier “R” in figure 7.

Table 3. Summary of selected stratigraphic section data, upper Umatilla River Basin, Oregon.

[The Confederated Tribes of the Umatilla Indian Reservation (CTUIR) is the agency retaining the stratigraphic section data. All unit tops elevations are in feet above North American Vertical Datum of 1988. **CTUIR sitename**: Nearest topographical feature. **CTUIR identification No.**: Unique number assigned by the CTUIR and recorded in the CTUIR database. **Abbreviations**: *, unit not present at location; ft, foot; NA, not available]

CTUIR sitename	CTUIR identification No.	Latitude (decimal degrees)	Longitude (decimal degrees)	Land surface elevation (top of section) (ft)	Top of Saddle Mountains basalt unit	Top of Wanapum basalt unit	Top of Vantage Horizon	Top of Grande Ronde basalt unit	Land surface elevation (bottom of section) (ft)
Reservation Mountain	1827	45.7371980	-118.3762070	2,950	2,950	2,900	2,520	2,510	1,380
Gibbon Ridge	1828	45.6647970	-118.3797970	3,280	*	*	*	3,280	850
Iskuulpa	1829	45.6397990	-118.4283030	3,450	*	*	*	3,450	2,795
Buckaroo (Kanine)	1830	45.6253180	-118.4984520	3,520	*	3,520	3,225	3,225	2,225
Emigrant	1831	45.5840980	-118.5272610	3,400	*	3,400	3,160	3,160	2,715
Table Rock	1832	45.5427200	-118.6232100	3,615	*	3,615	3,580	3,580	2,305
North Fork Umatilla River	1842	45.7399980	-118.0438970	5,045	5,045	5,010	NA	4,920	NA
Wilbur Mountain	1843	45.4900990	-118.2562000	4,120	*	*	*	4,120	NA
unnamed	1844	45.3694050	-118.5987060	4,355	NA	NA	NA	4,355	NA

Table 4. List of selected wells with borehole geophysical data, upper Umatilla River Basin, Oregon.

[**USGS site identification No**.: Site identification number permanently assigned to the well by the U.S. Geological Survey (USGS) and recorded in National Water Information System, a national computer database maintained by USGS. **Well log identifier**: Unique identifier combining a four-letter county code and a well-log number with as many as five digits, which is assigned to the well when a water well report is filed by the well driller with the Oregon Water Resources Deparment (OWRD) and recorded in Ground Water Resource Information Distribution, a statewide computer database maintained by OWRD. **CTUIR well identification No.**: Unique number assigned to the well by the CTUIR when a well report is filed by the driller with CTUIR and recorded in the CTUIR database. **Abbreviations**: ft, foot]

USGS site identification No.	USGS sitename	Well log identifier	CTUIR well identification No.	Well depth (ft)	Well seal depth (ft)	Logged interval (ft)
453842118432501	02N/33E-20BBB	UMAT 1015	240	880	0–62	1–880
453620118430901	02N/33E-32CCA1	UMAT 1061/1060	533	965	0–103	0–965
[1]454526118311901	03N/34E-11AAC	UMAT 1444/55063	669	1,030	0–341	0–1,024
[2]453956118424001	02N/33E-08DBD3	UMAT 909/55262	27	968	0–64	0–968
453634118404801	02.00N/33.00E-34BCD01	UMAT 57015	1141	1,068	0–400, 0–700	0–673, 700–1,068

[1]Indicates well with multi-decade data; see table 6. For well location, see map identifier “X” in figure 7.

[2]Indicates well with multi-decade data; see table 6. For well location, see map identifier “K” in figure 7.

Hydrogeologic Units

Sedimentary Unit

The sedimentary deposits overlying the CRBG consist of four types of Tertiary and Quaternary sediments defined by Hogenson (1964) and refined by Ferns and Ely (2006) (figs. 3 and 6): (1) recent stream alluvium, including Pleistocene terrace deposits (Qal), (2) Quaternary alluvial fan deposits (Qf), (3) Quaternary landslide deposits (Qls), (4) loess and fine-grained sandstone (QTs) interpreted as late Miocene wind-reworked, fine grained deposits correlative to the McKay Formation, and (5) late-Miocene to early-Pliocene conglomerate of the McKay Formation (Tms) (fig. 3). Total thickness of the sedimentary unit within the study area ranges from less than 10 to 320 ft (fig. 6).

The reworked loess and basaltic gravel from the Blue Mountain uplands form the recent stream alluvium (Qal) along present-day streams. The large proportion of silt results in low permeability. Within the stream alluvium, limited interbeds of reworked white volcanic ash form terraces along the canyon bottoms and adjacent slopes. Upstream from Pendleton there is a 7-mi stretch of approximately 40-ft thick alluvium primarily composed of gravel (Hogenson, 1964). The alluvium is generally not more than 50 ft thick (Mark L. Ferns, Oregon Department of Geology and Mineral Industries, written commun., 2014).

Coalescing, alluvial fan deposits located along the western edge of the Blue Mountains are mapped as Qf. The Quaternary fan deposits are primarily unconsolidated deposits of coarse gravel, gravels and sands which overlie the basalt and McKay formations (Ferns, 2006a, 2006b, 2006c, 2006d, 2006e; Ferns and Ely, 2006).

Permeable loess and fine sands (QTs) overlie the pre-Pleistocene rock units in the area, and is derived partly from glaciolacustrine sediments found at lower altitudes and from fine grained alluvial plain deposits. These deposits were previously interpreted as the older loess Pleistocene Palouse Formation by Hogenson (1964) and Walker (1973); however, it is correlative to the middle Miocene to Pliocene McKay Formation (Mark L. Ferns, Oregon Department of Geology and Mineral Industries, written commun., 2014), and overlies and interbeds with the Saddle Mountains basalt unit (Ferns, 2006a, 2006b, 2006c, 2006d, 2006e; Ferns and Ely, 2006). The sandy to fine silt loess ranges in thickness from 1 to 2 ft in the upland area of the Blue Mountain region, more than 50 ft near Helix (Hogenson, 1964), to as much as 160 ft northward (Ferns, DOGAMI, written commun., 2014).

Poorly bedded, consolidated conglomerate that composes the McKay Formation (Tms) is deposited primarily in the trough of the northeast-trending Agency syncline near the Hawtmi fault zone at the foot of the Blue Mountain slope. The low-permeability deposit primarily consists of pebble to cobble-sized basalt, with additional basalt fragments ranging in size from grit to boulders, and silt and sand lenses that can be several hundred feet long and as much as 40 ft thick (Hogenson, 1964). Total formation thickness may be as much as 300 ft (Ferns and McConnell, 2006). Where present, the conglomerate directly overlies the CRBG, and underlies the widespread loess and alluvial fan deposits (QTs and Qf).

Hydraulic properties of the sedimentary unit are highly variable because of the diversity of deposits. Values of hydraulic conductivity for glacial till, loess, and silty sand deposits range from 10^{-6} to 10^{-1} ft/d, 10^{-4} to 1 ft/d, and 10^{-2} to 10^{2} ft/d, respectively (Freeze and Cherry, 1979).

Mean hydraulic conductivity and storage coefficient values for the sedimentary unit were determined from well data in the Hermiston-Umatilla area and estimated to be 24,000 ft/d and 0.15, respectively (Davies-Smith and others, 1988). Specific capacity data from 882 wells open to basin-fill units in the Yakima River Basin provide a mean horizontal hydraulic conductivity value of 182 ft/day (similar to the reported magnitude of silty sand deposits by Freeze and Cherry [1979]), with a minimum value of 0.01 ft/day and a maximum value of 17,715 ft/day (Vaccaro and others, 2009). These hydrologically different sedimentary materials directly overlie the less permeable CRBG.

Columbia River Basalt Group

The CRBG formations present in the upper Umatilla River Basin are the Saddle Mountains Basalt (Tsu), Wanapum Basalt (Twu), and Grande Ronde Basalt (Tgu) (figs. 3–6). Individual flows range in thickness from 5 to greater than 100 ft, and total thickness of the series of flows in the study area, as calculated during this study, may be as much as 6,800 ft (fig. 6). The top and bottom of individual flows are vesicular and commonly brecciated. When the hiatus between flows was sufficiently long, soil or sediments accumulated on the surface. When preserved to form interbeds between flows, these sediments are assigned to the Ellensburg Formation. Where present the interbeds between the Grande Ronde and the Wanapum Basalts (Vantage Member of the Ellensburg Formation) are an important stratigraphic marker, and are informally referred to as the 'Vantage Horizon'. The Vantage Horizon is generally marked by a thin red to brown zone which includes siltstone, claystone, pebble gravels, red paleosols, and pillow lavas and breccias. Where exposed at the surface, the Vantage horizon may be marked by spring lines (Ferns and others, 2004, Swanson and others, 1979); however, the interbed is typically less than 2 ft thick and commonly not found in outcrops in the study area, with the exception of exposed outcrops in Pendleton. Further analysis of geochemistry and geophysical well logs by CTUIR resulted in a refinement of the location of the contact between the Wanapum Basalt and the top of the Grande Ronde Basalt in the upper Umatilla River Basin.

The vesicular and brecciated flow tops and bottoms of individual flows are commonly permeable and form the principal aquifers in the CRBG. Between these interflow zones, the dense flow interiors are relatively impermeable. Conceptually, the CRBG is a series of productive aquifers consisting of relatively high permeability interflow zones separated by the low permeability flow interiors. The uppermost part of the CRBG is often permeable and unconfined, and has a good hydraulic connection with the overlying alluvial aquifer and, in some cases, streams. Permeable interflow zones at depth are confined by the flow interiors. Although interflow zones may yield large amounts of water initially, continued withdrawals result in large declines in water levels because of low storage properties and limited recharge of water reaching these productive zones through the low-permeability flow interiors. Upland areas in the Blue Mountains where permeable interflow zones intersect land surface likely provide recharge to CRBG aquifers at depth.

The youngest CRBG formation present in the upper Umatilla River Basin is the Saddle Mountains Basalt. It is typically overlain by sedimentary deposits throughout the study area, though it outcrops in the Wildhorse Creek stream channel near Athena, and erosional remnants are present in the upper reaches of the Umatilla River channel upstream of Gibbon. Only one lava flow of the Saddle Mountains Basalt is present in the upper Umatilla River Basin. The flow is generally less than 100 ft thick near Adams and Athena and thickens, where not eroded through by streams, to the north and northwest to about 150 ft at the boundary of the study area (fig. 6). The Saddle Mountains Basalt is not present southwest of Adams.

The Wanapum Basalt underlies both the sedimentary unit and the Saddle Mountains Basalt in the upper Umatilla River Basin; it is exposed along stream channels and as erosional remnants at higher elevations in the Blue Mountain uplands. The faulted and uplifted Blue Mountains results in younger Wanapum Basalt in the lowland juxtaposed with older Grand Ronde Basalt in the uplifted block. Flows of the Frenchman Springs Member of the Wanapum Basalt known to be present in the upper Umatilla River Basin are the Sentinel Gap and Sand Hollow. The Basalt of Dodge is the only flow of the Eckler Mountain Member present in the study area. The total thickness of the Wanapum basalt unit is as much as 870 ft in the northern and northwestern part of the study area, between 600 and 700 ft thick near Helix and Adams, Oregon, 400–500 ft thick near Mission, Oregon, and thins to less than 100 ft in areas near Pendleton and near the southwestern boundary of the study area (fig. 6). Erosional remnants in the Blue Mountain uplands range from 10 to 350 ft thick.

The oldest CRBG formation in the study area is the Grande Ronde Basalt. It is present at land surface in the upper Umatilla River Basin east and southeast of Mission and Cayuse. The northeast-trending Kanine Ridge, Wilahatya, and Hawtmi fault zones mark the edge of the Blue Mountain slope and generally mark the surficial extent of the Grande Ronde Basalt to the west and northwest (fig. 3) (Ferns, 2006a, 2006b, 2006c, 2006d, 2006e); however, it is present at depth to the west and northwest (figs. 4 and 6). The Grande Ronde Basalt is estimated to consist of more than 100 flows in the Umatilla River Basin (Reidel and others, 1989). Multiple flow members are present in the upper basin and include ferroandesite of Fiddlers Hell, feeder dikes and vent deposits, and magnetostratigraphic units R1, N1, R2, and N2 (which includes the prominent Sentinel Bluffs and Winter Water Members). Individual flows range from a few feet to 200 ft thick. Unit thicknesses also include the scattered, capping flows of mid-Miocene olivine basalts and trachyandesite lavas (Powder River Volcanic Field rocks) which overlie the Grand Ronde Basalt in the eastern upland region of the Blue Mountains (Ferns and McClaughry, 2013; Ferns and others, 2002), where it is present well above the regional water table. Grande Ronde basalt unit thickness in the study area, except where incised by stream drainages, generally ranges from 3,000 to 4,000 ft, and thickens to the northwest, reaching 6,100 ft near Helix (fig. 6).

Mean values of hydraulic conductivity determined from about 1,700 short-duration specific capacity tests in the Umatilla River Basin are 18 ft/d for the Saddle Mountains basalt unit, 170 ft/d for the Wanapum basalt unit, and 65 ft/d for the Grande Ronde basalt unit (Davies-Smith and others, 1988). Values of transmissivity for the CRBG derived from the numerical model of the Umatilla River Basin by Davies-Smith and others (1988) ranged from 0.005 to 0.25 ft^2/s. Hydraulic conductivity values estimated for specific-capacity data from 573 basalt wells in the entire Columbia Plateau Regional Aquifer System study ranged from 0.1 to 58,000 ft/d, with a mean of 800 ft/d and a median of 70 ft/d (Kahle and others, 2011).

Storage coefficient values derived during the Davies-Smith and others (1988) study from model calibration results average 0.01, 0.0045, and 0.0050 for the Saddle Mountains basalt unit, Wanapum basalt unit, and Grande Ronde basalt unit, respectively. Davies-Smith and others (1988) tabulated other storage coefficient values from (1) OWRD aquifer tests, (2) a study that calculated storage coefficients using volumetric analysis, and (3) a previous basalt groundwater-flow model in the Walla Walla River Basin (McNish and Barker, 1976). These storage coefficient values ranged from 0.00001 to 0.0065 (higher values are typical of leaky artesian conditions) for the basalt aquifers.

Groundwater Elevations and Flow Directions

Groundwater elevations provide insight into the spatial distribution of hydraulic head that drives groundwater flow. The CRBG contains multiple permeable zones (aquifers) separated by less permeable confining units. Groundwater flows from high water-level elevations (high head) to areas of low water-level elevations (low heads). Because wells in the study area are commonly open to multiple permeable zones, the water levels in wells can represent a composite head representing a range of depths. Consequently, the three-dimensional distribution of hydraulic head in this study area can only be partially understood given available data.

Data Sets and Limitations

The CTUIR collected water-level measurements during autumn 2008 and spring 2009 for 158 and 193 wells (appendix A), respectively, that were less than 400 ft deep to understand seasonal water level changes. Between January 3, 2012, and June 18, 2012, monthly water-level measurements were made at 110 field-located wells tapping basalt aquifers to delineate head distribution and horizontal and vertical flow (appendix A). During that period, a subset of 56 wells was measured monthly to evaluate monthly variability in water levels. Only 2 of the 56 wells had water levels that varied more than 10 ft between January and June 2012. Measurements from April and May were generally used to represent water level elevations for spring 2012.

The large open intervals in most of the measured wells limits understanding vertical gradients over the full range of the aquifer system and creates uncertainty in measured hydraulic heads at greater depth within the aquifer system because measured water levels are a composite of the head in aquifers from various depths. The general direction of vertical flow was determined in some locations using proximate well pairs that were completed in individual hydrogeologic units of different depths or sufficiently different in completed depth such that even the composite heads provided an indication of the direction of the vertical gradient.

Because springs occur where the land surface intersects the water table spring elevations can be used to estimate the water table elevation. In August to September 2009, CTUIR conducted a survey of 19 springs (all located in the study area or on the Umatilla Indian Reservation) (fig. 7 and table 5).

General Horizontal and Vertical Flow Directions

The regional pattern of groundwater flow in the CRBG is from the upland areas in the southeast and north, generally toward the Umatilla River, where heads are lowest (fig. 8). Horizontal hydraulic gradients inferred from wells less than 400 ft deep are typically 40–50 ft/mi in the lowland area. Gradients steepen to 400–500 ft/mi along the slope of the Blue Mountains and are locally influenced by streams. Horizontal hydraulic gradients inferred from wells greater than 400 ft deep in the lowland area are typically greater than 50 ft/mi north of the Umatilla River, and about 100 ft/mi south of the Umatilla River. Scarcity of data prevents quantifying deeper horizontal gradients in the Blue Mountain uplands and as they transition across the Blue Mountain slope. Lack of measured water level information in the sedimentary unit precludes delineation of horizontal gradients; however, work by Jones and others (2007) and Poole and others (2008) indicates that hyporheic exchange is prevalent along the main-stem Umatilla River, suggesting that shallow horizontal head gradients are similar to the stream gradient in the floodplain.

Table 5. Summary of Confederated Tribes of the Umatilla Indian Reservation 2009 survey data of springs, upper Umatilla River Basin, Oregon.

[All elevations are in feet above North American Vertical Datum of 1988 The Confederated Tribes of the Umatilla Indian Reservation (CTUIR) is the agency retaining the spring survey data. **Abbreviations**: ft, foot; acre-ft/yr, acre-foot per year; NA, not measurable or not accessible]

CTUIR identifier	Survey date	Latitude (decimal degrees)	Longitude (decimal degrees)	Land surface elevation (ft)	Discharge rate on survey date (acre-ft/yr)
1577	08-10-09	45.68239316	-118.6844668	1,329	63.2
1216	08-10-09	45.66535096	-118.6699883	1,225	NA
1325	08-24-09	45.51160778	-118.6610685	2,078	15.7
1335	08-24-09	45.50732003	-118.6797477	1,878	37.4
1338	08-24-09	45.50637487	-118.6606713	1,866	1.9
1699	08-26-09	45.57775805	-118.5575179	2,992	7.5
1387	08-26-09	45.57780993	-118.5563529	2,975	NA
1425	08-28-09	45.34852168	-118.59739	4,492	3.3
1347	09-01-09	45.61610174	-118.5024775	3,560	NA
1231	09-01-09	45.6273954	-118.5054092	3,295	NA
1683	09-01-09	45.6861318	-118.3929072	1,794	3.7
1698	09-09-09	45.65377074	-118.3990225	2,005	NA
1218	09-21-09	45.62588238	-118.6161292	1,822	77.3
1680	09-21-09	45.64561009	-118.6054549	1,623	9.9
1690	09-23-09	45.72197076	-118.4092567	2,677	NA
1250	09-23-09	45.69026702	-118.5371739	1,669	8.5
1246	09-23-09	45.68725864	-118.5089794	1,560	NA
1254	09-10-09	45.719169	-118.187233	2,474	23
972	unknown	45.684367	-118.483544	1,525	NA

In general, recharge areas have downward vertical gradients and discharge areas have upward gradients. Although data are scarce, decreasing head with depth in the CRBG in areas higher than the valley floor generally indicates that upland areas constitute a recharge zone. As the elevation of the bottom of the open interval in wells decrease, the measured water levels generally decrease. Water level measurements at City of Pilot Rock wells 01S/32E-17ACD (shallow) and 01S/32E-17DBA (fig. 7, map letter E and F, respectively) (deep) completed in the Grande Ronde basalt unit (fig. 7) indicate a downward vertical gradient. A downward vertical gradient is also evident at a shallow/deep well pair where the shallow well (01N/33E-03DDD1; fig. 7, map letter C) is completed to 121 ft in the upper Grande Ronde basalt unit and the deep well (01N/33E-03DDD2; fig. 7, map letter D) is completed to 1,150 ft (and cased to 26 ft) in the Grande Ronde basalt unit (fig. 7). This well pair is located at the base of the Blue Mountain slope in the southwestern part of the study area. Water level measurement records indicate the deep well was originally completed to 255 ft and had water levels similar to the shallow well until it was deepened in 1981. Spring 2012 water level elevations were 1,823 ft and 1,568 ft for the shallow and deep wells, respectively—a difference of 255 ft, and evidence of a downward vertical gradient. There are no well pairs at high elevations in the basin to confirm downward head gradients in upland areas.

Water levels measured near the Umatilla River, where discharge is to be expected, generally indicate an upward vertical gradient; however, in areas of intensive pumping from the Grande Ronde basalt unit near the Umatilla River, a downward vertical gradient is evident. This is demonstrated in the study area between Pendleton and Mission, where a downward vertical gradient is apparent directly to the west of an area with an upward vertical gradient (where pumping is primarily from the Wanapum basalt unit). This is discussed further in the section, Trends in Groundwater Levels. There are no data available to determine vertical gradients near the Umatilla River in the Pendleton area; however, pumping from the Grande Ronde basalt unit has lowered water levels. Measured water levels from wells completed in the Grande Ronde basalt unit near Pendleton typically are about 800 ft elevation, whereas water level measurements near Pendleton in the late 1960s typically were about 900 ft.

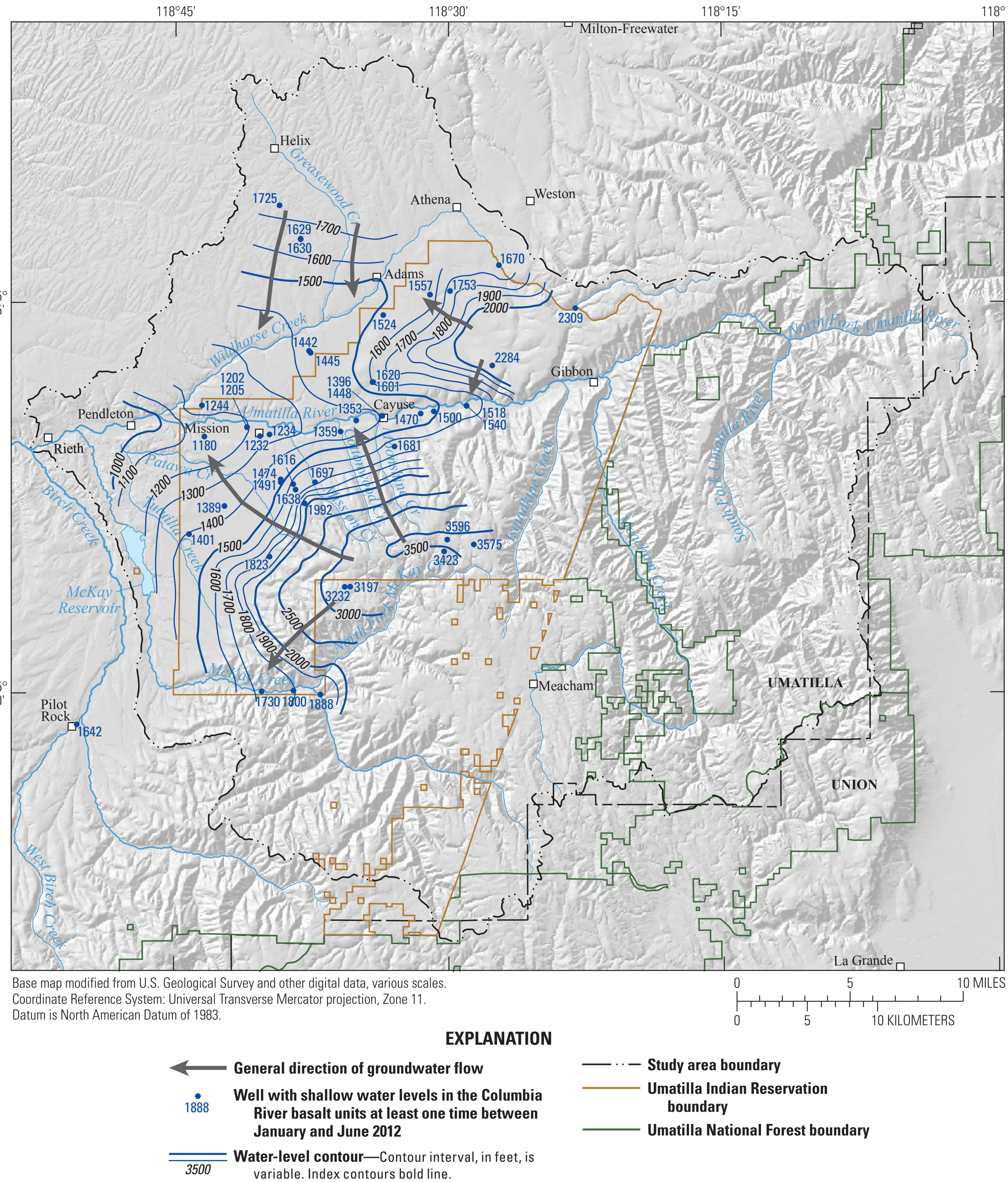


Figure 8. Generalized lines of equal hydraulic head and groundwater flow direction in the Columbia River Basalt Group, upper Umatilla River Basin, Oregon. Water level contours reflect the top of the saturated zone and do not fully reflect incised topography.

Trends in Groundwater Levels

Analysis of long-term data on groundwater levels can provide insights into the response to natural and artificial stresses such as changes in recharge or groundwater pumping. The CTUIR (2007) assessed groundwater level trends in the upper Umatilla River Basin. A summary of those interpretations, an assessment of new data from the USGS National Water Information System database, and additional data published by Snyder and Haynes (2010) and Burns and others (2012) are presented herein. These data are sufficient to establish some general temporal patterns in groundwater levels in the Umatilla River Basin study area, but the analysis is inherently limited by the small number (29) of wells with multi-decade groundwater level data (fig. 7 and table 6) and the absence of broad geographic coverage in those data.

Groundwater levels in alluvial gravels and Wanapum basalt aquifers in the upper Umatilla River Basin have been approximately stable over a period of decades. Available groundwater level data for alluvial gravels in the floodplain of the Umatilla River show seasonal fluctuations that are related to river stage, but groundwater levels are stable at longer timeframes (CTUIR, 2007). Groundwater level fluctuations in well 02N/33E-09ADA1 (map letter M, figs. 7 and fig. 9) are typical of wells in alluvial gravels.

Table 6. Wells with multi-decade groundwater level data, upper Umatilla River Basin, Oregon.

[Water-level data is recorded and maintained by either USGS or OWRD, or both. All elevations are in feet above North American Vertical Datum of 1988. **Map identifier**: Matches well to location on figure 7. **USGS site identification No.**: Site identification number permanently assigned to the well by the U.S. Geological Survey (USGS) and recorded in National Water Information System, a national computer database maintained by USGS. **Well log identifier**: Unique identifier combining a four-letter county code and a well-log number with as many as five digits, which is assigned to the well when a water well report is filed by the well driller with the Oregon Water Resources Deparment (OWRD) and recorded in Ground Water Resource Information Distribution, a statewide computer database maintained by OWRD. **CTUIR well identification No.**: Unique number assigned to the well by the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) when a well report is filed by the driller with CTUIR and recorded in the CTUIR database. **Period of record**: a, water-level data is recorded and maintained by the CTUIR. **Abbreviation**: ft, foot]

Map identifier	USGS site identification No.	USGS sitename	Well log identifier	CTUIR well identification No.	Land surface elevation (ft)	Well depth (ft)	Period of record
A	453230118464601	01N/32E-26CAC	UMAT 326	1735	1,580	1,100	1976–2006
B	453221118512201	01N/32E-30ACB2	UMAT 332	1774	1,599	600	1978–2006
C	453516118394401	01N/33E-03DDD1	UMAT 55430	9	1,833	121	1974–2012
D	453519118395201	01N/33E-03DDD2	UMAT 341	252	1,819	1,150	1971–2012
E	452850118501501	01S/32E-17ACD	UMAT 90	967	1,700	309	1945–2005
F	452842118502301	01S/32E-17DBA	UMAT 89	968	1,650	486	1956–2005
G	452751118461501	01S/32E-23DAA	UMAT 6472	1781	2,000	794	1950–2006
H	454033118465801	02N/32E-02CCD	UMAT 530	74	1,070	700	1958–2004
I	453949118514901	02N/32E-07CCA	UMAT 55330	1098	980	287	1942–2016
J	453934118491701	02N/32E-16BAB	UMAT 583	1015	1,066	1,500	1965–2005
K	453956118424001	02N/33E-08DBD3	UMAT 909/55262	27	1,205	968	1953–2012; 2013–2016a
L	454004118412701	02N/33E-09ACC3	UMAT 915	562	1,226	220	1981–2011
M	454014118410101	02N/33E-09ADA1	UMAT 55286	500	1,214	25	1979–2012
N	454014118410102	02N/33E-09ADA2	UMAT 55285	501	1,214	255	1979–2012
O	454001118405901	02N/33E-09DAA3	UMAT 5929	582	1,215	1,057	1996–2013a
P	453958118394901	02N/33E-10DAA1	UMAT 951/6078	475	1,242	190	1978–2012
Q	453954118401601	02N/33E-10DBC1	UMAT 943	563	1,230	182	1981–2012
R	454005118384301	02N/33E-11ADC4	UMAT 5930	789	1,277	1,100	1996–2013a
S	454041118333501	02N/34E-04DDA2	UMAT 55051	498	1,406	13	1979–2012
T	454041118333502	02N/34E-04DDA3	UMAT 55050	499	1,406	103	1979–2012
U	454104118285901	02N/35E-06ACA3	UMAT 55287	502	1,529	18	1979–2012
V	454104118285902	02N/35E-06ACA4	UMAT 55288	503	1,529	52	1979–2012
W	454625118330901	03N/34E-03BAC	UMAT 1432	666	1,544	1,263	1953–2016
X	454526118311901	03N/34E-11AAC	UMAT 1444/55063	669	1,659	1,030	1940–2012
Y	454352118313801	03N/34E-23ABB1	UMAT 1452	191	1,779	660	1968–2016
Z	454353118313901	03N/34E-23ABB2	UMAT 1453	195	1,775	936	1968–2016
AA	454832118295001	04N/34E-24DAD	UMAT 50183	1078	1,700	1,145	1946–2005
BB	454643118335501	04N/34E-33DCA	UMAT 6433	1052	1,555	1,575	1951–2016
CC	454904118254201	04N/35E-22AAA	UMAT 3092	1715	1,980	1,000	1955–2016

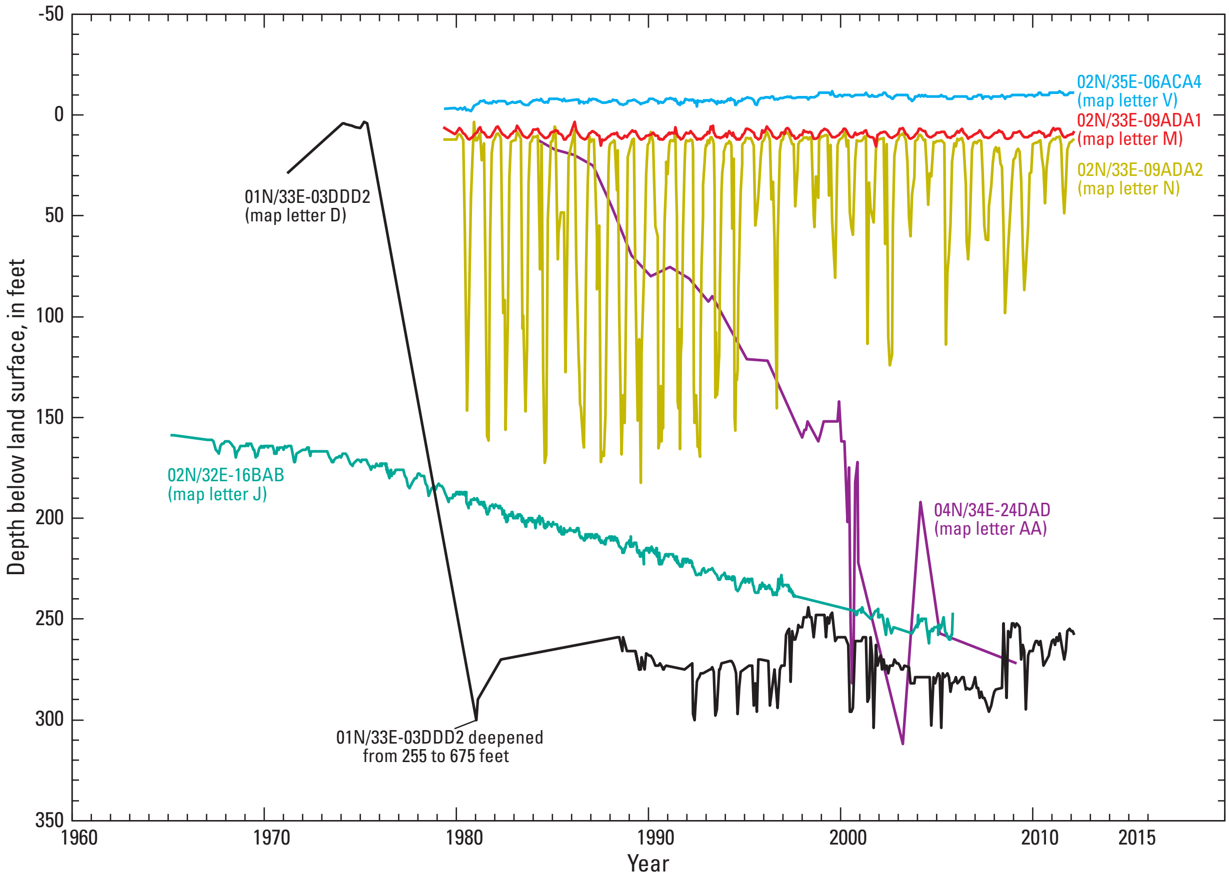


Figure 9. Selected wells, upper Umatilla River Basin, Oregon. Groundwater levels from 02N/33E-09ADA1, alluvial gravels; 02N/35E-06ACA4 and 02N/33E-09ADA2, Wanapum basalt unit; and 01N/33E-03DDD2, 02N/32E-16BAB, and 04N/34E-24DAD, primarily Grande Ronde basalt unit. See figure 7 for well (map letter) locations.

Groundwater levels in the Wanapum basalt unit, both in the vicinity of centers of groundwater pumping and distant from such centers, are variable at short (months to years) timescales but stable at longer (decades) timescales. Short-term variability includes fluctuations resulting from climate, shown as immediate or delayed changes in water levels that are a response to annual and seasonal precipitation (for example, the changes in groundwater levels that align with wet and dry periods shown in a well near Mission, 02N/33E-09ADA1, and a well east of Mission, 02N/35E-06ACA4 [map letters M and V, respectively, figs. 7 and 9]), and from a combination of localized pumping effects and climate (for example, the steep decrease in groundwater levels during months of increased water use, as well as changes that align with wet and dry periods, shown in a well near Mission, 02N/33E-09ADA2 [map letter N, figs. 7 and 9]; CTUIR, 2007). Aquifer response to climate variability that is observed in the upper Umatilla River Basin study area is also observed more broadly in the Columbia Plateau, where variability in recharge and groundwater levels is linked to the interannual (year-to-year) variability of precipitation (Ely and others, 2014). These short-term fluctuations aside, the Wanapum basalt unit groundwater levels are approximately stable over longer timeframes.

Groundwater levels in the Grande Ronde basalt unit exhibit long-term trends that in some cases differ from those observed in the Wanapum basalt unit in the Umatilla River Basin. Well 01N/33E-03DDD2 (map letter D, figs. 7 and 9), located south of Mission is cased primarily in the Grande Ronde basalt unit. Groundwater levels dropped sharply in 1981 when the well was deepened (reflecting a strong downward gradient), but have remained approximately stable since 1981. In contrast, wells 02N/32E-16BAB, located near Pendleton, and 04N/34E-24DAD (map letters J and AA, respectively, figs. 7 and 9), located near Athena, tap groundwater in the Grande Ronde basalt unit and show clear evidence of multi-decade groundwater level declines (figs. 7 and 9). In both cases, groundwater level declines have been attributed to groundwater pumping (CTUIR, 2007).

Groundwater-level declines in the Grande Ronde basalt unit have occurred near Mission, Pendleton, Adams, Weston, McKay Reservoir, Pilot Rock (CTUIR, 2007) and west of the upper Umatilla River Basin study area. February water levels measured in wells 02N/32E-02CCD, 02N/32E-07CCA, 02N/32E-16BAB, and 03N/31E-30ABC (map letters H, I, and J, fig. 7; and off-map, respectively) near Pendleton have similar elevations and show an average decline of 3 ft/yr from the 1970–2005 (figs. 10 and 11). Figure 11 shows groundwater levels on a normalized axis by plotting the difference between the groundwater elevation and the mean of all February groundwater elevations for the well. After 2005, the rate of decline diminished to about 1 ft/yr in wells 02N/32E-07CCA and 03N/31E-30ABC (fig. 11). The reduction in the rate of decline in these wells near Pendleton could be due to increases in precipitation and therefore groundwater recharge, reductions in pumping in the area, and artificial recharge in the Grande Ronde basalt unit by the City of Pendleton which started in the mid-2000s (City of Pendleton, 2016). Water levels in a well in Mission (02N/33E-09DAA3, fig. 7, map letter O) have a shorter record starting in 1997 and appear to decline until 2005 (fig. 11). The rate of apparent decline is greater than in wells in or near Pendleton. It is unclear if the declines in Mission are related to the declines near Pendleton because (1) it is difficult to determine trends and rates of trends in the Mission well because of the large variation in water levels in the well, especially after 2005, (2) the large difference in water elevations (fig. 10) between the Pendleton and Mission areas suggests that the two areas have a poor hydraulic connection, and (3) water levels in a well (02N/33E-08DBD3, fig. 7, map letter K) open to both the Wanapum basalt unit and Grande Ronde basalt unit and located between Pendleton and Mission increase from 2006 to 2016 suggesting that water level declines are not continuous between Pendleton and Mission. Presently, available data are insufficient to determine the cause of declines and the hydraulic connection of Pendleton and Mission areas.

Snyder and Haynes (2010) determined that groundwater-level declines were widespread across the Columbia Plateau. Wanapum basalt unit groundwater-level declines were mostly small to moderate, with few areas of large declines. Grande Ronde basalt unit groundwater-level declines were moderate in most areas, with some greater than 200 ft. Although comparable, trends in groundwater levels in the upper Umatilla River Basin are generally more consistent with trends observed in the lower Umatilla River Basin (Burns and others, 2012). In the Umatilla River Basin, Burns and others (2012) determined that groundwater levels were declining in deeper CRBG aquifers, while a small group of shallow CRBG aquifers have either stable or slightly rising water levels. Similarly, groundwater levels in the upper Umatilla River Basin indicate long-term water level declines in the Grande Ronde basalt unit in localized areas. In contrast, groundwater levels in wells completed in the Wanapum basalt unit do not show long-term declines in the upper Umatilla River Basin.

Trends in groundwater levels across the Columbia Plateau were attributed to groundwater pumping, changes in recharge (from the introduction of irrigation and from variable climate), and commingling (Ely and others, 2014). Commingling is the connection of multiple aquifer units by an open borehole that crosses low-permeability units. In the upper Umatilla River Basin, the presence of groundwater-level declines in the Grande Ronde basalt unit, and not (to date) in the Wanapum basalt unit, indicates that commingling between basalt aquifer units in the Wanapum and Grande Ronde basalt units is not responsible for the observed groundwater-level declines in the study area; however, commingling between multiple water-bearing zones likely influences water levels within the Grande Ronde basalt unit in areas of the upper Umatilla River Basin. Groundwater pumping appears to be the dominant driver of long-term (on the scale of decades) groundwater-level declines that have been observed in Grande Ronde basalt unit in the upper Umatilla River Basin.

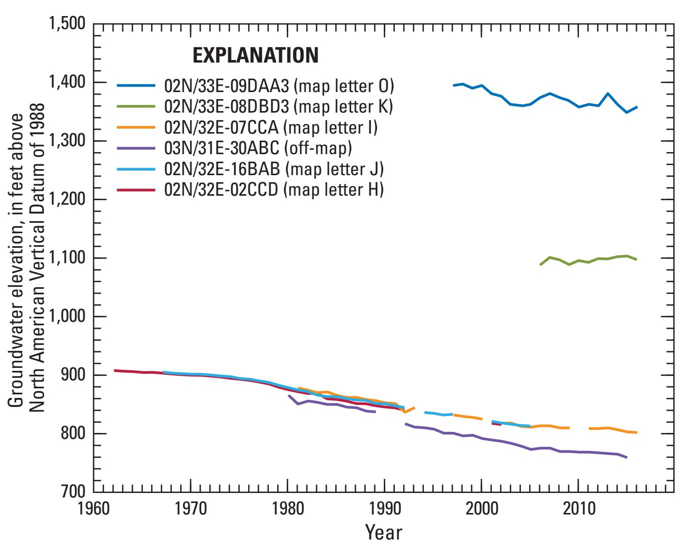


Figure 10. Groundwater elevations for selected wells near Pendleton and Mission, upper Umatilla River Basin, Oregon. See figure 7 for well (map letter) locations.

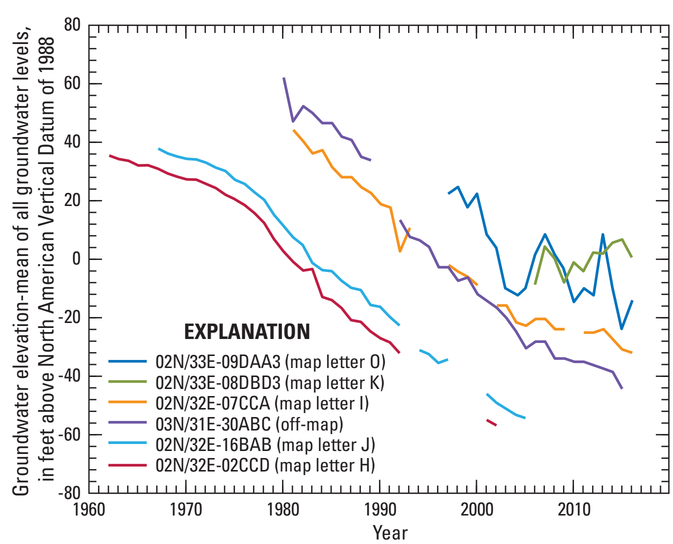


Figure 11. Groundwater elevations for selected wells during month of February, upper Umatilla River Basin, Oregon. See figure 7 for well (map letter) locations.

Groundwater Budget

The groundwater budget is an accounting of the amount of groundwater moving in and out of the study area by various processes. The components of the groundwater budget in the upper Umatilla River Basin study area include groundwater recharge; groundwater discharge to surface water, evapotranspiration, and wells; subsurface flow into and out of the basin; and changes in groundwater storage. The groundwater budget can be represented as:

$$\text{INFLOW} = \text{OUTFLOW} \pm \text{STORAGE} \tag{1}$$

$$\text{INFLOW} = \text{RECHARGE} + \text{SUB}_{\text{IN}} \tag{2}$$

$$\text{OUTFLOW} = \text{DISCHARGE} + \text{ET} + \text{PUMPING} + \text{SUB}_{\text{OUT}} \tag{3}$$

where

STORAGE is the change in the volume of water stored in the groundwater system,
RECHARGE is recharge to the groundwater system from precipitation, irrigation, and streams,
SUB_{IN} is the subsurface flow of groundwater into the study area,
DISCHARGE is discharge of groundwater to streams and springs,
ET is evapotranspiration directly from aquifers,
PUMPING is discharge of groundwater to wells, and
SUB_{OUT} is the subsurface flow of groundwater out of the study area.

Each of these components is described and quantified with the exception of evapotranspiration from the aquifer system. Although evapotranspiration from the soil zone is a very large component of the overall hydrologic budget, evapotranspiration directly from aquifers is a very small component of the groundwater budget. Evapotranspiration from the aquifer system in the upper Umatilla River Basin is likely to occur only in vegetated areas of very shallow groundwater near the Umatilla River and its tributaries, and adjacent to springs. In most areas of the basin, depth to water precludes evapotranspiration directly from aquifers, and it is assumed to be a small component of the groundwater budget.

Recharge from Precipitation and Applied Irrigation Waters

Recharge to aquifers in the upper Umatilla River Basin occurs through natural and artificial means. Precipitation and stream leakage are natural sources of recharge. Infiltration of irrigation water is an artificial source of recharge.

Recharge from infiltration of precipitation is estimated using a regression equation developed by Bauer and Vaccaro (1990) relating annual recharge to annual calendar year precipitation:

$$R = (P^2 \times 0.00865) + (P \times 0.1416) - 1.28 \tag{4}$$

where

R is recharge, in inches, and
P is precipitation, in inches.

Equation 4 was developed using a daily-time-step moisture and energy balance model (Deep Percolation Model, Bauer and Vaccaro, 1987) on the Columbia Plateau for 1956–77. The regression equation predicts the simulated recharge values as a function of mean annual precipitation with a correlation coefficient of 0.92. Equation 4 yields negative values when annual precipitation is less than 6.48 in. In areas with annual precipitation of less than 6.48 in., recharge from precipitation is assumed to be zero. This did not limit calculations during the recharge estimate period of record because recorded annual precipitation was 6.48 in. or greater in all parts of the study area during 1951–2010.

For this study, annual recharge estimates were calculated for 60 water years (1951–2010) using 4 km gridded precipitation values from PRISM for the upper Umatilla River Basin (Precipitation-elevation Regressions on Independent Slopes Model) (Oregon Climate Service, 2011) (fig. 12). The start year, 1951, was selected because it coincides with the beginning of groundwater pumping for irrigation in the Umatilla River Basin. Annual water year recharge estimates were used to estimate monthly recharge by proportioning the annual water year recharge into monthly values based on monthly landscape evapotranspiration (ET). Monthly landscape ET was estimated using the Thornthwaite method (Dunne and Leopold, 1978) which is based on air temperature. Monthly air temperature data (1951–2010) were taken from the PRISM model (PRISM Climate Group, 2014). Monthly net precipitation was then calculated (precipitation minus evapotranspiration), and the calculated annual water year recharge amount was apportioned to months having net precipitation greater than zero, starting in September and then going backward through the water year to October. An example of this method is shown for a single 4-km PRISM cell within the study area for the 2010 water year (fig. 13*A* and table 7), which assumes a lag between the onset of fall precipitation and replenishment of the summer soil moisture deficit, resulting in a late winter and spring recharge pulse. Water levels from shallow wells (for example 02N/33E-09ADA1, map letter M, figs. 7 and 9) reflect this timing.

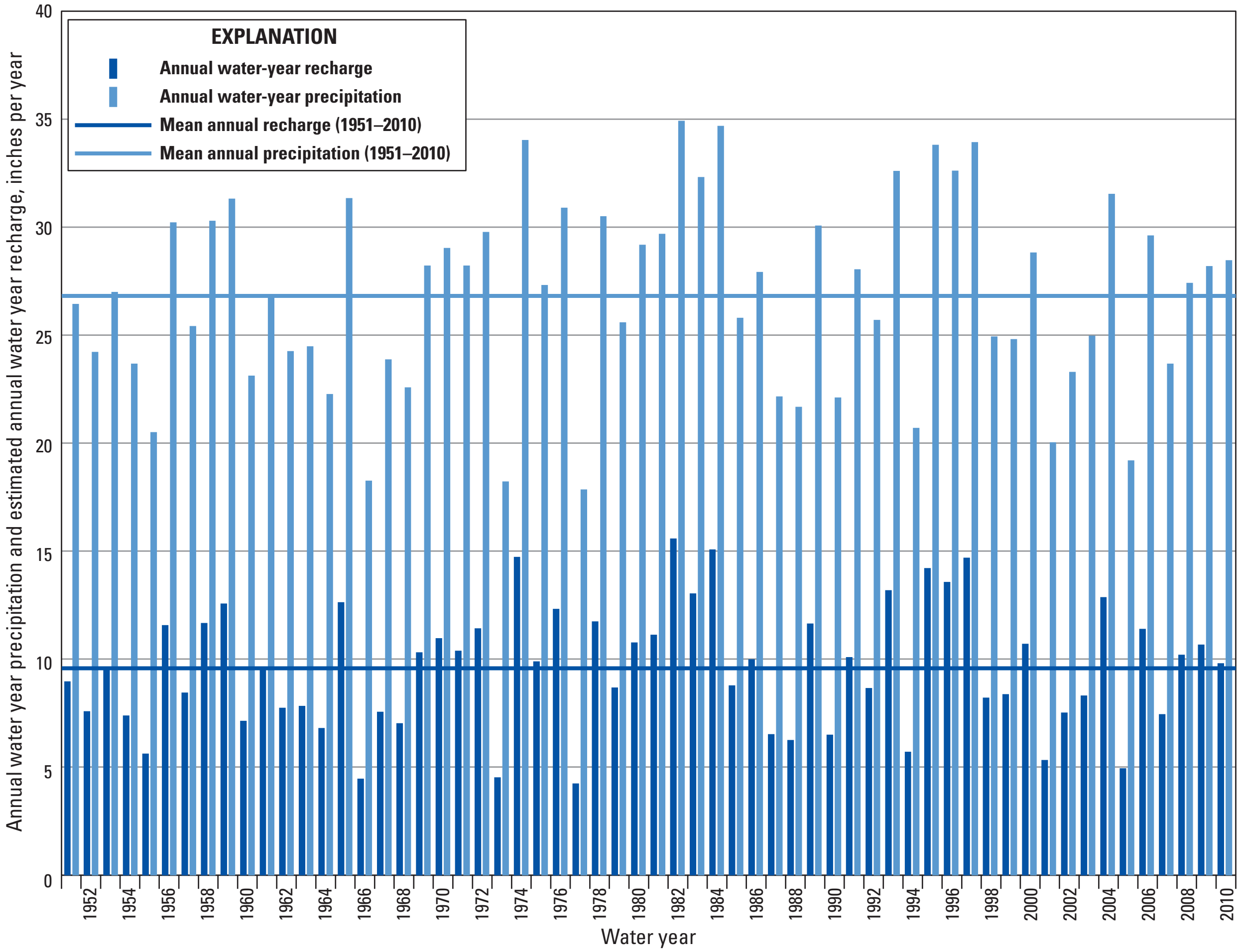


Figure 12. Annual water year precipitation and estimated annual water year recharge from infiltration of precipitation, upper Umatilla River Basin, Oregon, 1951–2010.

Table 7. Example of recharge estimate method for a single 4-km PRISM cell using precipitation, landscape evapotranspiration, net precipitation, and recharge for water year 2010, upper Umatilla River Basin, Oregon.

[Precipitation from monthly 4 km PRISM, evapotranspiration calculated from Thornthwaite method, annual recharge estimated using a modified Bauer and Vacarro (1990) regression equation. Example location shown on figure 11. All values are in inches. Values are rounded. **Abbreviations**: ET, evapotranspiration; NA, not applicable]

Component	October	November	December	January	February	March	April	May	June	July	August	September	Total
Precipitation	1.51	1.71	1.65	2.02	0.67	1.33	2.35	3.29	2.59	0.19	0.30	1.39	18.97
Potential ET	1.45	0.84	0.00	0.59	0.83	1.14	1.58	2.08	3.04	4.18	3.14	2.88	21.77
Net precipitation	0.06	0.87	1.65	1.43	-0.17	0.19	0.77	1.20	-0.45	-3.99	-2.85	-1.50	NA
Recharge	0.00	0.00	0.92	1.43	0.00	0.19	0.77	1.20	0.00	0.00	0.00	0.00	4.52

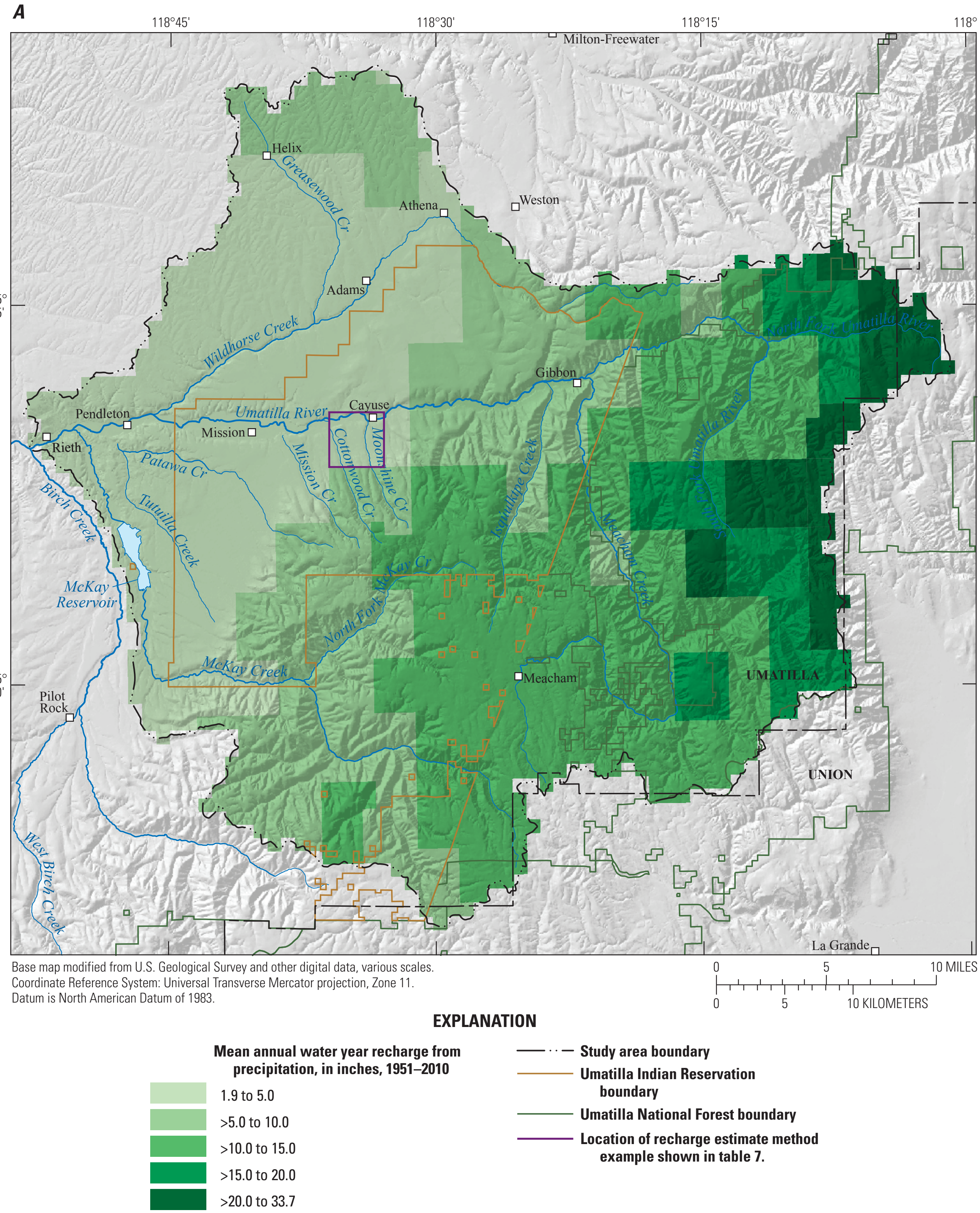


Figure 13. Estimated mean annual recharge from (*A*) infiltration of precipitation for 1951–2010, and from (*B*) infiltration of irrigation water for 1985–2007, upper Umatilla River Basin, Oregon.

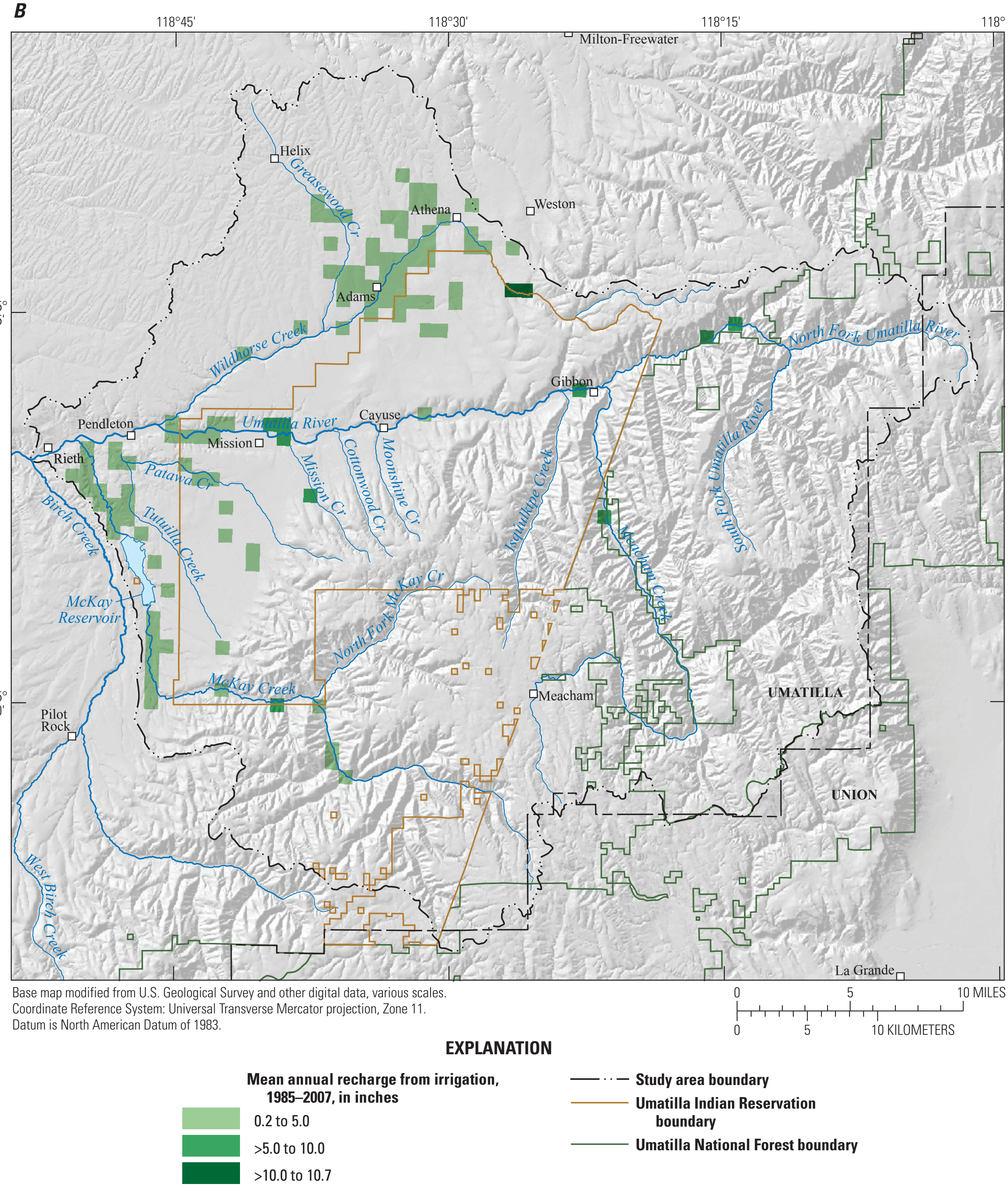


Figure 13.—Continued

Mean annual (water year) recharge from infiltration of precipitation is correlated with observed precipitation and occurs mostly from November to May (fig. 14). Mean water year recharge from precipitation for 1951–2010 (fig. 11) is about 9.6 in/yr, or 467,500 acre-ft/yr over the entire upper basin. Mean water year recharge from precipitation for 1951–2010 ranged from 1.9 to 33.7 in. over the study area (fig. 13*A*), and for water year 2010 ranged from 3 in. in the west-northwest region of the study area to nearly 30 in. in the Blue Mountains. The mean recharge for the upper Umatilla River Basin for water year 2010 was 9.8 in; equivalent to about 478,500 acre-ft/yr. Estimated mean monthly recharge for 2000–10 ranges from 0 to 2.3 in. (fig. 14). The upland areas contribute about 85 percent of the recharge to the groundwater system in the study area.

In agricultural areas, irrigation water is commonly the principal source of recharge from April through October. For irrigated areas, data from the soil water balance model (SOWAT) results described in detail in Kahle and others (2011) was used to estimate recharge from infiltration of irrigation for calendar years 1985–2007 (fig. 13*B*) (J. Haynes, U.S. Geological Survey, written commun., 2012). Methods from Kahle and others (2011) were used to estimate a mean annual recharge rate of 1,500 acre-ft/yr (about 2.2 in/yr) for the approximately 13 mi^2 of groundwater and surface water irrigated land in the upper Umatilla River Basin.

Discharge to Springs

The upper Umatilla River Basin contains numerous springs. During September–August 2009, measured discharge to springs surveyed by the CTUIR ranged from no discernable flow to 77.3 acre-ft/yr (0.1 cubic feet per second), with largest flows occurring at faults, fractures, or flow contacts (table 5). This work complemented a spring inventory completed by the U.S. Forest Service (USFS) in the Umatilla National Forest during July–October 2008, where 39 springs in the upper Umatilla River Basin were located and inventoried (Johnson and Clifton, 2008). Discharge from springs in the survey conducted by the USFS ranged from 0.2 to 32 acre-ft/yr, with a mean discharge of 4.3 acre-ft/yr. Thirteen of the 39 springs were located on or near the geologic contact associated with the Vantage Horizon. This suggests the Vantage Horizon has low permeability and induces horizontal flow along this contact where the sedimentary interbed is present (Johnson and Clifton, 2008). In the groundwater budget, spring discharge is assumed to be included in estimates of discharge to streams.

Recharge from and Discharge to Streams

Streamflow consists of surface runoff and groundwater discharge (baseflow). Streamflow data from the study area were analyzed to determine the relative proportions of runoff and groundwater discharge. The hydrologic character of each stream reach was evaluated using both hydrograph separation and seepage run data analyses.

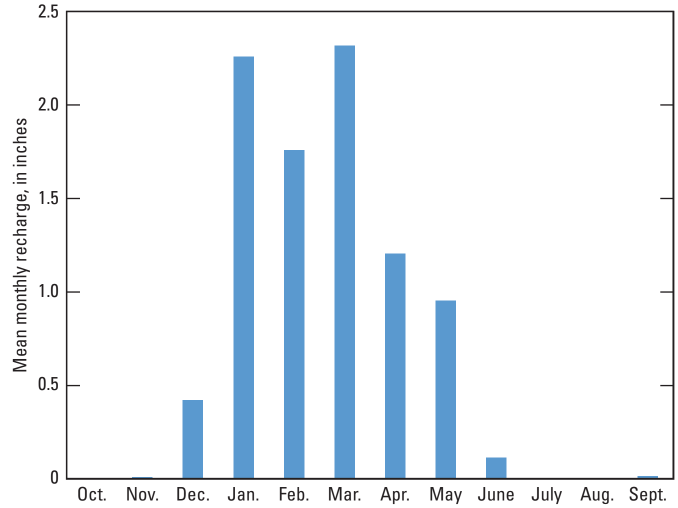


Figure 14. Estimated mean monthly recharge for 2000–10 from infiltration of precipitation, upper Umatilla River Basin, Oregon.

The analyses in this study relied on historical streamflow records from 23 sites in the upper Umatilla River Basin (table 8; fig. 7) that include 16 USGS, 4 OWRD, and 3 USFS streamflow-gaging stations. Periods of record range from 4 to 86 years. Daily streamflow data were used to calculate mean monthly and annual streamflows.

Baseflow Analysis

Hydrograph separation is a method for differentiating the component of streamflow originating as groundwater discharge from the runoff component in stream hydrographs. Hydrograph separation was performed on hydrographs from 23 streamgages in the upper Umatilla River Basin using the PART computer program (Rutledge, 1998, 2007). Six of the 23 streamgages were selected to represent the total baseflow originating from the upper Umatilla River Basin (table 8). Total drainage area for the 6 streamgages is about 828 square-miles, and includes all high-elevation, relatively wet drainage basins in the study area. Average annual baseflow estimates for these 6 streamgages total 374,400 acre-ft. Hydrograph separation integrates conditions in the entire drainage upstream of the analyzed streamgage. Consequently, hydrograph separation can provide insights into groundwater conditions in watersheds high in the basin.

Baseflow analysis indicates that all streams in the upper Umatilla River Basin are composed of a large component of groundwater. The percentage of annual flow consisting of baseflow varies from 65 percent at the upper Wildhorse Creek near Athena (streamflow-gaging station 14020900) to 87 percent at the North Fork Umatilla River (streamflow-gaging station 14019500). Annual baseflow yields per unit of drainage area are greatest in the high-elevation, relatively wet, eastern portion of the basin and smallest in the low-elevation, relatively dry, western portion of the basin.

Table 8. Mean annual baseflow and annual recharge at streamflow-gaging stations in upper Umatilla River Basin, Oregon.

[**Bold** signifies streamflow-gaging station used in calculation of total discharge to streams in groundwater budget (table 11). **Map identifier**: Correlates to streamflow-gaging stations shown on figure 7. **Mean annual recharge**: Period of record is 1951–2010. **Abbreviations**: ft^3/s, cubic feet per second; in., inch; mi^2, square mile; OR, Oregon; NR, near; NA, not applicable; USFS, streamflow-gaging station maintained by U.S. Forest Service]

Map identifier	Station name	Station ID	Class	Drainage area (mi^2)	Record length (years)	Baseflow time period (calendar year)	Annual precipitation (in.)	Mean annual baseflow		Baseflow/ stream flow (percent)	Mean annual recharge (in.)
								(ft^3/s)	(in.)		
1	North Fork Umatilla River near Gibbon, OR	14019500, USFS	1	31	23.0	1982–1996	48.3	60.4	26.5	87.0	23.5
2	South Fork Umatilla River near Gibbon, OR	USFS	1	48.4	16.0	1982–1996	42.2	62.8	17.6	78.5	17.8
3	Umatilla River near Corporation, OR	USFS	1	91.4	16.0	1982–1996	44.4	147.8	22.0	83.0	19.9
4	Umatilla River above Meacham Creek, near Gibbon, OR	14020000	1	131	77.5	1934–2009	41.8	180.5	18.7	79.7	17.4
5	Meacham Creek at Gibbon, OR	14020300	1	176	35.2	1976–2009	34.9	150.2	11.6	73.8	14.0
6	Isqu'ulktpe Creek near Gibbon, OR	14020520	1	32.6	8.4	1999–2006	33.3	20.7	8.6	70.0	11.6
7	**Umatilla River near Cayuse, OR**	**14020700**	**1**	**384**	**7.0**	**1969–1974**	**36.3**	**423.8**	**15.0**	**72.8**	**14.3**
8	**Moonshine Creek near Mission, OR**	**14020740**	**1**	**4.62**	**12.2**	**1992–2003**	**29.5**	**2.3**	**6.8**	**76.8**	**9.0**
9	**Cottonwood Creek near Mission, OR**	**14020760**	**1**	**4.01**	**5.9**	**1992–1996**	**28.2**	**1.6**	**5.5**	**70.5**	**8.4**
10	Umatilla River at West Reservation Boundry near Pendleton, OR	14020850	1	440.8	15.0	1996–2009	34.4	390.5	12.0	74.2	13.2
11	Wildhorse Creek near Athena, OR	14020900	1	15.5	23.0	1967–1977	29.1	7.1	6.2	65.2	9.4
12	**Wildhorse Creek at Pendleton, OR**	**14020990**	**2**	**195**	**11.0**	**1999–2009**	**19.7**	**12.9**	**0.9**	**74.2**	**5.0**
13	Umatilla River at Pendleton, OR	14021000	2	637	85.9	1935–1988	29.8	368.1	7.8	73.4	10.7
14	Patawa Creek at West Boundary near Pendleton, OR	14021980	1	30.0	12.2	1992–2003	20.0	3.9	1.8	76.6	5.0
15	**Tutuilla Creek at Pendleton, OR**	**14021990**	**1**	**60.3**	**4.0**	**2007–2007**	**18.4**	**1.5**	**0.3**	**64.2**	**4.4**
16	Umatilla River above Mckay Creek near Pendleton, OR	14022000	2	700	11.0	1924–1933	28.7	337.5	6.5	72.6	10.0
17	North Fork Mckay Creek near Pilot Rock, OR	14022200	1	48.6	30.7	1974–2003	31.7	31.4	8.8	74.4	10.4
18	**Mckay Creek near Pilot Rock, OR**	**14022500**	**1**	**180**	**68.4**	**1930–1988**	**27.8**	**74.7**	**5.6**	**73.3**	**8.9**
19	West Birch Creek at Pilot Rock, OR	14024100	1	122	4.0	2007–2009	22.6	15.5	1.7	79.7	NA
20	East Birch Creek near Pilot Rock, OR	14024200	1	69.7	5.7	1968–1972	28.2	25.1	4.9	79.3	NA
21	East Birch Creek at Pilot Rock, OR	14024300	1	91.9	4.0	2007–2009	26.4	26.3	3.9	81.0	NA
22	Birch Creek near Pilot Rock, OR	14024500	2	240	7.9	1920–1926	23.7	40.8	2.3	75.7	NA
23	Birch Creek at Rieth, OR	14025000	2	291	55.4	1930–1975	22.2	38.0	1.8	77.8	NA

Seepage Run Analysis

A seepage run is a series of streamflow measurements made over a short period of time along a specific reach of river to quantify gains and losses along the reach. After accounting for all tributary inflows and diversions, and assuming that evaporation is negligible, the difference in discharge between streamflow measurement locations is attributed to groundwater. In contrast to hydrograph separation analyses, which integrate conditions for entire drainage basins upstream of the streamgage locations, seepage runs provide information only for the lower-elevation part of the main-stem Umatilla River. Two seepage runs were made on the Umatilla River and tributaries in late summer on September 19 and 25, 2007 (figs. 15*A*–*B*, appendix B) that span the river from the confluence of the north and south forks (river mile 89.5) downstream to about the town of Umatilla (river mile 2.1).

Sources of uncertainty in seepage runs include error in the streamflow measurements and changing conditions along the stream during the period which measurements were made. Because of the intrinsic error in streamflow measurements, differences in streamflow between measurement sites of less than 5 percent were not considered significant. Active USGS streamgages on the main stem of the Umatilla River showed that there was little variation of streamflow during the seepage runs. The most variability occurred at the streamflow-gaging station Umatilla River at west reservation boundary near Pendleton (14020850, fig. 7, map number 10,) on September 19. The range of the streamgage for that day was 10 percent of the daily mean discharge. All other ranges for the 2 days were less than 5 percent. Weather was typical for eastern Oregon in late summer. Daytime highs were 21 and 23 °C, respectively, on the measurement days, and there was a trace of rain on September 19 and no rain on September 25 (National Oceanic and Atmospheric Administration, 2012).

Overall, gaining and losing reaches are fairly evenly distributed along the reach of the Umatilla River evaluated with seepage runs (fig. 15*A*–*B*). Gain and loss rates along the stream in the upper Umatilla River Basin generally were less than 3 (ft^3/s)/mi, but there were a few reaches with losses ranging from 5 to 34 (ft^3/s)/mi. The largest change (-34 [ft^3/s]/mi) was the loss between river miles 73.5 and 73.2 on the September 19 seepage run, and that is attributable to hyporheic exchange with a large gravel deposit in this reach (Scott O'Daniel, CTUIR, oral commun., 2012). Measurement sites at river miles 73.5 and 73.2 were selected to verify if possible inflow from or outflow to the Thorn Hollow Fault Zone affected streamflow. The hyporheic flow in gravel deposits and floodplains confounds the effect, if any, of faults as a pathway for groundwater-surface water exchange.

Gains and losses along the reach of the main stem evaluated using seepage runs relate to geology and topography. Large gains or losses are generally attributable to hyporheic flow into and out of gravel deposits along the stream channel (Jones and others, 2007; Poole and others, 2008). The Umatilla River gains water in the high-elevation, relatively wetter part of the basin, where the river is restricted to a relatively small channel through the Grande Ronde Basalt. As the channel begins to widen westward in the low, dry part of the basin, where the river flows on a relatively thin sediment layer over the basalt, the river begins to lose water to the subsurface as indicated by the data from both the September 19 and 25 seepage runs (fig. 15). Data from the September 19 seepage run also show several segments where the Umatilla River gains and then loses over short distances, indicating hyporheic flow into and out of the sediments overlying the Wanapum Basalt.

Where the geologic contact between the Grande Ronde Basalt and the Wanapum Basalt occurs beneath the alluvium, measurements indicate a net gain to the stream (measured stream segments were 1.4 and 1.7 mi). This net gain may be attributable to either hyporheic flow, or that the contact is relatively impermeable and promotes discharge where the contact intersects land surface (Johnson and Clifton, 2008), or both. Flow gains cannot be confirmed with data from the September 25 seepage run because data collection points were more widely spaced in the upper basin on that day.

Measured flows on the Umatilla River main stem were within 4 ft^3/s at comparable locations between the September 19 and September 25 seepage runs (appendix B). The cumulative change in streamflows measured at comparable locations between the September 19 and September 25 seepage runs were within 9 ft^3/s. The cumulative change (when accounting for diversions or tributary inflow) in streamflow for the measured reaches between the North Fork Umatilla River and the Umatilla River at Pendleton during the September 19 and 25 seepage runs were -15.3 and -6.5 ft^3/s (about 11,100 and 4,700 acre-ft/yr), respectively. The cumulative change in streamflow for the measured reaches between the North Fork Umatilla River and just outside the study area at Umatilla River upstream of Coombs Canal were -18.2 and -11.1 ft^3/s (about 13,200 and 8,000 acre-ft/yr), respectively. These values are small compared to the total estimated annual discharge of baseflow to streams (374,400 acre-ft/yr). Because the gains and losses along the mainstem of the Umatilla River in the upper basin are generally attributed to hyporheic flow, and not a net gain from or loss to groundwater, values are not included in the groundwater budget.

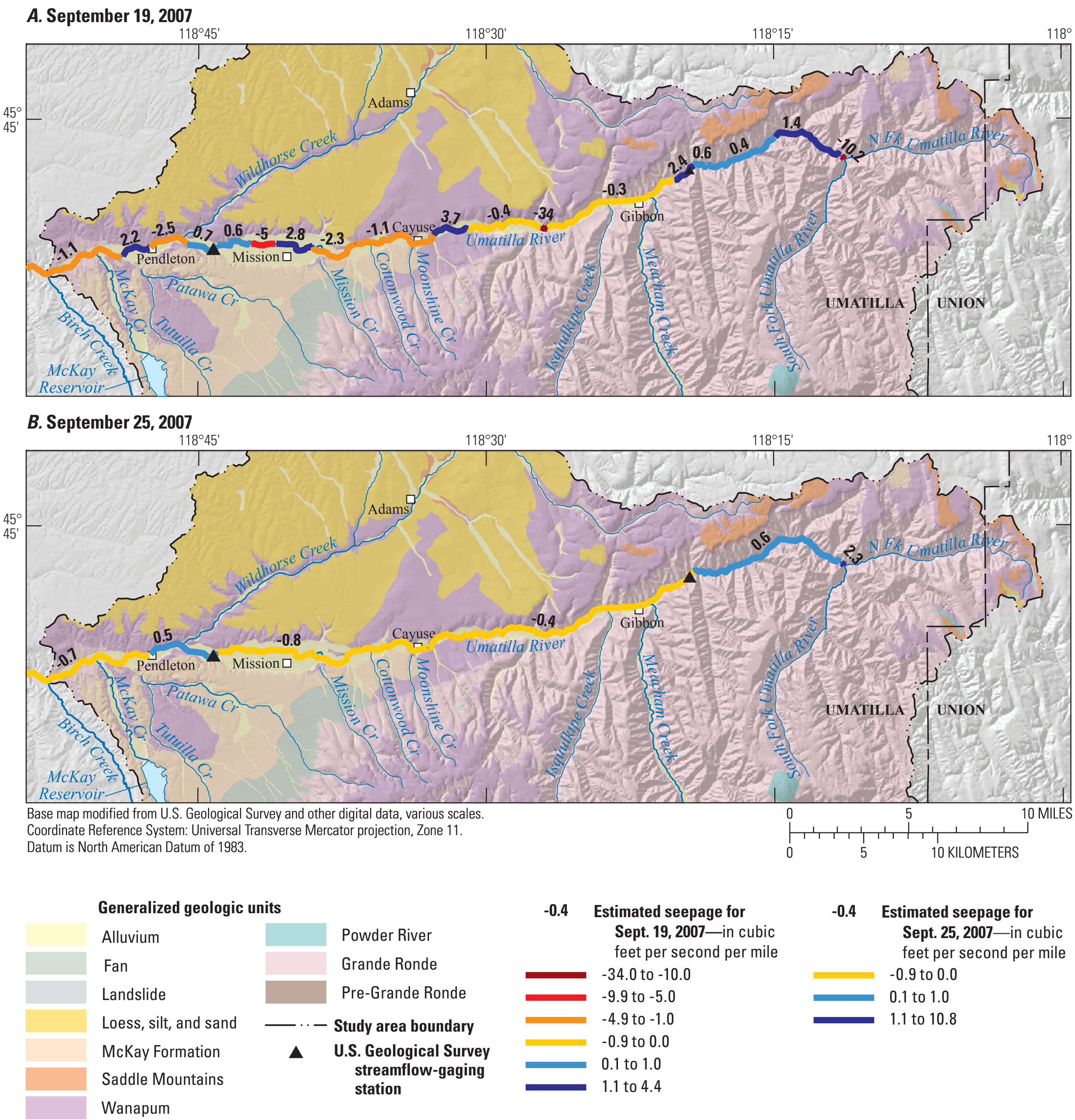


Figure 15. Estimated seepage for selected Umatilla River reaches on (*A*) September 19, 2007, and (*B*) September 25, 2007, upper Umatilla River Basin, Oregon.

Discharge to Wells

Groundwater in the upper Umatilla River Basin is primarily used for agricultural-irrigation, municipal, or domestic use (fig. 16). Municipal water use includes all water distributed by public supply systems and is used for drinking, industrial, commercial, and urban landscape irrigation purposes. Domestic water use includes all water pumped from private or grouped domestic wells.

Agricultural groundwater use was estimated using water rights information from 2011 OWRD files and 2013 information from the CTUIR. Google Earth Imagery from 2009, 2011, and 2012 were used to determine whether areas with mapped water rights were actively irrigated. During that time period, about 13 mi^2 (8,528 acres) were irrigated with groundwater and surface water. The area included both primary groundwater rights, where groundwater is the only source of irrigation water, and supplemental groundwater rights, where groundwater is only used when surface water is not available for irrigation.

The distribution of pumping among wells was determined using OWRD data. In cases where there were multiple wells associated with a single groundwater right, the estimated pumping volume was distributed equally among the wells. In 2012, there were 22 supplemental groundwater rights in the study area. For supplemental groundwater rights, it was assumed that one-sixth of the total water use was derived from surface water, and five-sixths of the total water use was derived from groundwater. The division of water volumes is based on typical surface water availability for 1 month of the 6-month irrigation season in the upper Umatilla River Basin.

In water year 2010, 142 of 211 active OWRD groundwater rights and CTUIR water permits had metered wells. Meter readings from water year 2010 for the 142 wells were used to determine an average irrigation groundwater rate of use (about 1 acre-ft/acre). This average use value was applied to irrigated parcels associated with the 69 non-metered wells to estimate total irrigation groundwater use of 7,575 acre-ft for water year 2010 (table 9).

Municipal groundwater use by the City of Pendleton and the Umatilla Indian Reservation was determined using data from public works departments, which provide OWRD annual withdrawal volumes by wells. For the Cities of Adams, Athena, Helix, and Rieth, which did not have water use data available through 2010, municipal use for water year 2010 was extrapolated based on a linear regression of the total use from previous years (table 10). On average, population increases have been less than 1 percent per year from 2000 to 2010 (U.S. Census Bureau, 2014). Total water year 2010 estimated volume of use was apportioned between a city's active municipal wells based on relative pumpage volumes between those wells in the most recent 2 or 3 years of available groundwater use data (table 10). Values of monthly well use obtained from each city for the city's municipal well that contributed the greatest volume of groundwater were averaged on a monthly basis over the most recent 3 years of record to estimate monthly municipal groundwater use. During water year 2010, 3,173 acre-feet of municipal water use in the upper Umatilla River Basin was estimated as coming from groundwater (table 9).

Domestic well water use data were estimated using OWRD's well log database and CTUIR's Water Resources Department database. Only wells determined to be domestic use within the study area were considered. Each domestic well was assigned an average annual use of 0.3 acre-ft/yr based on an estimated per capita use of groundwater for each dwelling unit in the upper Umatilla River Basin (fig. 16). This value was derived from the assumption that per capita use of groundwater in Oregon is approximately equal to 100 gal/d (0.11 acre-ft/yr) (Maupin and others, 2014, p. 22).

Table 9. Groundwater withdrawals for water year 2010, upper Umatilla River Basin, Oregon.

[All values are in acre-feet.]

Month	Year	Irrigation	Municipal	Domestic	Total
October	2009	379	236	25	640
November	2009	0	119	17	136
December	2009	0	129	22	151
January	2010	0	61	30	91
February	2010	0	52	36	88
March	2010	0	66	41	107
April	2010	0	109	42	151
May	2010	379	90	42	511
June	2010	757	216	44	1,017
July	2010	1,894	764	60	2,718
August	2010	2,272	824	64	3,160
September	2010	1,894	507	43	2,444
Total by use		**7,575**	**3,173**	**466**	**11,214**

Table 10. Mean annual municipal groundwater use, period of record, upper Umatilla River Basin, Oregon.

[**Population served:** From U.S. Census Bureau (2010); Rieth population estimate from City of Pendleton (2014; http://pendleton.or.us/fire-ambulance/area-and-population-served)]

Municipal system	Population served	Period of record	Record length	Groundwater use (acre-feet)
Adams	350	1991–2013	24	60
Athena	1,126	1988–2008	21	313
Helix	184	1988–2002	11	84
Mission[1]	1,037	1998–2013	16	773
Pendleton	16,612	1988–2013	26	1,874
Pilot Rock[2]	1,502	1988–2008	19	466
Rieth[2]	150	1989–2006	11	68
Weston[2]	667	1988–2013	26	184

[1]Mission census-dedicated-community is serviced by Confederated Tribes of the Umatilla Indian Reservation municipal wells.

[2]Borders study area.

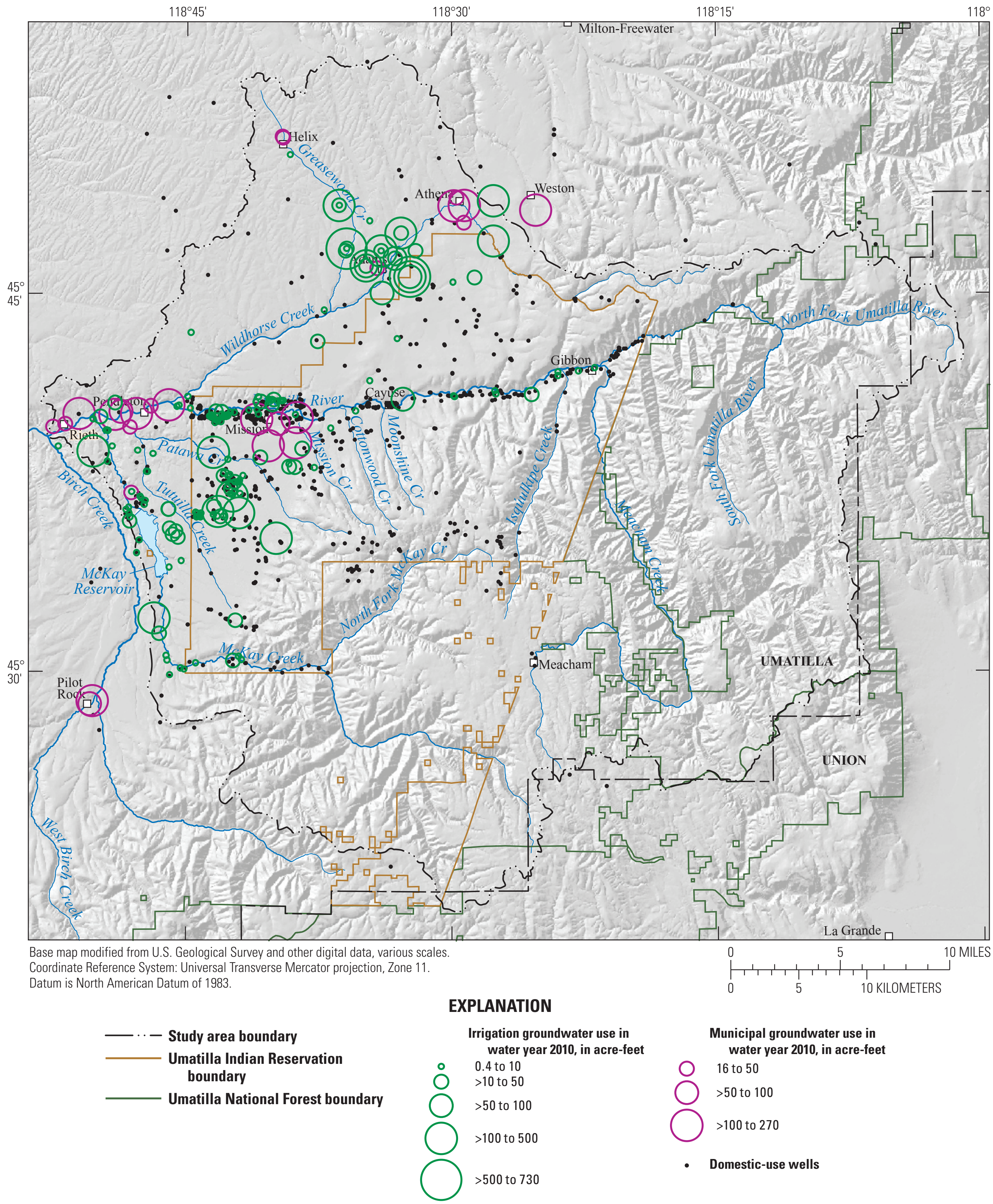


Figure 16. Location and primary use of groundwater in the upper Umatilla River Basin, Oregon, water year 2010.

The estimated population in the study area not served by municipal systems (excluding Weston and Pilot Rock), is 4,158. Average household size for Umatilla County, Oregon, is 2.67 persons (U.S. Census Bureau, 2010), and results in 1,557 households supplied by groundwater from wells. CTUIR records for this analysis indicate 1,911 total wells in study area (26 municipal, 222 irrigation wells, and 1,663 domestic wells). Total domestic use in the study area is estimated to be 466 acre-feet/yr (table 9).

Monthly groundwater use for water year 2010 is summarized in table 9. Total groundwater use in 2010 was approximately 11,214 acre-ft, and total surface water use was 4,720 acre-ft (appendix C). Groundwater use is about 2.5 percent of the estimated total out from the groundwater budget in the upper Umatilla River Basin. Of the groundwater withdrawals in 2010, 67.5 percent (7,575 acre-ft) was for irrigation, 28.3 percent (3,173 acre-ft) was for municipal use, and 4.2 percent (466 acre-ft) was for domestic use.

Subsurface Flow Across Study-Area Boundaries

The southern and eastern study area boundaries correspond to natural drainage divides across which little or no groundwater flow occurs. The western boundary (Birch Creek) and the northern boundary, both of which correspond to local drainage divides, may have groundwater flow across them. The amount of groundwater flow into or out of the study area across such boundaries (subsurface flow) depends on geology and hydraulic head distribution. Estimates of subsurface flow into and out of the study area were calculated using the Columbia Plateau regional groundwater flow model (Ely and others, 2014).

The regional model indicates that both subsurface inflow and outflow occur. Subsurface flow into the study area ranged from 32,300 to 35,200 acre-ft/yr during the 1951–2007 simulation period (table 11), and the flow is reasonably assumed, based on groundwater flow directions, to largely occur along the northern and northeastern boundaries. The average simulated inflow to the study area was 33,400 acre-ft/yr. Subsurface flow out of the study area ranged from 57,500 to 62,700 acre-ft/yr during the same period and is assumed to generally occur along the western boundaries. The average simulated outflow from the study area was 59,600 acre-ft/yr. Net subsurface flow is outward, and ranged from 25,000 to 27,700 acre-ft/yr during the simulation with an average of 26,100 acre-ft/yr (table 11). Simulated subsurface flow values for the sedimentary unit and the Saddle Mountains basalt unit are generally small compared to other hydrogeologic units. The Wanapum basalt unit and Grande Ronde basalt unit are the most areally extensive and thickest units in the study area, and most subsurface flow occurs within these units. Simulated net subsurface flow for the Wanapum and Grande Ronde basalt units is approximately 5 percent of the total groundwater budget.

Budget Summary

Recharge is the largest component of the groundwater budget (table 11). Total recharge estimates for the upper Umatilla River Basin average 467,500 acre-ft/yr from precipitation and 1,500 acre-ft from irrigation. Average annual discharge to rivers (baseflow) estimates indicate about 374,400 acre-ft of groundwater leaves the upper Umatilla River Basin through discharge to streams (tables 8 and 11). For the period 1951-2010, mean water year recharge from precipitation ranged from 207,000 to 760,000 acre-ft. As a percentage, estimates of baseflow exhibit a similar range of values due to the correlation between precipitation and streamflow (from which the baseflow estimates are derived). Because streamflow and baseflow are directly correlated with precipitation, the uncertainty surrounding baseflow values can be directly attributed to values derived from data collected over different periods of record and different climate signatures during those periods. For the six streamflow-gaging stations used to estimate annual baseflow for the upper Umatilla River Basin, periods of record range from 4 to over 68 years.

Other components of the groundwater budget are small relative to recharge. Net subsurface flow out of the study area is simulated as 26,100 acre-ft annually, which is about 5 percent of annual inputs to the groundwater system. Withdrawals by wells in water year 2010 were 11,214 acre-ft, or 2 percent of long-term mean water year recharge in the study area (tables 9 and 11). Long-term changes in storage, primarily caused by pumping, are probably small (CTUIR, 2007), and present at only a few locations in the upper Umatilla River Basin. Overall, water supply and demand in the upper Umatilla River Basin follows typical patterns with the greatest demand for groundwater during the summer when surface water supplies are at their lowest levels (fig. 17).

Because there is uncertainty in the groundwater budget estimates, there is a discrepancy between the total in and total out for the groundwater budget components of 56,900 acre-ft. In addition to the effects of climate variability during the period of analysis, estimates of recharge, baseflow, and boundary flux are sensitive to the method used to provide the estimate. Because baseflow is often used as a surrogate of recharge, a comparison of the results of the baseflow analysis (groundwater leaving the system) to the estimate of recharge (water entering the groundwater system) demonstrates differences in most drainage areas in the upper Umatilla River Basin, and the implicit uncertainty associated with these estimates (tables 8 and 11). Further analysis of methods to estimate recharge and baseflow are outside the scope of this study; however, additional analysis should be considered for future work. Most uncertainty in the groundwater budget is attributed to these estimates, which are the largest components of the groundwater budget.

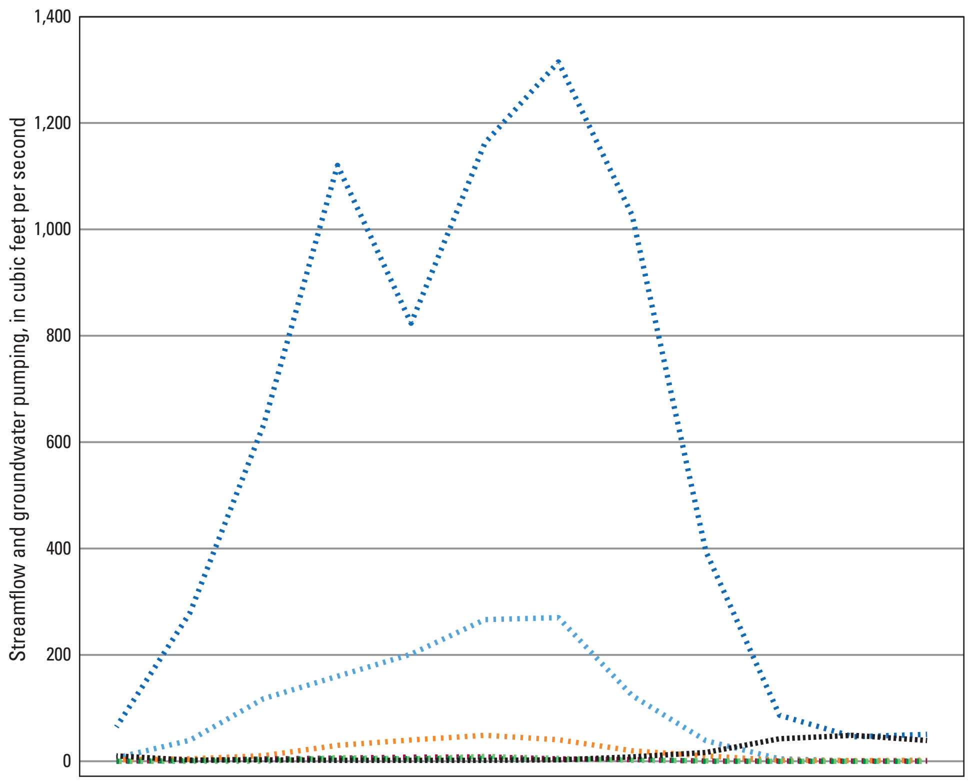
Table 11. Estimates of groundwater budget components, upper Umatilla River Basin, Oregon.

[**Bold** numbers are used to calculate Total IN and Total OUT. **Kaf**: Kaf is kilo acre feet. **Value** and **Range** expressed in thousand acre-feet per year. Source and remarks: PRISM, PRISM Climate Group, Oregon State University; SOWAT, soil water balance model (Kahle and others, 2011)]

Budget item	Kaf		Source and remarks
	Value	Range	
IN:			
Precipitation			
Precipitation (this study)	1,388		Water year 2010 from PRISM Climate Group (2011)
Precipitation (this study)	1,307		Water years 1951–2010 mean, from PRISM Climate Group (2011)
Recharge from precipitation			
Recharge from precipitation (this study)	478.5		Water year 2010, estimated using Bauer and Vacarro (1990) regression equation
Recharge from precipitation (this study)	**467.5**	207–760	Water years 1951–2010 mean, estimated using Bauer and Vacarro (1990) regression equation, , minimum (1977) and maximum (1984)
Recharge from irrigation	**1.5**		Based on 1985–2007 annual average, calendar year, estimated using Kahle and others (2011) soil water balance model (SOWAT)
Subsuface flow, gross in	**33.4**	32.3–35.2	1951–2007 annual average, calendar year, simulated subsurface inflow from Columbia Plateau regional groundwater flow model (Ely and others, 2014)
Total in (Ely and others, 2014)	497		1951–2007 annual average, calendar year, simulated recharge from Columbia Plateau regional groundwater model (Ely and others, 2014)
Total IN	[2]**502.4**		
OUT:			
Discharge to streams			
Umatilla River near Cayuse, Oregon	307.0		Mean annual baseflow (12.2 years) - Station ID 14020700
Moonshine Creek near Mission, Oregon	1.7		Mean annual baseflow (7.0 years) - Station ID 14020740
Cottonwood Creek near Mission, Oregon	1.2		Mean annual baseflow (5.9 years) - Station ID 14020760
Wildhorse Creek at Pendleton, Oregon	9.3		Mean annual baseflow (11.0 years) - Station ID 14020990
Tutuilla Creek at Pendleton, Oregon	1.1		Mean annual baseflow (4.0 years) - Station ID 14021990
McKay Creek near Pilot Rock, Oregon	54.1		Mean annual baseflow (68.4 years) - Station ID 14022500
Total discharge to streams (this study)	**374.4**		
Discharge to wells			
Discharge to wells (irrigation)	7.6		Based on water year 2010 primary irrigation, groundwater
Discharge to wells (municipal)	3.2		Based on water year 2010 metered use or averaged value
Discharge to wells (domestic)	0.5		Based on 2010 U.S. Census Bureau (2010) population estimates
Total discharge to wells (this study)	[1]**11.2**		
Evapotranspiration			
Discharge to evapotranspiration	**0.3**		2007, irrigated areas (Kahle and others, 2011)
Subsurface flow			
Subsurface flow, gross out	**59.6**	57.5–62.7	1951–2007 annual average, calendar year, simulated subsurface outflow from Columbia Plateau regional groundwater flow model (Ely and others, 2014)
Subsurface flow, net out	[1]26.1	25.0–27.7	1951–2007 annual average, calendar year, net simulated subsurface outflow from Columbia Plateau regional groundwater flow model (Ely and others, 2014)
Total OUT	[2]**445.5**		

[1]Differences due to rounding.

[2]Differences between Total IN and Total OUT are the result of uncertainty in independently estimated values.



EXPLANATION	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
Groundwater pumping, water year 2010	9.9	2.3	2.5	1.5	1.6	1.9	2.7	8.0	16.4	42.1	48.8	38.9
14020700 Umatilla River near Cayuse, OR	64.4	279.4	633.4	1,120	823	1,162	1,315	1,026	394	86.6	46.1	50.5
14022500 Mckay Creek near Pilot Rock, OR	6.1	39.5	117.9	159.7	201.5	266.1	269.8	123.4	38.5	4.5	0.7	1.7
14020990 Wildhorse Cr at Pendleton, OR	2.8	4.3	10.6	29.7	40.2	48.6	40.2	19.5	9.9	1.7	1.4	1.6
14021990 Tutuilla Creek at Pendleton, OR	0.0	0.0	0.0	6.8	4.6	8.9	5.4	1.6	0.5	0.0	0.0	0.0
14020740 Moonshine Creek near Mission, OR	0.2	1.4	4.6	6.0	7.7	8.2	4.4	3.1	0.5	0.1	0.1	0.1
14020760 Cottonwood Creek near Mission, OR	0.0	1.4	4.0	4.8	5.1	5.2	2.8	4.2	0.1	0.0	0.0	0.0

Figure 17. Mean monthly pumping (water year 2010) and streamflow for select streamgages (station ID and station name) used in calculation of total discharge to streams in groundwater budget, during period of record in the upper Umatilla River Basin, Oregon.

Data Needs

Data needs were identified during analysis of the hydrogeology of the upper Umatilla River Basin. A key need is improvement of the spatial and temporal distribution of water-level data collection. This includes measuring more wells in upland areas, more uniform well coverage in lowland areas, and more focus in areas of highest water use. Monitoring would ideally be periodic and include both shallow and deep wells throughout the upper Umatilla River Basin. In particular, instrumentation of deep wells in both the Pendleton and Mission areas would provide important information to help determine the spatial effects of groundwater pumping in the upper basin.

Time-series measurements of water levels in “well pairs” (wells located near to one another, but open to different aquifers) would be useful for determining seasonal changes in vertical head gradients. An improved network of deep wells with short open intervals to provide long-term groundwater level data would help determine if commingling in basalt aquifers might be affecting water levels in parts of the upper Umatilla River Basin.

Continued measurement of streamflow at active streamflow-gaging stations, including USFS and USGS streamflow-gaging stations subjected to minimal effects from water diversions and overlapping basin areas between drainage basins, would help minimize temporal climate signals evident in streamflow data collected in short-term intervals. Exploration of remote sensing applications, water-balance modeling, tracer methods or geophysical techniques would help to improve understanding and better quantify recharge processes in the upper Umatilla River Basin.

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Appendix A. Summary of Water-Level Elevation Measurements for Selected Wells in the Upper Umatilla River Basin, Oregon, 2008, 2009, and 2012

Table A1. Summary of water-level elevation measurements for selected wells in the upper Umatilla River Basin, Oregon, 2008, 2009, and 2012.

[**USGS site identification No.:** Site identification number permanently assigned to the well by the U.S. Geological Survey (USGS) and recorded in National Water Information System, a national computer database maintained by USGS. Selected well locations shown in figure 7. **Well log identifier**: Unique identifier combining a four-letter county code and a well-log number with as many as five digits, which is assigned to the well when a water well report is filed by the well driller with the Oregon Water Resources Deparment (OWRD) and recorded in Ground Water Resource Information Distribution, a statewide computer database maintained by OWRD. **CTUIR well identification No.**: Unique number assigned to the well by the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) when a well report is filed by the driller with CTUIR and recorded in the CTUIR database. 2008, 2009, and 2012: Water level elevation above North American Vertical Datum of 1988 and date measurement was taken. **Source:** The agency recording and retaining the groundwater elevation data. **Abbreviations:** ft, foot]

USGS site identification No.	Well log identifier	CTUIR well identification No.	2008		2009		2012		Land surface elevation (ft)	Well depth (ft)		Well location		Source
			Water level (ft)	Date measured	Water level (ft)	Date measured	Water level (ft)	Date measured		2012	Original	Latitude (decimal degrees)	Longitude (decimal degrees)	
452730118514801	UMAT 94	1739	–	–	–	–	1,760	02-24-12	1,805	937	937	45.4578803	-118.8648282	OWRD
452751118461501	UMAT 6472	1781	–	–	1,920	–	–	02-24-12	794	794		45.4640203	-118.7719241	OWRD
452842118502301	UMAT 89	968	–	–	–	–	1,612	05-14-12	1,650	486	486	45.4783271	-118.8409074	CTUIR
452850118501501	UMAT 90	967	–	–	–	–	1,642	05-14-12	1,655	309	309	45.4801980	-118.8386617	CTUIR
NONE	UMAT 122	580	–	–	1,885	04-70-09	1,888	04-27-12	1,906	125	125	45.4996153	-118.6167360	CTUIR
NONE	UMAT 54788	914	1,726	10-09-08	1,728	04-07-09	1,730	04-27-12	1,753	240	240	45.5014604	-118.6705365	CTUIR
NONE	NONE	338	1,798	10-09-08	1,799	04-07-09	1,800	04-27-12	1,803	75	75	45.5020888	-118.6414729	CTUIR
NONE	NONE	364	–	–	1,541	04-07-09	–	–	1,540	211	211	45.5026227	-118.7503813	CTUIR
NONE	UMAT 55199	920	1,624	10-09-08	1,627	04-07-09	–	–	1,639	105	105	45.5068667	-118.7096893	CTUIR
NONE	UMAT 132	362	1,628	10-09-08	1,629	04-07-09	–	–	1,628	88	88	45.5086829	-118.7062111	CTUIR
NONE	UMAT 372	359	–	–	1,920	04-07-09	–	–	1,990	232	232	45.5294693	-118.6939435	CTUIR
453148118410701	UMAT 365	601	1,938	09-18-08	1,943	04-07-09	–	–	2,043	180	180	45.5299248	-118.6862732	CTUIR
NONE	UMAT 5950	818	2,063	09-18-08	2,065	04-07-09	–	–	2,080	330	330	45.5301481	-118.6839491	CTUIR
NONE	UMAT 5949	831	1,803	09-18-08	1,802	04-07-09	–	–	1,839	203	203	45.5347948	-118.7116627	CTUIR
453230118464601	UMAT 326	1735	–	–	–	–	1,332	02-24-12	1,580	400	400	45.5349460	-118.7806988	OWRD
NONE	UMAT 370	361	1,814	09-18-08	1,815	04-07-09	–	–	1,853	313	313	45.5352961	-118.7118445	CTUIR
NONE	UMAT 364	190	–	–	–	–	1,707	04-18-12	1,780	434	434	45.5381665	-118.7179003	CTUIR
453221118512201	UMAT 332	1774	–	–	–	–	1,491	02-24-12	1,615	600	600	45.5390561	-118.8571577	OWRD
NONE	UMAT 408	700	–	–	–	–	3,232	04-24-12	3,406	320	320	45.5685303	-118.5948117	CTUIR
NONE	UMAT 410	695	–	–	–	–	3,197	04-24-12	3,355	300	300	45.5686005	-118.5897773	CTUIR
NONE	UMAT 55984	941	–	–	1,791	03-30-09	–	–	1,879	201	201	45.5743314	-118.6749905	CTUIR
453443118474501	UMAT 292	1761	–	–	–	–	1,294	05-14-12	1,460	700	700	45.5783417	-118.7969235	CTUIR
NONE	UMAT 299	1762	–	–	–	–	1,291	05-14-12	1,456	525	525	45.5790941	-118.7974576	CTUIR
NONE	UMAT 354	602	1,507	09-18-08	1,511	03-26-09	–	–	1,659	210	210	45.5806145	-118.7041719	CTUIR

Table A1. Summary of water-level elevation measurements for selected wells in the upper Umatilla River Basin, Oregon, 2008, 2009, and 2012.—Continued

USGS site identification No.	Well log identifier	CTUIR well identification No.	2008		2009		2012		Land surface elevation (ft)	Well depth (ft)		Well location		Source
			Water level (ft)	Date measured	Water level (ft)	Date measured	Water level (ft)	Date measured		2012	Original	Latitude (decimal degrees)	Longitude (decimal degrees)	
NONE	UMAT 53832	900	1,505	09-18-08	1,507	03-26-09	–	–	1,661	304	304	45.5811527	-118.7024834	CTUIR
453510118275001	UMAT 417	231	–	–	–	–	3,636	05-01-12	3,733	421	421	45.5862759	-118.4668897	CTUIR
NONE	UMAT 5781	812	1,498	09-18-08	1,511	03-26-09	1,505	04-18-12	1,652	405	405	45.5873710	-118.6965308	CTUIR
453516118394401	UMAT 55430	9	1,818	10-01-08	1,817	04-01-09	1,823	05-02-12	1,826	121	121	45.5877331	-118.6633514	CTUIR
453519118395201	UMAT 339, 340, 341, 6430	252	–	–	–	–	1,568	05-02-12	1,817	1,150	255	45.5880710	-118.6654895	CTUIR
NONE	UMAT 347	121	–	–	1,517	03-30-09	–	–	1,680	195	195	45.5886031	-118.6856581	CTUIR
454307118373101	UMAT 414	293	–	–	–	–	3,375	05-01-12	3,770	450	450	45.5895538	-118.4555139	CTUIR
NONE	UMAT 381	431	–	–	3,474	04-13-09	–	–	3,588	131	131	45.5904654	-118.5563566	CTUIR
NONE	UMAT 56010	945	–	–	3,454	04-13-09	–	–	3,563	250	250	45.5907743	-118.4872375	CTUIR
NONE	UMAT 376	267	–	–	–	–	3,423	04-23-12	3,518	283	283	45.5911494	-118.5042811	CTUIR
NONE	UMAT 384	219	–	–	3,519	04-13-09	–	–	3,585	360	360	45.5912986	-118.5546617	CTUIR
NONE	UMAT 383	409	–	–	–	–	3,411	04-24-12	3,571	500	143	45.5924400	-118.5580907	CTUIR
NONE	UMAT 380	621	–	–	3,406	04-13-09	3,247	04-24-12	3,569	465	465	45.5927540	-118.5581635	CTUIR
NONE	NONE	646	1,494	09-18-08	1,497	03-26-09	–	–	1,573	240	240	45.5940602	-118.7048995	CTUIR
NONE	UMAT 344	685	–	–	1,511	03-30-09	–	–	1,650	191	191	45.5949716	-118.6841180	CTUIR
453859118401901	UMAT 345	358	–	–	1,512	03-30-09	–	–	1,608	215	215	45.5956327	-118.6905485	CTUIR
NONE	UMAT 388	388	–	–		–	3,575	04-23-12	3,635	283	283	45.5956491	-118.4771219	CTUIR
NONE	UMAT 53744	895	1,506	09-08-08	1,512	03-30-09			1,600	242	242	45.5965443	-118.6909862	CTUIR
NONE	UMAT 375	421	–	–	–	–	3,596	04-23-12	3,653	291	291	45.5987185	-118.5012825	CTUIR
NONE	UMAT 343	604	1,500	10-09-08	1,503	03-30-09	–	–	1,567	185	185	45.6002323	-118.6941872	CTUIR
NONE	UMAT 349	592	1,493	09-08-08	1,496	03-26-09	–	–	1,526	120	120	45.6013256	-118.7054017	CTUIR
NONE	UMAT 5947	830	–	–	1,383	03-24-09	–	–	1,403	375	375	45.6015767	-118.7406594	CTUIR
453609118440801	UMAT 1074	339	–	–	–	–	1,401	04-26-12	1,412	292	292	45.6021731	-118.7369592	CTUIR
NONE	UMAT 1070	569	1,383	09-08-08	1,387	03-26-09	–	–	1,401	380	380	45.6022483	-118.7379361	CTUIR
NONE	NONE	759	1,500	09-08-08	1,502	03-30-09	–	–	1,559	155	155	45.6024440	-118.6937537	CTUIR
NONE	UMAT 53583	888	–	–	1,476	03-26-09	–	–	1,472	350	350	45.6027897	-118.7206030	CTUIR
NONE	UMAT 50209	860	–	–	1,474	03-24-09	1,461	04-18-12	1,490	600	600	45.6029517	-118.7152222	CTUIR
NONE	UMAT 1072	551	–	–	–	–	1,388	04-18-12	1,408	525	525	45.6033840	-118.7372402	CTUIR
NONE	UMAT 55988	943	–	–	1,384	03-26-09	–	–	1,389	383	383	45.6036607	-118.7415318	CTUIR
NONE	UMAT 53695	881	–	–	1,420	03-26-09	–	–	1,450	205	205	45.6036716	-118.7247976	CTUIR
NONE	UMAT 50310	854	–	–	1,388	03-26-09	–	–	1,398	120	120	45.6047127	-118.7398331	CTUIR
NONE	UMAT 509	617	–	–	–	–	1,390	04-18-12	1,412	475	475	45.6048068	-118.7366045	CTUIR
NONE	UMAT 55772	936	–	–	1,388	03-26-09	–		1,392	144	144	45.6051473	-118.7414367	CTUIR
NONE	UMAT 53426	879	–	–	–	–	1,435	04-18-12	1,443	850	600	45.6068809	-118.7244728	CTUIR
NONE	UMAT 57015	1141	–	–	–	–	1,520	04-27-12	1,573	1,068	1,068	45.6095010	-118.6803335	CTUIR

Table A1. Summary of water-level elevation measurements for selected wells in the upper Umatilla River Basin, Oregon, 2008, 2009, and 2012.—Continued

USGS site identification No.	Well log identifier	CTUIR well identification No.	2008		2009		2012		Land surface elevation (ft)	Well depth (ft)		Well location		Source
			Water level (ft)	Date measured	Water level (ft)	Date measured	Water level (ft)	Date measured		2012	Original	Latitude (decimal degrees)	Longitude (decimal degrees)	
NONE	UMAT 5776	813	–	–	–	–	1,375	04-18-12	1,463	500	500	45.6158175	-118.7263500	CTUIR
NONE	UMAT 53718	893	–	–	1,471	03-30-09	–	–	1,499	180	180	45.6161105	-118.6893041	CTUIR
NONE	UMAT 1084	254	1,369	09-08-08	1,415	04-01-09	–	–	1,448	140	140	45.6162552	-118.7038021	CTUIR
NONE	UMAT 5779	817	1,404	09-05-08	1,406	03-31-09	–	–	1,474	180	180	45.6163615	-118.7302531	CTUIR
NONE	NONE	739	1,346	09-05-08	1,349	03-31-09	–	–	1,479	360	360	45.6167535	-118.7382303	CTUIR
NONE	UMAT 6592	849	1,379	09-09-08	1,409	04-01-09	–	–	1,431	200	200	45.6174106	-118.7084033	CTUIR
NONE	UMAT 54783	1823	–	–	–	–	1,137	06-18-12	1,245	284	284	45.6183628	-118.7953718	CTUIR
NONE	UMAT 50148	858	1,352	09-09-08	1,407	04-01-09	–	–	1,421	228	228	45.6190220	-118.7089910	CTUIR
NONE	UMAT 1034	560	1,391	10-01-08	1,407	04-01-09	1,389	05-02-12	1,420	315	315	45.6202125	-118.7046147	CTUIR
NONE	UMAT 6079	635	1,440	09-08-08	1,453	04-01-09	–	–	1,482	100	100	45.6204879	-118.6848435	CTUIR
NONE	NONE	880	1,437	09-08-08	1,452	04-01-09	–	–	1,480	185	185	45.6207872	-118.6846857	CTUIR
NONE	UMAT 1054	629	1,371	09-05-08	1,407	04-01-09	–	–	1,415	225	225	45.6211120	-118.7052576	CTUIR
NONE	UMAT 50134	857	1,805	09-11-08	1,809	04-02-09	–	–	2,010	399	399	45.6212254	-118.6290408	CTUIR
NONE	UMAT 55746	934	1,442	09-08-08	1,456	04-01-09	–	–	1,479	202	202	45.6212451	-118.6853792	CTUIR
NONE	UMAT 6064	836	1,367	09-09-08	1,392	04-01-09	–	–	1,399	225	225	45.6214441	-118.7149396	CTUIR
NONE	UMAT 54329	906	1,982	09-02-08	1,986	04-02-09	1,992	05-01-12	2,070	140	140	45.6218994	-118.6316387	CTUIR
NONE	UMAT 6059	842	1,365	09-09-08	1,389	03-31-09	–	–	1,398	200	200	45.6222897	-118.7113736	CTUIR
NONE	UMAT 6060	840	1,368	09-09-08	1,389	03-31-09	–	–	1,396	200	200	45.6223802	-118.7137367	CTUIR
NONE	UMAT 1055	628	1,359	09-05-08	1,394	04-01-09	–	–	1,404	208	208	45.6229179	-118.7060821	CTUIR
NONE	UMAT 5791	658	1,361	09-05-08	1,363	03-31-09	–	–	1,434	280	280	45.6235738	-118.7253310	CTUIR
NONE	UMAT 1069	532	1,353	09-05-08	1,355	03-31-09	–	–	1,433	360	360	45.6252714	-118.7261656	CTUIR
NONE	UMAT 1046	245	1,384	09-09-08	1,406	04-01-09	–	–	1,408	325	210	45.6254024	-118.7030530	CTUIR
NONE	UMAT 1047	243	1,378	09-09-08	1,391	04-01-09	–	–	1,399	105	105	45.6254686	-118.7046457	CTUIR
NONE	UMAT 1027	464	–	–	1,804	04-08-09	–	–	1,837	195	195	45.6263616	-118.6299080	CTUIR
NONE	UMAT 5778	771	1,356	09-16-08	1,362	03-31-09	–	–	1,388	105	105	45.6265809	-118.7151219	CTUIR
NONE	UMAT 55282	939	1,293	09-05-08	1,292	03-31-09	–	–	1,374	217	205	45.6266936	-118.7451187	CTUIR
NONE	UMAT 55711	932	1,360	09-09-08	1,371	04-01-09	–	–	1,386	300	300	45.6282060	-118.7057807	CTUIR
NONE	UMAT 5647	773	–	–	–	–	1,364	04-18-12	1,371	630	630	45.6283207	-118.7113520	CTUIR
NONE	UMAT 5789	820	1,445	09-08-08	1,457	04-01-09	–	–	1,475	261	261	45.6287015	-118.6716575	CTUIR
NONE	NONE	377	1,393	09-09-08	1,399	03-31-09	–	–	1,415	211	211	45.6291444	-118.6941346	CTUIR
NONE	UMAT 1063	508	1,349	09-16-08	1,352	03-31-09	–	–	1,390	315	315	45.6291986	-118.7152274	CTUIR
NONE	UMAT 53944	902	1,275	09-09-08	1,354	03-31-09	–	–	1,365	305	305	45.6294379	-118.7106804	CTUIR
453747118413801	UMAT 1042	476	1,386	09-05-08	1,392	03-31-09	–	–	1,403	300	300	45.6297386	-118.6965516	CTUIR
NONE	UMAT 1057	545	1,348	09-05-08	1,350	03-31-09	–	–	1,402	155	155	45.6299708	-118.7171497	CTUIR
NONE	UMAT 54200	905	1,342	09-09-08	1,360	03-31-09	–	–	1,369	263	263	45.6302210	-118.7088696	CTUIR
NONE	NONE	156	1,633	09-02-08	1,633	04-02-09	1,638	04-18-12	1,696	182	182	45.6306402	-118.6397569	CTUIR
NONE	UMAT 55599	930	1,343	09-05-08	1,346	03-31-09	–	–	1,381	290	290	45.6310287	-118.7150395	CTUIR

Table A1. Summary of water-level elevation measurements for selected wells in the upper Umatilla River Basin, Oregon, 2008, 2009, and 2012.—Continued

USGS site identification No.	Well log identifier	CTUIR well identification No.	2008		2009		2012		Land surface elevation (ft)	Well depth (ft)		Well location		Source
			Water level (ft)	Date measured	Water level (ft)	Date measured	Water level (ft)	Date measured		2012	Original	Latitude (decimal degrees)	Longitude (decimal degrees)	
NONE	UMAT 1017	94	1,377	09-11-08	1,380	03-31-09	–	–	1,390	51	51	45.6314105	-118.6967047	CTUIR
NONE	UMAT 1025	186	–	–	1,723	04-08-09	–	–	1,756	58	58	45.6325629	-118.6236215	CTUIR
NONE	UMAT 55598	929	1,613	09-02-08	1,613	04-02-09	1,616	04-18-12	1,638	400	400	45.6342827	-118.6418390	CTUIR
NONE	UMAT 1010	590	1,344	09-05-08	1,346	03-31-09	–	–	1,352	145	145	45.6344090	-118.7129102	CTUIR
NONE	UMAT 5471	766	–	–	1,634	04-08-09	–	–	1,692	175	175	45.6351967	-118.6327047	CTUIR
NONE	NONE	643	–	–	1,673	04-08-09	–	–	1,696	165	165	45.6352165	-118.6237367	CTUIR
NONE	UMAT 1021	543	1,468	09-02-08	1,480	04-02-09	1,491	04-08-12	1,539	360	360	45.6354063	-118.6531756	CTUIR
NONE	UMAT 53427	884	1,689	09-02-08	1694	04-02-09	1,697	05-12-12	1,766	250	250	45.6354934	-118.6219869	CTUIR
NONE	UMAT 1134	241	–	–	1,795	04-10-09	–	–	1,868	247	247	45.6365307	-118.6027064	CTUIR
NONE	UMAT 5790	822	1,577	07-25-08	1,606	04-02-09	–	–	1,664	353	353	45.6369301	-118.6342306	CTUIR
NONE	UMAT 50574	868	1,455	09-02-08	1,470	04-02-09	1,474	04-18-12	1,532	325	325	45.6372781	-118.6532050	CTUIR
NONE	UMAT 1020	221	1,378	09-02-08	1,385	04-08-09	–	–	1,401	155	155	45.6415149	-118.6823556	CTUIR
NONE	UMAT 5777	772	1,326	09-05-08	1,328	03-31-09	–	–	1,365	210	210	45.6415651	-118.7050698	CTUIR
453831118404501	NONE	530	1,365	09-02-08	1,377	04-08-09	–	–	1,401	260	260	45.6417661	-118.6805795	CTUIR
NONE	NONE	911	1,358	09-05-08	1,362	03-31-09	–	–	1,406	245	245	45.6427598	-118.6937366	CTUIR
NONE	UMAT 1023	355	1,530	09-02-08	1,527	04-02-09	–	–	1,569	112	112	45.6455641	-118.6365991	CTUIR
NONE	UMAT 1129	455	1,588	09-02-08	1,591	04-02-09	–	–	1,595	181	181	45.6477016	-118.6052195	CTUIR
NONE	UMAT 1130	450	1,583	09-02-08	1,586	04-02-09	–	–	1,598	156	156	45.6477326	-118.6042964	CTUIR
453859118401901	UMAT 53456	898	–	–	–	–	1,198	05-03-12	1,438	975	975	45.6494446	-118.6731730	CTUIR
NONE	UMAT 1123	616	1,760	09-04-08	1,758	04-02-09	–		1,837	225	225	45.6498769	-118.5586433	CTUIR
453904118384501	UMAT 5590	262	–	–	–	–	1,388	04-27-12	1,463	800	452	45.6512554	-118.6470580	CTUIR
NONE	NONE	320	1,466	09-02-08	1,467	04-02-09	–	–	1,528	120	120	45.6527702	-118.6032210	CTUIR
NONE	UMAT 1132	118	–	–	1,478	04-09-09	–	–	1,496	57	57	45.6528051	-118.6090617	CTUIR
NONE	NONE	374	1,271	09-05-08	1,275	03-31-09	–	–	1,347	273	273	45.6530537	-118.7264159	CTUIR
NONE	UMAT 1003	443	1,407	09-02-08	1,438	04-02-09	–	–	1,513	256	256	45.6531633	-118.6219195	CTUIR
NONE	UMAT 1004	444	1,407	09-02-08	1,438	04-02-09	–	–	1,476	231	231	45.6566050	-118.6235848	CTUIR
NONE	UMAT 1007	463	1,264	09-05-08	1,272	03-31-09	–	–	1,379	290	290	45.6570020	-118.7254335	CTUIR
NONE	UMAT 1122	232	1,676	09-04-08	1,680	04-03-09	1,681	04-17-12	1,721	380	258	45.6584719	-118.5494474	CTUIR
NONE	UMAT 55915	916			1,371	04-02-09	–	–	1,390	200	200	45.6598021	-118.6417249	CTUIR
NONE	UMAT 1124	490	1,472	09-04-08	1,475	04-02-09	–	–	1,516	181	181	45.6600684	-118.5956249	CTUIR
NONE	UMAT 55903	908	1,351	09-04-08	1,373	04-02-09	–	–	1,383	127	127	45.6606585	-118.6410054	CTUIR
NONE	UMAT 1116	228	1,476	09-04-08	1,484	04-02-09	–	–	1,492	120	120	45.6606897	-118.5943204	CTUIR
NONE	UMAT 55275	922	–	–	1,476	04-02-09	–	–	1,498	240	240	45.6613176	-118.5931829	CTUIR
453942118481201	UMAT 53636	36	–	–	–	–	822	01-03-12	1,081	1,009	1,009	45.6614749	-118.8035403	OWRD
453949118514901	UMAT 55330	1098	–	–	–	–	809	02-24-12	980	287	287	45.6635286	-118.8650958	OWRD
453954118432701	UMAT 893	394	–	–	–	–	1,133	04-13-12	1,250	575	222	45.6644039	-118.7252244	CTUIR
454000118502901	UMAT 870	515	–	–	1,128	04-06-09	–	–	1,238	431	138	45.6645942	-118.7233560	CTUIR

Table A1. Summary of water-level elevation measurements for selected wells in the upper Umatilla River Basin, Oregon, 2008, 2009, and 2012.—Continued

USGS site identification No.	Well log identifier	CTUIR well identification No.	2008		2009		2012		Land surface elevation (ft)	Well depth (ft)		Well location		Source
			Water level (ft)	Date measured	Water level (ft)	Date measured	Water level (ft)	Date measured		2012	Original	Latitude (decimal degrees)	Longitude (decimal degrees)	
NONE	UMAT 897	180	–	–	1,173	04-07-09	1,180	04-13-12	1,232	135	135	45.6645996	-118.7229968	CTUIR
453954118401601	UMAT 943	563	1,212	10-01-08	1,233	04-01-09	1,232	05-02-12	1,230	182	182	45.6649217	-118.6722606	CTUIR
453956118424001	UMAT 55262	27	–	–	–	–	1,102	05-02-12	1,204	968	604	45.6654041	-118.7119941	CTUIR
453958118394901	UMAT 951, 6078	475	1,206	10-01-08	1,222	03-04-09	1,234	05-02-12	1,245	190	190	45.6660198	-118.6636279	CTUIR
NONE	UMAT 902	261	–	–	–	–	805	04-13-12	1,219	570	64	45.6662042	-118.7246250	CTUIR
NONE	UMAT 888	723	–	–	–	–	871	04-13-12	1,203	587	85	45.6663565	-118.7204960	CTUIR
454001118405901	UMAT 5929	582	–	–	–	–	1,349	05-03-12	1,215	1,057	1,057	45.6668441	-118.6841543	CTUIR
454002118404201	NONE	615	1,136	09-05-08	1,195	03-31-09	–	–	1,219	400	220	45.6669278	-118.6803054	CTUIR
NONE	UMAT 914	593	1,119	09-10-08	1,180	04-02-09	–	–	1,204	180	180	45.6672072	-118.7045774	CTUIR
NONE	NONE	647	1,117	09-10-08	–	–	–	–	1,204	204	204	45.6672319	-118.7035254	CTUIR
454004118412701	UMAT 915	562	1,144	10-01-08	1,187	04-01-09	–	–	1226	220	220	45.6677730	-118.6919491	CTUIR
454005118384301	UMAT 5930	789	–	–	–	–	1,378	05-03-12	1,283	1,100	1,100	45.6678236	-118.6459905	CTUIR
NONE	UMAT 56289	950	–	–	1,359	04-03-09	1,359	04-17-12	1,390	110	110	45.6679097	-118.5987363	CTUIR
NONE	UMAT 986	106	1,201	09-16-08	–	–	–	–	1,252	119	44	45.6679881	-118.6619787	CTUIR
NONE	UMAT 959	90	1,210	09-05-08	1,209	03-31-09	–	–	1,222	85	85	45.6680224	-118.6793240	CTUIR
NONE	UMAT 818	229	1,118	09-10-08	1,126	04-03-09	–	–	1,195	96	96	45.6682672	-118.7262932	CTUIR
NONE	UMAT 824	435	–	–	–	–	803	04-25-12	1,200	525	80	45.6683917	-118.7269903	CTUIR
NONE	UMAT 829	564	–	–	–	–	1,097	04-19-12	1,235	575	420	45.6689162	-118.7333613	CTUIR
NONE	UMAT 857	417	–	–	1,094	04-02-09	–	–	1,176	206	206	45.6692720	-118.7097626	CTUIR
454012118405701	UMAT 6077	512	1,139	09-05-08	1,199	03-31-09	–	–	1,217	280	280	45.6692783	-118.6832772	CTUIR
NONE	UMAT 782	614	–	–	–	–	797	04-19-12	1,138	460	460	45.6693361	-118.7359420	CTUIR
NONE	UMAT 540	717	–	–	1,084	04-06-09	–	–	1,128	200	200	45.6695875	-118.7442562	CTUIR
NONE	UMAT 5451	632	1,079	09-10-08	1,094	04-02-09	–	–	1,169	200	200	45.6696935	-118.7146669	CTUIR
454011118412101	UMAT 925	76	1,167	09-10-08	1,191	04-02-09	–	–	1,204	125	125	45.6698412	-118.6902654	CTUIR
NONE	UMAT 6072	494	–	–		–	1,032	04-19-12	1,171	525	175	45.6698798	-118.7281029	CTUIR
NONE	UMAT 992	348	1,286	07-18-08	1,290	03-30-09	–	–	1,300	130	130	45.6700464	-118.6315867	CTUIR
454013118412401	UMAT 911	623	1,126	09-10-08	1,187	04-02-09	–	–	1,203	300	300	45.6702647	-118.6908431	CTUIR
NONE	NONE	883	1,127	09-10-08	1,187	04-02-09	–	–	1,202	227	227	45.6702747	-118.6913826	CTUIR
454014118474701	UMAT 53635	19	–	–	–	–	806	01-03-12	1,053	761	761	45.6703271	-118.7975594	OWRD
454014118510302	UMAT 54072	966	–	–	–	–	802	01-03-12	1,048	826	1,086	45.6703842	-118.85099	OWRD
NONE	NONE	886	–	–	–	–	794	04-19-12	1,155	480	480	45.6705033	-118.7296101	CTUIR
454014118410101	UMAT 55286	500	–	–	–	–	1,205	05-02-12	1,214	25	25	45.6705601	-118.6842529	CTUIR
454014118410102	UMAT 55285	501	1,148	10-01-08	1,197	04-01-09	1,202	05-02-12	1,214	255	255	45.6705606	-118.6842144	CTUIR
NONE	UMAT 2538	407	1,061	09-17-08	1,095	04-02-09	–	–	1,168	220	131	45.6710280	-118.7103039	CTUIR
NONE	NONE	317	1,147	09-05-08	1,197	03-31-09	–	–	1,213	120	120	45.6712909	-118.6841336	CTUIR
454018118423001	UMAT 871	284	1,094	09-10-08	1,094	04-02-09	–	–	1,169	143	143	45.6715174	-118.7088809	CTUIR

Table A1. Summary of water-level elevation measurements for selected wells in the upper Umatilla River Basin, Oregon, 2008, 2009, and 2012.—Continued

USGS site identification No.	Well log identifier	CTUIR well identification No.	2008		2009		2012		Land surface elevation (ft)	Well depth (ft)		Well location		Source
			Water level (ft)	Date measured	Water level (ft)	Date measured	Water level (ft)	Date measured		2012	Original	Latitude (decimal degrees)	Longitude (decimal degrees)	
454019118421601	UMAT 855	584	–	–	–	–	1,049	04-13-12	1,177	655	480	45.6716454	-118.7051358	CTUIR
NONE	UMAT 783	610	1,124	09-10-08	1,126	04-3-09	–	–	1,142	75	75	45.6716716	-118.7315077	CTUIR
454018118484001	UMAT 55619	1106	–	–	–	–	801	01-03-12	1,045	852	852	45.6718727	-118.8125278	OWRD
NONE	UMAT 6343	844	1,056	09-10-08	1,092	04-02-09	1,121	04-19-12	1,163	418	418	45.6719628	-118.7121941	CTUIR
NONE	NONE	298	–	–	1,091	04-02-09	–	–	1,163	210	210	45.6720067	-118.7110656	CTUIR
NONE	UMAT 6338	843	1,139	07-16-08	1,198	03-31-09	–	–	1,213	254	254	45.6721341	-118.6837224	CTUIR
NONE	UMAT 837	97	1,122	09-10-08	1,124	04-03-09	–	–	1,141	54	54	45.6721968	-118.7313057	CTUIR
NONE	NONE	337	1,227	09-05-08	1,243	03-31-09	–	–	1,236	100	100	45.6722455	-118.6681520	CTUIR
NONE	UMAT 930	158	1,187	09-05-08	1,198	03-31-09	–	–	1,200	72	72	45.6725656	-118.6928896	CTUIR
NONE	UMAT 201	81	1,194	09-05-08	1,192	03-31-09	–	–	1,201	114	114	45.6727158	-118.6918670	CTUIR
NONE	UMAT 952	344	–	–	1,205	03-31-09	–	–	1,228	191	191	45.6728597	-118.6723173	CTUIR
NONE	UMAT 55846	937	1,086	09-10-08	1,125	04-02-09	–	–	1,173	205	205	45.6729296	-118.7053289	CTUIR
NONE	NONE	597	1,197	09-08-08	1,201	03-31-09	–	–	1,210	90	90	45.6737092	-118.6843345	CTUIR
NONE	UMAT 50166	867	1,198	07-16-08	1,201	03-31-09	–	–	1,211	85	85	45.6738940	-118.6827865	CTUIR
NONE	UMAT 819	227	1,105	09-10-08	1,110	04-08-09	–	–	1,132	120	120	45.6739634	-118.7370737	CTUIR
NONE	UMAT 55131	919	1,192	09-09-08	1,226	03-30-09	–	–	1,244	225	225	45.6740740	-118.6618893	CTUIR
NONE	NONE	640	1,213	09-08-08	1,237	03-30-09	–	–	1,252	105	105	45.6741613	-118.6583610	CTUIR
NONE	UMAT 987	103	1,258	09-08-08	1,264	03-30-09	–	–	1,278	57	57	45.6748115	-118.6426389	CTUIR
NONE	UMAT 50464	863	1,351	09-04-08	1,356	04-03-09	1,353	04-17-12	1,383	207	207	45.6749394	-118.5845304	CTUIR
NONE	NONE	885	1,436	09-04-08	1,438	04-03-09	–	–	1,538	185	185	45.6750703	-118.5500596	CTUIR
NONE	UMAT 6383	847	1,401	09-04-08	1,404	04-03-09	–	–	1,402	302	302	45.6751666	-118.5713376	CTUIR
NONE	UMAT 55555	917	1,257	09-09-08	1,263	03-30-09	–	–	1,279	215	215	45.6753168	-118.6413055	CTUIR
454033118465801	UMAT 530	74	–	–	–	–	795	01-03-12	1,070	700	700	45.6756974	-118.7839928	OWRD
NONE	UMAT 743	440	1,276	09-09-08	1,277	03-29-09	–	–	1,285	120	120	45.6758908	-118.6395632	CTUIR
NONE	NONE	639	1,225	09-08-08	1,238	03-30-09	–	–	1,260	145	145	45.6760769	-118.6559909	CTUIR
NONE	UMAT 749	418	–	–	1,266	03-30-09	–	–	1,275	173	173	45.6761027	-118.6454886	CTUIR
NONE	UMAT 746	454	1,250	09-08-08	1,260	03-30-09	–	–	1,271	120	120	45.6761332	-118.6464910	CTUIR
454033118455801	UMAT 531	25	–	–	–	–	821	01-03-12	1,120	935	935	45.6761962	-118.7669572	OWRD
NONE	UMAT 50521	864	1,207	09-08-08	–	–	–	–	1,221	176	176	45.6768474	-118.6759799	CTUIR
NONE	UMAT 6070	522	1,217	09-08-08	1,237	03-30-09	–	–	1,255	80	80	45.6770706	-118.6594614	CTUIR
NONE	UMAT 772	187	1,191	09-05-08	1,208	03-31-09	1,209	04-19-12	1,216	410	410	45.6773224	-118.6846869	CTUIR
NONE	NONE	329	1,404	09-02-08	1,404	04-03-09	–	–	1,405	200	200	45.6777465	-118.5617411	CTUIR
454041118333502	UMAT 55050	499	1,446	10-01-08	1,448	04-01-09	1,448	05-02-12	1,406	103	103	45.6778867	-118.5607050	CTUIR
454041118333501	UMAT 55051	498	–	–	–	–	1,396	05-02-12	1,406	13	13	45.6778876	-118.5606408	CTUIR
NONE	UMAT 5755	805	1,193	09-08-08	1,205	03-31-09	–	–	1,219	250	250	45.6779739	-118.6801739	CTUIR
NONE	UMAT 50087	856	1,447	09-02-08	1,447	04-03-09	–	–	1,447	178	178	45.6782495	-118.5552194	CTUIR
NONE	UMAT 55339	925	1,192	09-05-08	1,207	03-31-09	–	–	1,218	120	120	45.6784296	-118.6846817	CTUIR

Table A1. Summary of water-level elevation measurements for selected wells in the upper Umatilla River Basin, Oregon, 2008, 2009, and 2012.—Continued

USGS site identification No.	Well log identifier	CTUIR well identification No.	2008		2009		2012		Land surface elevation (ft)	Well depth (ft)		Well location		Source
			Water level (ft)	Date measured	Water level (ft)	Date measured	Water level (ft)	Date measured		2012	Original	Latitude (decimal degrees)	Longitude (decimal degrees)	
NONE	UMAT 5794	819	1,234	09-08-08	1,250	03-30-09	1,252	04-19-12	1,291	405	405	45.6792609	-118.6542871	CTUIR
NONE	UMAT 771	236	1,146	09-04-08	1,172	03-31-09	–	–	1,191	252	252	45.6792908	-118.7000649	CTUIR
NONE	UMAT 752	289	1,237	08-28-08	1,253	04-09-09	–	–	1,260	105	105	45.6793759	-118.6618665	CTUIR
NONE	UMAT 53222	887	1,467	09-03-08	1,468	04-03-09	1,470	04-17-12	1,611	242	242	45.6794152	-118.5255127	CTUIR
NONE	NONE	334	1,564	09-03-08	1,567	04-06-09	–	–	1,602	110	110	45.6797919	-118.4616018	CTUIR
NONE	UMAT 744	595	1,265	09-08-08	1,269	03-30-09	–	–	1,312	132	132	45.6798077	-118.6425925	CTUIR
NONE	UMAT 55307	924	1,206	09-08-08	1,221	03-30-09	–	–	1,236	170	170	45.6799122	-118.6719881	CTUIR
NONE	UMAT 760	509	–	–	–	–	1,214	04-18-12	1,271	410	410	45.6799785	-118.6678887	CTUIR
NONE	UMAT 50096	855	–	–	–	–	800	05-05-12	1,252	628	628	45.6800786	-118.7445181	CTUIR
NONE	NONE	651	–	–	1,271	03-30-09	–	–	1,329	160	160	45.6800793	-118.6418557	CTUIR
NONE	UMAT 6385	850	1,262	09-08-08	1,266	03-30-09	–	–	1,303	300	300	45.6806898	-118.6432218	CTUIR
NONE	UMAT 56235	1,763	–	–	–	–	1,500	04-17-12	1,677	307	307	45.6808528	-118.5135326	CTUIR
NONE	UMAT 776	709	–	–	–	–	738	05-15-12	1,165	531	531	45.6814052	-118.7448803	CTUIR
NONE	NONE	328	1,595	09-03-08	1,596	04-06-09	–	–	1,599	120	120	45.6815259	-118.4505522	CTUIR
454053118405601	UMAT 768	260		–	1,232	04-10-09	–	–	1,370	481	481	45.6815848	-118.6825163	CTUIR
NONE	UMAT 51254	873	1,332	09-02-08	1,343	04-10-09	–	–	1,547	352	352	45.6816073	-118.5807636	CTUIR
454104118285902	UMAT 55288	503	1,537	10-01-08	1,538	04-01-09	1,540	05-02-12	1,529	52	52	45.6843857	-118.4836809	CTUIR
454104118285901	UMAT 55287	502	–	–	–	–	1,518	05-02-12	1,529	18	18	45.6843859	-118.4836680	CTUIR
NONE	UMAT 774	164	1,241	09-10-08	1,241	04-03-090	1,244	05-15-12	1,370	300	122	45.6845471	-118.7252915	CTUIR
NONE	UMAT 5796	825	1,577	09-03-08	1,580	04-06-09	–	–	1,620	132	132	45.6857364	-118.4535377	CTUIR
NONE	UMAT 53585	891	1,677	09-03-08	–	–	–	–	1,798	260	260	45.6932226	-118.4026262	CTUIR
NONE	UMAT 50622	876	1,666	09-03-08	1,670	04-06-09	–	–	1,676	105	105	45.6958600	-118.4055436	CTUIR
NONE	UMAT 51582	875	1,677	09-03-08	1,681	04-06-09	–	–	1,773	185	185	45.6959519	-118.3958483	CTUIR
NONE	UMAT 1514	487	1,928	09-03-08	1,929	04-06-09	–	–	1,988	255	220	45.6969303	-118.3473456	CTUIR
454200118340301	UMAT 1458	127	1,597	09-09-08	1,598	04-09-09	1,601	04-17-12	1,653	200	200	45.6995822	-118.5696580	CTUIR
NONE	UMAT 1457	354	–	–	1,650	04-09-09	1,620	04-17-12	1,650	252	252	45.6996918	-118.5688904	CTUIR
454210118355901	NONE	40	–	–	1,486	04-09-09	–	–	1,539	159	159	45.7026779	-118.6008320	CTUIR
NONE	UMAT 1472	570	–	–	2,246	04-06-09	2,247	04-17-12	2,263	603	603	45.7063176	-118.4431899	CTUIR
NONE	UMAT 1471	586	2,234	09-04-08	–	–	–	–	2,263	100	100	45.7063268	-118.4431772	CTUIR
454237118273401	UMAT 1474	171	2,279	09-04-08	2,280	04-06-09	2,284	05-16-12	2,295	145	65	45.7101977	-118.4601331	CTUIR
NONE	UMAT 1499	314	1,815	09-03-08	1,817	04-06-09	–	–	1,825	92	92	45.7131947	-118.3420061	CTUIR
NONE	UMAT 1512	565	1,825	09-03-08	1,828	04-06-09	–	–	1,836	130	130	45.7144722	-118.3420624	CTUIR
454307118373101	UMAT 1414	465	1,360	09-02-08		–	1,445	05-02-12	1,498	400	400	45.7182696	-118.6261669	CTUIR
NONE	UMAT 1413	416	1,377	09-18-08	1,435	04-10-09	1,442	05-02-12	1,495	280	280	45.7195350	-118.6276942	CTUIR
NONE	NONE	63	–	–	1,811	–	–	04-09-09	2,059	470	470	45.7235505	-118.4576666	CTUIR
NONE	UMAT 55976	940	1,825	08-04-08	1,823	04-06-09	–		1,983	286	286	45.7285710	-118.4767410	CTUIR
454352118313801	UMAT 1452	191	–	–	–	–	1,720	02-24-12	1,780	660	660	45.7310021	-118.5279964	CTUIR

Table A1. Summary of water-level elevation measurements for selected wells in the upper Umatilla River Basin, Oregon, 2008, 2009, and 2012.—Continued

USGS site identification No.	Well log identifier	CTUIR well identification No.	2008		2009		2012		Land surface elevation (ft)	Well depth (ft)		Well location		Source
			Water level (ft)	Date measured	Water level (ft)	Date measured	Water level (ft)	Date measured		2012	Original	Latitude (decimal degrees)	Longitude (decimal degrees)	
NONE	UMAT 1469	626	–	–	–	–	1,581	04-17-12	1,815	700	700	45.7322590	-118.4949091	CTUIR
NONE	UMAT 1468	538	1,895	09-04-08	–	–	–	–	2,014	380	380	45.7327009	-118.4761558	CTUIR
454415118334901	UMAT 1448	83	–	–	1,495	04-09-09	–	–	1,532	285	285	45.7372025	-118.5646578	CTUIR
NONE	NONE	946	–	–	1,491	04-09-09	–	–	1,532	165	165	45.7373923	-118.5652544	CTUIR
NONE	UMAT 5797	824	1,503	09-03-08	1,514	04-09-09	1,524	05-07-12	1,564	205	205	45.7425699	-118.5598328	CTUIR
NONE	UMAT 1441	585	1,693	09-03-08	1,694	04-09-09	–	–	1,740	130	130	45.7467137	-118.5323205	CTUIR
NONE	UMAT 55266	921	2,307	08-22-08	–	–	2,309	05-07-12	2,322	112	112	45.7469334	-118.3839540	CTUIR
454450118303301	NONE	41	1,714	09-03-08	1,715	04-09-09	–	–	1,718	140	140	45.7472043	-118.5103499	CTUIR
NONE	UMAT 1464	402	–	–	–	–	2,103	05-07-12	2,131	550	550	45.7505419	-118.4386595	CTUIR
NONE	UMAT 1442	470	1,611	09-03-08	1,649	04-09-09	–	–	1,681	260	260	45.7545155	-118.5176318	CTUIR
NONE	NONE	341	1,540	09-03-08	1,544	04-09-09	1,557	05-02-12	1,687	300	300	45.7556585	-118.5169556	CTUIR
454526118311901	UMAT 1444, 55063	669	–	–		–	1,547	05-02-12	1,657	1030	340	45.7570992	-118.5229996	CTUIR
NONE	UMAT 55515	928	1,747	09-03-08	1,751	04-06-09	1,753	04-17-12	1,768	205	205	45.7578541	-118.4985887	CTUIR
454537118332901	UMAT 1440	1051	–	–	–	–	1,481	05-07-12	1,520	451	241	45.7604286	-118.5590960	CTUIR
454602118340801	UMAT 5331	1066	–	–	–	–	1,480	02-24-12	1,580	1,725	1,725	45.7669483	-118.5700421	OWRD
454625118330901	UMAT 1432	666	–	–	–	–	1,488	02-24-12	1,544	1,263	298	45.7736092	-118.5535596	OWRD
NONE	UMAT 6587	853	1,761	09-04-08	–	–	1,670	05-07-12	1,896	385	385	45.7744258	-118.4539240	CTUIR
454643118335501	UMAT 6433	1052	–	–	–	–	1,481	02-24-12	1,554	1,270	414	45.7784658	-118.5663649	OWRD
NONE	NONE	1788	–	–	–	–	1,630	05-11-12	1,700	102	102	45.7910616	-118.6354624	CTUIR
NONE	NONE	1787	–	–	–	–	1,629	05-11-12	1,705	160	160	45.7913581	-118.6354968	CTUIR
454751118291301	UMAT 6151	230	–	–	–	–	1,651	03-01-12	1,889	746	746	45.7971245	-118.4882662	OWRD
454829118291301	UMAT 54034	1088	–	–	–	–	1,550	03-01-12	1,720	1,206	1,206	45.8080221	-118.4877456	CTUIR
454832118295001	UMAT 50183	1078	–	–	–	–	1,548	03-01-12	1,700	1,145	1,148	45.8083254	-118.4975995	CTUIR
NONE	NONE	1789	–	–	–	–	1,725	05-11-12	1,795	92	92	45.8127018	-118.6546691	CTUIR
454904118254201	UMAT 3092	1715	–	–	–	–	1,599	02-24-12	1,980	1,000	1,000	45.8175550	-118.4161331	OWRD
NONE	UMAT 3035	1764	–	–	–	–	1,850	05-08-12	1,957	405	405	45.8606601	-118.5109204	CTUIR
455418118333001	UMAT 3879	1064	–	–	–	–	1,988	02-15-12	2,122	228	228	45.9048165	-118.5611743	OWRD

Appendix B. Measurements Used to Define Gains and Losses on September 19 and 25, 2007, for the Umatilla River, Oregon

Table B1. Measurements used to define gains and losses on September 19 and 25, 2007, for the Umatilla River, Oregon.

[Calculations may vary because of rounding. **Abbreviations**: ft, foot; ft³/s, cubic foot per second; (ft³/s)/mi, cubic foot per second per mile; mi, mile; nd, no data. **Symbols**: →, inflow; ←, outflow; <, less than 0.01 ft³/s; –, not applicable]

Site name	River mile	Elevation (ft)	September 19, 2007 Main stem (ft³/s) Measured	Main stem Difference (gain/loss)	Main stem Percent difference	Inflows and diversions (ft³/s) Tributary inflow	Inflows and diversions Diversion outflow	Cumulative change from upstream end of reach (ft³/s)	Gain/loss per mile [(ft³/s)/mi]	Reach length (mi)
→ North Fork Umatilla River	89.5	2,338	–	–	–	30.2	–	–	–	–
→ South Fork Umatilla River	89.5	2,338	–	–	–	8.89	–	–	–	–
Confluence of North and South Umatilla River	89.5	2,338	[1]39.1	–	–	–	–	–	–	–
Umatilla River at Corporation	89.0	2,297	34.0	-5.1	-15.1	–	–	-5.1	-10.24	0.5
→ Bear Creek	87.1	2,172	–	–	–	0.04	–	–	–	–
→ Bingham Springs	86.5	2,145	–	–	–	<	–	–	–	–
→ Rock Creek	86.3	2,137	–	–	–	0.03	–	–	–	–
Umatilla River below Bar M Ranch	85.5	2,104	39.0	4.9	12.6		–	-0.2	1.41	3.5
→ Bobsled Creek	84.6	2,034	–	–	–	0.00	–	–	–	–
→ Unknown Stream	84.5	2,032	–	–	–	0.00	–	–	–	–
→ Hagar Creek	84.2	2,024	–	–	–	0.08	–	–	–	–
→ Unknown Stream	84.0	2,019	–	–	–	0.00	–	–	–	–
→ Hagen Creek	83.5	2,006	–	–	–	0.08	–	–	–	–
→ Unknown Stream	83.0	1,994	–	–	–	0.00	–	–	–	–
→ Unknown Seeps at road	82.9	1,991	–	–	–	<	–	–	–	–
→ Unknown Stream	82.8	1,989	–	–	–	0.00	–	–	–	–
→ Unknown Stream at Mile Post 24.8	82.7	1,986	–	–	–	<	–	–	–	–
→ Unknown Stream	82.2	1,973	–	–	–	<	–	–	–	–
Umatilla River above Ryan Creek	81.9	1,955	40.7	1.6	3.9	–	–	1.4	0.44	3.6
→ Ryan Creek	81.8	1,942	–	–	–	1.23	–	–	–	–
Umatilla River above Meacham Creek near Gibbon	81.2	1,883	42.4	0.4	0.9	–	–	1.8	0.57	0.7
Umatilla River above Meacham at Bridge	80.0	1,815	45.3	2.9	6.4	–	–	4.7	2.41	1.2
→ Meacham Creek at Gibbon	78.8	1,762	–	–	–	[2]9.5	–	–	–	–
→ Iskuulpa Creek near Gibbon	76.6	1,675	–	–	–	1.1	–	–	–	–
Umatilla River above Flat near Thornhollow	73.5	1,575	54.0	-1.9	-3.6	–	–	2.8	-0.30	6.5
→ Buckaroo Creek at Star Logger	73.4	1,571	–	–	–	0.03	–	–	–	–
Umatilla River below Flat near Thornhollow	73.2	1,564	43.8	-10.2	-23.3	–	–	-7.4	-34.00	0.3
Umatilla River below Homly Cemetary	69.5	1,456	42.2	-1.6	-3.7	–	–	-9.0	-0.42	3.7
→ Coonskin Creek	68.0	1,417	–	–	–	0.15	–	–	–	–

Table B1. Measurements used to define gains and losses on September 19 and 25, 2007, for the Umatilla River, Oregon.—Continued

Site name	River mile	Elevation (ft)	September 19, 2007: Main stem (ft³/s)			Inflows and diversions (ft³/s)		Cumulative change from upstream end of reach (ft³/s)	Gain/loss per mile [(ft³/s)/mi]	Reach length (mi)
			Measured	Difference (gain/loss)	Percent difference	Tributary inflow	Diversion outflow			
Umatilla River above Cayuse Bridge	67.8	1,412	48.6	6.2	12.8	–	–	-2.8	3.66	1.7
Umatilla River below Cayuse Bridge	67.4	1,402	–	–	–	–	–	–	–	–
→ Unknown Stream	67.3	1,399	–	–	–	0.00	–	–	–	–
→ Moonshine Creek	67.2	1,396	–	–	–	0.20	–	–	–	–
→ Unknown Stream	65.5	1,351	–	–	–	0.00	–	–	–	–
→ Cottonwood Creek	64.6	1,326	–	–	–	0.00	–	–	–	–
Umatilla River below Minthorn Spring	63.8	1,306	44.4	-4.4	-10.0	–	–	-7.2	-1.11	4.0
→ Unknown Stream	63.7	1,304	–	–	–	0.00	–	–	–	–
→ Spring off Wilson Road	63.7	1,304	–	–	–	<	–	–	–	–
→ Mission Creek	62.7	1,284	–	–	–	0.04	–	–	–	–
Umatilla River	61.5	1,261	39.0	-5.4	-13.8	–	–	-12.6	-2.34	2.3
Umatilla River above Hwy 331 Bridge	59.6	1,203	44.4	5.4	12.1	–	–	-7.2	2.83	1.9
Umatilla River below Hwy 331 Bridge	58.5	1,170	38.9	-5.5	-14.1	–	–	-12.7	-5.00	1.1
Umatilla River at West Boundary	56.8	1,129	39.9	1.0	2.5	–	–	-11.7	0.59	1.7
Umatilla River below Hwy 11 Bridge	55.3	1,096	40.9	1.0	2.4	–	–	-10.7	0.67	1.5
→ Wildhorse Creek above Lindell Bridge	55.0	1,087	–	–	–	1.63	–		–	–
Umatilla River at Pendleton	53.5	1,046	[3]38.0	-4.5	-12.0	–	–	-15.3	-2.52	1.8
Umatilla River below Tutuilla Creek	52.1	1,020	41.1	3.1	7.6	–	–	-12.1	2.24	1.4
→ McKay Creek near Pendleton	50.5	990	–	–	–	[3]78.0	–	–	–	–
← Wyss Pump	49.4	970	–	–	–		–	–	–	–
→ Birch Creek	48.4	952	–	–	–	[4]0.01	–	–	–	–
← Taylor Pump	48.4	951	–	–	–	–	–	–	–	–
← Browns Dairy Pump	47.0	949	–	–	–	–	–	–	–	–
Umatilla River above Coombs Canyon	46.7	922	113.0	-6.1	-5.4	–	–	-18.2	-1.13	5.4
← Dean Forth Pump	43.6	874	–	–	–	–	–	–	–	–
← B & G Pump	40.1	833	–	–	–	–	–	–	–	–
← Beebee upper Pump	38.8	812	–	–	–	–	–	–	–	–
← McCullough Pump	38.2	805	–	–	–	–	–	–	–	–
← Hendrickson Pump	37.3	794	–	–	–	–	–	–	–	–
← Beebee lower Pump	37.2	787	–	–	–	–	–	–	–	–
← Skillman Pump	37.1	772	–	–	–	–	–	–	–	–
Umatilla River at Yoakum	36.9	770	120.0	7.0	5.8	–	–	-11.2	0.71	9.8
← Cunningham Sheep Pump	35.5	748	–	–	–	–	–	–	–	–

Table B1. Measurements used to define gains and losses on September 19 and 25, 2007, for the Umatilla River, Oregon.—Continued

Site name	River mile	Elevation (ft)	September 19, 2007: Main stem (ft^3/s) Measured	Main stem Difference (gain/loss)	Main stem Percent difference	Inflows and diversions (ft^3/s) Tributary inflow	Inflows and diversions Diversion outflow	Cumulative change from upstream end of reach (ft^3/s)	Gain/loss per mile [(ft^3/s)/mi]	Reach length (mi)
Umatilla River above Nolin Bridge	34.8	737	105.0	-15.0	-14.3	–	–	-26.2	-6.98	2.1
← Bork pump	33.7	721	–	–	–	–	–	–	–	–
← Bork pump	33.2	715	–	–	–	–	–	–	–	–
← Furnish Canal	32.4	706	–	–	–	–	[3]0.00	–	–	–
← Bork pump	32.2	704	–	–	–	–	–	–	–	–
← Piercy Pump	28.3	660	–	–	–	–	–	–	–	–
← Feed Canal	28.3	660	–	–	–	–	[3]0.00	–	–	–
Umatilla River near Echo	28.2	658	[3]108.0	3.0	2.8	–	–	-23.2	0.46	6.6
← Westland Canal near Echo	27.3	645	–	–	–	–	14.2	–	–	–
← Allen Canal	27.3	645	–	–	–	–	11.5	–	–	–
← WID Pumps 1, 2, 3 & 4	27.3	645	–	–	–	–	–	–	–	–
← McBee Well	27.2	643	–	–	–	–	–	–	–	–
Umatilla River at Echo Bridge	26.3	629	–	–	–	–	–	–	–	–
← Yunkers Pump	26.0	624	–	–	–	–	–	–	–	–
← Dillon Canal	25.0	608	–	–	–	–	4.99	–	–	–
Umatilla River at I-84 near Stanfield	24.4	599	67.0	-10.2	-15.3	–	–	-33.5	-2.69	3.8
← Mills Pump	23.4	587	–			–	–	–	–	–
Umatilla River at Johnson Street Bridge	22.9	583	72.5	5.5	7.6	–	–	-28.0	3.67	1.5
← Staley Pump	22.7	582	–	–	–	–	–	–	–	–
→ Pioneer Drain	22.6	581	–	–	–	0.00	–	–	–	–
← City of Stanfield Pump	22.0	577	–	–	–	–	–	–	–	–
→ Standfield Drain	21.9	576	–	–	–	11.7	–	–	–	–
→ Dillon Drain East	20.1	563	–	–	–	0.00	–	–	–	–
Umatilla River below Dillon East Drain	19.9	562	–	–	–	–	–	–	–	–
→ Dillon Drain West	18.3	551	–	–	–	0.00	–	–	–	–
→ Courtney Drain	17.0	541	–	–	–	–	–	–	–	–
← Simplot Pump	16.5	538	–	–	–	–	–	–	–	–
← Maxwell Canal	15.4	530	–	–	–	–	[3]33.87	–	–	–

Table B1. Measurements used to define gains and losses on September 19 and 25, 2007, for the Umatilla River, Oregon.—Continued

Site name	River mile	Elevation (ft)	September 19, 2007							
			Main stem (ft³/s)			Inflows and diversions (ft³/s)		Cumulative change from upstream end of reach (ft³/s)	Gain/loss per mile [(ft³/s)/mi]	Reach length (mi)
			Measured	Difference (gain/loss)	Percent difference	Tributary inflow	Diversion outflow			
Umatilla River above Butter Creek	15.4	530	[3]52.1	1.8	3.5	–	–	-26.2	0.24	7.5
→ Butter Creek at mouth	15.2	528	–	–	–	–	–	–	–	–
← Turner Pump	13.3	508	–	–	–	–	–	–	–	–
→ Null Spill	12.7	501	–	–	–	–	–	–	–	–
← McKenzie Pump	11.7	488	–	–	–	–	–	–	–	–
← Mabry Pump	10.7	476	–	–	–	–	–	–	–	–
← Quick Pump	10.3	471	–	–	–	–	–	–	–	–
→ Minnehaha	10.1	469	–	–	–	4.22	–	–	–	–
← Boyd Hydro Diversion Ditch	10.0	468	–	–	–	–	–	–	–	–
Umatilla River at Boyd Hydro Gage	9.5	462	–	–	–	–	–	–	–	–
→ Maxwell Drain	9.0	456	–	–	–	0.00	–	–	–	–
→ Spring #1	8.6	451	–	–	–	–	–	–	–	–
→ Spring #2	8.6	451	–	–	–	–	–	–	–	–
→ Spring #3	8.6	451	–	–	–	–	–	–	–	–
→ South Hermiston Drain	7.0	431	–	–	–	5.56	–	–	–	–
← Maahs Pump	5.4	412	–	–	–	–	–	–	–	–
← Grow Pump	5.4	412	–	–	–	–	–	–	–	–
→ North Hermiston Drain	5.3	411	–	–	–	0.10	–	–	–	–
Umatilla River at Wadekamper	5.1	408	–	–	–	–	–	–	–	–
→ F Canal North Drain	4.8	405	–	–	–	–	–	–	–	–
← Flink Pump	4.8	403	–	–	–	–	–	–	–	–
← Erickson Pump	4.7	403	–	–	–	–	–	–	–	–
← Monahan Pump	4.7	403	–	–	–	–	–	–	–	–
← Heiple Pump	4.6	402	–	–	–	–	–	–	–	–
← Boullester Pump	4.5	401	–	–	–	–	–	–	–	–
← Davis Pump	4.5	401	–	–	–	–	–	–	–	–
← WEID Canal	3.8	390	–	–	–	–	–	–	–	–
→ HID RF Pt 6	3.6	381	–	–	–	–	–	–	–	–
→ HID RF Pt 4	2.3	328	–	–	–	–	–	–	–	–
→ HID RF Pt 5	2.3	328	–	–	–	–	–	–	–	–

Table B1. Measurements used to define gains and losses on September 19 and 25, 2007, for the Umatilla River, Oregon.—Continued

Site name	River mile	Elevation (ft)	September 19, 2007							
			Main stem (ft^3/s)			Inflows and diversions (ft^3/s)		Cumulative change from upstream end of reach (ft^3/s)	Gain/loss per mile [(ft^3/s)/mi]	Reach length (mi)
			Measured	Difference (gain/loss)	Percent difference	Tributary inflow	Diversion outflow			
Umatilla River near Umatilla	2.1	328	[2]120	58.0	48.4	–	–	–	4.36	13.3
→ Umatilla Spring	2.0	328	–	–	–	–	–	–	–	–
← Brownell Ditch	1.9	328	–	–	–	–	–	–	–	–
→ Umatilla Canal Spring	1.9	328	–	–	–	–	–	–	–	–
→ Umatilla River Drain	1.9	328	–	–	–	–	–	–	–	–
→ WEID Canal Spill	1.7	328	–	–	–	–	–	–	–	–
→ Col Exchange Spring	1.6	328	–	–	–	–	–	–	–	–
← Umatilla School	1.4	328	–	–	–	–	–	–	–	–
Umatilla River Walk Bridge	0.7	328	–	–	–	–	–	–	–	–

Table B1. Measurements used to define gains and losses on September 19 and 25, 2007, for the Umatilla River, Oregon.—Continued

Site name	River mile	Elevation (ft)	September 25, 2007: Main stem (ft³/s)			Inflows and diversions (ft³/s)		Cumulative change from upstream end of reach (ft³/s)	Gain/loss per mile [(ft³/s)/mi]	Reach length (mi)
			Measured	Difference (gain/loss)	Percent difference	Tributary inflow	Diversion outflow			
→ North Fork Umatilla River	89.5	2,338	–	–	–	27.5	–	–	–	–
→ South Fork Umatilla River	89.5	2,338	–	–	–	7.80	–	–	–	–
Confluence of North and South Umatilla River	89.5	2,338	[1]35.3	–	–	–	–	–	–	–
Umatilla River at Corporation	89.0	2,297	36.4	1.1	3.1	–	–	1.1	2.26	0.5
→ Bear Creek	87.1	2,172	–	–	–	0.04	–	–	–	–
→ Bingham Springs	86.5	2,145	–	–	–	–	–	–	–	–
→ Rock Creek	86.3	2,137	–	–	–	0.03	–	–	–	–
Umatilla River below Bar M Ranch	85.5	2,104	–	–	–	–	–	–	–	–
→ Bobsled Creek	84.6	2,034	–	–	–	–	–	–	–	–
→ Unknown Stream	84.5	2,032	–	–	–	–	–	–	–	–
→ Hagar Creek	84.2	2,024	–	–	–	–	–	–	–	–
→ Unknown Stream	84.0	2,019	–	–	–	–	–	–	–	–
→ Hagen Creek	83.5	2,006	–	–	–	–	–	–	–	–
→ Unknown Stream	83.0	1,994	–	–	–	–	–	–	–	–
→ Unknown Seeps at road	82.9	1,991	–	–	–	–	–	–	–	–
→ Unknown Stream	82.8	1,989	–	–	–	–	–	–	–	–
→ Unknown Stream at Mile Post 24.8	82.7	1,986	–	–	–	–	–	–	–	–
→ Unknown Stream	82.2	1,973	–	–	–	–	–	–	–	–
Umatilla River above Ryan Creek	81.9	1,955	–	–	–	–	–	–	–	–
→ Ryan Creek	81.8	1,942	–	–	–	–	–	–	–	–
Umatilla River above Meacham Creek near Gibbon	81.2	1,883	[2]41.0	4.5	11.0	–	–	5.6	0.58	7.8
Umatilla River above Meacham at Bridge	80.0	1,815	–	–	–	–	–	–	–	–
→ Meacham Creek at Gibbon	78.8	1,762	–	–	–	[2]9.30	–	–	–	–
→ Iskuulpa Creek near Gibbon	76.6	1,675	–	–	–	–	–	–	–	–
Umatilla River above Flat near Thornhollow	73.5	1,575	–	–	–	–	–	–	–	–
→ Buckaroo Creek at Star Logger	73.4	1,571	–	–	–	–	–	–	–	–
Umatilla River below Flat near Thornhollow	73.2	1,564	–	–	–	–	–	–	–	–
Umatilla River below Homly Cemetary	69.5	1,456	–	–	–	–	–	–	–	–
→ Coonskin Creek	68.0	1,417	–	–	–	0.15	–	–	–	–

Table B1. Measurements used to define gains and losses on September 19 and 25, 2007, for the Umatilla River, Oregon.—Continued

Site name	River mile	Elevation (ft)	September 25, 2007: Main stem (ft³/s)			Inflows and diversions (ft³/s)		Cumulative change from upstream end of reach (ft³/s)	Gain/loss per mile [(ft³/s)/mi]	Reach length (mi)
			Measured	Difference (gain/loss)	Percent difference	Tributary inflow	Diversion outflow			
Umatilla River above Cayuse Bridge	67.8	1,412	–	–	–	–	–	–	–	–
Umatilla River below Cayuse Bridge	67.4	1,402	44.7	-5.8	-13.0	–	–	-0.2	-0.42	13.8
→ Unknown Stream	67.3	1,399		–	–	–	–	–	–	–
→ Moonshine Creek	67.2	1,396	–	–	–	0.20	–	–	–	–
→ Unknown Stream	65.5	1,351	–	–	–	0.00	–	–	–	–
→ Cottonwood Creek	64.6	1,326	–	–	–	0.00	–	–	–	–
Umatilla River below Minthorn Spring	63.8	1,306	–	–	–	–	–	–	–	–
→ Unknown Stream	63.7	1,304	–	–	–	0.00	–	–	–	–
→ Spring off Wilson Road	63.7	1,304	–	–	–	<	–	–	–	–
→ Mission Creek	62.7	1,284	–	–	–	0.04	–	–	–	–
Umatilla River	61.5	1,261	–	–	–	–	–	–	–	–
Umatilla River above Hwy 331 Bridge	59.6	1,203	–	–	–	–	–	–	–	–
Umatilla River below Hwy 331 Bridge	58.5	1,170	–	–	–	–	–	–	–	–
Umatilla River at West Boundary	56.8	1,129	[2]37	-7.9	-21.4	–	–	-8.1	-0.75	11
Umatilla River below Hwy 11 Bridge	55.3	1,096	–	–	–	–	–	–	–	–
→ Wildhorse Creek above Lindell Bridge	55.0	1,087	–	–	–	[3]1.78	–	–	–	–
Umatilla River at Pendleton	53.5	1,046	[3]40.4	1.6	4.0	–	–	-6.5	0.49	3.3
Umatilla River below Tutuilla Creek	52.1	1,020	–	–	–	–	–	–	–	–
→ McKay Creek near Pendleton	50.5	990	–	–	–	[3]77.3	–	–	–	–
← Wyss Pump	49.4	970	–	–	–	–	1.06	–	–	–
→ Birch Creek	48.4	952	–	–	–	0.00	–	–	–	–
← Taylor Pump	48.4	951	–	–	–	–	0.00	–	–	–
← Browns Dairy Pump	47.0	949	–	–	–	–	0.00	–	–	–
Umatilla River above Coombs Canyon	46.7	922	112	-4.6	-4.1	–	–	-11.1	-0.68	6.8
← Dean Forth Pump	43.6	874	–	–	–	–	0.00	–	–	–
← B & G Pump	40.1	833	–	–	–	–	0.00	–	–	–
← Beebee upper Pump	38.8	812	–	–	–	–	0.00	–	–	–
← McCullough Pump	38.2	805	–	–	–	–	0.00	–	–	–
← Hendrickson Pump	37.3	794	–	–	–	–	0.00	–	–	–
← Beebee lower Pump	37.2	787	–	–	–	–	0.00	–	–	–
← Skillman Pump	37.1	772	–	–	–	–	0.00	–	–	–
Umatilla River at Yoakum	36.9	770	[3]111	–	-0.9	–	–	-12.1	-0.10	9.8
← Cunningham Sheep Pump	35.5	748	–	–	–	–	0.00	–	–	–

Table B1. Measurements used to define gains and losses on September 19 and 25, 2007, for the Umatilla River, Oregon.—Continued

Site name	River mile	Elevation (ft)	September 25, 2007: Main stem (ft^3/s)			Inflows and diversions (ft^3/s)		Cumulative change from upstream end of reach (ft^3/s)	Gain/loss per mile [(ft^3/s)/mi]	Reach length (mi)
			Measured	Difference (gain/loss)	Percent difference	Tributary inflow	Diversion outflow			
Umatilla River above Nolin Bridge	34.8	737	115	4.0	3.5	–	–	-8.1	1.86	2.1
← Bork pump	33.7	721	–	–	–	–	0.00	–	–	–
← Bork pump	33.2	715	–	–	–	–	0.00	–	–	–
← Furnish Canal	32.4	706	–	–	–	–	[3]0.00	–	–	–
← Bork pump	32.2	704	–	–	–	–	0.00	–	–	–
← Piercy Pump	28.3	660	–	–	–	–	2.20	–	–	–
← Feed Canal	28.3	660	–	–	–	–	[3]0.00	–	–	–
Umatilla River near Echo	28.2	658	[3]111	-1.8	-1.6	–	–	-9.9	-0.27	6.6
← Westland Canal near Echo	27.3	645	–	–	–	–	27.6	–	–	–
← Allen Canal	27.3	645	–	–	–	–	[4]1.09	–	–	–
← WID Pumps 1, 2, 3 & 4	27.3	645	–	–	–	–	[3]0.00	–	–	–
← McBee Well	27.2	643	–	–	–	–	0.00	–	–	–
Umatilla River at Echo Bridge	26.3	629	86.4	4.1	4.7	–	–	-5.8	2.10	1.9
← Yunkers Pump	26.0	624	–	–	–	–	0.00	–	–	–
← Dillon Canal	25.0	608	–	–	–	–	[3]5.61	–	–	–
Umatilla River at I-84 near Stanfield	24.4	599	[3]74	-6.8	-9.2	–	–	-12.6	-3.57	1.9
← Mills Pump	23.4	587	–	–	–	–	0.00	–	–	–
Umatilla River at Johnson Street Bridge	22.9	583	–	–	–	–	–	–	–	–
← Staley Pump	22.7	582	–	–	–	–	0.00	–	–	–
→ Pioneer Drain	22.6	581	–	–	–	0.01	–	–	–	–
← City of Stanfield Pump	22.0	577	–	–	–	–	0.00	–	–	–
→ Standfield Drain	21.9	576	–	–	–	9.80	–	–	–	–
→ Dillon Drain East	20.1	563	–	–	–	0.00	–	–	–	–
Umatilla River below Dillon East Drain	19.9	562	106	22.2	20.9	–	–	9.6	4.93	4.5
→ Dillon Drain West	18.3	551	–	–	–	0.27	–	–	–	–
→ Courtney Drain	17.0	541	–	–	–	0.00	–	–	–	–
← Simplot Pump	16.5	538	–	–	–	–	1.43	–	–	–
← Maxwell Canal	15.4	530	–	–	–	–	[3]33.73	–	–	–

Table B1. Measurements used to define gains and losses on September 19 and 25, 2007, for the Umatilla River, Oregon.—Continued

Site name	River mile	Elevation (ft)	September 25, 2007							
			Main stem (ft^3/s)			Inflows and diversions (ft^3/s)		Cumulative change from upstream end of reach (ft^3/s)	Gain/loss per mile [(ft^3/s)/mi]	Reach length (mi)
			Measured	Difference (gain/loss)	Percent difference	Tributary inflow	Diversion outflow			
Umatilla River above Butter Creek	15.4	530	62.2	-8.9	-14.3	–	–	0.7	-1.98	4.5
→ Butter Creek at mouth	15.2	528	–	–	–	0.00	–	–	–	–
← Turner Pump	13.3	508	–	–	–	–	0.00	–	–	–
→ Null Spill	12.7	501	–	–	–	8.56	–	–	–	–
← McKenzie Pump	11.7	488	–	–	–	–	0.00	–	–	–
← Mabry Pump	10.7	476	–	–	–	–	0.00	–	–	–
← Quick Pump	10.3	471	–	–	–	–	1.10	–	–	–
→ Minnehaha	10.1	469	–	–	–	4.37	–	–	–	–
← Boyd Hydro Diversion Ditch	10.0	468	–	–	–	–	0.00	–	–	–
Umatilla River at Boyd Hydro Gage	9.5	462	104	30.4	29.1	–	–	31.0	5.15	5.9
→ Maxwell Drain	9.0	456	–	–	–	0.02	–	–	–	–
→ Spring #1	8.6	451	–	–	–	0.16	–	–	–	–
→ Spring #2	8.6	451	–	–	–	<	–	–	–	–
→ Spring #3	8.6	451	–	–	–	0.25	–	–	–	–
→ South Hermiston Drain	7.0	431	–	–	–	4.80	–	–	–	–
← Maahs Pump	5.4	412	–	–	–	–	0.00	–	–	–
← Grow Pump	5.4	412	–	–	–	–	0.00	–	–	–
→ North Hermiston Drain	5.3	411	–	–	–	0.36	–	–	–	–
Umatilla River at Wadekamper	5.1	408	95.8	-14.3	-14.9	–	–	16.8	-3.24	4.4
→ F Canal North Drain	4.8	405	–	–	–	0.03	–	–	–	–
← Flink Pump	4.8	403	–	–	–	–	0.16	–	–	–
← Erickson Pump	4.7	403	–	–	–	–	0.00	–	–	–
← Monahan Pump	4.7	403	–	–	–	–	0.00	–	–	–
← Heiple Pump	4.6	402	–	–	–	–	0.00	–	–	–
← Boullester Pump	4.5	401	–	–	–	–	0.00	–	–	–
← Davis Pump	4.5	401	–	–	–	–	0.00	–	–	–
← WEID Canal	3.8	390	–	–	–	–	0.00	–	–	–
→ HID RF Pt 6	3.6	381	–	–	–	0.01	–	–	–	–
→ HID RF Pt 4	2.3	328	–	–	–	0.00	–	–	–	–
→ HID RF Pt 5	2.3	328	–	–	–	1.02	–	–	–	–

Table B1. Measurements used to define gains and losses on September 19 and 25, 2007, for the Umatilla River, Oregon.—Continued

Site name	River mile	Elevation (ft)	September 25, 2007							
			Main stem (ft³/s)			Inflows and diversions (ft³/s)		Cumulative change from upstream end of reach (ft³/s)	Gain/loss per mile [(ft³/s)/mi]	Reach length (mi)
			Measured	Difference (gain/loss)	Percent difference	Tributary inflow	Diversion outflow			
Umatilla River near Umatilla	2.1	328	[2]129	32.3	25.1	–	–	49.1	10.78	3.0
→ Umatilla Spring	2.0	328	–	–	–	1.10	–	–	–	–
← Brownell Ditch	1.9	328	–	–	–		0.00	–	–	–
→ Umatilla Canal Spring	1.9	328	–	–	–	0.19	–	–	–	–
→ Umatilla River Drain	1.9	328	–	–	–	1.13	–	–	–	–
→ WEID Canal Spill	1.7	328	–	–	–	1.00	–	–	–	–
→ Col Exchange Spring	1.6	328	–	–	–	0.00	–	–	–	–
← Umatilla School	1.4	328	–	–	–	–	0.00	–	–	–
Umatilla River Walk Bridge	0.7	328	126	-6.5	-5.2	–	–	42.6	-1.40	3.1

[1]Discharge at confluence of North and South Umatilla Rivers dervied by summation of branches.

[2]Discharge from U.S. Geological Survey streamgage.

[3]Discharge from U.S. Bureau of Reclamation streamgage.

[4]Discharge from Oregon Water Resources Department streamgage.

Appendix C. Estimated Groundwater and Surface Water Withdrawals, upper Umatilla River Basin, Oregon, Water Year 2010

Table C1. Estimated groundwater and surface water withdrawals, upper Umatilla River Basin, Oregon, water year 2010.

[All values are in acre-feet. **Abbreviations**: GW, groundwater; SW, surface water; ALL, both groundwater and surface water]

Month	Year	Irrigation		Municipal		Domestic	Total		
		GW	SW	GW	SW	GW	GW	SW	ALL
October	2009	379	0	236	147	25	640	147	787
November	2009	0	0	119	140	17	136	140	276
December	2009	0	0	129	207	22	151	207	358
January	2010	0	0	61	396	30	91	396	487
February	2010	0	0	52	489	36	88	489	577
March	2010	0	0	66	549	41	107	549	656
April	2010	0	0	109	535	42	151	535	686
May	2010	379	811	90	550	42	511	1,361	1,872
June	2010	757	0	216	450	44	1,017	450	1,467
July	2010	1,894	0	764	150	60	2,718	150	2,868
August	2010	2,272	0	824	149	64	3,160	149	3,309
September	2010	1,894	0	507	147	43	2,444	147	2,591
Water year 2010 totals		**7,575**	**811**	**3,173**	**3,909**	**466**	**11,214**	**4,720**	**15,934**

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