Hydrogeologic Framework and Groundwater/Surface-Water Interactions of the Chehalis River Basin, Washington

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Introduction

The Chehalis River has the largest drainage basin (fig. 1) of any river entirely contained within the state of Washington with a watershed of about 2,700 mi^2 and has diverse geology, land uses, and demands for water resources. Local citizens and governments of the Chehalis River basin have coordinated with Federal, state and tribal agencies through the Chehalis Basin Partnership to develop a long-term watershed management plan. The recognition of the interdependence of groundwater and surface-water resources of the Chehalis River basin and their complex interaction became the impetus for this study, the purpose of which is to describe the hydrogeologic framework and groundwater-surface water interactions of the basin. The basin-wide hydrogeologic framework was generalized by combining surficial geologic maps with more than 372 drillers' lithostratigraphic logs. The framework consists of five hydrogeologic units that include aquifers within unconsolidated glacial and alluvial sediments separated by discontinuous confining units. These five units are bounded by a basal confining unit comprised of Tertiary bedrock. Generalized groundwater flow directions in the surficial aquifers were delineated from water-levels measured in wells between August and September 2009. Synoptic streamflows during August 2010 and water levels in wells during the 2010 water year were measured to characterize groundwater-surface water interactions in the Chehalis River basin. The streamflow mesurements revealed alternating gains and losses of streamflow, which became more pronounced on the Chehalis River downstream of its confluence with the Black River. Groundwater levels measured in wells fluctuated with changes in streamflow. These fluctuations were influenced by precipitation events in the upper Chehalis River basin and tidal effects from of the Pacific Ocean in the lower Chehalis River basin.

Base from U.S. Geological Survey Digital Data, 1:100,000, 1985
Universal Transverse Mercator projection, Zone 10
North American Datum of 1983

Figure 1. Location of the Chehalis River basin, Washington.

Groundwater/Surface-Water Interactions

Surface-water bodies such as rivers and lakes can readily interact with groundwater and exchange appreciable quantities of water and solutes. This exchange, or seepage, provides both recharge of aquifers and maintenance of streamflows and has the potential to affect water quality of groundwater and surface water bodies. When the groundwater level in the underlying aquifer is higher than the river stage, an upward hydraulic gradient drives the movement of water from the groundwater to the river resulting in a gaining river. Conversely, a downward hydraulic gradient exists when the river elevation is higher than the groundwater level causing the river to lose water to the underlying aquifer.

Well Monitoring

Water levels in wells completed in the aquifers within several kilometers of the Chehalis River (fig. 2) fluctuated with the changes in river stage that were driven by precipitation events in the upper Chehalis River and tides within the lower Chehalis River. Wells completed in close proximity to the Chehalis River and its tributaries, notably well 14N/02W-07B02 (fig. 2A), fluctuated directly with river stage as measured at streamflow-gaging stations. The minimal delay in the peak of the well 14N/02W-07B02 hydrograph from the streamflow-gaging station in response to precipitation events was caused largely by the high hydrologic conductivities of the overlying sediments and lack of confining layers. The well 15N/04W-03R02 (fig. 2B) fluctuated with the streamflow hydrograph, but the amplitude of the fluctuations is lower because it is farther away from the Chehalis River and other streams. The stage of the Chehalis River is influenced by ocean tides downstream of the confluence of the Chehalis River with the Satsop River. Water levels of well 17N/07W-08K02 (fig. 3) which is completed in the unit A (fig. 4) fluctuate closely with the stage measured at a nearby USGS streamflow-gaging station (12035100). These well hydrograph fluctuations are attenuated approximately 75 percent from stream hydrograph fluctuations.

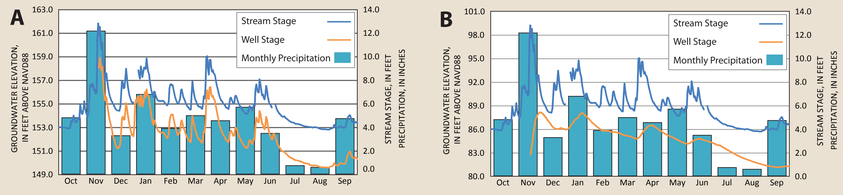


Figure 2. Continuous water levels in wells, stream stage at U.S. Geological Survey streamflow gaging station 120227500, Chehalis River at Grand Mound, and total monthly precipitation at Centralia, September 2009 – September 2010 for wells 14N/02W-07B02 (A) and 15N/04W-03R02 (B).

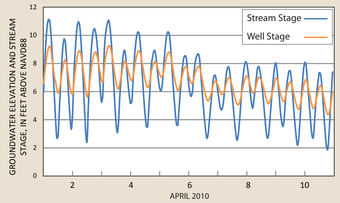
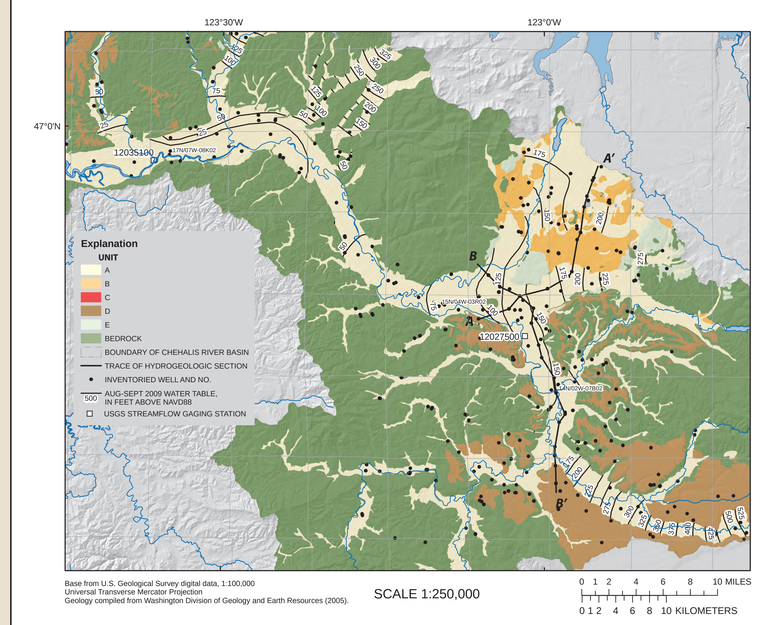
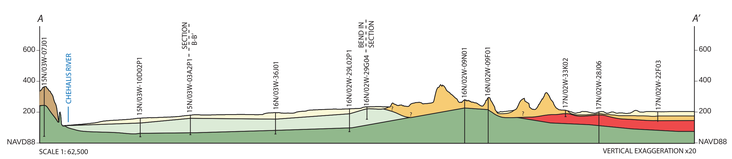


Figure 3. Water levels in well 17N/07W-08K02 and stream stage at U.S. Geological Survey streamflow-gaging station 12035100, Chehalis River at Montesano, April 1 – April 11, 2010.



Base from U.S. Geological Survey digital data, 1:100,000
Universal Transverse Mercator Projection
Geology compiled from Washington Division of Geology and Earth Resources (2005).



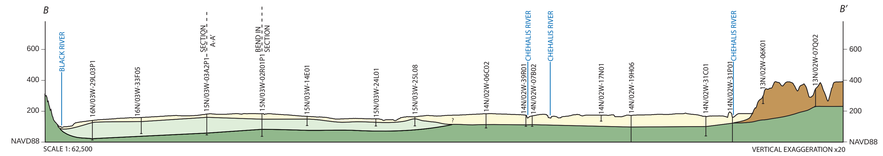
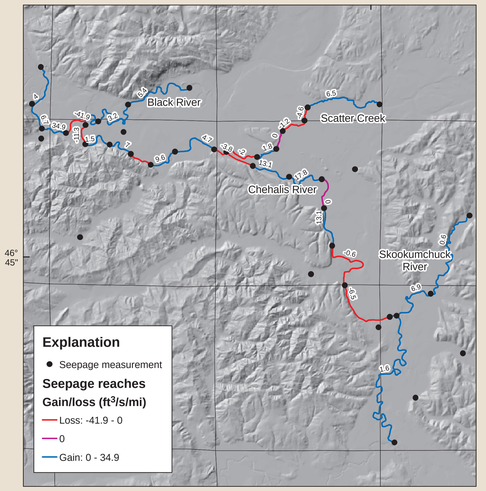


Figure 4. Map and cross sections showing hydrogeologic units within Chehalis River basin, Washington.



Base from U.S. Geological Survey Digital Data, 1:100,000
Universal Transverse Mercator projection,
Zone 10 North american Datum of 1983

0 1 2 3 4 5 MILES
0 1 2 3 4 5 KILOMETERS

Figure 5. Streamflow gains and losses, August 2010.

August 2010 Seepage Run

A series of streamflow measurements to identify gaining and losing reaches, termed a seepage run, were made during summer base flow conditions in August 2010 when streamflow was at its lowest, and the relative contribution of groundwater was at its annual maximum, and the contribution of precipitation was minimal. Synoptic discharge measurements were made at 41 locations and streamflow gains and losses were calculated for 28 reaches from August 17 to 19, 2010 (fig. 5). The seepage run reveals a pattern of alternating gains and losses of streamflow throughout the extent of the river system. Of the 28 reaches, 17 (61 percent) gained streamflow, 9 (32 percent) lost streamflow and 2 (7 percent) had no net gain or loss of streamflow (fig. 5). Gains and losses of streamflow were minimal upstream of the confluence of the Chehalis and Black Rivers, but became more dynamic downstream with gains and losses as much as 34.9 ft^3/s/mi and -41.9 ft^3/s/mi, respectively. Most streamflow gains and losses were small relative to the compounded error in streamflow measurements demonstrating the difficulty in measuring streamflow gains and losses. Ungaged diversions and return flows between streamflow measurements may cause an overestimation or underestimation of loses or gains, respectively.

Hydrogeologic Units

Five hydrogeologic units and bedrock were differentiated based on their lithologic and hydraulic characteristics (fig. 4).

Unit A - Alluvium and Vashon Recessional Outwash (Aquifer) – The Unit A aquifer extends throughout the major river valleys and lowland prairies of the Chehalis River and its tributaries and comprises the most areally extensive surficial aquifer. This aquifer interacts readily with surficial water features sustaining summer streamflows and recharging during winter. This unit contains alluvial sediments of glacial and non-glacial origins with silt, sand, gravel, and coarse materials. Significant heterogeneity exists within this aquifer including the presence of local confining layers.

Unit B - Vashon Till and Morainal Deposits (Confining Unit) – The B confining unit is distributed in the northern part of the Chehalis River basin and is comprised of unsorted and unstratified deposits with clay to boulder-sized particles although irregularly distributed layers of sand and gravel containing small amounts of groundwater occur locally. This unit was deposited during the last glacial advance at the southern margin of the Puget Lobe of the Cordilleran Ice Sheet.

Unit C - Vashon Advance Outwash (Aquifer) – Advance glacial outwash of Vashon age and pre-Vashon age outwash in hydrologic connection with each other form the C aquifer where they are confined by the B confining unit in the northern part of the Chehalis River basin.

Unit D - Quaternary Alpine Glacial Outwash (Aquifer) – Alpine glacial outwash emanating from the Cascade and Olympic Mountains comprises the Unit D aquifer on the bedrock uplands of the Chehalis River basin. Several episodes of alpine glaciation have been documented since the early Pleistocene and their deposits consist of Cascade and Olympic-derived Tertiary volcanic and sedimentary rocks. The top parts of these deposits have been extensively weathered into clay confining groundwater where this unit is saturated.

Unit E - Pre-Vashon Glacial Drift (Aquifers and Confining Units) – The E unit is comprised of Pre-Vashon tills and outwash sequences deposited in the northern Chehalis River basin as far south as Centralia. Groundwater within the E unit occurs under confined conditions within the coarse grained outwash sequences. The outwash is separated from stratigraphically higher A and C aquifers by till layers. Multiple aquifers and confining units within the E unit may exist where they have not been eroded.

Bedrock – The Tertiary sedimentary and volcanic bedrock forms the basal confining unit of the groundwater-flow system and is relatively impermeable in relation to the unconsolidated sediments stratigraphically above it. Bedrock locally yields water sufficient for domestic use through fracture flow.

References Cited

Washington Division of Geology and Earth Resources, 2005, Digital 1:100,000-scale geology of Washington State, version 1.0: Washington Division of Geology and Earth Resources Open-File Report 2005-3, accessed January 5, 2011, at http://www.dnr.wa.gov/ResearchScience/Topics/GeosciencesData/Pages/gis_data.asp.

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