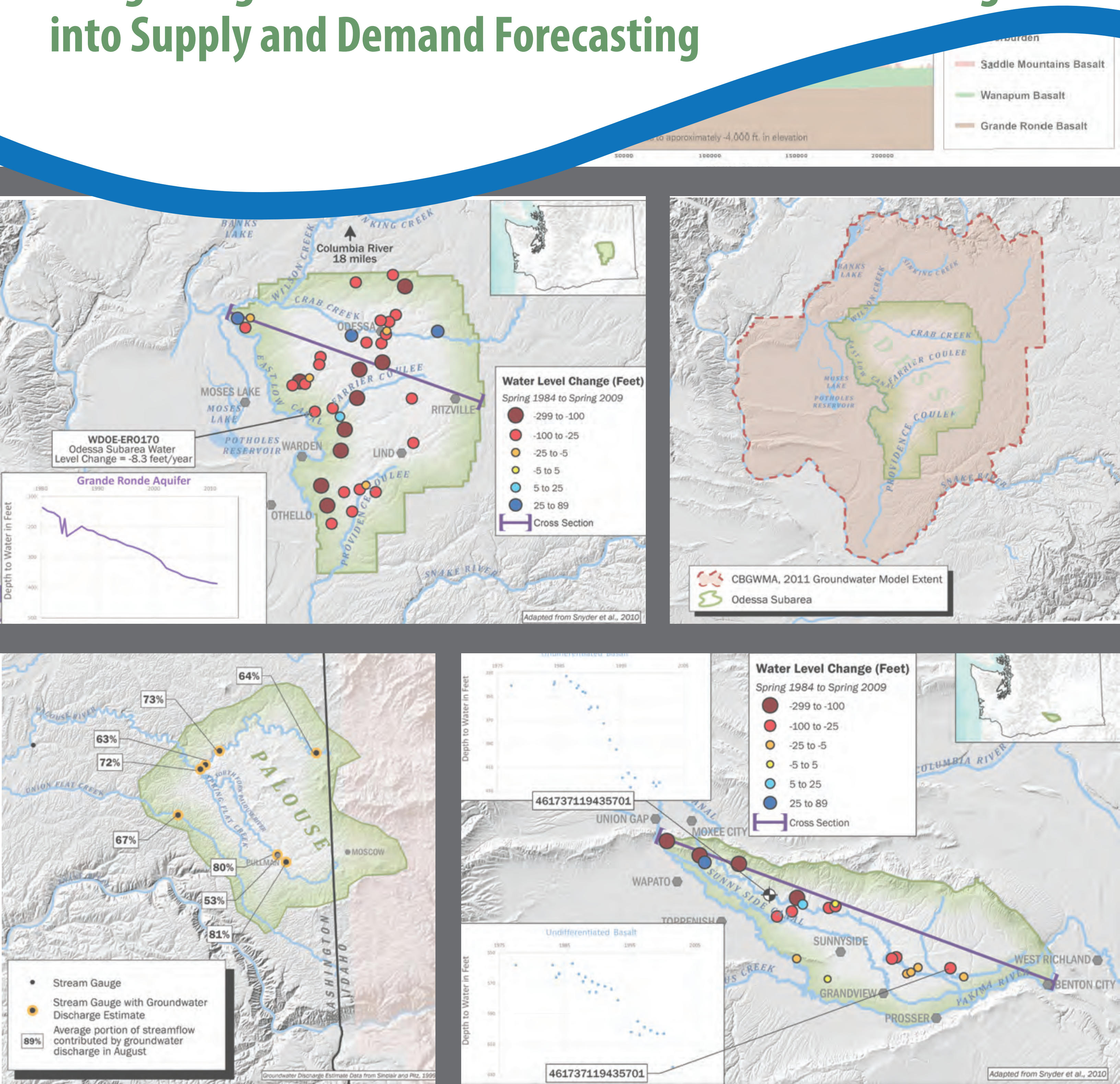
Washington State Legislative Report

Columbia River Basin
Long-Term Water Supply and Demand Forecast

Integrating Groundwater Declines in Eastern Washington into Supply and Demand Forecasting



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Executive Summary

In the 2006 and 2011 Water Supply and Demand Forecasts, groundwater supplies were not presumed to be limiting when supplying water rights. As a result, economic implications of groundwater limitations were also not considered. Groundwater is declining in some areas in Washington, which could result in curtailment of both groundwater rights and surface water rights where there is hydraulic continuity with groundwater.

WSU evaluated 10 areas of Washington State with groundwater declines documented by the Department of Ecology and the United States Geologic Survey. This evaluation provides summaries of groundwater declines, geographic extent of the groundwater body, aquifer cross-sections and descriptions, groundwater model information, water right data, and supply-side and demand-side options to reducing groundwater declines. Key findings of this investigation include:

- Greater monitoring of the declining groundwater areas is likely warranted, including aquifer levels, metering data, stream gages, and pump testing.
- Public outreach to water right holders in declining groundwater areas should be implemented to inform and incentivize demand-side conservation measures.
- State and County government should consider whether existing policies and regulations are sufficient in these areas to protect public water supplies and prevent unintended economic consequences.
- The State should consider water supply projects that could stabilize, reverse, or offset declining groundwater supplies.
- Declining groundwater areas should be incorporated into the 2021 forecast so water right holder responses are predicted.
- Use of a more robust curtailment model to predict the supply, demand, and economic effects of groundwater declines could be most-readily integrated into 2021 forecasting.

Introduction

Groundwater is a limited resource in the Columbia River basin, with declining groundwater levels documented in many locations. Groundwater scarcity has impacts on:

- Individual farmer crop choices based on varying water duties (e.g. orchard/vineyard versus seasonal crops)
- Long term economic and public finance outcomes for groundwater users and groundwater-dependent communities.
- Surface water supplies for both instream and ecological uses, and out-of-stream uses, based on increasing use of surface water and impacts to instream flows from declining groundwater levels.
- Public water supplies (use of groundwater may be more preferable and economical than treating surface water).

Previous Water Supply and Demand Forecasts presumed groundwater availability was not limiting the ability of water users to exercise water rights. The analysis and summary described here and in the area summary sheets in the 2016 Water Supply and Demand Forecast represent initial steps to integrate groundwater into the Forecast. The long-term goal of this work is to support better prediction of future water demand and the reliability of existing groundwater rights. In addition, this groundwater integration module provides decision makers with supporting documentation to prioritize investments in water supply development based on risk, feasibility of supply alternatives, review of existing projects addressing declining groundwater, and potential investigation needs.

Approach

The groundwater module consists of two key elements. The first element consisted of a focused literature and data review and summary of declining groundwater across select areas in the Columbia Plateau. The second component has been outreach to inform key stakeholder groups about the incremental addition of groundwater supplies into the Forecast.

Methodology

A select list of declining groundwater areas was developed through a literature review and consultations with the Washington State Department of Ecology (Ecology). Those areas are presented in Figure 1 and include:

- Black Rock – Moxee Area (Yakima County);
- Odessa Subarea;
- Palouse Groundwater Basin (Whitman County);
- Red Mountain – Badger Mountain Area (Benton County);
- Southwest Flank of the Rattlesnake Hills (Yakima and Benton Counties);
- Walla Walla Basin;
- West Plaines of Spokane;
- West Richland;
- White Salmon Groundwater Supply; and
- Horse Heaven Hills Area (Klickitat and Benton Counties).

Each of these areas were evaluated through a combination of literature review and GIS analysis.

Research was conducted using Water Availability Focus Sheets, Water Resource Inventory Area (WRIA) planning documents, and scientific literature from USGS and others. The literature review also included an assessment of available groundwater models that included the study areas.

As part of the GIS analysis, data was from the following sources:

- Ecology, Washington Department of Natural Resources (DNR), and United States Geological Survey (USGS) monitoring well databases;
- A state-wide Aquifer Storage and Recover (ASR) feasibility study (Gibson and Campana, 2014);
- The USGS stream gage database;
- A state-wide compilation of surface water baseflow estimates (Sinclair and Pitz, 1999);
- The Washington Department of Health (DOH) Sentry water system database; and
- Federal Census Data.

These data were then brought into a GIS framework, organized by area and summarized. Through research and GIS analysis, the hydrogeologic context, scope of groundwater decline, management context, risk, potential solutions, and data gaps were evaluated and summarized in each of the area summaries.

This executive summary discusses general trends in groundwater availability issues identified across the areas. The GIS framework will also available in electronic form.

Outreach

As part of initiating integration of groundwater into the forecast, public outreach was conducted to inform key stakeholder groups about this work. Outreach meetings included:

- The Columbia River Policy Advisor Group (CRPAG), on January 29, 2015 and August 4, 2016.
- The County Commissioners Policy Advisory Group on August X, 2015.
- The Water Resources Advisory Committee (WRAC) on March 16, 2015 and July 18, 2016.
- Outreach letters sent to county commissioners, watershed planning units, state and federal agencies, and tribes in July 2015.
- Multi-agency meetings with the Washington Department of Fish and Wildlife (WDFW), DOH, DNR, the Washington State Department of Agriculture, and Ecology on May 12, 2015 and August 4, 2016.
- Public open houses in Wenatchee, Kennewick, and Spokane on June 21-23, 2016.

Guide to Area Summaries

Graphical Area Summaries (4 pages each) of our findings for each of the areas of declining groundwater are included as part of the 2016 Forecast. The Area Summaries are organized into eight sections that describe the scope of declining groundwater, investigation needs, and potential and planned solutions. General findings from the study regarding groundwater occurrence and declines are summarized in Section 4 of this Executive Summary.

A key to the summaries is presented in Figure 2. The eight sections included are:

- Hydrogeologic Conceptual Model
- Surface Water-Groundwater Interaction
- Management Context
- Scope of Groundwater Decline
- Available Groundwater Models
- Potential Solutions
- Data Gaps
- Risk Factors

Findings on Groundwater Occurrence and Declines

The Area Summaries present area-specific findings on groundwater occurrence and declines; however, there are general trends that are apparent throughout the Columbia River Basin. Our work builds upon and corroborates findings documented by USGS studies of groundwater availability across the Columbia Plateau (Vaccaro et al. 2015; Burns et al., 2012; and Snyder and Haynes, 2010). These studies documented key groundwater availability issues that are prevalent in the Columbia Plateau in Washington State (Burns et al., 2012):

- Widespread water-level declines due to pumping; and
- Reduction to stream baseflows and associated effects on water temperature and quality.

Our key general findings include:

- Most groundwater use in the Columbia Basin is derived from the Columbia Plateau Regional Aquifer System

(CPRAS), an extensive series of basalt flows. The hydrogeologic setting is described in more detail later in this summary.

- Current volumes of groundwater withdrawals exceed quantities locally replenished by recharge from precipitation or surface water infiltration, and as a result, decreases in groundwater levels are occurring in many areas.
- Groundwater declines are further exacerbated in some areas by aquifer isolation related to geologic structures, including faults and folds. These can limit groundwater movement lateral and vertically.
- Instream flow requirements and senior surface water rights also drive limitations on groundwater supply in many areas, particularly in shallow overburden aquifers that are hydraulically well connected with surface water
- Groundwater levels in wells are declining at rates up to approximately 25 feet per year in the basin. The largest and most widespread declines occur in the Odessa Subarea in the central Columbia Plateau, and along the Southwest Flank of the Rattlesnake Hills in the Yakima Valley. Large localized groundwater declines have been documented in other areas such as the Horse Heaven Hills Area and the Black Rock - Moxee Area.
- Groundwater declines have been documented for many decades in most of the study areas. Municipalities in the Palouse groundwater basin have documented steady declines in groundwater levels since the early 20th century. Most of the study areas experienced increasing rates of groundwater decline through the 1970s and 1980s due to increased agricultural production and irrigation, with rates of decline continuing to the present day.
- Declining levels of groundwater may potentially be magnified and accelerated by the effects of global climate change in the coming years and decades (Pitz, 2016). For example, groundwater withdrawals may increase as a response to decreases in surface water availability resulting from climate change. Increases in irrigation demand due to warmer and drier conditions may also result. Increases in shallow groundwater demand due to climate change could also degrade the ability of groundwater discharge to maintain aquatic habitat quality.

Additional general background, findings, and trends identified in the study are presented below.

Hydrogeologic Setting

All of the study areas include aquifers within the CPRAS, the regional basalt aquifer system that provides much of the Columbia Basin's groundwater. This regional, multi-aquifer system covers approximately 44,000 mi2 within southeast Washington, northeast Oregon, and western Idaho.

The CPRAS is widespread and highly transmissive in its aquifer zones, and large quantities of water can typically be withdrawn from properly constructed wells. The aquifer is highly compartmentalized both vertically and horizontally and receives very limited recharge, particularly to deeper aquifer zones). While the aquifers are very transmissive, the aquifers store a relatively small amount of water, because they are made up of relatively thin basalt flow boundaries. Low storage, compartmentalization, and limited recharge lead to large declines in groundwater due to pumping.

CRRAS aquifer zones are made up of several thin but productive layers located between thick basalt flows with limited groundwater occurrence. The major aquifers from youngest to oldest are:

- Overburden deposits. Overburden deposits, where they exist, overlie basalt flows and are made up of unconsolidated to semi-consolidated sedimentary deposits and volcanic deposits. While the Wanapum and Grande Ronde supply most of the groundwater used in the Columbia Plateau. The overburden also contains productive and heavily utilized aquifers in some area such as the Southwest Flank of the Rattlesnake Hills in the Yakima Valley.
- Saddle Mountain Basalt. This unit is the shallowest and least widespread of the basalt aquifers. It occurs mostly in the west central portion of the CPRAS. The Saddle Mountain can be up to 1,000 feet.
- Wanapum Basalt. The Wanapum Basalt formation lies below the Saddle Mountain Basalt and is present throughout most of the study area. The thickness of the Wanapum ranges up to 1,200 feet.
- Grande Ronde Basalt. The Grande Ronde is the deepest and most extensive of the basalt formations that are heavily used for groundwater production. The thickness of the Grande Ronde is largely unknown but it may be greater than 14,000 ft. in some locations.

Other findings regarding the hydrogeologic setting include:

- Although the CPRAS is wide spread, groundwater flow is highly compartmentalized due to structure and horizontal layering within CRBG (Kahle et al., 2011; Kinnison and Sceva, 1963; Hansen et al., 1994; Bauer and Hansen, 2000; Vaccaro et al., 2009).
- Because the interiors of individual basalt flows, or layers, are far more dense and massive than the interflow zones, they limit vertical flow between aquifers. As a result, groundwater flow occurs primarily horizontally through the interflow zones (Kahle et al., 2011), and there is little vertical flow of groundwater between aquifers and little recharge to deeper aquifers.
- Horizontally, groundwater flow is also compartmentalized by faults and folds that offset and truncate the highly transmissive interflow zones, particularly within the area known as the Yakima Fold Belt. Aquifer compartmentalization exacerbates groundwater declines from pumping because it restricts groundwater supply to a smaller area.
- Areas that have a high degree of aquifer compartmentalization include the Black Rock – Moxee Area, Horse Heaven Hills Area, West Richland, the Red Mountain – Badger Mountain Area, the Palouse Groundwater Basin, the West Plains of Spokane, and the City of White Salmon Water Supply Aquifer.
- Groundwater flow in the CPRAS is typically controlled by topography. The highest recharge from precipitation occurs along the margins of the CPRAS near the mountains. Groundwater discharges from the CPRAS along the major rivers of the Columbia River Basin.

Surface Water-Groundwater Interaction

Overburden aquifers are typically connected with streams in many areas including the Walla Walla and Yakima Basins (Vaccaro, 2011; GSI, 2007). Instream flow needs can impose limitations on groundwater supply from overburden aquifers in many areas. These include the Southwest Flank of Rattlesnake Hills in the Yakima Valley and in the Walla Walla Basin. Basalt aquifers, by contrast, are more hydraulically separated from surface water in most areas due to depth and compartmentalization by faulting, folding, and dense basalt flow interiors. More hydraulic connection can exist where river canyons have incised deep into the basalt, such as along the Columbia and Snake Rivers, portions of the Yakima River, and in the West Planes of Spokane. In areas such as these, streams can gain flow from basalt aquifers and loose flow to recharge basalt aquifers (Kahle et. al., 2011; Ecology, 2013c; and Drost, 1997).

Management Context

The management context refers to the regulation of the surface and groundwater within the Area Summaries, including groundwater management areas and instream flow rules. Existing instream flow rules established by Ecology and Surface Water Source Limitations (SWSLs) established by WDFW can impose regulatory restrictions on groundwater use from aquifers in connection with surface water in areas such as the Yakima and Walla Walla Basins. This is particularly the case in overburden aquifers which are typically hydraulically well connected with streams and rivers.

Of the selected areas, only the Odessa Subarea is included in a groundwater management area. Legislation that established the area (chapter 173-128A, 173-130) limits groundwater withdrawals such that declines don't exceed 300 feet or 30 feet in 3 years. As groundwater declines continue, Ecology will likely face additional pressure to adopt formal regulatory frameworks in basins where these are lacking now.

Risk Factors

Large communities of people and several agricultural economies depend on groundwater resources in the study areas. Many of areas rely on groundwater primarily for agriculture, including the Odessa Subarea, Southwest Flank of the Rattlesnake Hills, Black Rock – Moxee Area, Horse Heaven Hills Area, and Red Mountain – Badger Mountain Area.

Several areas also rely on groundwater for municipal use as a primary water source, or during peak times and the dry season including the Odessa Area, Southwest Flank of the Rattlesnake Hills, West Plains of Spokane, Palouse Groundwater Basin, Walla Walla Basin, West Richland, and White Salmon.

The areas summarize in this report include an estimated total of 580,000 acres irrigated with groundwater and approximately 232,000 people served by public water systems that rely on groundwater.

Solutions

Several projects either are planned or in progress in many of the areas to alleviate declining groundwater, and additional solutions are potentially feasible. These include both demand-oriented and supply-oriented solutions.

Supply-oriented solutions include moving groundwater users from groundwater to surface water sources. For example, a plan is underway to switch approximately 90,000 acres in the Odessa Subarea from groundwater irrigation to surface water irrigation. The switch to surface water is intended to reduce withdrawals and associated groundwater level declines with the local aquifers.

It may be impractical or costly switch to surface water in many areas, because surface water is often fully appropriated. In these areas, other solutions potentially available include Aquifer Storage and Recovery (ASR) and the creation of new surface water storage reservoirs. These options may be technically feasible in many of these areas, taking advantage of more abundant surface water during the winter with storage for later use during the summer. Similarly, shallow aquifer recharge is beneficial in many areas to maintain healthy stream flows during the summer by boosting groundwater discharge to streams.

Storage projects of all types are planned and being implemented in many of the areas including the Odessa Subarea, Horse Heaven Hills Area, White Salmon, South West Flank of the Rattlesnake Hills, and the Walla Walla Basin. Additional projects may be physically feasible in the Palouse, West Planes of Spokane, Red Mountain – Badger Mountain Area, and West Richland. While these solutions are considered physically feasible based on the aquifer setting and potential availability of surface, project feasibility will also depend on economics and regulatory considerations that have not been considered in detail in this study.

Demand side solutions are also being implemented or are feasible in many of the areas. Conservation plans are common in municipalities. Additional conservation measures can be implemented in many areas including xeriscaping, use of reclaimed water, crop type changes, and improved irrigation efficiencies. Currently, demand side solutions are largely voluntary or incentive based. As groundwater declines become more significant, mandatory measures instituted by state and local governments may become more common.

Each of the Area Summaries contains supply-side and demand-side measures that are applicable to each declining groundwater body.

Ongoing Integration of Groundwater into the Forecast

Summary of Potential Investigation Needs

This assessment of declining groundwater issues in Washington State was supported and made possible by existing documentation of research on groundwater availability that has been carried out in Washington State and made available to the public. Data gaps in knowledge regarding declining groundwater in the basin do exist, and additional investigation to both design solutions to existing problems and investigate new problems will be needed.

In addition, ongoing and expanded groundwater monitoring is essential. Additional modeling of groundwater availability is also considered needed to support management of groundwater into the future. Population increases, industry and agriculture changes, and climate change are all expected to alter patterns of groundwater use and aquifer water balances as time goes on. Potential investigation needs in the select areas of declining groundwater are summarized below:

Groundwater Monitoring

- We recommend that long-term groundwater monitoring be continued in many areas and that ease of access to groundwater level data be improved. The collection and analysis of water level elevations in wells through time is essential for the continuing evaluation of groundwater availability.
- Access to widespread and long term groundwater monitoring data allowed the USGS to estimate current trends in groundwater availability throughout the Columbia Basin (Vaccaro et al. 2015; Burns et al., 2012; and Snyder and Haynes, 2010). Monitoring should be continued and expanded to evaluate availability into the future with more refinement and to provide continued historical trend information.
- A review of water level databases maintained by Ecology and the USGS indicated that for some areas with declining groundwater, historical water level monitoring has not continued into the present day or has not been uploaded to the databases. We recommend long-term monitoring with an expanded well network, and continued monitoring at wells that have historical data.
- In many areas, comprehensive groundwater monitoring efforts are being conducted by basin committees, irrigation districts, local water utilities and the Department of Natural Resources; however, not all data is not readily available in an easy to access central location on line.
- Ecology's monitoring well database is an effective and easy to use tool where water level data is consolidated and retrievable. An increase in submission of existing and future monitoring data would improve access to data and ease groundwater availability assessment. Our research indicates that there may be water level data in West Richland, White Salmon, Palouse, West Planes of Spokane, and Walla Walla that can be submitted to the Ecology database.

Groundwater Modeling

- Groundwater modeling can support assessments of groundwater availability and historical trends and future impacts. An example of this is the assessment of regional trends in groundwater availability and water balances that Vaccaro et al. (2015) conducted for the CPRAS, and Ely et al. (2011) completed for the Yakima Valley. These models could be maintained and updated periodically with current water use data, climate projections, and additional data on the hydrogeologic systems to support accurate forecasts into the future.
- Local scale models could also be constructed to provide detailed analysis of groundwater availability and water balances within specific areas. In addition, smaller scale models can be useful for the assessment and design of potential storage projects such as ASR.

Hydrogeological Studies

- Additional hydrogeologic studies can support the siting and design of storage projects, and also can be used to refine new or existing groundwater models for supporting groundwater management.
- Literature and WRIA planning documents reviewed as part of this study identified the need for a more refined characterization of aquifer compartmentalization and location of hydraulic barriers in the Horse Heaven Hills Area and the Palouse Groundwater Basin (WRIA 31 Planning Unit, 2008; TerraGraphics, 2011).
- WRIA planning documents also recommended increased exploration of the Grande Ronde aquifer for potential new sources of groundwater (WRIA 31 Planning Unit, 2008).

Storage Feasibility and Pilot Studies

- ASR and SAR have been identified as potentially physically feasible within many areas (Gibson and Campana, 2014). These storage solutions have the potential to reduce declining groundwater or improve aquatic habitat by increasing groundwater discharge to streams.
- Prior to project implementation, potential additional analyses needed include hydrogeologic studies, including groundwater modeling, economic analysis, and pilot studies.

Conservation and Management Strategies

Moving from voluntary to either incentive-based or mandated conservation strategies will likely be needed in some areas just to minimize groundwater decline-related impacts on existing water users. Because these efforts are likely to be best-received by the regulated community if they are initiated at the local level, County government and watershed planning units in areas with groundwater declines should be engaged to improve awareness and initiate conservation programs.

Model Integration for 2021 Forecast

Decreases in surface water availability usually leads water users to switch to groundwater sources wherever groundwater is available and accessible. Because groundwater offers supplies that are often buffered from yearly hydrologic fluctuations, and in many cases from recharge over a geologic time-step, this has been a typical transfer protocol that has been encouraged by state agencies. However, users in the areas described in this document will find it harder to convert their supplies to surface water because supply is generally not available in the summer without frequent interruption. These users instead may be forced into more extreme adaptation including crop change, field fallowing, participation in water supply projects with a mandatory cost-recovery component, strict conservation, or reuse.

WSU believes that OCR forecasting in 2021 would benefit from expanded assessment of these water right holders. We considered two approaches:

1. Direct integration of existing and new groundwater models with the existing modeling effort;
2. A more robust curtailment model that helps predict the effects of emerging groundwater curtailment on supply, demand, and economic factors.

The first option would allow assessment of the hydrologic aspects of surface and groundwater interactions, enabling quantification of the delayed effects of drought relief pumping on surface water availability in highly connected systems, improved assessment of return flows from irrigation water and conveyance losses, etc. However, direct integration of groundwater models with the current hydrologic models that are used for the Forecast is technically challenging, computationally intensive, and limited by the availability of consistent groundwater models over key areas in eastern Washington. Over time, we anticipate that the state-of-the-science will continue to evolve such that this more direct integration will be feasible for future forecasts. Alternatively, for the next forecast, we plan to instead focus on the role that groundwater plays within the regulatory context.

As part of the 2021 Forecast WSU proposes to identify the areas with declining groundwater and its potential links to surface water availability through a curtailment model, based in part on historical data. As a part of the 2016 Forecast, a surface water curtailment model has been developed which accounts for surface water availability and priority of water right holders to execute curtailment. The surface water curtailment model will be expanded for the 2021 Forecast to dynamically account for transitions between surface and groundwater use. Results from this curtailment model, historical groundwater information, and local observation wells will be used to establish a relationship between surface water and groundwater that can be analyzed as a function of current and future climate and water demand.

WSU envisions several focused efforts that will contribute to the predictive effort of a curtailment model that integrates declining groundwater areas, including:

1. Emerging areas of increased regulation either at the groundwater subbasin scale through closures, or targeted efforts through interviews with Ecology water masters.
2. County and State health jurisdiction efforts to ensure reliable public water supplies.
3. Assessments of priority-schemes in each declining groundwater subbasin to define those water rights most likely to first feel the brunt of new curtailment efforts, and the economic implications thereof.
4. Historical water use information from surface-to-ground and ground-to-surface transfers, as well as supplemental and emergency well authorizations, to help to identify the areas and conditions where water rights holders are switching between sources.

In order for this effort to be successful, WSU recommends more robust and continued investments in the data gaps shown on the Area Summaries to better understand declining groundwater levels and how dependence on groundwater may change, including in response to future climate change.

The groundwater module helped inform Ecology on the areas in Eastern Washington to prioritize for information gathering, outreach, and governmental coordination, if effects of groundwater declines on future forecasts are going to be better understood. Ecology uses each Forecast as an investment tool for future grant funding of supply projects, and will consider additional efforts to better understand how its water supply mission should be prioritized to address areas of groundwater decline.

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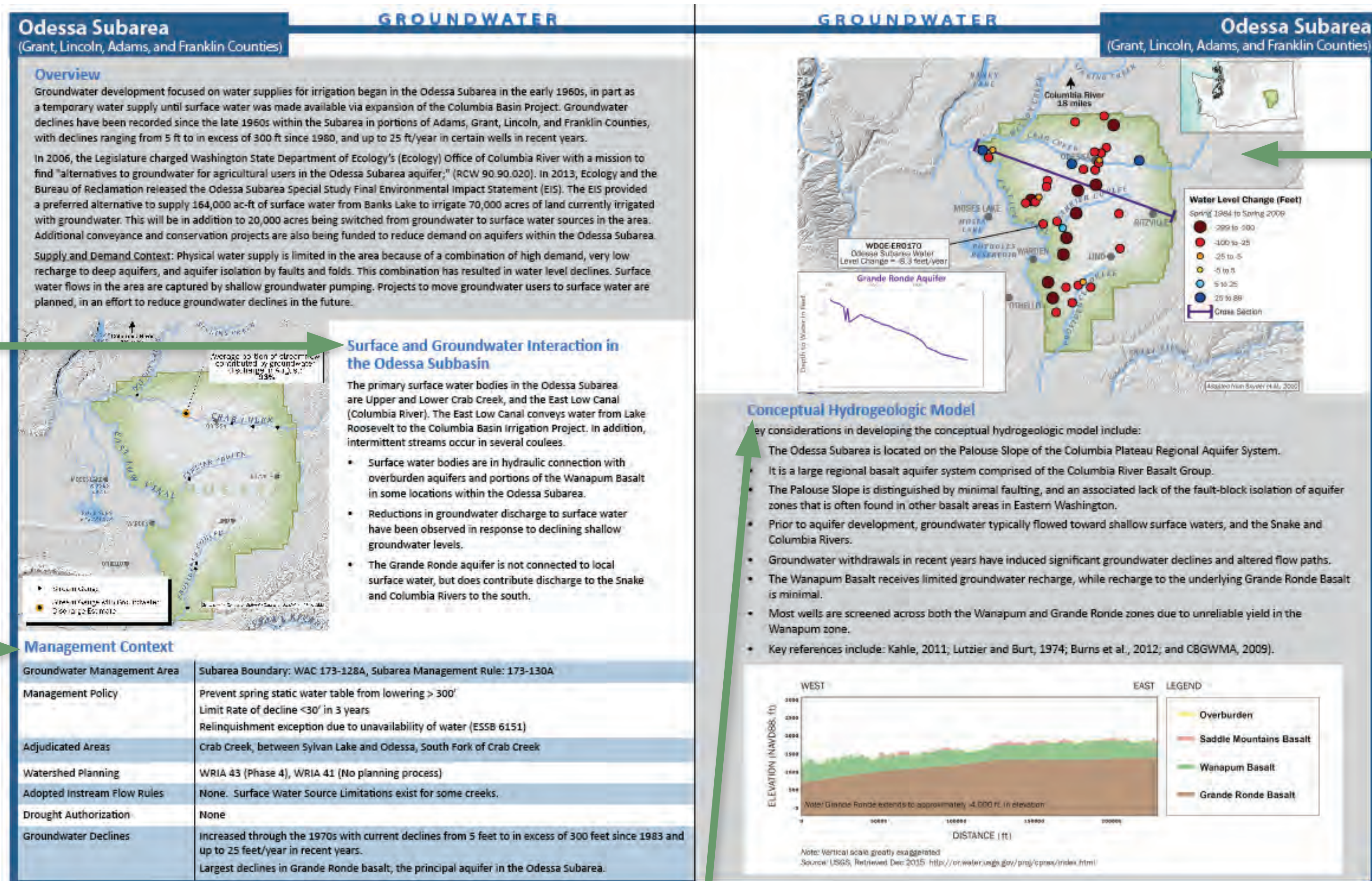
Figure 2: **Guide to Understanding the Area Summaries**



Measurements of groundwater declines are presented in maps for each geographic area. Maps include scaled dots or graphs representing the change in water levels over time.

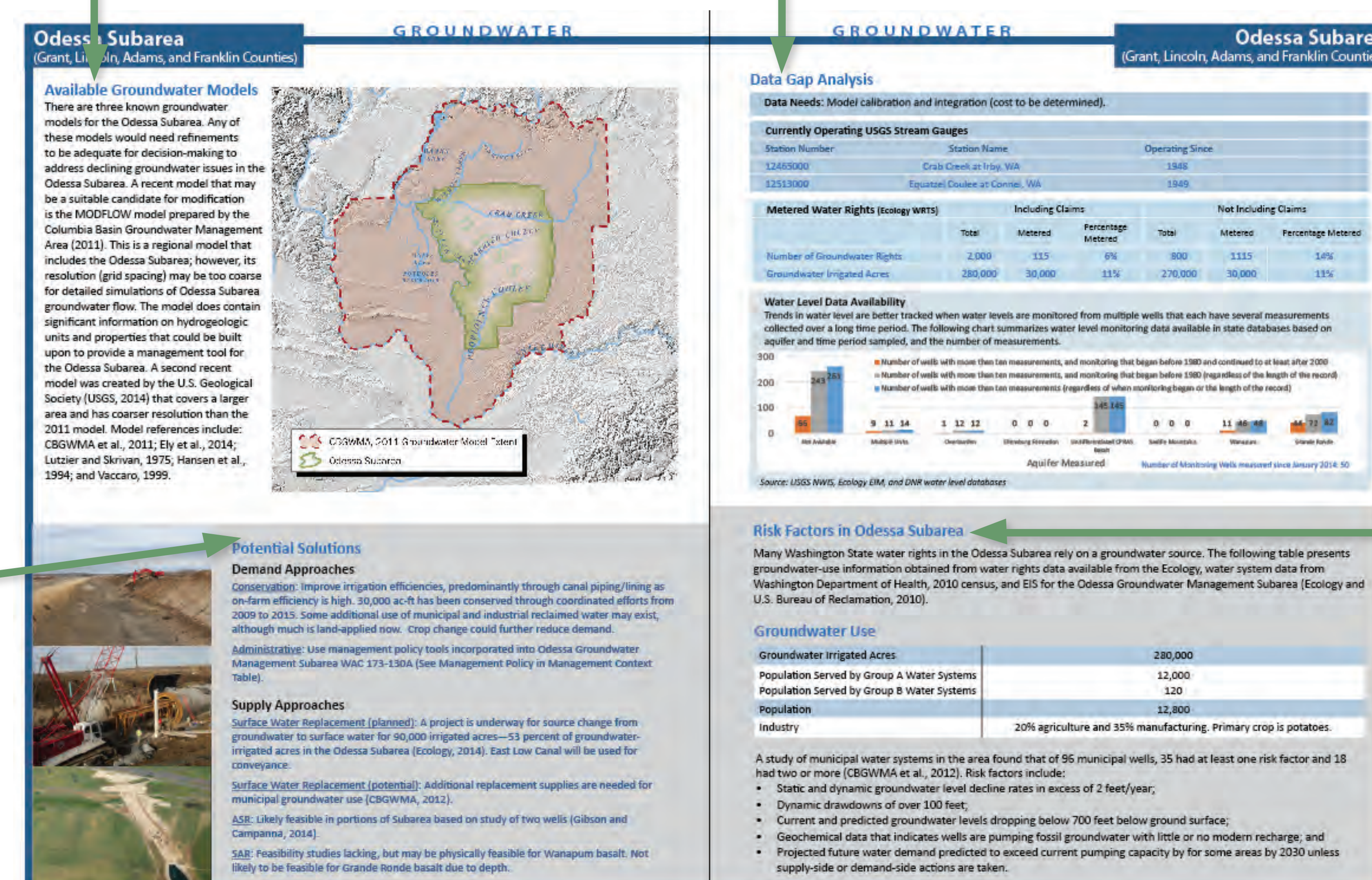
This section summarizes metered water use data, stream flow data, and water level data available from Ecology and USGS databases in each area. Recommendations for future investigation, data collection, and studies are provided.

This section summarizes the availability of groundwater models in each of the areas. Numerical computer models of groundwater flow are an essential tool in groundwater resource management. Models can support forecasting of future groundwater availability, siting and design of water supply solutions.

This section comments on the risks associated with existing and future groundwater level declines. Where available, a summary of the number of residents, scale and nature of economic drivers, and acres of agriculture that rely on groundwater in each area is presented.

This section summarizes research on the degree of connectivity between surface water and important aquifers in each area. Groundwater discharge to surface water plays an important part in maintaining the quality of aquatic habitat in many Columbia Plateau streams by augmenting flows and maintaining cool temperatures during the summer. In some areas, surface water may also recharge groundwater.

The hydrogeologic conceptual model describe the hydraulic and geologic characteristics that aff¬ect groundwater availability and impacts from pumping. Hydrogeologic conditions, including the degree of aquifer compartmentalization, availability of recharge, and prominence of di-fferent aquifer zones vary between areas of the basin. A cross section illustrating the stratigraphy and compartmentalization is also included where available.



This section provides a summary of area groundwater policies, watershed planning, instream flow restrictions, water right adjudications, and other management criteria.

This section summarizes water supply or demand solutions that may be feasible, being planned or being implemented in each area. Supply side solutions include switching to new sources of water or storage. Demand oriented solutions work to decrease water use through measures such as conservation.

Odessa Subarea
(Grant, Lincoln, Adams, and Franklin Counties)

Overview

Groundwater development focused on water supplies for irrigation began in the Odessa Subarea in the early 1960s, in part as a temporary water supply until surface water was made available via expansion of the Columbia Basin Project. Groundwater declines have been recorded since the late 1960s within the Subarea in portions of Adams, Grant, Lincoln, and Franklin Counties, with declines ranging from 5 ft to in excess of 300 ft since 1980, and up to 25 ft/year in certain wells in recent years.

In 2006, the Legislature charged Washington State Department of Ecology's (Ecology) Office of Columbia River with a mission to find "alternatives to groundwater for agricultural users in the Odessa Subarea aquifer;" (RCW 90.90.020). In 2013, Ecology and the Bureau of Reclamation released the Odessa Subarea Special Study Final Environmental Impact Statement (EIS). The EIS provided a preferred alternative to supply 164,000 ac-ft of surface water from Banks Lake to irrigate 70,000 acres of land currently irrigated with groundwater. This will be in addition to 20,000 acres being switched from groundwater to surface water sources in the area. Additional conveyance and conservation projects are also being funded to reduce demand on aquifers within the Odessa Subarea.

Supply and Demand Context: Physical water supply is limited in the area because of a combination of high demand, very low recharge to deep aquifers, and aquifer isolation by faults and folds. This combination has resulted in water level declines. Surface water flows in the area are captured by shallow groundwater pumping. Projects to move groundwater users to surface water are planned, in an effort to reduce groundwater declines in the future.

Surface and Groundwater Interaction in the Odessa Subbasin

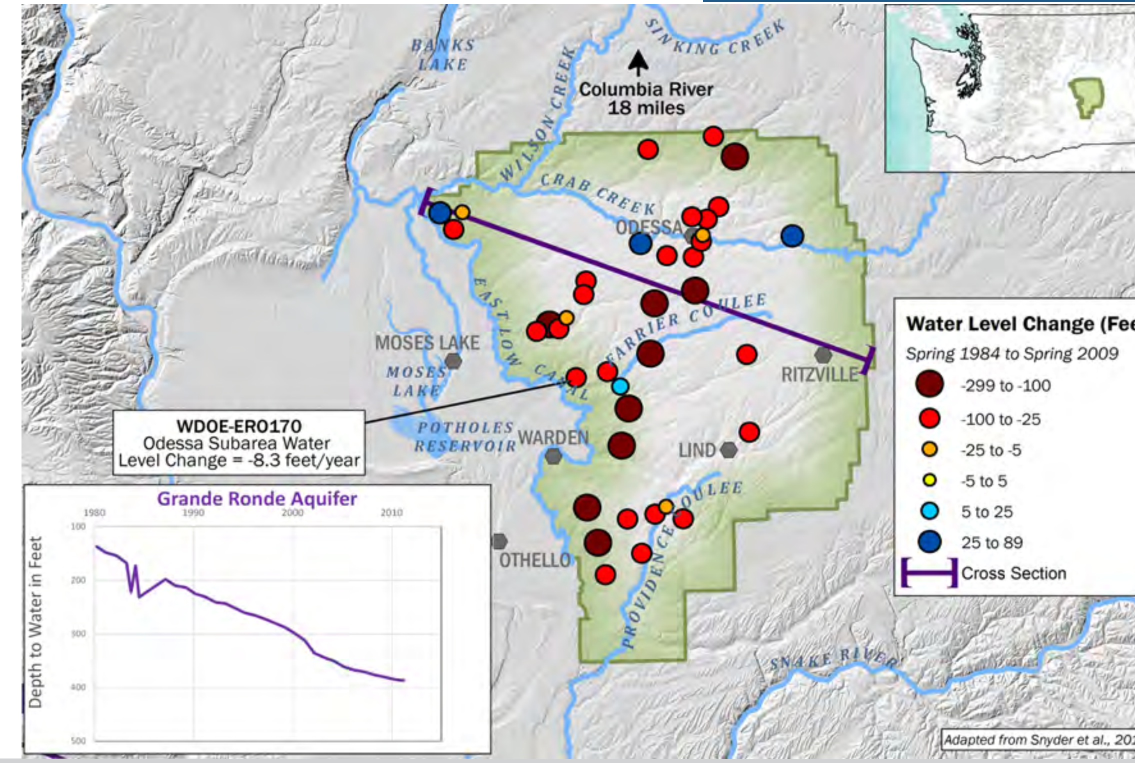
The primary surface water bodies in the Odessa Subarea are Upper and Lower Crab Creek, and the East Low Canal (Columbia River). The East Low Canal conveys water from Lake Roosevelt to the Columbia Basin Irrigation Project. In addition, intermittent streams occur in several coulees.

- Surface water bodies are in hydraulic connection with overburden aquifers and portions of the Wanapum Basalt in some locations within the Odessa Subarea.
- Reductions in groundwater discharge to surface water have been observed in response to declining shallow groundwater levels.
- The Grande Ronde aquifer is not connected to local surface water, but does contribute discharge to the Snake and Columbia Rivers to the south.

Management Context

Groundwater Management Area	Subarea Boundary: WAC 173-128A, Subarea Management Rule: 173-130A
Management Policy	Prevent spring static water table from lowering > 300' Limit Rate of decline <30' in 3 years Relinquishment exception due to unavailability of water (ESSB 6151)
Adjudicated Areas	Crab Creek, between Sylvan Lake and Odessa, South Fork of Crab Creek
Watershed Planning	WRIA 43 (Phase 4), WRIA 41 (No planning process)
Adopted Instream Flow Rules	None. Surface Water Source Limitations exist for some creeks.
Drought Authorization	None
Groundwater Declines	Increased through the 1970s with current declines from 5 feet to in excess of 300 feet since 1983 and up to 25 feet/year in recent years. Largest declines in Grande Ronde basalt, the principal aquifer in the Odessa Subarea.

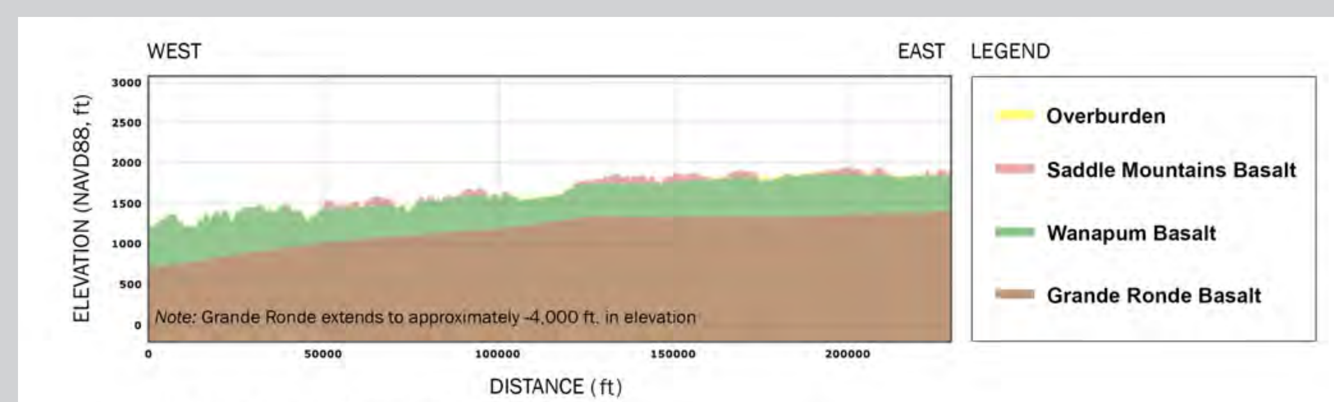
Odessa Subarea
(Grant, Lincoln, Adams, and Franklin Counties)



Conceptual Hydrogeologic Model

Key considerations in developing the conceptual hydrogeologic model include:

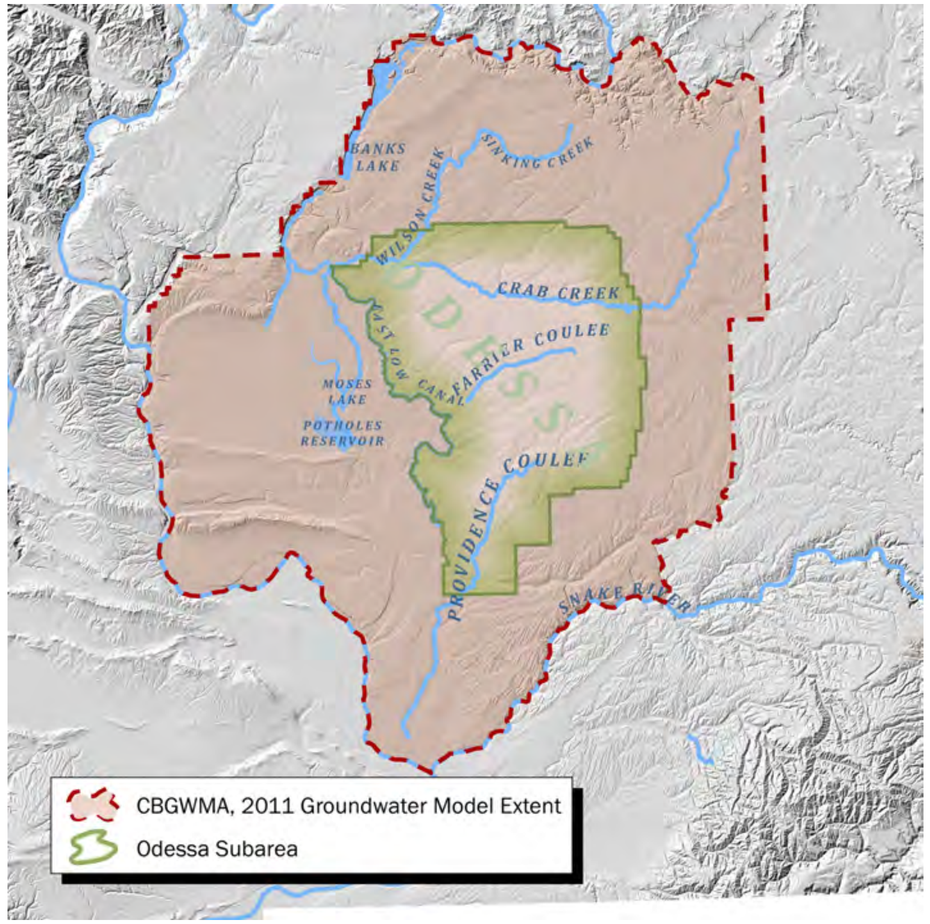
- The Odessa Subarea is located on the Palouse Slope of the Columbia Plateau Regional Aquifer System.
- It is a large regional basalt aquifer system comprised of the Columbia River Basalt Group.
- The Palouse Slope is distinguished by minimal faulting, and an associated lack of the fault-block isolation of aquifer zones that is often found in other basalt areas in Eastern Washington.
- Prior to aquifer development, groundwater typically flowed toward shallow surface waters, and the Snake and Columbia Rivers.
- Groundwater withdrawals in recent years have induced significant groundwater declines and altered flow paths.
- The Wanapum Basalt receives limited groundwater recharge, while recharge to the underlying Grande Ronde Basalt is minimal.
- Most wells are screened across both the Wanapum and Grande Ronde zones due to unreliable yield in the Wanapum zone.
- Key references include: Kahle, 2011; Lutzier and Burt, 1974; Burns et al., 2012; and CBGWMA, 2009).



Note: Vertical scale greatly exaggerated
Source: USGS, Retrieved Dec 2015. http://or.water.usgs.gov/proj/cpras/index.html

Available Groundwater Models

There are three known groundwater models for the Odessa Subarea. Any of these models would need refinements to be adequate for decision-making to address declining groundwater issues in the Odessa Subarea. A recent model that may be a suitable candidate for modification is the MODFLOW model prepared by the Columbia Basin Groundwater Management Area (2011). This is a regional model that includes the Odessa Subarea; however, its resolution (grid spacing) may be too coarse for detailed simulations of Odessa Subarea groundwater flow. The model does contain significant information on hydrogeologic units and properties that could be built upon to provide a management tool for the Odessa Subarea. A second recent model was created by the U.S. Geological Society (USGS, 2014) that covers a larger area and has coarser resolution than the 2011 model. Model references include: CBGWMA et al., 2011; Ely et al., 2014; Lutzier and Skrivan, 1975; Hansen et al., 1994; and Vaccaro, 1999.



Potential Solutions

Demand Approaches

Conservation: Improve irrigation efficiencies, predominantly through canal piping/lining as on-farm efficiency is high. 30,000 ac-ft has been conserved through coordinated efforts from 2009 to 2015. Some additional use of municipal and industrial reclaimed water may exist, although much is land-applied now. Crop change could further reduce demand.

Administrative: Use management policy tools incorporated into Odessa Groundwater Management Subarea WAC 173-130A (See Management Policy in Management Context Table).

Supply Approaches

Surface Water Replacement (planned): A project is underway for source change from groundwater to surface water for 90,000 irrigated acres—53 percent of groundwater-irrigated acres in the Odessa Subarea (Ecology, 2014). East Low Canal will be used for conveyance.

Surface Water Replacement (potential): Additional replacement supplies are needed for municipal groundwater use (CBGWMA, 2012).

ASR: Likely feasible in portions of Subarea based on study of two wells (Gibson and Campanna, 2014).

SAR: Feasibility studies lacking, but may be physically feasible for Wanapum basalt. Not likely to be feasible for Grande Ronde basalt due to depth.

GROUNDWATER
Odessa Subarea
(Grant, Lincoln, Adams, and Franklin Counties)

Data Gap Analysis

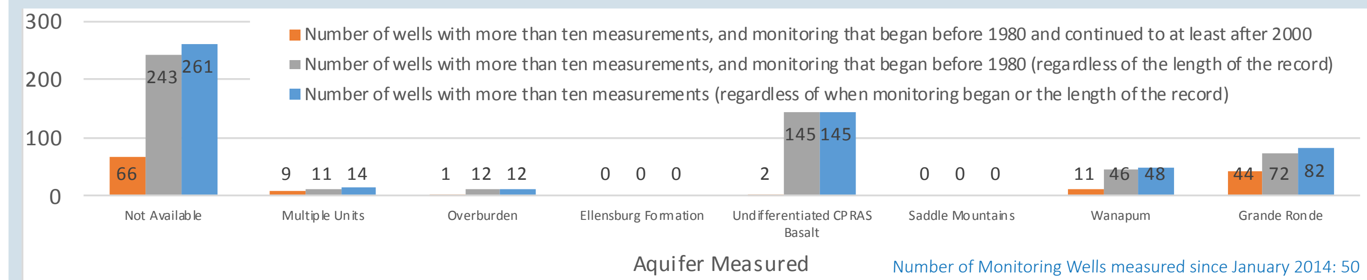
Data Needs: Model calibration and integration [estimated costs yet to be determined].

Currently Operating USGS Stream Gauges		
Station Number	Station Name	Operating Since
12465000	Crab Creek at Irby, WA	1948
12513000	Equatzel Coulee at Connel, WA	1949

Metered Water Rights (Ecology WRTS)	Including Claims			Not Including Claims		
	Total	Metered	Percentage Metered	Total	Metered	Percentage Metered
Number of Groundwater Rights	2,000	115	6%	800	1115	14%
Groundwater Irrigated Acres	280,000	30,000	11%	270,000	30,000	11%

Water Level Data Availability

Trends in water level are better tracked when water levels are monitored from multiple wells that each have several measurements collected over a long time period. The following chart summarizes water level monitoring data available in state databases based on aquifer and time period sampled, and the number of measurements.



Source: USGS NWIS, Ecology EIM, and DNR water level databases

Risk Factors in Odessa Subarea

Many Washington State water rights in the Odessa Subarea rely on a groundwater source. The following table presents groundwater-use information obtained from water rights data available from the Ecology, water system data from Washington Department of Health, 2010 census, and EIS for the Odessa Groundwater Management Subarea (Ecology and U.S. Bureau of Reclamation, 2010).

Groundwater Use

Groundwater Irrigated Acres	280,000
Population Served by Group A Water Systems Population Served by Group B Water Systems	12,000 120
Population	12,800
Industry	20% agriculture and 35% manufacturing. Primary crop is potatoes.

A study of municipal water systems in the area found that of 96 municipal wells, 35 had at least one risk factor and 18 had two or more (CBGWMA et al., 2012). Risk factors include:

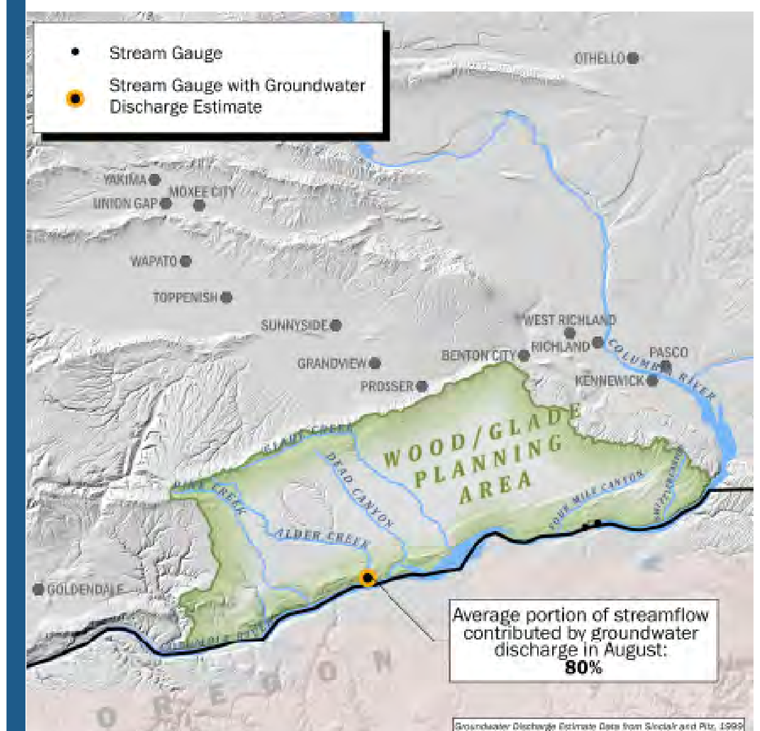
- Static and dynamic groundwater level decline rates in excess of 2 feet/year;
- Dynamic drawdowns of over 100 feet;
- Current and predicted groundwater levels dropping below 700 feet below ground surface;
- Geochemical data that indicates wells are pumping fossil groundwater with little or no modern recharge; and
- Projected future water demand predicted to exceed current pumping capacity by for some areas by 2030 unless supply-side or demand-side actions are taken.

Overview

Significant groundwater supply development for irrigation in the Horse Heaven Hills Area began in the 1960s and continued to expand through at least the 1990s. Water level data indicate groundwater levels have declined significantly in deeper basalt units between 1983 and 2009. Total groundwater withdrawals were estimated in 2004 to total approximately 63,000 ac-ft/year. WRIA studies conclude that hundreds of thousands of additional acres could be available for irrigation and economic development if new irrigation supplies could be obtained.

A U.S. Geological Survey (USGS) study noted groundwater level increases of 5 to 25 or more feet in three wells in the Saddle Mountain Basalt, likely due to infiltration from excess irrigation; however, declines of 100 to 250 feet in the Wanapum Basalt, and 5 to 25 feet in the Grande Ronde Basalt have been identified. Groundwater level declines are concentrated along the Klickitat/Benton county line, in a portion of the aquifer system that is isolated by vertical faults and folds.

Supply and Demand Context: Physical water supply is limited in the area because of a combination of high demand, very low recharge to deep aquifers, and aquifer isolation by faults and folds. This combination has resulted in water level declines.



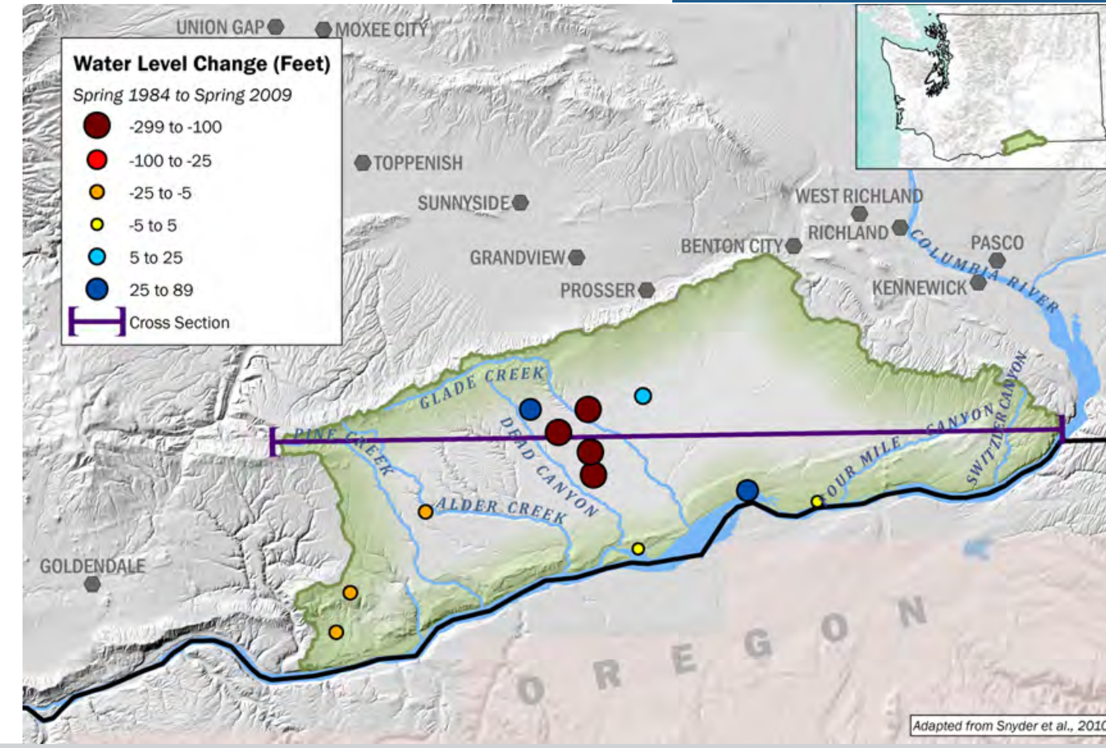
Surface and Groundwater Interaction in the Horse Heaven Hills Area

The primary surface water drainages in the Horse Heaven Hills Area are Wood Gulch, Pine, Alder, Dead, Glade, Four Mile, and Switzler Canyons, all of which drain to the Columbia River.

- Surface waters drain to the John Day Pool and portions of the McNary Pool of the Columbia River, which borders the planning area to the south. Groundwater not isolated by faults and folds also drains to the river. However, geologic folding in the Columbia Hills limits groundwater flow from much of the Horse Heaven Hills Area toward the Columbia River.
- All the major drainages in the Horse Heaven Hills Area are intermittent and with the exception of a few spring-fed reaches, stop running during the dry season (Aspect, 2004).
- Groundwater pumping results in a combination of decreases in groundwater discharge to the Columbia River and decreases in aquifer storage (i.e., groundwater declines).

Management Context

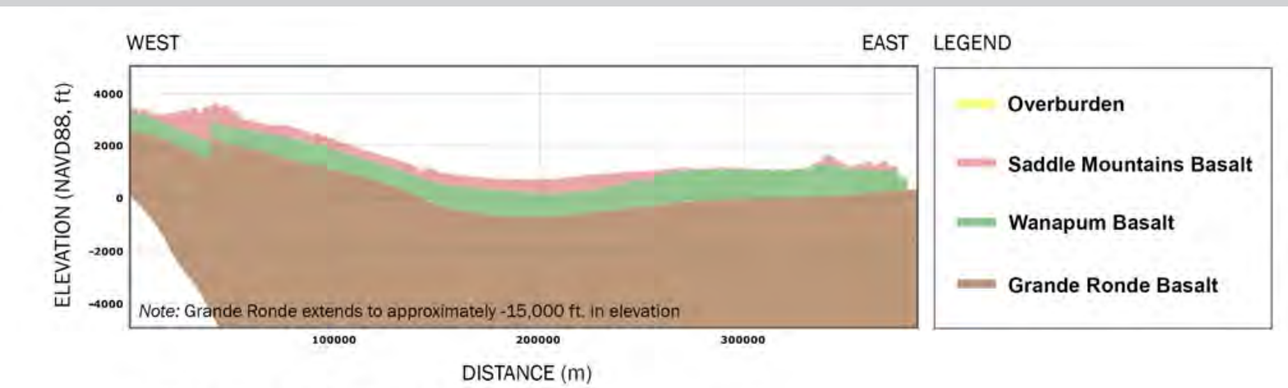
Adjudicated Areas	None (Ecology, 2006)
Watershed Planning	WRIA 31 (Plan completed [WRIA 31 Planning unit, 2008]; currently in phase 4, implementation)
Adopted Instream Flow Rules	Columbia River (WAC 173-563), John Day and McNary Pools (WAC 173-531A); No instream flow rules specific to WRIA 31, and none are planned.
Drought Authorization	Drought authorization program not in place.
Groundwater Declines	Steady declines in the Wanapum Basalt since the late 1970s with current declines in excess of 200 ft. Declines also observed in the Grande Ronde Basalt, but increases have been documented in the Saddle Mountain Basalt due to irrigation seepage.



Conceptual Hydrogeologic Model

Considerations in developing the conceptual hydrogeologic model include:

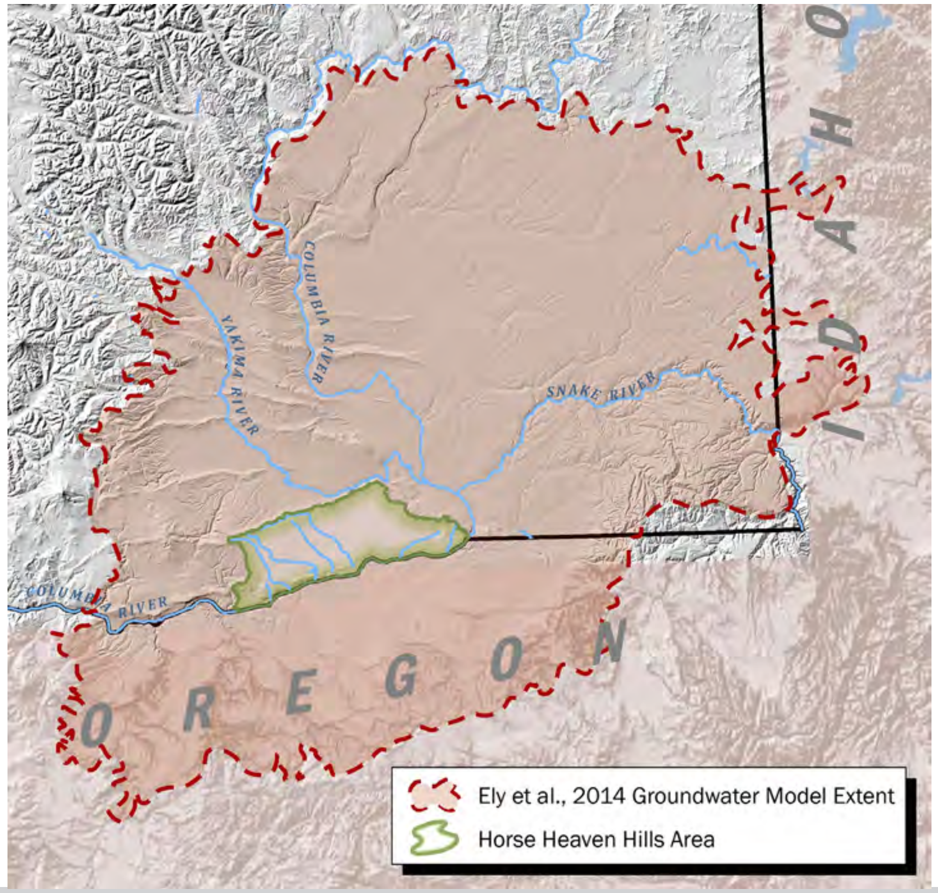
- Horse Heaven Hills Area aquifer zones are part of the Columbia Plateau Regional Aquifer System.
- The primary aquifer zones from shallowest to deepest are the Saddle Mountain Basalt and the Wanapum Basalt. The Grande Ronde Basalt is present below the Wanapum, and is largely unexplored. However, the Grande Ronde likely has high pumping lifts, low recharge, and low water quality that may not be suitable for irrigation of most crop types.
- Groundwater generally flows from the Horse Heaven Hills toward the Columbia River and local drainage basins, unless limited by fault isolation.
- Fault block isolation of aquifer zones act to enhance groundwater declines. Geologic folding in the Horse Heaven Hills and the Columbia Hills cause additional isolation.
- Intensive irrigation with Colombia River water and Wanapum groundwater appears to be causing increases in groundwater levels in the Saddle Mountain Basalt. However, most agricultural wells are completed in the Wanapum Basalt where water levels are declining.
- As of 2004, groundwater production was estimated to exceed recharge by approximately 40 percent.
- Key references: Packard et al., 1996; WRIA 31 Planning Unit, 2008; Aspect, 2004; Aspect, 2011; and Aspect, 2014.

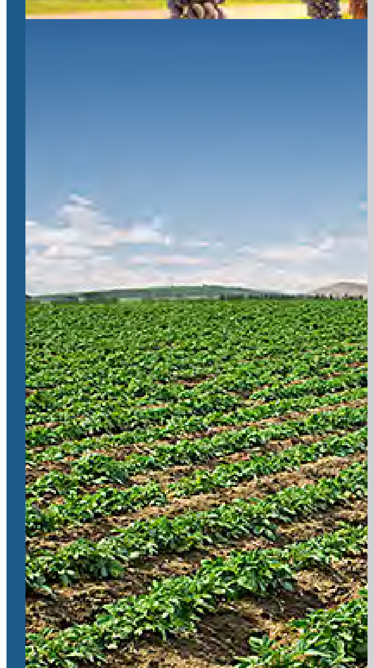


Note: Vertical scale greatly exaggerated
Source: USGS, Retrieved Dec 2015. http://or.water.usgs.gov/proj/cpras/index.html

Available Groundwater Models

Groundwater models of the Horse Heaven Hills Area that are up to date and built to an appropriate scale have not been identified. Developing a new groundwater model to support aquifer management could integrate key assumptions from regional modeling (Ely et al., 2014) and older local modeling (Packard, et al., 1996). Modeling references include: Ely et al., 2014; Packard, et al., 1996; Hansen et al.,1994; and Vaccaro, 1999.





Potential Solutions

Demand Approaches

Conservation: Improve irrigation efficiencies.

Administrative: A groundwater management plan was considered in the WRIA 31 watershed planning process, but to date, it has not been further developed.

Supply Approaches

Storage: Planning is underway for potential implantation of ASR; canal or off-channel storage (WRIA 31 Planning Unit, 2008).

Surface Water Replacement (potential): WAC Chapter 173-531A reserves supplies from the John Day and McNary Pools for 330,000 acres of irrigation to be developed by the year 2020, and 26,000 ac-ft/year of future municipal supply to the year 2020. Permitting is uncertain and may be limited by management related to salmonid survival and power production (WRIA 31 Planning Unit, 2008; Ecology, 2012).

Additional Groundwater: The Grande Ronde Basalt is largely unexplored, and may provide additional sources. However, low water quality may limit its usefulness (WRIA 31 Planning Unit, 2008).

ASR: Likely physically feasible in portions of area, based on a study of two wells in the area (Gibson and Campana, 2014).

SAR: Feasibility studies lacking, but likely physically feasible for the Saddle Mountain Basalt only based on existing groundwater increases in this unit.

WRIA 31 Planning: Detailed summary of potential and planned solutions can be found in the WRIA 31 planning documents

Data Gap Analysis

Data Needs: Aquifer testing to investigate geological structural controls, groundwater monitoring (particularly in all aquifers on the east side and in Grande Ronde), drilling exploration of the Grande Ronde, investigation of connectivity between basalt aquifers and Columbia River [estimated costs yet to be determined].

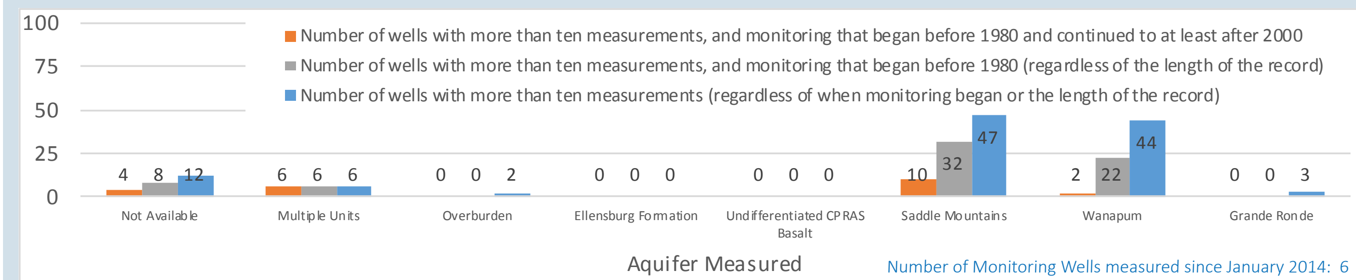
Currently Operating USGS Stream Gauges

No USGS are stream gauges currently in operation

Metered Water Rights (Ecology WRTS)	Including Claims			Not Including Claims		
	Total	Metered	Percentage Metered	Total	Metered	Percentage Metered
Number of Groundwater Rights	440	20	5%	130	20	15%
Groundwater Irrigated Acres	39,000	11,000	28%	37,000	11,000	30%

Water Level Data Availability

Trends in water level are better tracked when water levels are monitored from multiple wells that each have several measurements collected over a long time period. The following chart summarizes water level monitoring data available in state databases based on aquifer and time period sampled, and the number of measurements.



Source: USGS NWIS, Ecology EIM, and DNR water level databases

Risk Factors in Horse Heaven Hills Area

Many water rights in the Horse Heaven Hills Area rely on a groundwater source. The following table presents groundwater-use information obtained from water rights data available from the Washington Department of Ecology (Ecology), water system data from Washington Department of Health, and the 2010 census.

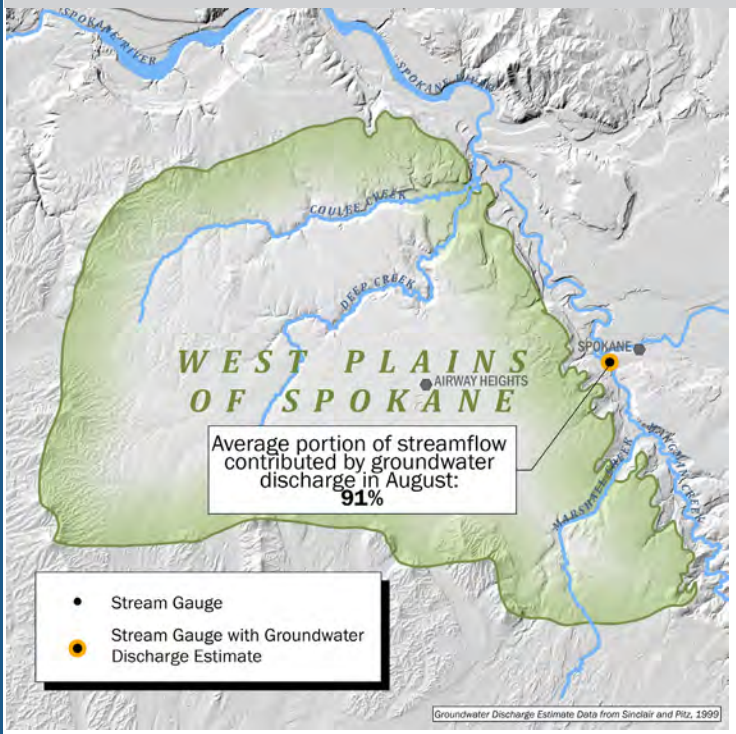
Groundwater Use

Groundwater Irrigated Acres *(Ecology Water Rights Database, Dec. 2014)*	39,000
Population Served by Group A Water Systems Population Served by Group B Water Systems *(WA DOH Sentry data base, Feb. 2010)*	760 240
Population *(Federal Census, 2010)*	1,570
Industry	Primarily Agriculture: food processing, vegetable farming, and wineries; Roosevelt Landfill

Overview

The West Plains of Spokane Area has experienced groundwater level declines in municipal water supply wells in recent years. Groundwater resources in the area consist of an isolated portion of the Columbia Plateau Regional Aquifer System that is reliant on local recharge. The aquifer system includes the Wanapum and Grande Ronde Basalts, and has a high degree of hydraulic connection with surface water. Existing instream flow rules and Surface Water Source Limitations implemented by the Washington Department of Fish and Wildlife limit the availability of new surface water supplies, along with groundwater in connection with surface water.

Supply and Demand Context: Physical water supply is limited in the West Plains of Spokane Area because of a combination of high demand, very low recharge to deep aquifers, and aquifer isolation due to aquifer boundaries where geologic layers thin and pinch out. This combination has resulted in water level declines. Surface water flows in the area are captured by shallow groundwater withdrawals, including withdrawals from the Wanapum Basalt, so new groundwater withdrawals are limited to prevent capture of flows from surface water sources that are closed or regulated.



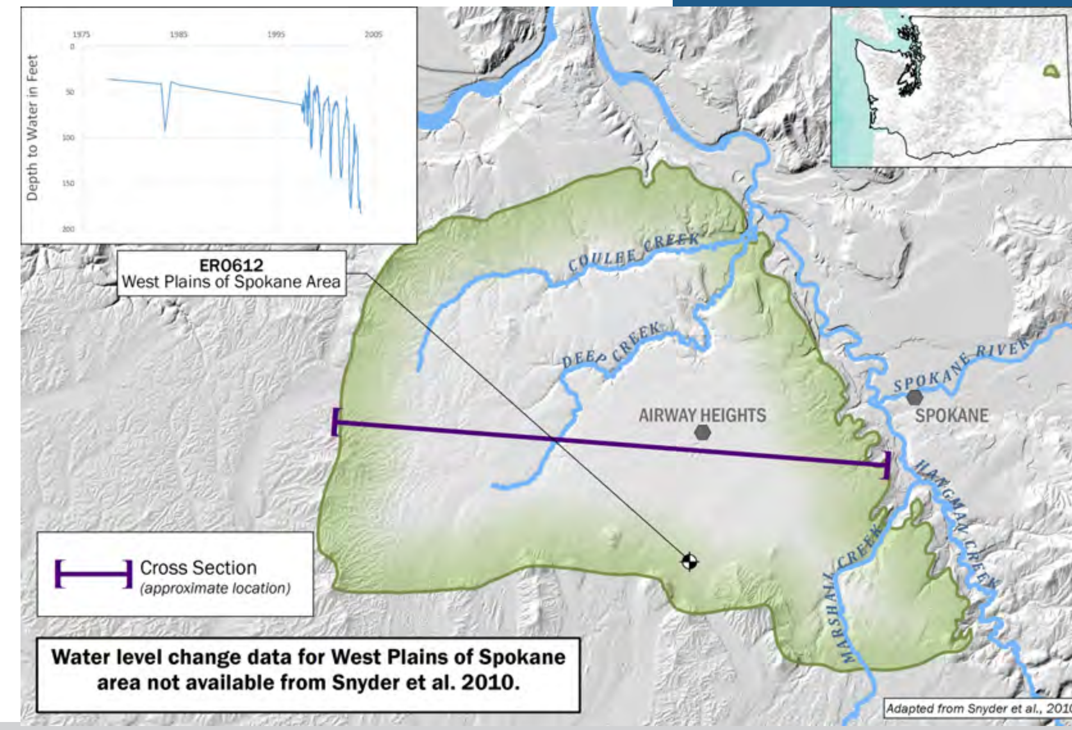
Surface and Groundwater Interaction in the West Plains of Spokane

Surface water bodies that drain the West Plains of Spokane Area eventually discharge to the Spokane River. These tributaries include Coulee Creek and Deep Creek, which flow directly into the Spokane River, and Marshal Creek, which drains into Hangman Creek.

- There is a high degree of hydraulic connection between surface water and the basalt aquifers.
- Coulee Creek, Deep Creek, and Marshall Creek receive base flow from the Wanapum Aquifer in upper reaches of the drainages, and provide recharge to unconsolidated overburden materials and the Grande Ronde Basalt in lower reaches of their drainages.

Management Context

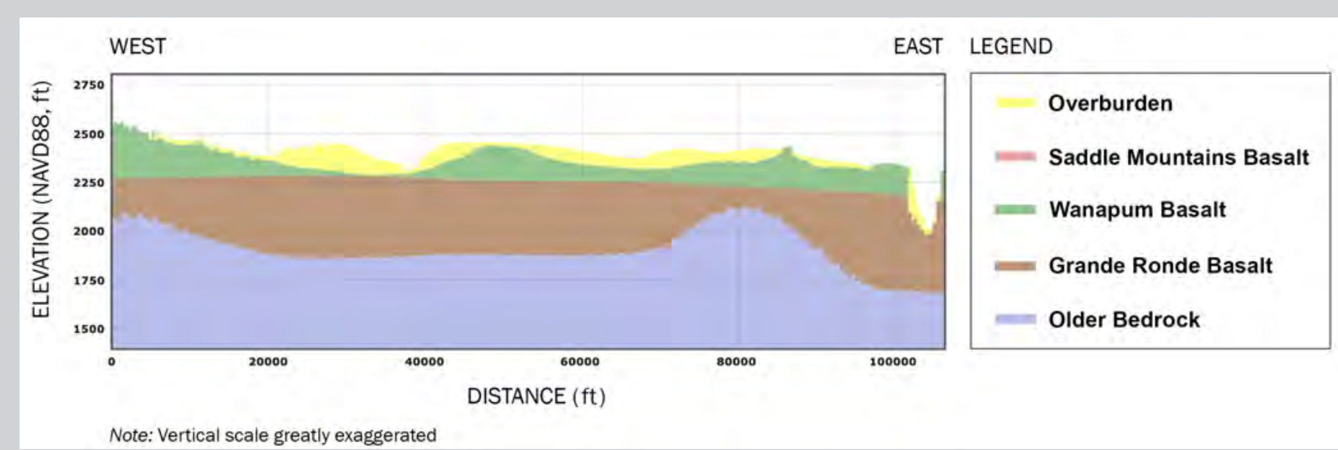
Groundwater Management Area	None present
Management Policy	No new permits being issued
Adjudicated Areas	Crystal Springs Basin
Watershed Planning	Portions of WRIAs 54 (Phase 4 – Implementation), 54 (Phase 3 – Planning), and 56 (Phase 4 - Implementation.
Adopted Instream Flow Rules	Surface Water Source Limitations in place, including closures of Deep Creek and Marshal Creek Basins; the Bureau of Reclamation has a reserve on unappropriated waters in the Spokane River (RCW 90.40.030). Instream flow rules in place for Spokane River and SVRP aquifer (WAC 173-557).
Drought Authorization	No drought authorization program in place.
Groundwater Declines	1 to 12 ft/year through the 2000s (McCollum and Hamilton, 2011).



Conceptual Hydrogeologic Model

Considerations in developing the conceptual hydrogeologic model include:

- The West Plains of Spokane Area is an isolated portion of the Columbia River Plateau Aquifer System that is bounded by older bedrock outcrops to the south and west, and Hangman Creek and the Spokane River to the north and east.
- The aquifer system in this area is reliant on local recharge, rather than the regional recharge that is more typical for the Columbia Plateau Regional Aquifer System.
- Recharge is estimated at 2.7 in/year, with groundwater flow generally northeast toward the Spokane River, toward other local surface water features, and toward the Spokane Valley-Rathdrum Prairie Aquifer.
- There is a high degree of hydraulic connection between surface water and groundwater in both the Wanapum and Grande Ronde Basalts.
- The Wanapum and overburden aquifers are isolated into distinct zones separated by the incised valleys of Coulee Creek, Deep Creek, and Marshall Creek
- The area is structurally complex with fracture zones, folding, and paleo channels, resulting in impedance of horizontal groundwater flow and atypical vertical hydraulic continuity between the Wanapum and Grande Ronde Basalts.
- Key references include: McCollum and Pritchard, 2010; Deobald and Buchanan, 1995; and Washington State Department of Ecology (Ecology), 2010, 2013a, 2013b.

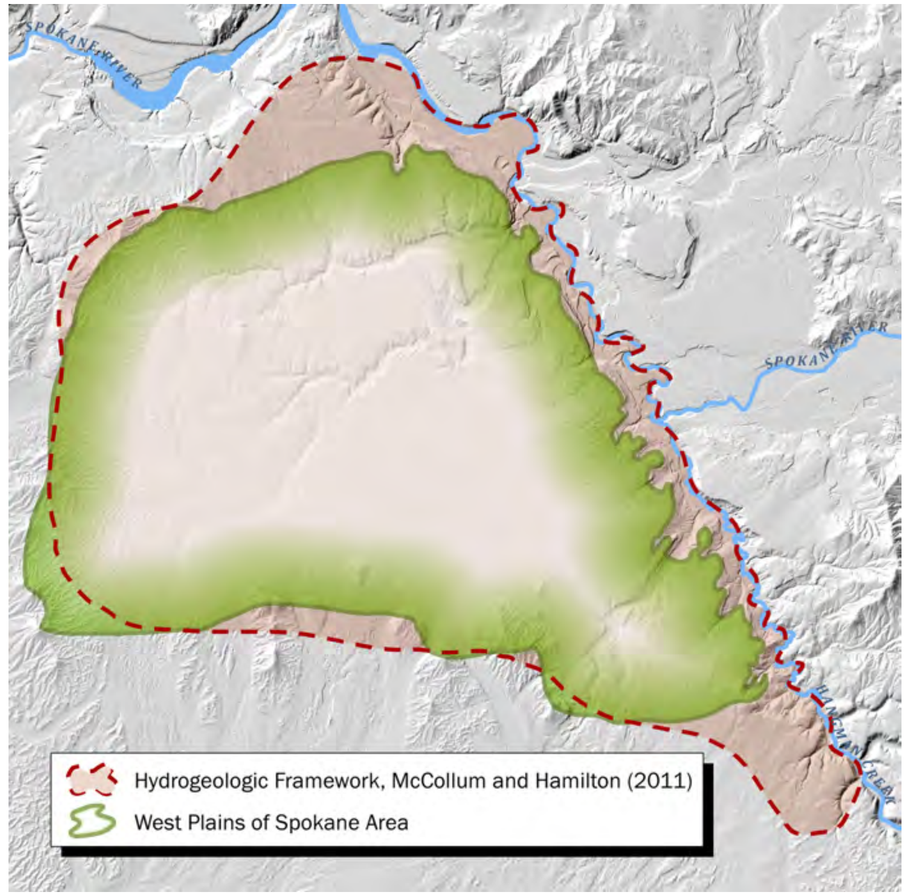


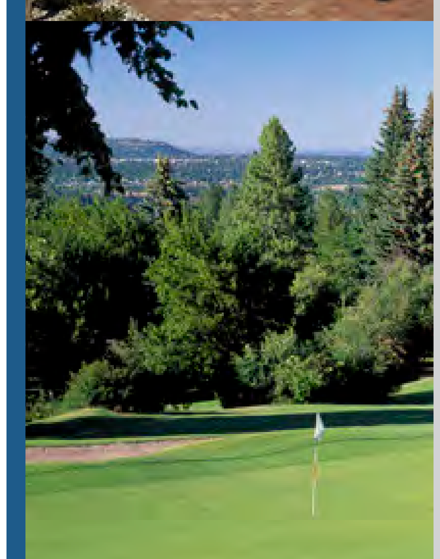
Note: Vertical scale greatly exaggerated

Available Groundwater Models

A review of the literature did not identify any known groundwater models that simulate the West Plains of Spokane Area; however, conceptual model elements and data have been assembled that could support construction of a groundwater model:

- McCollum and Hamilton (2011) developed a 3-dimensional hydrostratigraphic model.
- Ecology estimated recharge using the U.S. Geological Survey's (USGS) Deep Percolation Model (Ecology, 2013b).
- Groundwater/Surface Water Investigation (Ecology, 2013c)
- Groundwater Elevation monitoring and mapping (Ecology, 2013a).





Potential Solutions

Demand Approaches

Conservation: Greater domestic conservation for the City of Airway Heights and rural users could be implemented. Rural domestic uses with lawns that could be converted to xeriscaping. Agricultural uses could be acquired and put into trust for groundwater preservation.

Administrative: Ecology and Spokane County could collaborate on greater information sharing of risks to existing users. Future groundwater uses could be closed based on lack of physical availability.

Supply Approaches

Surface Water Replacement (potential): Streams within the area are limited by Surface Water Source Limitation. New appropriations from the Spokane River may be limited by a Bureau of Reclamation reserve (RCW 90.40.030; Ecology, 2015).

ASR: May be physically feasible in portions of the area, based on a study of five wells (Gibson and Campana, 2014).

SAR: May be physically feasible for the Wanapum Basalt.

GROUNDWATER
West Plains of Spokane
(Spokane County)

Data Gap Analysis

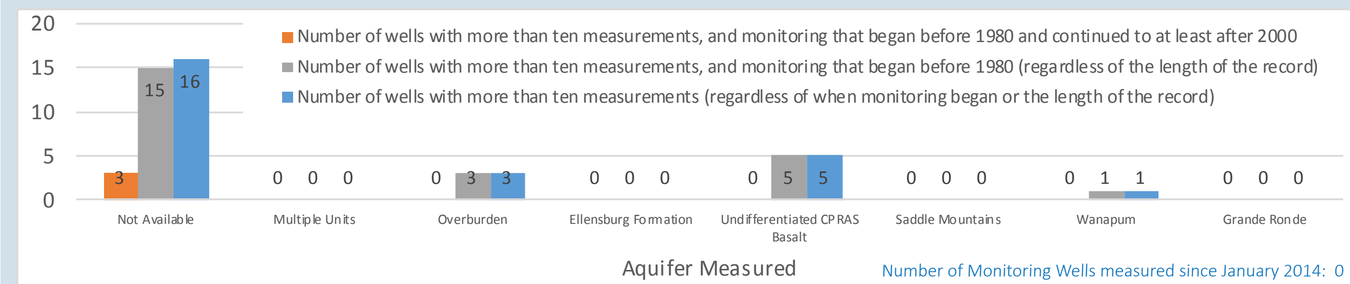
Data Needs: Continue long term groundwater monitoring of 75 wells initiated by Spokane County Water Resources (Ecology, 2013). A smaller subset of wells could be monitored based on availability of funds [estimated costs are $30,000 per year]. Stream gauging in Deep Creek, and Marshal Creek [estimated cost for installation of 2 gauges: $38,000, annual maintenance and operation costs: $34,000]

Currently Operating USGS Stream Gauges
No USGS are stream gauges currently in operation

Metered Water Rights (Ecology WRTS)	Including Claims			Not Including Claims		
	Total	Metered	Percentage Metered	Total	Metered	Percentage Metered
Number of Groundwater Rights	1,700	15	1%	260	15	6%
Groundwater Irrigated Acres	9,500	630	7%	7,500	630	8%

Water Level Data Availability

Trends in water level are better tracked when water levels are monitored from multiple wells that each have several measurements collected over a long time period. The following chart summarizes water level monitoring data available in state databases based on aquifer and time period sampled, and the number of measurements.



Source: USGS NWIS, Ecology EIM, and DNR water level databases

Risk Factors in West Plains of Spokane Area

Many water rights in the West Plains of Spokane Area rely on a groundwater source. The following table presents groundwater-use information obtained from water rights data available from Ecology, water system data from Washington Department of Health, and the 2010 census.

Groundwater Use

Groundwater Irrigated Acres	9,500
Population Served by Group A Water Systems	14,500
Population Served by Group B Water Systems	540
Population	27,000
Industry	Municipal and institutional: Fairchild Air Force Base, Spokane International Airport, Airway Heights, City-operated Golf Course, correctional facility, and small industry.

Black Rock - Moxee Area
(Yakima County)

Overview

Groundwater levels have declined on the order of 10 ft/year since the early 1980s in the Black Rock/Moxee Area in rural Yakima County. Groundwater is derived from a structurally isolated groundwater basin that lies within the Yakima Fold Belt. Local aquifers are part of the Columbia Plateau Regional Aquifer System, with groundwater declines observed in the Saddle Mountain, Wanapum, and Grande Ronde Basalt aquifer zones. The nearest surface water sources are the Roza Canal which supplies water to a small, southwestern portion of the area.

Groundwater use is primarily agricultural and small, rural domestic uses. Groundwater declines are greatest in the eastern portion of the Black Rock/Moxee Area. Deep groundwater declines are isolated from the western portion of the area, the Town of Moxee and the Yakima River, by the northeast-southwest trending Bird Canyon Fault.

Supply and Demand Context: Physical water supply is limited in the Black Rock/Moxee Area because of a combination of high demand, low recharge, and aquifer isolation by faults and folds. This combination has resulted in water level declines.

Surface and Groundwater Interaction in the Black Rock / Moxee Area

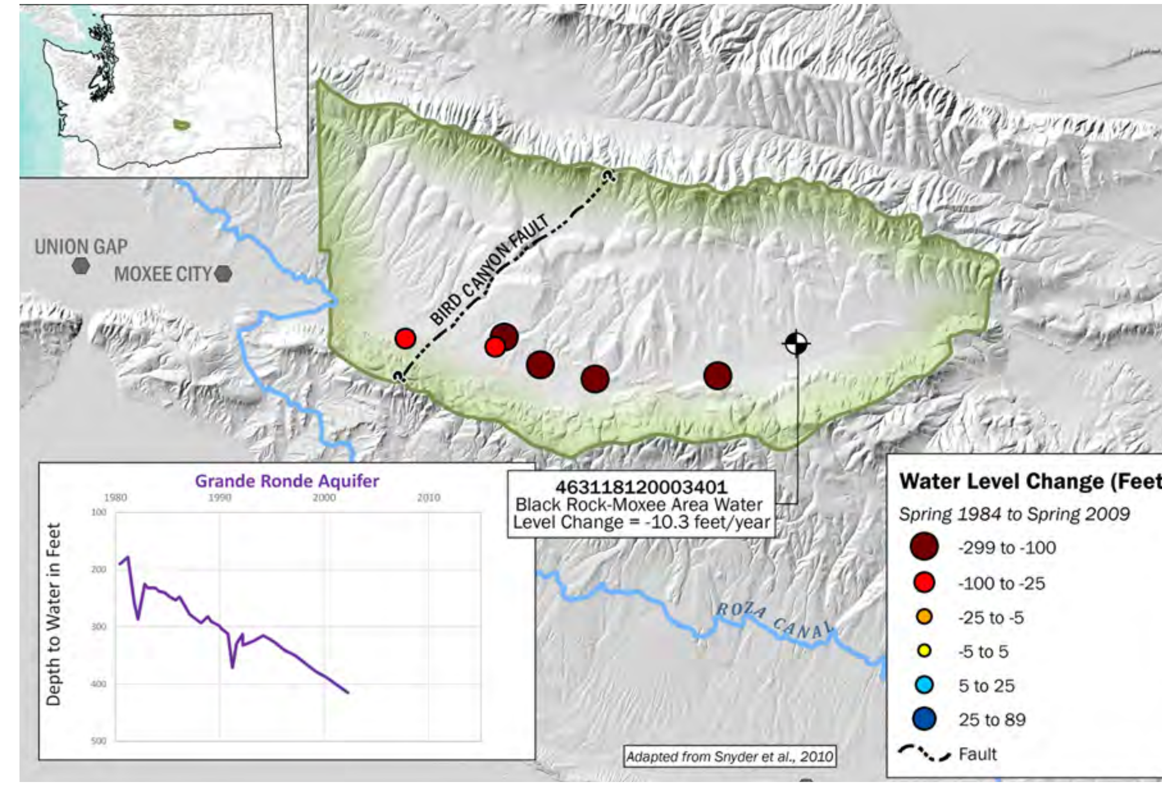
There are no perennial streams in the Black Rock/Moxee Area. The nearest major surface water bodies include the Yakima and Columbia Rivers, located several miles to the south and north of the area, respectively.

- The most prominent channel is Dry Creek, which is ephemeral and flows infrequently in response to intense precipitation events.
- Hydraulic connection between the two rivers and deep groundwater in the eastern portion Black Rock/Moxee Area is likely severely limited by barriers to flow created by faults and folds that bound the area. Shallow groundwater in the Saddle Mountain Basalt and overburden, and groundwater west of the Bird Canyon Fault are likely in hydraulic connection with the Yakima River.
- The Roza Irrigation District and Selah-Moxee Irrigation District, located south and west of the Black Rock/Moxee Area, convey water from the Yakima River. The Roza Irrigation District includes a small southwestern portion of the Black Rock/Moxee Area.

Management Context

Groundwater Management Area	None present
Management Policy	None in place
Adjudicated Areas	The Yakima River is currently under adjudication.
Watershed Planning	WRIA 37 (Currently in phase 4: Implementation)
Adopted Instream Flow Rules	Federal instream flow targets were set on the Yakima River at Parker and Prosser gages in the 1994 YRBWEP Phase II Act, Title XII of Public Law 103-434. Trust water quantities managed by Ecology are also added to these flow targets each year.
Drought Authorization	Supplemental wells authorized on a case-by-case basis in drought years (1:5 years on average). No drought applications were submitted during 2015 drought.
Groundwater Declines	Groundwater declines are greatest east of the Bird Canyon Fault: up to 6 ft/year in the Saddle Mountain unit, 12 ft/year in the Wanapum unit, and 13 ft/year in the Grande Ronde unit through the 1980s (Kirk and Mackie, 1993). Continued declines have persisted to the present (Snyder et al., 2010).

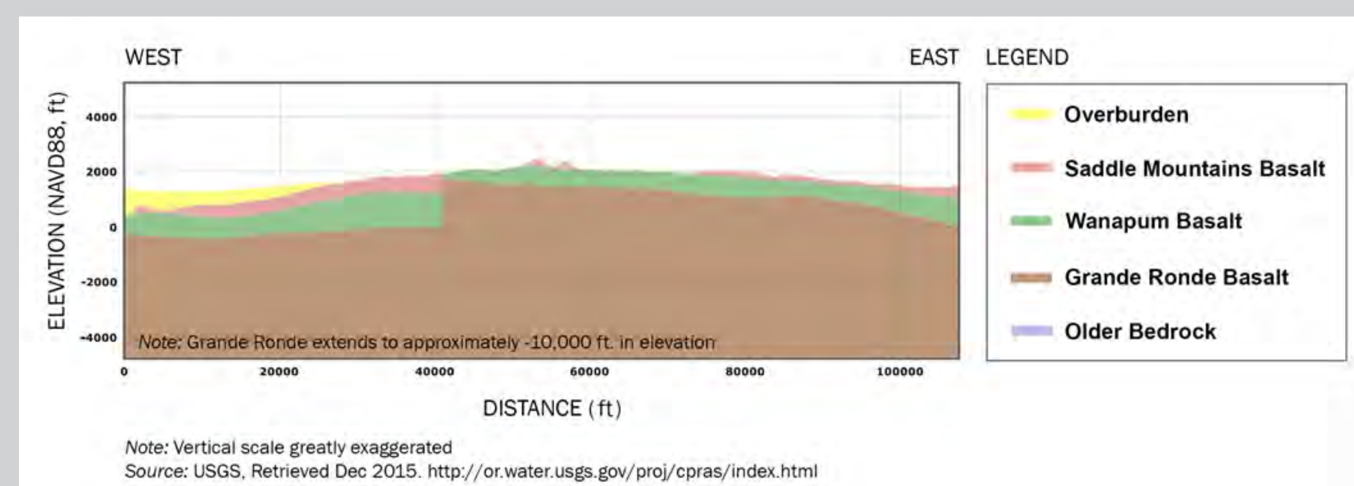
Black Rock - Moxee Area
(Yakima County)



Conceptual Hydrogeologic Model

Key considerations in developing the conceptual hydrogeologic model include:

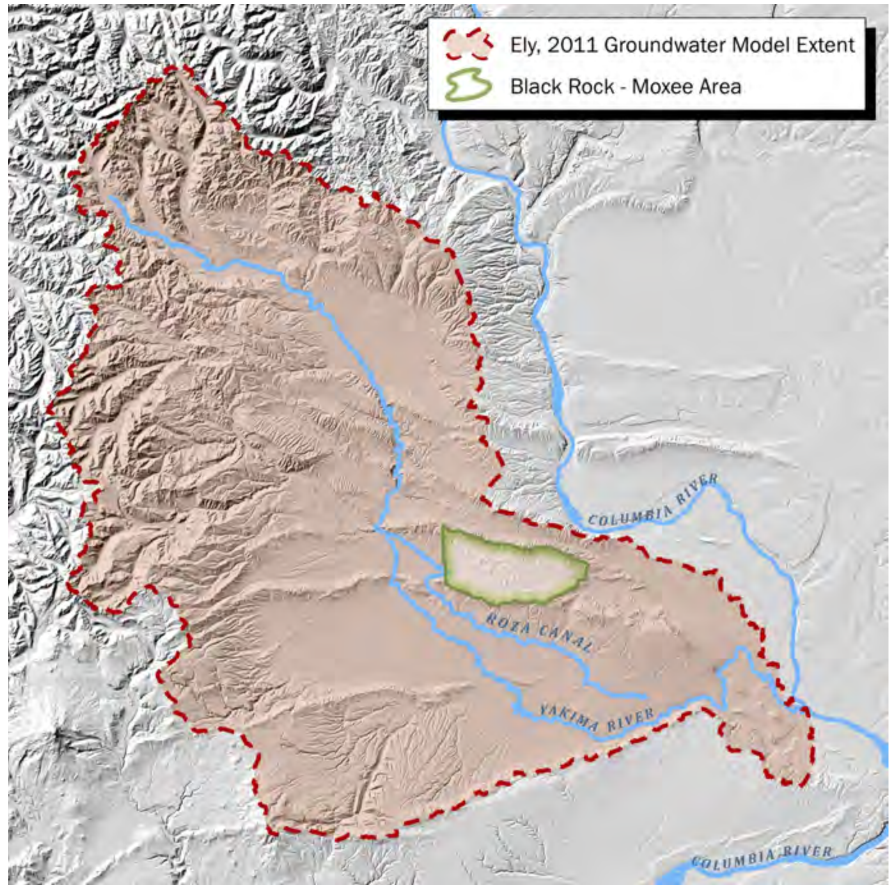
- The primary water source is the Columbia Plateau Regional Aquifer System.
- The Black Rock/Moxee Area lies in the Yakima fold belt, characterized by east-west trending anticlines and isolated aquifer blocks caused by vertical faulting that forms barriers to horizontal groundwater flow.
- Irrigation water is withdrawn from isolated aquifer zones bounded to the north by Yakima Ridge and the South by the Rattlesnake Hills.
- Aquifer zones are further isolated by the northeast-southwest trending Bird Canyon Fault, which divides water-bearing zones from the Wanapum and Grande Ronde Basalt into two compartments east and west of the fault.
- Key reference: Kirk and Mackie, 1993.

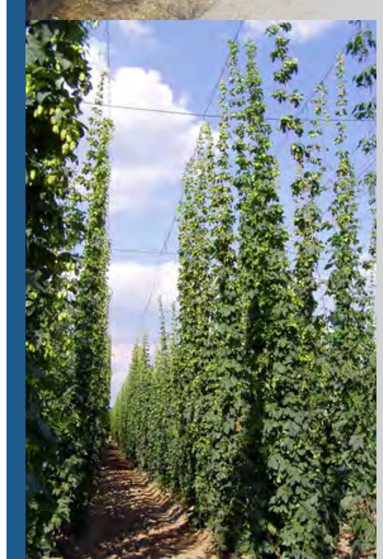


Black Rock - Moxee Area
(Yakima County)

Available Groundwater Models

Two known recent groundwater models have included the Black Rock/Moxee Area (Ely et al., 2014; and Ely et al., 2011). Both of these models would likely need refinements to be adequate to inform decision-making addressing declining groundwater issues in the Black Rock/Moxee Area. There are additional, older models in the area, but they lack current data and interpretations included in the more recent models. Of the two recent models, the MODFLOW model of the Yakima Basin prepared by the U.S. Geological Society (USGS; Ely, 2011) is smaller and has a higher resolution. This is a regional model that includes the Black Rock/Moxee Area; however, its resolution (grid spacing) is likely still too coarse for detailed simulations of Black Rock/Moxee groundwater flow. The model does contain significant information on hydrogeologic units and properties that could be built upon to provide a management tool for the area. Model references: Ely et al., 2014; Ely et al., 2011; Hansen et al., 1994; and Vaccaro, 1999.





Potential Solutions

Demand Approaches

Conservation: Irrigation in the area is largely from center-pivots, so there are limited opportunities for on-farm conservation. Rural domestic uses have small lawns that could be converted to xeriscaping. Agricultural uses could be acquired and put into trust for groundwater preservation.

Administrative: Washington State Department of Ecology (Ecology) and Yakima County could collaborate on greater information sharing on risks to existing users. Future groundwater uses could be closed based on lack of physical availability.

Supply Approaches

Surface Water Replacement (potential):

- A proposed reservoir storage project for the eastern portion of the Black Rock/Moxee Area was studied, but later abandoned (Bureau of Reclamation, 2004).
- Yakima River surface waters are unavailable for new use as a result of adjudication. Columbia River waters would need to be pumped over two large ridges in order to be conveyed to the area.
- Canal service from Roza Irrigation District or Selah-Moxee Irrigation District could be extended to supply a larger portion of the Black Rock/Moxee Area as direct irrigation source replacement or ASR.

ASR: Literature review did not identify any ASR studies in the area (Gibson and Campana, 2014). However, the structural geology appears to be suitable for ASR, based on fault block isolation, if an out-of-area water source becomes available for supplying ASR.

SAR: This is not considered feasible for the basalt aquifers in this area due to depth.

Black Rock - Moxee Area
(Yakima County)

Data Gap Analysis

Data Needs: Model calibration and integration, augmenting historic long term groundwater monitoring [estimated costs are yet to be determined] and a feasibilty study on water supply solutions [estimated cost is $50,000].

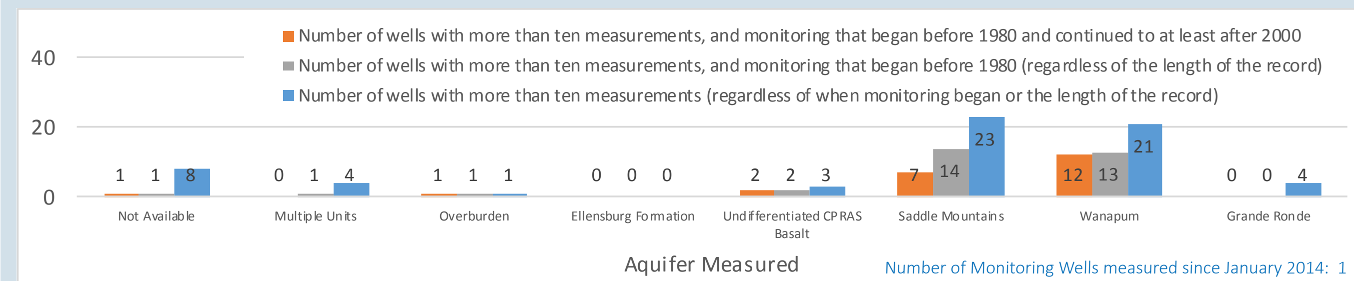
Currently Operating USGS Stream Gauges

Not Applicable

Metered Water Rights (Ecology WRTS)	Including Claims			Not Including Claims		
	Total	Metered	Percentage Metered	Total	Metered	Percentage Metered
Number of Groundwater Rights	160	14	9%	84	14	17%
Groundwater Irrigated Acres	18,000	3,000	17%	18,000	3,000	17%

Water Level Data Availability

Trends in water level are better tracked when water levels are monitored from multiple wells that each have several measurements collected over a long time period. The following chart summarizes water level monitoring data available in state databases based on aquifer and time period sampled, and the number of measurements.



Source: USGS NWIS, Ecology EIM, and DNR water level databases

Risk Factors in Black Rock / Moxee Area

Water rights in the Black Rock/Moxee Area rely on a declining groundwater source. The following table presents groundwater use information obtained from water rights data available from Ecology, water system data from Washington Department of Health, and the 2010 census.

Groundwater Use

Groundwater Irrigated Acres	18,000
Population Served by Group A Water Systems	0
Population Served by Group B Water Systems	57
Population	224
Industry	Agriculture and Dairy

GROUNDWATER
Red / Badger Mountain Area
(Benton County)

Overview

The Red Mountain/Badger Mountain Area is located south of the town of West Richland. Groundwater withdrawals to support irrigation began around 1975, with a significant increase beginning in 1985.

Groundwater declines were recorded in the range of 0.5 to 2.5 ft/year in 1987 in the Saddle Mountain and Wanapum Basalts. The area is used primarily for range and agricultural land. Groundwater in the area is isolated from the municipal supply wells of West Richland by faults and geologic folds.

Supply and Demand Context: Physical water supply is limited in the Red Mountain/Badger Mountain Area because of a combination of high demand, very low recharge, and aquifer isolation by faults and folds. This combination has resulted in water level declines.

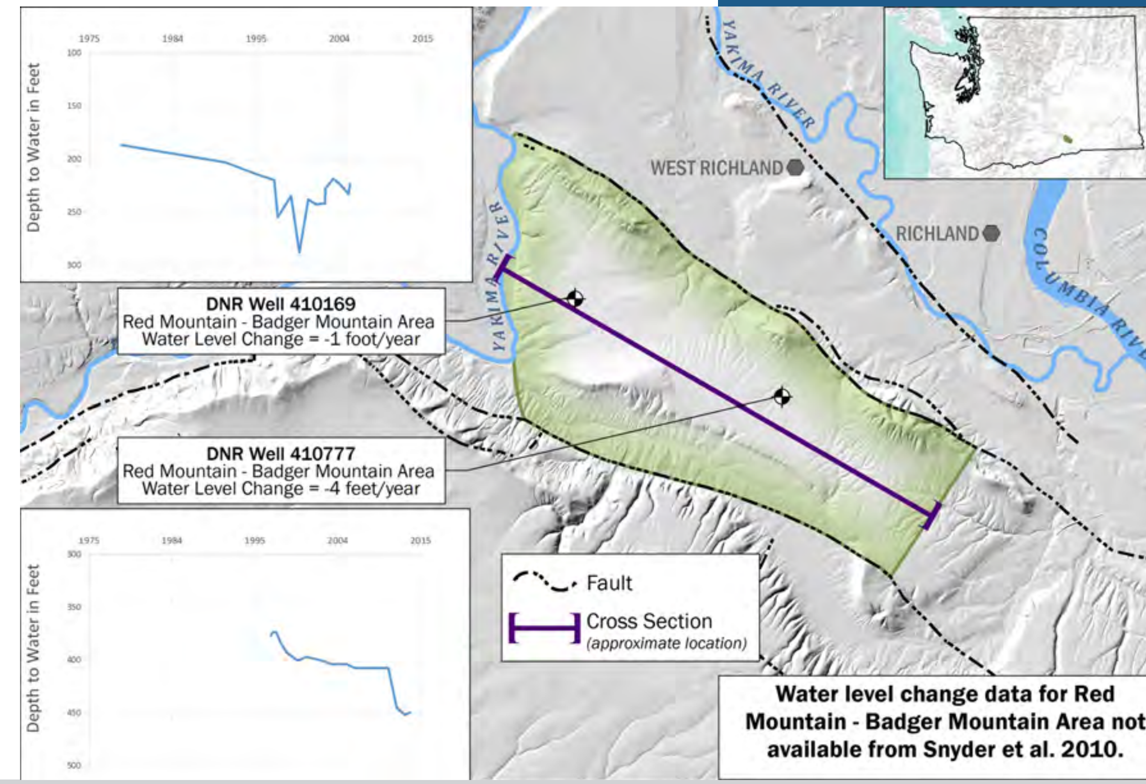
Surface and Groundwater Interaction in the Red Mountain/ Badger Mountain Area

The only major surface water body in the Red Mountain/Badger Mountain Area is the Yakima River, which flows along the northwestern edge of the area.

- The Saddle Mountain Basalt is exposed and receives surface water recharge along this reach of the Yakima River.

Management Context

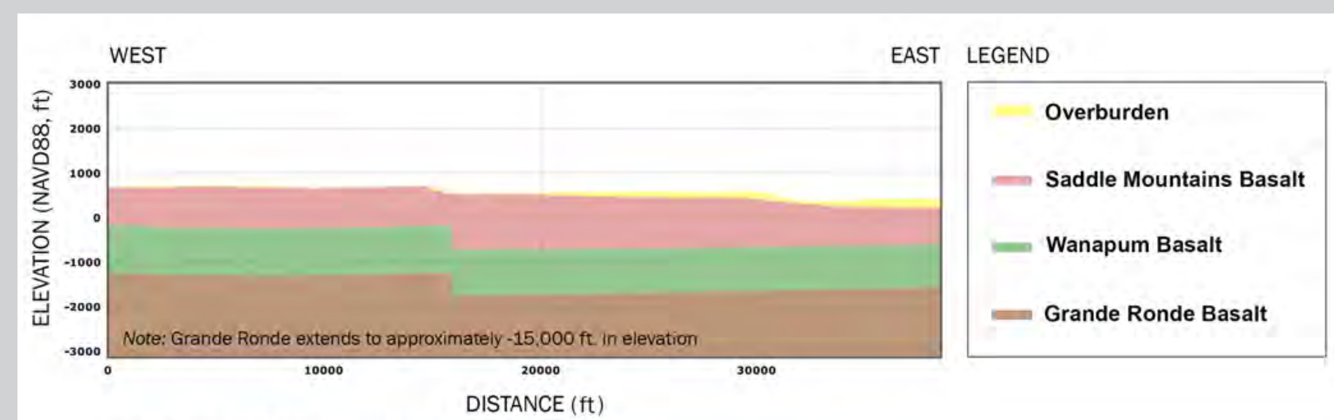
Groundwater Management Area	None present
Management Policy	None in place
Adjudicated Areas	Yakima River is currently under adjudication.
Watershed Planning	WRIA 37 (Phase 4 – implementation)
Adopted Instream Flow Rules	Target and instream flows managed by the Bureau of Reclamation.
Drought Authorization	Supplemental wells authorized on a case-by-case basis in drought years (1:5 years on average)
Groundwater Declines	As of 1987, declines of 0.5 to 2.5 ft/year were recorded in the Saddle Mountain and Wanapum Basalts.



Conceptual Hydrogeologic Model

Considerations in developing the conceptual hydrogeologic model include:

- The area is located in the Pasco Basin of the Columbia Plateau Regional Aquifer System.
- Key aquifer zones in the area include the Pasco Gravels, Saddle Mountain Basalt, and Wanapum Basalt.
- The Pasco Basin is distinguished from the greater regional basalt aquifer system by the presence of the Pasco Gravels, a productive aquifer zone located within the overburden.
- The Pasco Gravels are overlain by low-conductivity Touchet Beds that reduce recharge.
- The area is bounded by the Badger Mountain Fault to the north, and faults and folds to the south that are potential barriers to horizontal groundwater flow.
- The area is separated from the municipal supply wells and local aquifer of West Richland by the Badger Mountain Fault.
- Key references include: Kahle, 2011; Vaccaro, 2009, 2011; Drost et al., 1997; and Brown, 1979.

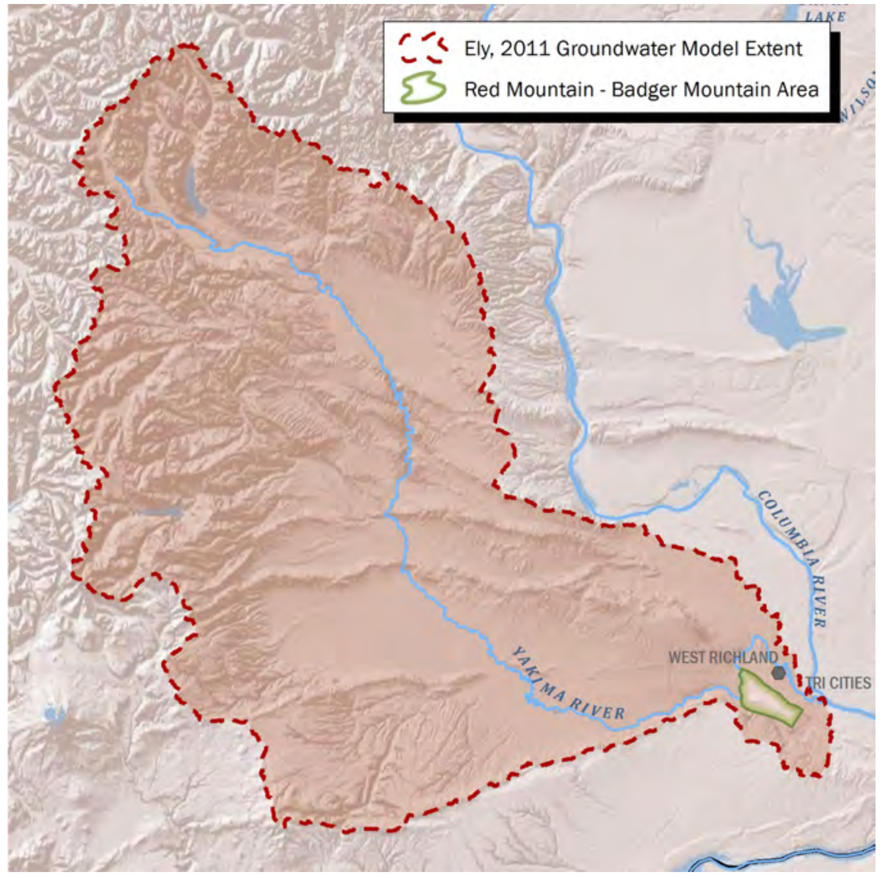


Note: Vertical scale greatly exaggerated
Source: USGS, Retrieved Dec 2015. http://or.water.usgs.gov/proj/cpras/index.html

GROUNDWATER
Red / Badger Mountain Area
(Benton County)

Available Groundwater Models

Two known, recent groundwater models have included the Red Mountain/Badger Mountain Area (Ely et al., 2014; and Ely et al., 2011). Both of these models would likely need refinements to be adequate for decision-making to address declining groundwater issues in the area. There are additional, older models that overlap the area, but they lack current data and understanding included in the more recent models. Of the two recent models, the regional MODFLOW model of the Yakima Basin prepared by the U.S. Geological Society (USGS; Ely, 2011) is smaller and has a higher resolution; however, its resolution (grid spacing) is likely too coarse for detailed simulations of local groundwater flow. The models contain significant information on hydrogeologic units and properties that could be refined and built upon to provide a management tool for the area. A model of the Eastern Pasco Basin was recently constructed by the USGS, but it does not include the Red Mountain/Badger Mountain Area. Model references: Ely et al., 2014; Ely et al. 2011; Hansen et al., 1994; Vaccaro, 1999; and Heywood et al., 2016.



Potential Solutions

Demand Approaches

Conservation: Irrigation in the area is largely from center-pivots, so there are limited opportunities for on-farm conservation. Rural domestic uses have small lawns that could be converted to xeriscaping. Agricultural uses could be acquired and put into trust for groundwater preservation.

Administrative: None anticipated.

Supply Approaches

Surface Water Replacement (potential):

- Yakima River surface waters are currently under adjudication.

ASR: Literature review did not identify any ASR studies in the area (Gibson and Campanna, 2014). However, the geology appears to be suitable for ASR if an out-of-area water source for ASR becomes available.

SAR: This is not considered feasible for the basalt aquifers in this area due to depth.

Data Gap Analysis

Data Needs: Determine monitoring well aquifer zone, and making data available in Ecology database [estimated costs are yet to be determined].

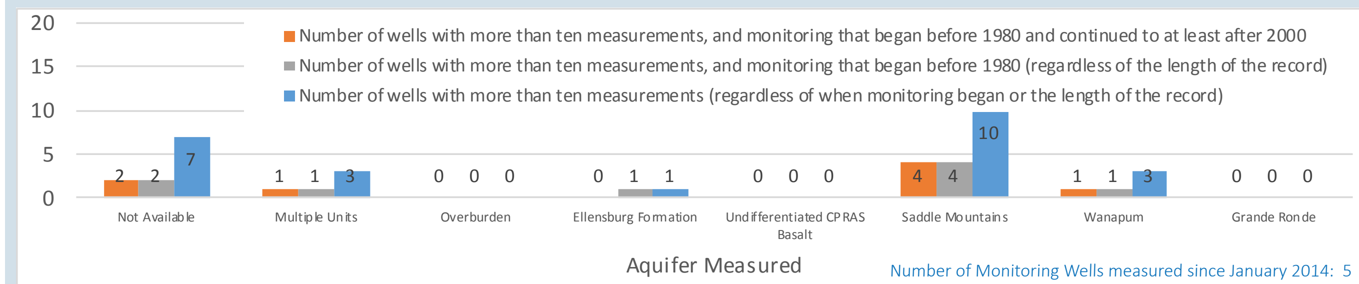
Currently Operating USGS Stream Gauges

There are currently no operating USGS stream gauges in this area.

Metered Water Rights (Ecology WRTS)	Including Claims			Not Including Claims		
	Total	Metered	Percentage Metered	Total	Metered	Percentage Metered
Number of Groundwater Rights	160	13	8%	122	13	11%
Groundwater Irrigated Acres	9,600	1,700	18%	9,000	1,700	19%

Water Level Data Availability

Trends in water level are better tracked when water levels are monitored from multiple wells that each have several measurements collected over a long time period. The following chart summarizes water level monitoring data available in state databases based on aquifer and time period sampled, and the number of measurements.



Source: USGS NWIS, Ecology EIM, and DNR water level databases

Risk Factors in the Red Mountain / Badger Mountain Area

Many water rights in the Red Mountain/Badger Mountain Area rely on a groundwater source. The following table presents groundwater-use information obtained from water rights data available from Ecology, water system data from Washington Department of Health, and the 2010 census.

Groundwater Use

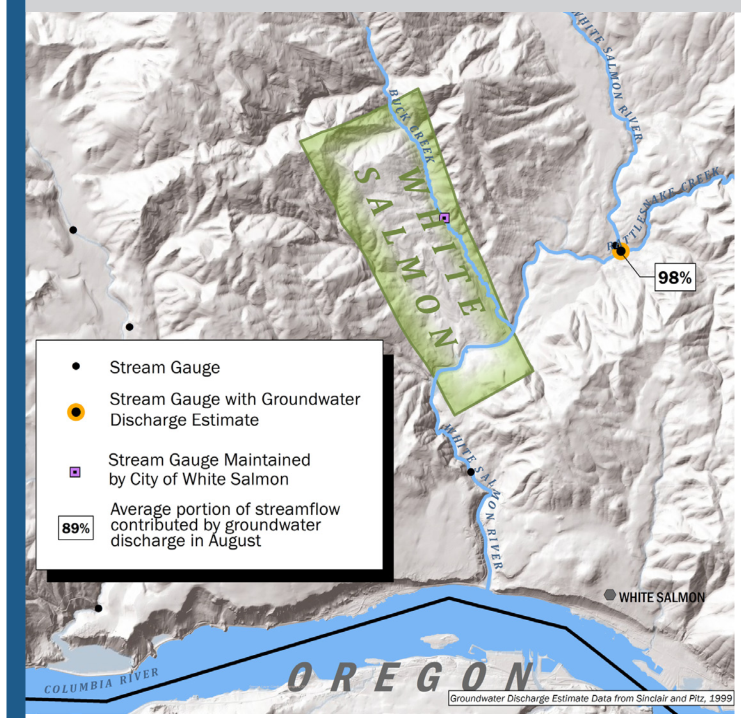
Groundwater Irrigated Acres	9,600
Population Served by Group A Water Systems	710
Population Served by Group B Water Systems	230
Population	3,800
Industry	Wineries and Agriculture (primarily vineyards)

Overview

In the early 2000s, the City of White Salmon (City) switched their supply from an unfiltered surface water source on Buck Creek to two groundwater wells. Although initially successful, the City soon experienced water supply shortages as a result of declining well yield in their flowing artesian wells caused by overuse of a hydrogeological bounded, low-recharge aquifer system. As a result, the City took a number of steps to ensure it maintained a reliable public water supply under Washington Department of Health rules, including:

- Implementing strict conservation measures, leak reductions, and rate adjustments to reduce demand.
- Reducing pumping rates from their wells.
- Constructing a new, slow sand filtration plant and reactivating their surface water diversion from Buck Creek.
- Developing an ASR project to store and recover treated water from Buck Creek.
- Pursuing new surface water rights and a new source on the White Salmon River.

Supply and Demand Context: Physical water supply is limited in the area because of a combination of high demand, very low recharge to deep aquifers, and aquifer isolation by faults. This combination has resulted in reduced well yield. Recent measures, including development of an ASR system, are expected to reduce groundwater declines in the future.



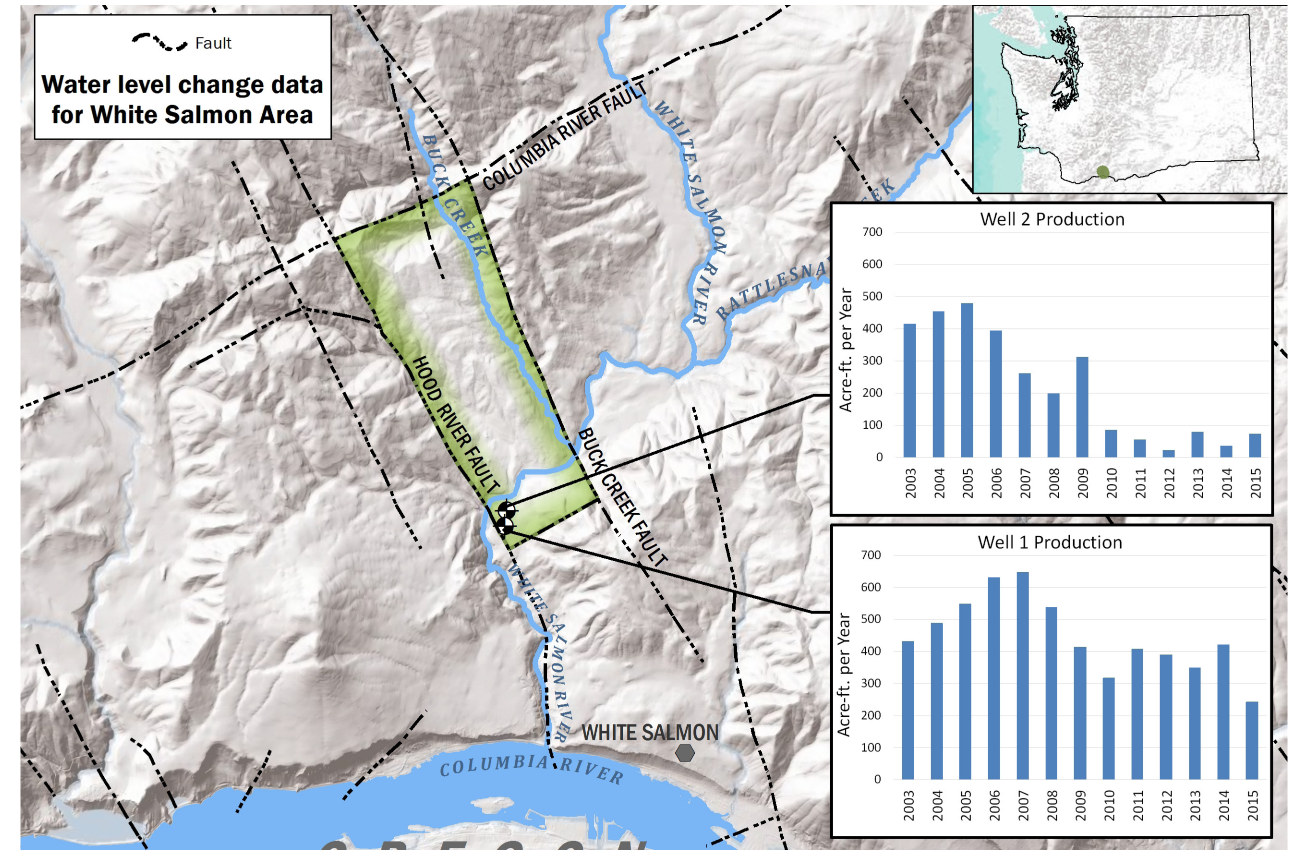
Surface and Groundwater Interaction in the White Salmon Area

Surface water bodies near the City's wells include Buck Creek, the White Salmon River, and the Columbia River (much further to the south).

- A nearby reach of the White Salmon River was formerly Northwestern Lake, which was drained in 2011 with the removal of Condit Dam.
- The City's artesian water supply well is hydraulically isolated by adjacent faults and overlying massive basalt layers, and is likely not in strong hydraulic connection with surface water.
- The City's other well is interpreted to be in hydraulic connection with the White Salmon River (formerly Northwestern Lake) via highly fractured basalt encountered while drilling this well.

Management Context

Groundwater Management Area	None present
Management Policy	The City is implementing source control measures and new water supply development.
Adjudicated Areas	None
Watershed Planning	WRIA 29b; phase I on hold
Adopted Instream Flow Rules	No instream flow rule exists on White Salmon River. An adopted instream flow rule (WAC 173-563) and federal biological opinion exists for the Columbia River.
Drought Authorization	None
Groundwater Declines	White Salmon Water Supply Well: Steady drop in yield and shut in pressure since 2000 (6 ft/yr).

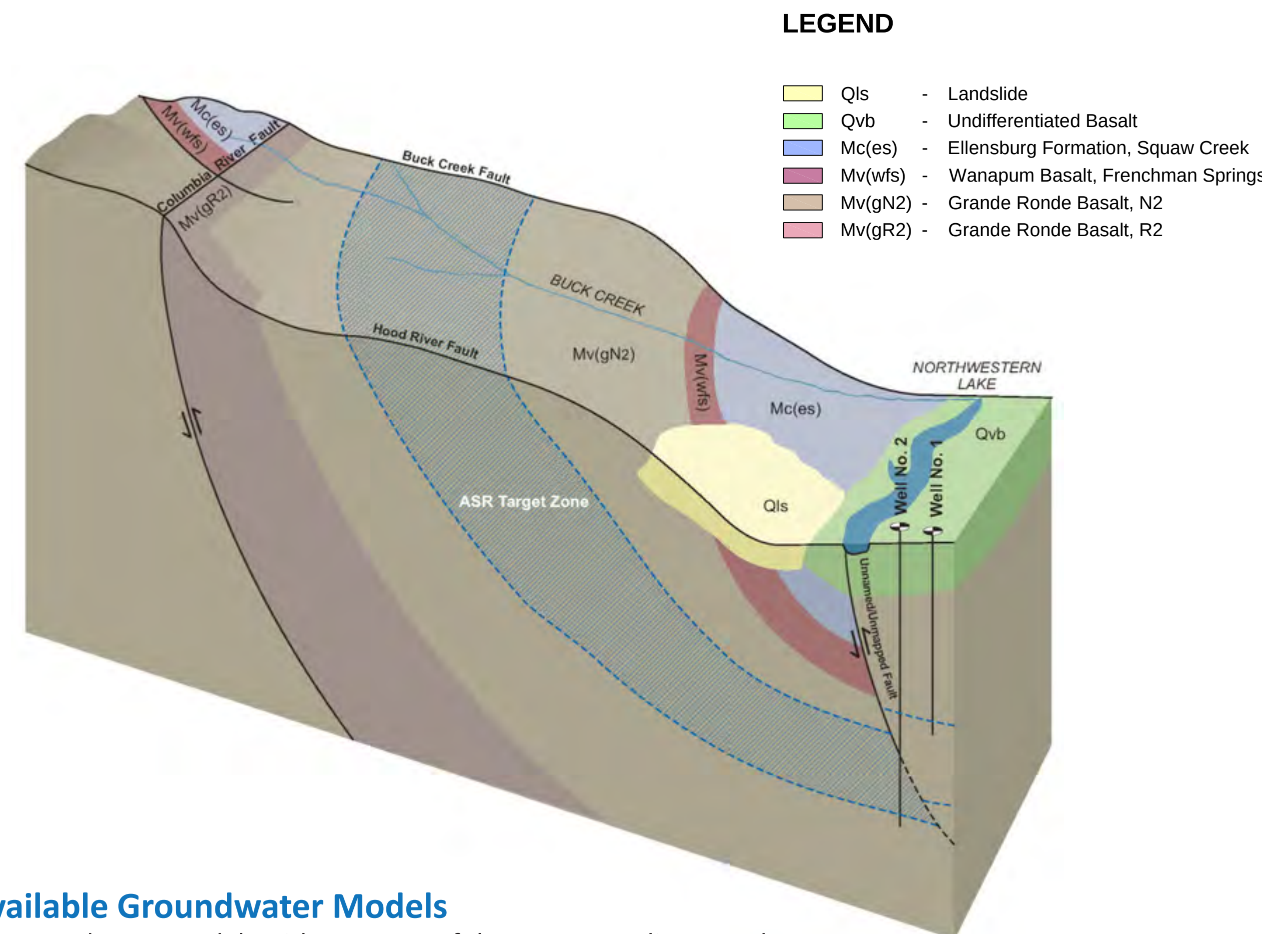


Conceptual Hydrogeologic Model

Key considerations in developing the conceptual hydrogeologic model include:

- The City of White Salmon Groundwater Supply relies on fault-block aquifers located in the Grand Ronde Basalt.
- The aquifers are located in a heavily faulted portion of the Columbia Plateau Regional Aquifer System.
- The aquifer tapped by the artesian well is isolated by the Buck Creek Fault to the east, the Hood River Fault to the west, the Columbia River Fault to the north and upgradient, and an unnamed fault to the south and downgradient.
- The unnamed fault to the south likely provides a hydraulic connection through fracture flow between surface water and the aquifer tapped by the City's other well.
- The aquifer tapped by the artesian well appears to be well suited for ASR, given its fault-block isolation and limited hydraulic connection to surface water or other aquifers.
- A cross section is provided on the following page .
- Key references include: Kahle, 2011; Aspect, 2011; Aspect, 2015; Mark Yinger and Associates, 1999; Mark Yinger and Associates, 2001; Mark Yinger and Associates, 2002; and Aspect, 2011.

GROUNDWATER
White Salmon Area
(Klickitat County)



Available Groundwater Models

No groundwater models with coverage of the area were discovered.

Data Gap Analysis

Data Needs: WRIA assessment and planning [estimated costs are yet to be determined], ASR full-scale operation [estimated costs: city-supplied pumping costs and monitoring], White Salmon source replacement [estimated cost is $60,000 for appraisal with design/construction costs yet to be determined].

Currently Operating USGS Stream Gauges

Station Number	Station Name	Operating Since
14123500	White Salmon River near Underwood, WA	2015

Currently Operating City of White Salmon Stream Gauges

Station Number	Station Name	Operating Since
N/A	City of White Salmon Buck Creek	2011

Metered Water Rights (Ecology WRTS)	Including Claims			Not Including Claims		
	Total	Metered	Percentage Metered	Total	Metered	Percentage Metered
Number of Groundwater Rights	16	1	6%	7	1	14%
Groundwater Irrigated Acres	7	0	0%	7	0	0%

Number of Wells with Current Water Level Measurements

No current water level measurements are available in the databases. However, water levels are monitored in Wells 1 and 2, and within monitoring wells in the Well 1 aquifer by the City of White Salmon.

Data Sources: USGS, Ecology, and Washington DNR water level databases

Potential Solutions

Demand Approaches

Conservation: The City adopted a new water system plan in 2014 with conservation targets and funding over the next 6 years to improve conservation. The City has modified pumps and pump controls from its wells to reduce aquifer declines.

Administrative: The City has drought-year curtailment resolutions in place for outdoor lawn watering.

Supply Approaches

Surface Water Replacement: The City is partnering with Washington State Department of Ecology (Ecology), Washington Water Trust, and other stakeholders on development of a new source on the White Salmon River.

ASR: The City of White Salmon has completed an ASR Pilot Study, and is currently in the permitting phase. The Pilot study indicated potential storage of 111 ac-ft (Aspect, 2015).

SAR: Likely not feasible for the Grand Ronde Basalt aquifer, given limited recharge pathways.

Risk Factors in White Salmon Area

The following table presents groundwater-use information obtained from water rights data available from Ecology, water system data from Washington Department of Health, 2010 census, and the City of White Salmon.

Groundwater Use

Groundwater Irrigated Acres	7
Population Served by Group A Water Systems	3,900
Population Served by Group B Water Systems	10 (Note: water systems serve a population outside the area.)
Population	650
Industry	Unmanned aeronautics manufacturing, agriculture, and outdoor recreation/tourism

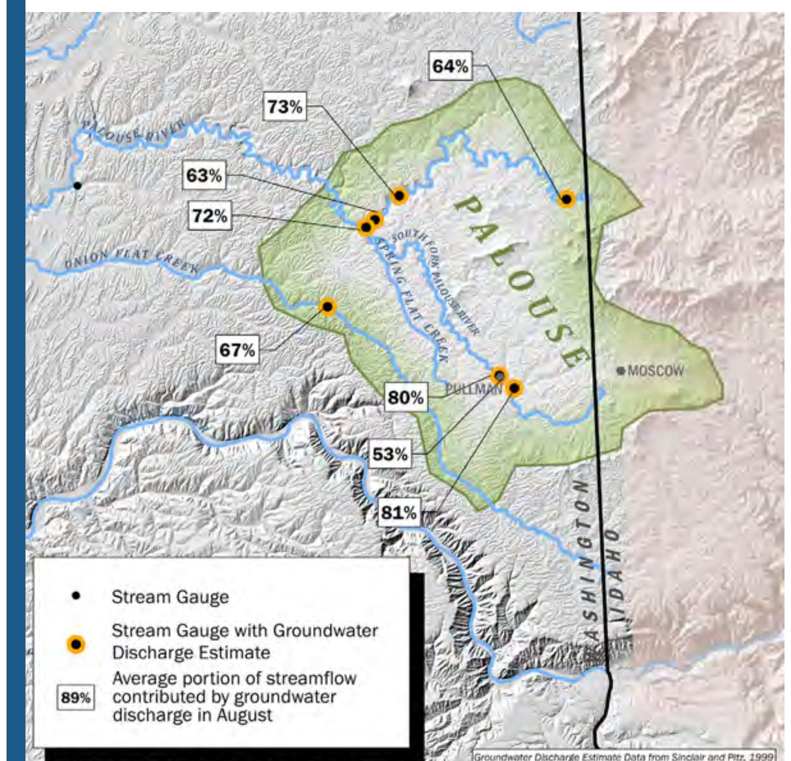
Palouse Groundwater Basin
(Whitman County)

Overview

Municipalities in the Palouse Groundwater Basin rely on groundwater supplied by deep basalt aquifers of the Columbia Plateau Regional Aquifer System that receive limited recharge. As a result, steady groundwater declines of 1 to 1.5 ft/year have been recorded in the basin since the 1910s.

Shallower aquifers, including overburden and Wanapum Basalt, are in hydraulic connection with surface bodies. Most groundwater withdrawals are from the Grande Ronde Basalt. Surface water relies on groundwater discharge to supply significant portions of dry season flows. Washington State Department of Ecology (Ecology) has concluded there is little to no groundwater available for new consumptive use.

Supply and Demand Context: Physical water supply is limited in the Palouse Groundwater Basin because of a combination of high demand, very low recharge to deep aquifers, and aquifer isolation by faults and aquifer boundaries where geologic layers thin and pinch out. This combination has resulted in water level declines. Surface water flows in the area are captured by groundwater pumping, including declines in the Wanapum Basalt, so new groundwater withdrawals are limited because they may capture flows from surface water sources that are closed or regulated.



Surface and Groundwater Interaction in the Palouse Groundwater Basin

The primary surface water bodies in the Palouse Groundwater Basin include Union Flat Creek, and the South Fork of the Palouse River and its tributaries: Spring Flat Creek and Fourmile Creek.

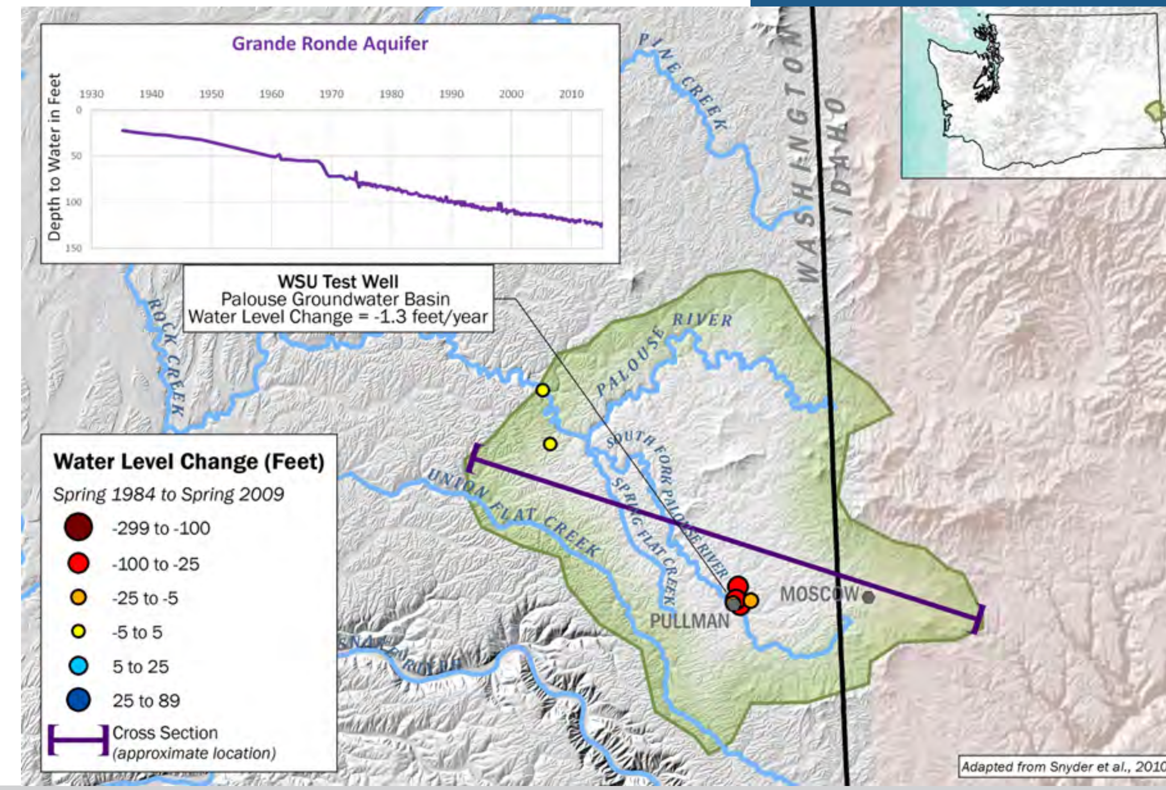
- The streams are in hydraulic connection with the Palouse Loess, Scabland deposits, and Wanapum Basalt.
- Discharge is highest where streams have incised into the Wanapum Basalt.
- A significant portion of streamflow during the dry season is supplied by groundwater discharge.
- Deeper aquifer isolation caused by faulting and other geologic contacts can isolate the effects on surface water baseflows due to pumping, but also exacerbate groundwater declines.

Management Context

Groundwater Management Area	None present
Management Policy	None in place
Adjudicated Areas	None
Watershed Planning	WRIA 34 (Currently in Phase 4: implementation)
Adopted Instream Flow Rules	Surface water sources are subject to seasonal SWSL closures.
Drought Authorization	None
Groundwater Declines	Steady declines of 1 to 1.5 ft/year in the city of Pullman since the 1910s. Continued constant declines in the City Palouse Wells despite a decrease in pumping.

GROUNDWATER

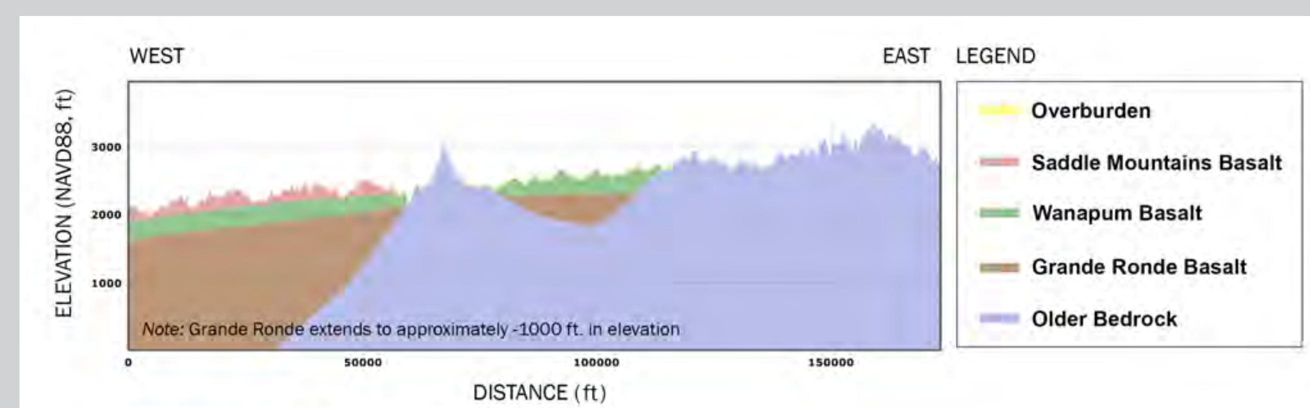
Palouse Groundwater Basin
(Whitman County)



Conceptual Hydrogeologic Model

Considerations in developing the conceptual hydrogeologic model include:

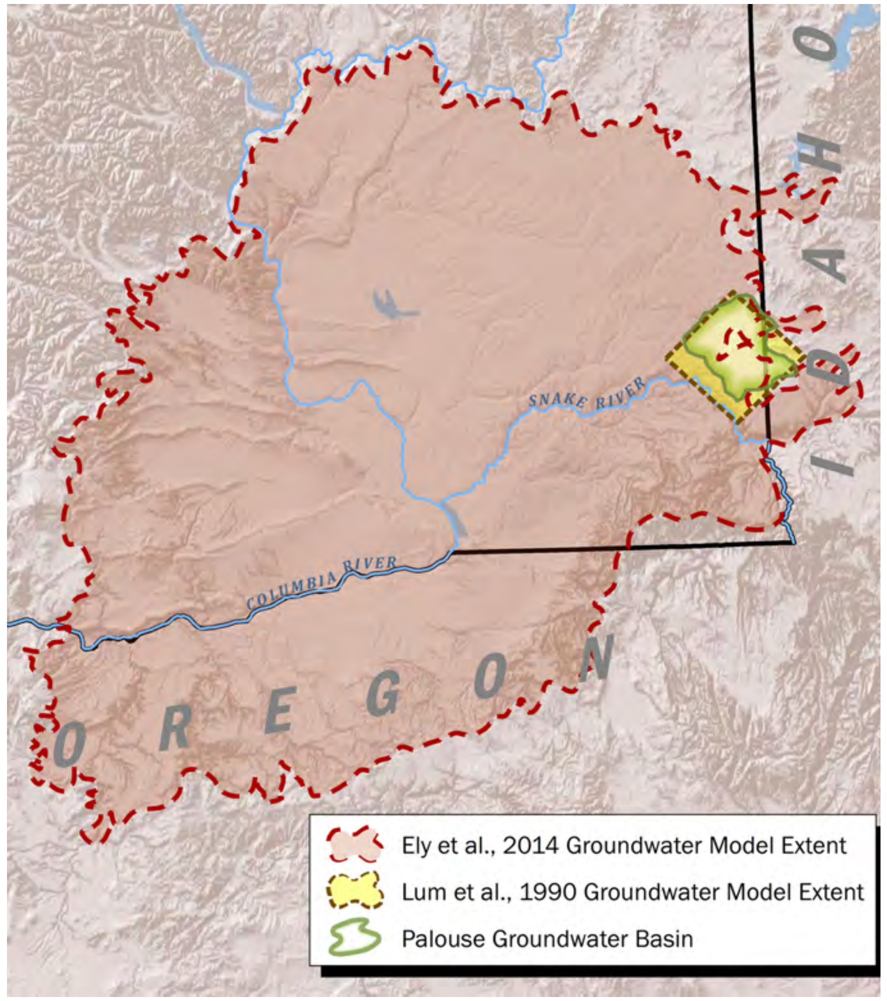
- The principal aquifer zones are the Wanapum and Grande Ronde Basalts, with the Grande Ronde used most heavily by municipalities and others.
- The eastern edge of the Palouse slope exhibits a high degree of aquifer isolation, due to faulting and contacts with older basement rocks.
- Overburden materials are important for supporting surface water baseflows, but are not widely used for water supply, due to low aquifer yields.
- Groundwater flow is generally southwest toward the Columbia, Snake, and Walla Walla Rivers.
- Significant recharge is limited to overburden and shallow basalts.
- Key references include: Folnagy, 2012; TerraGraphics, 2011; Larson, 1997; Hatthorn and Berber, 1994; Lum et al., 1990; Kahle, 2011; Golder, 2004; Heinman, 1994; and Lutziar and Burt, 1974.

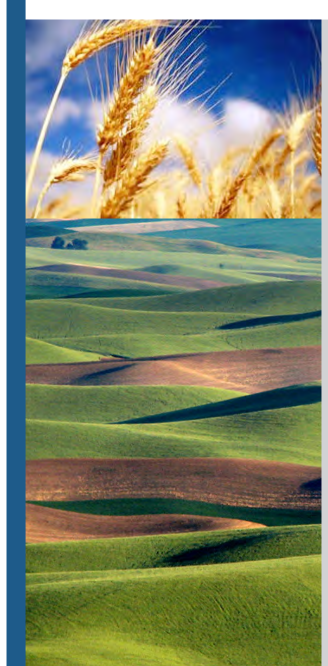


Note: Vertical scale greatly exaggerated
Source: USGS, Retrieved Dec 2015. http://or.water.usgs.gov/proj/cpras/index.html

Available Groundwater Models

Two known, recent groundwater models exist for the Palouse Groundwater Basin. Both of these models would need significant refinements to be adequate to aid decision-making that addresses declining groundwater issues in the Palouse Groundwater Basin. Known groundwater models include one focused on the Palouse Basin prepared by Lum et al., (1990) and modified in 1996, and a second more recent groundwater model constructed by Ely et al., (2014) that simulates the entire Columbia River Regional Aquifer System. This regional model includes portions of the Palouse Groundwater Basin; however, its resolution (grid spacing) is too coarse for detailed simulations of Palouse groundwater flow. The Lum et al., model has a more focused coverage of the Palouse Groundwater Basin, but it also has coarse grid spacing, and is based on data collected prior to 1985. The two models do contain significant information on hydrogeologic units and properties that could be built upon to provide a management tool for the Palouse Groundwater Basin. Model references include: Ely et al., 2014; Folnagy, 2012; Johnson et al., 1996; Lum et al., 1990; Lutzier and Skrivan, 1975; Hansen et al., 1994; Vaccaro, 1999; Barker, 1979; and Smoot, 1987.





Potential Solutions

Demand Approaches

Conservation: Cities of Palouse and Moscow have implemented several conservation measures: incentives and education to increase domestic water conservation with high efficiency appliances and xeriscaping; ordinances limiting lawn and garden irrigation; and upgrades to city irrigation systems.

Administrative: None planned

Supply Approaches

Surface Water Replacement (potential): Limited by Surface Water Source Limitation (SWSL) seasonal closures.

ASR: Likely physically feasible in portions of area based on study of two wells (one of two wells suitable) (Gibson and Campana, 2014).

SAR: May be physically feasible for augmenting surface water flows, but would not be feasible for augmenting deeper basalt aquifer zones.

Data Gap Analysis

A comprehensive data gaps analysis identified the following "high priority" data needs for the Palouse Groundwater Basin (TerraGraphics, 2011): Investigation of vertical groundwater barriers in West Pullman, surface water/groundwater interaction studies northwest of Pullman, yield optimization studies in Pullman-Moscow area for the Wanapum Basalt, and construction of a new groundwater modeling tool [estimated costs are yet to be determined].

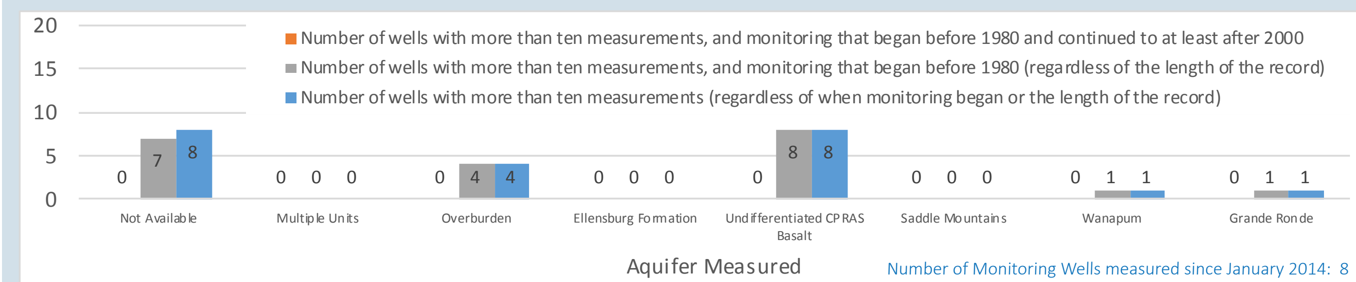
Currently Operating USGS Stream Gauges

Station Number	Station Name	Operating Since
13346000	Palouse River Near Colfax, WA	1955
13348000	South Fork Palouse River At Pullman, WA	1947
13348500	Missouri Flat Creek At Pullman, WA	1954
13350500	Union Flat Creek Near Colfax, WA	1953

Metered Water Rights (Ecology WRTS)	Including Claims			Not Including Claims		
	Total	Metered	Percentage Metered	Total	Metered	Percentage Metered
Number of Groundwater Rights	820	20	2%	95	20	21%
Groundwater Irrigated Acres	11,000	0	0%	300	0	0%

Water Level Data Availability

Trends in water level are better tracked when water levels are monitored from multiple wells that each have several measurements collected over a long time period. The following chart summarizes water level monitoring data available in state databases based on aquifer and time period sampled, and the number of measurements.



Source: USGS NWIS, Ecology EIM, and DNR water level databases

Risk Factors in the Palouse Basin

Many water rights in the Palouse Groundwater Basin rely on a groundwater source. The following table presents groundwater-use information obtained from water rights data available from Ecology, water system data from Washington Department of Health, and the 2010 census.

Groundwater Use

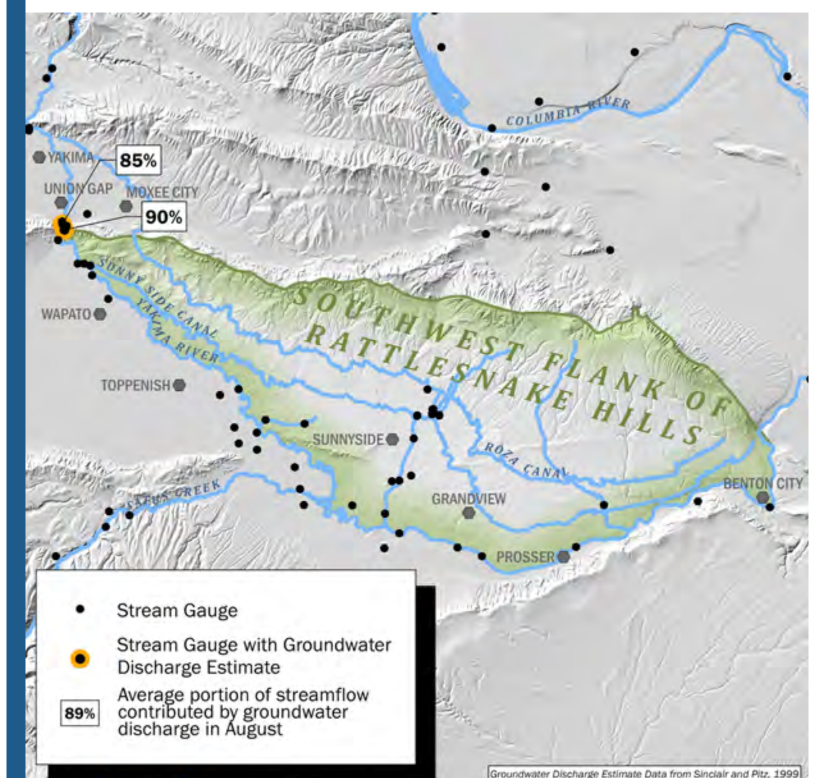
Groundwater Irrigated Acres	11,000
Population Served by Group A Water Systems	36,000
Population Served by Group B Water Systems	170
Population	38,000
Industry	Washington State University; Mostly agriculture: barley, wheat, dry peas, and lentils

SW Flank of Rattlesnake Hills
(Yakima and Benton Counties)

Overview

The Southwest Flank of Rattlesnake Hills is adjacent to the Yakima River. The area supports significant agriculture and several municipalities that rely on both over-appropriated surface water supply and declining groundwater supplies. Groundwater declines from 21 ft to more than 150 ft have been recorded between 1986 and 2002. Groundwater declines have been documented in both the unconsolidated aquifer system and the underlying basalts of the Columbia Plateau Regional Aquifer System. Major projects are planned to address water resources and ecosystem issues in the Yakima Basin, including this area, under the Yakima River Basin Integrated Water Resource Management Plan.

Supply and Demand Context: Water supply is limited in this area due to intense pumping of aquifers that receive little recharge, and are interconnected with surface water systems reliant on baseflow. Groundwater demands increase in drought years when groundwater is used to supplement limited surface water supply. This combination results in groundwater declines and limitations in new groundwater withdrawals. Surface water flows are also impacted by groundwater withdrawals, including withdrawals from basalt aquifers, so new withdrawals are limited because they may impact surface water flows that are closed or regulated. Some projects implemented under the Yakima River Basin Integrated Water Resource Management Plan are expected to reduce groundwater declines and mitigate surface water impacts from pumping in the future.



Surface and Groundwater Interaction in the Rattlesnake Hills

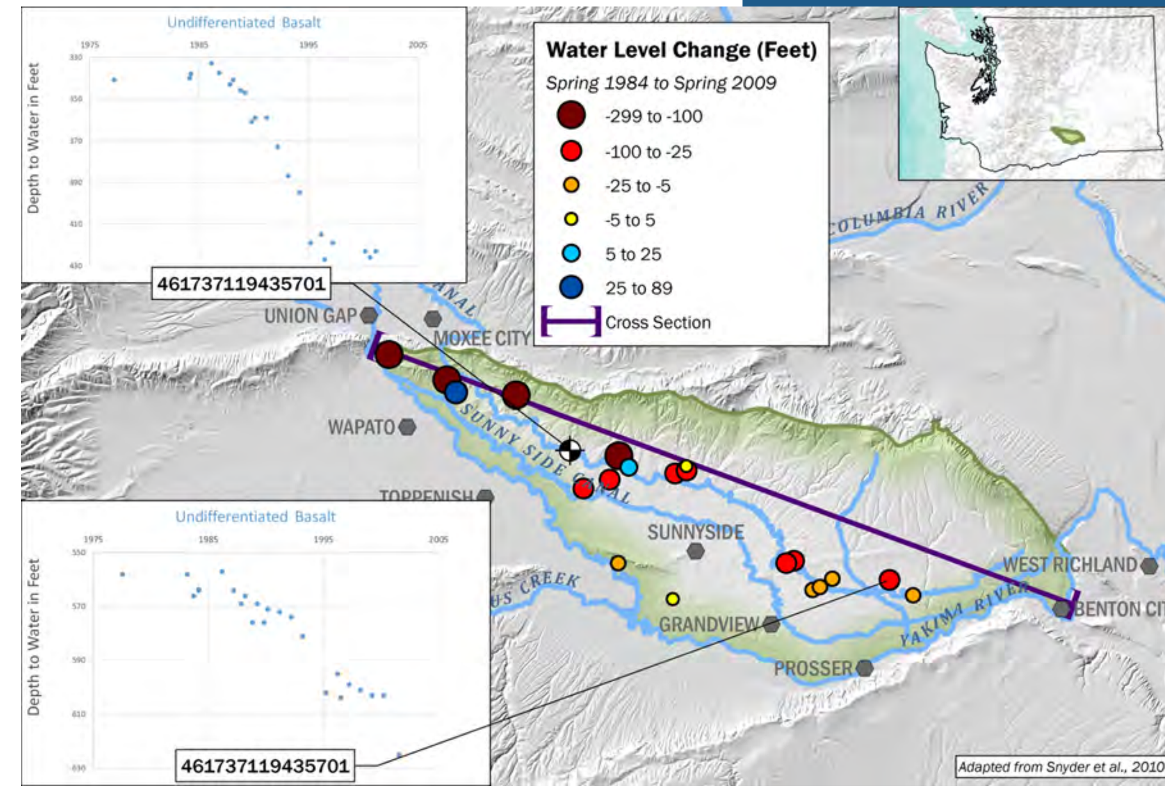
The primary surface water bodies in the Rattlesnake Hills include the Yakima River, and the Roza and Sunnyside Canals that supply Yakima River water to those respective irrigation districts.

- Groundwater in the area generally flows southwest toward the Yakima River.
- The Yakima River relies on groundwater discharge for much of its flow during the low-flow season.
- Pumping from both the overburden and basalt aquifers results in decreased discharge to the Yakima River, particularly from the overburden.
- Surface water shortages during drought years lead to increased groundwater demand.

Management Context

Groundwater Management Area	None present.
Management Policy	None at this time.
Adjudicated Areas	The Yakima River is currently under adjudication.
Watershed Planning	WRIA 37 (Phase 4 – implementation).
Adopted Instream Flow Rules	Target flows managed by the Bureau of Reclamation.
Drought Authorization	Case-by-case authorization, Roza alternate source wells.
Groundwater Declines	Generally between 21 and 150 ft from 1986 to 2002, and greater than 150 ft near Konnowak Pass.

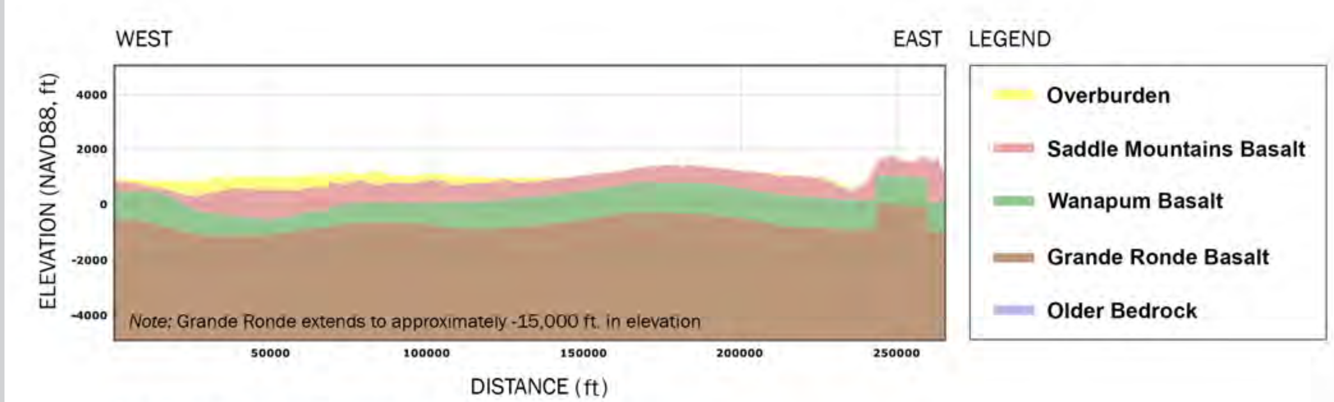
SW Flank of Rattlesnake Hills
(Yakima and Benton Counties)



Conceptual Hydrogeologic Model

Key considerations in developing the conceptual hydrogeologic model include:

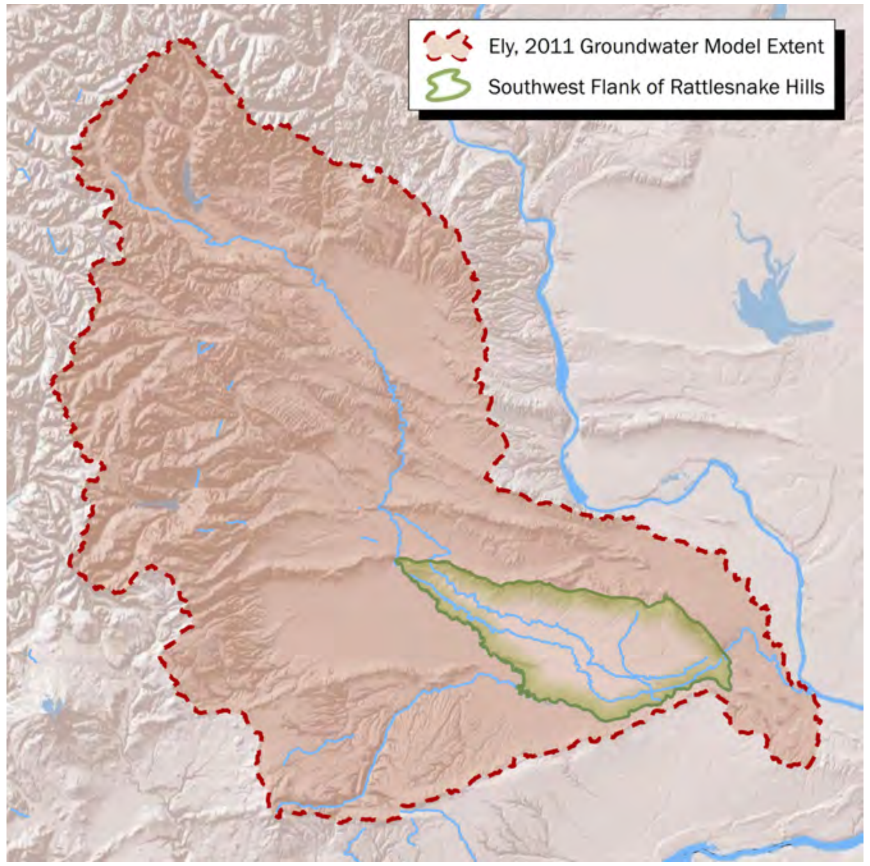
- The area is located in the Toppenish Basin of the Columbia Plateau Regional Aquifer System.
- In addition to productive basalt aquifers, the area also contains thick sequences of productive gravels in the overburden.
- The area is bounded to the northwest by the Rattlesnake Hills, an anticlinal fold that creates a barrier to horizontal groundwater flow across the ridge northwest of Grandview.
- The overburden aquifers are heavily utilized. Wells further from the river and southeast of Grandview rely on groundwater withdrawals from the Saddle Mountain and Wanapum Basalts.
- Key references include: Kahle, 2011; Vaccaro, 2009, 2011; Ely, 2011; and Jones et al., 2006.
- Groundwater in this area discharges to wells and the Yakima River.

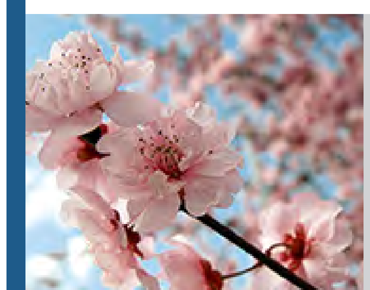


Note: Vertical scale greatly exaggerated
Source: USGS, Retrieved Dec 2015. http://or.water.usgs.gov/proj/cpras/index.html

Available Groundwater Models

The U.S. Geological Survey (USGS) has constructed a model of the Yakima Basin that provides good coverage of the Southwest Flank of the Rattlesnake Hills (Ely et al., 2011). The model scale is appropriate for assessing area-wide trends in groundwater conditions; however, it should be refined with current data to reflect current conditions. The model resolution (grid spacing) is too coarse for detailed simulations on a smaller scale for evaluation of potential groundwater recharge/enhancement projects. The model does contain significant information on hydrogeologic units and properties that could be used to support construction of a targeted higher-resolution model of the local areas. Another recent regional model constructed by the USGS is available that provides wider coverage of the area than the Yakima Basin model (Ely et al., 2014). Additional models are available, but they are broadly regional and/or are out of date. Model references: Ely et al., 2014; Ely et al. 2011; Hansen et al., 1994; and Vaccaro, 1999.





Potential Solutions

The Bureau of Reclamation and the Washington Department of Ecology (Ecology) have prepared a plan focused on solutions to meet the water resources and ecosystem needs of the Yakima Basin as part of the Yakima River Basin Integrated Water Resource Management Plan (Bureau of Reclamation and Ecology, 2012).

Demand Approaches

Conservation: Conservation measures are currently being carried out under the Yakima River Basin Water Enhancement Project Phase II and by various private organizations. Additional conservation measures for both municipal and agricultural uses are planned under the Yakima Basin Integrated Plan.

Administrative: None anticipated.

Supply Approaches

Surface Water Replacement (planned): Several new surface water storage projects and enhancements to new storage projects are included in the preferred alternative under the Yakima Basin Integrated Plan.

Surface Water Replacement (potential): Yakima River water is currently under adjudication.

ASR: Likely physically feasible in some portions of the area, based on a study of five wells, with three determined to be unsuitable, one marginally suitable, and one suitable (Gibson and Campana, 2014). ASR is anticipated as part of the preferred alternative under the Yakima Basin Integrated Plan. The City of Yakima has planned a 5,000 to 10,000 ac-ft/year ASR program upstream of the Rattlesnake Hills Area.

SAR: SAR is anticipated as part of the preferred alternative under the Yakima Basin Integrated Plan. It is likely feasible for aquatic habitat enhancement. Pilot studies are planned.

Data Gap Analysis

Data Needs: Continue historic groundwater modeling, and ASR/SAR pilot studies are planned [estimated costs are yet to be determined].

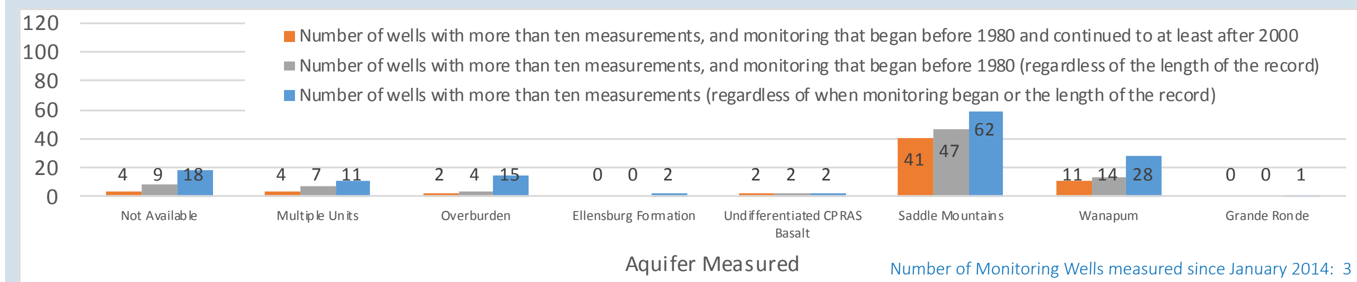
Currently Operating USGS Stream Gauges

Station Number	Station Name	Operating Since
12505450	Granger Drain at Granger, WA	1975
12510500	Yakima River at Kiona, WA	1948

Metered Water Rights (Ecology WRTS)	Including Claims			Not Including Claims		
	Total	Metered	Percentage Metered	Total	Metered	Percentage Metered
Number of Groundwater Rights	4,500	77	2%	905	77	9%
Groundwater Irrigated Acres	66,000	4,800	7%	63,000	4,800	8%

Water Level Data Availability

Trends in water level are better tracked when water levels are monitored from multiple wells that each have several measurements collected over a long time period. The following chart summarizes water level monitoring data available in state databases based on aquifer and time period sampled, and the number of measurements.



Source: USGS NWIS, Ecology EIM, and DNR water level databases

Risk Factors in the Southwest Flank of the Rattlesnake Hills

Many water rights in the area rely on a groundwater source. The following table presents groundwater-use information obtained from water rights data available from Ecology, water system data from Washington Department of Health, the 2010 census, and Vaccaro (2009).

Groundwater Use

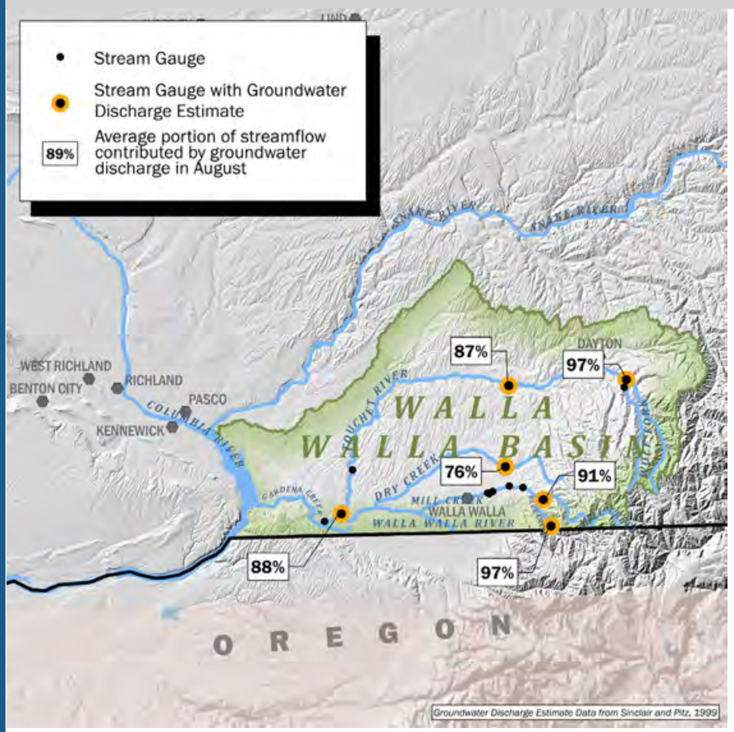
Groundwater Irrigated Acres	66,000
Population Served by Group A Water Systems	45,000
Population Served by Group B Water Systems	1,700
Population	67,000
Hatcheries	Prosser Hatchery (Falll Chinnook and Coho Salmon
Industry	Agriculture includes orchards, grapes, and mixed row crops

Overview

Groundwater is estimated to be declining at a rate of 0.1 to 3.5 ft/year in the Walla Walla Basin in Washington. The basin extends south into Oregon, where declines have also been recorded. Groundwater declines have been documented in both the unconsolidated aquifer system and in the underlying Basalt of the Columbia Plateau Regional Aquifer System. The largest groundwater declines have occurred in the Wanapum Basalt unit of the regional aquifer system.

Groundwater use in the basin is primarily for irrigation. Municipal use of groundwater is generally limited to deep basalt wells that are used for emergency and peak supply. The unconsolidated aquifer has a high degree of connection with surface water and is subject to instream flow rules (WAC 173-532). One of the most significant recharge areas for the entire regional basalt aquifer system is along the east side of the basin in the Blue Mountains.

Supply and Demand Context: Physical water supply is limited in the area because of a combination of high demand, very low recharge to deep aquifers, and aquifer isolation by faults and aquifer boundaries where geologic layers thin and pinch out. This combination has resulted in water level declines. Surface water flows in the area are captured by shallow groundwater withdrawals from the unconsolidated aquifer, so new groundwater withdrawals are limited because they may capture flows from surface water sources that are closed or regulated. A recently permitted ASR system is expected to eventually reduce groundwater declines in the deep Wanapum basalt aquifers. Recently implemented SAR systems are expected to reduce impacts to surface water flows.



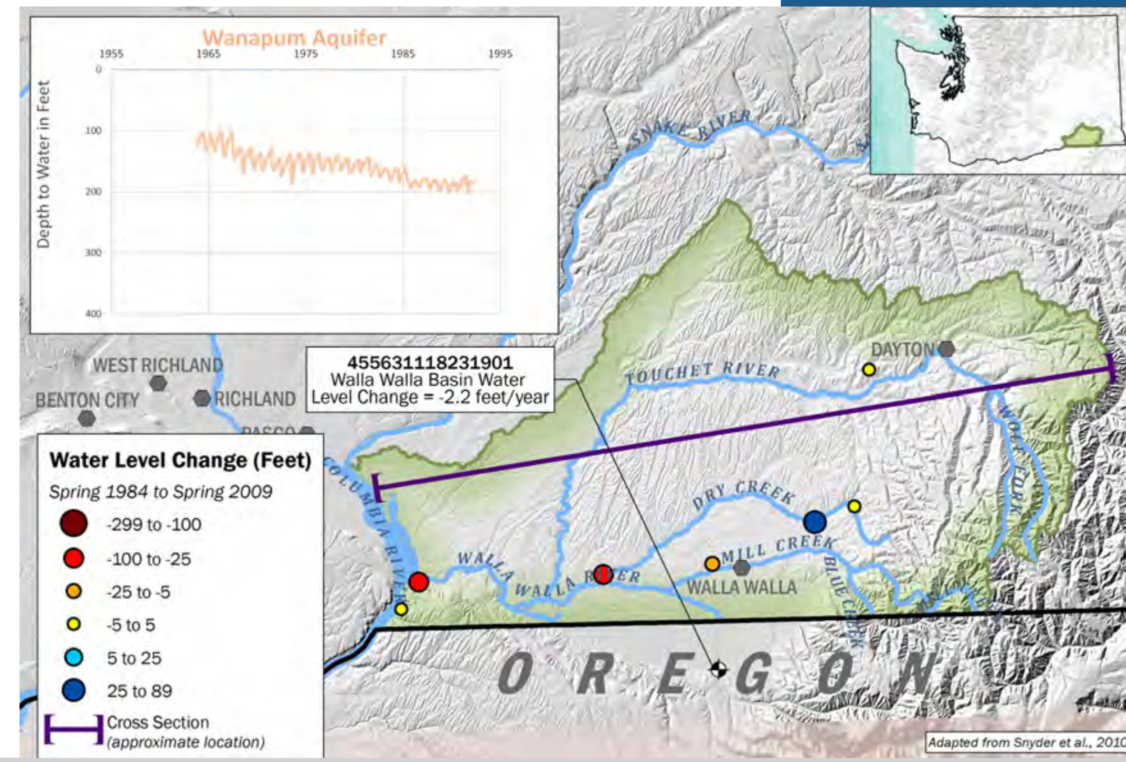
Surface and Groundwater Interaction in the Walla Walla Basin

Major surface water bodies in the Walla Walla Basin include the Walla Walla River, Mill Creek, the Touchet River, and the North Fork of the Touchet River.

- Mill Creek is an important supply source for the City of Walla Walla.
- The rivers provide important salmon habitat.
- Surface waters are highly connected to the unconsolidated aquifer and are reliant on groundwater to maintain flows during the dry season.
- Unconsolidated aquifer withdrawals are limited by the 2007 instream flow rule.

Management Context

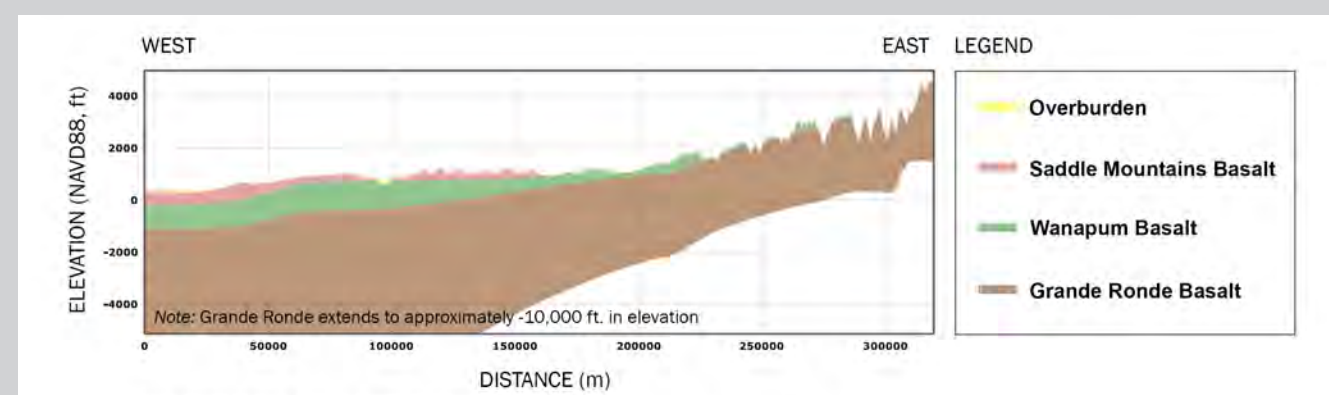
Groundwater Management Area	None present
Management Policy	Limited to Instream flow rule (WAC 173-532)
Adjudicated Areas	Walla Walla River, Upper Stone Creek, Doan Creek, Touchet River, Dry Creek
Watershed Planning	WRIA 32 (currently in phase 4 implementation)
Adopted Instream Flow Rules	Walla Walla River, and its tributaries and headwaters (WAC173-532). Seasonal closures and no further consumptive appropriation of surface waters and shallow gravel aquifer water.
Drought Authorization	None
Groundwater Declines	Washington: 0.1 to 3.5 ft./year; Oregon: 6 to 7.5 ft./year (Burns et al., 2012).



Conceptual Hydrogeologic Model

Considerations in developing the conceptual hydrogeologic model include:

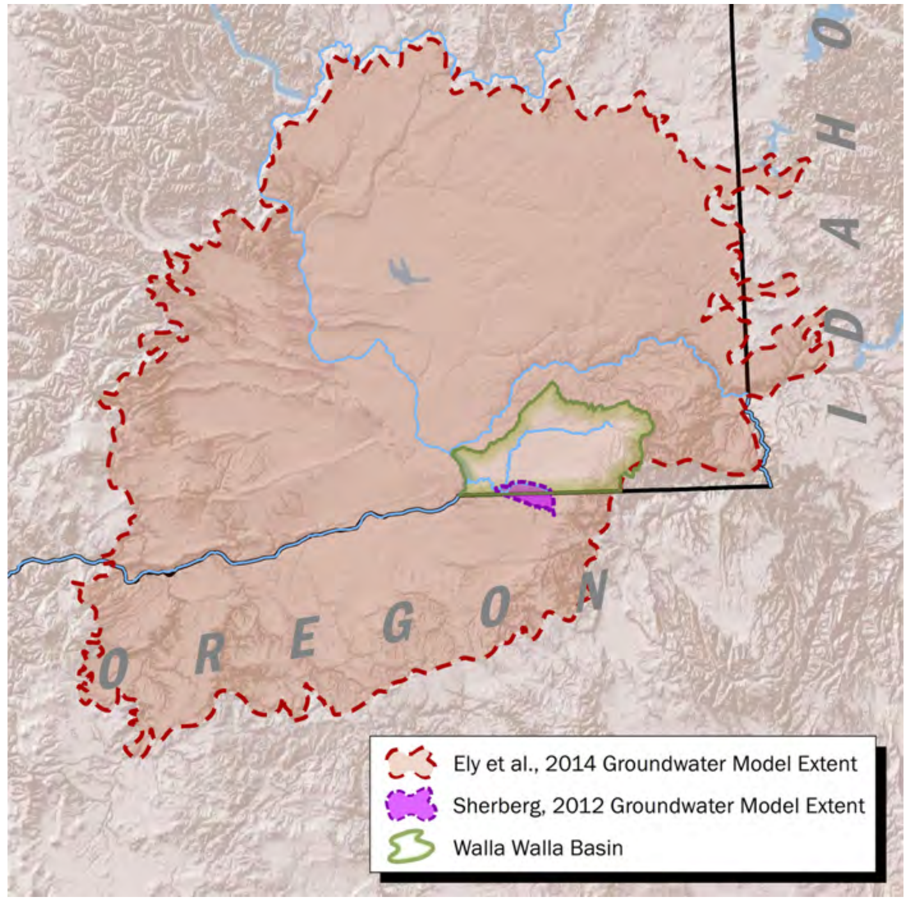
- Key aquifers in the Walla Walla Basin include the unconsolidated aquifer system and the underlying Columbia Plateau Regional Aquifer System.
- The unconsolidated aquifer system is also referred to as the suprabasalt or overburden aquifer in various documents.
- The unconsolidated system includes three coarse-grained units, which are separated by two fine-grained units, all of which are assumed by the Washington State Department of Ecology (Ecology) to have a high degree of hydraulic connection to surface water (WAC 173-532).
- Columbia Plateau Regional Aquifer System units from shallowest to deepest include the Saddle Mountain, Wanapum, and Grande Ronde Basalts.
- The Blue Mountains on the upland (east) end of the Walla Walla Basin comprise a significant recharge area for the entire basalt aquifer system (approximately 20 in/year).
- Basalt aquifers in the basin have a high degree of isolation caused by vertical faults that serve as barriers to groundwater flow, making them prone to groundwater declines.
- Key references include: Burns et al., 2012; GSI, 2007; HDR, 2013; Tolan et al., 1989; Kahle, 2011; Snyder et al., 2010; and PGG, 1995.

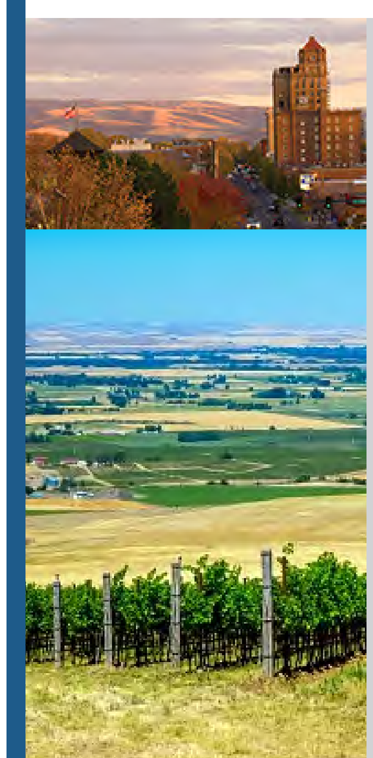


Note: Vertical scale greatly exaggerated
Source: USGS, Retrieved Dec 2015. http://or.water.usgs.gov/proj/cpras/index.html

Available Groundwater Models

At least three groundwater models have been developed for portions of the Walla Walla Basin. It is expected that any of these models would need refinements to be adequate for decision-making to address declining groundwater issues in the Walla Walla Basin. A candidate for building upon is the MODFLOW model prepared by Ely et al., (2014). This is a regional scale model covering the entire Columbia Plateau Regional Aquifer System. The model does contain significant information on hydrogeologic units and properties that could be used to support construction of a targeted, higher-resolution model of the basin. Model references in addition to Ely et al., include: Sherberg, 2012; Petrides-Jimenez et al., 2008; MacNish and Barker, 1976; Hansen et al., 1994; and Vaccaro, 1999.





Potential Solutions

Demand Approaches

Conservation: Irrigation efficiency improvements implemented. Walla Walla Water System Conservation Plan has been implemented.

Administrative: Instream flow rules have been implemented that restrict use of the unconsolidated aquifer.

Supply Approaches

Surface Water Replacement (potential): Closed to new consumptive appropriation by instream flow rules. Source exchange projects using Columbia River water are a possible option in lower portions of the basin.

Surface Water Storage: One pilot project complete in Washington (WWBWC, 2016).

ASR: Permit issued for city of Walla Walla in 2015. Future ASR projects may be considered.

SAR: Several projects implemented since 2007: Two sites in Washington, eight sites in Oregon (WWBWC, 2016). Most feasible in unconsolidated aquifer system.

Data Gap Analysis

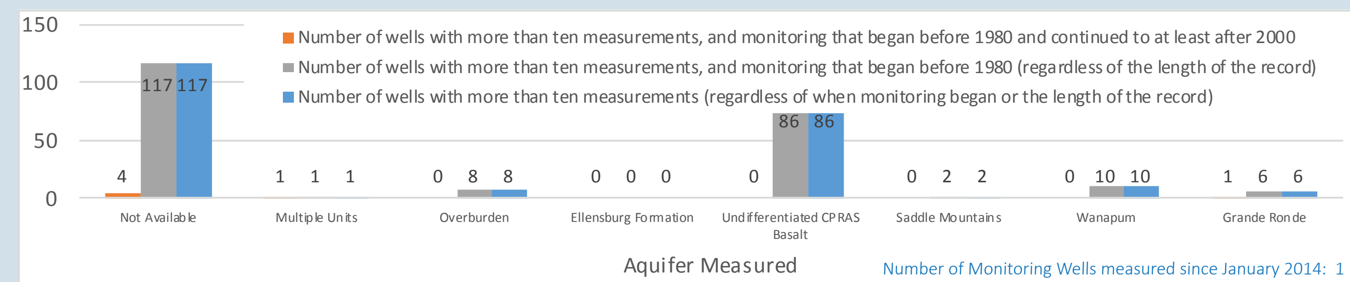
Data Needs: Groundwater modeling, and ASR feasibility and pilot studies [estimated costs are yet to be determined].

Currently Operating USGS Stream Gauges		
Station Number	Station Name	Operating Since
14013000	Mill Creek near Walla Walla, WA	1924
14013500	Blue Creek near Walla Walla, WA	1973
14013700	Mill Creek at Five Mile Road Br near Walla Walla, WA	1997
14014000	Yellowhawk Creek at Walla Walla, WA	1952
14014500	Garrison Creek at Walla Walla, WA	1952
14015000	Mill Creek at Walla Walla, WA	1924
14016000	Dry Creek near Walla Walla, WA	1977
14018500	Walla Walla River near Touchet, WA	1951

Metered Water Rights (Ecology WRTS)	Including Claims			Not Including Claims		
	Total	Metered	Percentage Metered	Total	Metered	Percentage Metered
Number of Groundwater Rights	4,300	181	4%	1,700	181	11%
Groundwater Irrigated Acres	78,000	6,900	9%	70,000	3,000	4%

Water Level Data Availability

Trends in water level are better tracked when water levels are monitored from multiple wells that each have several measurements collected over a long time period. The following chart summarizes water level monitoring data available in state databases based on aquifer and time period sampled, and the number of measurements.



Source: USGS NWIS, Ecology EIM, and DNR water level databases

Risk Factors in the Walla Walla Basin

Many water rights in the Walla Walla Basin rely on a groundwater source. The following table presents groundwater-use information obtained from water rights data available from Ecology, water system data from Washington Department of Health, and the 2010 census.

Groundwater Use

Groundwater Irrigated Acres	78,000
Population Served by Group A Water Systems	54,000
Population Served by Group B Water Systems	300
Population	58,800
Industry	Agriculture (14%), service industries (70%), manufacturing (13%)