RECLAMATION *Managing Water in the West*

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The Knowledge Stream

Research Update

Managing Future Water Resources in the Upper Deschutes Basin, Oregon

Applying existing tools to simulate integrated surface and ground water response to climate change

Bottom Line

By incorporating climate change models and local models, this study predicts how ground water responses to potential climate change will vary in the Upper Deschutes Basin, depending on the location, and spatial scale of the flow systems and their aquifer characteristics.

Better, Faster, Cheaper

This study provides a predictive tool to help water resource managers and water users in developing effective resource management strategies for adapting to potential hydrologic changes.

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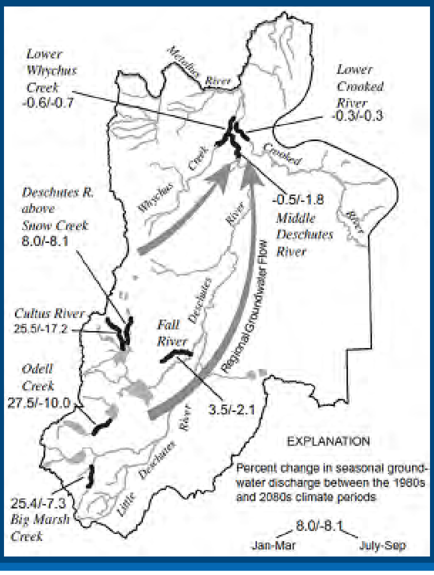
Collaborators

- **U.S. Geological Survey (USGS)**
- **Portland State University, Oregon**



Percent changes in winter and summer ground water discharge to spring-fed streams and stream reaches in the Upper Deschutes Basin between the 1980s and 2080s climate periods.

Problem

Water resource management typically relies on records of historical streamflows. However, this approach assumes that future streamflows will resemble past streamflows, which may be problematic in light of global warming and the changing climate.

Ground water plays a key role in determining the response of stream systems to climate change, and understanding how an aquifer system changes locally to climate change as these responses will also affect surface water. However, the relation between aquifer system scales (and diffusive characteristics) and the response to climate change has not previously been analyzed. Projected warming is anticipated to shift precipitation toward more rain and less snow in mountainous areas in the Pacific Northwest. This would result in smaller winter snowpack and in a shift in the timing of runoff to earlier in the year over the next century. This would cause changes in recharge timing and distribution through the ground water system that lead to changes in the timing and volume of ground water discharge to springs and streams.

Analyzing how local ground water recharge responds climate change is significant because many of the largest rivers in the Pacific Northwest originate in seasonal snow-dominated regions of the Cascade Range, where ground water-fed streams are common. Anticipated changes in snow hydrology, therefore, have important consequences for water supplies and aquatic ecosystems in the region.

In the Upper Deschutes Basin in Oregon's Cascade Range, for example, most precipitation now starts as snowpack in mountainous areas, which leads to substantial aquifer recharge during spring-snowmelt period, with higher recharge efficiency under snowmelt conditions compared to what would occur during winter rainfall-runoff events. As climate warming occurs, questions emerge about not only shift of recharge timing from spring to winter, but also efficiency as recharge is supported more by rainfall rather than snowmelt.

Changes in recharge and runoff in the Upper Deschutes Basin could markedly affect ground water levels, ground water discharge, and streamflow—which in turn affects water operations (modifying storage reservoirs to accommodate changes in ground water inflow timing) and ecosystems (changing timing for ground water-fed wetlands). Water managers need to understand and plan for these changes.

Solution

To provide insights into the way regional ground water systems that span spatial scales might respond to climate change, future climate projections were applied to water balance and ground water flow models in the Upper Deschutes Basin. To explore a range of possible future climate conditions in the study area, investigators used downscaled climate projections provided by the University of Washington from eight different global climate models and climate forcing scenarios spanning lower to higher greenhouse gas emissions.

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To simulate surface hydrology, runoff, and aquifer recharge in the Upper Deschutes Basin, a daily mass and energy balance model, the Deep Percolation Model (DPM), was used with historical daily climate data from weather stations in the basin to drive the model. To simulate aquifer discharge to streams, the recharge from DPM was used to drive a regional ground water simulation model, the U.S. Geological Survey's MODFLOW, which was applied to the Upper Deschutes Basin. Future runoff, recharge and discharge conditions were assessed by creating climate-adjusted weather inputs for the DPM model corresponding to the downscaled climate data.

Application Results

In general, the analysis showed that changes in the seasonal distribution of ground water discharge to springs and streams will be more prominent (relative to mean discharge) in upland areas near recharge areas where ground water flow paths are relatively short. Conversely, changes in seasonality of ground water discharge will be less prominent relative to mean discharge to major discharge areas at the terminal ends of regional ground water flow systems. As in-place seasonal recharge timing shifts earlier, smaller streams near the Cascade Range margin and in the upper portion of the basin, will likely experience shifts in timing of peak discharge through the 21st century in response to warming. Springs-feeding streams in the northern and central portions of the basin, such as the Deschutes River, lack a prominent seasonal signal.

Ground water discharge to streams varies, depending on the scale of the ground water system (length of flow path) and location. About 80 percent of the annual discharge of the Deschutes River, which drains most of the east side of the Cascade Range, originates as ground water discharge. This flow comes from discharge at a wide range of spring locations from small high-elevation spring complexes with relatively short flow paths (100 to 101 kilometers [km]) as well as large high-volume regional spring complexes with long flow paths (101 to 102 km) in the interior parts of the basin.

The response of aquifer systems to climate-driven changes in the seasonality of recharge will vary with spatial scale. Simulation results show that short flow path ground water systems, such as those providing baseflow to many headwater streams, will likely have substantial changes in the timing of discharge in response changes in seasonality of recharge. Regional-scale aquifer systems with long flow paths, in contrast, are much less affected by changes in seasonality of recharge. Flow systems at all spatial scales, however, are likely to reflect interannual changes in total recharge.

Bend Diversion Dam on the Deschutes River. It diverts water for the North Unit and Pilot Butte Canals.

Crooked River (tributary of the Deschutes River) near Crooked River Ranch several miles above Lake Billy Chinook.

Fall River Headwater Spring is a spring-fed tributary of the Deschutes River with a mean annual flow of about 150 cubic feet per second.

Quinn Creek is a spring-fed stream in the Upper Deschutes Basin that flows into Hosmer Lake. All photographs by Marshall Gannett, U.S. Geological Survey.

"More accurate predictions of hydrologic changes will help water managers more effectively plan water operations over the next century. Insights from the Upper Deschutes Basin have general applicability to other regional ground water systems with mountainous recharge areas."

Marshall Gannett
Hydrologist, U.S. Geological Survey

Future Plans

Understanding the impacts of climate change on aquifer systems is important because of the potential effects on a range of boundary flows (such as discharge to streams, springs, and wetlands), and implications for ground water users, human infrastructure, and water management. These coupled models can be used in future work as a predictive tool to help water resource managers make resource strategies and decisions. Results from these analyses provide valuable insights into the possible impacts of climate change to other regional aquifer systems, and the streams they support, where discharge points represent a range of flow system scales.

More Information

Waibel, M.S., M.W. Gannett, H. Chang, and C.L. Hube. 2013. *Spatial Variability of the Response to Climate Change in Regional Groundwater Systems–Examples From Simulations in the Deschutes Basin, Oregon*. Journal of Hydrology 486 (2013) 187 - 201.

Waibel, M.S. 2011. *Model Analysis of the Hydrologic Response to Climate Change in the Upper Deschutes Basin, Oregon*. Masters thesis, Geology:Geohydrology, Portland State University.

www.usbr.gov/research/projects/detail.cfm?id=2885