Research Brief

FALL 2017

Groundwater Wells in the Western United States

Introduction

Western U.S. groundwater is a strategic resource. Groundwater supplies drinking water to municipalities and rural communities, and sustains crop production through irrigated agriculture. Unfortunately, groundwater resources are declining in parts of the West. Declining groundwater levels can threaten water and agricultural security by reducing the rate that wells can pump water or causing them to dry entirely. There is anecdotal evidence that wells are drying or becoming unproductive due to declining water tables, but the lack of well construction information and water level measurements across jurisdictions makes it difficult to assess which wells have been impacted by declining water levels. In California, there is also anecdotal evidence that wells used for domestic purposes are more susceptible to drying than wells used for agricultural purposes, because domestic wells are shallower than agricultural wells.

Photo Credit: Debra Perrone

We examined the spatial density of groundwater wells in 17 western states, and their depths and purposes, stitching together well completion records across numerous jurisdictional boundaries. We use this information to approximate where wells are impacted by declining groundwater levels. Our study finds that:

1. Approximately 1-in-30 western U.S. wells constructed in flat areas between 1950 and 2015 are shallower than nearby 2013-2015 water level measurements, suggesting that these wells were dry.
2. Domestic wells are significantly shallower, and more vulnerable to drying, than agricultural wells in some parts of the West, including the California Central Valley.
3. Significant data gaps exist that may limit informed groundwater management.

Well completion records are collated at the county or state scale, and these records are rarely stitched together across jurisdictional boundaries. Our compilation of groundwater well infrastructure is the first characterization of groundwater wells at the continental scale in nearly three-decades[1] (Figure 1).

1 Hindall S M & Eberle M 1989. National and regional trends in water-well drilling in the United States, 1964-84. *U.S. Geological Survey Circular* 1029. Reston, VA: United States Geological Survey.

About the Researchers

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1-in-30 Western U.S. Wells Were Dry Between 2013 and 2015

Finding: By combining well construction information and water level measurements across jurisdictions, we find that the depths of 1-in-30 wells were shallower than the 2013-2015 groundwater levels in nearby wells, suggesting that these 1-in-30 wells were dry. Dry wells are concentrated in rural regions. In some of these rural areas more than 1-in-5 wells were dry sometime during the 2-year period. During 2013-2015, groundwater levels were within 10m of the bottom of nearly one-fifth of all western US wells.

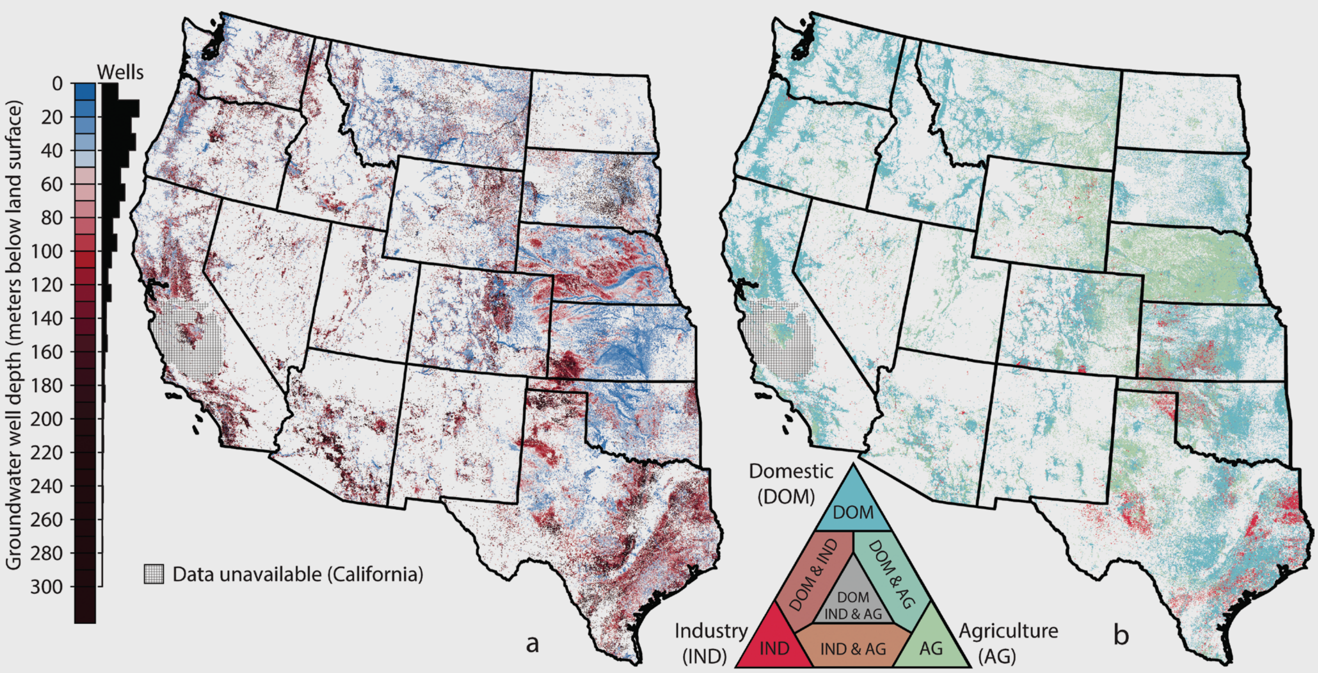
Implications: Excessive groundwater pumping and reductions in groundwater recharge can cause loss of groundwater storage, land subsidence, streamflow depletion, ecosystem harm, and seawater intrusion. The prevalence of dry wells highlights another undesirable impact associated with groundwater level declines. Rural communities often feel the impacts of groundwater depletion more severely, because they are more likely to rely solely on groundwater and constructing new wells can be costly.

The depth to the pump in a well is shallower than the well bottom; consequently, our estimates of dry wells are likely conservative. Groundwater pumping induces a localized drawdown of the water table known as the cone of depression; consequently, well productivity can be impacted even where the water table depth has not dropped below the pump intake.

Domestic *and* agricultural wells vulnerable to drying

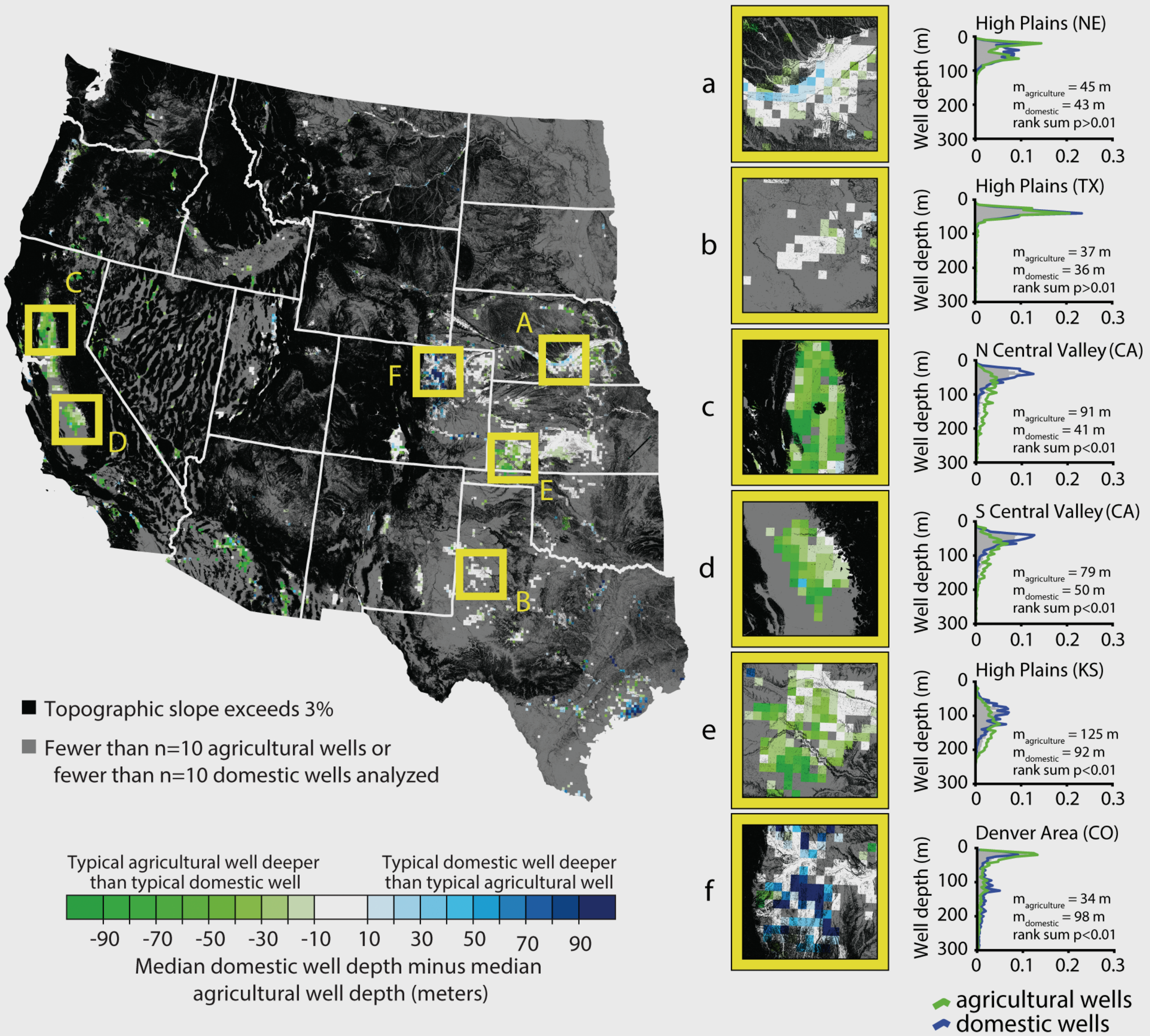
Finding: Our results support anecdotal evidence that wells used for domestic purposes are more susceptible

FIGURE 1



Groundwater well depths and purposes vary substantially across the western U.S. (a) Recorded well depths vary considerably with an upper and lower quartile range of 30m to 92m, and a median of 55m. More than 95 percent of wells have total construction depths less than 200m below the land surface. (b) Domestic wells (i.e., self supply and public supply) comprise 73 percent of wells in our dataset. Agricultural wells (i.e., irrigation and livestock watering) represent 23 percent of wells, and the remaining wells in our dataset (4 percent) are for industrial purposes (e.g., commercial uses, primary energy production).

FIGURE 2



Comparison of agricultural versus domestic well depths. Green grids represent regions where the median agricultural well depth is deeper than the median domestic well depth; blue grids represent areas where the median domestic well depth is deeper than the median agricultural well depth. Seven regions are highlighted in yellow boxes, each of which links to the subplots a-f. Each subplot shows the normalized histogram of groundwater well depths for (i) all wells (grey), (ii) agricultural wells (green), and (iii) domestic wells (blue); the horizontal axis represents the proportion of all wells in the specified area.

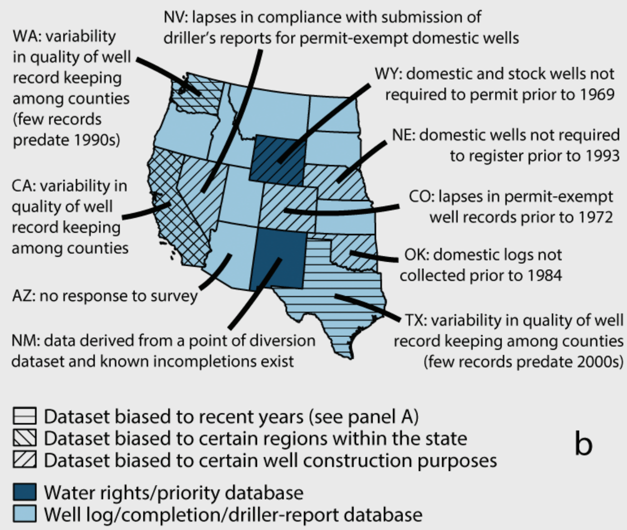
to drying than wells used for agricultural purposes throughout California's Central Valley; agricultural wells tend to be deeper than domestic wells in the Central Valley. Agricultural wells, however, are not significantly deeper than domestic wells in all regions (e.g., Denver area in Colorado) (Figure 2).

Implications: We find that typical agricultural wells can be tens of meters deeper than typical domestic water wells in some areas key to U.S. food production (e.g., Central Valley of California, High Plains of southwest Kansas), implying agricultural wells are more resilient than domestic wells to drying should the water table decline. In the majority of areas we analyzed, however, median domestic and agricultural well depths are similar. Our finding suggests that, all else equal, declining groundwater levels will impact domestic and agricultural wells proportionately in these areas. In short, declining groundwater levels are impacting both domestic and agricultural water security.

Data Gaps Have Key Implications for Groundwater Management

Finding: Our compilation highlights data gaps among the various state databases that limit research and groundwater management to (i) newer wells (e.g., Texas, Washington), (ii) non-domestic groundwater users (e.g., Nebraska, Oklahoma, Wyoming, Nevada), and (iii) select counties due to lacking data in some regions (e.g., California's southernmost Central Valley) (Figure 3).

FIGURE 3



Limitations associated with compiled groundwater well construction record data as indicated by state data managers in our data quality survey. Most of the western 17 states provided a well log, completion or driller report database (as indicated by the light blue shade). Key limitations with the state groundwater construction databases are marked by black lines, and include biases in the compiled data towards better record keeping of more recently constructed wells (e.g., Texas), of wells of a certain construction purpose (e.g., Nebraska), and of wells in certain regions of the state (e.g., California).


Photo Credit: Flickr/hjl


Photo Credit: Mark Gunn

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Implications: Because groundwater construction databases are managed at the state level, data limitations provide a glimpse into the evolution of strategic groundwater policies—or lack thereof—associated with each state. Well records provide a snapshot of millions of local-scale decisions and map the widespread existence of infrastructure used to extract groundwater across the western U.S. Well construction data benchmark well locations, depths, and purposes and highlight the importance of digitized data for managing groundwater. Mapping wells is one step towards better understanding where groundwater is being extracted. Well data are valuable to demand-side planning efforts, such as identifying areas to reform and improve management, focus conservation campaigns, or tailor economic incentives. Groundwater well locations and depths can be especially vital for mapping the impacts of groundwater pumping on surface waters. On the supply-side of groundwater management, well locations can provide valuable information about aquifer systems, especially where drilling records contain detailed hydrogeologic data (e.g., pump tests, lithologic logs), and may be used to target optimal areas for managed aquifer recharge projects.[2]

2 Perrone, D. and M. Rohde. (2016) "Benefits and Economic Costs of Managed Aquifer Recharge in California." *San Francisco Estuary and Watershed Science.* doi: 10.15447/sfews.2016v14iss2art5.

Conclusion

Dry wells highlight yet another undesirable impact associated with declines in groundwater levels from depletion or reduction in groundwater recharge. Our analysis can help identify areas where wells were impacted by declining groundwater levels; these areas are ripe for demand-side or supply-side groundwater management improvements.

The data gaps outlined in Figure 3 can impede metering and reporting efforts, inhibit assessments of groundwater users' vulnerability to declining water levels, and delay efforts to identify which communities could benefit most from emergency funding designed to relieve water stress[3]. Although most states have made significant progress in their collection of groundwater well records, there still exists a patchwork of data across the western 17 states. Because some aquifers span multiple jurisdictions, it can be difficult to reconcile the data due to different data collection methods. We recommend that all western states adopt similar data collection and dissemination practices to promote the integration of data and inform transboundary aquifer management.

3 Hanak E, Mount J, Chappelle C, Lund J, Medellín-Azuara J, Moyle P & Seavy N 2015. What if California's drought continues? San Francisco, California: Public Policy Institute of California. Accessed from *http://www.ppic.org/publication/what-if-californias-drought-continues/*

This research brief is based on the paper "Dry groundwater wells in the Western United States" by Debra Perrone and Scott Jasechko published in the journal *Environmental Research Letters*. View the paper at iopscience.iop.org/article/10.1088/1748-9326/aa8ac0.

About Water in the West

Water in the West, a joint program of the Stanford Woods Institute for the Environment and the Bill Lane Center for the American West, marshals the resources of one of the world's preeminent research universities to answer one of the most urgent questions about the American West's future—how can the region continue to thrive despite growing water scarcity? Through Water in the West, Stanford University's world-class faculty, researchers and students are working to address the West's growing water crisis and to create new solutions that move the region toward a more sustainable water future. Learn more: waterinthewest.stanford.edu

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