Understanding Upper Deschutes Basin Groundwater Levels

September 2022

Prepared for:

CENTRAL OREGON CITIES ORGANIZATION

Bend, Culver, La Pine, Madras, Maupin
Metolius, Prineville, Redmond, Sisters

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Introduction

Groundwater from the Upper Deschutes Basin is a main water supply for the member cities of the Central Oregon Cities Organization (COCO), established in 2002. The current cities that belong to COCO (Bend, Culver, La Pine, Madras, Maupin, Metolius, Prineville, Redmond, and Sisters) have a strong interest in this water source and take pride in being responsible stewards of the resource.

The nine member cities have a combined population of over 150,000 people. COCO's purpose is to effectively and efficiently promote common interests of the cities in Central Oregon, including issues related to water. COCO is committed to finding basin-wide solutions and is an active member of the Deschutes Basin Water Collaborative. This commitment can be observed in the member cities' conservation efforts:

- The City of Prineville has won two Excellence in Communications Awards from the Pacific Northwest Section of the American Water Works Association for publications related to conservation.
- The City of Bend tied for first place for the Oregon Water Resources Department's (OWRD's) 2018 Stewardship and Conservation Award.
- The City of Bend was the first city in the country to be reviewed and receive a Silver rating from the Alliance for Water Efficiency for compliance with American Water Works Association standards for water conservation programs.
- The City of Redmond has rigorous water conservation programs to reduce outdoor water use through incentives, as described in its water management and conservation plans.

Some areas of the Upper Deschutes Basin are currently experiencing varying rates of groundwater level declines. This, in turn, has caused increased scrutiny of new groundwater permit applications in the basin. In November 2021, OWRD's Groundwater Section completed a review that concluded that groundwater is not available within the capacity of the groundwater resource for a new proposed use in the basin. This review and other public communication from OWRD indicate the possibility that the agency will terminate issuance of new groundwater permits within the Upper Deschutes Basin due to concerns that additional appropriations would cause over-appropriation or significantly impair the function or character of the resource.

COCO respects OWRD's efforts to manage and protect the groundwater resource in the Upper Deschutes Basin; however, OWRD's recent actions do not adequately consider the hydrogeologic framework of the basin. COCO presents this white paper to provide context for historically and current groundwater declines in the Deschutes groundwater flow system (Deschutes aquifer) by describing the hydrogeologic framework, historical changes to the system, aquifer stressors, and magnitudes of groundwater recharge and withdrawals.

Key Issues

There are five key issues about the Upper Deschutes Basin that provide background information for understanding groundwater levels in this area:

- **Precipitation drives the groundwater flow system in the Upper Deschutes Basin.** Groundwater levels in wells near the Cascades closely reflect variability in annual precipitation. In wells more distant from the Cascades, the response of groundwater levels to precipitation is attenuated. Recent groundwater level trends seen at these wells reflect a long-term precipitation deficit.

- **Groundwater level declines in the Upper Deschutes Basin are being driven by climate variability.** Recent groundwater declines are primarily the result of long-term drought and are not without historical precedent. Precipitation data shows similar periods of long-term drought occurred during the dust-bowl era, with similar effects on the groundwater system. In contrast, climate change models generally predict equal or slightly greater precipitation in the Central Oregon Cascades. While models predict a decline in snowpack that will affect the timing of surface water flows, whether precipitation falls as rain or snow is not expected to influence groundwater levels in the larger regional aquifer.

- **The Deschutes aquifer is very thick in the Upper Deschutes Basin.** The Deschutes aquifer has a saturated thickness of approximately 1,000 feet within a single geologic formation. Even assuming that groundwater levels would continue to decline at recent rates (which is not supported by the evidence), the declines would be less than 15 percent of the total saturated thickness of the aquifer after 100 years.

- **Groundwater allocation decisions should not be made based on wells that only penetrate the uppermost saturated zone of the aquifer.** Concerns have been raised about the need for some groundwater users in the Deschutes aquifer to deepen their wells or groundwater users losing their ability to access the resource entirely. Providing assistance for users of domestic water supply wells that penetrate only a small amount into the saturated zone of the Deschutes aquifer has and should continue to be a priority for regional and state officials. However, identifying such concerns as a basis for negative groundwater findings is inconsistent with basic principles of prior appropriation. Groundwater users with shallow wells that penetrate only the uppermost portion of the saturated thickness of the Deschutes aquifer should not force the closure of the resource to future groundwater appropriation. Typically, these well users would be required to deepen their wells to more fully penetrate the aquifer. Wells in the Upper Deschutes Basin that are drilled into localized alluvial aquifers can be impacted by various factors; the causes of those impacts are not addressed here.

- **The groundwater flow system is not over-appropriated in the Upper Deschutes Basin.** The Upper Deschutes Basin receives over 4,000 cubic feet per second (cfs) of annual recharge. Groundwater pumping is equivalent to approximately 2 percent of the annual groundwater recharge (Gannett et al., 2017).

Understanding the Upper Deschutes Basin Groundwater Flow System

As defined by the U.S. Geological Survey (USGS) in Gannett et al. (2001), the Upper Deschutes Basin groundwater flow system encompasses about 4,500 square miles.[1] Groundwater in the upper Deschutes system originates as precipitation, primarily in the Cascade Range. Precipitation rapidly infiltrates the relatively young and highly permeable volcanic rocks and is termed recharge. Groundwater flows generally to the east towards the basin interior, discharging to springs near the base of the Cascade Range (including the Metolius River) and to springs in the Deschutes and Crooked River canyons. Most groundwater in the Upper Deschutes Basin flows through volcanic deposits of the Cascade Range, and through the Deschutes Formation. The groundwater flow system is bounded by low permeability, hydrothermally altered rocks at depth beneath the Cascade Range and pre-Deschutes Formation rocks of the John Day Formation elsewhere in the basin (Gannett et al., 2001). The low permeability deposits are not a significant source of groundwater supplies, and inhibit groundwater flow beneath the Deschutes Formation, as well as on the northern and eastern boundaries of the basin.

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[1] This definition is consistent with the boundaries of the Upper Deschutes Basin study area, which includes the Upper Deschutes Basin from the crest of the Cascades, to Prineville Reservoir and Ochoco Reservoir to the east. The Crooked River Basin above these two storage reservoirs is not included in the study area.

Precipitation and Recharge

Precipitation is the main driver of the groundwater flow system in the Upper Deschutes Basin. Gannett et al. (2017) estimated a total recharge rate of 4,436 cfs for the Upper Deschutes Basin based on data from 1980 through 2013. Of this amount, 3,031 cfs is estimated to come from direct in-basin precipitation, 994 cfs from interbasin flow (mostly into the Metolius subbasin), and 411 cfs from canal leakage. However, the amount of precipitation and recharge is not constant. Variations in precipitation (and recharge) over time in the Cascade Range are evidenced from records of precipitation at Crater Lake, which provides the longest consistently available precipitation record for the Cascade Range. Figure 1 shows Crater Lake precipitation trends from 1921 through 2021.

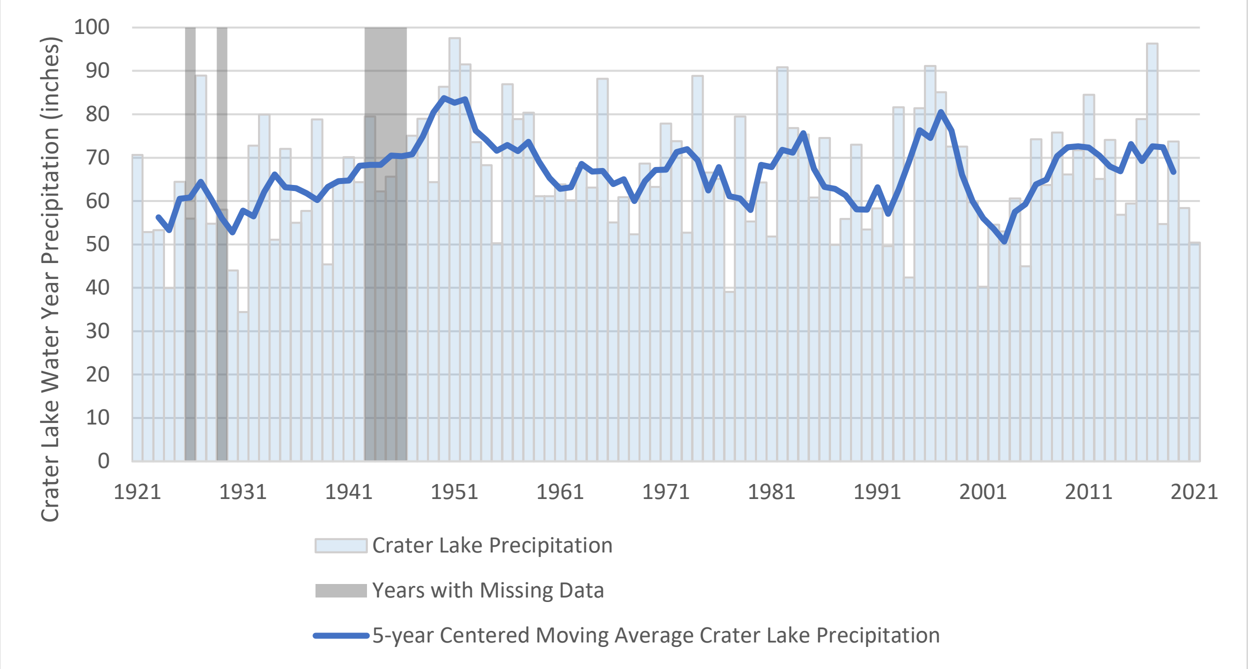

Figure 1. Annual water year precipitation at Crater Lake National Park, Oregon, and 5-year rolling average precipitation from 1921 through 2021. Years with missing data indicate years when over 50 percent of daily precipitation totals for the Crater Lake weather station were missing. Throughout the 1921 through 2021 time period, missing daily totals for Crater Lake were estimated based on monthly correlations with Klamath Falls weather station following a similar approach to that employed by Gannett et al. (2007).

These precipitation records are reflected in flow measurements in spring-fed streams such as Fall River. Figure 2 shows the relationship between Crater Lake precipitation and mean monthly Fall River discharge, as measured at USGS gage 14057500, located approximately 5 miles downstream of the Fall River headwater springs. The gage was installed in July 1938. The chart also shows miscellaneous measurements made by water resources staff prior to the installation of the gage. The hydrograph for Fall River illustrates that discharge rates fluctuate on a decadal scale due to changes in precipitation, but also shows the current discharge to be similar to the late 1930s, demonstrating the relationship between long-term, cyclic precipitation patterns and groundwater recharge near the Cascade crest.

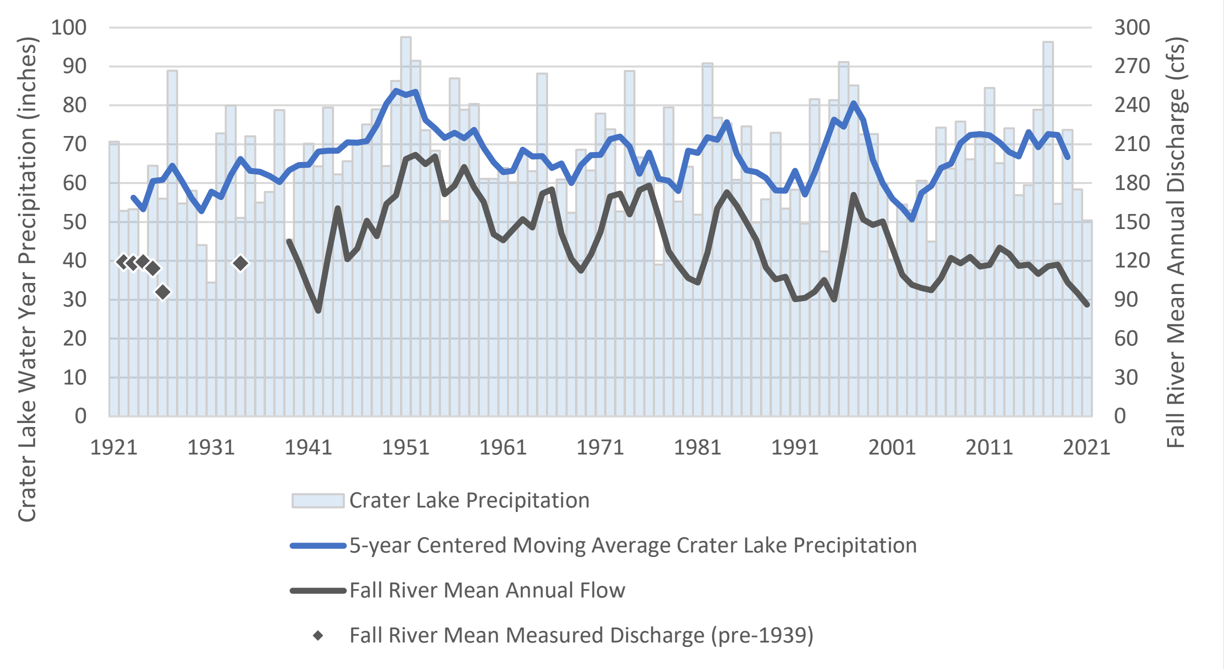

Figure 2. Annual water year precipitation at Crater Lake National Park, Oregon, 5-year rolling average precipitation from 1921 through 2021, and Fall River mean annual discharge measured at USGS gage 14057500 (1939 through 2021 water year). Also included are averages of a small number of field measurements made by the Oregon State Engineer's office from 1922 through 1926 and 1934.

The short-term precipitation pattern is also reflected in the hydrograph for DESC 3016, a well located in Sisters (about 13 miles away from the crest of the Cascades). The hydrograph for DESC 3016 shows a remarkably similar trend to the discharge trend for Fall River, which originates in headwater springs located a similar distance (17 miles) from the Cascade crest. Figure 3 shows Crater Lake precipitation, Fall River discharge, and the hydrograph for DESC 3016.

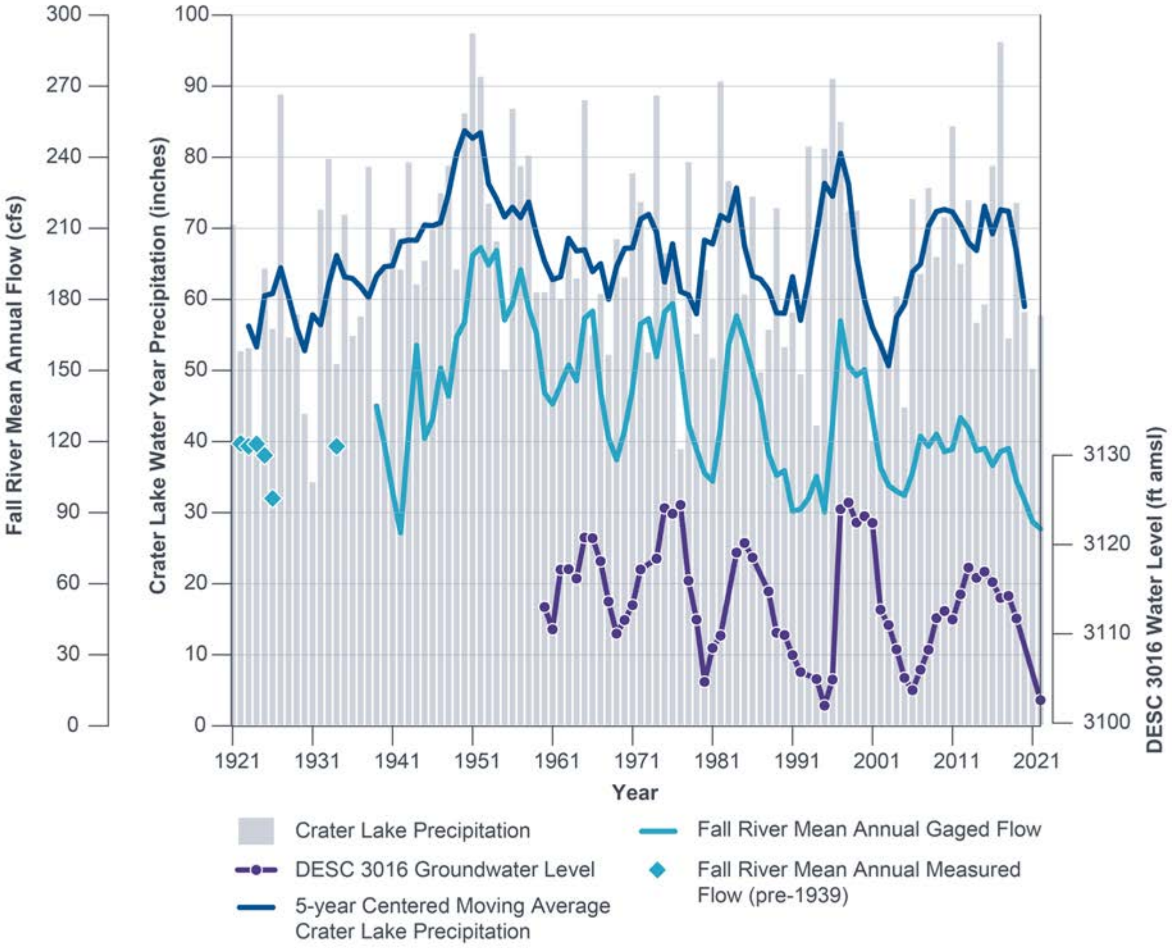

Figure 3. Annual water year precipitation at Crater Lake National Park, Oregon, 5-year rolling average precipitation from 1921 through 2021, Fall River mean annual discharge measured at USGS gage 14057500 (1939–2021 water year), and DESC 3016 groundwater levels (1960 through 2021).

The long-term precipitation trend is reflected in the hydrograph trend for a well (DESC 3903) near Redmond (located approximately 30 miles from the Cascade crest). DESC 3903 shows a delayed and muted response to relatively large recharge events in the Cascade Range. Figure 4 shows the hydrograph for DESC 3903 along with Crater Lake precipitation and Fall River discharge.

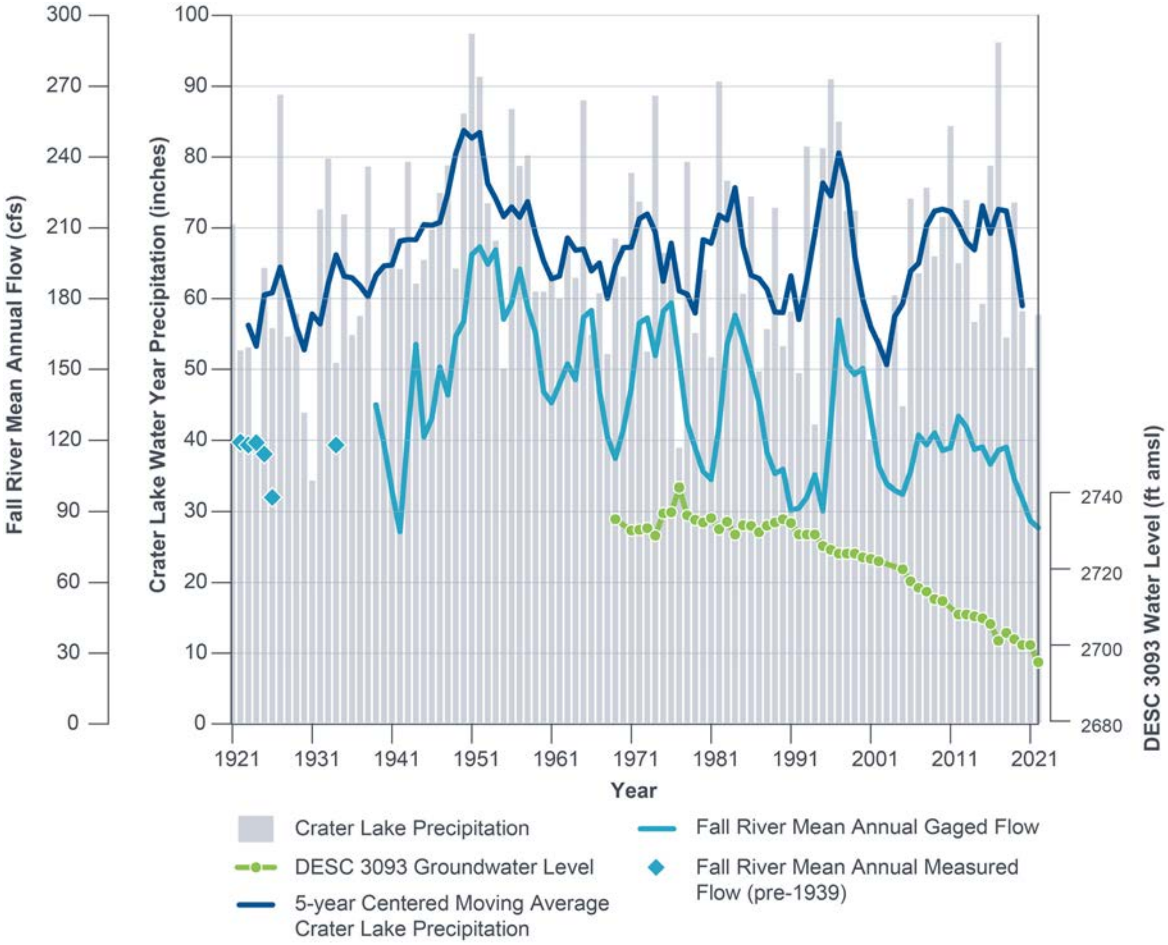

Figure 4. Annual water year precipitation at Crater Lake National Park, Oregon, 5-year rolling average precipitation from 1921 through 2021, Fall River mean annual discharge measured at USGS gage 14057500 (1939–2021 water year), and DESC 3093 groundwater levels (1969 through 2021).

The long-term precipitation trend is also reflected in water-level data from a well (LAKE 113) just east of the Deschutes basin, in the northwest quadrant of the Fort Rock basin, located approximately 52 miles from the crest of the Cascade Range. This well provides a much longer period of record than DESC 3093 for evaluating the response of the aquifer to precipitation. The hydrograph for LAKE 113, shown in Figure 5, illustrates the impacts of low precipitation during the 1930s, followed by higher precipitation amounts in the late 1940s and 1950s. The amount of annual precipitation (recharge) is important in determining how far the pressure response in the groundwater flow system travels away from the principle recharge area in the Cascade Range. As shown in the hydrograph for LAKE 113, the long-term decline in water levels is interspersed with short-term increases during multi-year periods of high precipitation (e.g., water levels increased from 1996 through 1999). However, the prevailing declining trend from the 1970s through the present is reflective of the declining precipitation trend during the same period.

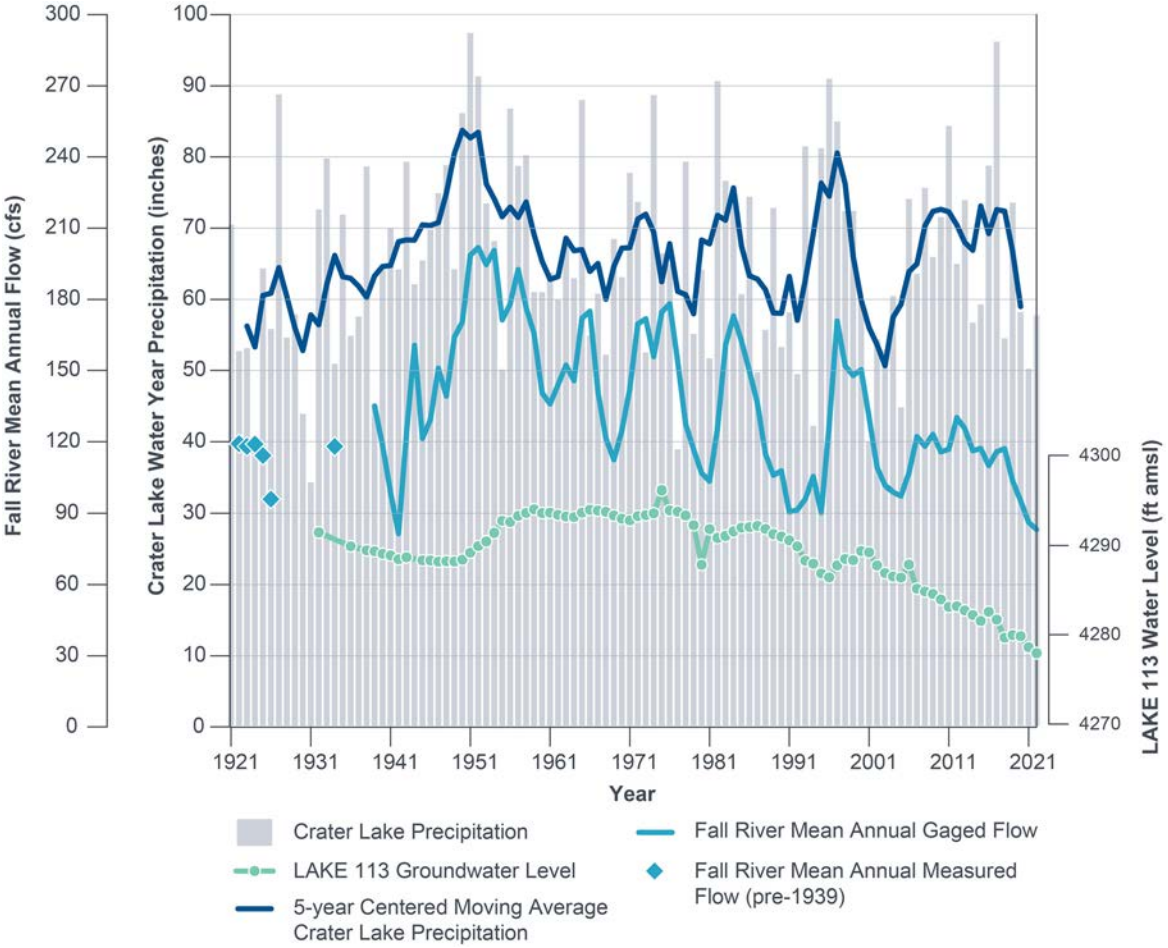

Figure 5. Annual water year precipitation at Crater Lake National Park, Oregon, 5-year rolling average precipitation from 1921 through 2021, Fall River mean annual discharge measured at USGS gage 14057500 (1939–2021 water year), and LAKE 113 groundwater levels (1932 through 2021).

As described by Gannett and Lite (2013), and illustrated in the preceding figures, distance from the principal recharge areas is the main influence on groundwater response to cyclic variability in recharge. Figure 6 reproduces hydrographs from Gannett and Lite (2013), further demonstrating this relationship in the Deschutes basin.[2]

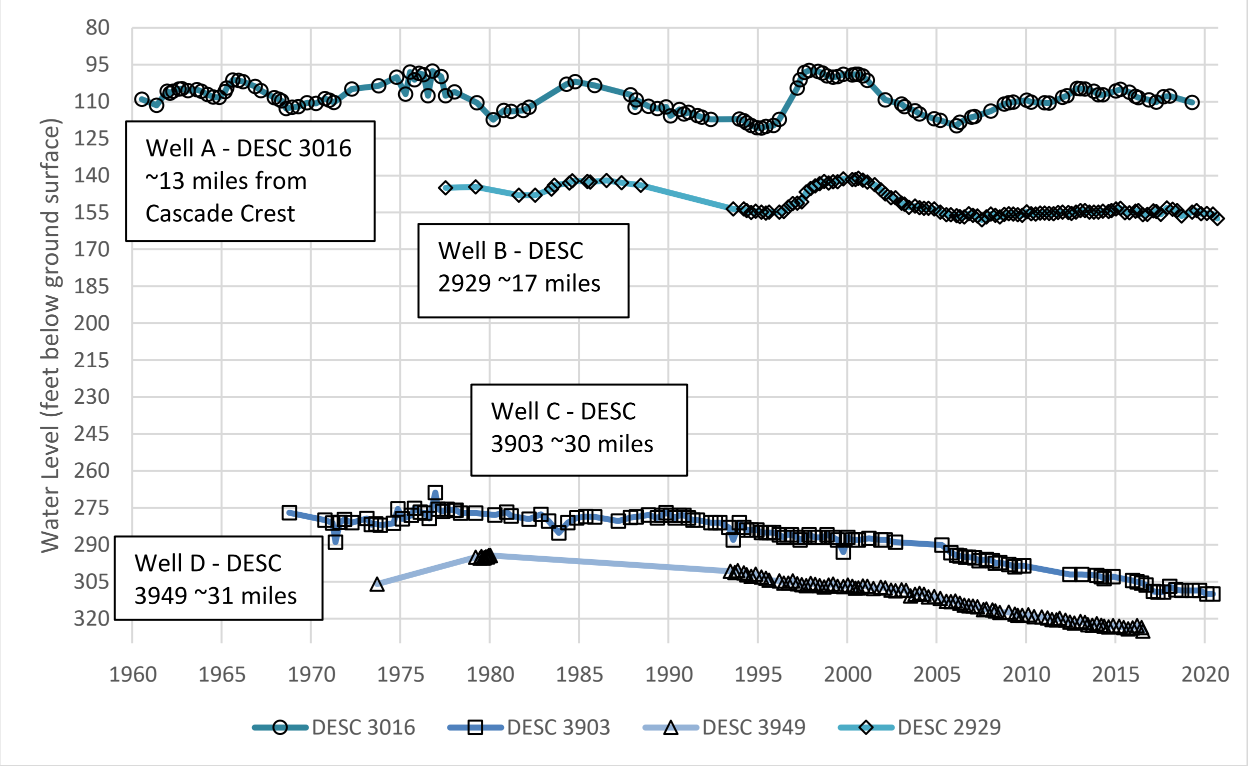

Figure 6. Water level trends from observation wells selected by Gannett and Lite (2013) contrasting water level trends in wells nearer to the Cascade crest (Wells A and B) with water level trends in wells further from the Cascade crest (Wells C and D).

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[2] Also see Figures 5 (A), (B), and (C) in Gannett and Lite (2013).

Recharge Rate, Canal Leakage, and Groundwater Use

Gannett et al. (2017) estimated a total recharge rate of 4,436 cfs for the Upper Deschutes Basin based on data from 1980 through 2013. Of this amount, 3,031 cfs is estimated to come from direct in-basin precipitation, 994 cfs from interbasin flow (mostly into the Metolius subbasin), and 411 cfs from canal leakage. Interbasin flow is mostly recharge from precipitation derived from outside the geographic boundary of the basin, as discussed in Gannett and Lite (2004). Based on the canal losses reported in Gannett et al. (2017), canal leakage contributes 9 percent of recharge to the entire Deschutes aquifer. By comparison, groundwater pumping (76 cfs) was estimated to be equivalent to less than 2 percent of total annual recharge.

It is important to note that surface water diversion and groundwater pumping are generally concentrated outside of the Metolius subbasin. Gannett et al. (2001) estimated about 500 cfs was recharged directly into the Metolius subbasin. When interbasin flow (994 cfs) and recharge directly into the Metolius subbasin (500 cfs) are subtracted from the total recharge (4,436 cfs), the total recharge to the basin outside of the Metolius subbasin is about 2,942 cfs. Therefore, excluding the Metolius, the estimated contribution of canal leakage is about 14 percent of the total annual recharge and groundwater pumping would be about 2.6 percent of the total annual recharge.

Irrigation districts in the Upper Deschutes Basin have received state and federal funding commitments to pipe main canals and large sub laterals within their distribution systems. COCO supports these efforts. Canal piping will reduce leakage, improve distribution efficiency, and provide needed instream flow benefits. However, with an estimated reduction in canal leakage of approximately 200 cfs over the coming decades, canal piping will result in a reduction in recharge and have associated impacts to groundwater levels.

Aquifer Thickness and Groundwater Decline Trends

As described above, the groundwater flow system is contained within permeable deposits of the Deschutes Formation throughout much of the Upper Deschutes Basin as described in Lite and Gannett (2002). The greatest measured thickness of the Deschutes Formation is at Green Ridge, where it is approximately 3,000 feet thick (Conrey, 1985).

Hydrologic data from seepage measurements along the Deschutes and Crooked Rivers reported in Gannett et al. (2001) show the saturated thickness of the Deschutes aquifer system is approximately 1,000 feet. As discussed and diagrammatically illustrated in Gannett et al. (2001) and shown here in Figure 7, the Deschutes aquifer discharges to the Deschutes River between elevation 2,600 feet near Lower Bridge and elevation 1,600 feet near Pelton Dam, providing further support for an estimated aquifer thickness of approximately 1,000 feet.

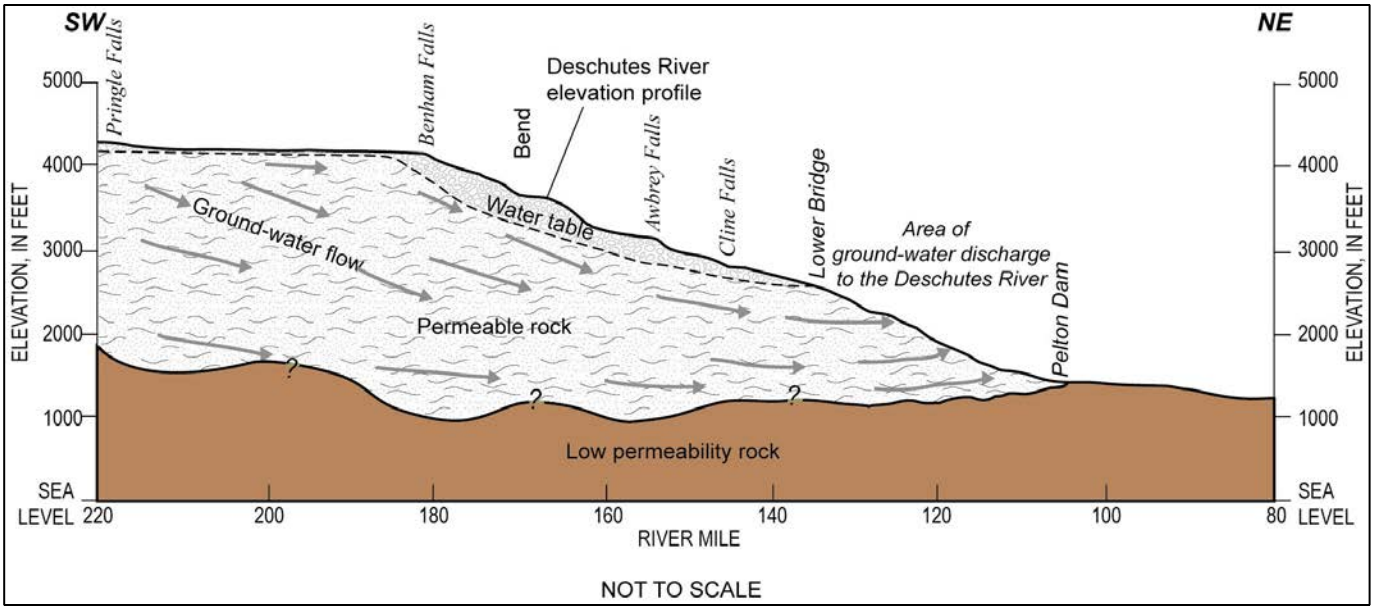

Figure 7. Diagrammatic profile along the Deschutes River showing geologic control on groundwater discharge.

Geological cross-sections depicting estimated thicknesses of the Deschutes Formation throughout the basin are also shown in Lite and Gannett (2002) and Sherrod et al. (2004). Figure 8 shows segments of two of the geological cross-sections drawn through the Redmond area. The Redmond area is in the vicinity of the “bend in section” and “Highway 97” on the Lite and Gannett (2002) and Sherrod et al. (2004) cross-sections, respectively.

Figure 8 also shows the estimated saturated thickness of the aquifer in the Redmond area. Based on the elevation of the bottom of the Deschutes Formation (the top of the John Day Formation) in Lite and Gannett (2002) and Sherrod et al. (2004) and the water-level elevation at well DESC 3903 in March 2022, the saturated thickness of the aquifer in 2022 is between about 870 and 1,219 feet thick.

Data from wells that fully penetrate the Deschutes Formation are sparse, typically occurring near the eastern and northern boundaries of the Upper Deschutes Basin. However, two relatively deep wells located at Opal Springs (JEFF 50263) and Redmond (DESC 51647) that do not fully penetrate the Deschutes Formation have chemically distinct Deschutes Formation rocks at elevations of 1,210 feet above mean sea level (amsl) and 2,212 feet amsl, respectively (see Table 2 in Lite and Gannett, 2002). Those data further support the conclusion that the Deschutes Formation is very thick in the central part of the Upper Deschutes Basin.

As discussed above, groundwater level trends vary with distance from the primary recharge area as well as proximity to discharge areas, local groundwater pumping, and local recharge sources such as irrigation canals. In areas where groundwater level declines are ongoing, it is important to understand to what extent the aquifer is being impacted regardless of the causes. For example, the hydrograph for DESC 3903 shows a mostly downward trend since 1990 (see Figure 3). The groundwater elevation in DESC 3903 was 2,729 feet amsl when measured in March 1971, as compared to 2,695 feet amsl in March 2022—a total decline of 34 feet, as shown in Figure 5.

Precipitation accounts for most of the groundwater-level decline in the vicinity of DESC 3903, but water use, and lining and piping of canals are also contributing factors. A groundwater flow model simulation for the period from 1997 to 2008 reported in Gannett and Lite (2013) calculates 20 to 25 percent of groundwater-level decline between Cline Butte and Redmond is attributed to groundwater pumping. While 5 to 10 percent of the decline was calculated for canal lining and piping during the same 1997 to 2008 time period. As much as 75 percent (an overwhelming majority) of groundwater decline was, and continues to be, caused by an extended period of lower precipitation that began in the early 1990s. Regardless, the data do not indicate that these declines would significantly impair the function or character of the resource or preclude the perpetual use of the aquifer as declines in DESC 3903 amount to less than 4 percent of the saturated thickness of the aquifer.

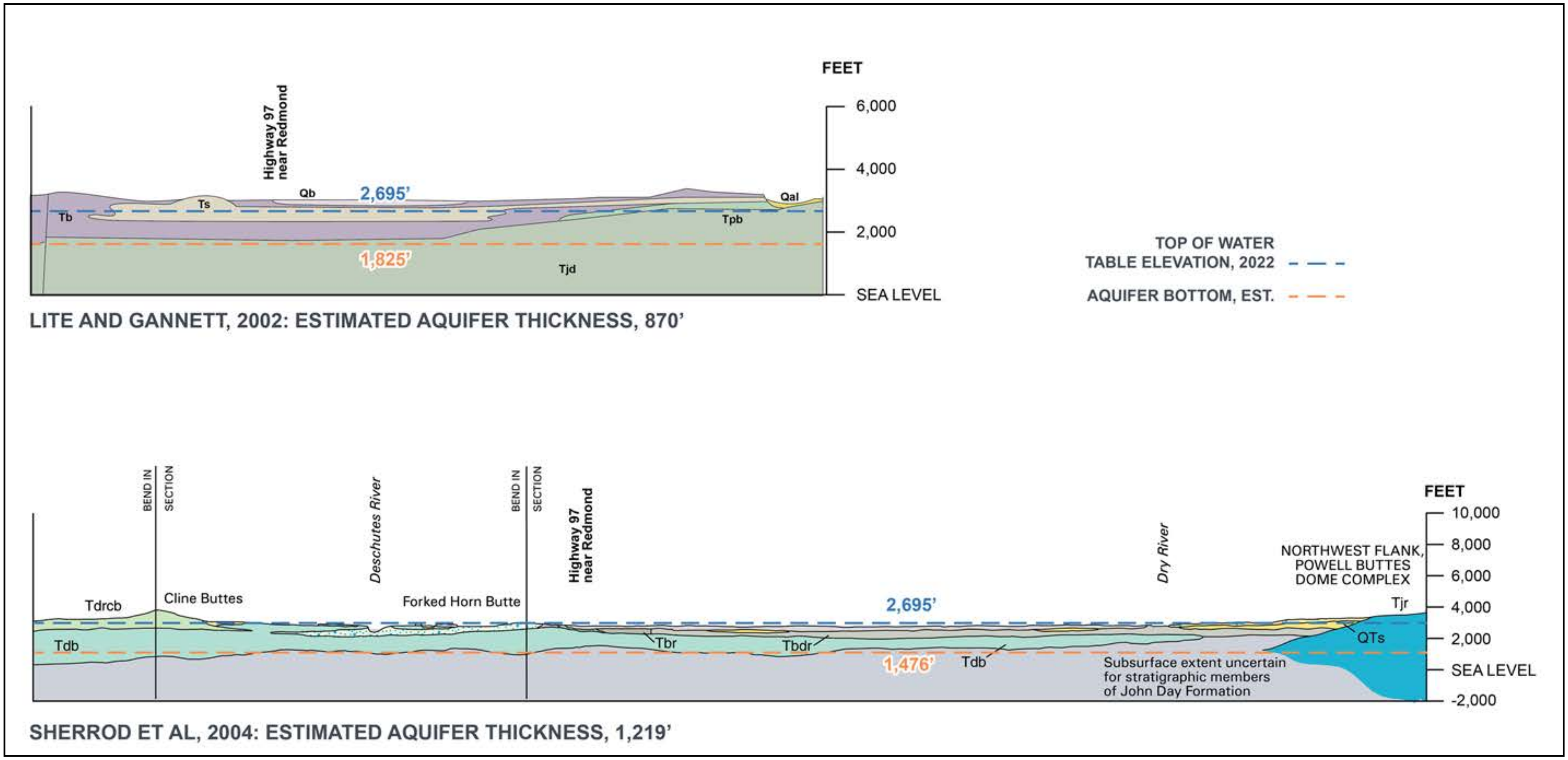

Figure 8. Geologic cross-sections of the Deschutes Formation and John Day Formation through the Redmond Area. Sections have been cropped from Lite and Gannet (2002) and Sherrod et al. (2004).

Climate Change

With the Upper Deschutes Basin experiencing a prolonged period of lower than average precipitation, it is easy to attribute the cause of long-term precipitation declines in the Cascade Range to anthropogenic climate change, leading to the assumption that things will only get worse in the coming decades. However, evidence shows that the Upper Deschutes Basin experiences cyclical droughts. Although climate models do predict warmer temperatures, the models generally do not predict that precipitation will decrease due to climate change.

The Bureau of Reclamation conducted a review of regional climate models for inclusion in hydrologic modeling for the 2019 Upper Deschutes River Basin Study (Bureau of Reclamation et al., 2018; Bureau of Reclamation et al., 2019). The Basin Study evaluated climate conditions approximately 10 to 50 years in the future. Models used in the study project that average basin-wide temperatures will increase by an estimated range of 1.4 degrees Celsius (°C) to 3.4°C. However, future annual precipitation is projected to increase by 5 percent for median projections, with a potential range from a 3 percent decrease to an 11 percent increase.

Waibel et al. (2013) simulated changes in groundwater recharge and spring discharge from a base period of 1970 through 1999 to 2010 through 2099 using an ensemble mean of eight global climate models. The climate models identified no systematic trends in annual mean precipitation averaged over the basin. In combination with groundwater models, the authors found no significant change in average recharge over the basin. The simulation projected seasonal impacts to discharge of headwater springs attributable to the changing timing and form of precipitation, but projected minimal changes in discharge from springs fed by the Deschutes aquifer in the lower Crooked River, lower Whychus Creek, and middle Deschutes River as a result of climate change.

In summary, in the Upper Deschutes Basin, climate models project that climate change will shift precipitation peaks to earlier in the year and will cause more precipitation to fall as rain and less precipitation to fall as snow. As a result, the timing of runoff and groundwater recharge is expected to change but basin-wide recharge is not expected to change significantly as a result of climate change. For the regional aquifer where the greatest groundwater declines have been observed, groundwater level responses are attenuated over many years. Consequently, whether precipitation falls as rain or snow will have minimal impact on groundwater levels in the Deschutes aquifer.

In a memo dated August 30, 2021, OWRD incorrectly stated that “observed changes in precipitation and snowpack due to climate change have already been shown to impact groundwater levels in the region,” (Thoma et al., 2021) citing Gannett and Lite (2013). However, Gannett and Lite (2013) makes no such attribution. Historical precipitation data and climate models both support the contention that climatic variability, not anthropogenic climate change, is the primary driver of recently observed groundwater declines.

Summary

COCO supports efforts to manage the groundwater resource in a way that balances beneficial groundwater uses and protection of the resource. However, recent agency decisions, and statements made by agency staff and members of the public that ignore the unique hydrogeologic framework of the Upper Deschutes Basin are concerning to COCO's member cities. When making groundwater allocation decisions for the Upper Deschutes Basin, water policy makers and technical staff should consider the information described in this paper. Taken together, the information provided here demonstrates that:

1. Groundwater level declines in the Deschutes aquifer in the Upper Deschutes Basin are driven by short-term and long-term climate variability—precipitation drives the groundwater flow system in the Upper Deschutes Basin.
2. Short-term and long-term climatic variability is different than climate change—models used in the Upper Deschutes Basin indicate that future annual precipitation is projected to increase by 5 percent for median projections, with a potential range from a 3 percent decrease to an 11 percent increase.
3. The saturated thickness of the Deschutes aquifer (approximately 1,000 feet thick) in the Upper Deschutes Basin is sufficient to ensure that even during cyclical periods of groundwater declines the aquifer has more than sufficient capacity to allow perpetual use—the groundwater flow system is very thick.
4. The Upper Deschutes Basin receives over 4,000 cfs of annual recharge. Groundwater pumping is equivalent to approximately 2 percent of the annual groundwater recharge—the groundwater flow system is not over-appropriated and OWRD should consider the total saturated thickness of the aquifer when assessing impacts.
5. Water levels in the Deschutes aquifer peaked in the 1970s and 1980s following several years of increased precipitation and recharge from irrigation canals, based on the period of record of groundwater measurements. Unfortunately, many domestic use wells constructed during this period may have only penetrated the uppermost saturated zone of the Deschutes aquifer—state officials should continue to provide resources to assist well owners, but not manage the groundwater resource based on well depths that do not sufficiently penetrate the aquifer. Wells in the Upper Deschutes Basin that are drilled into localized alluvial aquifers can be impacted by various factors; the causes of those impacts are not addressed here.

Any changes to Oregon's groundwater allocation policies related to the Upper Deschutes Basin groundwater flow system should be based on data, science, and an understanding of this basin. Policy changes need to be well-informed and based on local recharge mechanisms and on the characteristics of the subject aquifer.

COCO and its member cities look forward to working with OWRD and other stakeholders in the basin to identify a sensible pathway forward that protects the groundwater resource and ensures the security of groundwater supplies for water users in the future.

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