Groundwater Report for the Harney Basin Critical Groundwater Area Rulemaking

Draft: June 17, 2024

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2024

EXPIRES: 7/1/2025

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Introduction

Oregon Administrative Rule 690-10 (Division 10) guides the implementation of the critical groundwater area statutes, ORS 537.730 to 537.742. The Division 10 rules provide the framework for designation of a critical groundwater area where certain criteria are met and outline the requirements for the critical groundwater area rulemaking process. OAR 690-10-0130(4)(c) requires the Oregon Water Resources Department (OWRD) to prepare a draft report based on the best available science and information which includes the following three parts:

1. *Identify and characterize the groundwater reservoir subject to the proposed critical groundwater area designation.*
2. *Identify the criteria met under ORS 537.730(1)(a) – (g).*
3. *Identify the corrective control measures likely to resolve the problems that resulted in the recommendation to designate a critical groundwater area.*

This document (herein after termed "report") serves to satisfy the requirements for the draft report under OAR 690-10-0130(4)(c) for the Harney Basin and the OAR 690-512 Malheur Lake Basin Program (Division 512) rulemaking.

Technical Foundation for Report

In response to declining groundwater levels in the Harney Basin the U.S. Geological Survey and OWRD conducted a cooperative study of the groundwater resources of the Harney Basin during 2016-2022 (study). This report is largely based on the results of the groundwater study but does not attempt to summarize the complete study findings in detail. The full details of the groundwater study are provided in Gingerich and others (2022), Garcia and others (2022), and other supporting publications and data releases listed at the end of this report. A summary of the groundwater study results is also provided in U.S. Geological Survey Fact Sheet 2022-3052 (Gingerich, Garcia, and Johnson, 2022). In addition to the primary study reports, a numerical groundwater-flow model of the Harney Basin was also developed to test the conceptualization of the groundwater-flow system and simulate its response to historical pumpage, current conditions, and future groundwater-withdrawal scenarios (Gingerich and others, 2024).

Identification and Characterization of the Groundwater Reservoir

The Harney Basin, which covers about 5,240 square miles in southeastern Oregon lies mostly within Harney County, and includes smaller portions of Grant, Lake, and Crook Counties (Figure 1). The basin is a closed surface-water basin with three major perennial streams and numerous smaller, intermittent streams that drain into Malheur and Harney Lakes. Groundwater within the Harney Basin is hydraulically connected both laterally and vertically throughout the area, however, groundwater occurs in multiple hydraulically connected geologic units, often follows divergent or convergent flow paths, and varies spatially in terms of horizontal and vertical hydraulic gradient and local rates and magnitudes of recharge and discharge (Gingerich and others, 2022). Groundwater occurs within a complex groundwater flow system that can produce substantial amounts of water to wells in some areas but little water in other areas depending on the underlying rocks and sediments, and the local rate and magnitude of groundwater recharge and discharge. Groundwater flows through the basin from recharge areas where water enters the groundwater system toward discharge areas where water leaves the groundwater system.

Since the early 1990s groundwater development, primarily for irrigated agriculture, has increased substantially in the Harney Basin. Some areas of the basin have experienced groundwater level declines of more than 100 feet and some shallow wells have gone dry. The groundwater study identified that the groundwater budget in the Harney Basin lowlands is substantially out of balance – total discharge of groundwater including natural discharge (groundwater discharging to streams, springs, and native vegetation) in the lowlands exceeds recharge to the lowlands by 110,000 acre-feet per year (Figure 2). This imbalance results from groundwater pumping, primarily for irrigated agriculture, accounting for 95 percent of all groundwater use in the basin. The imbalance in the groundwater budget has led to widespread groundwater level declines, with substantial declines occurring in areas with intensive groundwater pumping, minimal recharge, and surrounded by low-permeability rocks and sediments that limit the replenishment of groundwater removed from storage by pumping. The groundwater study further identified that most groundwater pumped from lowland areas is ancient and not being replenished at meaningful human timescales. Ongoing groundwater level data collection across the Harney Basin continues to support the findings of the groundwater study – groundwater levels continue to decline year after year in many areas.

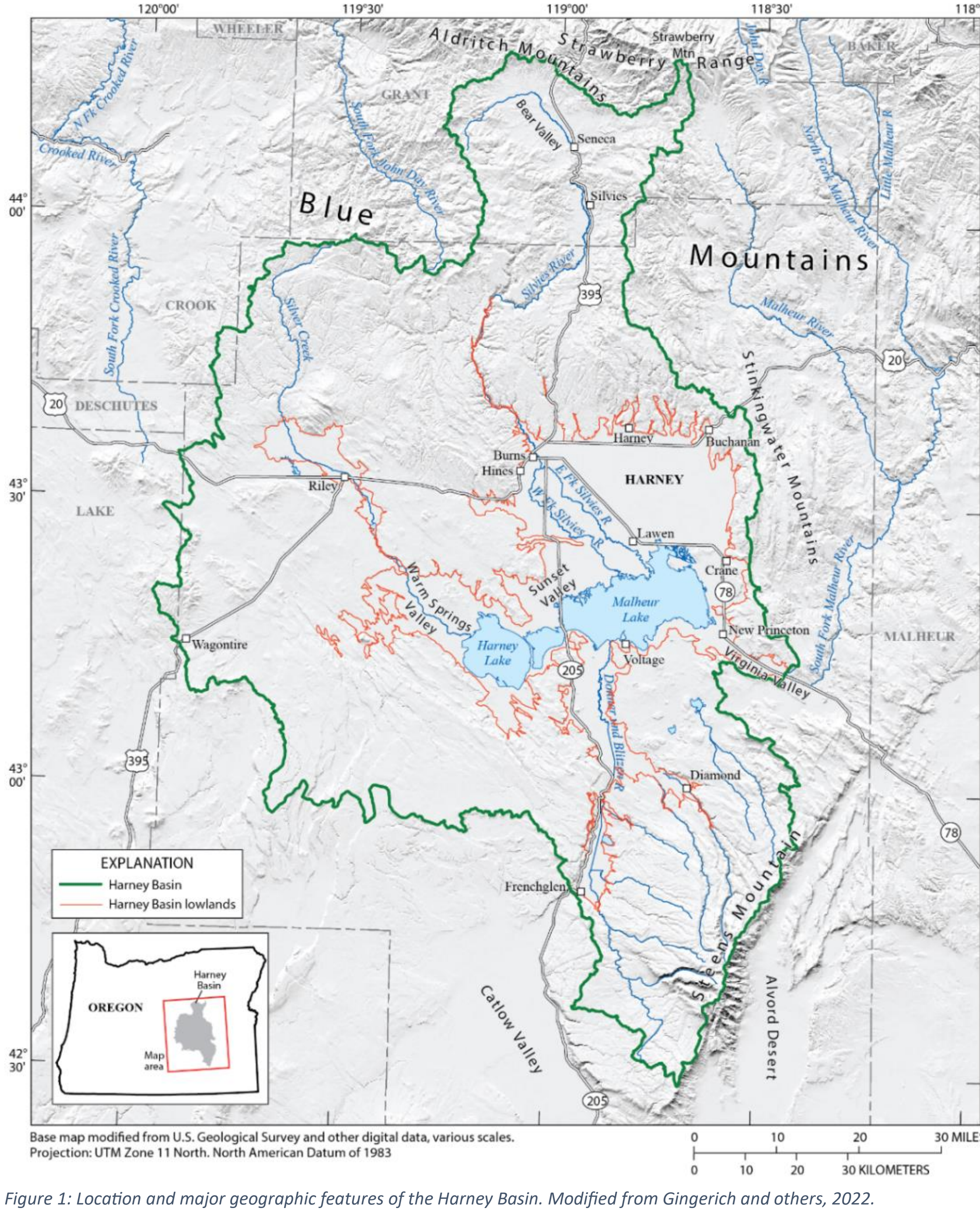

Figure 1: Location and major geographic features of the Harney Basin. Modified from Gingerich and others, 2022.

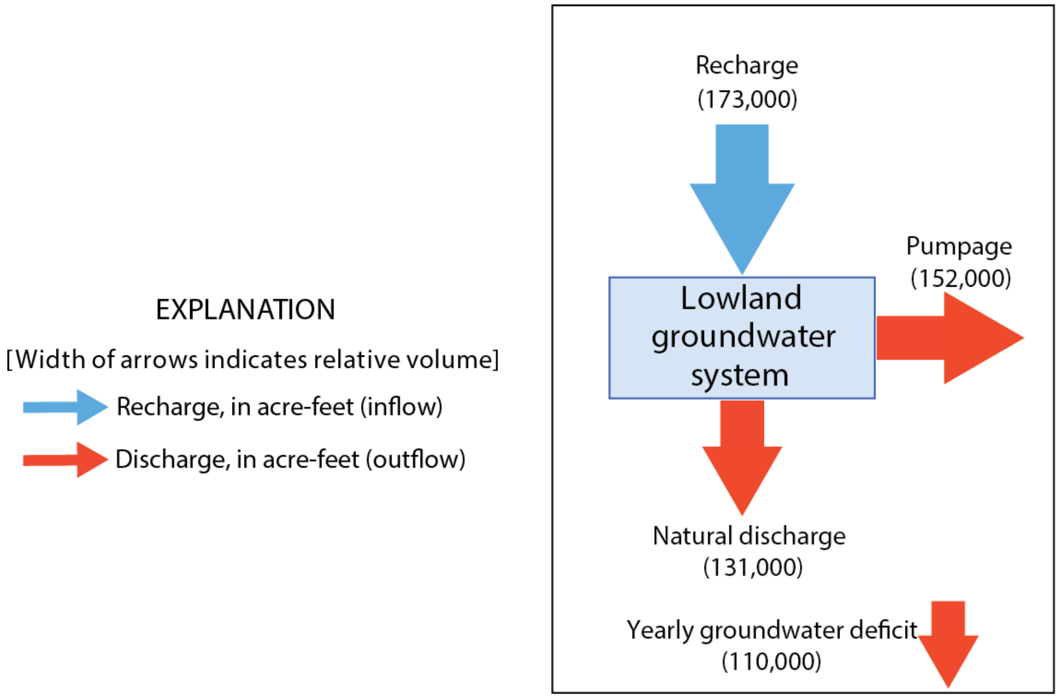

Figure 2: Mean annual lowland groundwater budget for the Harney Basin. Modified from Gingrich, Garcia and Johnson, 2022.

ORS 537.515(6) defines a groundwater reservoir as a designated body of standing or moving groundwater having exterior boundaries which may be ascertained or reasonably inferred. Groundwater in the Harney Basin occurs within a single groundwater-flow system that includes several distinct, yet hydraulically connected areas distinguished by local geology, location in the basin-wide groundwater-flow system, and local rate and magnitude of recharge and discharge (Gingerich and others, 2022; pg. 65). In the Harney Basin, the exterior boundaries of the groundwater reservoir coincide with the boundaries of the Harney Basin (Figure 1), encompassing the entire groundwater-flow system from the recharge areas, through groundwater flow along various flow paths, to the discharge areas.

Identification of the Criteria met under ORS 537.730(1)(a) – (g)

OAR 690-010-0120 (Required Criteria for Designation of Critical Groundwater Area) states that the Commission may adopt rules to designate an area of the state a critical groundwater area if any of the requirements under ORS 537.730(1)(a)–(g) are met. The requirements under ORS 537.730(1)(a)–(g) are as follows:

> *ORS 537.730 Designation of a critical ground water area; rules; notice.*
> *(1) The Water Resources Commission by rule may designate an area of the state a critical ground water area if:*
> *(a) Groundwater levels in the area in question are declining or have declined excessively;*
> *(b) The Water Resources Department finds a pattern of substantial interference between wells within the area in question;*
> *(c) The department finds a pattern of interference or potential interference between wells of groundwater claimants or appropriators within the area in question with the production of geothermal resources from an area regulated under ORS chapter 522;*

(d) The department finds a pattern of substantial interference between wells within the area in question and:
(A) An appropriator of surface water whose water right has an earlier priority date; or
(B) A restriction imposed on surface water appropriation or a minimum perennial streamflow that has an effective date earlier than the priority date of the groundwater appropriation
(e) The available groundwater supply in the area in question is being or is about to be overdrawn;
(f) The purity of the groundwater in the area in question has been or reasonably may be expected to become polluted to an extent contrary to the public welfare, health and safety; or
(g) Groundwater temperatures in the area in question are expected to be, are being or have been substantially altered except as specified in ORS 537.796.

In the Harney Basin the following requirements from ORS 537.730(1)(a)-(g) have been met:

1. 537.730(1)(a): Groundwater levels are declining or have declined excessively.
2. 537.730(1)(e): The available groundwater supply is being or is about to be overdrawn.

537.730(1)(a): Groundwater Levels have Declined Excessively

Groundwater levels in several areas of the Harney Basin have Declined Excessively as defined in OAR 690-008-0001(4)(d):

OAR 690-008-0001
(4) "Declined Excessively" means any cumulative lowering of the water levels in a ground water reservoir or a part thereof which:
(d) Constitutes a lowering of the annual high water level within a ground water reservoir, or part thereof, greater than 50 feet below the highest known water level;

The map in Figure 3 shows the individual wells with available groundwater level data that meet the definition of Declined Excessively as per OAR 690-008-0001(4)(d) as of April 2, 2024. These wells are also listed in Table 1. Note that there are additional wells with available groundwater level data that are expected to meet the definition of Declined Excessively within the next few years given the current rate of year-to-year groundwater level decline at those wells.Figure 3 The groundwater level contours shown in Figure 3 depict focused areas where substantial groundwater level declines have occurred, and it is likely that additional wells within these areas that do not have groundwater level data available would also meet the definition of Declined Excessively. The evaluation for Declined Excessively is further limited by the lack of historical groundwater level measurements to establish the highest known water level for many wells.

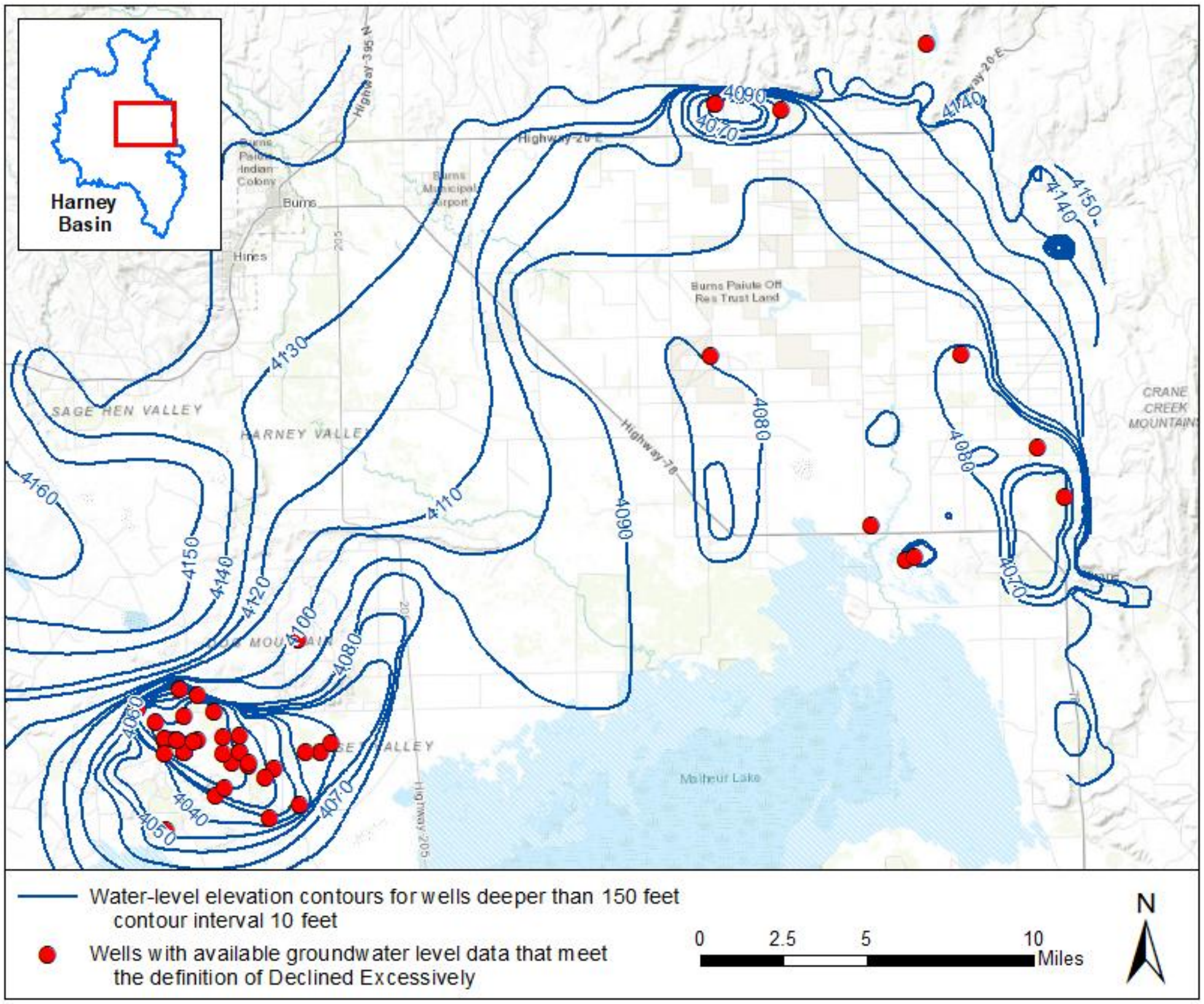

Figure 3: Wells with available groundwater level data that meet the definition of Declined Excessively as per OAR 690-008-0001(4)(d) as of April 2, 2024; Groundwater level elevation contours for wells deeper than 150 feet.

*Table 1: List of wells with available groundwater level data that meet the definition of Declined Excessively as per OAR 690-008-0001(4)(d) as of April 2, 2024.*Wells located in Grant County not shown on Figure 3. Click each well log ID in the table to view hydrograph.*

HARN0001028	HARN0001990	HARN0051233	HARN0051760	HARN0052003
HARN0001061	HARN0050179	HARN0051259	HARN0051765	HARN0052028
HARN0001094	HARN0050315	HARN0051272	HARN0051783	HARN0052064
HARN0001096	HARN0050362	HARN0051445	HARN0051791	HARN0052121
HARN0001097	HARN0050422	HARN0051448	HARN0051825	HARN0052170
HARN0001098	HARN0050516	HARN0051507	HARN0051836	HARN0052834
HARN0001318	HARN0050741	HARN0051586	HARN0051847	GRAN0051009*
HARN0001322	HARN0050766	HARN0051693	HARN0051871	GRAN0051271*
HARN0001323	HARN0050887	HARN0051694	HARN0051904	
HARN0001335	HARN0051146	HARN0051701	HARN0051970	

537.730(1)(a): Groundwater Levels are Excessively Declining

Groundwater levels in several areas of the Harney Basin are Excessively Declining as defined in OAR 690-008-0001(6)(b):

> *OAR 690-008-0001*
> *(6) "Excessively Declining Water Levels" (Note: "Excessively" as used in ORS 537.730(1)(a) is taken to modify both "are declining" and "have declined") means any ongoing lowering of the water level in a ground water reservoir or part thereof which:*
> *(b) Represents an average downward trend of three or more feet per year for at least 10 years;*

The map in Figure 4 shows the individual wells with available groundwater level data that meet the definition of Excessively Declining as per OAR 690-008-0001(6)(b) as of April 2, 2024. These wells are also listed in Table 2. Note that there are additional wells that are expected to meet the definition of Excessively Declining within several years given the current rate of year-to-year groundwater level decline at those wells.Figure 4 The groundwater level contours shown in Figure 4 depict focused areas where substantial groundwater level declines have occurred, and it is likely that additional wells within these areas that do not have groundwater level data available would also meet the definition of Excessively Declining.

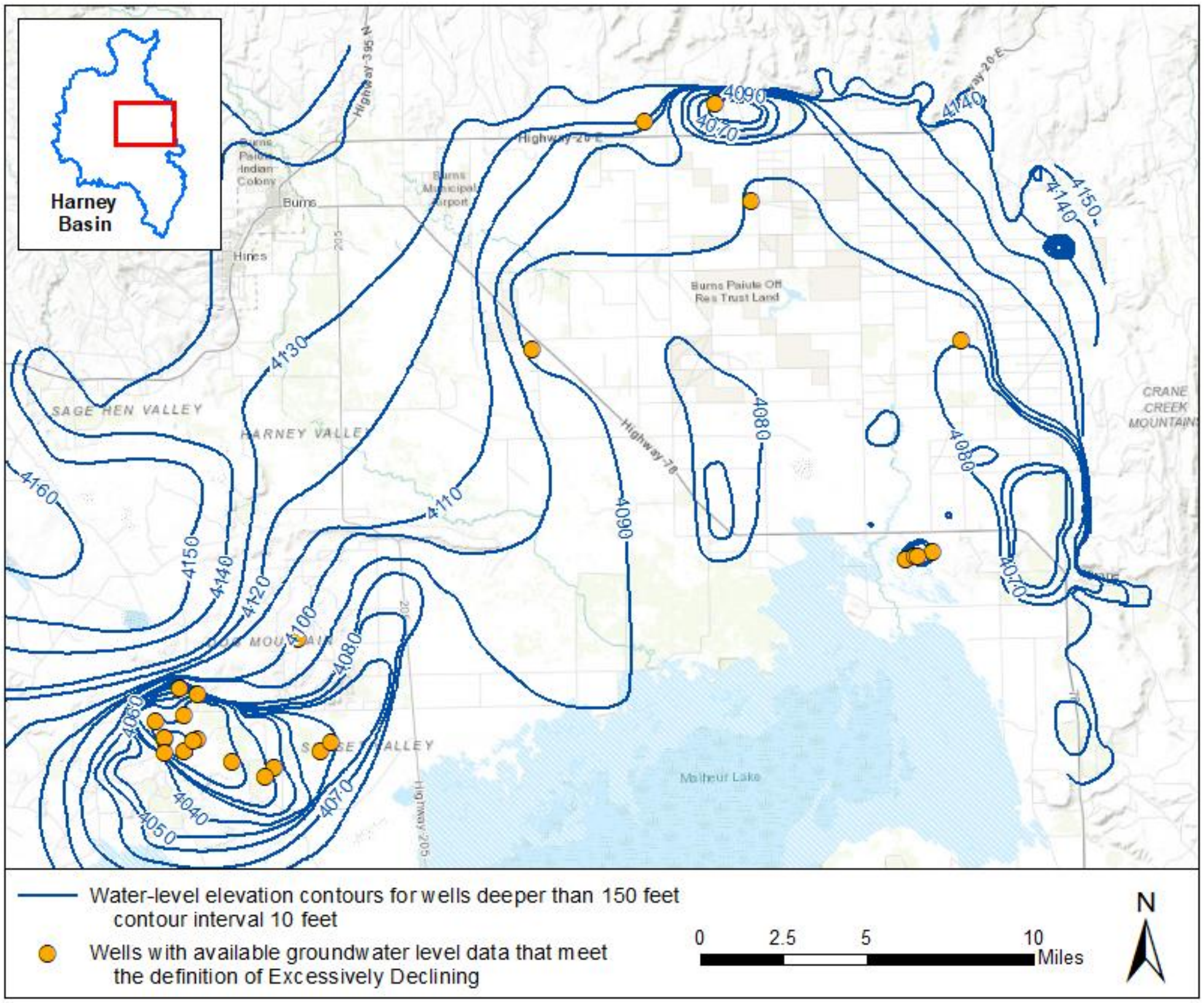

Figure 4: Wells with available groundwater level data that meet the definition of Excessively Declining as per OAR 690-008-0001(6)(b) as of April 2, 2024; Groundwater level elevation contours for wells deeper than 150 feet.

Table 2: List of wells with available groundwater level data that meet the definition of Excessively Declining as per OAR 690-008-0001(6)(b) as of April 2, 2024. Click each well log ID in the table to view hydrograph.

HARN0000901	HARN0050362	HARN0051272	HARN0051586	HARN0051701
HARN0001094	HARN0050516	HARN0051353	HARN0051587	HARN0051765
HARN0001096	HARN0051146	HARN0051445	HARN0051637	HARN0051783
HARN0001990	HARN0051233	HARN0051448	HARN0051693	HARN0051904
HARN0050315	HARN0051259	HARN0051585	HARN0051694	HARN0052050

537.730(1)(e): The available groundwater supply is being or is about to be overdrawn

The results of the Harney Basin groundwater study groundwater budget (Garcia and others, 2022) demonstrate that portions of the Harney Basin are already, or are about to be Overdrawn as per the definition in OAR 690-008-0001(7)(a):

> *690-008-0001*
> *(7) "Overdraw" means to artificially produce water, in any one-year period, from a ground water reservoir, or part thereof, at an annual rate that:*
> *(a) Exceeds the average annual recharge to that ground water supply over the period of record;*

The definition of Overdraw from OAR 690-008-0001 does not consider the natural discharge component of the water budget (groundwater discharging to streams, springs, and native vegetation). Consequently, if a groundwater reservoir is found to be in a condition meeting this definition then eventually the groundwater discharging naturally to streams, springs, and native vegetation will be captured by groundwater pumping.

For the purposes of discussion and analysis of the groundwater budget, Garcia and others (2022) divided the Harney Basin into three regions (northern, southern, and western), each dominated by one of the three major streams and including tributary and similar watersheds (Figure 5). In the lowlands, regions are based on presumed groundwater-flow paths during 2018 hydrologic conditions. Garcia and others (2022) acknowledge that pumping-induced changes in hydrologic conditions could cause changes in the region boundaries in the lowlands as groundwater is hydraulically connected across these boundaries, but they were considered steady for the purposes of water-budget accounting (Garcia and others, 2022). Separate groundwater budgets were also developed for upland and lowland areas (Figure 1; Figure 5) to avoid double counting water that recharges in the uplands, discharges to streams and springs in the uplands, and then flows downstream to the lowlands providing recharge to the lowland part of the groundwater system.

In the northern water budget region (Figure 5) the 2017-2018 mean groundwater pumpage exceeds average annual recharge for the northern water budget region lowlands by 2,700 acre-feet (Table 3; Table 4) which meets the definition for Overdrawn as per OAR 690-008-0001(7)(a). The 2017-2018 mean groundwater pumpage in the northern water budget region represents about 103% of the average annual recharge for the northern water budget region lowlands. Additionally, the 2017-2018 mean groundwater pumpage in the northern water budget region represents approximately 46% of the total authorized groundwater rights in that area. The total volume of groundwater pumpage authorized for irrigation use annually within the northern water budget region is more than two times the mean annual recharge in that region (Table 5). Further development of the groundwater rights authorized in the northern water budget region will further overdraw this part of the groundwater reservoir.

In the western water budget region (Figure 5) the 2017-2018 mean groundwater pumpage is just 4,500 acre-feet less than average annual recharge for the western water budget region lowlands (Table 3; Table 4). The 2017-2018 mean groundwater pumpage in the western water budget region represents about 90% of the average annual recharge for the western water budget region lowlands. Additionally, the 2017-2018 mean groundwater pumpage in the western water budget region represents approximately 65% of the total authorized groundwater rights in that area. The total volume of groundwater authorized for irrigation use annually within the western water budget region is 1.4 times the mean annual recharge in that region (Table 5). Further development of the groundwater rights authorized in the western water budget region can exceed the threshold for Overdrawn in this part of the groundwater reservoir.

Table 3: Total estimated annual groundwater pumpage by region in the Harney Basin for select years 1991-2018 and the 2017-2018 mean. Regions are shown on Figure 5. Groundwater pumpage is rounded to the nearest 100 acre-feet. All but 0.1 percent of pumpage occurs either within the lowland boundary or within 2 miles of the lowland boundary. From Garcia and others, 2022.

Year	Groundwater pumpage (acre-feet)			
	Northern region	Southern region	Western region	Total
1991	31,900	7,100	11,900	50,900
1992	33,500	8,800	14,100	56,400
1994	39,700	9,400	15,000	64,100
2000	51,000	8,400	23,900	83,300
2001	47,200	9,600	24,200	81,000
2005	40,700	8,500	20,100	69,300
2009	53,200	11,600	24,700	89,500
2011	53,600	12,500	24,100	90,200
2014	73,800	19,800	40,600	134,200
2015	64,700	17,600	37,100	119,400
2016	79,200	20,500	40,800	140,500
2017	84,900	21,500	43,900	150,300
2018	76,500	21,700	41,000	139,200
2017–18 mean	80,700	21,600	42,500	144,800

Table 4: Estimated mean annual groundwater recharge by region, 1982-2016 (From Garcia and others, 2022 (Table 23)). Regions and lowland boundary are shown on Figure 5. [1]Includes a portion of upland runoff and base flow. [2]Difference between estimates from Garcia and others (2022) tables 20 and 22. In the southern region, recharge from streams and floodwater is mostly accounted for in irrigated areas, and channel losses are assumed to be equally offset by base-flow gains between Frenchglen and Diamond Ln.[3]Estimate is basin wide, but 99.9 percent occurs either within the lowland boundary or within two miles outside of the lowland boundary.

Geographic position	Recharge source water	Mean annual recharge by region (acre-feet)			
		Northern	Southern	Western	Harney Basin
Upland	Precipitation and snowmelt	86,000	157,000	45,000	288,000
Lowland	Groundwater inflow from uplands	9,000	20,000	20,000	49,000
	Streams and floodwater (natural) [1,2]	40,000	900	18,000	59,000
	Malheur and Harney Lakes[1]	47	—	160	210
	Surface water (irrigation) [1]	24,000	26,000	7,300	57,000
	Groundwater irrigation and non-irrigation use[3]	4,800	1,200	2,200	8,200
	Total without pumpage	73,000	47,000	45,000	165,000
	Total	78,000	48,000	47,000	173,000

Table 5: Mean annual recharge, mean annual groundwater pumpage, and authorized irrigation use by water budget region. Regions and lowland boundary are shown on Figure 5.

Water Budget Region	Mean annual lowland recharge (acre-feet)*	2017-2018 mean groundwater pumpage (acre-feet)**	Difference between lowland recharge and 2017-18 mean pumpage (acre-feet)	Authorized use (acre-ft/yr)***	Difference between lowland recharge and authorized use (acre-feet/yr)
Northern region	78,000	80,700	-2,700	174,454	-96,454
Southern region	48,000	21,600	26,400	37,443	10,557
Western region	47,000	42,500	4,500	65,204	-18,204
Harney Basin	173,000	144,800	28,200	277,101	-104,101

*Estimated mean annual lowland groundwater recharge by region 1982-2016. From Garcia and others, 2022.

**From Garcia and others, 2022.

***Authorized primary and supplemental irrigation use assuming 3 acre-feet per acre duty.
Does not include municipal, commercial, and other authorized non-irrigation uses.
Does not include exempt uses.
Authorized acres calculated from mapped places of use April 5, 2024.

Summary of Criteria Met under ORS 537.730(1)(a) – (g)

The results of the 6-year collaborative groundwater study with the USGS along with ongoing groundwater level data collection demonstrate that the groundwater reservoir in the Harney Basin or parts thereof meet the criteria for designating a critical groundwater area. OWRD has substantial evidence of groundwater levels that have Declined Excessively or are Excessively Declining (537.730(1)(a)). In two out of the three water budget regions the available groundwater supply is being or is about to be overdrawn (537.730(1)(e)).

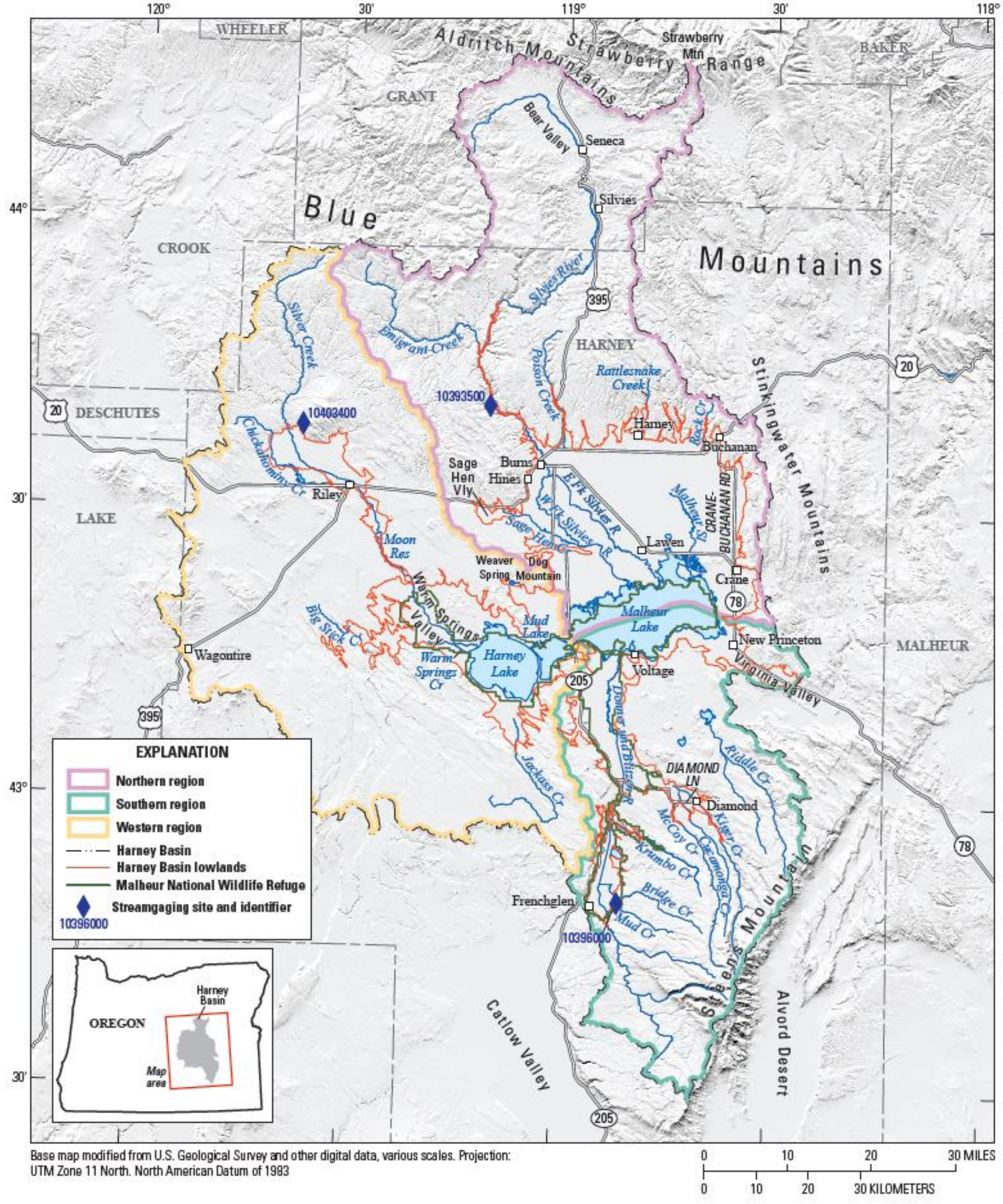

Figure 5: Location of the Harney Basin showing Harney Basin lowlands and northern, southern, and western water budget regions. From Garcia and others, 2022.

Identification of Corrective Control Measures

When designating a critical groundwater area, OWRD may identify corrective control measures to address the reason for the designation. As explained above, the groundwater level declines are attributed to groundwater pumping that exceeds groundwater recharge. Therefore, stabilizing excessive groundwater level declines across the basin will require reductions in the total volume of groundwater pumped from the groundwater reservoir each year.

OAR 690-010-0160(2) specifies the corrective control provisions under ORS 537.735(3)(a) that may be included in a critical groundwater area rule that may be applied to the entire critical groundwater area or to designated subareas of the critical groundwater area:

> *690-010-0160*
> *(2) A critical groundwater area rule may include any one or more of the corrective control provisions under ORS 537.735(3)(a)–(f) that may be applied to the entire critical groundwater area or to designated subareas of the critical groundwater area. These corrective control provisions include:*
> *(a) A provision closing the critical groundwater area to any further appropriation of groundwater, in which event the commission shall thereafter refuse to accept any application for a permit to appropriate groundwater located within such critical area;*
> *(b) A provision determining the permissible total withdrawal of groundwater in the critical area each day, month or year;*
> *(c) The disposition of any application for a water right permit for the use of water in the area that is pending at the time the commission initiates the rulemaking process or that is received during the rulemaking process;*
> *(d) Any one or more provisions making such additional requirements as are necessary to protect the public welfare, health and safety in accordance with the intent, purposes and requirements of ORS 537.505 to 537.795 and 537.992;*
> *(e) A provision closing all or part of the critical groundwater area to further appropriation of groundwater for its thermal characteristics;*
> *(f) A provision determining the permissible change in thermal characteristics of groundwater in all or part of the critical groundwater area each day, month or year. Insofar as may be reasonably done, the Water Resources Director shall apportion the permissible total temperature impact among those appropriators whose exercise of valid rights in the critical area affect the thermal characteristics of the groundwater, in accordance with the relative dates of priority of such rights.*

The Department identifies the following corrective control provisions as likely to resolve the problems that resulted in the recommendation to designate a critical groundwater area:

1. A provision closing the critical groundwater area to any further appropriation of groundwater, in which event the commission shall thereafter refuse to accept any application for a permit to appropriate groundwater located within such critical area.
2. The disposition of any application for a water right permit for the use of water in the area that is pending at the time the commission initiates the rulemaking process or that is received during the rulemaking process.

3. A provision determining the annual permissible total withdrawal (PTW) of groundwater in the critical area or part(s) thereof.
4. Any one or more provisions making such additional requirements as are necessary to protect the public welfare, health and safety in accordance with the intent purposes and requirements of ORS 537.505-537.795 and 537.992.

Summary and Conclusion

The groundwater reservoir in the Harney Basin has been well characterized through a cooperative study of the groundwater resources of the basin by OWRD and the U.S. Geological Survey. The full details of the groundwater study are provided in Gingerich and others (2022), Garcia and others (2022), and other supporting publications and data releases listed in the references section of this report. A summary of the groundwater study results is provided in U.S. Geological Survey Fact Sheet 2022-3052 (Gingerich, Garcia, and Johnson, 2022).

In the Harney Basin, the exterior boundaries of the groundwater reservoir coincide with the boundaries of the Harney Basin (Figure 1), encompassing the entire groundwater-flow system from the recharge areas, through groundwater flow along various flow paths, to the discharge areas. Groundwater levels in several areas of the Harney Basin have Declined Excessively or are Excessively Declining (537.730(1)(a)). In two out of the three water budget regions the available groundwater supply is being or is about to be overdrawn (537.730(1)(e)).

The imbalance in the lowland groundwater budget and consequent groundwater level declines in the Harney basin are a result of groundwater pumping, primarily for irrigated agriculture. Ongoing groundwater level data collection across the Harney Basin continues to support the findings of the groundwater study – groundwater levels continue to decline year after year in many areas. Stabilizing the groundwater level declines across the basin will require reductions in the total volume of groundwater pumped from the basin each year. The criteria for designating a critical groundwater area under ORS 537.730(1)(a)–(g) have been met for the groundwater reservoir or parts thereof, and implementation of the corrective control measures under OAR 690-010-0160(2) and ORS 537.735(3) identified above will provide the regulatory framework to manage the groundwater level declines in the basin.

References

Beamer, J.P., and Hoskinson, M.D., 2021, Historical irrigation water use and groundwater pumpage estimates in the Harney Basin, Oregon, 1991–2018: Oregon Water Resources Department Open File Report 2021–02, 53 p. [Also available at https://www.oregon.gov/owrd/wrdreports/OWRD_OFR_2021-02_Harney_Basin_METRIC_Irrigation_Use_Report.pdf.]

Boschmann, D.E., 2021, Generalized geologic compilation map of the Harney Basin: Oregon Water Resources Department Open File Report 2021–01, 57 p. [Also available at https://www.oregon.gov/owrd/wrdreports/OFR_2021-01_report.pdf.]

Corson-Dosch, N.T., and Garcia, C.G., 2022, Soil-water-balance (SWB) model archive used to simulate mean annual upland recharge from infiltration of precipitation and snowmelt in Harney Basin, Oregon, 1982–2016: U.S. Geological Survey data release. [Also available at https://www.sciencebase.gov/catalog/item/5f06302a82ce21d4c3f8ae59.]

Garcia, C.A., Corson-Dosch, N.T., Beamer, J.P., Gingerich, S.B., Grondin, G.H., Overstreet, B.T., Haynes, J.V., and Hoskinson, M.D., 2022, Hydrologic budget of the Harney Basin groundwater system, Oregon: U.S. Geological Survey Scientific Investigations Report 2021–5128, 140 p. [Also available at https://pubs.usgs.gov/publication/sir20215128.]

Garcia, C.A., Haynes, J.V., Overstreet, B., and Corson-Dosch, N., 2021, Supplemental data—Hydrologic budget of the Harney Basin groundwater system, Oregon: U.S. Geological Survey data release. [Also available at https://www.sciencebase.gov/catalog/item/6092dfd7d34e791692e40fb1.]

Gingerich, S.B., Johnson, H.M., Boschmann, D.E., Grondin, G.H., and Garcia, C.A., 2021, Contour data-set of the potentiometric surfaces of shallow and deep groundwater-level altitudes in Harney Basin, Oregon, February–March 2018: U.S. Geological Survey data release. [Also available at https://doi.org/10.5066/P9ZJTZUV.]

Gingerich, S.B., Johnson, H.M., Boschmann, D.E., Grondin, G.H., and Garcia, C.A., 2022, Groundwater resources of the Harney Basin, Oregon: U.S. Geological Survey Scientific Investigations Report 2021–5103, 116 p. [Also available at https://doi.org/10.3133/sir20215103.]

Gingerich, S.B., Garcia, C.A., and Johnson, H.M., 2022, Groundwater resources of the Harney Basin, southeastern Oregon: U.S. Geological Survey Fact Sheet 2022-3052. 6p. [Also available at https://pubs.usgs.gov/fs/2022/3052/fs20223052.pdf]

Gingerich, S.B., Boschmann, D.E., Grondin, G.H., and Schibel, H.J., 2024, Groundwater model of the Harney Basin, southeastern Oregon: U.S. Geological Survey Scientific Investigations Report 2024–5017, 104 p., [Also available at https://doi.org/10.3133/sir20245017]

Grondin, G.H., 2021, Methods and results for estimating groundwater pumped, returned, and consumed for non-irrigation uses in the Harney Basin, Oregon: Oregon Water Resources Department Open File Report 2021–03, 28 p. [Also available at https://www.oregon.gov/owrd/wrdreports/OWRD_OFR_2021-003_Harney_Basin_non_irrigation_GW_use_report_stamped.pdf.]

Grondin, G.H., Boschmann, D.E., Barnett, H.J., and Scandella, B.P., 2021, Methods and results for estimating the hydraulic characteristics of the subsurface materials in the Harney Basin, Oregon: Oregon

Water Resources Department Open File Report 2021–04, 63 p. [Also available at https://www.oregon.gov/owrd/wrdreports/OFR_2021-04_Harney_Basin_subsurface_hydraulic_properties.pdf.]

Schibel, H.J., and Grondin, G.H., 2023, Methods and Results for estimating 1930-2018 well pumpage in the Harney Basin, Oregon: Oregon Water Resources Department Open File Report 2023-01, 72 p. [Also available at https://www.oregon.gov/owrd/WRDReports/OWRD_OFR_2023_01.pdf]