Technical Memorandum

Date: December 10, 2020

To: Harney Basin Water Collaborative

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Subject: Estimates of Harney Basin Groundwater Use for Irrigation

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Contents

Purpose and Scope

The Department is providing information to help the Collaborative generally understand groundwater development and use for irrigated crops in Harney Basin. This information is intended to complement the OWRD Technical Memo summarizing Harney Basin groundwater level declines (dated 12/10/2020). The information contained in this memo, in particular how groundwater use for irrigation water estimates and the estimation results, was originally compiled by the OWRD Surface Water section for the cooperative Harney Basin Groundwater Study and presented in an Open File Report (Beamer and Hoskinson, M. D., 2021) - currently in review.

This memo includes four maps that were adapted from the Open File Report. Two maps display the mapped irrigated fields by water source type (surface water irrigated, groundwater irrigated, or combination) in the Greater Harney Valley Area (GHVA) for the years 1991 (earliest year processed) and 2018 (latest year fully processed). The other two maps display the seasonal (May to September) net evapotranspiration depth, defined as crop evapotranspiration (ET) minus precipitation for the irrigated fields in the GHVA for 1991 and 2018. The units for the estimated net ET depth is in feet. The maps are accompanied by graphs showing groundwater development over time, including an annual time series of mapped irrigated acres and groundwater pumpage volume estimates, in acre-feet, for the GHVA.[1] This memo also includes a high-level discussion of methods used to generate maps and figures summarized from the Open Files Report.

This memo is an interim product to support planning efforts and discussions in the basin while the OWRD Open File and USGS Harney Basin Groundwater Study reports are undergoing peer review and should not be considered as representative of the larger body of work. The Study Reports are expected to be published in 2021 and will provide a more comprehensive understanding of the groundwater system and groundwater budget.

Background

The Harney Basin is a hydrologic area defined by and including the drainages that feed into Harney and Malheur Lakes (Silvies River, Silver Creek, Donner Und Blitzen River). In April 2016 the Water Resources Commission updated the Malheur Lake Basin Program rules to designate a Greater Harney Valley Groundwater Area of Concern within the Harney Basin. This update to the rules was in response to analysis of groundwater-level data and aquifer recharge estimates that indicated annual groundwater use and other discharge likely exceeded annual groundwater recharge in the Harney Basin. In addition to the designation of a groundwater area of concern, the Department began a multi-year groundwater basin study in cooperation with the US Geological Survey to improve understanding of the Harney Basin groundwater system and also began working with the community and other interested stakeholders to determine future management actions to achieve reasonably stable groundwater levels. The Department is working with the community and groundwater users to identify and encourage voluntary actions to reduce groundwater use while also pursuing regulatory actions in the event that voluntary actions do not succeed in achieving reasonably stable groundwater levels.

At the final meeting of the Harney Basin Groundwater Study Advisory Committee (SAC) on December 13, 2019, committee members requested information about the distribution and characteristics of groundwater decline areas within the Harney Basin, including current decline rates, total measured declines, and estimated groundwater use within those areas. Following subsequent conversations, the SAC request became a technical assistance (TA) request for the Collaborative to inform the collaborative planning efforts. This document and the accompanying map, tables, and figures describe the estimated groundwater use for irrigated agriculture. An accompanying memo describes the decline rates and overall declines (dated 12/10/20).

The information contained in this memo and supporting memos can support multiple ongoing conversations and initiatives, including, but not limited to:

- Increase basin-wide awareness and understanding of groundwater-level declines;
- Support conversations of the Collaborative to define “reasonably stable” groundwater levels consistent with Oregon statutes and rules;
- Assist with prioritization or identification of focus areas for different projects pursued by the Collaborative; and,

[1] These estimates can be compared to estimates contained in the OWRD Technical Memo on the development and relative priority dates of groundwater rights (dated 4/16/18).

- Support conversations between groundwater users interested in pursuing voluntary agreements.

The Collaborative may request additional information or analysis for areas of interest or focus areas. These areas will be determined by the Collaborative with input and feedback from the Department. At this time the Department has not delineated management areas and any discussion of an "area" is for analysis purposes only. Questions about this TA request should be directed to the Department through the Harney Basin Community-Based Water Collaborative (http://hcwatershedcouncil.com/community-based-water-planning/).

Methods

Sources of data

The primary datasets used for this analysis are remotely-sensed estimated evapotranspiration (ET), precipitation, reference ET, mapped irrigated field boundaries, water rights information, ground-based ET measurements, and groundwater pumpage data. ET is the process by which water is transferred from the land surface to the atmosphere and includes transpiration by plants and evaporation from bare soils and surface-water bodies. The primary tasks of this project were to 1) apply a remotely-sensed ET model with high resolution Landsat satellite data to generate maps of historical actual ET estimates, 2) compare the estimated ET with ET measurements and pumpage data, 3) isolate the ET signal associated with applied irrigation water by clipping monthly ET maps to mapped irrigated field polygons and summarizing total ET and net ET (total ET less precipitation) for specific growing season time periods, and 4) make basin-wide estimates for crop ET and groundwater pumpage.

Estimated field-scale crop evapotranspiration from irrigation

Monthly crop ET was estimated with a surface-energy-balance approach using the model called Mapping EvapoTranspiration at high Resolution with Internalized Calibration (METRIC) (Allen and others, 2007) combined with Landsat satellite imagery and gridded climate data. METRIC is a thermal and optical ET model developed at the University of Idaho in conjunction with the Idaho Department of Water Resources and has been extensively applied for water management in the western United States. The METRIC model has been validated and compared with ground-based ET in Oregon and surrounding states (Allen and others, 2007; Cuenca and others, 2013; Morton and others, 2013). The main advantage of using thermal and reflectance data from Landsat imagery collected at 30-m (0.22 acre) resolution every 8-16 days is the ability to account for variability in vegetation vigor and water stress in space and time at the appropriate spatial scale for irrigated field-scale analysis. In this study we applied the Python implementation of METRIC (pyMETRIC), an open-source code available on Github.

Precipitation and alfalfa reference ET (ETr) values were derived from gridMET, which is a daily 4 km gridded weather dataset produced by the University of Idaho, and is a combination of the North American Land Data Assimilation System Phase 2 (NLDAS-2) and Parameter-elevation Regressions on Independent Slopes Model (PRISM) (Abatzoglou, 2013). Precipitation from gridMET was used to estimate annual and monthly precipitation and in the formulation of net ET for agricultural areas. It was assumed that the growing season net ET from an irrigated field represents the lower bound of crop water use because it assumes all precipitation used for ET (100% effective). The ASCE Penman-Monteih reference ET from gridMET was used as input into METRIC to compute daily, monthly, and annual reference ET.

The measured ET data is from an eddy covariance (EC) station located in an irrigated alfalfa field in the basin and was used to calibrate the historical monthly and seasonal ET estimates produced by METRIC by developing a mean monthly ratio of measured ET and METRIC ET at the field containing the ET station. Field-scale monthly ET was summarized by averaging METRIC ET rasters to agricultural field boundaries based on the common land unit (CLU) polygons (USDA, 2008). CLU field boundaries were manually edited for each study year to reflect changes in agricultural land use over time. Each mapped field boundary was assigned a water source type (groundwater, surface water, or a combination) based primarily on the OWRD water rights mapped place of use (POU) dataset and water rights information system (WRIS) database. A GIS assessment was used to determine irrigation system types by field and irrigation source type. The historical user reported pumpage data from selected irrigation wells was gathered from the OWRD water use reporting system. This pumpage data was correlated with the remotely sensed ET data using simple linear regression in order to predict groundwater pumpage.

The pyMETRIC model was run for the select 13 years in the study period 1991 to 2018. Based on the ratio on mean monthly station ET and METRIC ET, monthly adjustment factors were applied to the monthly ET data which was then summarized using zonal statistics to the annual mapped irrigated field boundaries. Monthly, seasonal, and annual rasters of ETr, PPT, ETa, and net ET (ETa minus PPT) were generated for each year processed for the entire GHVA area.

Estimated groundwater pumpage for irrigation

Based on a comparison of estimated net ET volumes and reported pumpage from 25 irrigation wells the average ET-pumping ratio was 70% (pumpage = 1.4*net ET). For fields irrigated with primary groundwater, it was assumed that 100% of the crop ET was from pumped groundwater with an average efficiency of 70%. Based on literature review and limited pumpage data, for fields identified by water rights as irrigated with both groundwater and surface water, it was assumed that 50% of the crop water use (ET) was supplied by pumped GW with an average efficiency of 60%. The lower efficiency value for supplemental GW irrigation systems was assumed based on the GIS assessment which indicated that these fields irrigated with lower efficiency systems (flood and sprinkler) than the pivots systems used to irrigated primary groundwater fields. In reality, the partitioning between surface water and groundwater use for fields irrigated with both sources of water likely varies by weather and priority date. A detailed description of how field boundaries were attributed groundwater and combination irrigation source type, comparison of field scale ET with reported pumpage data, and irrigation efficiency determination can be found in the Open File Report once that is published.

By dividing the seasonal net ET volumes for all fields irrigated with pumped groundwater (primary and supplemental) with the assumed irrigation efficiency for the fields, estimates of total groundwater withdrawals for each year were made for groundwater irrigated fields in the entire GHVA:

$$Total\ GW\ Withdrawal = \frac{ET_{GW}}{0.7} + \frac{ET_{GW+SW} \times 0.5}{0.6} \quad (1)$$

Where ET_{GW} is net ET volume for fields irrigated with primary groundwater, and ET_{GW+SW} is the net ET volume for fields irrigated with primary surface water and supplemental groundwater.

Results

Agricultural fields used for this analysis were delineated by irrigation source types shown in Figure 1 for 1991 and Figure 2 for 2018. The comparison of 1991 and 2018 of ET and irrigated acreage shows the large increase in the irrigated footprint and water use between 1991 and 2018.

Total May-September net ET computed by pyMETRIC clipped to mapped irrigated fields is shown in Figure 3 for 1991 and Figure 4 for 2018. Each figure demonstrates the spatial ET variation within individual fields and different parts of the valley, with May-September net ET values averaging between 1.3 and 1.6 feet (Table 1) ranging from close to 0 feet in unirrigated areas to exceeding 2.5 feet (similar to ETr) in fully irrigated fields (max = 2.6 feet) and flood irrigated areas in the refuge (max = 3.1 feet). These figures also highlight the change in irrigated footprint between 1991 and 2018, with a noticeable increase in the groundwater irrigated fields (mostly circular center pivots).

Figure 5 shows the change in mapped irrigated acreage for years between 1991 and 2018. The acreage of groundwater irrigated fields shows an increasing trend ranging from a minimum in 1991 of 20,200 acres for primary and 10,400 acres for supplemental groundwater irrigation (30,600 acres total), to a maximum in 2018 of 57,900 acres for primary and 16,200 acres for supplemental (74,100 acres total), representing an increase of 43,500 acres irrigated with groundwater. Fields irrigated with surface water have more year to year variability due to precipitation and runoff but lack a strong increasing trend, and average around 66,000 acres. By 1991 there was very little to know surface water available in the basin. Field data on the wildlife refuge were provided by refuge staff, and the same dataset was used for each year thus the area was a constant 46,300 acres per year.

Figure 6 shows the time series of modeled seasonal net ET volume by irrigation source type for the 13 sampled years from 1991 to 2018. This figure shows the combined influence of the inter-annual change in irrigated acreage with differences in the area-weighted net ET rates in terms of an annual ET volume. As reflected in the higher degree of inter-annual variability in irrigated acreage and net ET rates, the net ET volumes for the surface water irrigated fields have the largest inter-annual variability in the group. The surface water irrigated net ET volume increases from the early 1990's (a very dry period) to early 2000's then generally remains between 60,000 to 120,000 acre-feet. For groundwater irrigated fields the trend is upward starting around 28,000 acre-feet in the 1991 to 84,000 acre-feet in 2018. This figure corresponds with data in Table 2.

Applying an average irrigation efficiency value of 70% (pumping = 1.4*netET), the mean annual pumpage rate from groundwater irrigated fields in the Harney Basin was estimated at 2.16 feet per year. For fields irrigated with both surface water and groundwater, assuming a 50-50 split between groundwater and surface water contributions to ET and a 60% average irrigation efficiency, the basin-wide average supplemental groundwater pumpage rate was estimated as 1.24 feet per year.

Figure 7 is a time series of basin-wide estimated groundwater pumpage from primary and supplemental groundwater irrigation, showing changes between 1991 and 2018. This figure, which corresponds with Table 3, indicates that between the early 1990s (1991) and current (2018) the total estimated groundwater withdrawals for irrigation for the Harney Basin increased from 51,000 AFY to 140,000 AFY, an increase of 89,000 AFY (175%). The largest rate of change appears to occur from a rapid increase in primary groundwater irrigation between the years to 2005 and 2014. The estimated pumpage stabilizes but continues to increase between 2014 and 2018. Groundwater pumpage from fields identified by water rights as irrigated with both groundwater and surface water ranges from 12,000 to 23,000 acre-feet but remains relatively flat during the time period 2000-2018.

Maps

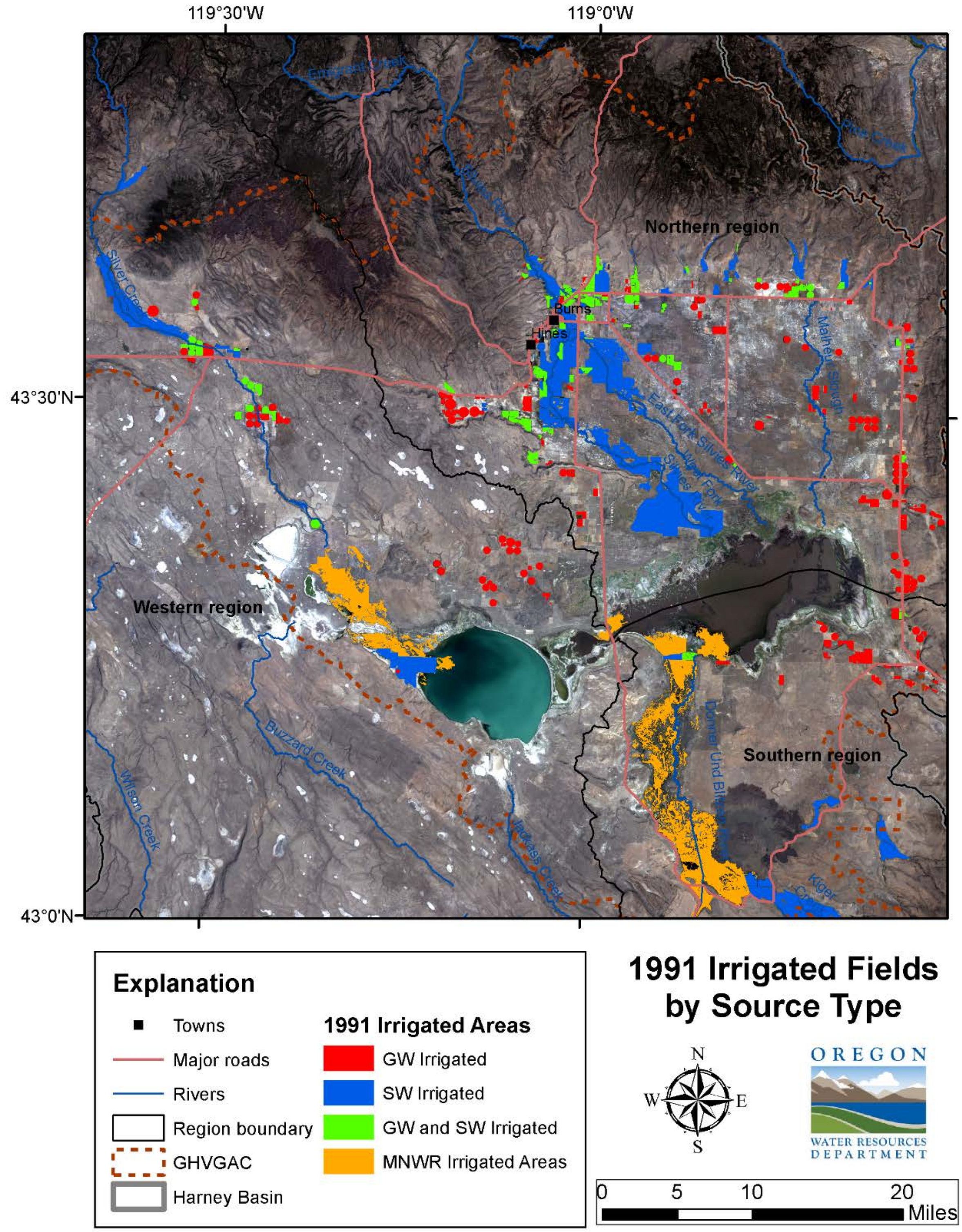

Figure 1. Irrigated fields by irrigation source type, Harney Basin, 1991. The basemap is Landsat 5 true color image from August 1991 and is also used in Figure 3.

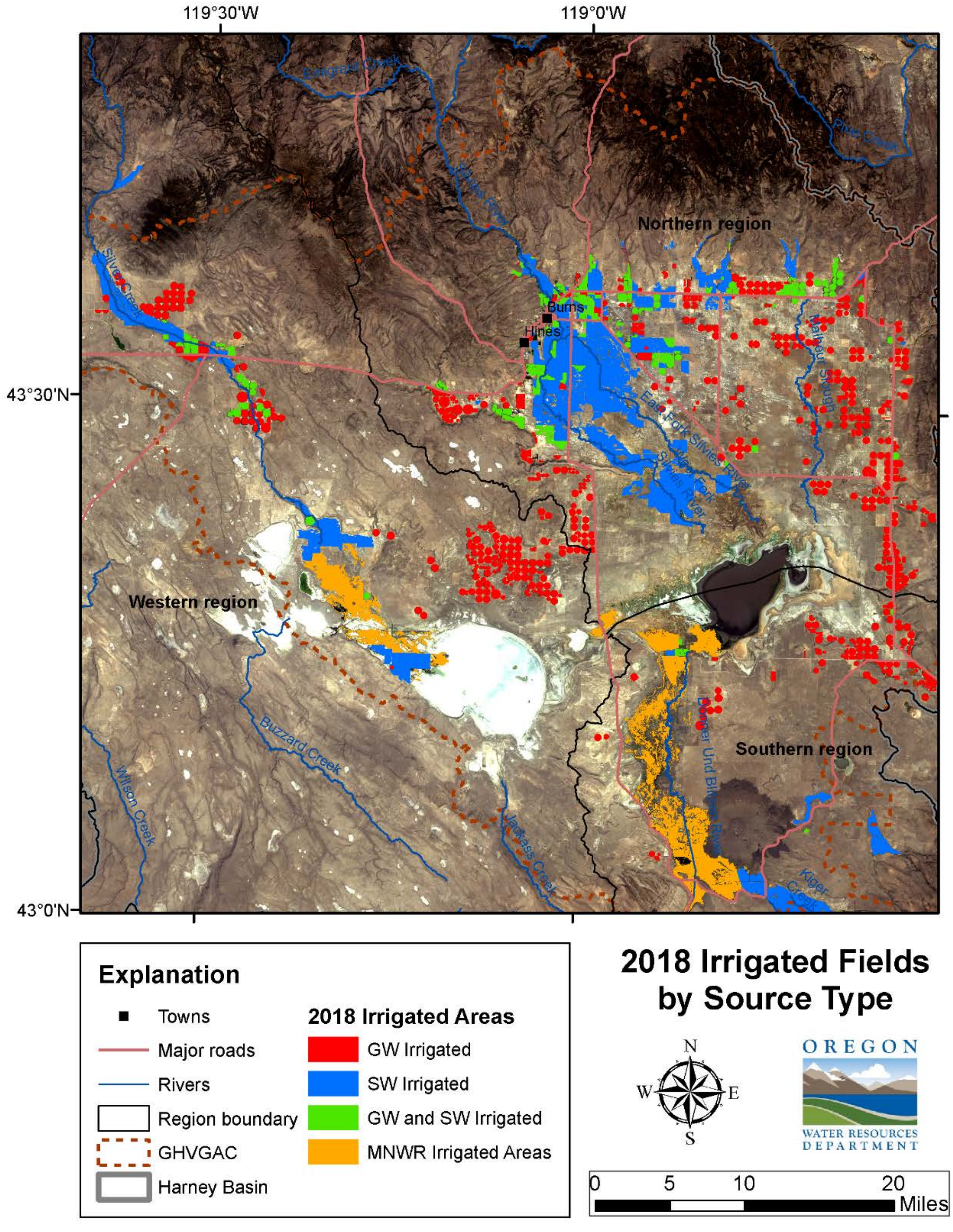

Figure 2. Irrigated fields by irrigation water source type, Harney Basin, 2018. The basemap is Landsat 8 true color image from August 2018 and is also used in Figure 4.

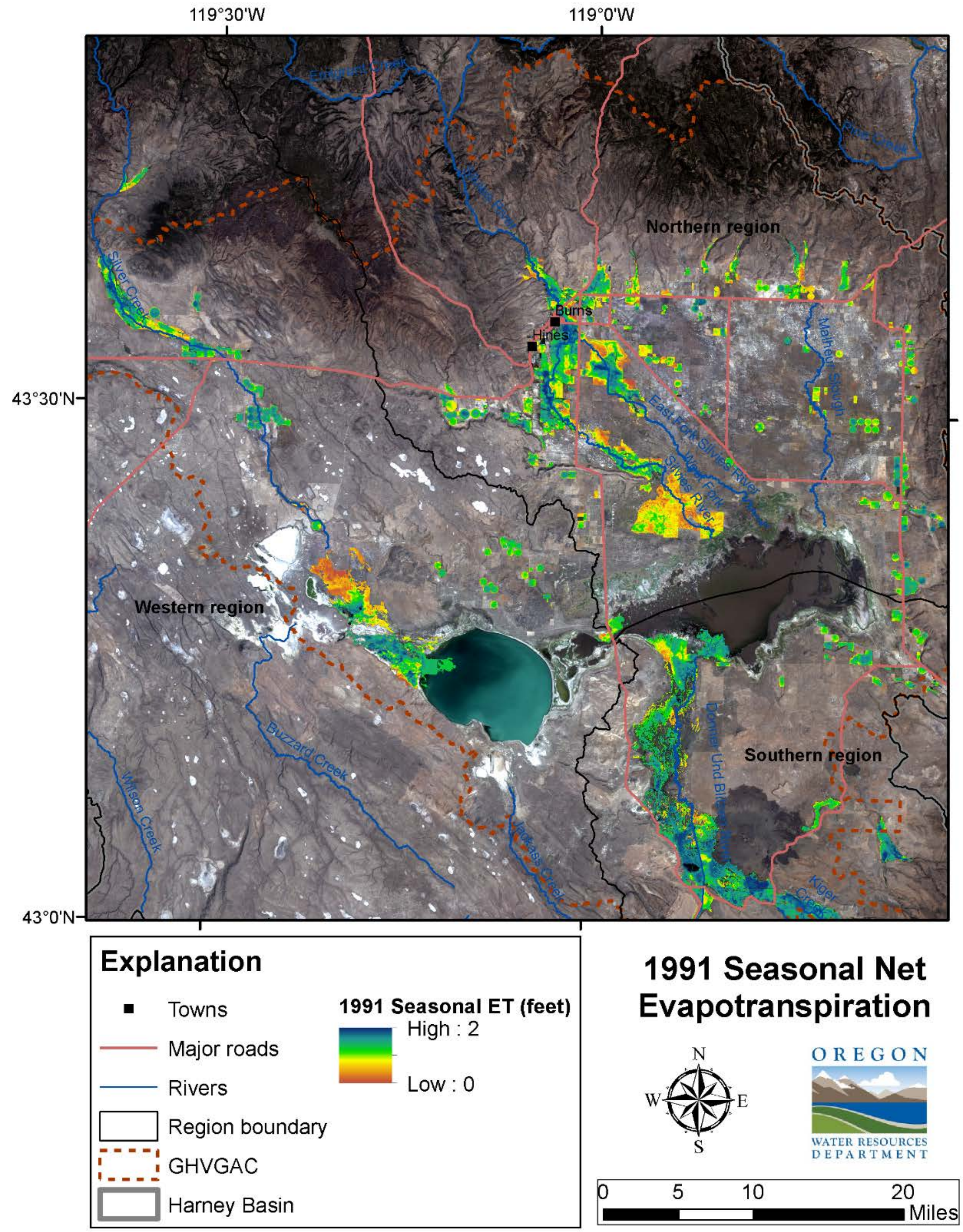

Figure 3. Net evapotranspiration for Harney Basin, May-September 1991.

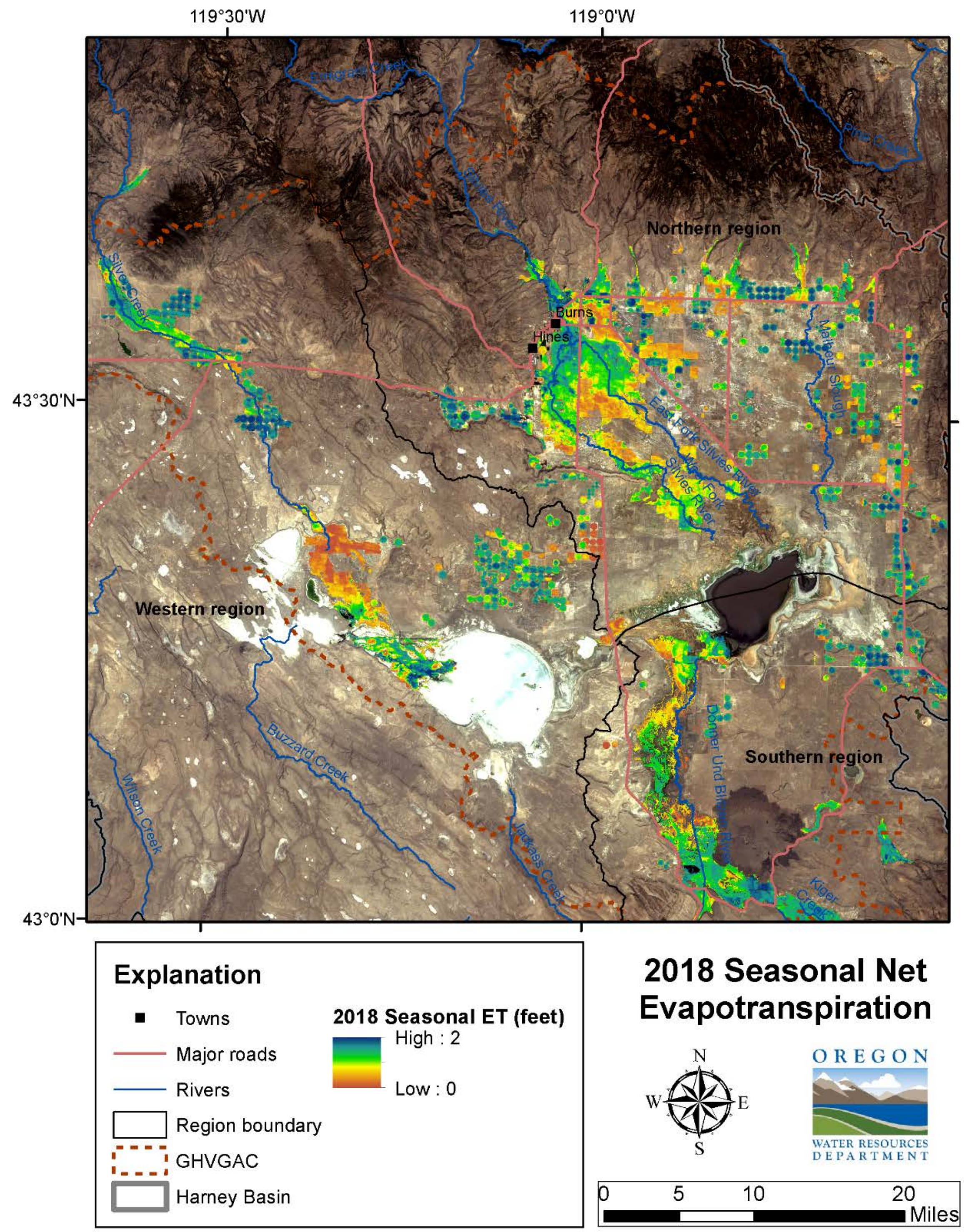

Figure 4. Net evapotranspiraiton for Harney Basin and location of eddy covariance ET station, May-September 2018.

Graphs

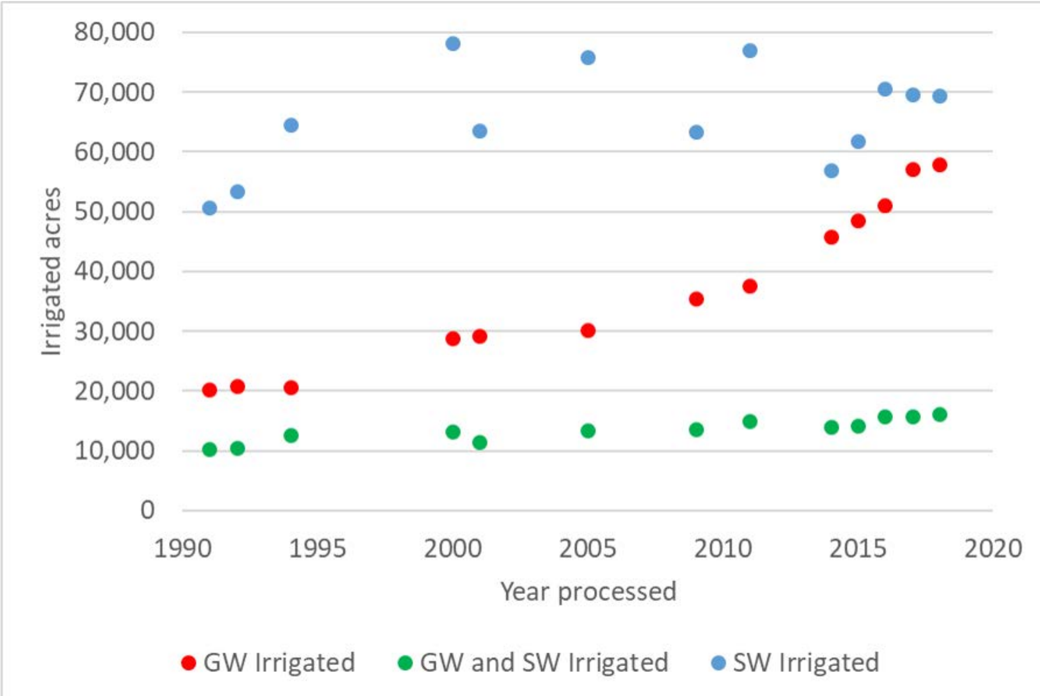

Figure 5. Annual time series of summed irrigated acres in the Harney Basin for all irrigated fields, by irrigation water source type.

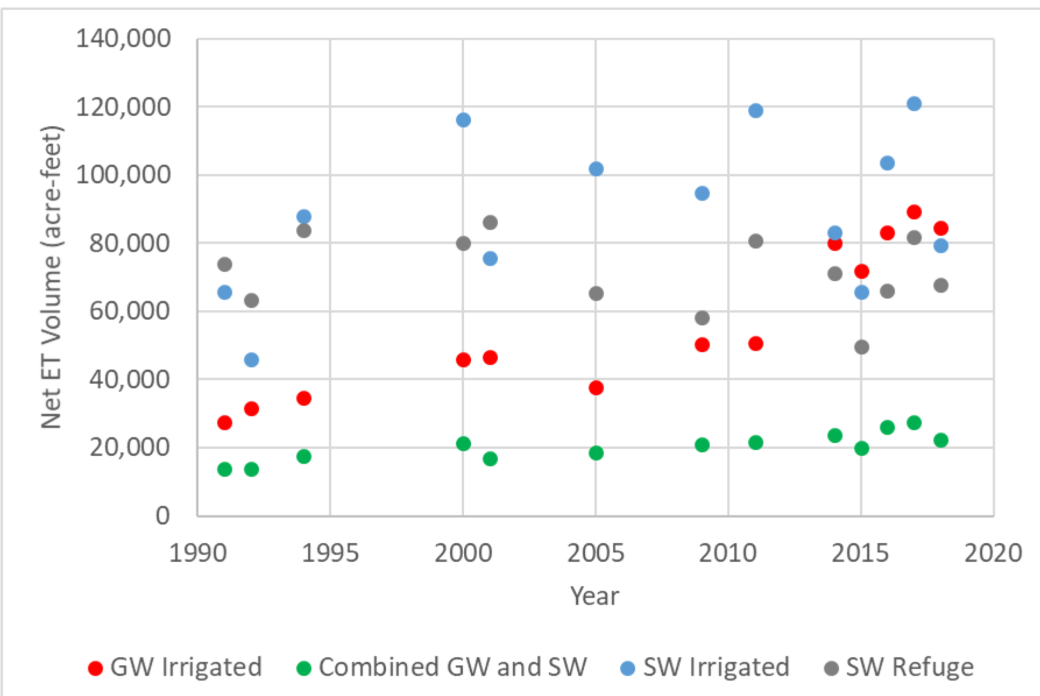

Figure 6. Time series of annual net evapotranspiration volume from irrigated areas by irrigation source type, Harney Basin, Oregon.

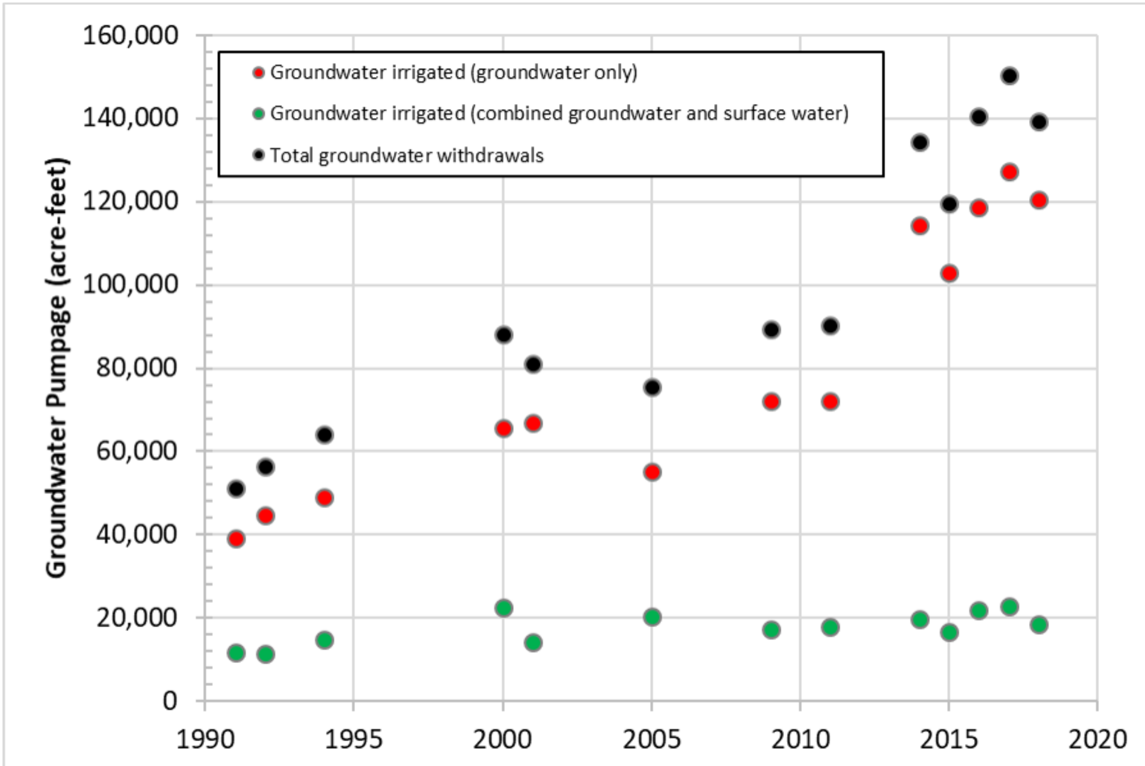

Figure 7. Time series of groundwater withdrawals (pumpage) in the Harney basin from 1991 to 2018.

Tables

Table 1. May to September net evapotranspiration rates, in feet, by irrigation source type

YEAR	Groundwater	Combined	Surface Water	SW - Refuge
1991	1.36	1.34	1.30	1.60
1992	1.51	1.31	0.86	1.37
1994	1.67	1.41	1.36	1.81
2000	1.60	1.60	1.49	1.73
2001	1.59	1.49	1.19	1.86
2005	1.25	1.38	1.34	1.41
2009	1.42	1.53	1.50	1.26
2011	1.35	1.44	1.55	1.74
2014	1.75	1.69	1.46	1.54
2015	1.48	1.40	1.06	1.08
2016	1.63	1.64	1.47	1.43
2017	1.56	1.75	1.74	1.76
2018	1.46	1.37	1.14	1.46
Mean	1.51	1.49	1.34	1.54
StDev	0.14	0.14	0.23	0.24

Table 2. May to September net evapotranspiration volumes, in acre-feet, by irrigation source type

YEAR	Groundwater	Combined	Surface Water	SW - Refuge	Total
1991	28,000	14,000	66,000	74,000	181,000
1992	32,000	14,000	46,000	64,000	155,000
1994	35,000	18,000	88,000	84,000	224,000
2000	46,000	21,000	116,000	80,000	264,000
2001	47,000	17,000	76,000	86,000	226,000
2005	38,000	19,000	102,000	65,000	224,000
2009	50,000	21,000	95,000	58,000	225,000
2011	51,000	22,000	119,000	81,000	272,000
2014	80,000	24,000	83,000	71,000	259,000
2015	72,000	20,000	66,000	50,000	207,000
2016	83,000	26,000	104,000	66,000	279,000
2017	89,000	28,000	121,000	82,000	320,000
2018	84,000	22,000	80,000	68,000	254,000

Table 3. Total estimated seasonal groundwater pumpage from agricultural irrigation wells, Harney Basin, Oregon.

Total Seasonal groundwater pumpage: Computed as the ratio of net crop evapotranspiration and irrigation application efficiency (assumed 70% for fields with groundwater only and 60% for fields with both groundwater and surface water). Combined pumpage represents groundwater pumpage from fields irrigated by both groundwater and surface water (assumed 50% of supplied water from groundwater).

Year	Groundwater primary Pumpage (acre-feet)	Groundwater supplemental Pumpage (acre-feet)	Total Groundwater Pumpage (acre-feet)
1991	39,000	12,000	51,000
1992	45,000	11,000	56,000
1994	49,000	15,000	64,000
2000	66,000	18,000	83,000
2001	67,000	14,000	81,000
2005	54,000	15,000	69,000
2009	72,000	17,000	89,000
2011	72,000	18,000	90,000
2014	110,000	20,000	130,000
2015	100,000	17,000	120,000
2016	120,000	22,000	140,000
2017	130,000	23,000	150,000
2018	120,000	19,000	140,000

References

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