Wallowa County Water Assessment

Prepared for

Wallowa Resources
401 NE 1st Street, Suite A
Enterprise, OR 97828

Prepared by

Niklas Christensen and Ed Salminen
Watershed Professionals Network
701 June Street, Hood River, OR 97031
www.watershednet.com

Final - January 31, 2018

WPN Watershed Professionals Network, LLC

Executive Summary

This report provides an initial overview of water supply, water rights, and water use in Wallowa County. Using publicly available information this report 1) summarizes historical water supply and the factors affecting water supply, 2) documents current water use and water rights, 3) summarizes climate change projections and likely impacts on future water supply, 4) documents current water availability within the County, and 5) offers recommendations to refine our understanding of these items, including identifying data gaps and recommending future analyses. Key findings and recommendations include:

Key Findings

1. Although county-average water year precipitation has a high degree of variability, the 10-year moving average has remained between 15-20 inches per year from 1895-present.
2. Climate variability (e.g., El Nino/La Nino, Pacifica Decadal Oscillation) has caused decade-long cool/wet and warm/dry periods and should be considered when interpreting climate trends.
3. The basin has been experiencing a warming trend from 1950-present, with most warming occurring during the summer months (10-year moving average August temperatures shows an approximately 4° F warming from 1955-present).
4. Runoff is snowmelt dominated, with a majority of precipitation in high elevation areas falling as snow and contributing to spring/summer runoff with rapid recession.
5. Annual and summer runoff volumes show a decreasing trend (for all sub-basins except the Imnaha), but the trends are likely driven by the current dry Pacific Decadal Oscillation phase and not actual long-term trend.
6. Instream water rights are met on the Wallowa River at Enterprise all the time. Instream water rights on the Wallowa River at Water Can are met year-around except approximately 20 % of the time in August and September. Instream water rights on the Minam, Bear Creek, and Lostine are typically not met 50 % of the time in the winter, met April through July, and not met in August and September. Instream water rights on the Grande Ronde at Troy are met in all but a handful of days (and likely due to the lag time in regulating off junior users).
7. Summer streamflow is correlated with winter precipitation and snowpack and can be predicted with some accuracy based on regression analysis. However, available climate-runoff modeling results from the CIG are probably the most useful predictor of future streamflow currently available
8. Limited data existing on inflow to Wallowa Lake (period of record is intermittently in the 1920s and 1930, and then continuously 2015 through present), however it appears that typically only 15,000 (acre-feet) AF of active storage is used compared to an average annual inflow 82,000AF/yr.

9. Climate change is expected to increase basin-average air temperatures by 3 to 5° F by 2050, and 4 to10° F by 2080. Annual precipitation is expected to increase by 0-5% for the same period, with a 5-10% decrease in summer.
10. As a result of climate change, winter precipitation will shift from snow to a greater frequency of rain, resulting in a smaller snowpack. Lower elevation areas are expected to lose over 60% of their historical snowpack, while snowpack in upper elevation areas (roughly above 7,000 feet) will remain relatively unchanged. Averaged over the entire Wallowa sub-basin, the 2040s are expected to have 23% less snow than historical snowpack, while the 2080s are expected to have 49% less.
11. Due to increased temperature associated with climate change, natural Wallowa River July-September runoff is expected to decrease by 50% by the 2040s and 67% by the 2080s.
12. Municipal water is supplied by the cities of Joseph, Enterprise, Wallowa, Lostine and the Lake County Service District. Cumulative monthly average water use ranges from a low of 2 cfs in the winter to a high of 5 cfs in the summer (for a total of approximately 2,000 AF/year).
13. There are 681 domestic water rights in the Wallowa sub-basin. No data is available for water use for domestic rights, however, based on municipal use rates it's estimated that cumulative domestic use is on the order of 250 AF/year.
14. Commercial water rights in Wallowa County have a total water right of 35 cfs, though it's likely actual water use is significantly lower than the water rights.
15. 61,158 acres in the Wallowa sub-basin have irrigation water rights, which matches closely with the 2016 USDA estimate of 58,138 irrigated acres.
16. Water diversion data exists for less than 50% of the irrigated area, and no data exists on amount of return flows back to rivers.
17. Based on limited data, it appears the Associated Ditch Company diverts approximately 2.99 AF/acre and the Westside Poly/Allen diverts 3.15 AF/acre.
18. Total basin water diversions are estimated at 183,125 AF/year, compared against average USDA crop demand of 112,391 AF/year, up to 30k AF of which may be being met by in-season precipitation – to be discussed. The difference between the two values includes diversion return flows and water lost during the application process. It should be stressed that both the diversion and crop demand values are based on limited data and should be seen as an initial estimate.
19. The information documented in this report (e.g., water supply, storage, water use, streamflow, instream water rights, climate change) show a relatively 'water rich' basin for most of the year, however, the late summer period shows a deficit of water available with instream flows not met and irrigators needing to reduce diversions. Due to the hydrology of the basin (snowmelt-dominated), climate change is expected to severely exacerbate the shortages that already exist.

Recommended Next Steps (funding sources as well as items considered but not recommended can be found in Section 7)

Recommendation	Cost estimate
1. Assessment of irrigation water use & water conservation potential that would include: a) Water diversion data for all irrigated acreage b) On-farm delivery data for all irrigated acreage c) Actual crop water use d) Return flow amounts and locations e) Estimate of conveyance efficiency upgrades (cost and water savings) f) Estimate of on-farm efficiency upgrades (cost and water savings) g) Evaluate impacts of piping groundwater recharge and instream flows	$25,000 - $100,000 Depends on existing data and level of analysis
2. Assessment of shallow groundwater storage potential and impacts. Components include: a) Canal leakage and contribution to wetlands/instream flow b) Wetland loss, degradation, restoration - impacts on summer baseflow c) Value of winter use of ditch network to recharge GW and flood amelioration	$25,000 -$50,000
3. Wallowa Lake Storage Assessment: Evaluate if the opportunity exists to more actively use Wallowa Lake storage to meet instream and out-of-stream needs. This includes use of existing storage as well as restoring storage that is not currently used due to dam safety concerns.	$20,000
4. Quantitative monitoring to inform water management decisions and quantify conservation potential: a) return flows b) USBR Agrimet Station for Wallowa Valley c) Stream gage recommendations d) Water temperature monitoring sites	Monitoring plan: $10,000 - $25,000 Implementation varies by type, location, etc.
5. Perform instream habitat study (e.g., Instream Flow Incremental Methodology (IFIM) Study): a) Evaluate adequacy of existing studies b) Work with stakeholders to identify other priority locations c) Implement IFIM at selected sites	$80,000 - $250,000 Depends on # of sites selected
6. Perform watershed studies evaluating rainfall-runoff processes, potential to increase overall runoff volume, and increase groundwater baseflow. For example, watershed studies across the west have shown a strong correlation between stand density and annual runoff volume, while other studies have shown floodplain restoration can increase late summer baseflow.	$25,000-$150,000 Depends on type and scale of study
7. Water temperature study, elements include: a) Assemble, evaluate existing water temperature monitoring data b) Wallowa Lake CE-QUAL2E model to evaluate storage/release configuration impacts on lake and release temperatures, c) Wallowa River and tributary water temperature model development (to evaluate downstream impacts of future storage-flow-temperatures)	$50,000-$100,000 Depends on downstream extent and data availability
8. Develop water banking system to ameliorate flow impacts in drought years: a) Identify and map croplands, tax parcels, irrigation district, water right etc. b) Use IFIM or other habitat data to quantify benefits of saved water c) Develop outreach program to survey interest and participation of landowners	$50,000-$100,000
9. Develop a Wallowa Valley Water Management Plan that would: a) Use IFIM, water temperature model(s), and other fish/habitat data to quantitatively evaluate benefits/prioritize flow restoration b) Identify optimum Wallowa lake storage, release, outlet configuration c) Develop a basin-wide action plan that prioritizes projects, d) Identify funding sources, partnerships, and other implementation opportunities	$50,000-$200,000 Depending on completion of previous tasks. #1 required.

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1 Introduction

1.1 Purpose

This project is the first step in developing an understanding of the current state and future direction of water availability and use in Wallowa County, and will help County stakeholders (Wallowa Resources, ditch companies, County, the Nez Perce Tribe, municipalities, ODFW, OWRD, and others) identify and decide on future strategies to address water needs, identify gaps in knowledge, and outline follow-up studies that may be necessary to complete our understanding.

To accomplish this goal, we have summarized the current state of knowledge, and undertook some key analyses using existing information to improve our understanding of the current state and likely direction of water supply and demand. We have summarized these results in a concise and accessible format with adequate detail to serve as a platform for launching future actions.

Overall this report 1) summarizes historical water supply and the factors affecting water supply, 2) summarizes likely climate change and qualitative impacts on future supply, 3) current water availability within the County, 4) current water use and water rights, and 5) offers recommendations to refine our understanding of these items, including identifying data gaps and recommending future analyses.

1.2 Scope

All tasks were conducted using existing and readily available data, including public domain data and data provided by the stakeholders at project inception. The analysis presented here covers the Wallowa River (17060105) and Imnaha River (17060102) sub-basins; the Oregon-portions of the Lower Grande Ronde (17060106), Hells Canyon (17060101), and Lower Snake-Asotin (17060103) sub-basins; and the portion of the Brownlee Reservoir sub-basin that interests Wallowa County (Figure 1). The Upper Grande Ronde (17060104) sub-basin influences conditions in the Lower Grande Ronde River, but was not included in the analyses below except where noted.

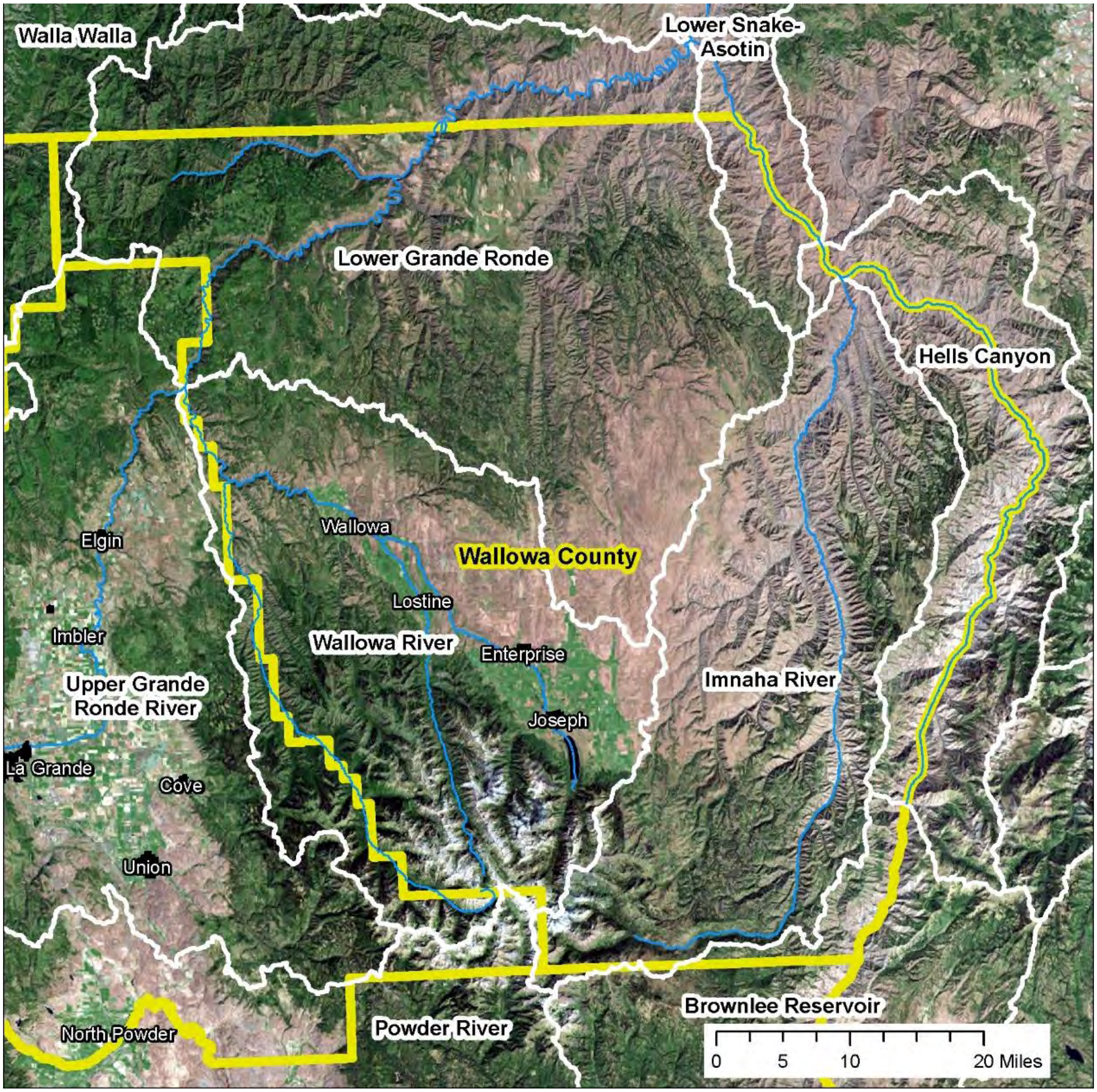


Figure 1. Project area and principal streams.

2 Historical Water Supply

This section of the report describes 1) existing water supply, 2) variability in the water supply and the components that affect supply, and 3) basin conditions that influence water supply.

2.1 Precipitation

The PRISM Group at Oregon State University (PRISM, 2012) has published digital maps of mean annual precipitation for the western United States that are based on available precipitation records for the period 1981 to 2010. The PRISM maps are produced using an analytical model that combines point precipitation data and digital elevation model (DEM) data to generate spatial estimates of annual and monthly precipitation. Mean annual precipitation within the project area generally varies with elevation (Figure 2). Mean annual precipitation ranges from 14 to 77 inches annually. Mean monthly data for the project area (PRISM, 2012) were summarized by sub-basin and shown in Figure 3. Highest monthly values occur for the months of November and December, and are generally around one inch in the summer months.

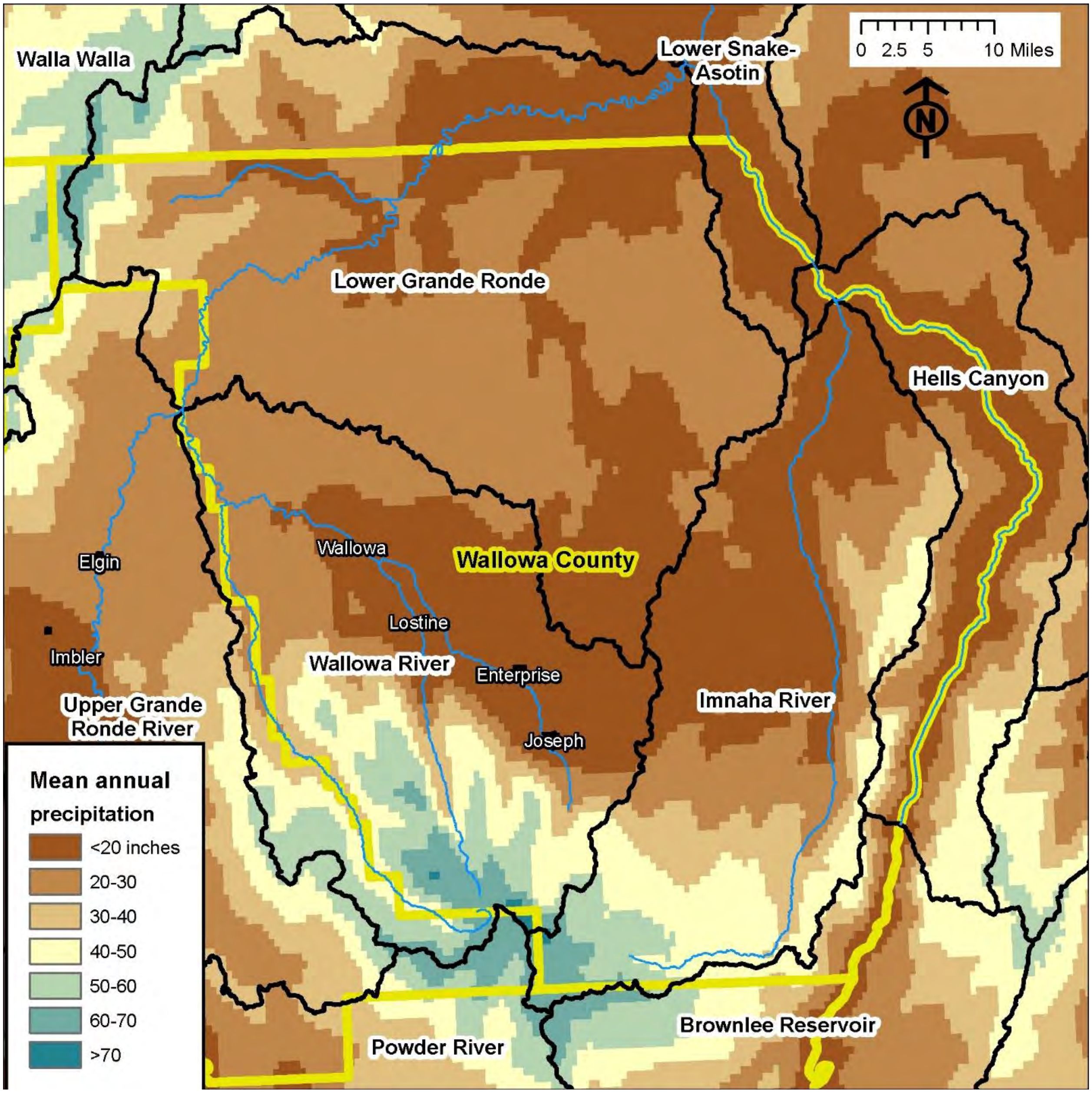


Figure 2. Mean annual precipitation. Source: PRISM (2012).

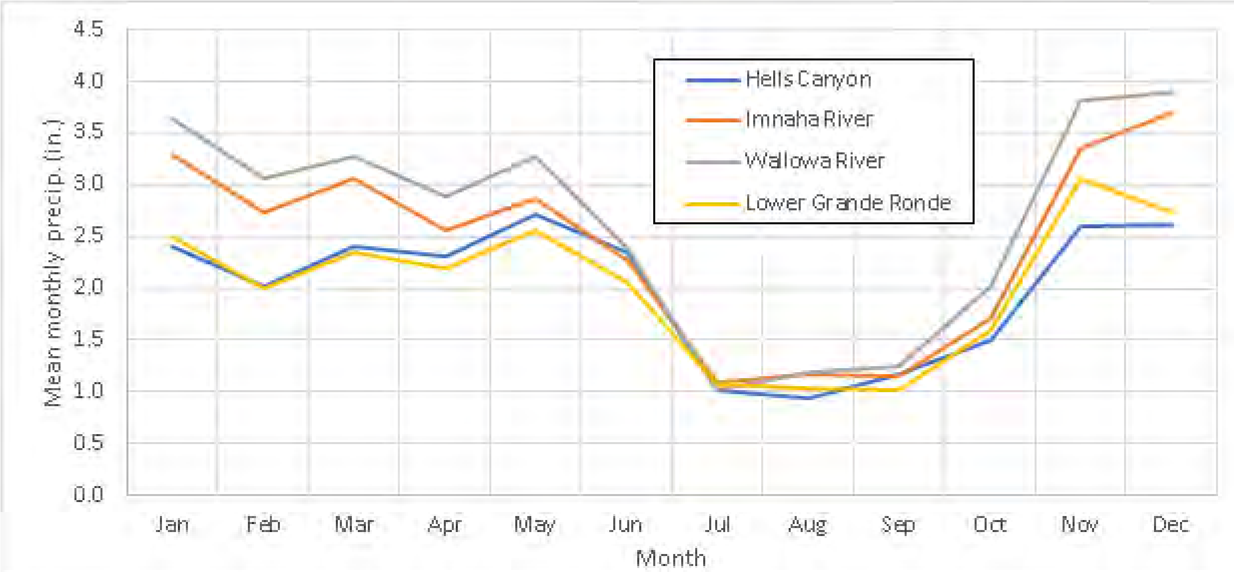


Figure 3. Mean monthly precipitation by sub-basin. Source: PRISM (2012).

Climate station data are available for 75 stations within or adjacent to the project area (Table 1. Figure 4). Data sources include the Natural Resources Conservation Service (NRCS) SNOTEL automated sites (continuous data generally available 1979-present)[1], NRCS snow course sites (1st-of-the-month measurements from early 1900's to resent), Remote Automatic Weather Stations (RAWS) run by the U.S. Forest Service (USFS) and Bureau of Land Management (BLM), and National Weather Service (NWS) National Climate Data Center (NCDC) Cooperative Observer Network (COOP) stations[2]. Recent data for these sites are available through the University of Utah Department of Atmospheric Sciences Mesowest web interface[3], which also includes additional sites (identified as "Mesowest" in Table 1. Figure 4) from other sources. The United States Historical Climatology Network (USHCN[4]) has selected approximately 1200 stations around the country that they have bias-corrected (For changes in station location, etc.) and filled gaps in thorough statistical methods using adjacent stations to produce long term continuous data sets for use in climate change analyses, etc. (Menne et al. (2014). One of these stations (NCDC coop # 358997) is located within the project area.

Year-to-year variability in precipitation was assessed using long-term records assembled by Menne et al. (2014) for the Wallowa weather station (NCDC coop # 358997). This long-term record covers the period from water year 1893 to 2014 (Figure 5).

1 https://www.wcc.nrcs.usda.gov/snow/
2 https://www.ncdc.noaa.gov/cdo-web/
3 http://mesowest.utah.edu/cgi-bin/droman/stn_state.cgi?state=OR
4 http://cdiac.ess-dive.lbl.gov/epubs/ndp/ushcn/daily_doc.html

Table 1. Meteorological stations in the vicinity of the project area.

Map ID	Station ID	Station Name	Elev. (ft.)	Source	Status	Begin	End	POR (yrs)
1	647	Moss Springs	5760	SNOTEL	Active	Oct-1979	Present	38
2	653	Mt. Howard	7910	SNOTEL	Active	Oct-1979	Present	38
3	302	Aneroid Lake #2	7400	SNOTEL	Active	Oct-1980	Present	37
4	1079	Milk Shakes	5580	SNOTEL	Active	May-2007	Present	11
5	17D11	Standley AM	7360	Snow course	Active	Feb-1961	Present	57
6	17D14	Big Sheep AM	6230	Snow course	Active	Feb-1963	Present	55
7	17D13	Mirror Lake AM	8120	Snow course	Active	Feb-1963	Present	55
8	17D16	Tv Ridge AM	7050	Snow course	Active	Feb-1965	Present	53
9	17D19	East Eagle	4400	Snow course	Active	Jan-1991	Present	27
10	17D06	Moss Springs	5850	Snow course	Disc.	Jan-1938	Mar-2003	65
11	17D02	Aneroid Lake #2	7300	Snow course	Disc.	Feb-1942	Jun-2002	60
12	17D01	Aneroid Lake #1 (Disc)	7480	Snow course	Disc.	Jan-1929	Dec-1978	50
13	17C04	Spruce Springs (Disc)	5700	Snow course	Disc.	Feb-1965	Dec-1982	18
14	17D03	Unit Lake (Disc)	7100	Snow course	Disc.	Feb-1929	Dec-1931	3
15	17D15	Tv Ridge (Disc)	5670	Snow course	Disc.	Feb-1963	Dec-1964	2
16	ENFO3	EDEN	4200	RAWS	Active	Oct-1998	Present	19
17	PLFI1	Pittsburg Landing	1357	RAWS	Active	Jul-1998	Present	19
18	PPFO3	Point Prom Ii	6607	RAWS	Active	Oct-1998	Present	19
19	BTFO3	Roberts Butte	4263	RAWS	Active	Oct-1998	Present	19
20	SRFI1	Snake River	4376	RAWS	Active	Jul-1998	Present	19
21	HRLO3	HARL BUTTE	6071	RAWS	Active	Jun-2001	Present	16
22	CRKI1	Corral Creek	2690	RAWS	Active	Sep-2005	Present	12
23	TR328	Minam Lodge-Portable	3575	RAWS	Disc.	Jun-2001	May-2014	13
24	TS017	Wallowa-Whitman Portable	5715	RAWS	Disc.	Aug-2003	Nov-2004	1
25	358997	Wallowa	2923	NCDC Coop	Active	Mar-1903	Present	115
26	352672	Enterprise RS	3815	NCDC Coop	Active	Jul-1948	Present	69
27	354147	Imnaha	1968	NCDC Coop	Active	Jul-1948	Present	69
28	354329	Joseph	4260	NCDC Coop	Active	Jul-1948	Present	69
29	353651	Harl Butte	5505	NCDC Coop	Active	Jul-1953	Present	64
30	353713	Hat Point	7005	NCDC Coop	Active	Jul-1953	Present	64
31	357044	Red Hill	5052	NCDC Coop	Active	Jul-1953	Present	64
32	358575	Tope Lookout	4203	NCDC Coop	Active	Jul-1953	Present	64
33	358998	Wallowa RS	2943	NCDC Coop	Active	Jul-1953	Present	64
34	358639	Troy	1586	NCDC Coop	Active	Mar-1955	Present	63
35	352678	Enterprise 20 NNE	3280	NCDC Coop	Active	Feb-1969	Present	49
36	355067	Lostine 4 NE	3780	NCDC Coop	Active	Feb-2002	Present	16
37	352675	Enterprise 2 S	3880	NCDC Coop	Disc.	Apr-1963	7/8/1995	32
38	355610	Minam 7 NE	3616	NCDC Coop	Disc.	Oct-1955	8/11/1986	31
39	350193	Aneroid Lake	7405	NCDC Coop	Disc.	Aug-1963	10/31/1976	13
40	352961	Flora 7 SSE	4803	NCDC Coop	Disc.	Sep-1964	10/31/1976	12
41	353559	Gumboot	4500	NCDC Coop	Disc.	Nov-1909	12/31/1921	12
42	358645	Troy 8 W	4003	NCDC Coop	Disc.	Sep-1966	10/31/1976	10
43	354066	Howardville	3573	NCDC Coop	Disc.	Jul-1948	10/31/1955	7
44	108282	Seven Devils Grd Stn	7156	NCDC Coop	Disc.	Oct-1969	9/30/1976	7
45	352679	Enterprise 21 NNE	3524	NCDC Coop	Disc.	Feb-1963	2/12/1969	6
46	356683	Pittsburg	1250	NCDC Coop	Disc.	Apr-1928	2/28/1934	6
47	352677	Enterprise 16 NNE	4334	NCDC Coop	Disc.	Jun-1958	2/28/1963	5
48	354151	Imnaha 5 N	1762	NCDC Coop	Disc.	Sep-1969	1/1/1975	5
49	354149	Imnaha 2	1982	NCDC Coop	Disc.	Feb-1962	9/13/1965	4
50	358994	Walloupa	2700	NCDC Coop	Disc.	Jun-1909	11/17/1913	4
51	351115	Bue	4500	NCDC Coop	Disc.	May-1915	7/31/1918	3
52	358647	Troy Eden	1616	NCDC Coop	Disc.	Nov-1940	2/28/1943	2
53	351045	Brockman Ranch	1310	NCDC Coop	Disc.	Mar-1926	8/31/1926	1

Table 1 (continued). Meteorological stations in the vicinity of the project area.

54	C1102	CW1102 Wallowa	2946	MesoWest	Active	Oct-2003	Present	14
55	C2049	CW2049 Imnaha	1978	MesoWest	Active	Apr-2004	Present	14
56	AP890	KB7DZR Joseph	3984	MesoWest	Active	Sep-2003	Present	14
57	IMHO3	Imnaha River at Imnaha	1984	MesoWest	Active	Mar-2007	Present	11
58	NTPO3	Ranger Station Near Enterprise 1W	3815	MesoWest	Active	Mar-2007	Present	11
59	C6808	CW6808 Imnaha	2870	MesoWest	Active	Sep-2007	Present	10
60	C7508	CW7508 Enterprise	3848	MesoWest	Active	Sep-2007	Present	10
61	D1597	DW1597 Troy	1612	MesoWest	Active	May-2009	Present	9
62	KJSY	Joseph State Airport AWOS	4120	MesoWest	Active	Mar-2010	Present	8
63	AT690	HOWARD Mt Howard	8150	MesoWest	Active	Aug-2010	Present	7
64	D9712	DW9712 Wallowa	3609	MesoWest	Active	Feb-2012	Present	6
65	E1810	EW1810 Lostine	3376	MesoWest	Active	Jan-2013	Present	5
66	TRYO3	Grande Ronde River at Troy	1594	MesoWest	Active	Mar-2013	Present	5
67	MNMO3	Minam River at Minam	2564	MesoWest	Active	Mar-2013	Present	5
68	E8320	EW8320 Lostine	3437	MesoWest	Active	Apr-2016	Present	2
69	F0023	FW0023 Troy 1N	2650	MesoWest	Active	Dec-2016	Present	1
70	F0922	FW0922 Joseph	4471	MesoWest	Active	Apr-2017	Present	1
71	C3808	CW3808 Enterprise	3927	MesoWest	Disc.	May-2005	Mar-2017	12
72	C7477	CW7477 Lostine	7002	MesoWest	Disc.	Feb-2007	Dec-2015	9
73	C1430	CW1430 Enterprise	3862	MesoWest	Disc.	Nov-2003	Aug-2009	6
74	JCRW1	Joseph Creek Near Mouth Near Anatone 9SE	1020	MesoWest	Disc.	Dec-2006	Oct-2012	6
75	C7506	CW7506 Lostine	3642	MesoWest	Disc.	Feb-2007	Feb-2008	1

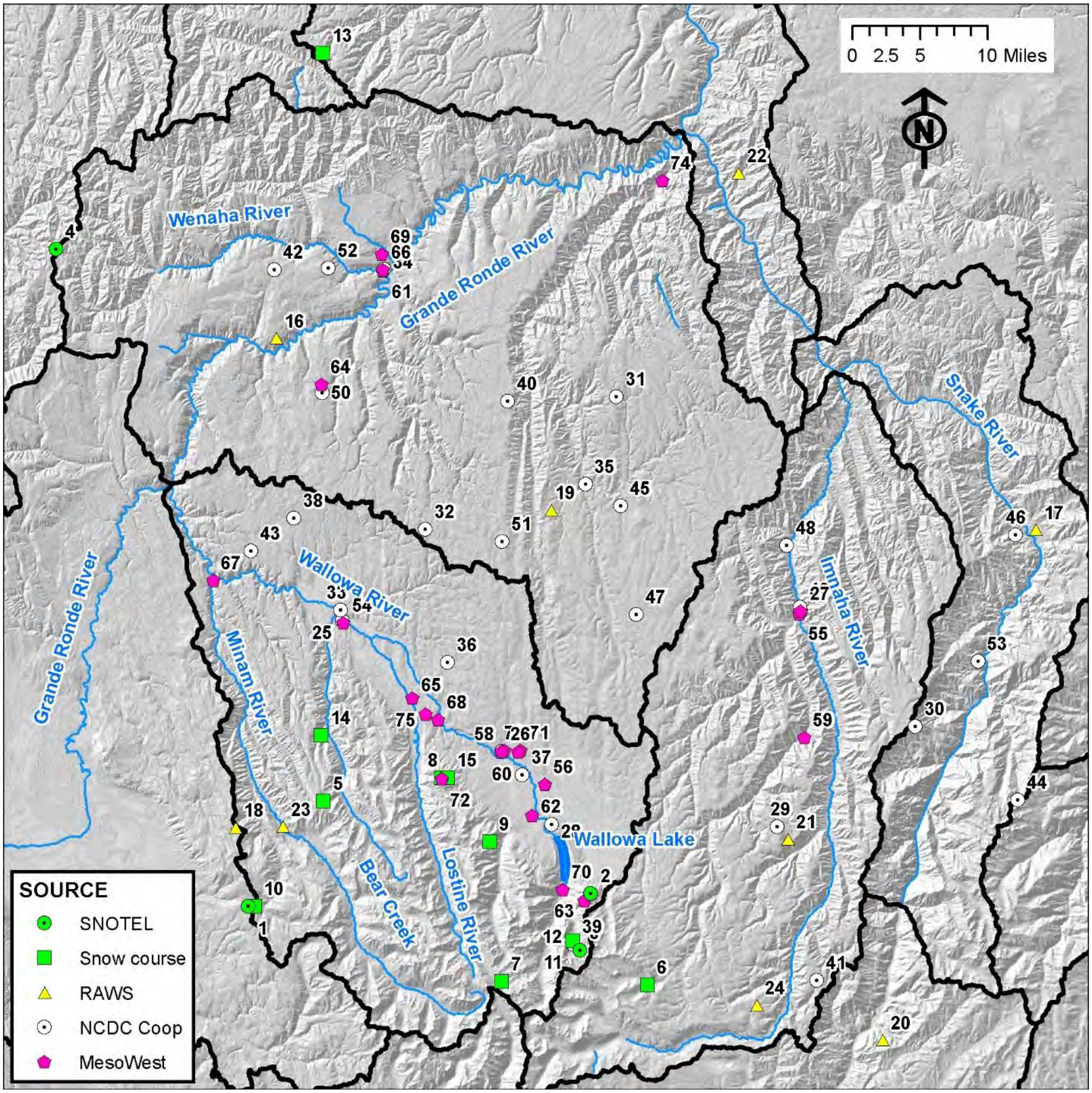


Figure 4. Meteorological stations.

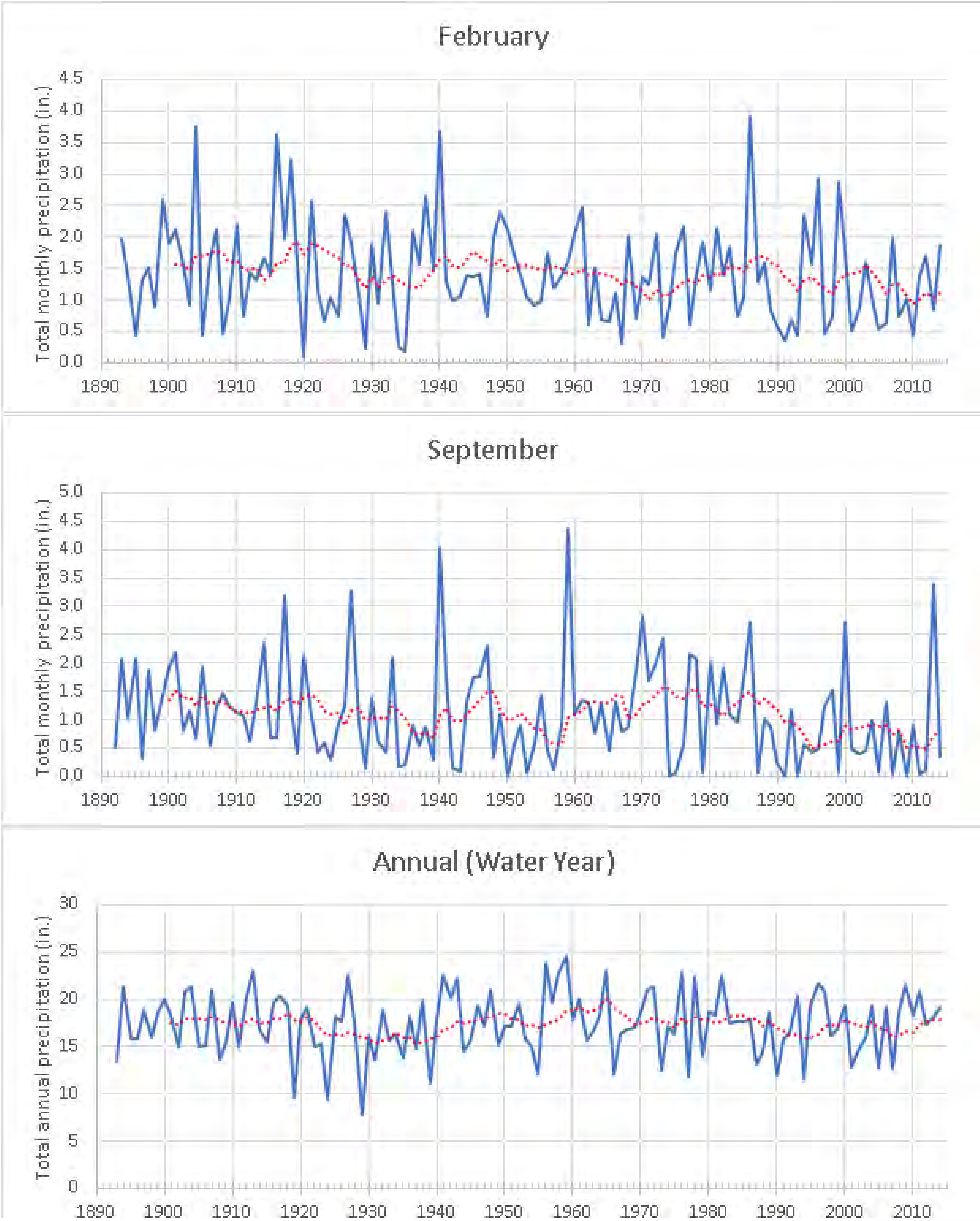


Figure 5. Total February (top), September (middle) and Annual precipitation at the Wallowa NCDC station (358997). Source: Menne et al. (2015). Red line is 10-year moving average.

A statistical trend analysis was performed to determine if significant time-trends exist for monthly and mean annual flow (based on water year) at the Wallowa NCDC station (358997). Kendall's rank-order correlation (Kendall and Gibbons, 1990[5]) was used to test for trends over time. Kendall's test is a non-parametric method of determining an increasing or decreasing trend in a paired data set. Values of the trend coefficient range from –1.0, which indicates a perfect inverse correlation, to 1.0, which indicates a perfect positive correlation. For this analysis, significance was defined at the $p< 0.05$ level. Mean annual precipitation showed no significant trends over the period of record (Figure 5, bottom graph; Table 2). This suggests there is no long-term trend (either decreasing or increasing) in annual precipitation. Only September precipitation showed a significant decrease over the period of record (Figure 5, middle graph; Table 2). February precipitation showed a weak decreasing trend over time (Figure 5, top graph; Table 2).

Table 2. Rank correlation results for monthly and annual (water year) precipitation at the Wallowa NCDC station (358997).

Month	tau	2-sided p-value
Jan	-0.03710	0.54161
Feb	-0.10500	0.08233
Mar	-0.03470	0.56879
Apr	0.01550	0.79952
May	0.04870	0.42230
Jun	0.03190	0.59957

Month	tau	2-sided p-value
Jul	0.04170	0.49327
Aug	0.06190	0.30956
Sep	-0.15700	0.00973
Oct	-0.02500	0.68310
Nov	-0.02800	0.64702
Dec	0.09680	0.11190
Water year	0.01300	0.83265

The two primary patterns of climatic variability that occur in the Pacific Northwest are the El Niño / Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO). The two climate oscillations have similar spatial climate fingerprints, but very different temporal behavior. PDO events persist for 20 to 30-year periods while ENSO events typically persist for 6 to 18 months (Mantua, 2001). The long-term precipitation data set from the Wallow station was used to identify PDO cycles in the project area. These data were processed as follows:

1. The mean and standard deviation was calculated over the period of record.
2. A standardized departure from normal was calculated for each water year by subtracting the overall mean annual precipitation from the annual precipitation for a given year, and dividing by the standard deviation.
3. A cumulative standardized departure from normal was then calculated by adding the standardized departure from normal for a given year to the cumulative standardized departure from the previous year (the cumulative standardized departure from normal for the first year in a station record was set to zero).

[5] Implemented using the R statistical package https://www.r-project.org/

This approach of using the cumulative standardized departure from normal provides a way to better illustrate patterns of increasing or decreasing precipitation over time by normalizing year-to-year variations in precipitation and smoothing the irregular nature of the data set. Values for the cumulative standardized departure from normal increase during wet periods and decrease during dry periods.

Results for the Wallowa station are shown on Figure 6. There appears to have been a cool/wet phase prior to 1918, followed by a warm/dry phase from at 1918 to 1939, followed by a cool / wet phase that persisted until 1986. It appears that we may be back in a warm / dry phase from 1986 to the present.

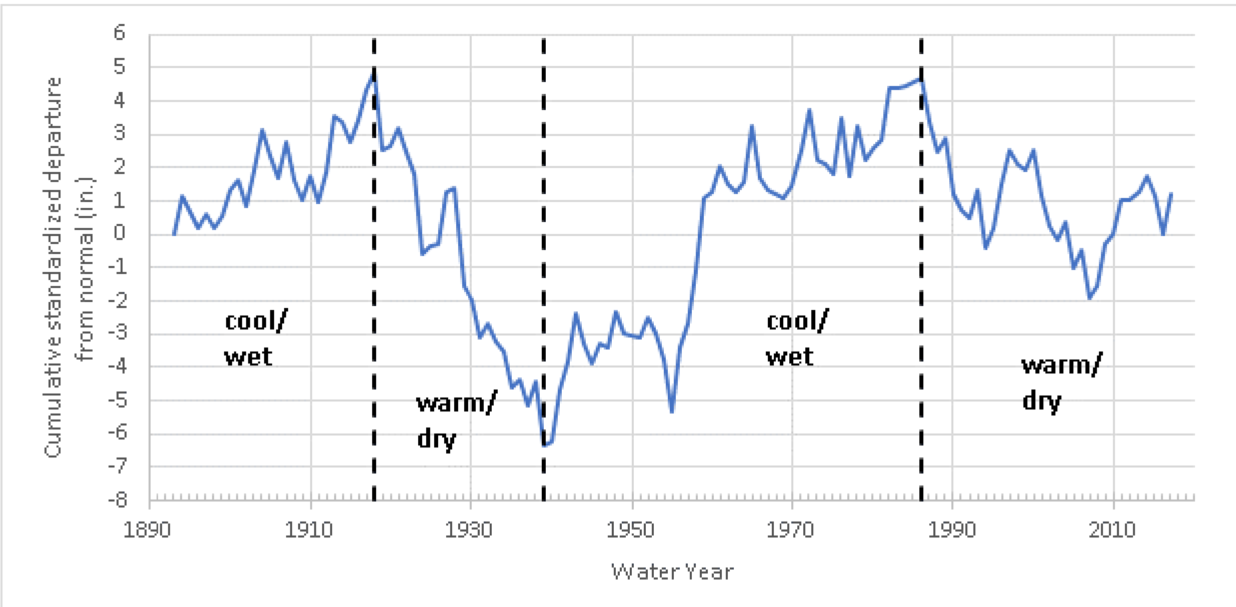


Figure 6. Cumulative standardized departure from normal of annual precipitation at the Wallowa weather station. Local PDO cycles are shown as vertical dashed lines.

2.2 Air Temperature

Mean monthly temperature, and mean annual air temperature data (by water year), are also available for the Wallowa weather station (NCDC coop # 358997) from water year 1894 to 2014 (Figure 7; Menne et al., 2012). A statistical trend analysis was performed to determine if significant time-trends exist for monthly and mean annual flow (based on water year). Kendall's rank-order correlation (Kendall and Gibbons, 1990) was used to test for trends over time. Mean annual air temperature, and mean monthly air temperatures for the months of February, March, June, August, and September, showed a significantly (at the $p < 0.05$ level) increasing trend over the period of record (Figure 7, Table 3).

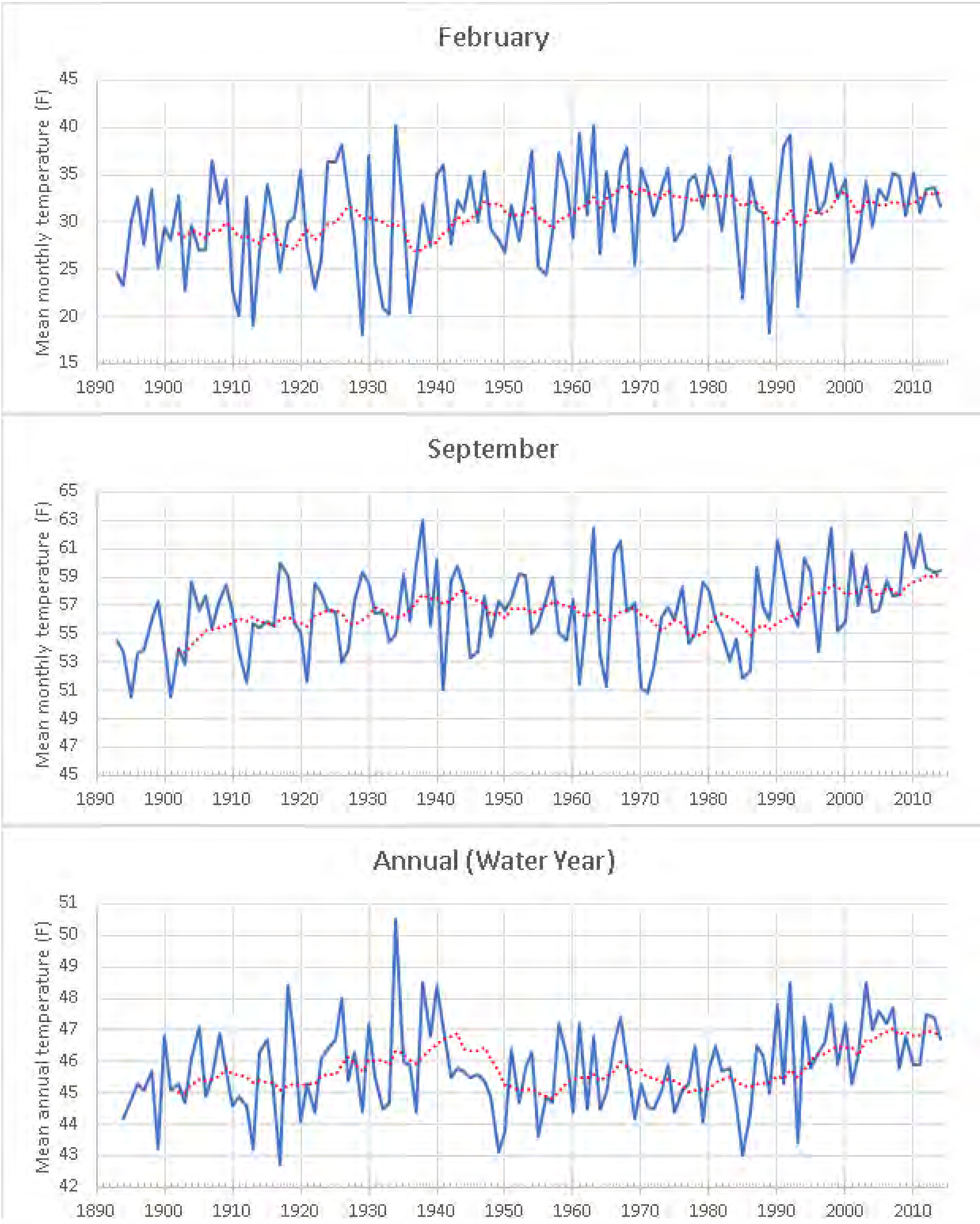


Figure 7. Mean February (top), September (middle) and Annual air temperature at the Wallowa NCDC station (358997). Source: Menne et al. (2015). Red line is 10-year moving average.

Table 3. Rank correlation results for mean monthly and mean annual (water year) air temperature at the Wallowa NCDC station (358997).

Month	tau	2-sided p-value
Jan	0.09780	0.10898
Feb	0.19600	0.00126
Mar	0.18000	0.00297
Apr	-0.03890	0.52333
May	0.10600	0.08043
Jun	0.13100	0.03191

Month	tau	2-sided p-value
Jul	0.11200	0.06608
Aug	0.14200	0.01988
Sep	0.21900	0.00032
Oct	-0.03190	0.60261
Nov	-0.05710	0.34961
Dec	-0.02700	0.65946
Water year	0.19300	0.00170

2.3 Snowpack

The NRCS has monitored snow pack in the project area for the past 80 years. Monitoring sites reflect the areas with significant snowpack. Eleven snow course sites (1st-of-the-month measurements from 1938 to present) are located within the project area, ten located in the Wallowa Mountains south of Enterprise, and one located due north of the Lower Grande Ronde sub-basin (Table 1, Figure 4). Four SNOTEL automated sites (continuous data generally available 1979-present), are in or near the project area; three located in the Wallowa Mountains south of Enterprise; and one located in the headwaters of the Wenaha River (Lower Grande Ronde sub-basin; Table 1, Figure 4).

Snowpack reaches peak accumulation generally between April 1st and mid-May (Figure 8). Snowpack is proportional to elevation; with median values at the SNOTEL sites peaking from 15-40 inches of SWE. April 1st snowpack at all snow course and SNOTEL sites are shown in Figure 9. A statistical trend analysis was performed to determine if significant time-trends exist for April 1st snowpack. Kendall's rank-order correlation (Kendall and Gibbons, 1990) was used to test for trends over time. Only the TV Ridge snow course site showed a significant declining trend in April 1st snowpack (Table 4; Figure 10; top). Other sites (e.g., Moss Springs snow course, Figure 10; bottom) suggest declining snowpack, but are not statistically significant. Additionally, due to the elevation of the sites (i.e. high elevation and typically well below freezing during the winter), it's likely total winter snow accumulation at the sites may be buffered against decreasing trends from warming temperatures, but that snow melt occurs earlier than historical, and hence less water may be available for late summer streamflow and consumptive uses. An analysis of May 1 and June 1 snowpack trends (a recommended action from this project) would identify if these trends do exist.

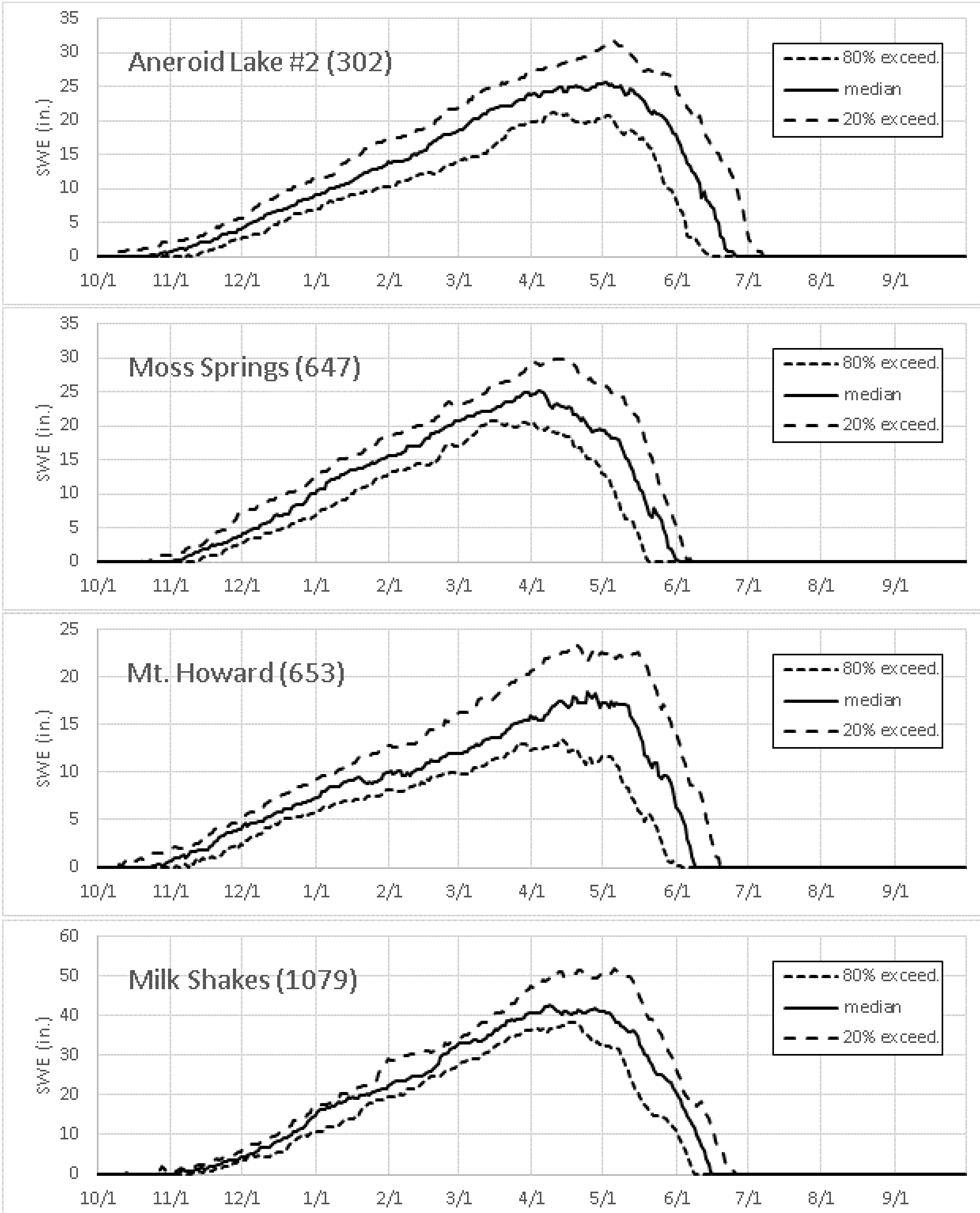


Figure 8. Snow water equivalent (SWE; inches) at four SNOTEL sites.

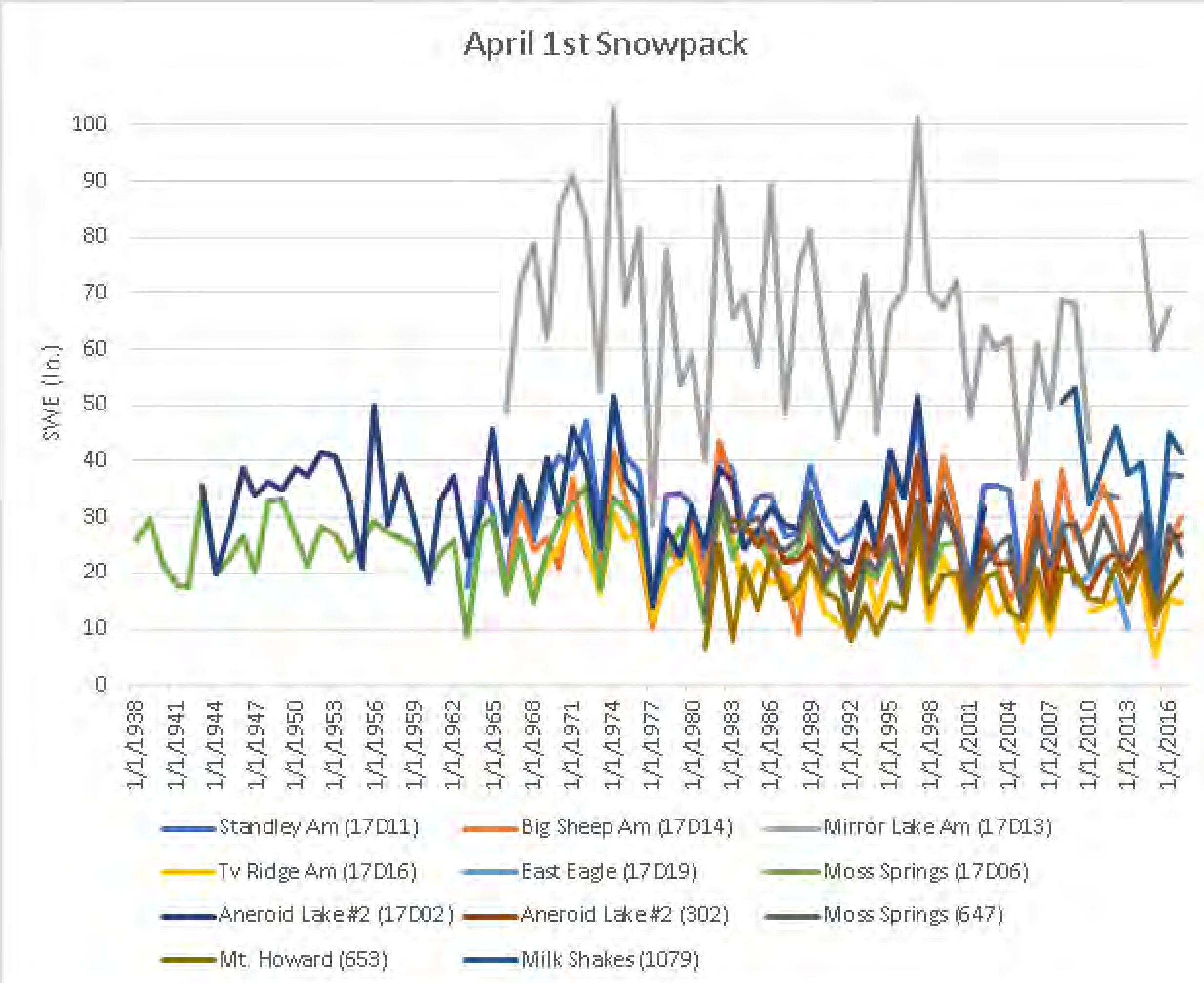


Figure 9. April 1st snowpack (inches SWE) at SNOTEL sites and selected snow courses.

Table 4. Rank correlation results for April 1st snowpack (inches SWE) at SNOTEL sites and selected snow courses.

Type	Site	Elevation (ft.)	n	tau	2-sided p-value
Snow course	Standley Am (17D11)	7,360	52	-0.03250	0.74030
Snow course	Big Sheep Am (17D14)	6,230	52	-0.01810	0.85596
Snow course	Mirror Lake Am (17D13)	8,120	49	-0.12600	0.20511
Snow course	Tv Ridge Am (17D16)	7,050	48	-0.35400	0.00042
Snow course	East Eagle (17D19)	4,400	14	-0.29700	0.15463
Snow course	Moss Springs (17D06)	5,850	64	-0.11400	0.18644
Snow course	Aneroid Lake #2 (17D02)	7,300	58	-0.14400	0.11333
SNOTEL	Aneroid Lake #2 (302)	7,400	35	-0.17500	0.14350
SNOTEL	Moss Springs (647)	5,760	37	-0.04220	0.72390
SNOTEL	Mt. Howard (653)	7,910	37	0.08580	0.46380
SNOTEL	Milk Shakes (1079)	5,580	10	-0.20000	0.47427

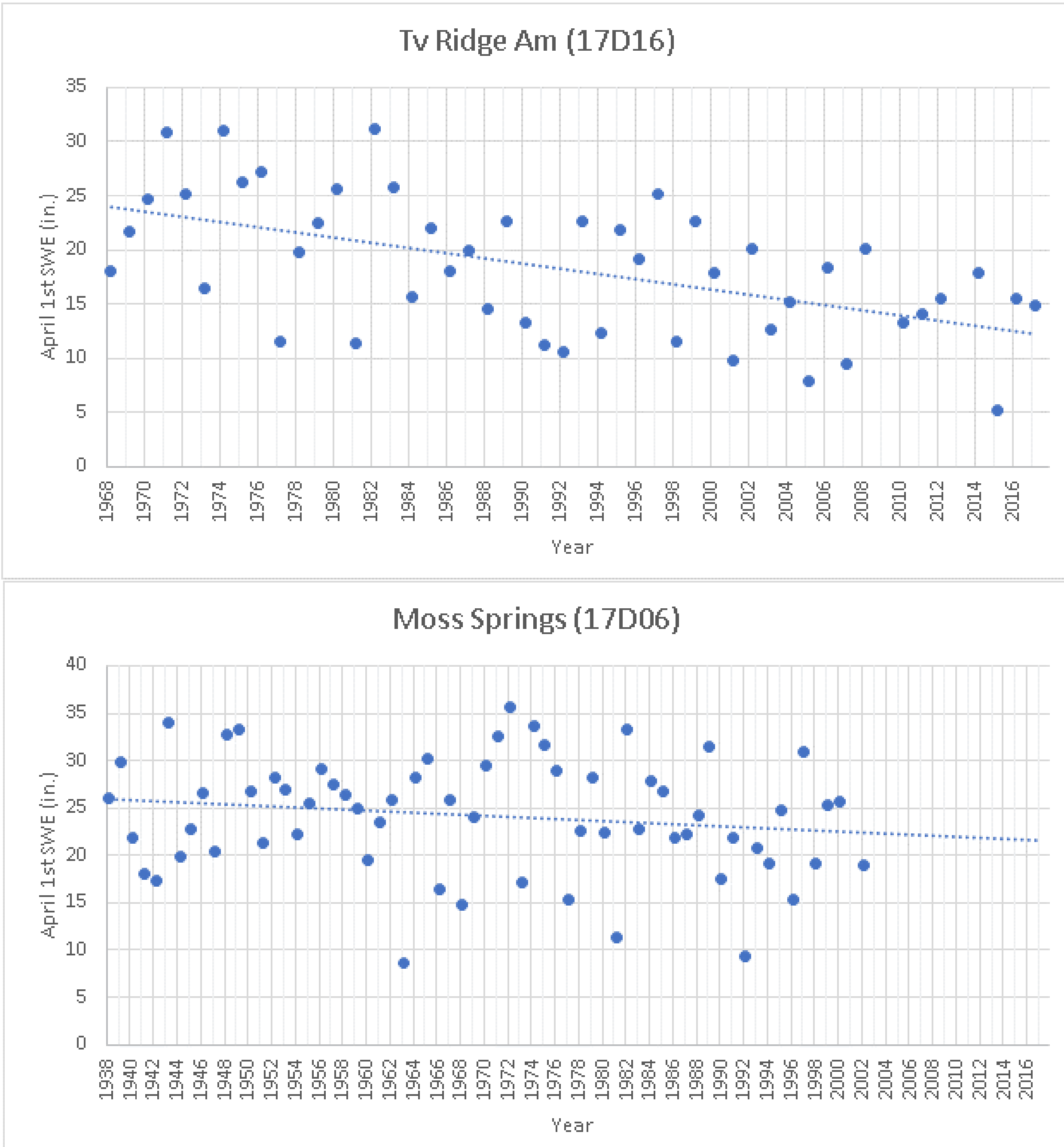


Figure 10. April 1st snowpack (inches SWE) at the TV Ridge (top) and Moss Springs (bottom) snow course sites.

2.4 Streamflow

Figure 11 and Table 5 show streamflow gauges in Wallowa County, from which the data for eight were analyzed in Figure 12 through Figure 19. The gauges that were analyzed are shown in bold in Table 5 and were selected based on a combination of location and length of record.

For each stream gauge location analyzed, figures below show the following:

- Median daily flow
- 20% exceedence daily flow
- 80% exceedence daily flow
- Minimum daily flow
- Maximum daily flow
- Instream Water Right (ISWR) where applicable
- Timeseries trend of annual streamflow. Note, only years that have 350 or greater days of record are used were used in annual trends.

Overall streamflow conditions are described as follows (more detailed, site specific conditions are discussed after Table 5):

- Smaller, high elevation drainages have low winter streamflow (due to winter precipitaion falling as snow), rapidly increasing late summer flow coinciding with peak snowmelt, peak around June 1, and then rapidly decreasing flow.
- Larger, low elevation drainages are more flashy in the winter since they're more likely to have rain and rain-on-snow events.
- Instream water rights are met on the Wallowa River at Enterprise all the time. Instream water rights on the Wallowa River at Water Can are met except approximately 20 % of the time in August and September.
- Instream water rights on the Minam, Bear Creek, and Lostine are typically not met 50 % of the time in the winter, met April through July, and not met in August and September.
- All streamflow records (with the exception of the Imnaha River) show a trend of decreasing annual and summer (X-X) streamflow. Although some of these trends may be significant, one should use caution interpreting or extrapolating the trends as some are based on short period of record. Additionally, it is likely that decadal-scale climate variability (see Figure 6) is influencing the trends, and the area will shift back to a wet period in the future.
- Although analzed at only two locations (Lostine River near Lostine and Bear Creek near Wallowa), a slight trend was found that showed higher winter streamflows in the last 15 years versus in the 1920s and 1930. No trend was fond however that showed an earlier peak streamflow (snowmelt) as would be expected from climate change.

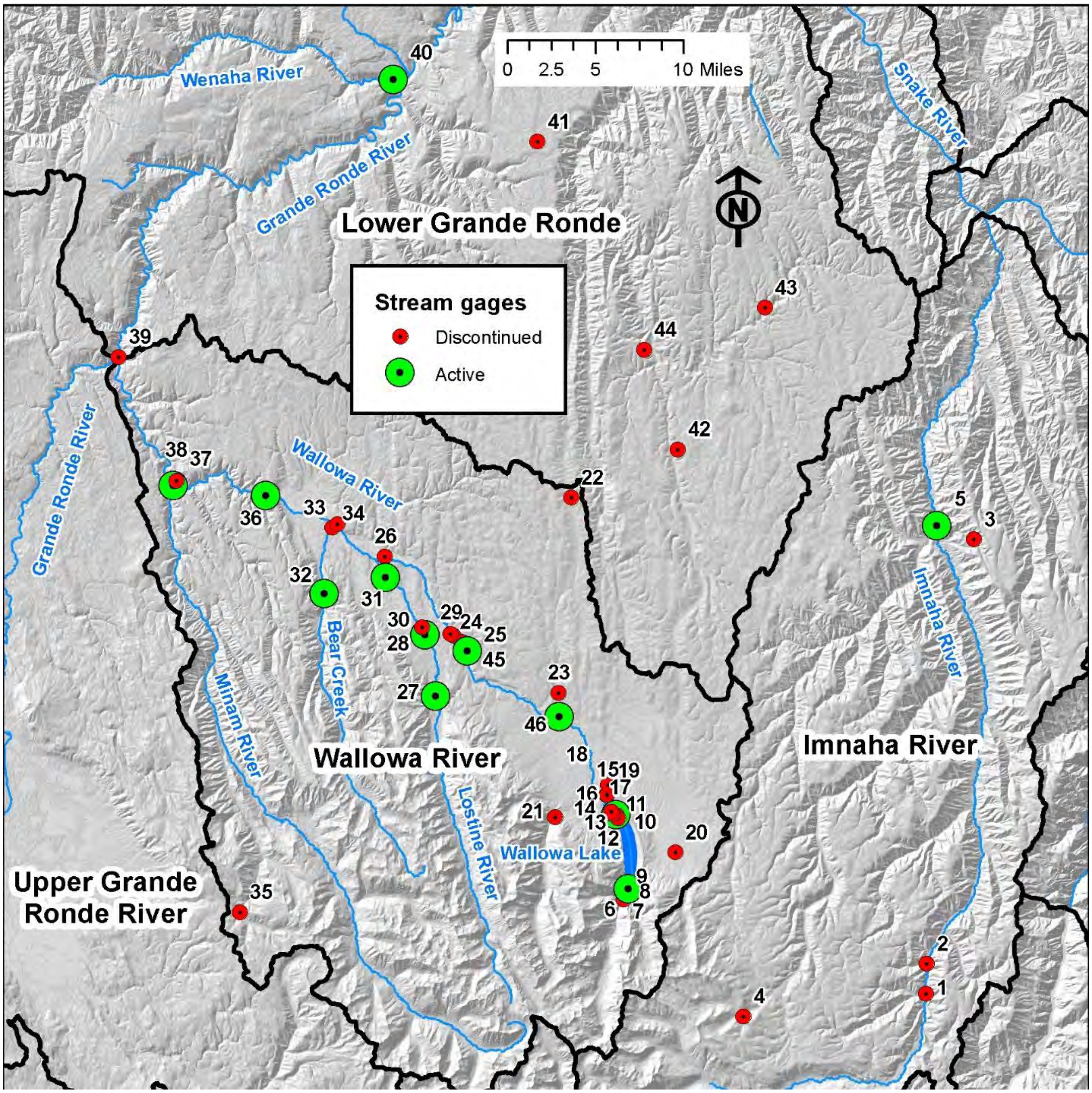


Figure 11. Stream gages within the project area.

Table 5. Stream gages within the project area.

Map ID	Station ID	Name	Type	Status	HUC4	From	To	MDF	Peak	Low	Notes	DA (mi2)	Elev (ft.)
1	13291000	Imnaha R Ab Gumboot Cr, Or	Runoff	Discontinued	17060102	10/1/1944	9/30/1953	9	9	9		99.6	3,813
2	13291200	Mahogany Cr Nr Homestead, Or	Runoff	Discontinued	17060102	4/30/1965	5/15/1975	0	10	0		4	3,740
3	13291400	Deer Cr Nr Imnaha, Or	Runoff	Discontinued	17060102	4/30/1965	4/5/1979	0	10	0		1.73	3,760
4	13291500	Big Sheep Cr Nr Joseph, Or	Unknown	Discontinued	17060102	-	-	0	0	0		12.5	6,100
5	**13292000**	**Imnaha R at Imnaha, Or**	**Runoff**	**Active**	**17060102**	**10/1/1928**	**present**	**83**	**79**	**79**		**622**	**1,941**
6	13324500	Wallowa Falls Pp Tailrace Nr Joseph, Or	Other	Discontinued	17060105	9/1/1924	9/30/1983	45	0	0		-	-
7	13325000	E Fk Wallowa R Nr Joseph, Or	Runoff	Discontinued	17060105	8/1/1924	9/30/1983	50	58	49		10.3	4,518
8	13325001	E Fk Wallowa R + Pp Tailrace Nr Joseph, Or	Runoff	Discontinued	17060105	10/1/1924	9/30/1983	59	1	1		-	-
9	**13325500**	**Wallowa R Ab Wallowa Lake Nr Joseph, Or**	**Runoff**	**Active**	**17060105**	**2/1/1924**	**present**	**11**	**13**	**10**		**43**	**4,400**
10	13326000	Wallowa Lake Nr Joseph, Or	Other	Active	17060105	7/1/2015	present	0	0	0	Reservoir stage	50.8	4,356
11	13326500	Joseph Powerplant Tailrace at Joseph, Or	Other	Discontinued	17060105	11/24/1929	7/31/1956	25	0	0		-	-
12	13327000	Silver Lake Ditch at Joseph, Or	Other	Discontinued	17060105	5/7/1926	8/13/1991	52	0	0		-	-
13	13327500	Wallowa R at Joseph, Or	Runoff	Discontinued	17060105	11/1/1903	9/30/1991	61	75	60		50.9	4,327
14	13328000	Farmers Cn At Joseph, Or	Other	Discontinued	17060105	4/17/1926	9/30/1989	62	0	0	Irrigation season only	-	-
15	13328500	Big Bend Cn At Joseph, Or	Other	Discontinued	17060105	5/23/1926	9/30/1989	62	0	0	Irrigation season only	-	-
16	13329000	Granger Cn At Joseph, Or	Other	Discontinued	17060105	5/3/1926	9/30/1989	62	0	0	Irrigation season only	-	-
17	13329010	Granger Lat Nr Joseph, Or	Other	Discontinued	17060105	6/1/1937	9/30/1979	42	0	0	Irrigation season only	-	-
18	13329020	Creighton Lat Nr Joseph, Or	Unknown	Discontinued	17060105	5/18/1937	9/30/1979	42	0	0	Irrigation season only	-	-
19	13329030	Dobbin Lat Nr Joseph, Or	Other	Discontinued	17060105	6/1/1937	9/30/1979	42	0	0	Irrigation season only	-	-
20	13329200	Prairie Cr Nr Joseph, Or	Unknown	Discontinued	17060105	-	-	0	0	0	Water quality site?	-	-
21	13329500	Hurricane Cr Nr Joseph, Or	Runoff	Discontinued	17060105	5/1/1915	9/30/1978	54	56	54		29.6	4,500
22	13329700	Trout Cr Trib Nr Chico, Or	Runoff	Discontinued	17060105	5/16/1967	2/21/1982	0	16	0		0.26	4,340
23	13329750	Trout Cr Trib At Enterprise, Or	Runoff	Discontinued	17060105	6/15/1967	1977	0	11	0		4.38	3,730
24	13329770	Wallowa R Ab Cross Country Cn Nr Enterprise, Or	Runoff	Discontinued	17060105	4/28/1995	6/24/2009	13	13	10		272	3,330
25	13329800	Wallow R Nr Lostine, Or	Unknown	Discontinued	17060105	7/13/1925	9/30/1925	0	0	0		-	-
26	13329900	Wallowa R at Wallowa, Or	Unknown	Discontinued	17060105	-	-	0	0	0		-	-
27	**13330000**	**Lostine R Nr Lostine, Or**	**Runoff**	**Active**	**17060105**	**9/1/1912**	**present**	**84**	**84**	**79**		**70.9**	**3,650**
28	13330050	Lostine R at Caudle Lane at Lostine, Or	Runoff	Active	17060105	8/1/1995	present	9	10	7		81.1	-
29	13330100	Cross Country Cn Nr Lostine, Or	Other	Discontinued	17060105	5/20/1974	9/30/1986	13	0	0	Irrigation season only	-	-
30	13330200	Lostine R at Lostine, Or	Unknown	Discontinued	17060105	-	-	0	0	0		-	-
31	13330300	Lostine R at Baker Rd, Nr Lostine, Or	Runoff	Active	17060105	6/1/1995	present	20	20	12		91.7	3,050
32	**13330500**	**Bear Cr Nr Wallowa, Or**	**Runoff**	**Active**	**17060105**	**4/1/1915**	**present**	**80**	**81**	**73**		**68**	**3,250**
33	13330700	Bear Cr At Wallowa, Or	Unknown	Discontinued	17060105	5/9/1995	9/30/2003	8	8	8		72.8	2,900
34	13331000	Wallowa R Nr Wallowa, Or	Unknown	Discontinued	17060105	-	-	0	0	0		-	-
35	13331400	Little Minam R Nr Cove, Or	Runoff	Discontinued	17060105	6/16/1938	9/30/1943	3	2	2		-	-
36	**13331450**	**Wallowa R Bl Water Can, Nr Wallowa, Or**	**Runoff**	**Active**	**17060105**	**8/16/1995**	**present**	**17**	**17**	**12**		**628**	**2,760**
37	**13331500**	**Minam R Nr Minam, Or**	**Runoff**	**Active**	**17060105**	**6/1/1912**	**present**	**49**	**43**	**43**		**240**	**2,540**
38	13332000	Wallowa R at Minam, Or	Unknown	Discontinued	17060105	11/1/1903	3/31/1914	5	9	5		880	2,520
39	13332500	Grande Ronde R at Rondowa, Or	Runoff	Discontinued	17060106	10/1/1926	3/5/1996	68	69	70		2555	2,282
40	**13333000**	**Grande Ronde R at Troy, Or**	**Runoff**	**Active**	**17060106**	**10/1/1944**	**present**	**69**	**63**	**63**		**3275**	**1,586**
41	13333050	Buford Cr Nr Flora, Or	Runoff	Discontinued	17060106	5/15/1967	2/19/1981	0	14	0		0.47	-
42	13333090	Crow Cr Nr Lewis, Or	Unknown	Discontinued	17060106	-	-	0	0	0		-	-
43	13333100	Doe Cr Nr Imnaha, Or	Runoff	Discontinued	17060106	4/30/1965	5/5/1979	0	15	0		5.49	3,750
44	13333500	Joseph Cr At Chico, Or	Unknown	Discontinued	17060106	-	-	0	0	0		280	3,190
45	**13329765**	**Wallowa R Nr Enterprise**	**Runoff**	**Active**	**17060105**	**10/21/2008**	**present**	**6**	**6**	**0**		**261**	**-**
46	13329100	Wallowa R at Enterprise	Runoff	Active	17060105	10/21/2015	present	0	0	0		-	3,745

Analysis of the individual streamflow records shows the following:

Wallowa River above Wallowa Lake:

- Streamflow record is listed as 1924-present, however it only contains 13 full years of record, with most data in the 1920s and 1930s. The gauge has been reactivated in 2014 and is now collecting data again.
- Streamflow is fairly constant (min/max range of 20 cfs) and low from November through March due to most precipitation falling as snow in its contributing area.
- Streamflow increases around April 1 due to lower elevation snow melt, with the upper elevations continuing to melt through June (see preceeding SNOTEL plots).
- Streamflow is highly variable in the summertime, with June low flows of 110 cfs and June high flows of 710 cfs.
- No instream water right exists for the reach.

Wallowa River near Enerprise:

- Streamflow is around 150 cfs in the winter and 400-600 during summer snowmelt.
- The typical range of streamflow (20/80 percentile) is small September through April due to being outside of snowmelt season and the effects of upstream storage.
- Average annual and average summer (calculated as July through September) streamflow show a declining trend over the period of record, with the summer streamflow decreases more than the overall annual streamflow.
- Streamflow has not dropped below the instrem water right for the period of record.

Wallowa River below Water Can:

- Streamflow during the winter has greater range (typically 200-500 cfs, with floods to 3,500 cfs) than upstream locations, likley due to additional lower elevation drainage area.
- Average annual and average summer streamflow show a declining trend over the period of record.
- Streamflow typically does not drop below the Instrem Water Right during the winter (except occasionally at the end of March), but does drop below it over 20% of the time in August.

Lostine River near Lostine:

- Streamflow is typically 30-70 cfs in the winter (with short duration isolated flood events up to 1,000 cfs) and approximately 700 cfs during peak snowmelt in June.
- The Lostine near Lostine has one of the longest, most complete streamflow records and shows no increasing or decreasing trend.
- The instream water right is not met most of the time during September, met roughly 50 % of the time in the winter, and is almost always exceeded in May through July.

Bear Creek near Wallowa:

- Bear Creek has a greater range of winter streamflow than other locations upstream, likely due to the lower elevation of it's drainage area.
- Bear Creek shows a slight decreasing trend in annual average streamflow, however this trend is likely influenced by a single year of high streamflow early in the record.
- The instream water right is not met a majority of the time in August through November, met roughly 50 % of the time November through February, and almost always exceeded in April through July.

Minam River near Minam:

- The Minam River near Minam has typical winter streamflows of 100-200 cfs, with occasional flood events of 1,000 and greater. Summer median streamflows are 1,500 cfs during peak snowmelt and receed quickly to below 200 cfs by August.
- Annual average and summertime streamflow show a small (likely statistically insignificant) decreasing trend.
- The instream water right is not met over 50 % of the time in September and October, not met approximately 20 % of the time in the winter, and exceeded in April through July 15.

Imnaha River at Imnaha:

- The Imnaha River has a typical winter streamflow between 120 and 250 cfs, and early summer streamflow of 1,000 to 2,000 cfs.
- The instream water rigth is typically always met with only a handful of late summer and winter days having less than the 85 cfs water right.
- Annual average and summertime streamflow show a small (likely statistically insignificant) increasing trend.

Grande Ronde at Troy:

- The Grande Ronde at Troy has late summer streamflow around 700 cfs, winter streamflows in the 1,000-2,000 cfs range, early summer flows around 7,000 cfs, and rapidly decreasing late summer streamflow. In December through June it has occasional large flood events with streamflow over 15,000 cfs which are typically caused by rain on snow events.
- Annual average and summertime streamflow show a decreasing trend.
- The instream water right of 420 cfs is met in all but a handful of days in late summer and early winter. This instream water right is senior (priority date of May 6,1961) to many irrigation water rights, and hence days the water right was not met in the late summer were likely due to a lag time on regulating junior water right holders.

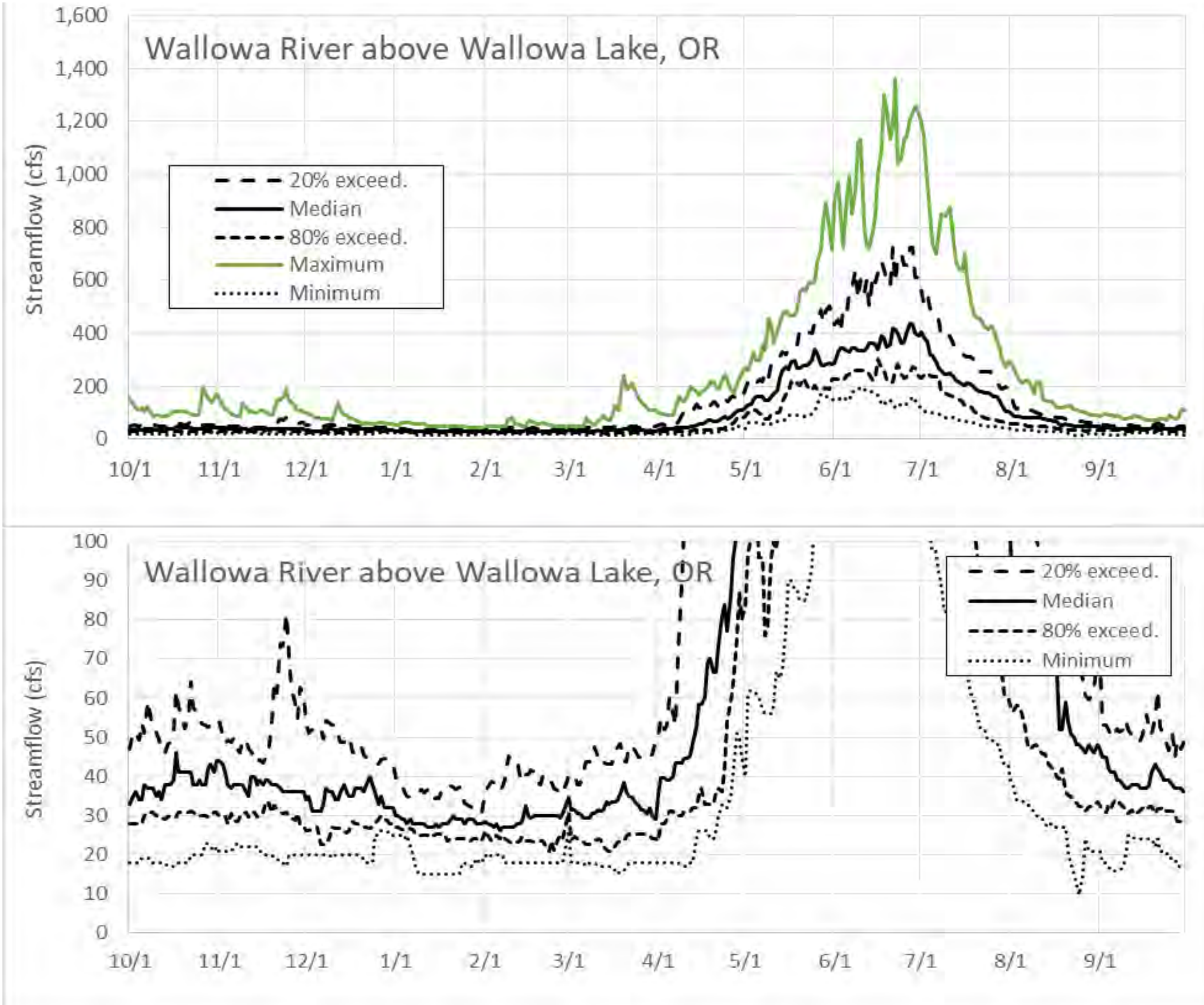


Figure 12. Streamflow characteristics for Wallowa River above Wallowa Lake.

No figure available for timeseries trend of annual streamflow due to intermitten period of streamflow record

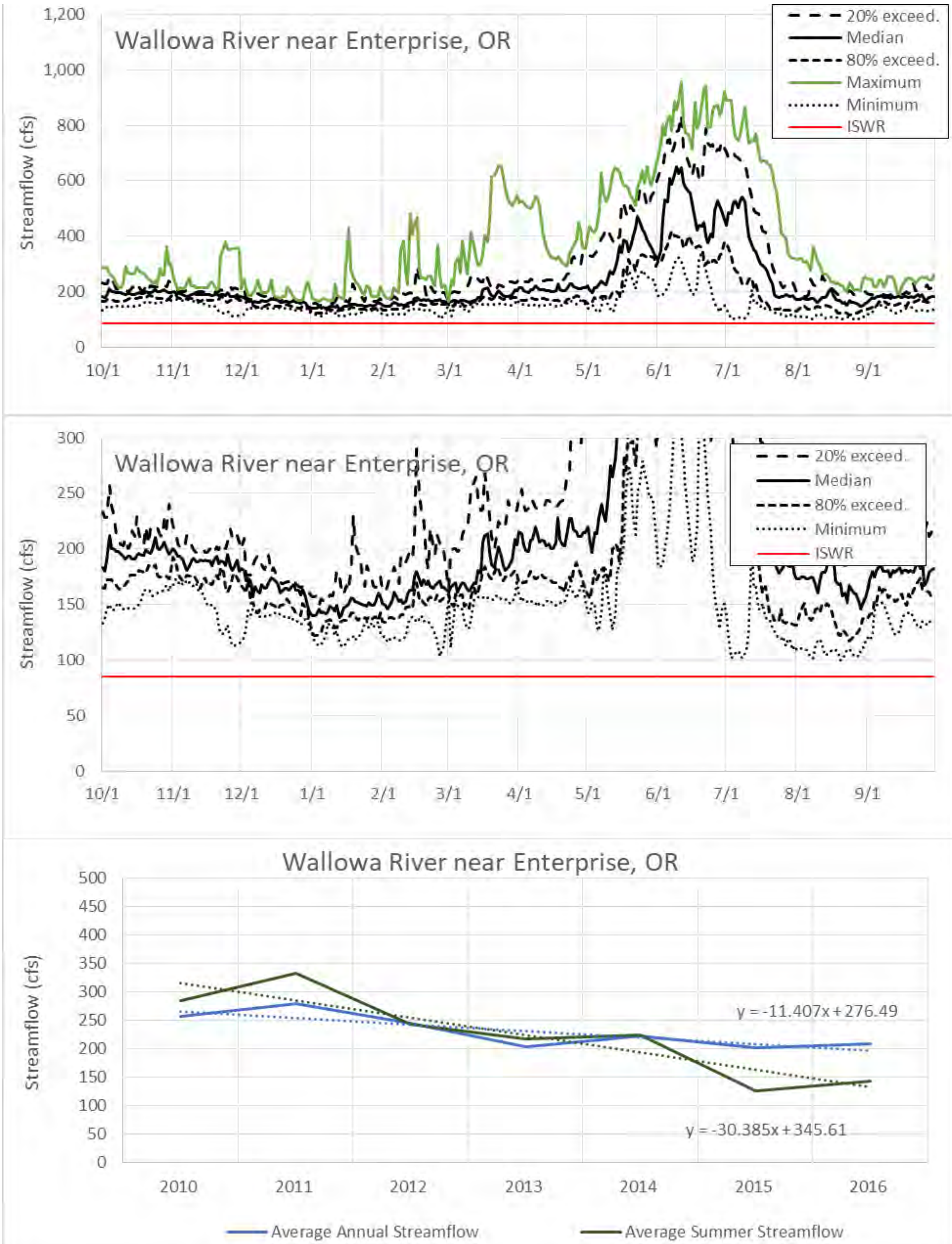


Figure 13. Streamflow characteristics for Wallowa River near Enterprise.

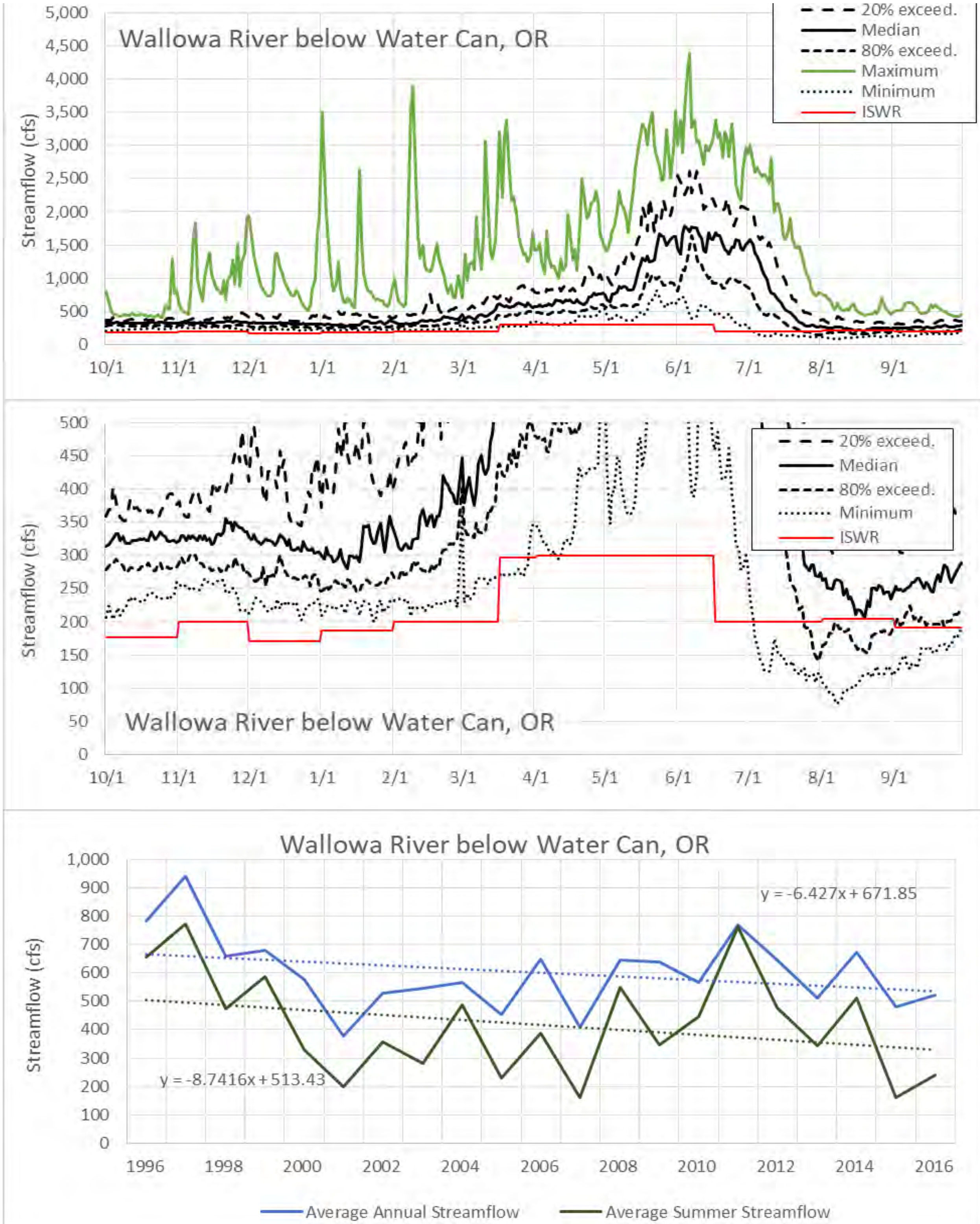


Figure 14. Streamflow characteristics for Wallowa River below Water Can.

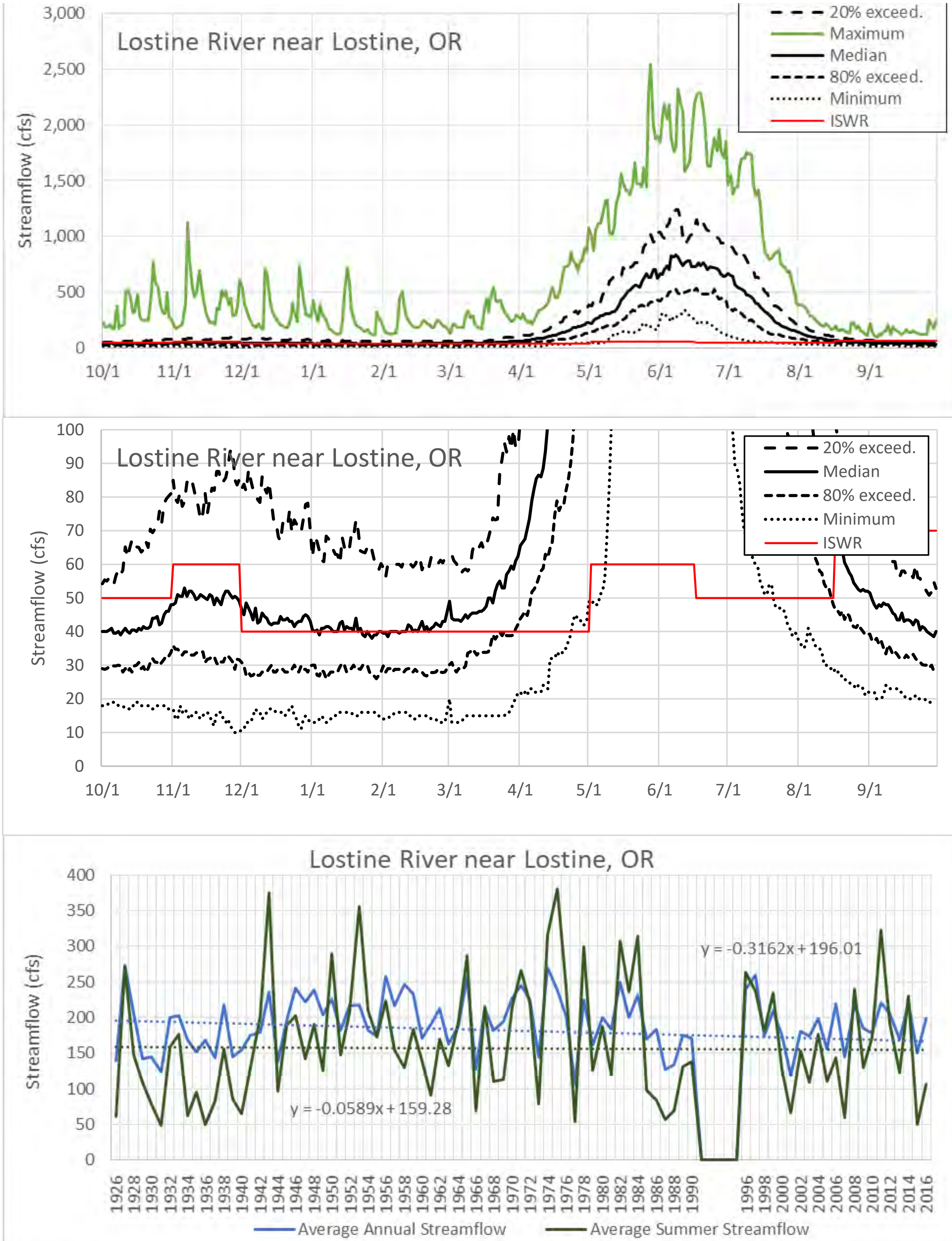


Figure 15. Streamflow characteristics for Lostine River near Lostine.

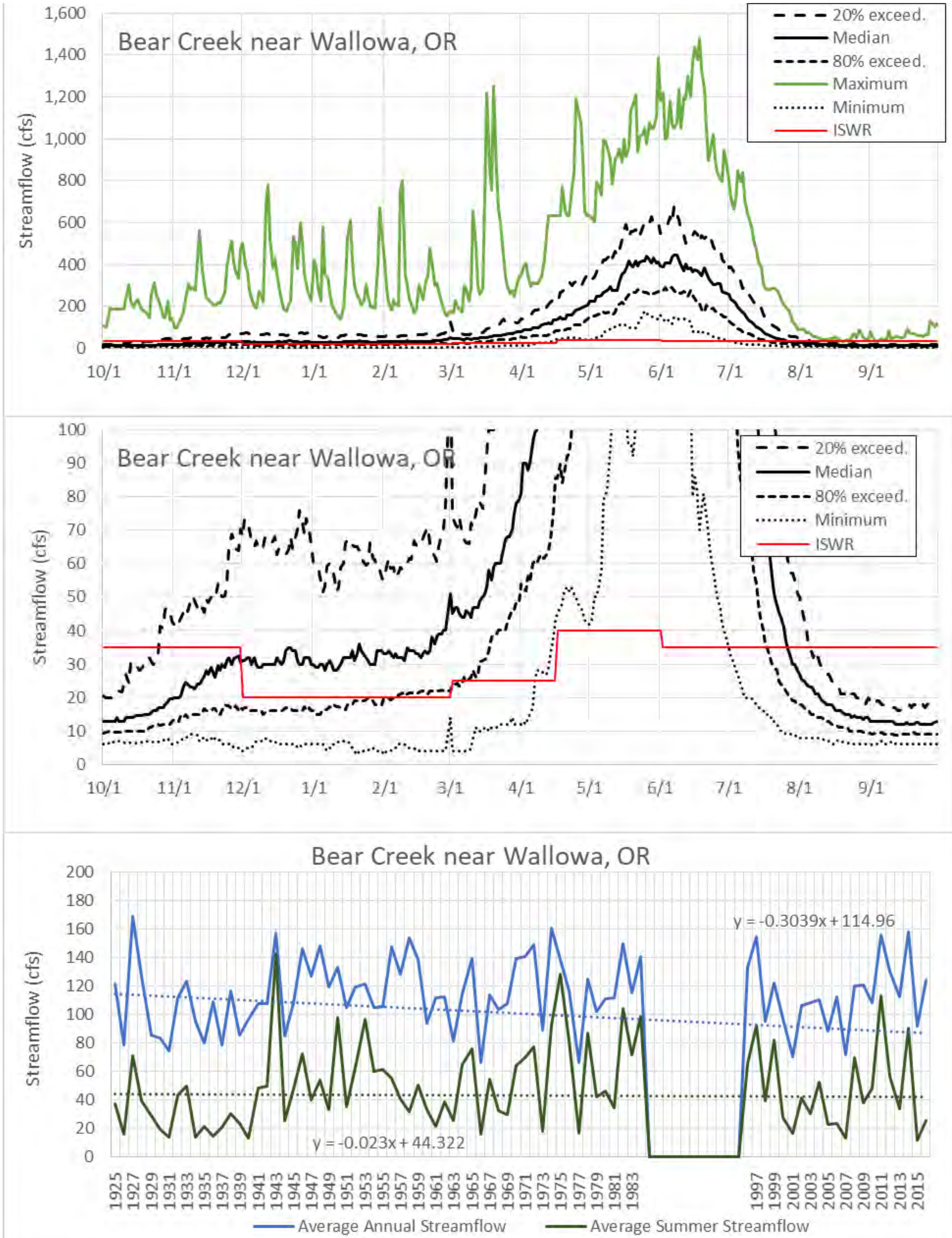


Figure 16. Streamflow characteristics for Bear Creek near Wallowa.

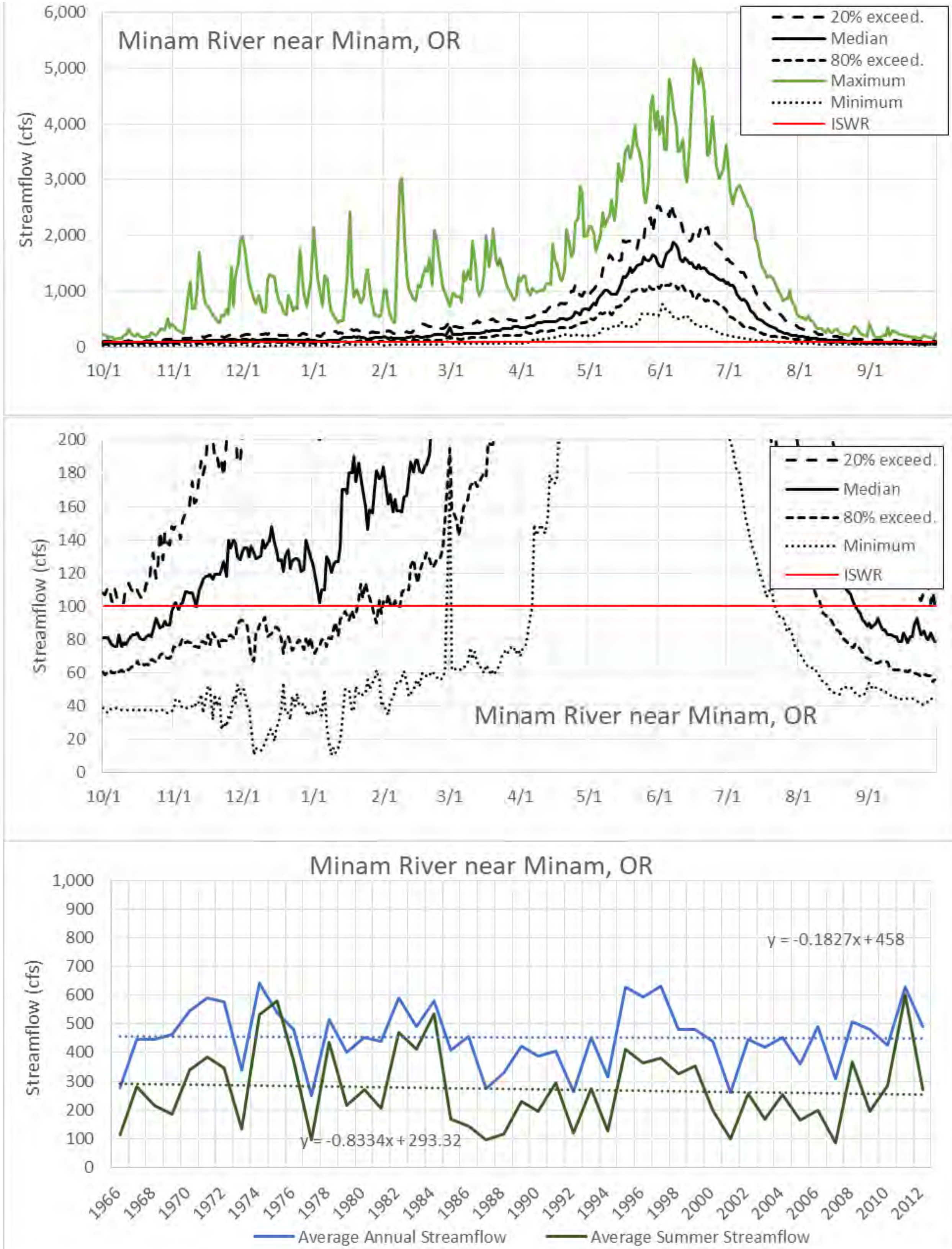


Figure 17. Streamflow characteristics for Minam River near Minam.

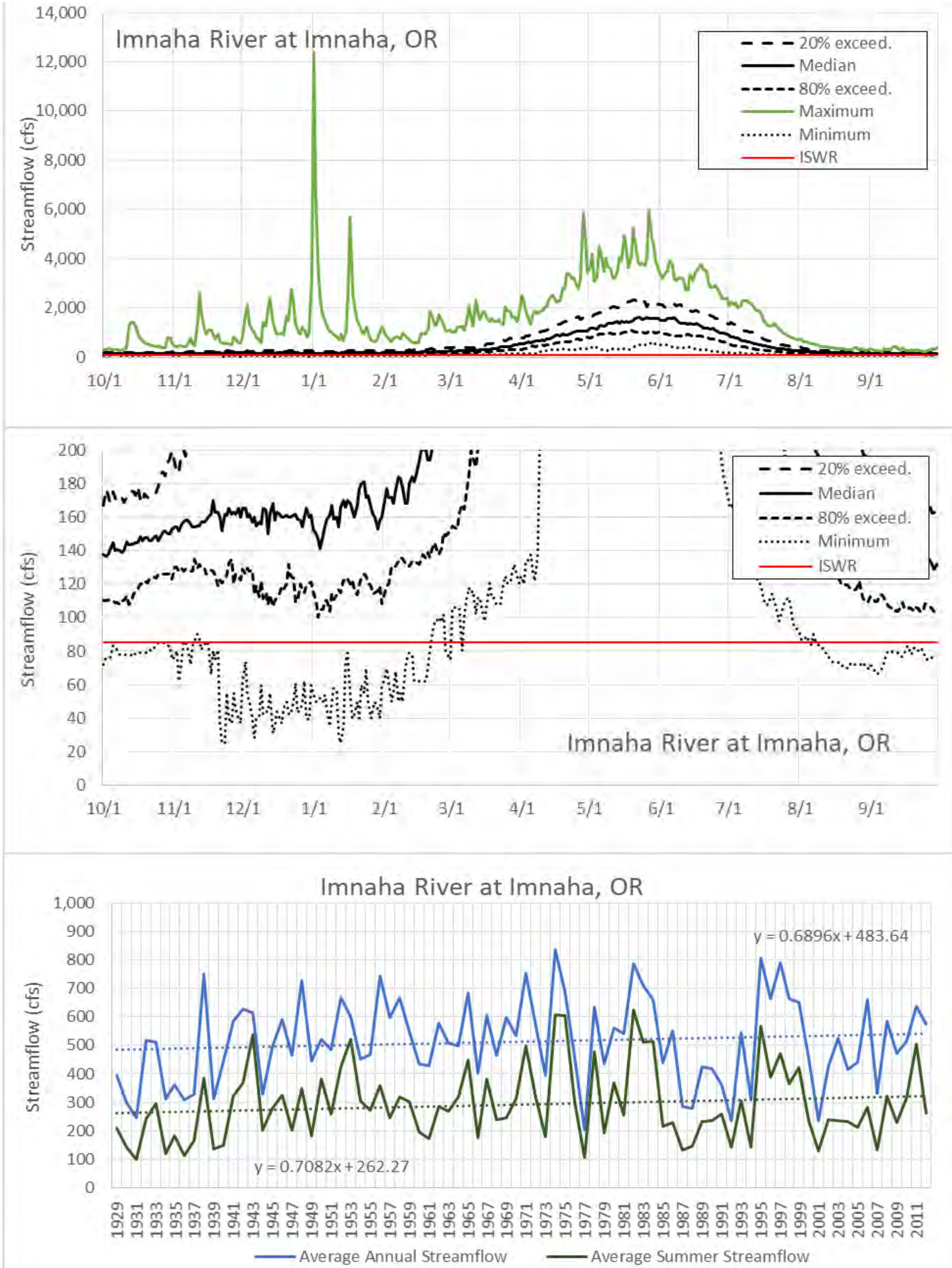


Figure 18. Streamflow characteristics for Imnaha River at Imnaha.

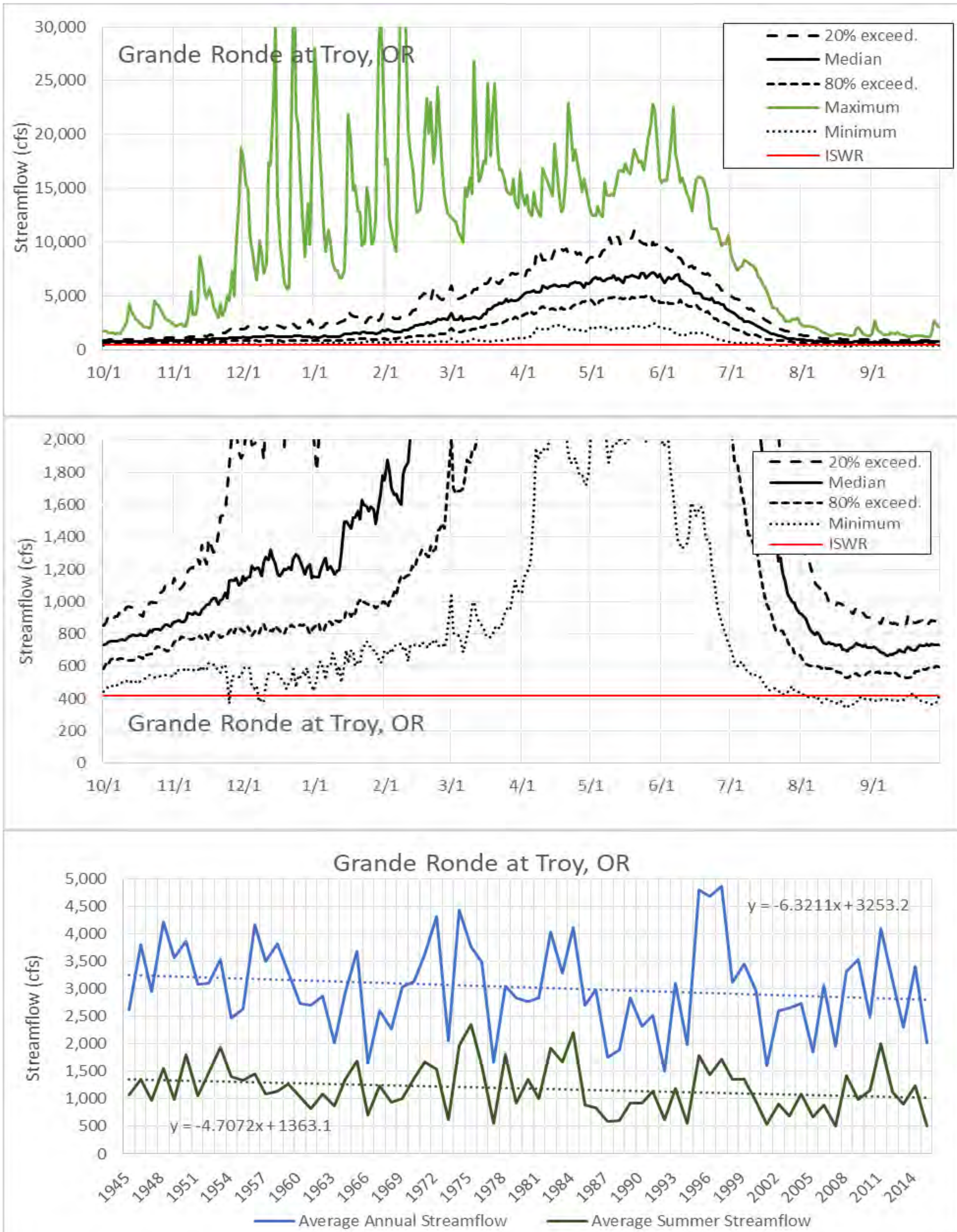


Figure 19. Streamflow characteristics for Grande Ronde near Troy.

2.5 Reservoir Storage

Wallowa Lake has storage capacity of 42,750 acre-feet (AF) at the spillway (Figure 20) but is subject to two restrictions that reduce the amount of water it can store. In 1961 the Milton Box company sued the dam operators for 'water trespass' which resulted in the loss of the top six feet of storage, and then in 1978 an additional six feet of storage was lost to dam safety concerns. Recent engineering studies have evaluated the cost and feasibility of addressing safety concerns and restoring the lost storage volume. A cross-section of the dam is shown in Figure 21 from one such study (MWH, 2002).

Figure 22 below show the monthly (maximum, minimum, median, and 20/80 percentiles) and annual timeseries trends of storage volume. Storage is typically at its lowest around October 1 with a median storage of 12,000 AF, and peaks in July with storage just over 30,000 AF. Additional discussion on the effects of precipitation, temperature, and snowpack on Wallowa Lake storage volume is presented in Section 2.6.3.

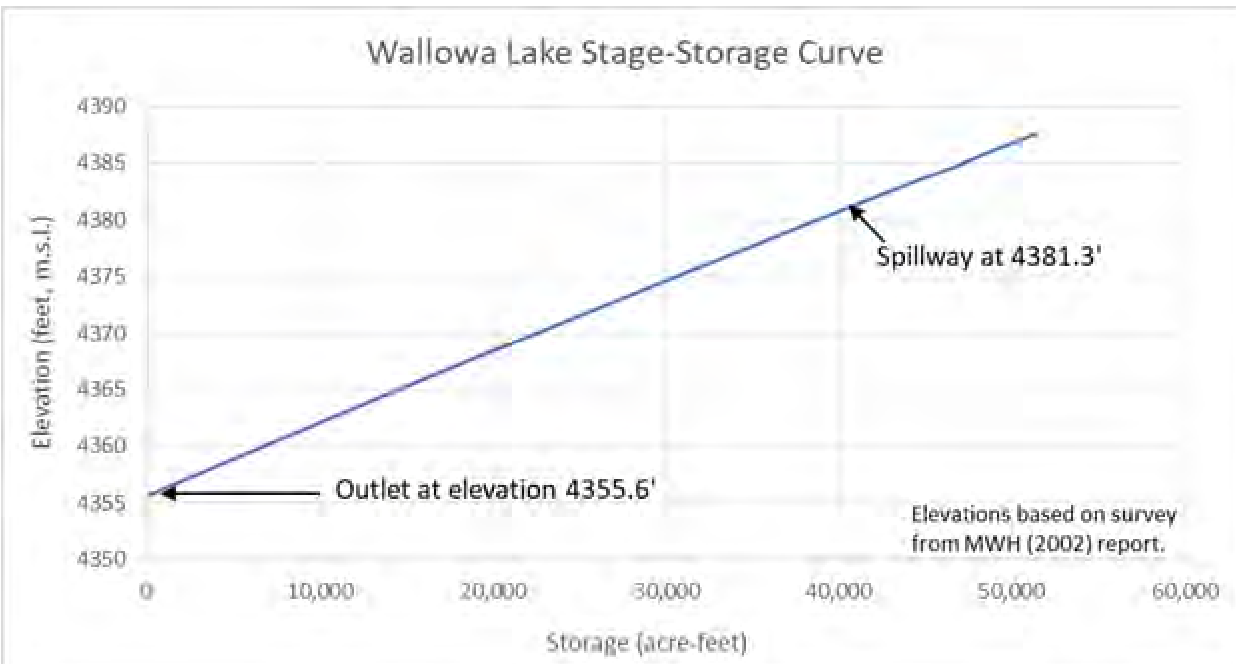


Figure 20. Stage-storage curve for Wallowa Lake Dam (MWH, 2002).

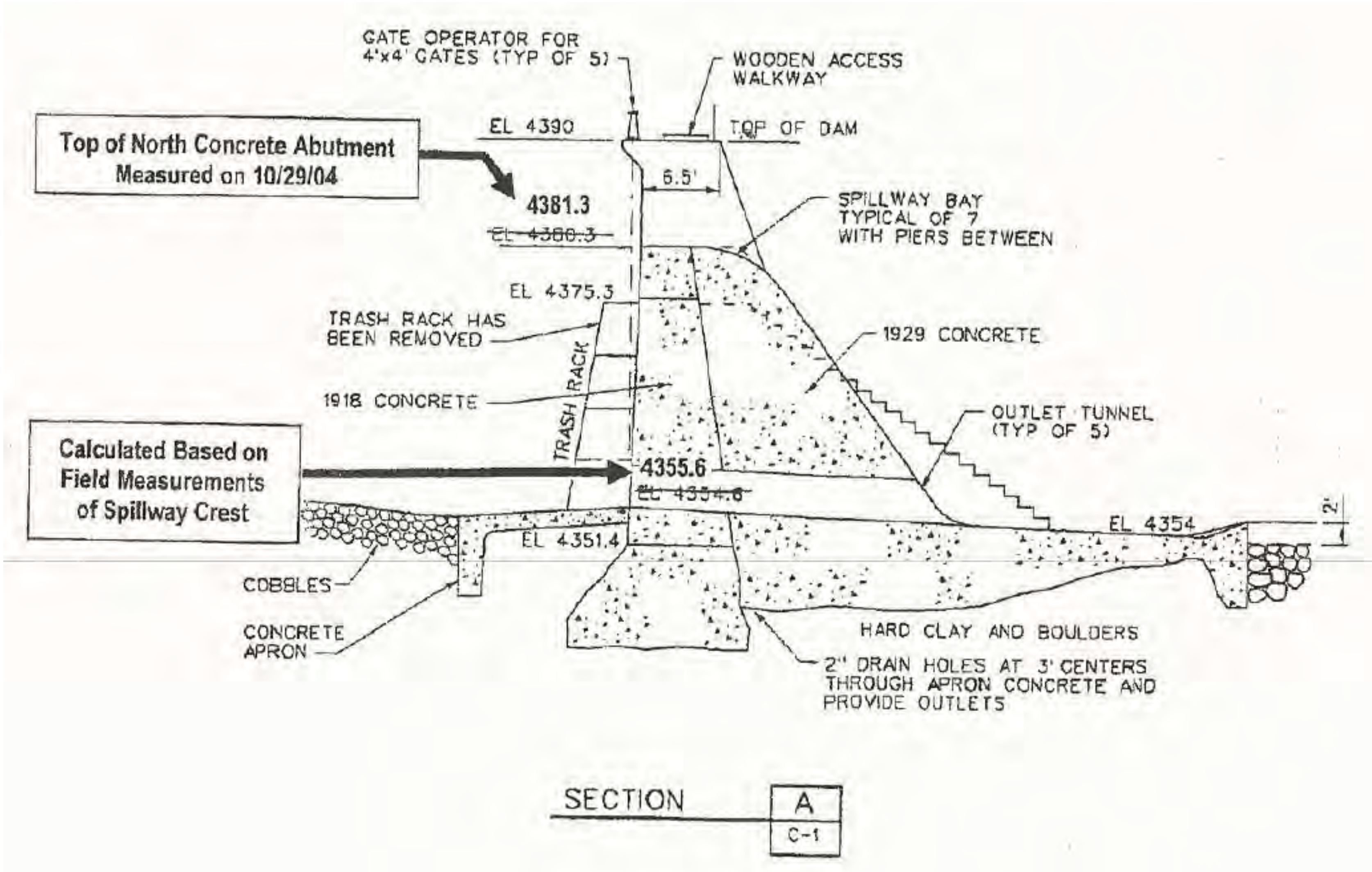


Figure 21. Cross-section of Wallowa Lake Dam (MWH, 2002).

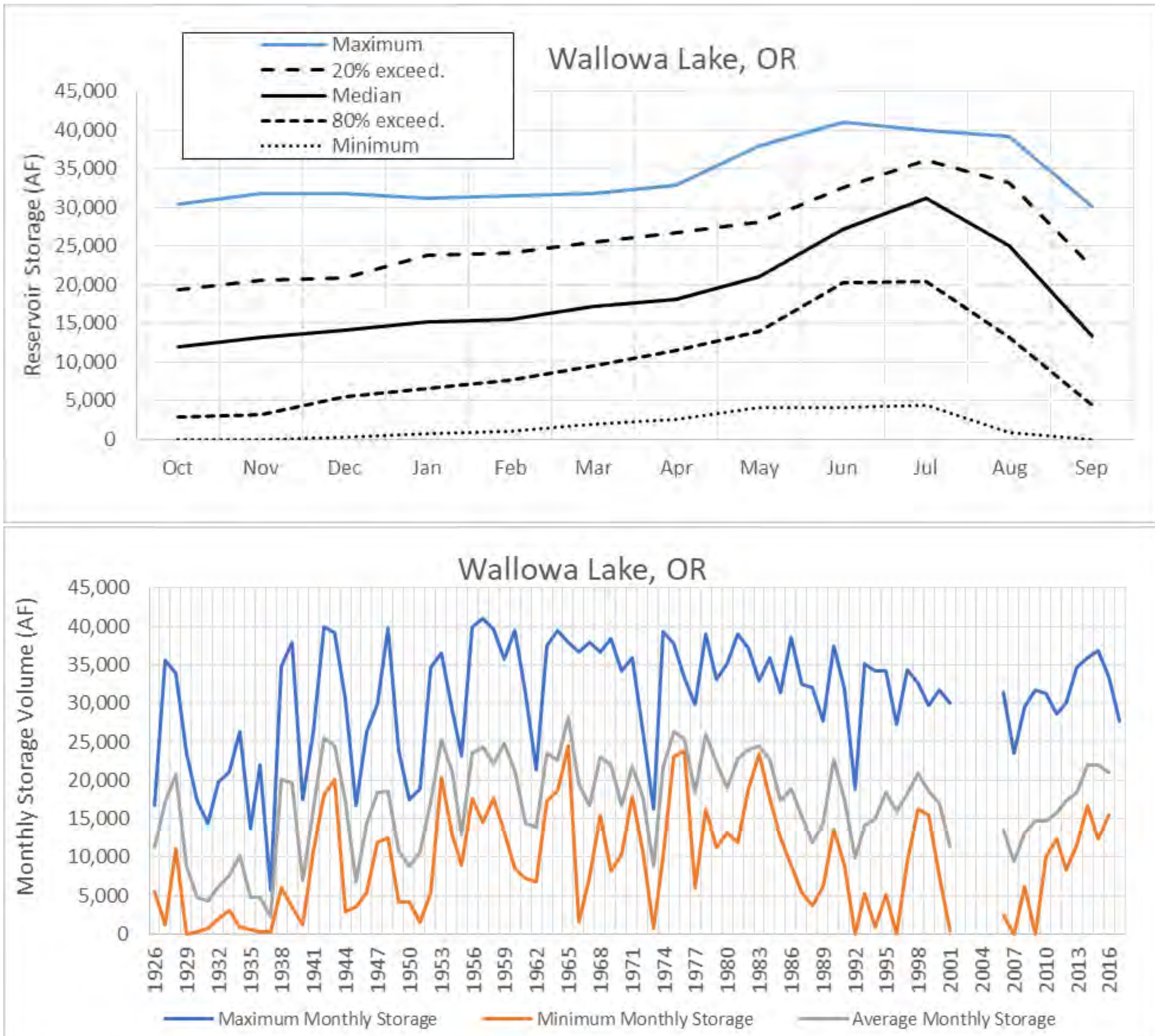


Figure 22. Storage characteristics for Wallowa Lake.

2.6 Precipitation, temperature, snowpack, runoff, and reservoir storage relationships

2.6.1 Relationships between precipitation, temperature, and snowpack

Figure 23 to Figure 29 below show the relationship (or lack of relationship) between precipitation, temperature, snowpack, runoff, and reservoir storage. Although the figures are not definitive, and some relationships may be improved with additional data analysis (e.g., the precipitation value is from the Wallowa NCDC station, not from the SNOTEL site), general conclusions include:

- There appears to be a slight inverse relationship between annual temperature and annual precipitation (Figure 23, top), with lower annual temperature typically coinciding with wetter years. The relationship does not hold if looking just at winter (defined as November through March) temperature and precipitation (Figure 24, top), hence one can conclude summer is the driving factor, with warmer summers typically having less precipitation (and vice versa).
- Not surprisingly, wetter years (Figure 23, middle), as well as wetter winters (Figure 24, middle), are associated with higher April 1 snowpack.
- Not as strong as a relationship as between precipitation and snowpack, but there also appears a slight trend with colder years (Figure 23, bottom) being associated with greater snowpack, and even less of a trend (but possible still discernable) with winter temperatures and April 1 snowpack.

Based on the relationships in Figure 23 and Figure 24 (discussed above), a regression analysis was completed trying to predict observed April 1 snowpack based on winter temperature and precipitation. Figure 25 (top) shows the quality (i.e. predictive ability) of the regression based on winter precipitation only, and Figure 25 (bottom) shows regression results based on both winter temperature and precipitation. As is evident from the lack of improvement between the top and bottom figure (as well as the large p-value for the temperature variable), the regression fit does not improve with the addition of the temperate variable. Additionally, although the regression shows the ability to generally predict April 1 snowpack, it under-predicts in high snowpack years and over-predicts in low snowpack years. Although beyond the scope of this report, it's likely that modifying the input parameters (e.g., using different stations, log-transforming the data) would improve the regression fit for low and high snowpack years.

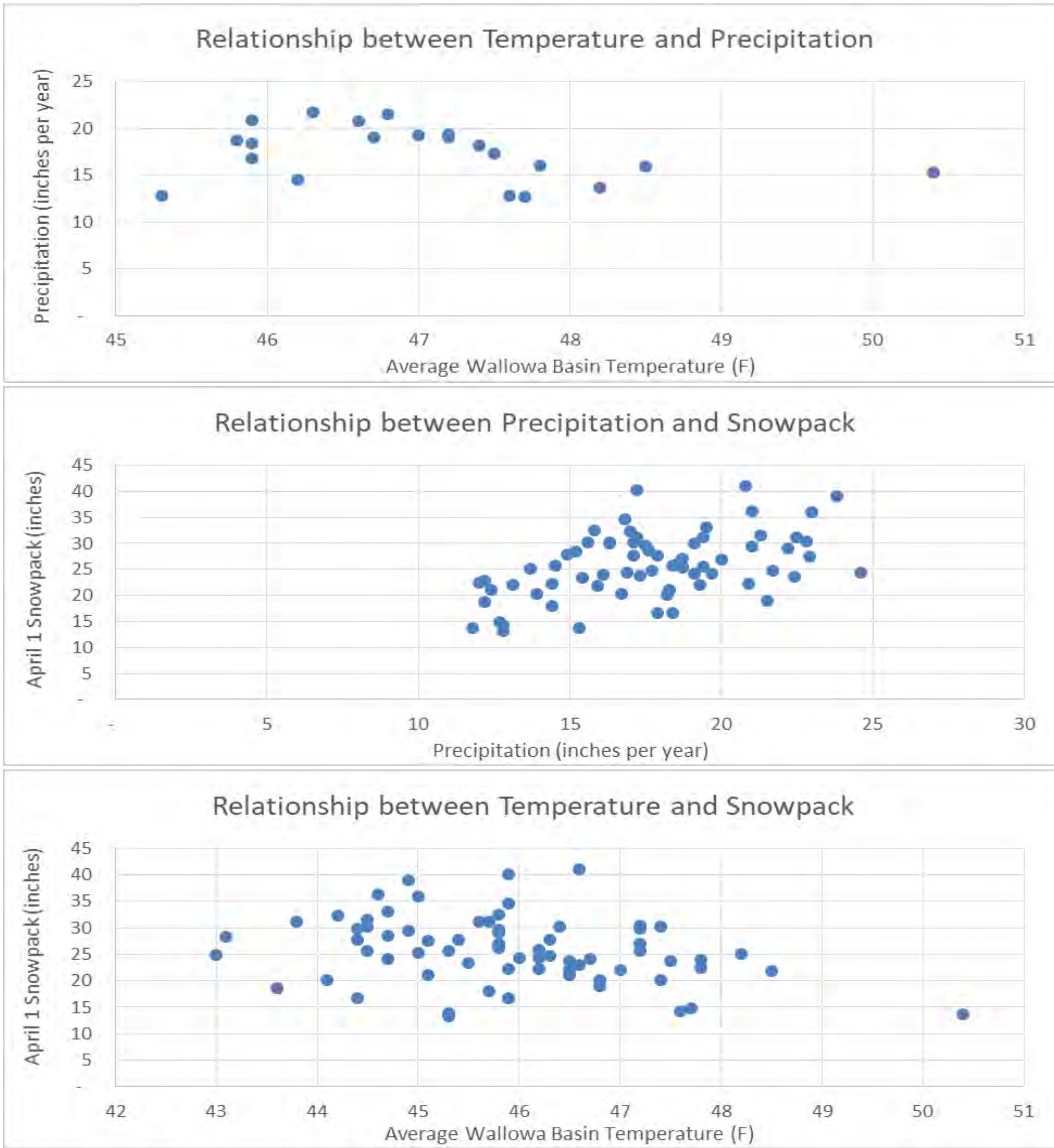


Figure 23. Relationship between temperature, precipitation, and snowpack.

Figures below based on <u>winter</u> precipitation and <u>winter</u> temperature.

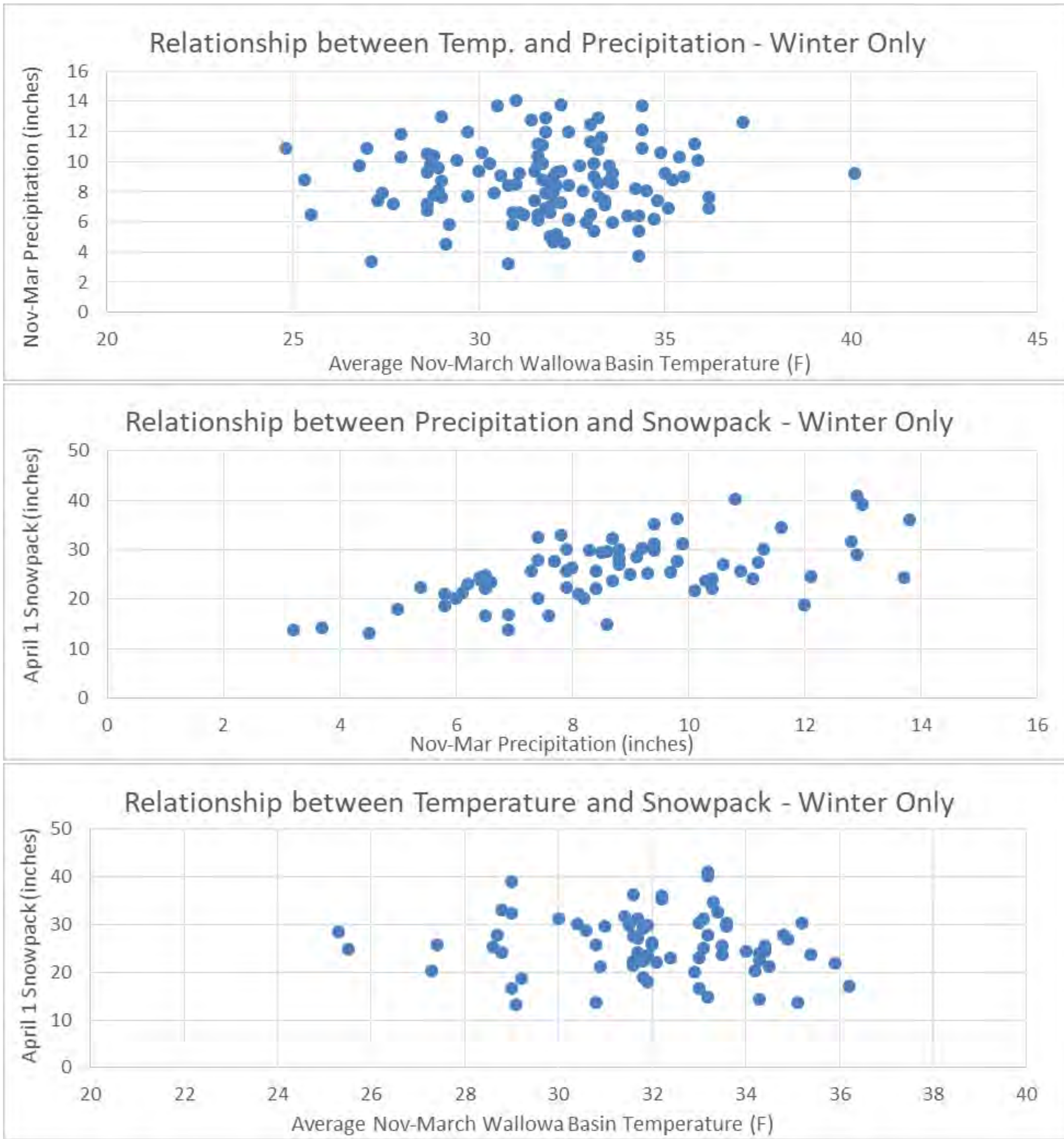


Figure 24. Relationship between winter temperature, winter precipitation, and snowpack.

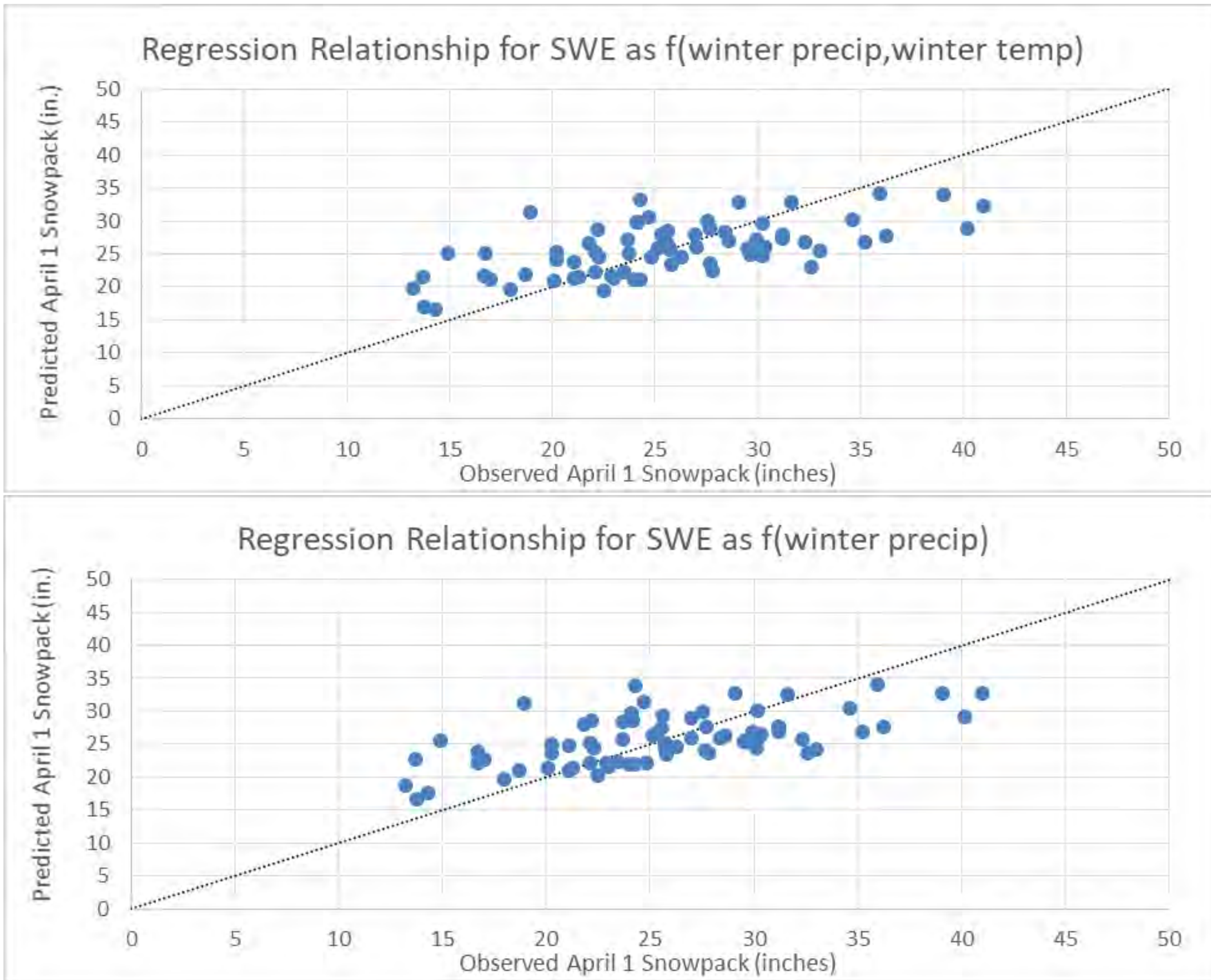
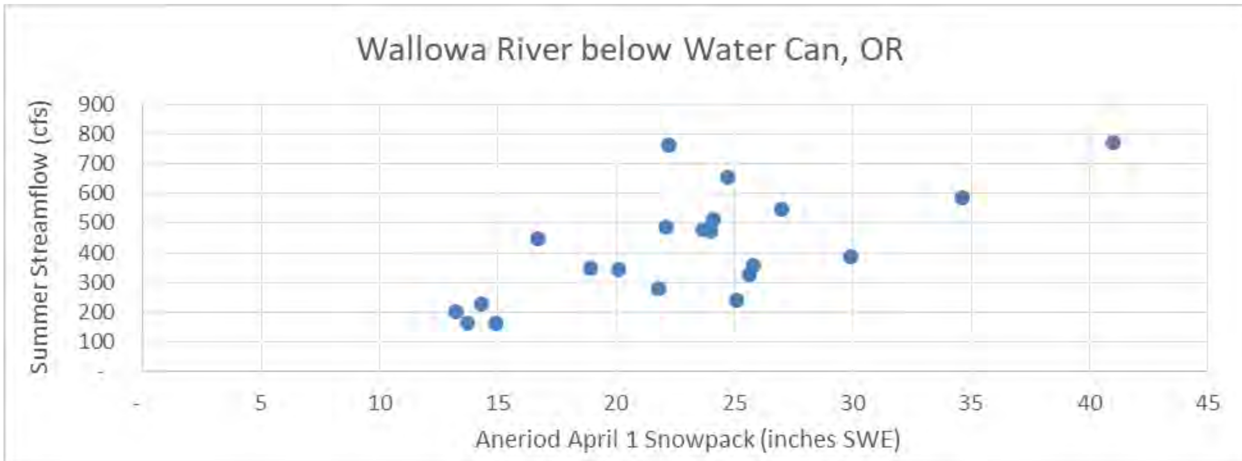
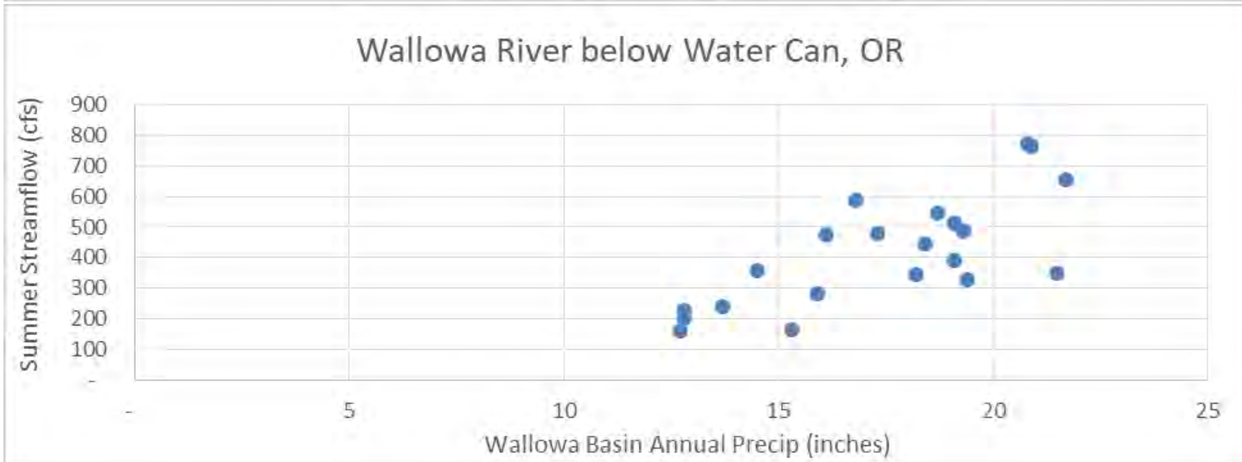


Figure 25. Regression fits for April 1 snowpack based on temperature and precipitation.

2.6.2 Relationship between Precipitation, Temperature, Snowpack, and Runoff

Information from the previous section is combined with Wallowa River and Lostine River summer streamflow (summer defined as July through September) below. For the Wallowa River, as expected, higher summer streamflow is correlated with higher snowpack (Figure 26, top), higher annual precipitation (Figure 26, middle), and lower basin temperatures (Figure 26, bottom). Regression relationships for Wallowa River summer streamflow based on the above variables are shown in Figure 27, from which it is evident that summer streamflow is highly dependent on the input variable, and hence the streamflow can be predicted with some degree of certainty. Similar relationships also hold for the Lostine River (Figure 28 and Figure 29) though the regression's predictive ability is not as good in high streamflow years.





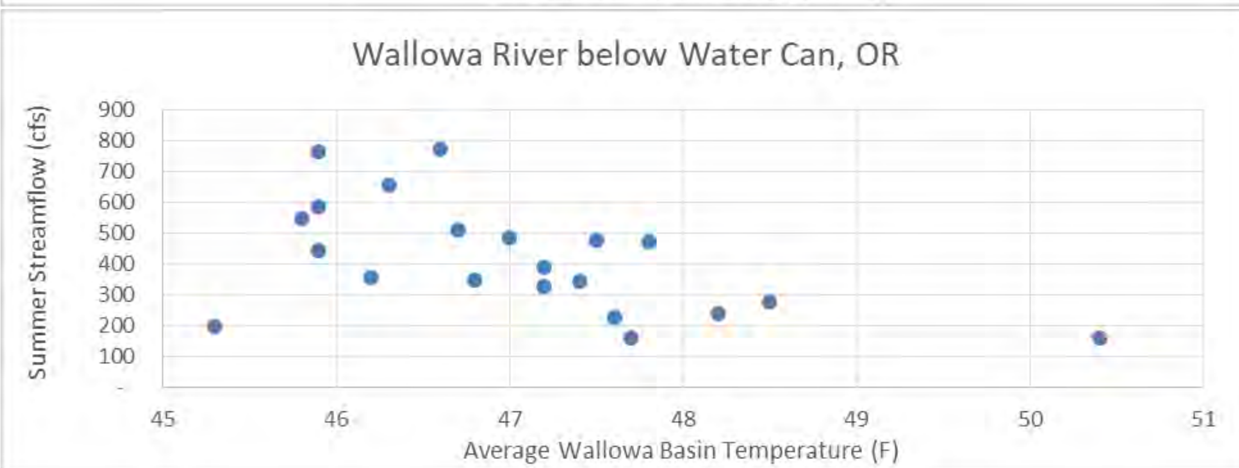


Figure 26. Relationship between Wallowa River streamflow and temperature, precipitation, and snowpack.

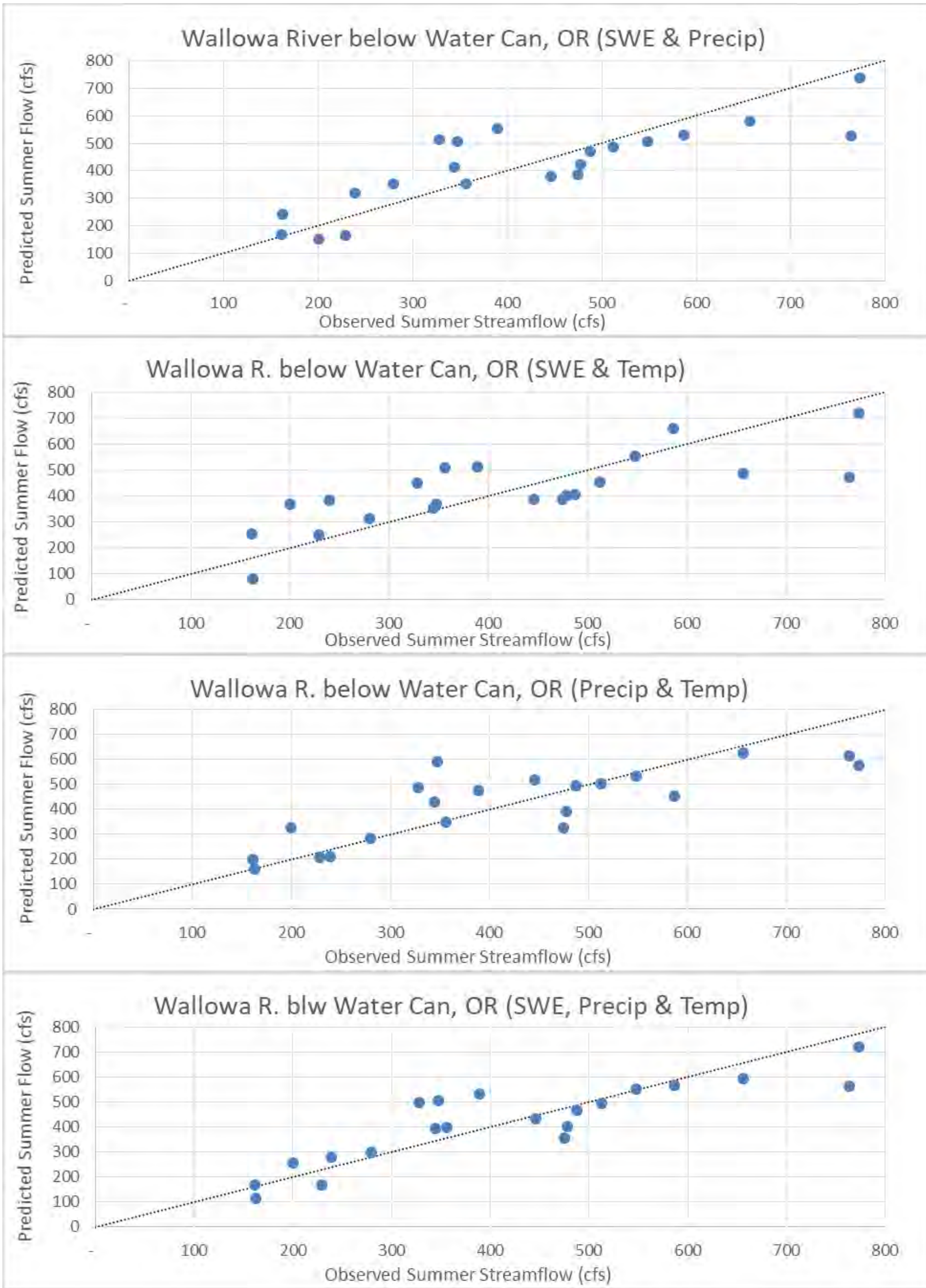


Figure 27. Regression fits for Wallowa River summer streamflow based on precipitation, temperature, and snowpack.

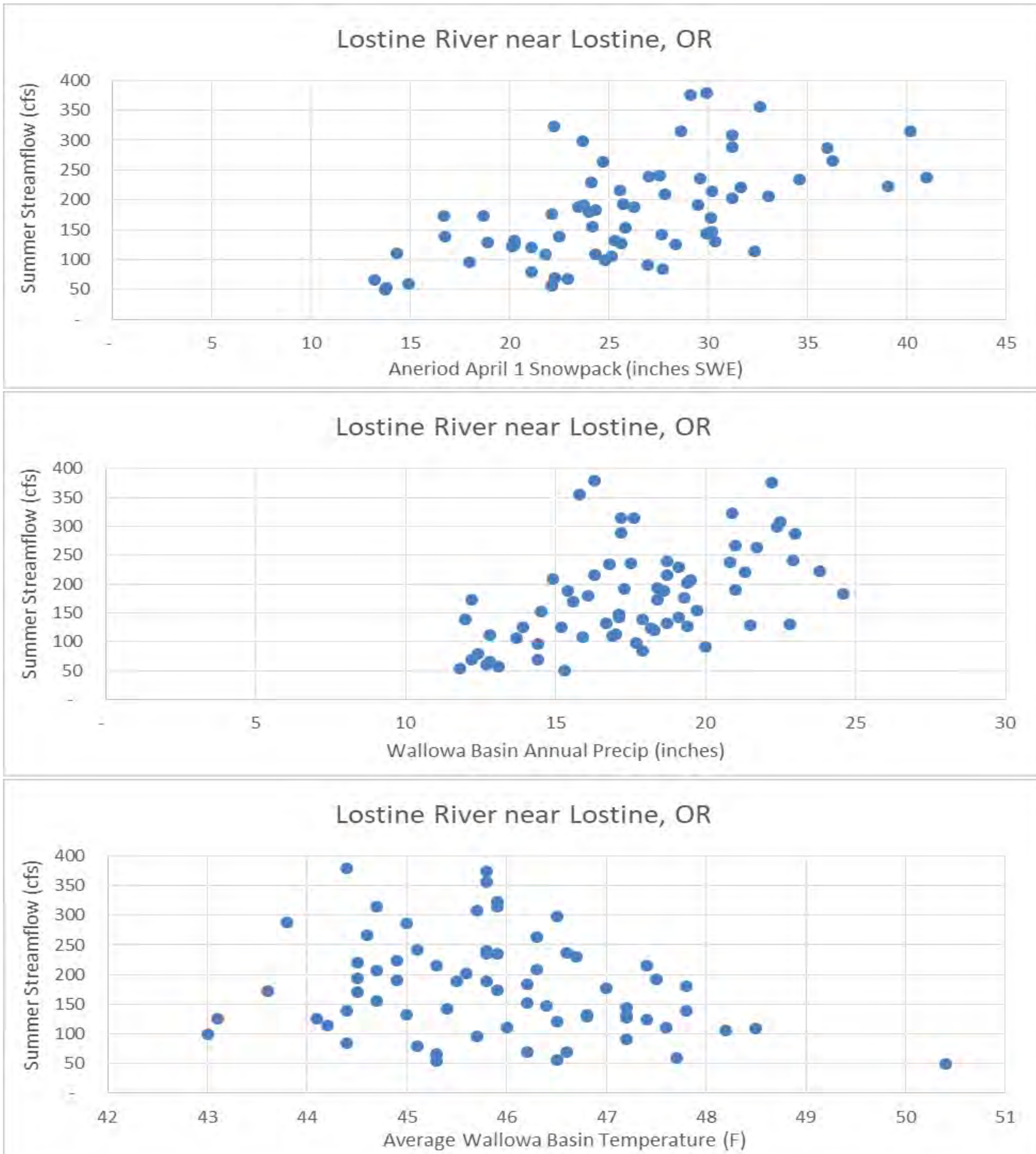


Figure 28. Relationship between Lostine River streamflow and temperature, precipitation, and snowpack.

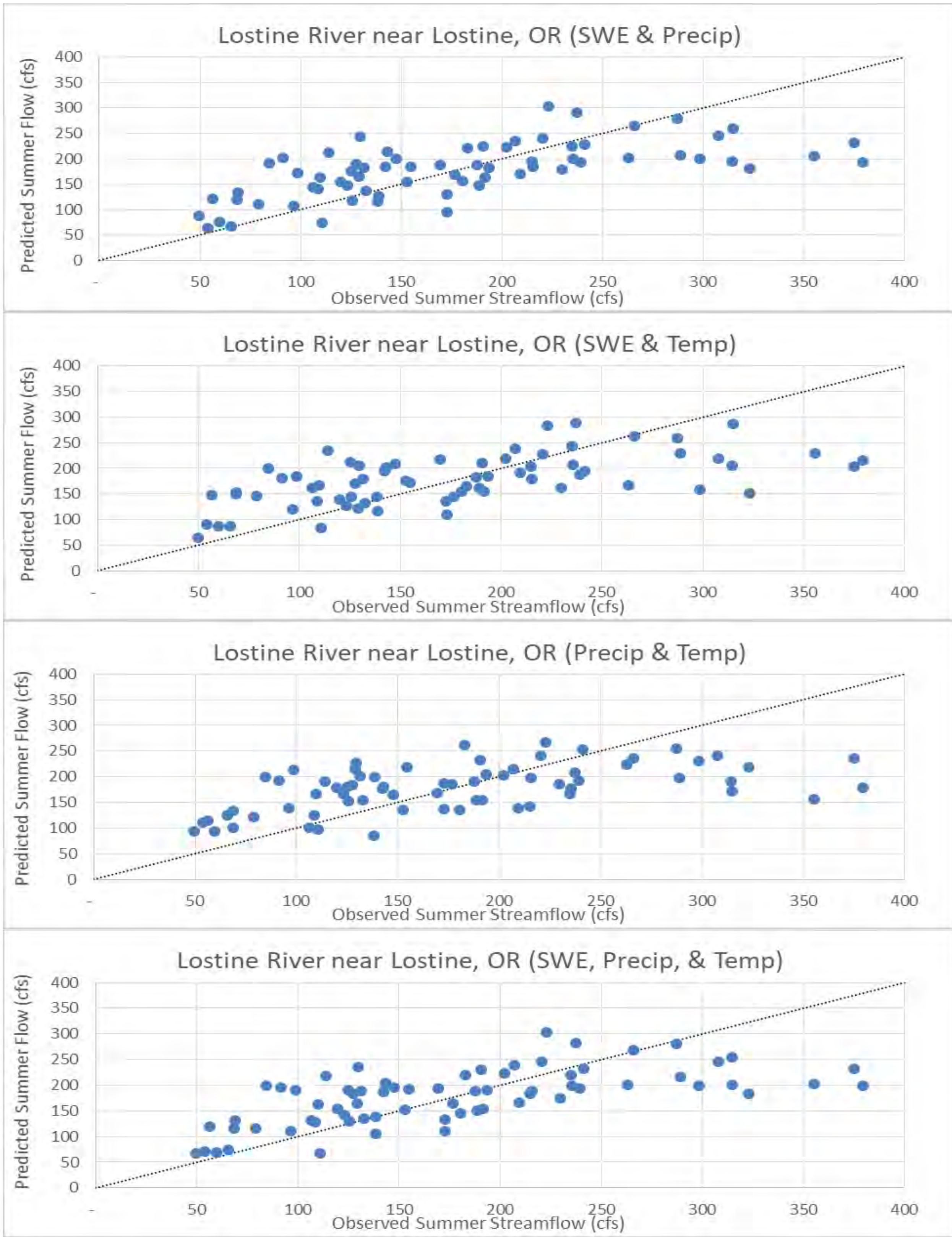


Figure 29. Regression fits for Wallowa River summer streamflow based on precipitation, temperature, and snowpack.

2.6.3 Relationship between Precipitation, Temperature, Snowpack, and Reservoir Storage

The relationship between Wallowa Lake storage, precipitation, temperature, and snowpack is shown in Figure 30 and Figure 31. Although some general trends are discernable (e.g., higher precipitation years have higher storage) the relationships are not as pronounced as the author anticipated and may be due to the large annual inflow volume relative to active storage volume. For example, annual inflow at the Wallowa River above Wallowa Lake gauge is 82,000 AF/yr whereas the difference between typical minimum and maximum storage within a year is 15,000 AF, and hence even low water years contain sufficient streamflow to fill the reservoir. Low snowpack years (i.e. smaller summer inflow to the reservoir) are likely to lead to lower storage volumes as the stored water provides a greater ratio of the overall water supply. Long-term records of reservoir spill were not available to the authors, however, it's apparent that active use of the reservoir storage, along with restoring the volume that is currently not accessible due to dam safety concerns, can have a significant positive impact on late summer irrigation deliveries and instream flows with minimal impact on the ability to fill the reservoir in any given year.

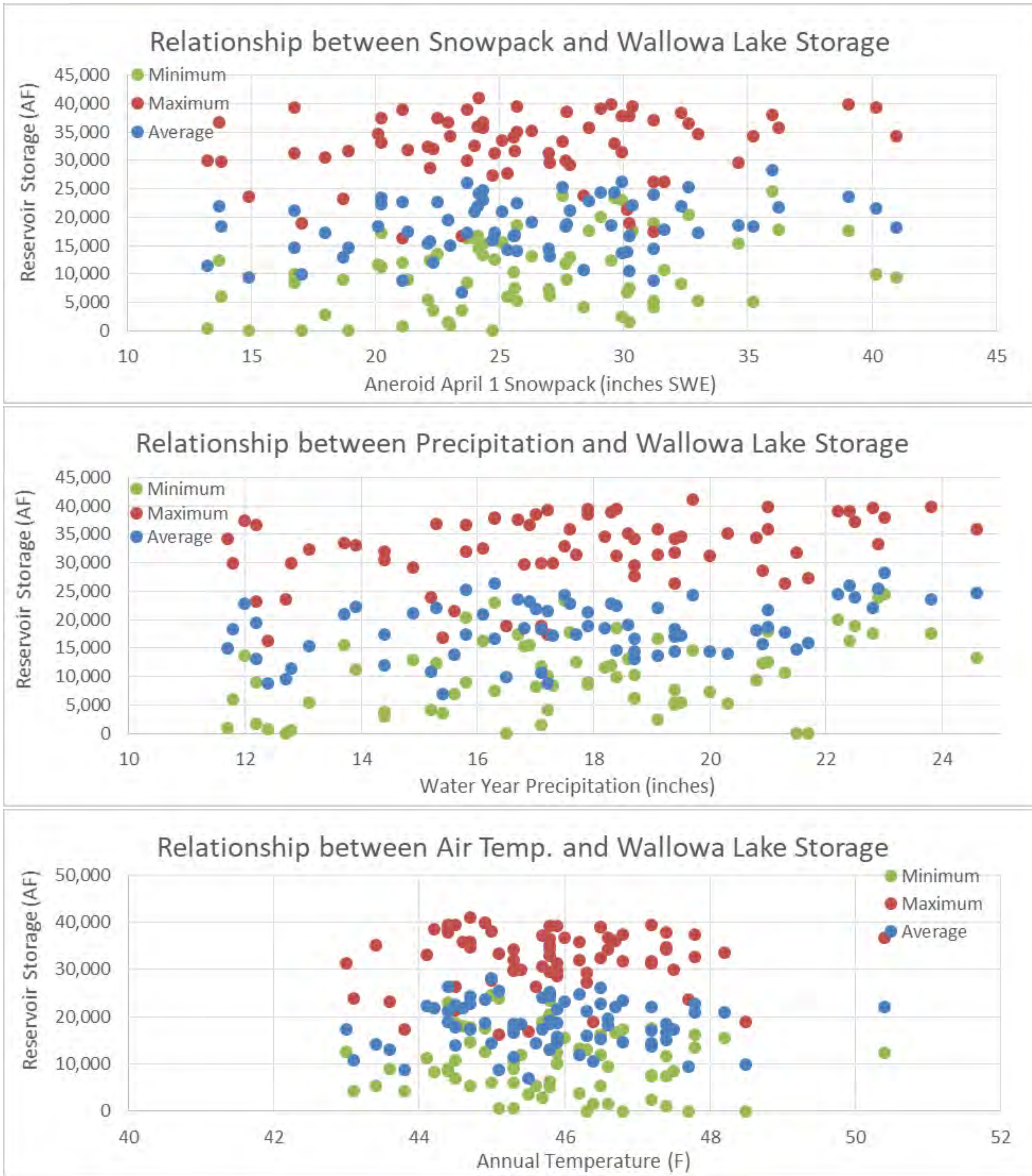


Figure 30. Relationship between snowpack, precipitation, and reservoir storage.

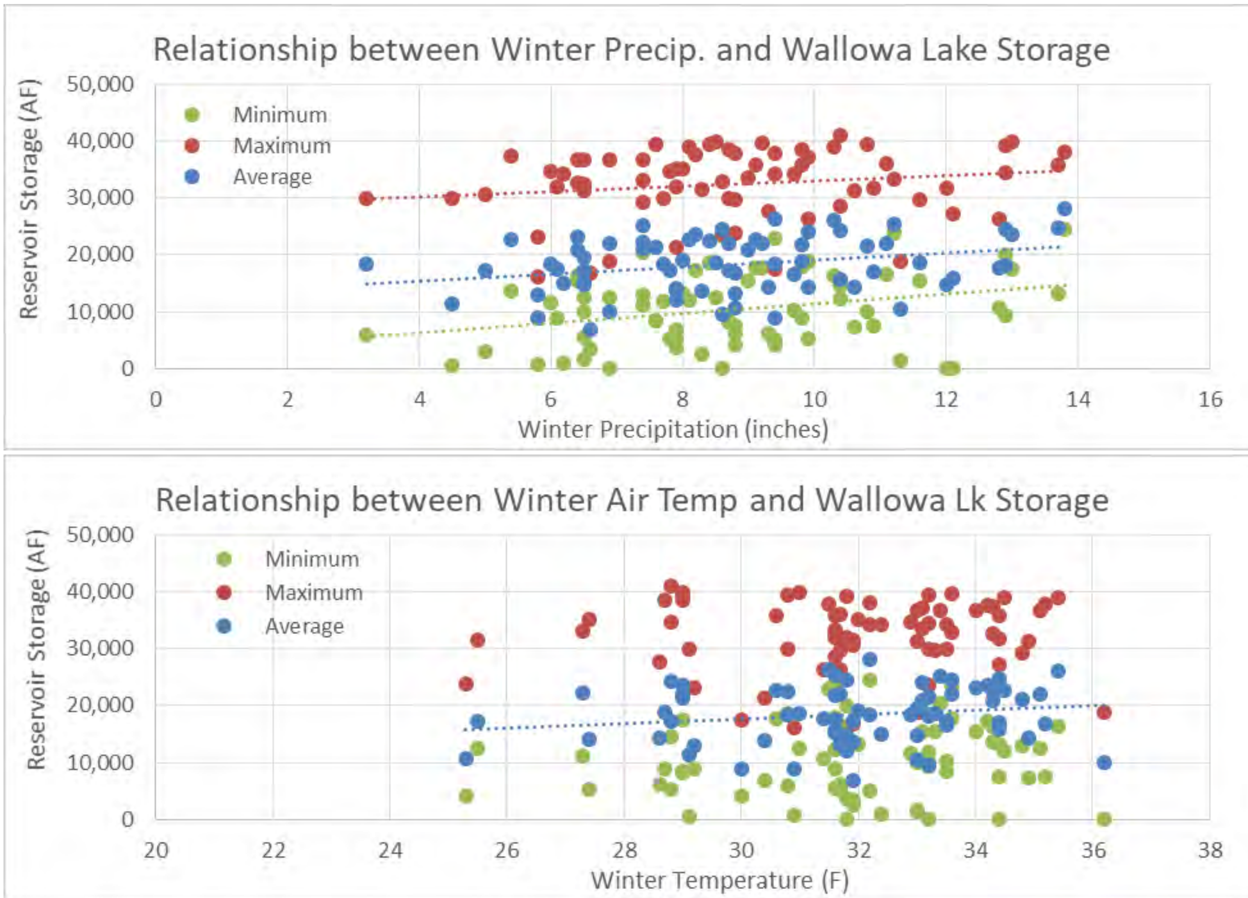


Figure 31. Relationship between winter precipitation, winter temperature, and storage.

3 Future Water Supply

Most climate change models fall into one of two types. Statistical models use historic information to make future predictions. Physical process models create a simplified series of spatial elements (cells), and use equations to create a dynamic prediction of future conditions. Many physical process models operate at coarse scales (for example ~300 km per cell side). Applying these predictions to landscapes at finer scales can be challenging (the "downscaling" problem). Because many summaries of climate change use averaged results from several models, the potential variability of some physical processes (for example, peak flows at a specific watershed) may be lost (Bakke, 2009). However, it is important to consider the results from multiple models since conclusions supported by one or a small number of models may be erroneous. Most climate models are not able to predict the variance in climate patterns caused by events such as the Pacific Decadal Oscillation (PDO) or the El Niño / Southern Oscillation (ENSO), and so are unable to contribute to a projection of future conditions for these events (Mote et al., 2008).

The Climate Impacts Group (CIG) at the University of Washington[6] has developed descriptions of future climate conditions in the Pacific Northwest, taken from a select group of global climate simulation models (i.e., models developed at a continental, not a regional scale). Results from the CIG climate analysis are summarized here.

3.1 Projected Precipitation and Temperature Changes

Projected change in average annual air temperature (relative to the baseline period of 1915-2006) for the region east of the Cascades are given in Figure 32 for two time periods centered on 2050 and 2080. Results show in Figure 32 are for two time-periods, four greenhouse gas emissions scenarios, and 30 separate Global Climate Models (GCMs). The solid horizontal line in the middle of the shade area is the median value from all 30 models, the upper and lower extent of the shaded box re the 25th and 75th percentiles, and the lines outside of the box are the minimum and maximum modeled results. Warming is projected for all emissions scenarios and all models. The median modeled increase in annual air temperature is from 3 to 5 degrees F by 2050, and 4-10 degrees F by 2080. Seasonal values (not shown) follow a similar trend.

[6] https://cig.uw.edu/

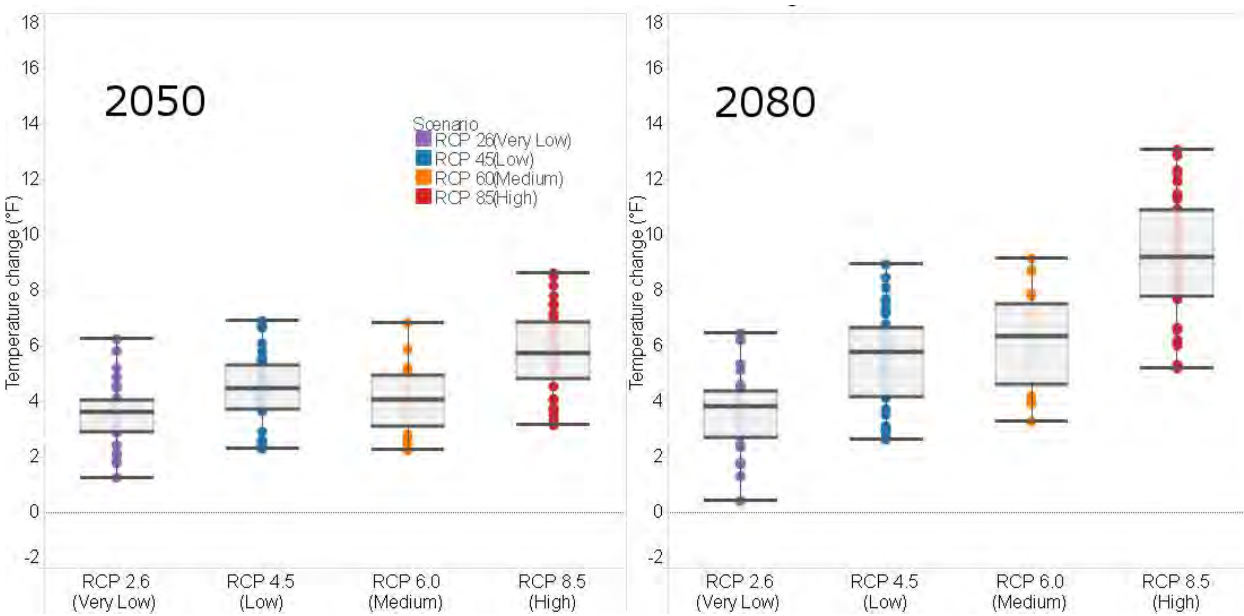


Figure 32. Projected change in average annual air temperature for the region east of the Cascades for the 2050's (left) and 2080's (right). Figure from University of Washington, Climate Impacts Group[7]; data source: Taylor et al. (2012).

Projected % change in total annual precipitation for the region east of the Cascades are given in Figure 33 (top) for two time periods centered on 2050 and 2080. As in Figure 32 the results are for two time-periods, four greenhouse gas emissions scenarios, and 30 separate GCMs. On an annual basis precipitation is not expected to vary much from current conditions, with a median predicted increase of less than 5%. For almost all emission scenarios and time periods the fall, winter, and spring precipitation volumes increase (not shown), while median summer precipitation is predicted to decrease by 5-10% (Figure 33, bottom).

[7] https://cig.uw.edu/resources/analysis-tools/projections/

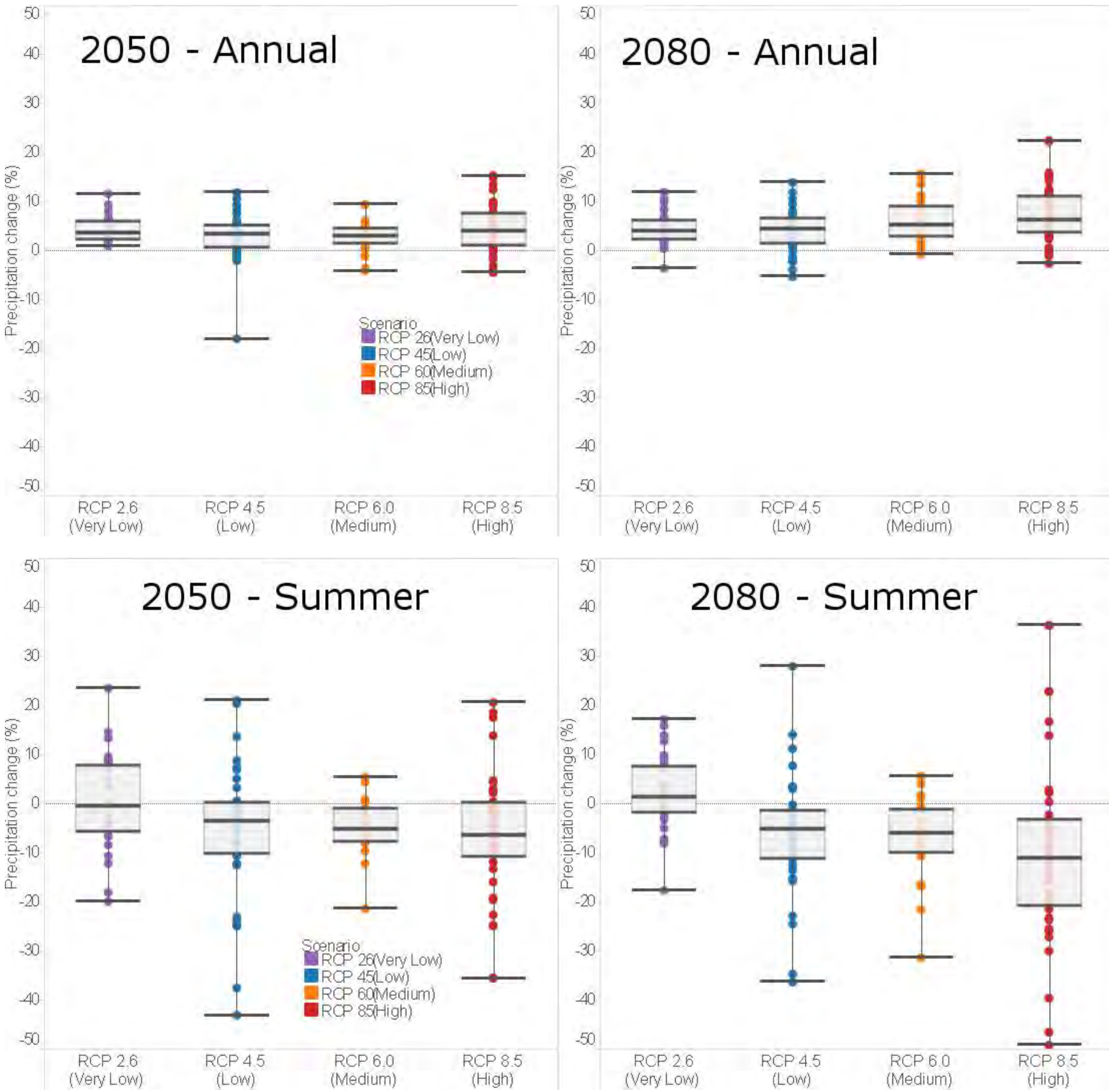


Figure 33. Projected % change in total annual precipitation for the region East of the Cascades in the 2050s (upper left) and 2080s (upper right); summer precipitation in the 2050s (lower left) and 2080s (lower right). Figure from University of Washington, Climate Impacts Group[8]; data source: Taylor et al. (2012).

[8] https://cig.uw.edu/resources/analysis-tools/projections/

3.2 Projected Snowpack Changes

Data products from the Western U.S. Hydroclimate Scenarios Project, available through the CIG[9], were used to characterize climate-change related impacts to snowpack and streamflow within the project area. Data from the CMIP3 global model archive for the A1B emission scenario (a "medium" emissions scenario, similar to the RCP 6.0 scenario in Figure 32 and Figure 33) was used, and included averages of the 10 best performing GCMs, along with four "bracketing" models, thereby encompassing the full range of temperature and precipitation projections. These data had a spatial resolution of 1/16th degree (~30 km^2). Gridded historical data (1915-2006) were used to characterize historic conditions, and were modified using the downscaled GCM products to characterize two future time periods; the "2040s" (average change for 2030-2059) and the "2080s" (average change for 2070-2099). Changes in hydrology and hydrologic-related variables were modeled with the Variable Infiltration Capacity (VIC) macroscale hydrologic model. Resultant spatial data sets and summary products, available from the CIG, were used in the following analyses. See Littell et al. (2014) for additional details.

Historic April 1st snowpack (expressed as inches of snow-water equivalent) is shown in Figure 34 (upper left). These are based on data from the 1915-2006 period. Projected April 1st snowpack, expressed as a percentage of historic values, are given for the 2040s (Figure 34; upper right) and 2080s (Figure 34; lower right). These results are based on the composite projection from the 10 best-performing GCMs. The majority of April 1st SWE occurs in the headwaters of the Wallowa and Imnaha sub-basins. Projected future impacts are generally proportional to elevation, with the higher elevational areas being somewhat buffered. The Wallowa sub-basin has approximately 30% of its area above 6,000 feet elevation, while the Imnaha sub-basin has ~15% and the Lower Grande Ronde <1% (Figure 35).

[9] https://cig.uw.edu/datasets/wus/

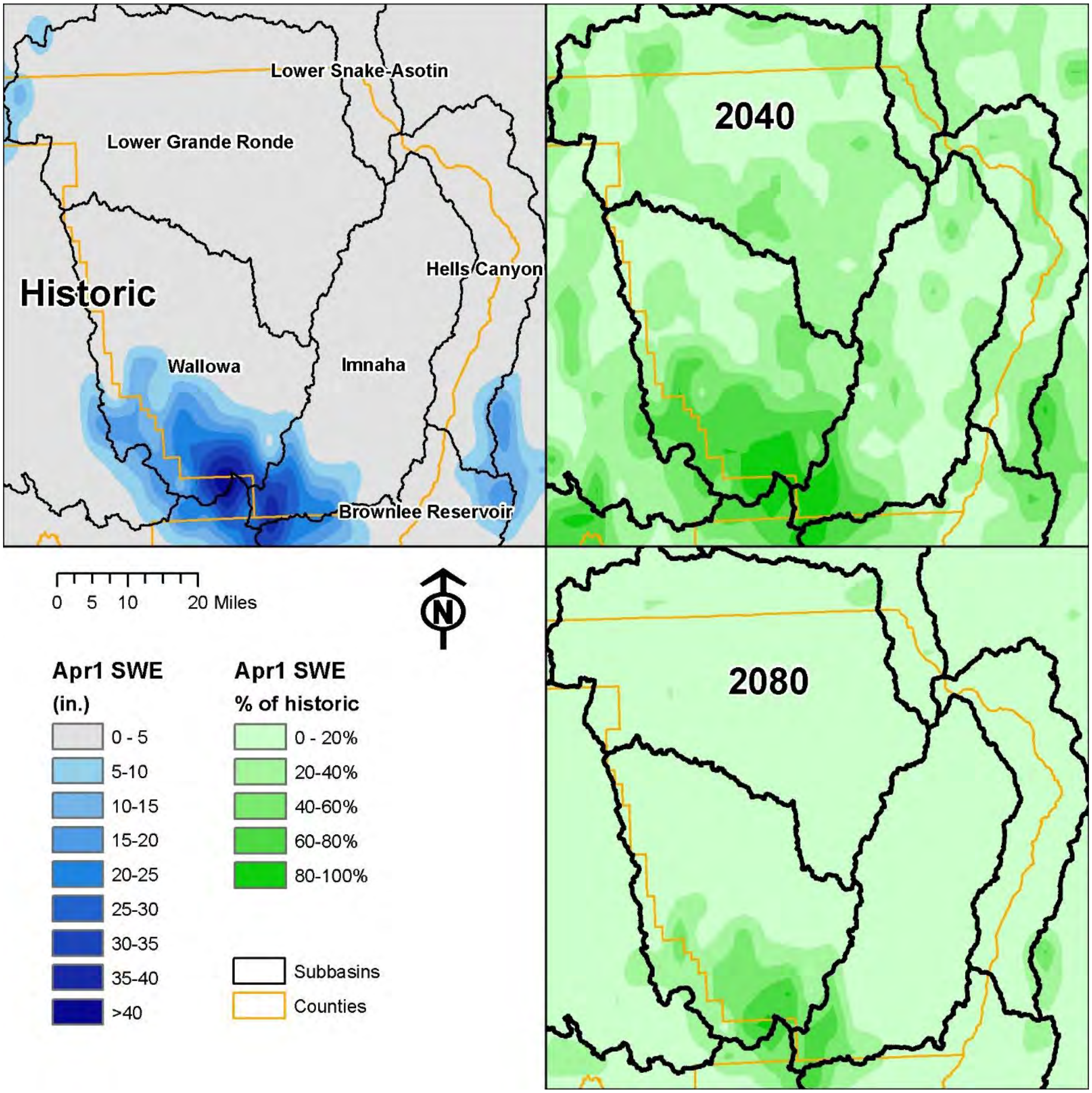


Figure 34. Historic April 1st snowpack (expressed as inches of snow-water equivalent; upper left), and projected April 1st snowpack expressed as a percentage of historic values for the 2040s (upper right) and 2080s (lower right). Data source: CIG[10]; see Littell et al. (2014) for additional details.

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[10] https://cig.uw.edu/datasets/wus/

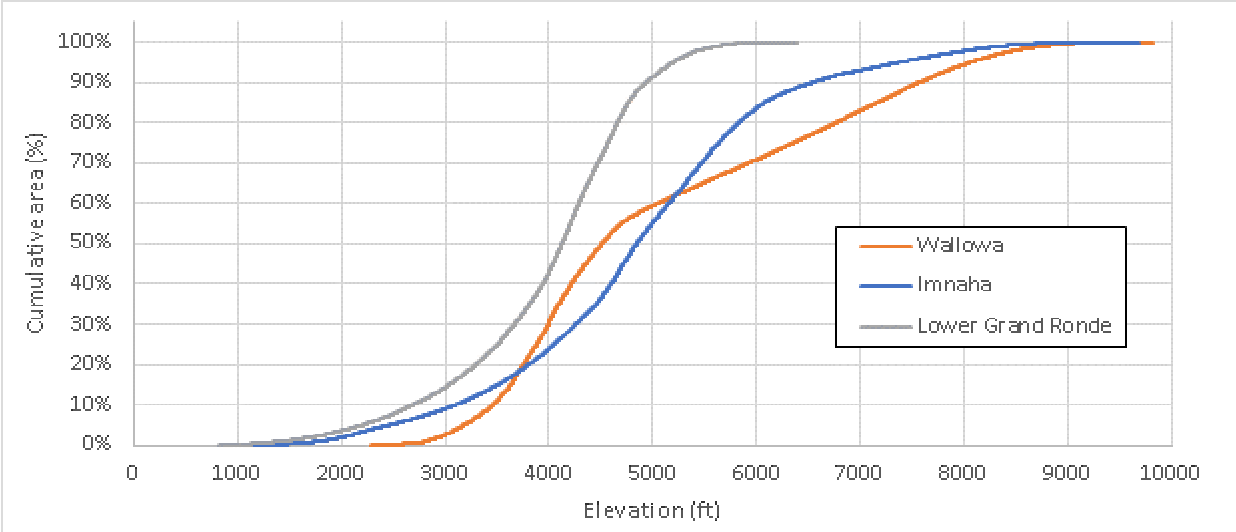


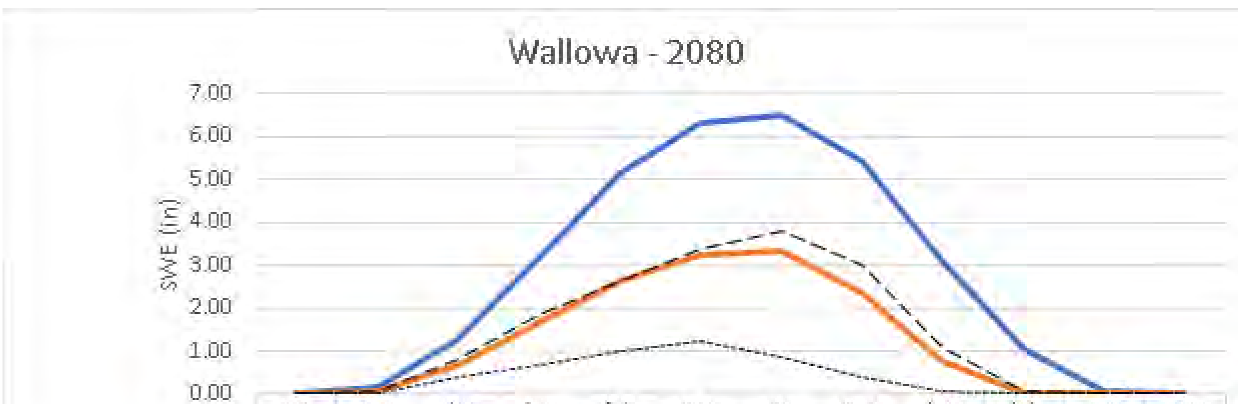
Figure 35. Elevation-area curves for the Wallowa, Imnaha, and Lower Grande Ronde sub-basins. Derived from USGS 30-meter resolution DEM data.

Mean monthly historical snowpack, and modeled snowpack using temperature and precipitation changes from several GCMs for future time periods centered on the years 2040 and 2080, are available from the CIG (Littell et al., 2014). Results for the Wallowa sub-basin are given in Figure 36. The "composite" values are modeled using the composite of temperature and precipitation changes from all 10 GCMs, and the minimum and maximum monthly snowpack values are the extremes from individual GCMs. The maximum sub-basin average snowpack is expected to decrease approximately 23% by the 2050s and 49% by the 2080s. Results are more extreme for the Lower Grande Ronde sub-basin (Figure 37) where maximum sub-basin average snowpack is expected to decrease approximately 60% and 79% by the 2050s and 2080s respectively. Results for the Imnaha River sub-basin (Figure 38) are similar in response as for the Wallowa, with a 34% and 59% decrease in the maximum sub-basin average snowpack by the 2050s and 2080s respectively. Results for the Brownlee Reservoir (Figure 39), Hells Canyon(Figure 40), and Lower Snake-Asotin (Figure 41) show similar modeled responses:

- Wallowa: 23% reduction in snowpack sub-basin wide by 2050; 49% reduction by 2080,
- Lower Grande Ronde: 60% reduction in snowpack sub-basin wide by 2050; 79% reduction by 2080,
- Imnaha: 34% reduction in snowpack sub-basin wide by 2050; 59% reduction by 2080,
- Brownlee Reservoir: 53% reduction in snowpack sub-basin wide by 2050; 77% reduction by 2080,
- Hells Canyon: 56% reduction in snowpack sub-basin wide by 2050; 81% reduction by 2080,

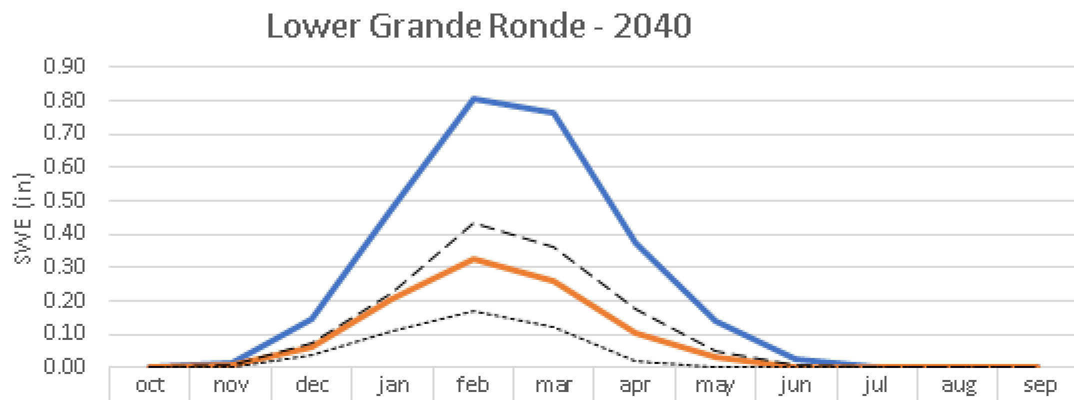
- Lower Snake-Asotin: 59% reduction in snowpack sub-basin wide by 2050; 72% reduction by 2080.

	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep
historical	0.00	0.15	1.30	3.16	5.17	6.33	6.52	5.44	3.12	1.03	0.05	0.00
composite	0.00	0.08	0.97	2.30	3.73	4.69	5.02	3.87	1.70	0.27	0.00	0.00
minimum	0.00	0.07	0.74	1.65	2.61	3.55	3.78	2.58	0.88	0.06	0.00	0.00
maximum	0.00	0.10	1.20	2.67	4.02	4.92	5.52	4.24	1.95	0.33	0.01	0.00

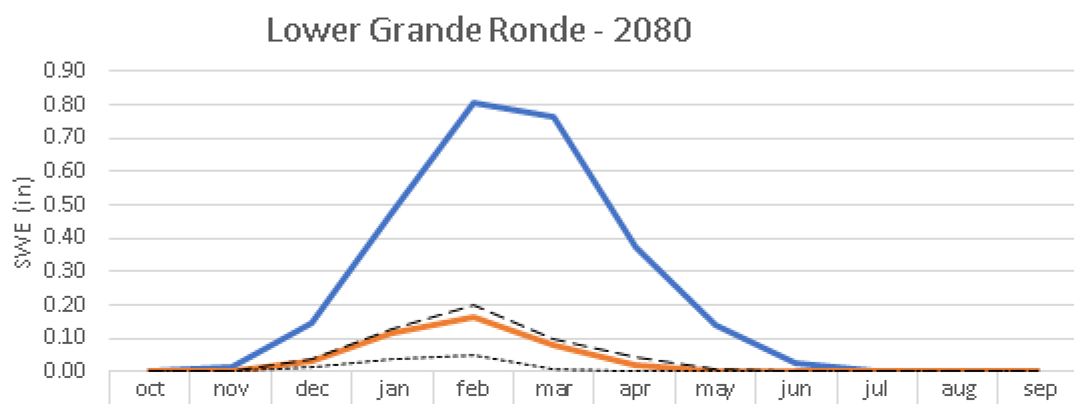


	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep
historical	0.00	0.15	1.30	3.16	5.17	6.33	6.52	5.44	3.12	1.03	0.05	0.00
composite	0.00	0.05	0.67	1.66	2.62	3.22	3.31	2.34	0.75	0.04	0.00	0.00
minimum	0.00	0.04	0.42	0.69	1.02	1.24	0.86	0.41	0.07	0.00	0.00	0.00
maximum	0.00	0.08	0.80	1.84	2.62	3.36	3.78	2.98	1.10	0.08	0.00	0.00

Figure 36. Mean monthly historical snowpack for the Wallowa River sub-basin (historical), modeled snowpack using the composite of temperature and precipitation changes from all 10 GCMs (composite), and the minimum and maximum monthly snowpack values from individual GCMs (minimum; maximum). Top graph is for a future time period centered on the year 2040; bottom graph for a future time period centered on the year 2080. Data Source: Littell et al. (2014).

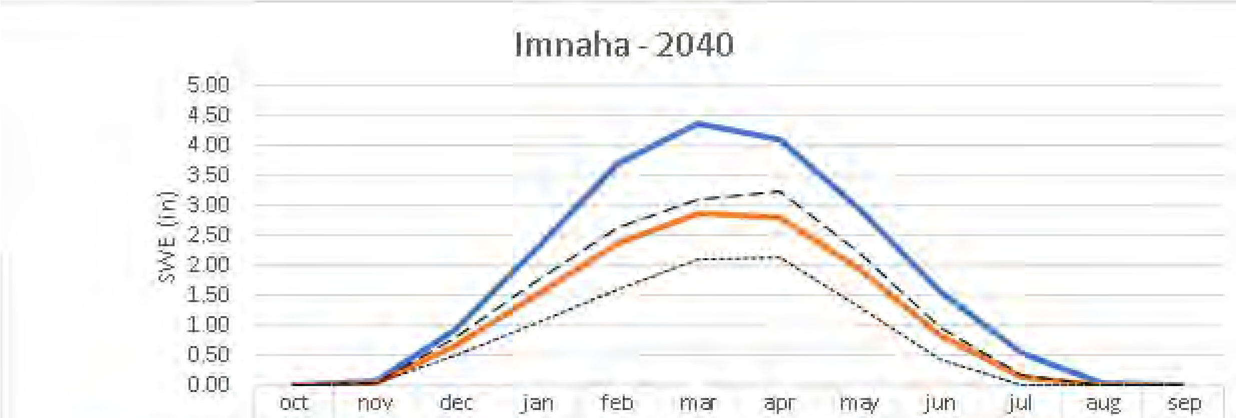


	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep
historical	0.00	0.01	0.15	0.48	0.81	0.77	0.37	0.14	0.03	0.00	0.00	0.00
composite	0.00	0.01	0.06	0.21	0.33	0.26	0.10	0.03	0.00	0.00	0.00	0.00
minimum	0.00	0.00	0.04	0.11	0.17	0.12	0.02	0.00	0.00	0.00	0.00	0.00
maximum	0.00	0.01	0.08	0.22	0.43	0.36	0.18	0.05	0.01	0.00	0.00	0.00

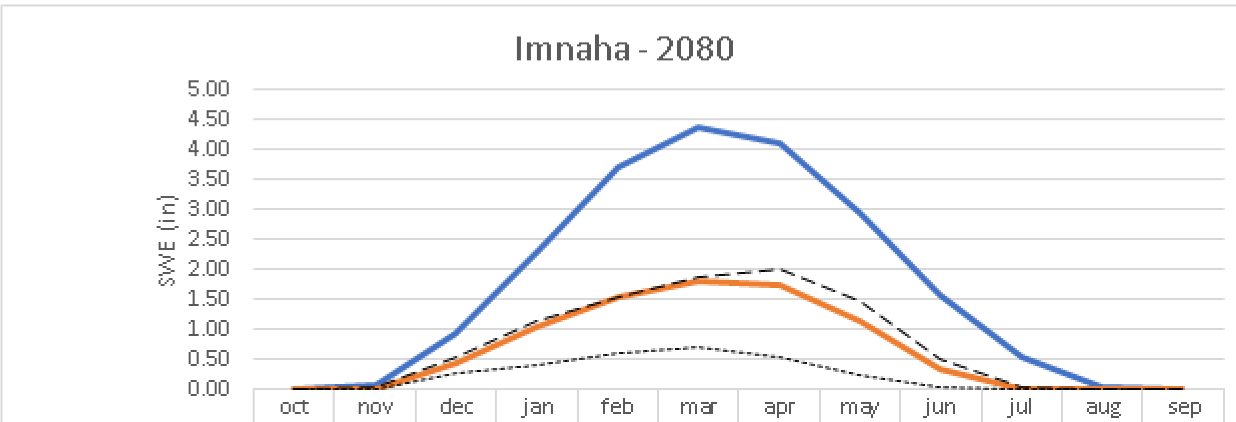


	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep
historical	0.00	0.01	0.15	0.48	0.81	0.77	0.37	0.14	0.03	0.00	0.00	0.00
composite	0.00	0.00	0.03	0.12	0.17	0.08	0.02	0.00	0.00	0.00	0.00	0.00
minimum	0.00	0.00	0.01	0.04	0.05	0.01	0.00	0.00	0.00	0.00	0.00	0.00
maximum	0.00	0.01	0.04	0.13	0.20	0.10	0.04	0.01	0.00	0.00	0.00	0.00

Figure 37. Mean monthly historical snowpack for the Lower Grande Ronde sub-basin (historical), modeled snowpack using the composite of temperature and precipitation changes from all 10 GCMs (composite), and the minimum and maximum monthly snowpack values from individual GCMs (minimum; maximum). Top graph is for a future time period centered on the year 2040; bottom graph for a future time period centered on the year 2080. Data Source: Littell et al. (2014).

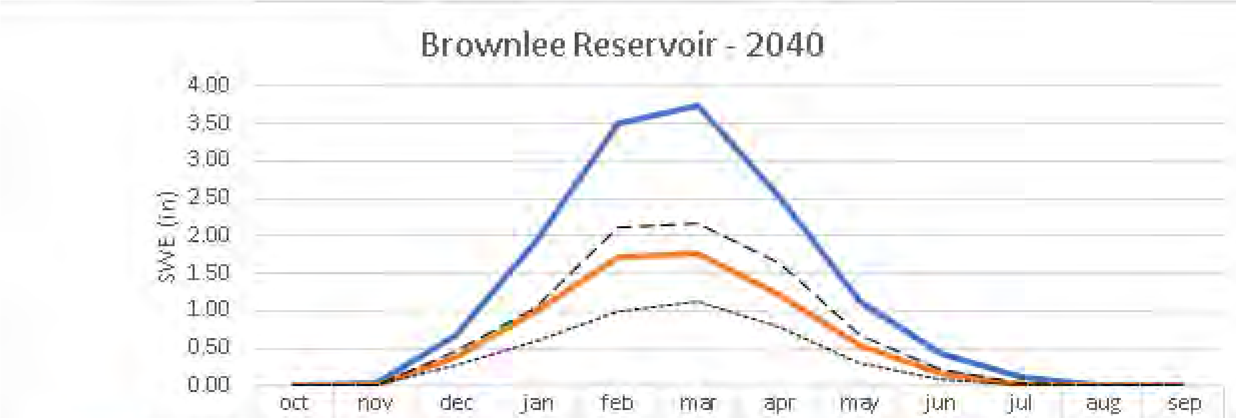


	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep
historical	0.00	0.10	0.95	2.28	3.72	4.38	4.11	2.94	1.58	0.55	0.04	0.00
composite	0.00	0.05	0.67	1.51	2.39	2.88	2.82	1.96	0.83	0.14	0.00	0.00
minimum	0.00	0.04	0.50	1.06	1.60	2.10	2.13	1.33	0.44	0.03	0.00	0.00
maximum	0.00	0.06	0.83	1.76	2.64	3.11	3.24	2.21	0.98	0.18	0.01	0.00

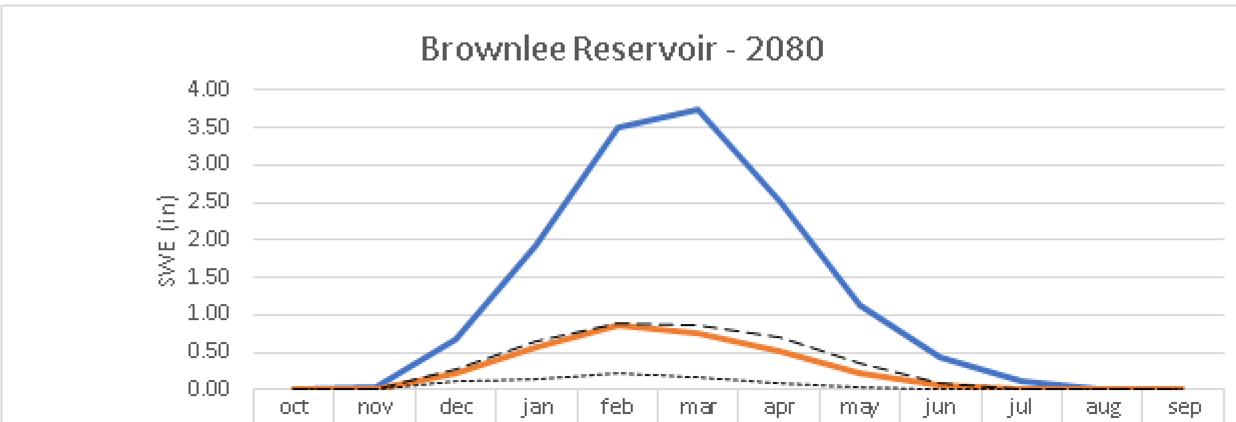


	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep
historical	0.00	0.10	0.95	2.28	3.72	4.38	4.11	2.94	1.58	0.55	0.04	0.00
composite	0.00	0.03	0.45	1.03	1.56	1.81	1.75	1.16	0.36	0.02	0.00	0.00
minimum	0.00	0.02	0.28	0.43	0.62	0.73	0.53	0.24	0.03	0.00	0.00	0.00
maximum	0.00	0.05	0.54	1.15	1.56	1.89	2.02	1.47	0.52	0.04	0.00	0.00

Figure 38. Mean monthly historical snowpack for the Imnaha River sub-basin (historical), modeled snowpack using the composite of temperature and precipitation changes from all 10 GCMs (composite), and the minimum and maximum monthly snowpack values from individual GCMs (minimum; maximum). Top graph is for a future time period centered on the year 2040; bottom graph for a future time period centered on the year 2080. Data Source: Littell et al. (2014).

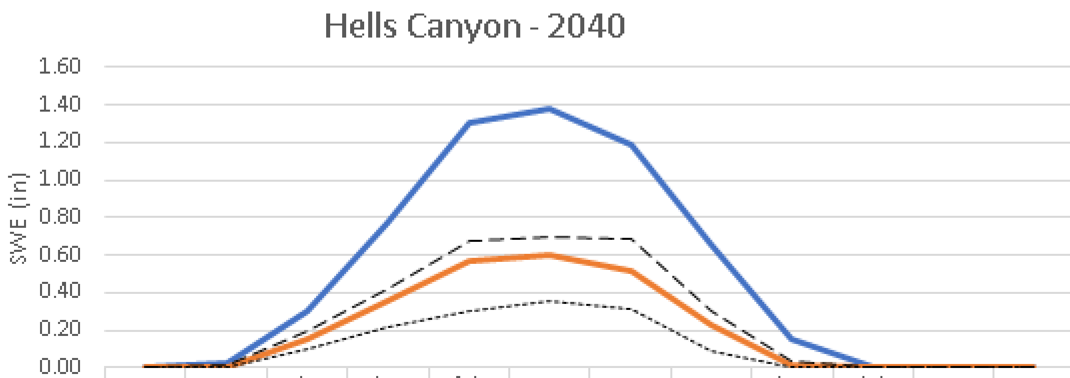


	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep
historical	0.00	0.04	0.67	1.94	3.49	3.74	2.51	1.14	0.43	0.12	0.01	0.00
composite	0.00	0.02	0.39	1.00	1.72	1.77	1.21	0.53	0.17	0.02	0.00	0.00
minimum	0.00	0.01	0.27	0.60	1.00	1.13	0.78	0.30	0.08	0.00	0.00	0.00
maximum	0.00	0.02	0.47	1.06	2.12	2.17	1.65	0.69	0.22	0.03	0.00	0.00

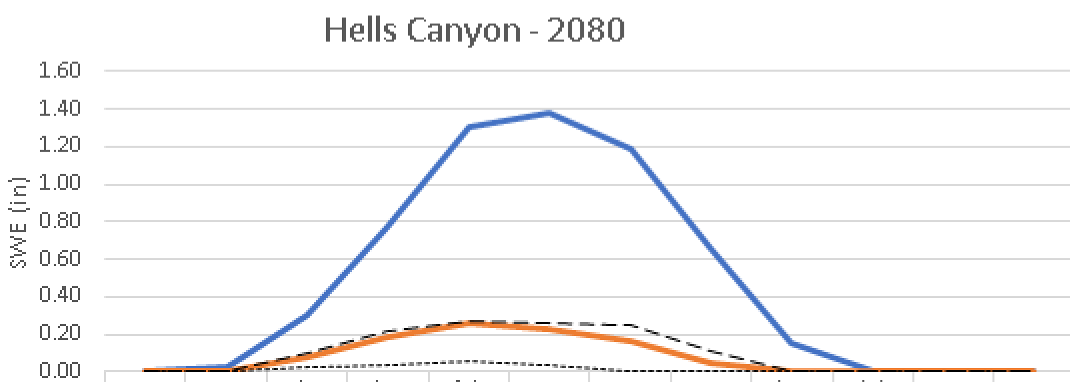


	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep
historical	0.00	0.04	0.67	1.94	3.49	3.74	2.51	1.14	0.43	0.12	0.01	0.00
composite	0.00	0.01	0.23	0.56	0.87	0.77	0.51	0.23	0.06	0.00	0.00	0.00
minimum	0.00	0.01	0.12	0.16	0.23	0.18	0.10	0.03	0.00	0.00	0.00	0.00
maximum	0.00	0.02	0.28	0.65	0.89	0.86	0.70	0.35	0.10	0.01	0.00	0.00

Figure 39. Mean monthly historical snowpack for the Brownlee Reservoir sub-basin (historical), modeled snowpack using the composite of temperature and precipitation changes from all 10 GCMs (composite), and the minimum and maximum monthly snowpack values from individual GCMs (minimum; maximum). Top graph is for a future time period centered on the year 2040; bottom graph for a future time period centered on the year 2080. Data Source: Littell et al. (2014).

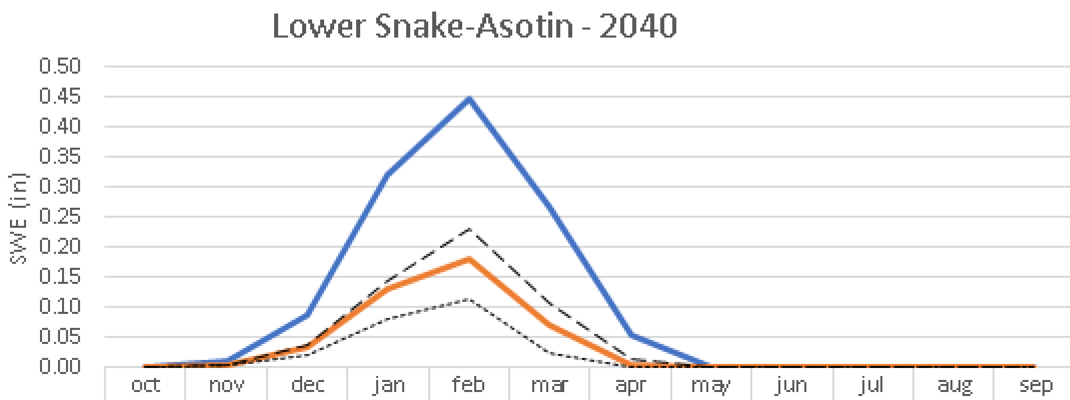


	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep
historical	0.00	0.02	0.30	0.78	1.31	1.38	1.18	0.65	0.15	0.01	0.00	0.00
composite	0.00	0.01	0.15	0.36	0.57	0.60	0.52	0.23	0.02	0.00	0.00	0.00
minimum	0.00	0.01	0.10	0.21	0.31	0.36	0.31	0.09	0.00	0.00	0.00	0.00
maximum	0.00	0.01	0.19	0.42	0.68	0.70	0.68	0.31	0.03	0.00	0.00	0.00

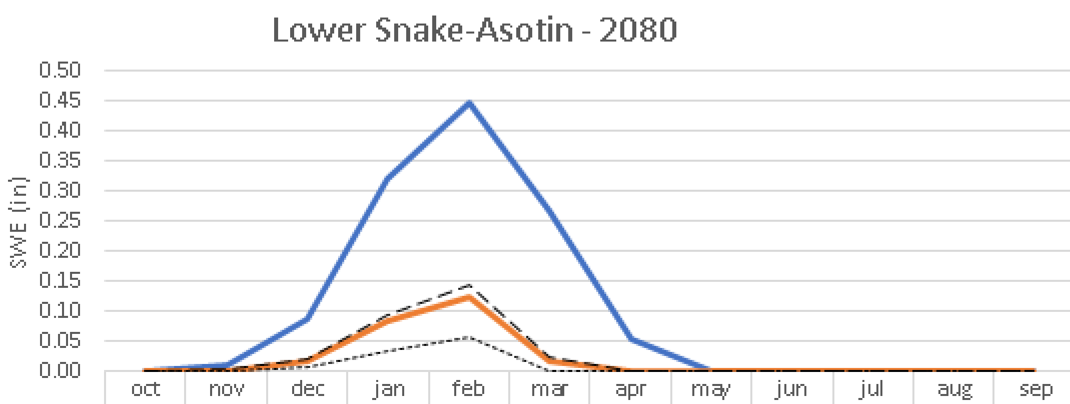


	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep
historical	0.00	0.02	0.30	0.78	1.31	1.38	1.18	0.65	0.15	0.01	0.00	0.00
composite	0.00	0.00	0.07	0.18	0.27	0.23	0.16	0.05	0.00	0.00	0.00	0.00
minimum	0.00	0.00	0.03	0.04	0.06	0.04	0.01	0.00	0.00	0.00	0.00	0.00
maximum	0.00	0.01	0.10	0.22	0.28	0.26	0.25	0.12	0.01	0.00	0.00	0.00

Figure 40. Mean monthly historical snowpack for the Hells Canyon sub-basin (historical), modeled snowpack using the composite of temperature and precipitation changes from all 10 GCMs (composite), and the minimum and maximum monthly snowpack values from individual GCMs (minimum; maximum). Top graph is for a future time period centered on the year 2040; bottom graph for a future time period centered on the year 2080. Data Source: Littell et al. (2014).



	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep
historical	0.00	0.01	0.09	0.32	0.45	0.27	0.05	0.00	0.00	0.00	0.00	0.00
composite	0.00	0.00	0.03	0.13	0.18	0.07	0.01	0.00	0.00	0.00	0.00	0.00
minimum	0.00	0.00	0.02	0.08	0.12	0.03	0.00	0.00	0.00	0.00	0.00	0.00
maximum	0.00	0.01	0.04	0.14	0.23	0.11	0.01	0.00	0.00	0.00	0.00	0.00



	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep
historical	0.00	0.01	0.09	0.32	0.45	0.27	0.05	0.00	0.00	0.00	0.00	0.00
composite	0.00	0.00	0.02	0.08	0.12	0.02	0.00	0.00	0.00	0.00	0.00	0.00
minimum	0.00	0.00	0.01	0.04	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
maximum	0.00	0.00	0.02	0.09	0.15	0.02	0.00	0.00	0.00	0.00	0.00	0.00

Figure 41. Mean monthly historical snowpack for the Lower Snake - Asotin sub-basin (historical), modeled snowpack using the composite of temperature and precipitation changes from all 10 GCMs (composite), and the minimum and maximum monthly snowpack values from individual GCMs (minimum; maximum). Top graph is for a future time period centered on the year 2040; bottom graph for a future time period centered on the year 2080. Data Source: Littell et al. (2014).

3.3 Projected Streamflow Changes

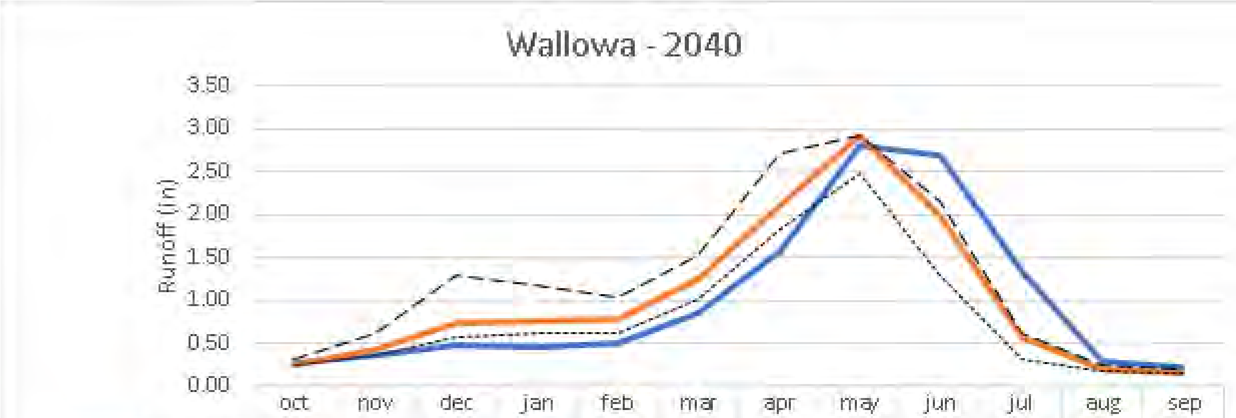
Littell et al. (2014) modeled monthly runoff at the outlet of each sub-basin for both historic and future conditions based on 10 GCMs. Future conditions were modeled using the composite of temperature and precipitation changes from all 10 GCMs (composite), and the minimum and maximum monthly values from individual GCMs (minimum; maximum). A summary of modeled streamflow changes at the outlet of each sub-basin for future time periods broken out by season is provided in Table 6. Shading in Table 6 indicates the magnitude of the modeled change from modeled historic conditions; darker red indicating a decrease in streamflow, and darker green indicating an increase.

Table 6. Summary of modeled streamflow changes at the outlet of each sub-basin for future time periods centered on the years 2040 and 2080. Values are % change in streamflow for the composite future scenario compared to historic. Shading indicates magnitude of change. Data Source: Littell et al. (2014).

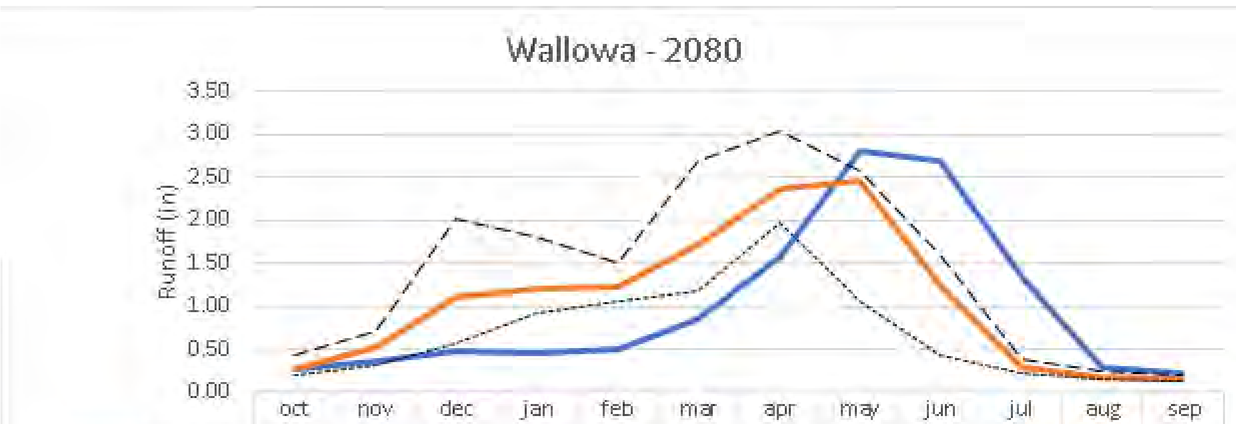
	Wallowa		Upper Grande Ronde		Lower Grande Ronde		Imnaha		Brownlee Reservoir		Hells Canyon		Lower Snake-Asotin	
Months	**2040**	**2080**	**2040**	**2080**	**2040**	**2080**	**2040**	**2080**	**2040**	**2080**	**2040**	**2080**	**2040**	**2080**
Oct - Dec	28%	73%	16%	35%	14%	28%	30%	74%	33%	67%	21%	43%	10%	19%
Jan - Mar	56%	133%	33%	60%	19%	31%	53%	108%	42%	76%	31%	55%	8%	14%
Apr - Jun	0%	-15%	-13%	-22%	-7%	-11%	-5%	-20%	-15%	-30%	-12%	-21%	-1%	-1%
Jul - Sep	-50%	-67%	-17%	-21%	-11%	-15%	-42%	-55%	-22%	-28%	-12%	-16%	-7%	-10%

Results summarized in Table 6 show generally similar patterns for all sub-basins; increased magnitude of Fall (Oct-Dec) and Winter (Jan-Mar) streamflows; decreasing Spring (Apr-Jun) streamflows, although the results vary with less impact in sub-basins having high snowpack (Wallowa and Imnaha) or low snowpack (Lower Snake-Asotin); with the largest magnitude streamflow decreases in the Summer (Jul-Sep) months. Summertime impacts are greater (on a percentage basis) in streams most dominated by snowpack (Wallowa and Imnaha).

Monthly modeled results are shown for all sub-basins in Figure 42 through Figure 48.

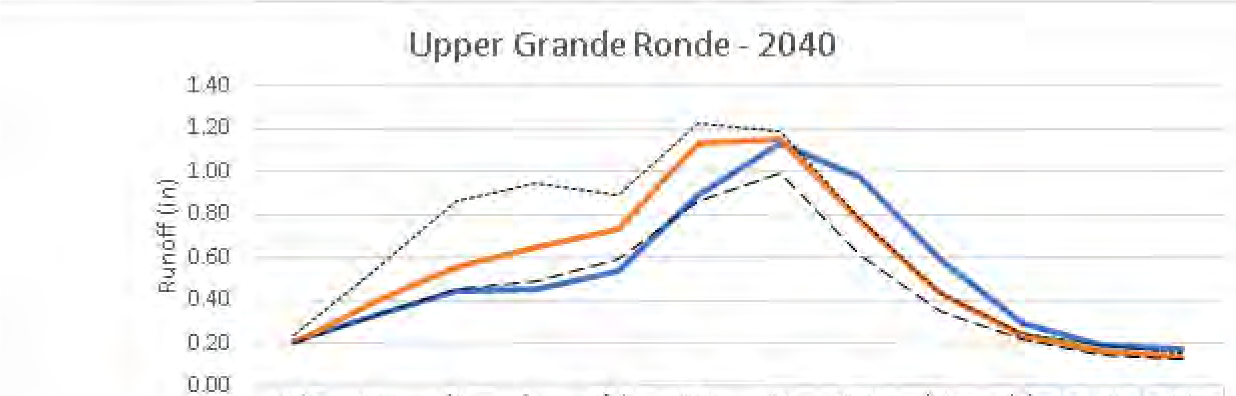


	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep
historical	0.27	0.35	0.48	0.45	0.50	0.84	1.58	2.81	2.70	1.33	0.29	0.21
composite	0.25	0.43	0.74	0.76	0.78	1.25	2.12	2.93	2.01	0.56	0.19	0.16
minimum	0.25	0.36	0.58	0.61	0.62	1.01	1.84	2.47	1.29	0.32	0.17	0.14
maximum	0.31	0.62	1.30	1.18	1.03	1.53	2.72	2.93	2.15	0.62	0.25	0.19

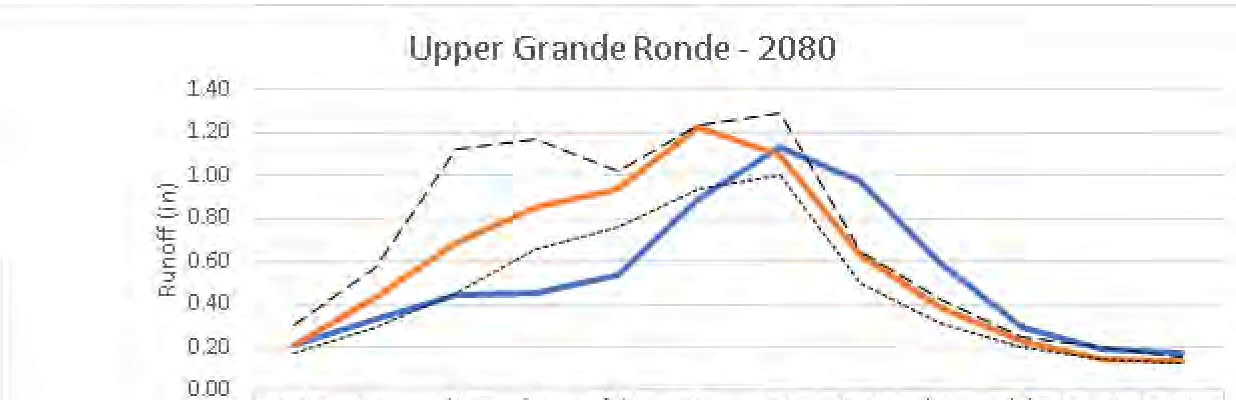


	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep
historical	0.27	0.35	0.48	0.45	0.50	0.84	1.58	2.81	2.70	1.33	0.29	0.21
composite	0.26	0.53	1.11	1.20	1.23	1.73	2.36	2.46	1.24	0.30	0.17	0.15
minimum	0.20	0.31	0.57	0.93	1.05	1.19	1.98	1.06	0.43	0.23	0.15	0.13
maximum	0.43	0.72	2.01	1.82	1.50	2.70	3.05	2.59	1.59	0.38	0.24	0.19

Figure 42. Average monthly historical runoff at the outlet of the Wallowa River sub-basin (historical), modeled runoff using the composite of temperature and precipitation changes from all 10 GCMs (composite), and the minimum and maximum monthly values from individual GCMs (minimum; maximum). Top graph is for a future time period cenetered on the year 2040; bottom graph for a future time period cenetered on the year 2080. Data Source: Littell et al. (2014).

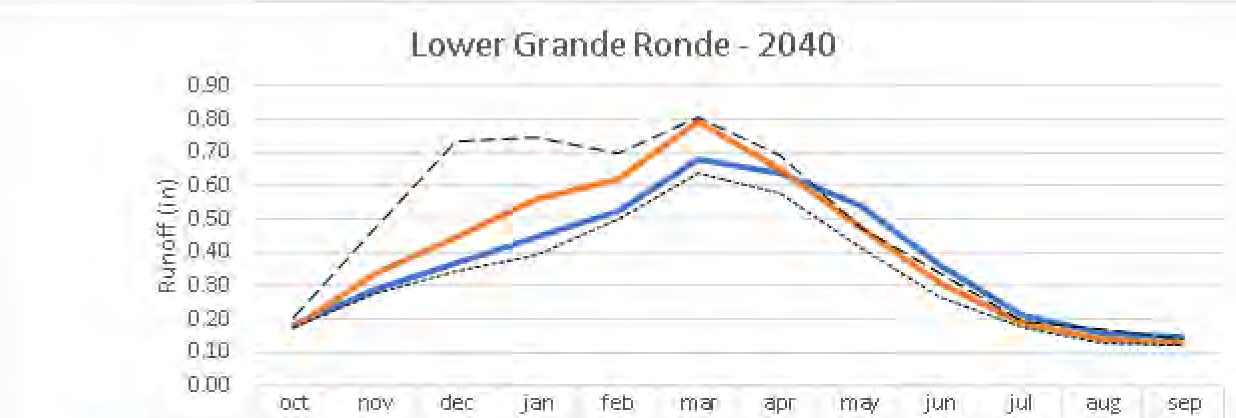


	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep
historical	0.21	0.33	0.44	0.45	0.54	0.90	1.13	0.98	0.59	0.29	0.19	0.17
composite	0.20	0.39	0.55	0.65	0.73	1.14	1.15	0.77	0.43	0.24	0.16	0.14
minimum	0.20	0.33	0.45	0.49	0.59	0.86	0.99	0.61	0.35	0.22	0.14	0.13
maximum	0.24	0.54	0.87	0.94	0.89	1.22	1.19	0.78	0.43	0.25	0.19	0.15

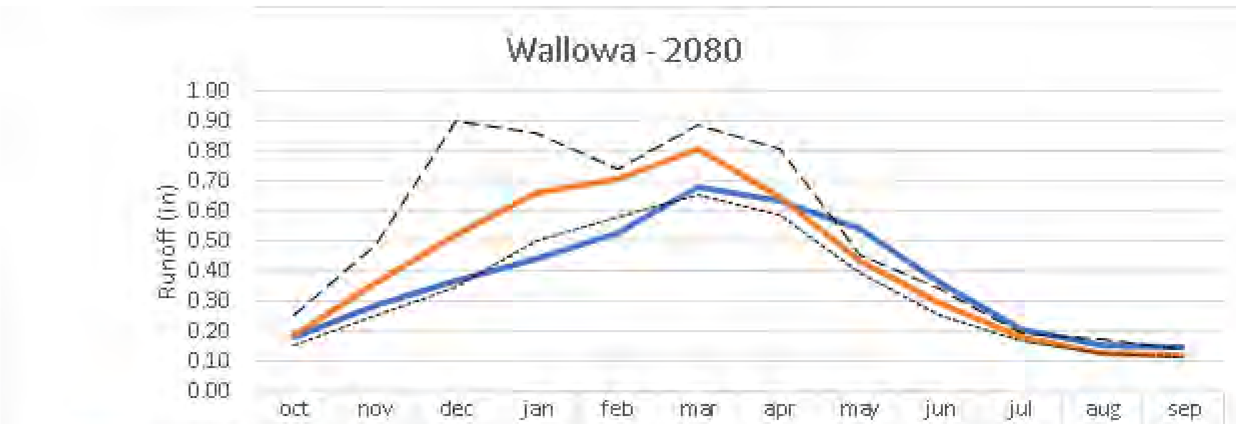


	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep
historical	0.21	0.33	0.44	0.45	0.54	0.90	1.13	0.98	0.59	0.29	0.19	0.17
composite	0.21	0.43	0.68	0.85	0.94	1.23	1.09	0.63	0.39	0.23	0.15	0.14
minimum	0.17	0.29	0.45	0.65	0.76	0.94	1.00	0.50	0.32	0.20	0.14	0.12
maximum	0.30	0.58	1.13	1.17	1.02	1.24	1.30	0.65	0.43	0.25	0.20	0.15

Figure 43. Average monthly historical runoff at the mouth of the Upper Grande Ronde River sub-basin (historical), modeled runoff using the composite of temperature and precipitation changes from all 10 GCMs (composite), and the minimum and maximum monthly values from individual GCMs (minimum; maximum). Top graph is for a future time period cenetered on the year 2040; bottom graph for a future time period cenetered on the year 2080. Data Source: Littell et al. (2014).

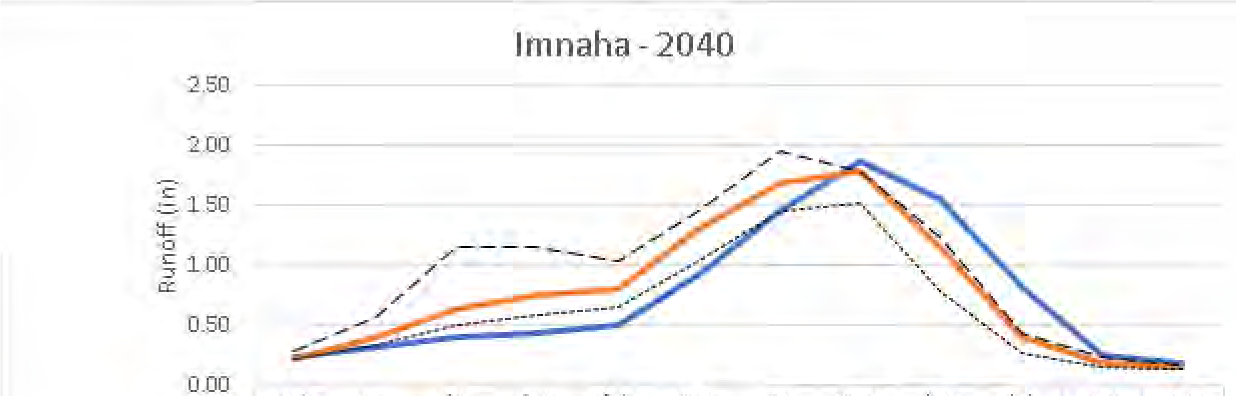


	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep
historical	0.18	0.29	0.37	0.44	0.53	0.68	0.64	0.54	0.37	0.21	0.16	0.15
composite	0.18	0.34	0.45	0.56	0.62	0.79	0.65	0.48	0.31	0.19	0.14	0.13
minimum	0.18	0.28	0.34	0.39	0.50	0.64	0.58	0.42	0.27	0.18	0.13	0.12
maximum	0.21	0.48	0.73	0.74	0.70	0.81	0.70	0.48	0.34	0.20	0.17	0.14



	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep
historical	0.18	0.29	0.37	0.44	0.53	0.68	0.64	0.54	0.37	0.21	0.16	0.15
composite	0.19	0.36	0.53	0.66	0.71	0.81	0.65	0.44	0.30	0.18	0.13	0.13
minimum	0.16	0.26	0.35	0.50	0.58	0.66	0.59	0.39	0.26	0.17	0.13	0.12
maximum	0.26	0.49	0.90	0.87	0.75	0.89	0.81	0.46	0.34	0.20	0.17	0.14

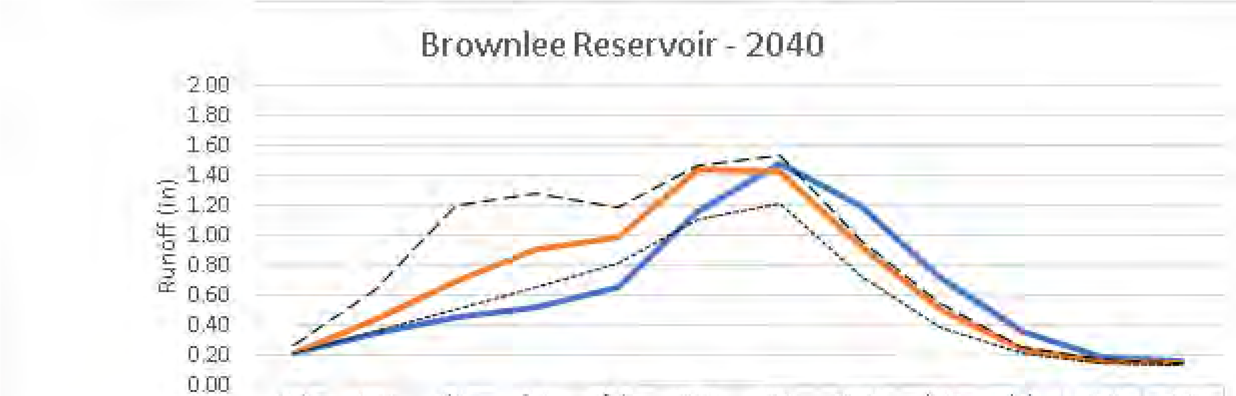
Figure 44. Average monthly historical runoff at the mouth of the Lower Grande Ronde River sub-basin (historical), modeled runoff using the composite of temperature and precipitation changes from all 10 GCMs (composite), and the minimum and maximum monthly values from individual GCMs (minimum; maximum). Top graph is for a future time period cenetered on the year 2040; bottom graph for a future time period cenetered on the year 2080. Data Source: Littell et al. (2014).



	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep
historical	0.24	0.33	0.41	0.44	0.52	0.93	1.46	1.88	1.56	0.83	0.26	0.19
composite	0.23	0.40	0.65	0.76	0.81	1.31	1.70	1.79	1.16	0.40	0.19	0.16
minimum	0.23	0.34	0.50	0.59	0.65	1.04	1.46	1.52	0.80	0.27	0.16	0.14
maximum	0.29	0.58	1.15	1.16	1.04	1.46	1.96	1.79	1.24	0.45	0.24	0.18

	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep
historical	0.24	0.33	0.41	0.44	0.52	0.93	1.46	1.88	1.56	0.83	0.26	0.19
composite	0.25	0.49	0.96	1.15	1.19	1.59	1.67	1.48	0.77	0.26	0.16	0.15
minimum	0.20	0.30	0.51	0.88	1.04	1.18	1.46	0.78	0.36	0.22	0.15	0.13
maximum	0.41	0.68	1.76	1.64	1.35	2.12	2.06	1.57	0.95	0.31	0.23	0.18

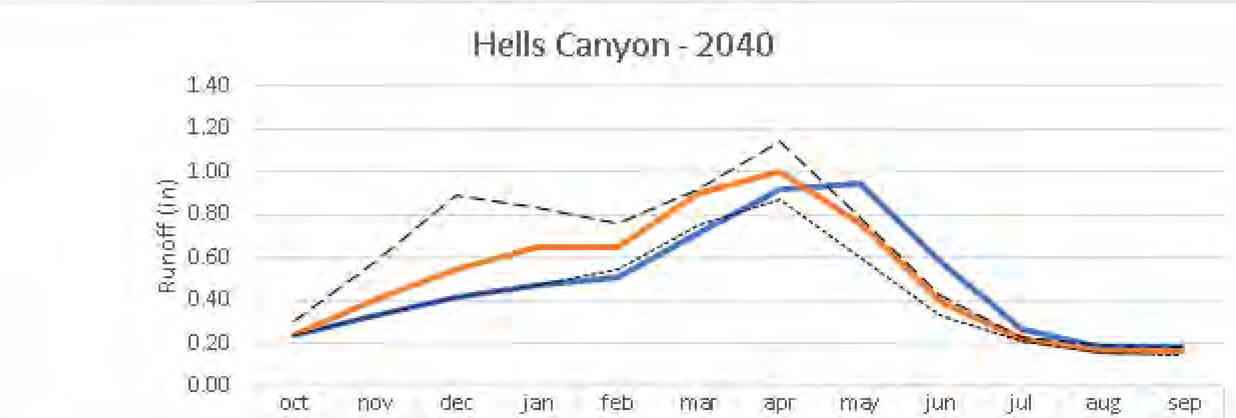
Figure 45. Average monthly historical runoff at the mouth of the Imnaha River sub-basin (historical), modeled runoff using the composite of temperature and precipitation changes from all 10 GCMs (composite), and the minimum and maximum monthly values from individual GCMs (minimum; maximum). Top graph is for a future time period cenetered on the year 2040; bottom graph for a future time period cenetered on the year 2080. Data Source: Littell et al. (2014).



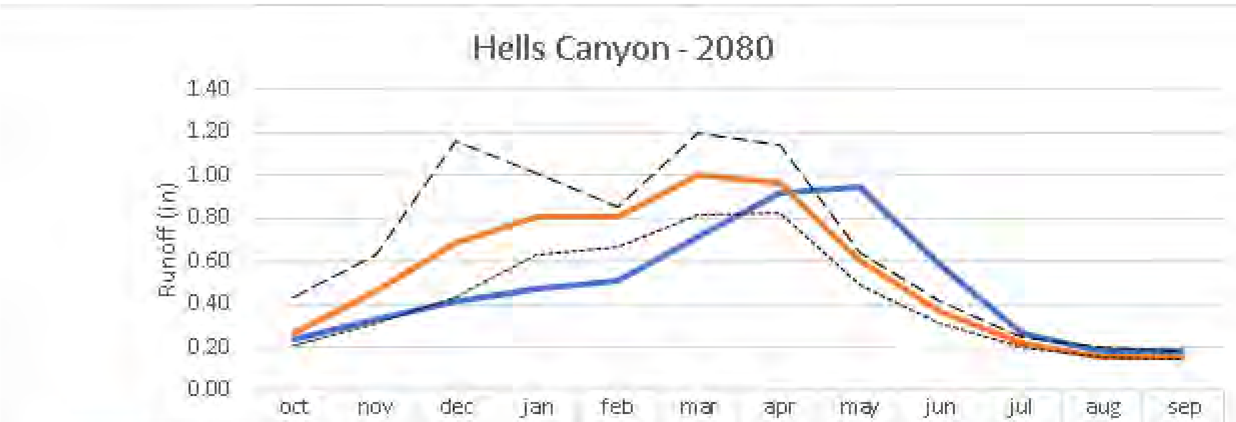
	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep
historical	0.22	0.35	0.45	0.53	0.66	1.17	1.48	1.21	0.72	0.37	0.19	0.16
composite	0.22	0.44	0.70	0.91	1.00	1.44	1.43	0.94	0.51	0.25	0.16	0.15
minimum	0.22	0.36	0.52	0.66	0.81	1.11	1.22	0.74	0.40	0.22	0.15	0.14
maximum	0.27	0.64	1.21	1.29	1.20	1.47	1.55	0.97	0.55	0.26	0.18	0.16

	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep
historical	0.22	0.35	0.45	0.53	0.66	1.17	1.48	1.21	0.72	0.37	0.19	0.16
composite	0.24	0.52	0.95	1.24	1.33	1.58	1.25	0.72	0.41	0.22	0.15	0.15
minimum	0.19	0.33	0.54	0.93	1.05	1.25	1.12	0.49	0.30	0.20	0.15	0.13
maximum	0.39	0.74	1.71	1.63	1.40	1.76	1.39	0.79	0.47	0.25	0.19	0.16

Figure 46. Average monthly historical runoff at the outlet of the Brownlee Reservoir sub-basin (historical), modeled runoff using the composite of temperature and precipitation changes from all 10 GCMs (composite), and the minimum and maximum monthly values from individual GCMs (minimum; maximum). Top graph is for a future time period cenetered on the year 2040; bottom graph for a future time period cenetered on the year 2080. Data Source: Littell et al. (2014).



	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep
historical	0.24	0.33	0.41	0.47	0.50	0.71	0.92	0.95	0.58	0.26	0.18	0.18
composite	0.24	0.41	0.55	0.65	0.65	0.90	1.00	0.76	0.40	0.22	0.17	0.16
minimum	0.24	0.33	0.41	0.47	0.55	0.75	0.87	0.60	0.33	0.21	0.16	0.15
maximum	0.31	0.58	0.89	0.84	0.76	0.92	1.14	0.79	0.43	0.23	0.19	0.18



	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep
historical	0.24	0.33	0.41	0.47	0.50	0.71	0.92	0.95	0.58	0.26	0.18	0.18
composite	0.26	0.46	0.68	0.80	0.81	1.01	0.97	0.60	0.37	0.21	0.16	0.16
minimum	0.21	0.31	0.43	0.63	0.67	0.82	0.83	0.49	0.31	0.20	0.15	0.14
maximum	0.43	0.63	1.16	1.01	0.85	1.20	1.14	0.63	0.42	0.24	0.20	0.18

Figure 47. Average monthly historical runoff at the outlet of the Hell's Canyon sub-basin (historical), modeled runoff using the composite of temperature and precipitation changes from all 10 GCMs (composite), and the minimum and maximum monthly values from individual GCMs (minimum; maximum). Top graph is for a future time period cenetered on the year 2040; bottom graph for a future time period cenetered on the year 2080. Data Source: Littell et al. (2014).

	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep
historical	0.17	0.25	0.30	0.34	0.38	0.46	0.40	0.36	0.27	0.18	0.16	0.15
composite	0.17	0.28	0.34	0.38	0.41	0.49	0.41	0.35	0.25	0.17	0.15	0.14
minimum	0.17	0.23	0.27	0.28	0.35	0.42	0.37	0.32	0.22	0.16	0.14	0.13
maximum	0.19	0.38	0.53	0.46	0.45	0.49	0.45	0.36	0.27	0.17	0.17	0.15

	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep
historical	0.17	0.25	0.30	0.34	0.38	0.46	0.40	0.36	0.27	0.18	0.16	0.15
composite	0.18	0.29	0.39	0.41	0.44	0.49	0.43	0.34	0.24	0.16	0.14	0.13
minimum	0.16	0.22	0.28	0.33	0.38	0.42	0.39	0.32	0.21	0.16	0.14	0.13
maximum	0.22	0.38	0.62	0.50	0.47	0.56	0.52	0.37	0.28	0.18	0.18	0.15

Figure 48. Average monthly historical runoff at the outlet of the Lower Snake Asotin sub-basin (historical), modeled runoff using the composite of temperature and precipitation changes from all 10 GCMs (composite), and the minimum and maximum monthly values from individual GCMs (minimum; maximum). Top graph is for a future time period cenetered on the year 2040; bottom graph for a future time period cenetered on the year 2080. Data Source: Littell et al. (2014).

4 Water Availability

The OWRD has estimated natural monthly streamflows at the mouths of 157 water availability basins (WABs) within the project area. The natural streamflow estimates available from the OWRD are the monthly 50% and 80% exceedance flows. The 50% exceedance streamflow is the streamflow that occurs at least 50% of the time in a given month. Conversely, the streamflow is also less than the 50% exceedance flow half the time. The 50% exceedance flow can be thought of as representing a "normal" streamflow for that month. The 80% exceedance streamflow is exceeded 80% of the time. The 80% flow is smaller than the 50% flow, and can be thought of as the streamflow that occurs in a dry month[11]. These exceedance streamflow statistics are used by the OWRD to set the standard for over-appropriation: the 50% exceedance flow for storage and the 80% exceedance flow for other appropriations. These estimates of natural monthly streamflows were made by the OWRD using statistical models derived from multiple linear regressions (Cooper, 2002).

A consumptive use is defined as any water use that causes a net reduction in streamflow. These uses are usually associated with an evaporative or transpirative loss. The OWRD recognizes four major categories of consumptive use: irrigation, municipal, storage, and all others (e.g., domestic, livestock). Uses are not estimated to be 100 % consumptive, and are estimated by multiplying a consumptive use coefficient (e.g., for domestic use, the coefficient is 0.20) by the maximum diversion rate allowed for the water right. The OWRD assumes that all of the non-consumed part of a diversion is returned to the stream from which it was diverted. The exception is when diversions are from one watershed to another, in which case the use is considered to be 100 % (i.e., the consumptive use equals the diversion rate). Consumptive use estimates available from the OWRD through the Water Availability Reporting System (WARS[12]) were used in this assessment. The net effect of water withdrawals on monthly streamflows were estimated in the following manner:

- The estimated monthly natural streamflows for average and dry years (represented by the 50% and 80% exceedance flow respectively) were first plotted for each location.
- The portion of all water withdrawals that does not return to the stream (i.e., the consumptive uses) was added to water diverted for storage for each month and plotted on the same graph.
- Instream water rights for the watershed were also shown on the graph
- Finally, the sum of instream water rights and consumptive uses was plotted on the graph.

[11] For example, the 50% exceedance flow at the mouth of the Wallowa River in the month of December is estimated to be 531 cfs, while the 80% exceedance flow for the same month is estimated as 412 cfs. The 50% and 80% exceedance flow at the same location for the month of August are 489 and 373 cfs

[12] http://apps.wrd.state.or.us/apps/wars/wars_display_wa_tables/MainMenu1.aspx

The estimated net effect of water withdrawals on monthly streamflow at the mouth of the Lostine River is shown in Figure 49. These estimates indicate that consumptive water uses are below the estimated volume of natural streamflow in all months, both in average (50% exceedance flows) and dry (80% exceedance flows) years. Instream water rights (ISWR) are at or exceed the 80% exceedance flows in all months except April – July, and exceed the 50% exceedance flows only in the months of September – November (Figure 49; green line). The red line in Figure 49 shows the net water allocated (sum of consumptive uses and ISWR), and indicates that water availability is limited to the months of April – August for the 80% flow, and January – July for the 50% exceedance flow.

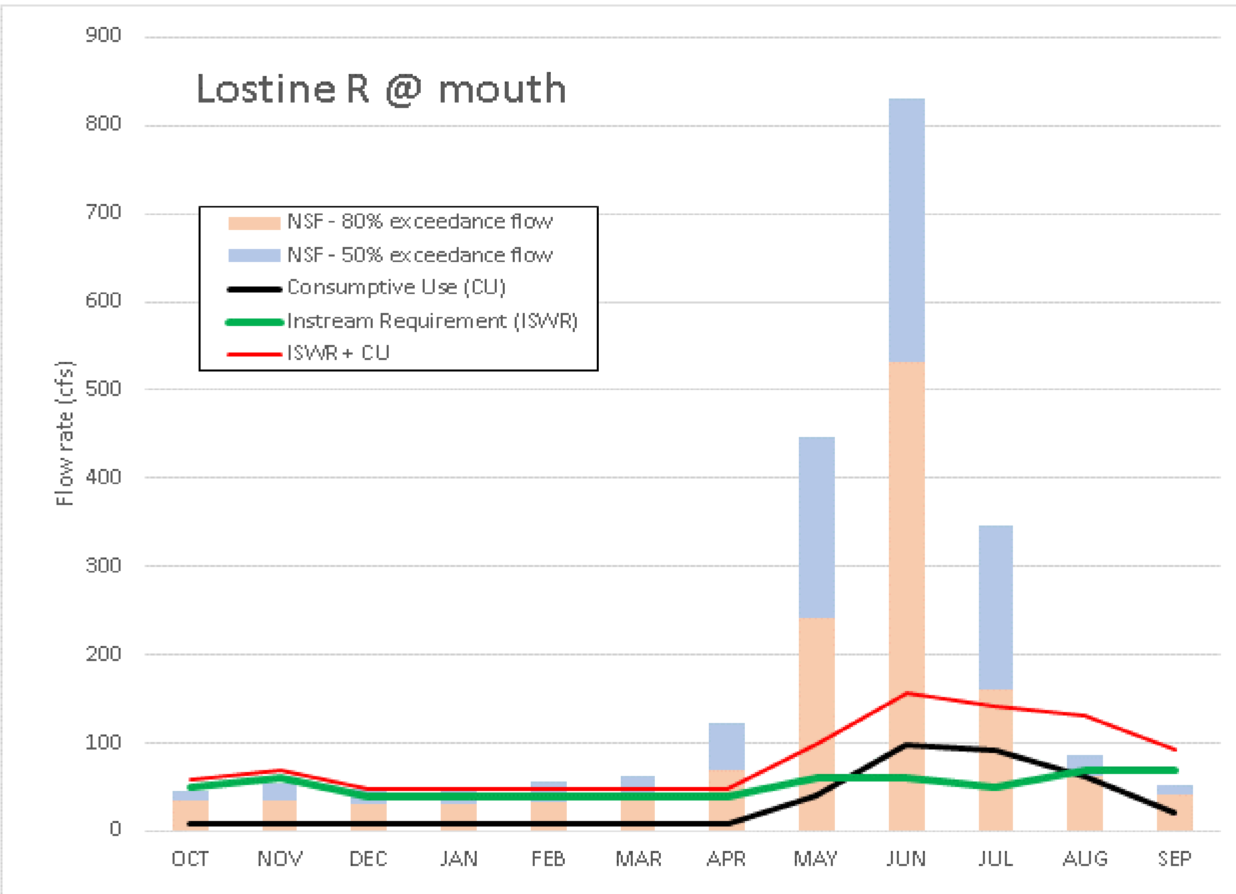


Figure 49. Estimated net effect of water withdrawals on monthly streamflows at the mouths of the Lostine River Water Availability Basin. Shown are estimated natural streamflows for average and dry years (50% and 80% exceedance flows); the sum of consumptive uses (CU); instream water rights; and the sum of instream water rights (IWR) and consumptive uses (CU). Data source: OWRD.

Water availability at the 50% exceedance value (used for determining storage availability) are shown for the months of January – June in Figure 50, and for the months of July – December in Figure 51. Water availability at the 80% exceedance value (used for determining availability for all other uses) are shown for the months of January – June in Figure 52, and for the months of July – December in Figure 53.

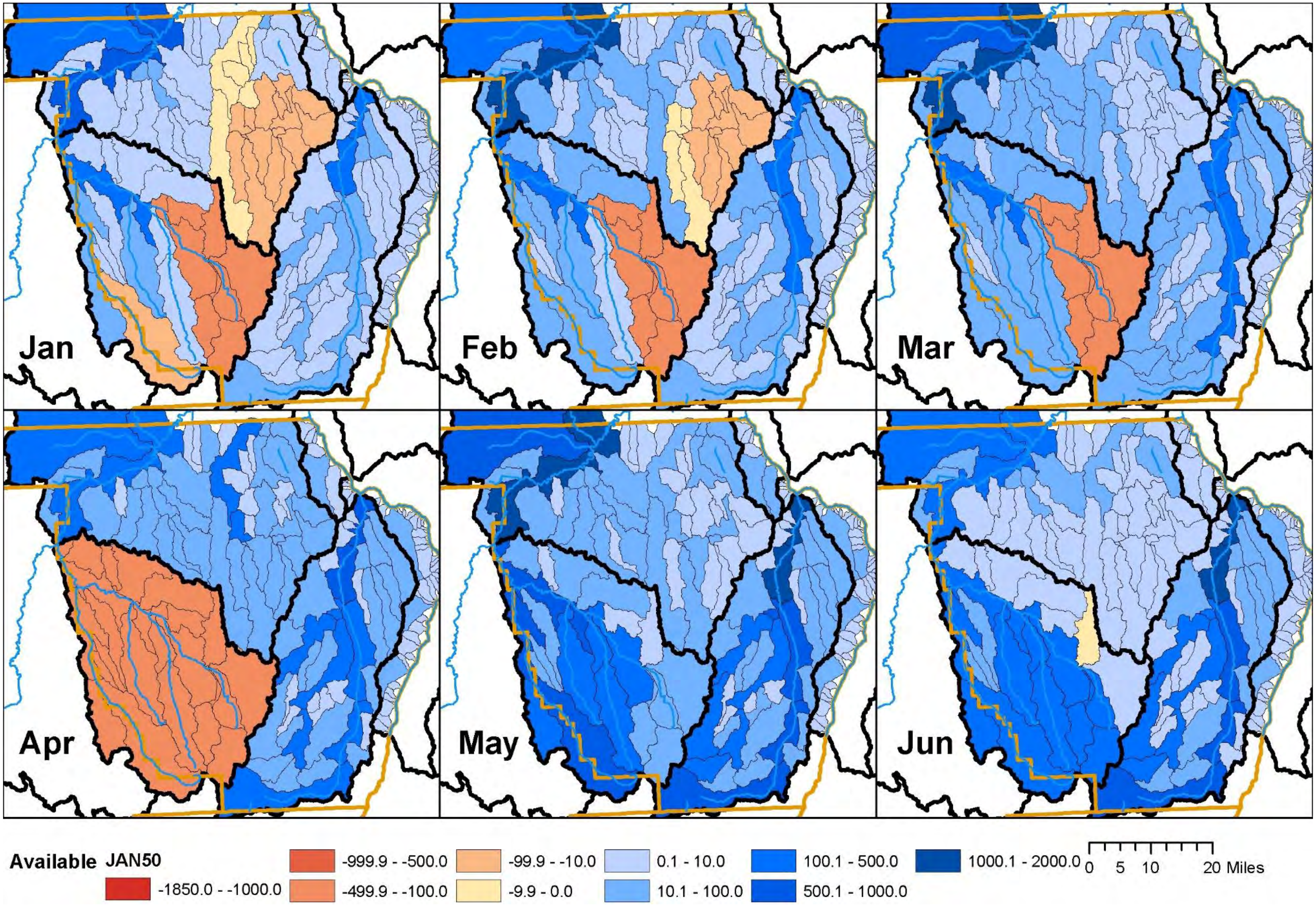


Figure 50. Water availability rate at the 50% exceedance value, January – June.

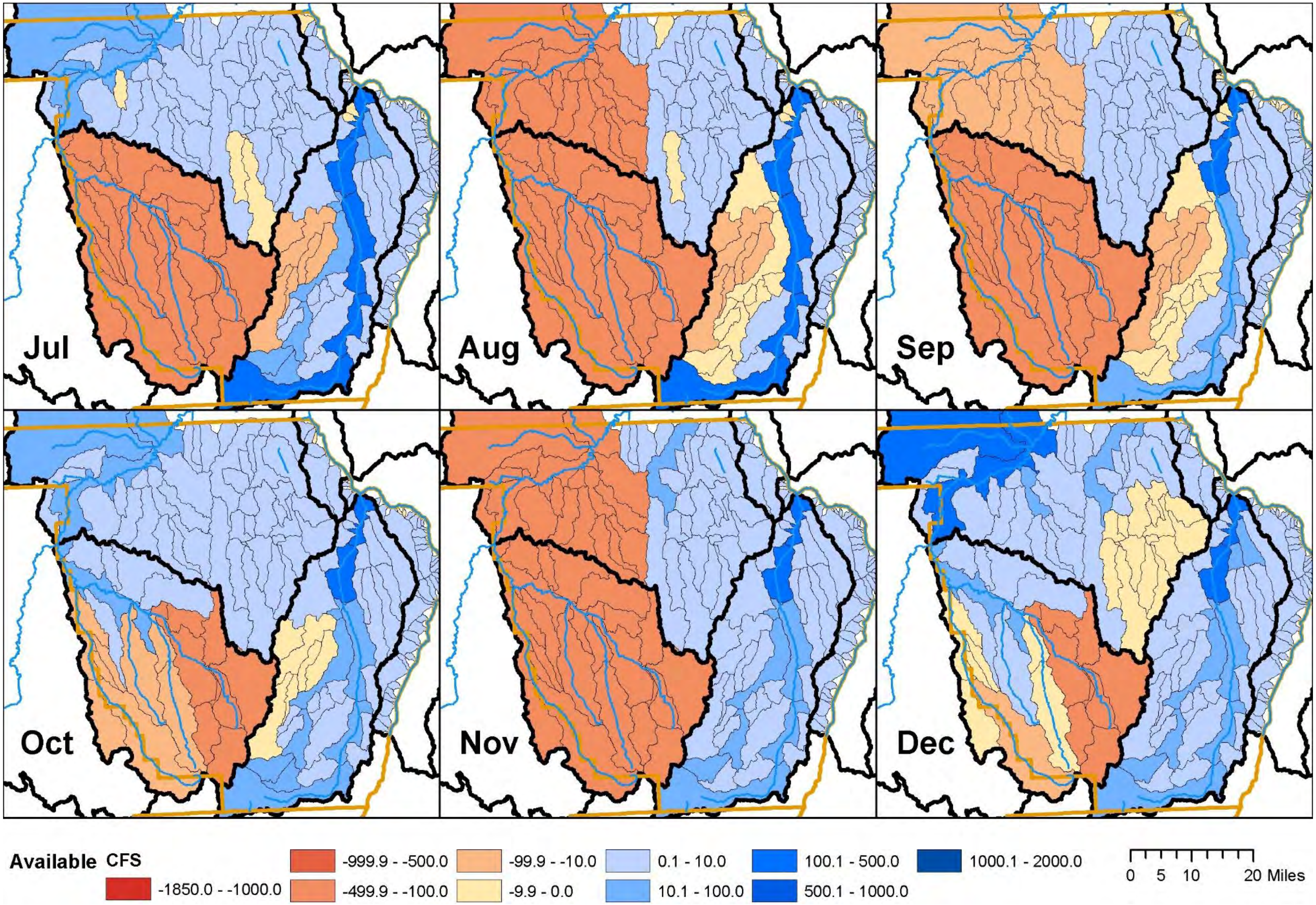


Figure 51. Water availability rate at the 50% exceedance value, July – December.

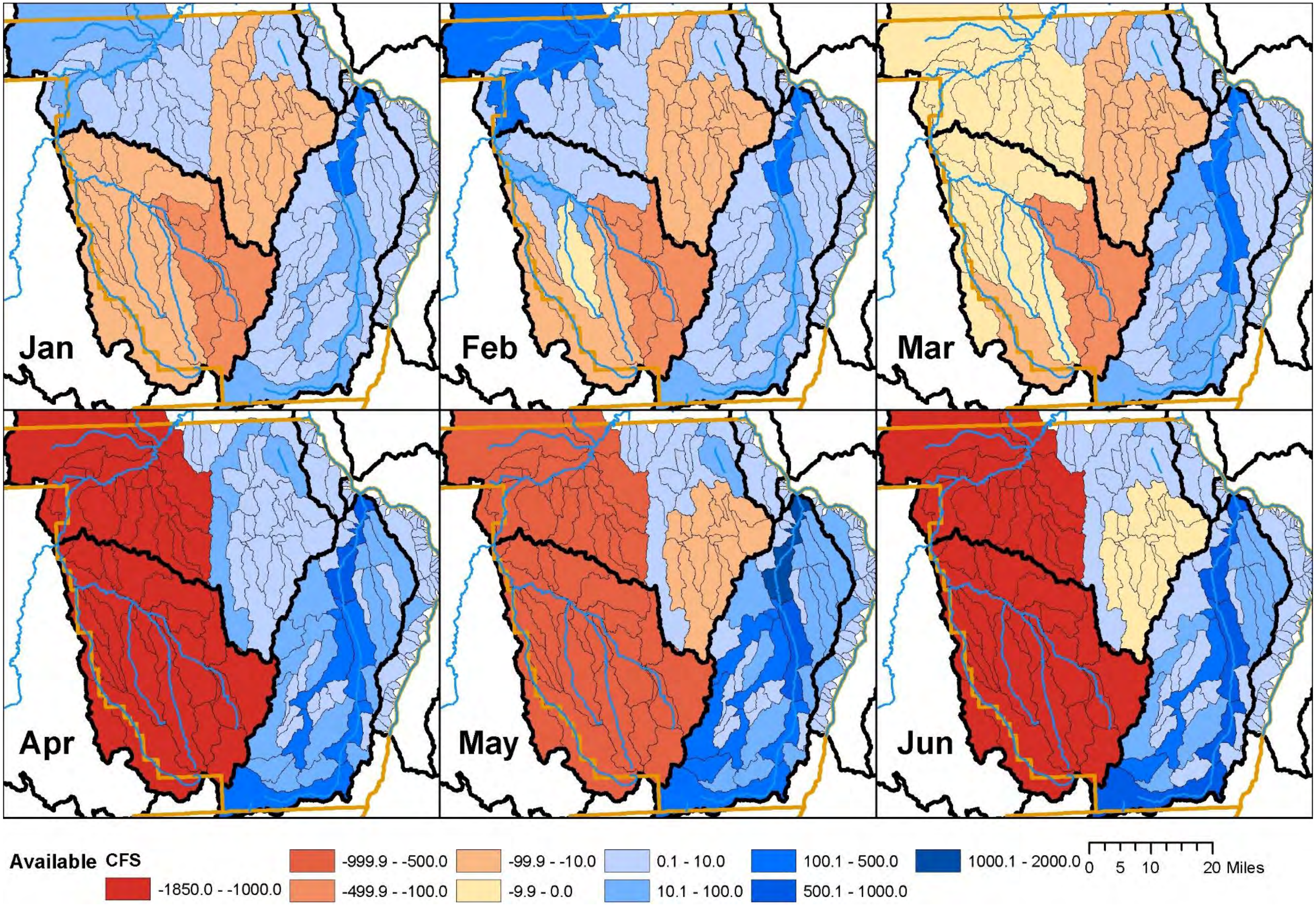


Figure 52. Water availability rate at the 80% exceedance value, January – June.

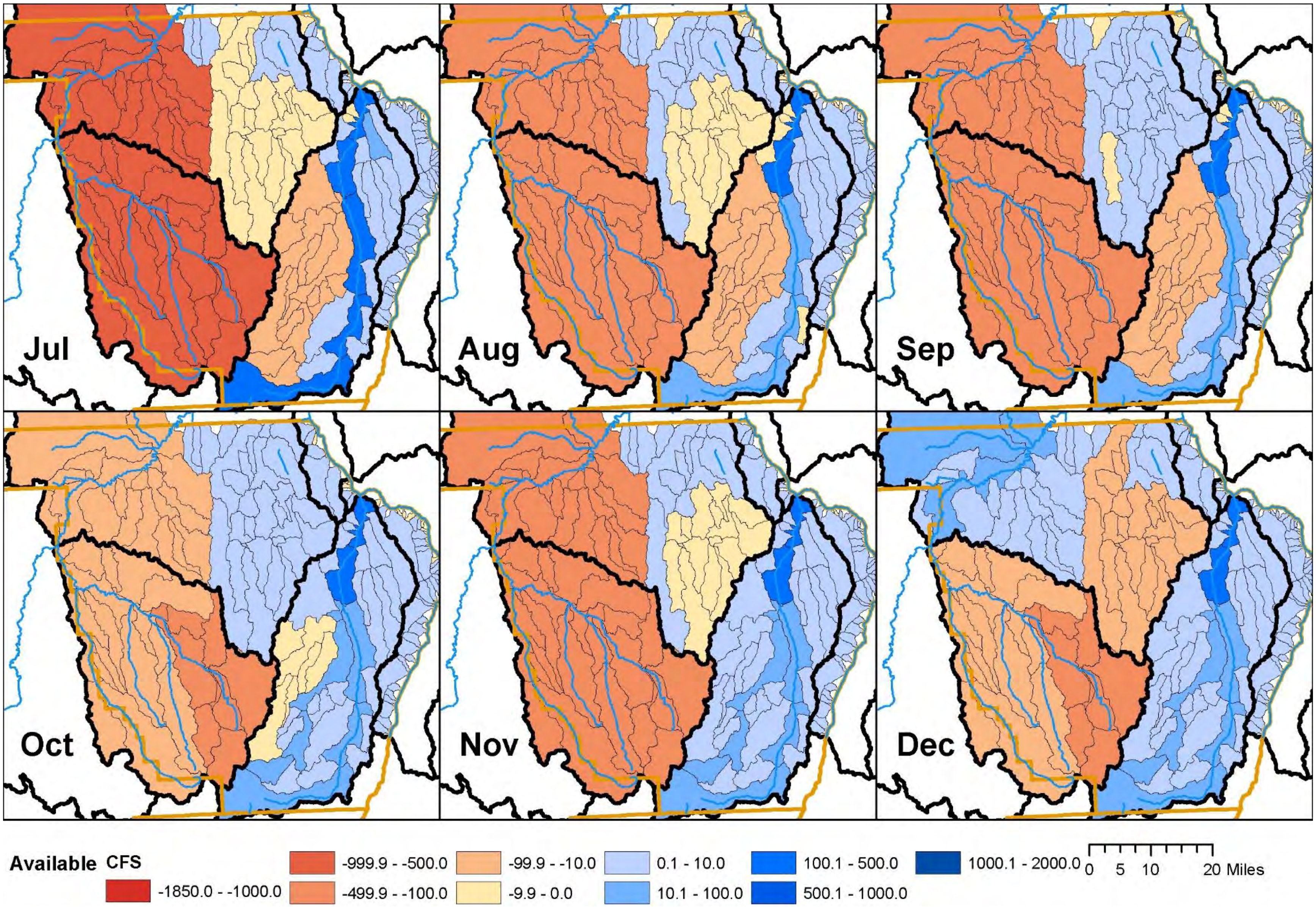


Figure 53. Water availability rate at the 80% exceedance value, July – December.

Wallowa Sub-Basin

Water availability is the most limited within the Wallowa sub-basin. No water is available at the 50% exceedance level in any WABs during the months of April (Figure 50), July – September, or November (Figure 51). In the remaining months water availability ranges from 16 – 785 cfs. At the 80% exceedance level water is only available during the month of February (18 cfs; Figure 52) and unavailable in all other months.

Lower Grande Ronde Sub-Basin

Water is available at the 50% exceedance level in all WABs of the Lower Grande Ronde during the months of March through June and October, and in some WABs for the remaining months (Figure 50 and Figure 51). The greatest deficit is -178 cfs (multiple WABs in the lower basin) during the month of November (Figure 51), and the greatest availability (1,570 cfs) is in WAB 227, the mainstem Grande Ronde reach above the state line (Figure 50). At the 80% exceedance level water is available during every month in at least some WABS (up to 420 cfs), however every month has some WABs that show a deficit in availability (as low as -1,850 cfs).

Imnaha Sub-Basin

Water is available at the 50% exceedance level in all WABs of the Imnaha sub-basin during the months of November through June (up to 1,720 cfs in May), and in some WABs for the remaining months (Figure 50 and Figure 51). The greatest deficit is -26.6 cfs (multiple WABs in the Sheep Creek system) during the month of August (Figure 51). At the 80% exceedance level water is also available in all WABs during the months of November through June (up to 1,190 cfs in May), and in some WABs for the remaining months (Figure 52 and Figure 53). The greatest deficit is -44.2 cfs in several WABs in the Sheep Creek system during the month of July (Figure 53).

Hells Canyon and Lower Snake-Asotin Sub-Basins

Water is available at the 50% exceedance level in all WABs of the Hells Canyon and Lower Snake-Asotin sub-basins during the months of October through June (up to 48.5 cfs in April), and in some WABs for the remaining months (Figure 50 and Figure 51). The greatest deficit is less than one cfs during the months of July - September (Figure 51). Note that one of the WABs include the mainstem of the Snake River. At the 80% exceedance level water is also available in all WABs during the months of October through June (up to 15.7 cfs in May), and in some WABs for the remaining months (Figure 52 and Figure 53). The greatest deficit is less than one cfs during the months of July - September (Figure 51).

5 Water Use and Water Rights

Public domain data from the OWRD Water Use Reporting (WUR) program and Water Right Information System (WRIS), as well as other sources, was used to summarize water use and water rights in Wallowa County for the following uses:

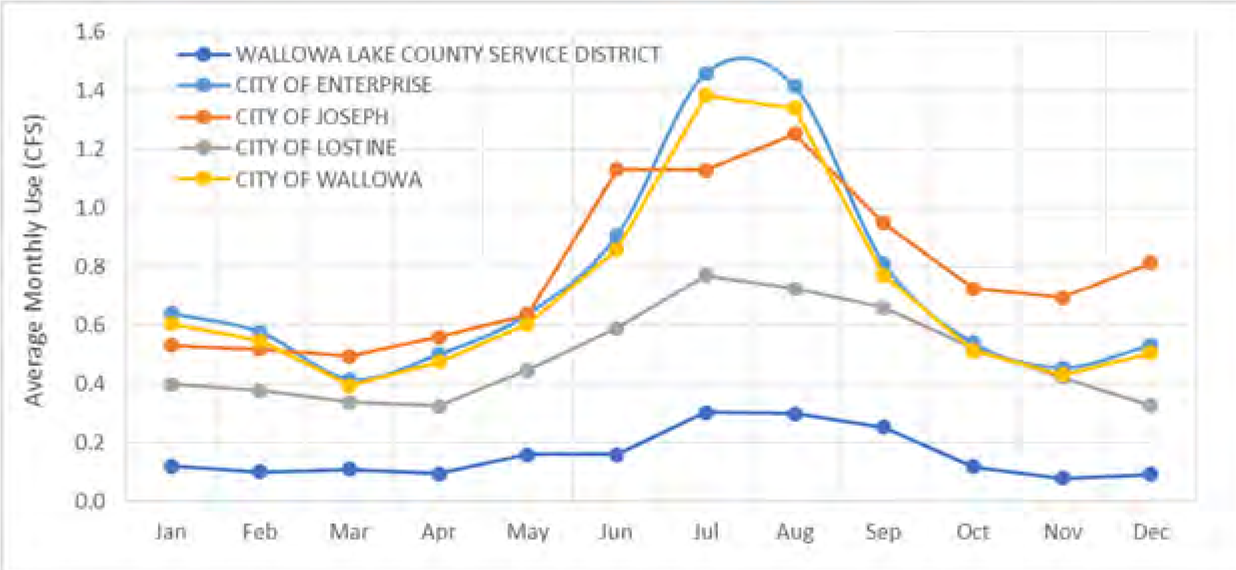
- Municipal
- Domestic
- Commercial
- Irrigation
- Instream

Additional information is also presented for crop water demand, fish distribution, and State Scenic Waterway flows.

5.1 Municipal

Municipal water use data is presented below for the four cities in the Wallowa Valley as well as Lake County Service District. The data is based on Water Use Reports filed by each entity with OWRD, however much of the Water Use Report information is missing or believed to be inaccurate and hence information from each entities Water Management and Conservation Plan (where available) was used to supplement the Water Use Report data.

Sections 5.1.1 -5.1.5 show more detailed information for each entity, but in summary, average cumulative municipal water use varies from a low of approximately 2 cfs in the winter to 5 cfs in the summer (Figure 54). Annual tends in water use are more difficult to discern since most entities have incomplete Water Use Reports (hence not reliable annual data) and outdated Water Management Conservation Plans (with the exception of the 2017 City of Enterprise plan). Although annual tend data is not available, one can expect that water use has not increased significantly since the population of the valley has remained relatively constant over the past 20 years. In fact, it's likely that increases in efficiency and eliminating leaks has led to an overall decline in municipal water use over the past 10 years (e.g., City of Enterprise as shown in Figure 54).



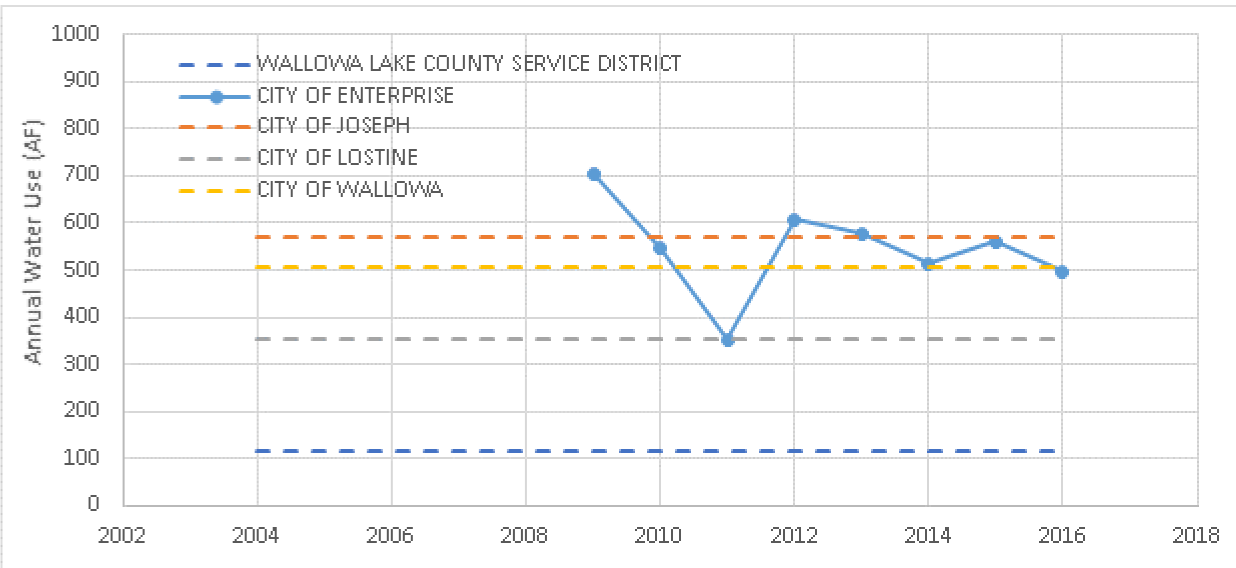


Figure 54. Municipal water use in Wallowa County.

5.1.1 City of Joseph

The City of Joseph has water rights to Wallowa Lake (1997 priority date for 480 AF/yr), the Wallowa River (1900 priority date of 6.0 cfs), and a well (2003 priority date for 1.08 cfs) (Table 7). OWRD Water Use Reports for "City of Joseph" contain missing and incorrect data, however the City manager provided water use reports for the "Citizen Water Ditch and Joseph Water System" which are shown in Table 8. From this information it is estimated that the city's current water use is approximately 570 AF/yr and has a peak rate of 1.3 cfs. It should be noted that the 2001 Joseph Water Management and Conservation Plan (Anderson Perry, 2001) estimated annual use at 440 AF so it appears the City of Joseph has seen a roughly 2% increase in use per year.

Table 7. Water rights held by the City of Joseph.

Permit	Priority Date	Source	Period	Permitted Amount (cfs unless noted)
15688	11/10/2003	A WELL	All year	1.08
53560	8/25/1997	WALLOWA LAKE	All year	480 AF/yr
	8/31/1900	WALLOWA RIVER	All year	6

Table 8. City of Joseph water use data[1].

Year	Unit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2014	AF	30	24	30	32	35	53	85	mis	mis	14	29	33	
2015	AF	31	30	30	31	33	58	80	68	46	39	32	37	514
2016	AF	33	33	30	36	43	78	56	83	68	48	52	61	622
2017	AF	59	51	50	36	43	48	65	84	56	mis	mis	mis	
Avg [2]	**AF**	**32**	**31**	**30**	**34**	**38**	**68**	**68**	**75**	**57**	**44**	**42**	**49**	**568**
	CFS	**0.5**	**0.5**	**0.5**	**0.6**	**0.6**	**1.1**	**1.1**	**1.3**	**0.9**	**0.7**	**0.7**	**0.8**	

Notes: [1] Data received from city manager, and is listed as "Citizens Water Ditch and Joseph Water System."
[2] Period used as "Avg" based on year 2015 and 2016.

5.1.2 City of Enterprise

The City of Enterprise has four municipal water rights ranging in priority dates from 1908 to 1995, plus an additional irrigation right of 1.0 cfs with a date of 1934 (Table 9). Water Use Reports filed with OWRD are shown below in Table 10, from which an annual use of 535 AF and peak monthly rate of 1.5 cfs is calculated. Of the city's water demand, approximately 79% of water use is residential and 21% commercial (Anderson Perry, 2017).

Table 9. Municipal water rights held by the City of Enterprise.

Permit	Priority Date	Source	Period	Permitted Amount (cfs)
	11/20/1908	A SPRING [1]	All year	7
36777	9/19/1972	UNNAMED STREAM 1 [2]	All year	7
		UNNAMED STREAM 2 [2]		4
		UNNAMED STREAM 3 [2]		3.75
39123	9/4/1973	UNNAMED SPRING 1 [3]	All year	4.25
		UNNAMED SPRING 2 [3]		4
		UNNAMED SPRING 3 [3]		4
13126	11/9/1995	A WELL	All year	2.67

Notes: [1] 1908 right is for irrigation and municipal
[2] Source referred to as "Dorrance."
[3] Source referred to as "Whitmore."

Table 10. Water Use Reports filed by City of Enterprise with OWRD.

Year	Unit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2004	AF										42	28	32	102
2005	AF	35	32	31	36	37	81	170	185	147	65	36	37	892
2006	AF	41	37	37	41	85	94	151	181	117				785
2007	AF										27	28	25	80
2008	AF	29	28	25	29	61	69	113	134	110	147	130	119	994
2009	AF	30	30	37	39	42	68	100	146	170	13	15	15	704
2010	AF	58	63	20	30	32	45	80	88	36	24	29	39	545
2011	AF	25	20	9	14	17	25	40	70	35	41	26	31	353
2012	AF	58	30	31	32	48	66	86	97	68	33	29	31	607
2013	AF	38	44	33	33	51	52	122	79	47	25	22	32	578
2014	AF	29	27	28	30	40	61	83	70	61	34	27	25	514
2015	AF	26	23	26	38	38	69	89	98	51	37	31	35	561
2016	AF	36	37	29	36	42	64	115	94	44				496
Avg [1]	**AF**	**39**	**35**	**25**	**30**	**38**	**55**	**88**	**85**	**49**	**32**	**27**	**32**	**535**
	CFS	**0.6**	**0.6**	**0.4**	**0.5**	**0.6**	**0.9**	**1.5**	**1.4**	**0.8**	**0.5**	**0.5**	**0.5**	

Notes: [1] Period used as average is 2010 – 2016.

5.1.3 City of Lostine

The City of Lostine has five water rights ranging in priority dates from 1881 through 2005 (Table 11). All water use (except for 5 AF in 2016) reported to OWRD was from the water right for Spring 2A. Of the water use reported to OWRD from 2004-2016, many years contain incomplete or erroneous data, and hence the data for water year 2016 is used to estimate City of Lostine's water demand of 355 AF/yr and a peak monthly rate of 0.8 cfs (Table 12).

Table 11. Municipal water rights held by the City of Lostine.

Permit	Priority Date	Source	Period	Permitted Amount (cfs)
37731	1/3/1975	SPRING 1	All year	0.5
		SPRING 2A		0.2
		SPRING 2B		0.4
		SPRING 3		0.7
		SPRING 4		1.2
38208	6/11/1975	A SPRING	All year	0.1133
		A SPRING		0.1133
		A SPRING		0.1133
	1/31/2005	A WELL	All year	0.557
	12/31/1881	A WELL	All year	0.557
	12/31/1881	LOSTINE RIVER	All year	1.943

Table 12. Water Use Reports filed by City of Lostine with OWRD.

Year	Unit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2004	AF										4	6	6	16
2005	AF	6	6	6	6	6	5	10	10	7	0	0	0	63
2006	AF	0	0	0	0	0	0	0	0	0				0
2007	AF										0	1	1	2
2008	AF	1	1	1	1	1	1	1	1	1				8
2009	AF													
2010	AF													
2011	AF													
2012	AF										3	6	6	15
2013	AF	6	6	6	6	6	5	11	8	3	2	6	6	71
2014	AF	6	5	5	5	5	4	9	8	5	2	6	6	64
2015	AF	6	6	6	6	6	9	11	4	3	31	25	20	134
2016	AF	24	23	20	20	27	36	46	44	40				279
Avg [1]	**AF**	**24**	**23**	**20**	**20**	**27**	**36**	**46**	**44**	**40**	**31**	**25**	**20**	**355**
	CFS	**0.4**	**0.4**	**0.3**	**0.3**	**0.4**	**0.6**	**0.8**	**0.7**	**0.7**	**0.5**	**0.4**	**0.3**	

Notes: [1] Period used as average is water year 2016.

5.1.4 City of Wallowa

The City of Wallowa has three municipal water rights (Table 13), of which it relies almost entirely on Well #1 to provide its municipal supply. The estimated capacity of the two wells (based on the city's 2010 WMCP) is 2.9 cfs for Well #1 and 0.38 cfs for the Bates Well. Due to incomplete Water Use Report data, the city's most recent WMCP (Table 14) was used to estimate current water use of 500 AF/yr and peak monthly rate of 1.4 cfs (Table 15). The city has roughly 500 connections, and it's estimated that approximately 80 % of water use is residential and 15 % irrigation (Anderson Perry, 2010).

Table 13. Water rights held by the City of Wallowa

Permit	Priority Date	Source	Period	Permitted Amount
3353	3/21/1967	BATES WELL	All year	0.39
	12/31/1883	BEAR CREEK	5/1-10/31	1.65 [1]
16912	4/12/1985	WELL #1	All year	4
	12/31/1906	BEAR CREEK	All year	6

Notes: [1] Water right type of use is "irrigation".

Table 14. City of Wallowa water user from most recent WMCP (Anderson Perry, 2010)

Year	Water Use (AF)
2002	446
2003	430
2004	430
2005	466
2006	562
2007	508
2008	492

Table 15. Water Use Reports filed by City of Wallowa with OWRD.

Year	Unit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2004	AF										23	20	22	65
2005	AF	23	20	20	21	27	49	94	97	51				401
2007	AF										32	30	32	94
2008	AF	34	31	31	31	43	55	81	64	46				414
2009	AF										25	21	21	67
2012	AF										25	21	21	67
2013	AF	23	20	22	22	40	62	80	69	33	28	27	29	456
2014	AF	29	25	25	23	26	30	73	70	42	19	17	9	386
2015	AF	1	1	11	16	24	64	40	44	20				222
2016	AF													
Avg [1]	**AF**													**507**
	CFS	**0.6**	**0.5**	**0.4**	**0.5**	**0.6**	**0.9**	**1.4**	**1.3**	**0.8**	**0.5**	**0.4**	**0.5**	

Notes: [1] Period used as average is water year 2005-2008 from City of Wallowa WMCP (Anderson Perry, 2010).

5.1.5 Wallowa Lake County Service District

Wallowa Lake County Service District has three municipal water rights that range in priority date from 1952-1987 (Table 16). Water User Reports filed with OWRD contain a wide range of reported water use (e.g., 41 AF in 2009, 473 AF in 2006), nonetheless all years in Table 17 below are used to estimate average annual use of 114 AF/yr and a peak monthly rate of 0.3 cfs. An alternative approach could be to not include 2006 in the average since it's an outlier, from which the new average annual use would be calculated at 68 AF with a peak rate of 0.18 cfs.

Table 16. Water rights held by the Wallowa Lake County Service District.

Permit	Priority Date	Source	Period	Permitted Amount (cfs)
21554	6/25/1952	UNNAMED CREEK	All year	0.5
12713	12/4/1987	A WELL	OWRD database says all year; Sept. and Nov. listed as "Domestic"	0.89
52474	12/9/1987	A SPRING	OWRD database says all year; Sept. and Nov. listed as "Domestic"	0.1

Table 17. Water Use Reports filed by Wallowa Lake County Service District with OWRD.

Year	Unit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2004	AF										4	3	4	12
2005	AF	4	3	4	3	4	6	11	16	10	46	25	31	164
2006	AF	34	37	41	30	39	49	91	90	53	3	3	3	473
2007	AF	4	3	4	4	5	7	14	12	9	4	4	4	75
2008	AF	5	4	4	4	5	4	12	9	4	3	2	2	59
2009	AF	2	2	2	2	2	3	7	7	6	2	3	2	41
2010	AF	2	3	2	3	26	5	8	9	43	2	2	2	107
2011	AF	2	2	2	2	3	5	9	10	10	3	3	3	52
2012	AF	2	2	2	3	6	8	14	9	11	5	4	4	69
2013	AF	3	3	4	4	10	11	15	19	10	5	4	5	92
2014	AF	5	6	7	7	5	8	14	12	6	0	0	1	72
2015	AF	18	0	0	0	1	1	6	4	5				35
2016	AF													
Avg [1]	**AF**	**7**	**6**	**7**	**6**	**10**	**10**	**18**	**18**	**15**	**7**	**5**	**6**	**114**
	CFS	**0.1**	**0.1**	**0.1**	**0.0**	**0.1**	**0.1**	**0.3**	**0.3**	**0.2**	**0.1**	**0.0**	**0.0**	

Notes: [1] Period used for average is 2004-2015.

5.2 Domestic

Domestic water rights in Wallowa County are shown in Table 18. A majority of these rights (681 of 946) are in the Wallowa sub-basin, but it's difficult to estimate with any degree of confidence cumulative water use from the rights. Nonetheless, as a rough order of magnitude, one can assume these are serving individual homes at 15,618 cubic-feet per year per account (based on City of Enterprise from 2017 WMPC), for a cumulate annual water use of 244 AF. These values should be used with caution as it's unlikely residential water use amount per customer within the City of Enterprise are representative of water use for domestic water rights (e.g., some domestic rights may not be in use).

Table 18. Number of domestic water rights in Wallowa County by HUC 8 basin.

Sub-Basin	Number of Domestic Rights
Lower Grande Ronde	22
Upper Grande Ronde	182
Wallowa	681
Lower Snake-Asotin	3
Imnaha	52
Hells Canyon	6
Total	**946**

5.3 Commercial

The number of commercial water rights and rate of use by sub-basin are shown in Table 19, while Table 20 shows more detailed information for commercial water rights within the Wallowa Valley. The predominant use of commercial water rights is for lumber processing. None of the entities listed in Table 20 file Water Use Reports with OWRD so the exact use in unknown, but it should be noted that commercial rights are rarely used at the full rate and actual use is likely well below the 36 cfs of rights.

Table 19. Commercial water rights in Wallowa County.

Sub-Basin	Number of Commercial Rights	Sum of POD Rate
Lower Grande Ronde	1	0
Upper Grande Ronde	56	54
Wallowa	23	35
Hells Canyon	1	0

Table 20. Commercial water rights in Wallowa HUC 8 sub-basin.

Sub-Basin	Source	POD Rate (cfs)
BOISE CASCADE CORP.	A WELL	0.9
	WALLOWA RIVER	1.36
CHIEF JOSEPH LUMBER CO.	ROUDOLPH SPR	1.02
COUNTY OF WALLOWA	A WELL	2.68
COUNTY OF WALLOWA; HEALTH CARE DISTRICT	A WELL	0.25
COUNTY OF WALLOWA; PUBLIC WORKS	A WELL	0.37
EAST OREGON LUMBER CO.	LITTLE HURRICANE CREEK	24
JOSEPH TIMBER CO. LLC	A WELL	0.007
MILLER MILL & MANUFACTURING CO.	WALLOWA RIVER	2
OREGON PARKS AND RECREATION DEPARTMENT; WALLOWA LAKE MGMT UNIT	A WELL	1.78
Total		**34.7**

5.4 Irrigation

Data presented in the sections below are based on information from the OWRD Water Rights Information System (WRIS), OWRD Water Use Reports (WUR), and other material provided by the stakeholder group. It is believed that some of the data contains errors or incomplete data, and hence a recommendation from this study is to develop a more robust and accurate accounting for overall irrigation water rights, water diversion, crop use, and return flows. This recommendation is based on irrigation water use being the primary water use in the valley and hence a better understanding of it gives a better understanding of the overall water budget.

5.4.1 Water Rights

Irrigation water rights in the study area cover 174,001 acres, of which 61,158 acres are in the Wallowa sub-basin (Table 21). The major irrigation rights in the Wallowa Valley are shown in Table 22, and the major rights in the Imnaha sub-basin are shown in Table 23. It should be noted that the acres listed in Table 22 and Table 23 are water right acres from the OWRD WRIS database and do not necessarily equal acres serves from ditches with similar names.

Table 21. Number of acres of irrigation water rights in Wallowa County by HUC 8 sub-basin.

Sub-Basin	Acres
Upper Grande Ronde	100,067
Wallowa	61,158
Imnaha	10,303
Lower Grande Ronde	2,208
Hells Canyon	200
Lower Snake-Asotin	64
Total	**174,001**

Table 22. Irrigation water rights 20 acres and greater in the Wallowa HUC 8 unit.

Entity	Acres[1]	Primary Source
Smaller users (company names not listed)	25,359	Multiple
BIG BEND DITCH CO.	6,395	WALLOWA RIVER
FARMERS WATER DITCH CO.	4,782	WALLOWA RIVER
ALDER SLOPE DITCH CO.	4,726	HURRICANE CREEK
SILVER LAKE WATER DITCH CO.	4,012	WALLOWA RIVER
WRENN AND DOBBIN DITCH CO.	3,196/546[2]	WALLOWA RIVER and RES.
DOBBIN DITCH CO.	2,024	WALLOWA RIVER
CHAMBERLAIN DITCH CO.	1,341	BEAR CREEK
HURRICANE CREEK IRRIGATING DITCH CO.	1,283	HURRICANE CREEK
WEST SIDE IRRIGATION AND WATER DITCH CO.	1,200[3]	LOSTINE RIVER
GRANGER WATER DITCH CO.	1,068	WALLOWA RIVER
CLEARWATER DITCH CO.	995	LOSTINE RIVER
LOWER VALLEY IMPROVEMENT DISTRICT	735[4]	WALLOWA RIVER
MOONSHINE DITCH CO.	705	HURRICANE CREEK
SHEEP RIDGE DITCH CO.	445	LOSTINE RIVER
COVE DITCH CO.	391	WALLOWA RIVER
ISLAND IRRIGATING WATER DITCH CO.	327	WALLOWA RIVER
CIRCLE M CATTLE CO.	280	WELL
SILVER CREEK DITCH CO.	246	SILVER CREEK
PINE TREE PIPELINE ASSOCIATION	242	HURRICANE CREEK
ALLEN CANYON SPRINKLER ASSOCIATION	225	LITTLE BEAR CREEK
STUBBLEFIELD DITCH CO.	158	HURRICANE CREEK
CITY OF WALLOWA	132	BEAR CREEK
CITIZENS WATER DITCH CO.	114	WALLOWA RIVER
CITY OF ENTERPRISE	100	TROUT C.(60) WALLOWA R.(40)
WOLFE HEREFORD RANCH WTK INC.	100	LOSTINE RIVER
UNION WALLOWA INVESTMENT CO.	74	REAVIS CREEK
WILSON DITCH ASSOCIATION	64	WALLOWA RIVER
FLYING A QUARTER CIRCLE RANCHES INC.	56	SPRINGS
MOORE BROTHERS	55	WALLOWA RIVER
J A EGGLESON FARMS INC.	45	SWAMP CREEK
LOSTINE DITCH CO.	33	LOSTINE RIVER
BAKER REVOCABLE TRUST	30	WALLOWA RIVER
OREGON STATE LAND BOARD	30	WALLOWA RIVER
COUNTY OF WALLOWA; FAIRGROUNDS FAIR BOARD	21	WELL
SUCCESSOR TO UNION WALLOWA INVESTMENT CO.	20	REAVIS CREEK
THE ASSOCIATED DITCH COMPANIES CORP.	20	RESERVOIR
WALLOWA LAKE FOREST INDUSTRIES	20	WALLOWA RIVER

Notes: [1] Acres listed are water right acres from the OWRD WRIS database and do not necessarily equal acres serves from ditches.
[2] OWRD database shows 3,196 acres but 2,650 acres are double layered.
[3] Westside Ditch serves 1,766 acres, Poley/Allen Ditch serves 745 acres.
[4] Lower Valley Improvement District diversion serves 1,534 acres.

Table 23. Irrigation water rights 10 acres and greater in the Imnaha HUC 8 unit.

Entity	Acres	Primary Source
WALLOWA VALLEY IMPROVEMENT DISTRICT 1	6,508	MCCULLY (5,162 acres)
Smaller users (company names not listed)	3,089	MCCULLY (962 acres)
GAULKE AND KERNAN	164	MCCULLY CREEK
STOCKMAR CORP.	147	BLACKMORE CREEK
CIRCLE M CATTLE CO.	67	GROUSE CREEK
TRUSTEE	55	LITTLE SHEEP CREEK
SILVER LAKE DITCH CO.	40	UNAMED CREEK
DAVIN MICHELLOD SHEEP & LAND CO.	33	CAMP CREEK
MARKS AND MARKS	29	JUDY CREEK
IMNAHA SPRINKLER ASSOCIATION	25	SCHLEUR CREEK
OLMSTED BROTHERS	25	BEAR CREEK
BRAGG INVESTMENT CO. INC.	20	IMNAHA RIVER
MARKS BROTHERS	18	CHALK CREEK
LITCH LAND AND CATTLE CO. INC.	15	COW CREEK
TIPPETT AND SON INC.	15	COW CREEK
CARPENTER LAND AND CATTLE CO.	13	IMNAHA RIVER
GAZELLE LAND AND TIMBER LLC	12	S. FK. PACKSADDLE CREEK

5.4.2 Water Diversions

Water diversion data for large irrigation entities is presented below in Figure 55 through Figure 57 and Table 24 through Table 28. The only entities that provide water use data directly to OWRD are the Lower Valley Improvement District and the Wallowa Valley Improvement District. Information for the ditch companies of Dobbins, Farmers, Silver Lake, Big Bend, Granger, and Creighton were provided by the OWRD Water Master, while information for Westside/Poley-Allen is from the 2016 Nez Perce Assessment (Anderson Perry, 2016).

The information below is preliminary in nature and likely contains some errors. For example, Wallowa Valley Improvement District's Water Use Report states diversions of 14,358 AF in 2011 and 3,558 AF in 2012, while the Lower Valley Improvement District flow measuring device has operated under backwater conditions in the past and therefore likely reads too high. Additionally, it should be stressed that the values in this section are 'total diversions' and should not be construed as on-farm deliveries. The irrigation ditch systems have a significant amount of return flows (i.e. water that passes on-farm turnouts and returns to the river) and are also used as flood control. As such, the diversion values presented below are higher than actual water deliveries and therefore caution should be used in interpreting and applying these values.

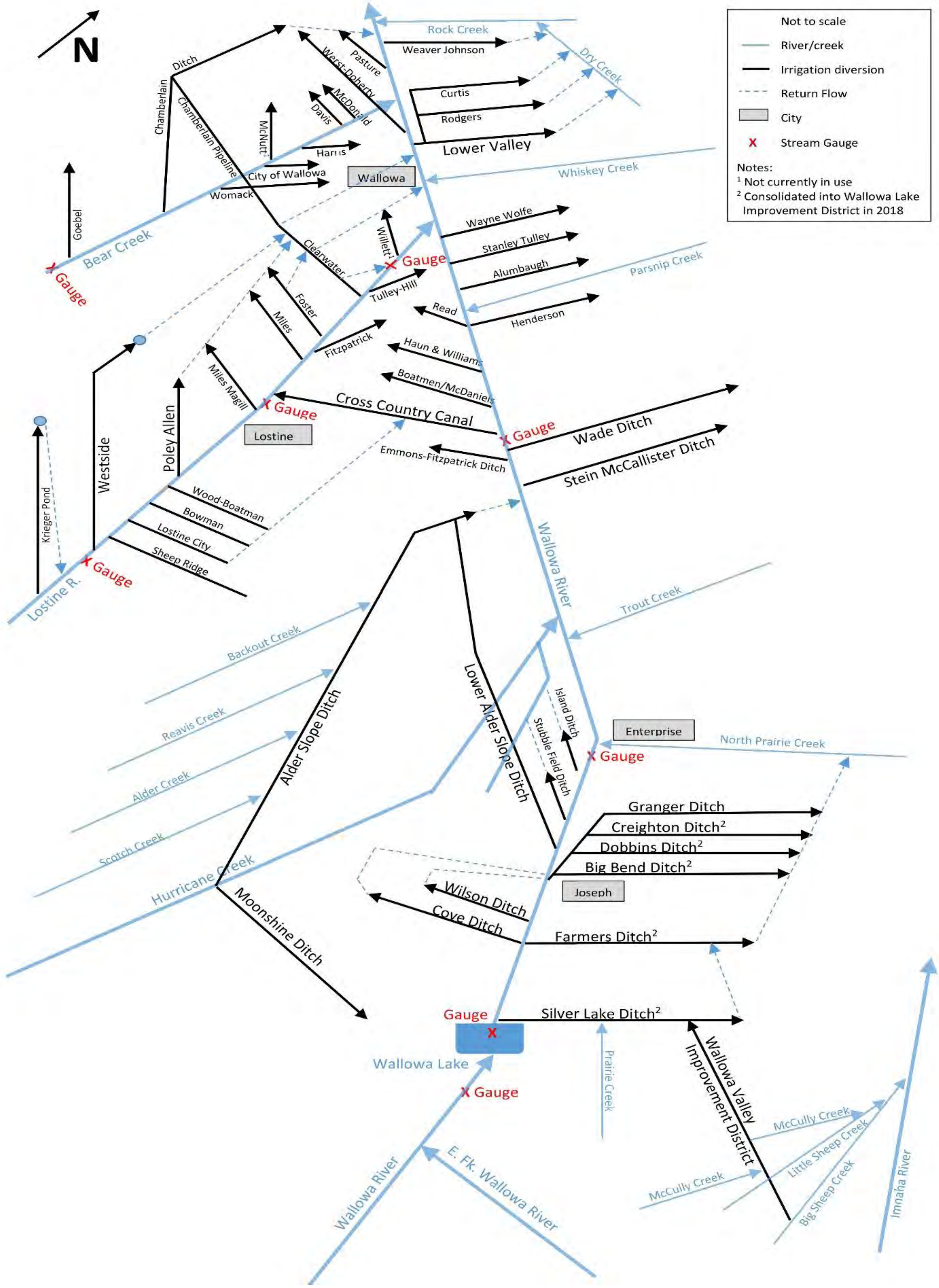


Figure 55. Schematic of Wallowa sub-basin storage, rivers, and irrigation diversions and return flow locations.

Figure 56. Average monthly diversions for major irrigation entities in Wallowa (top), Lostine (middle), and Imnaha (bottom) basins.

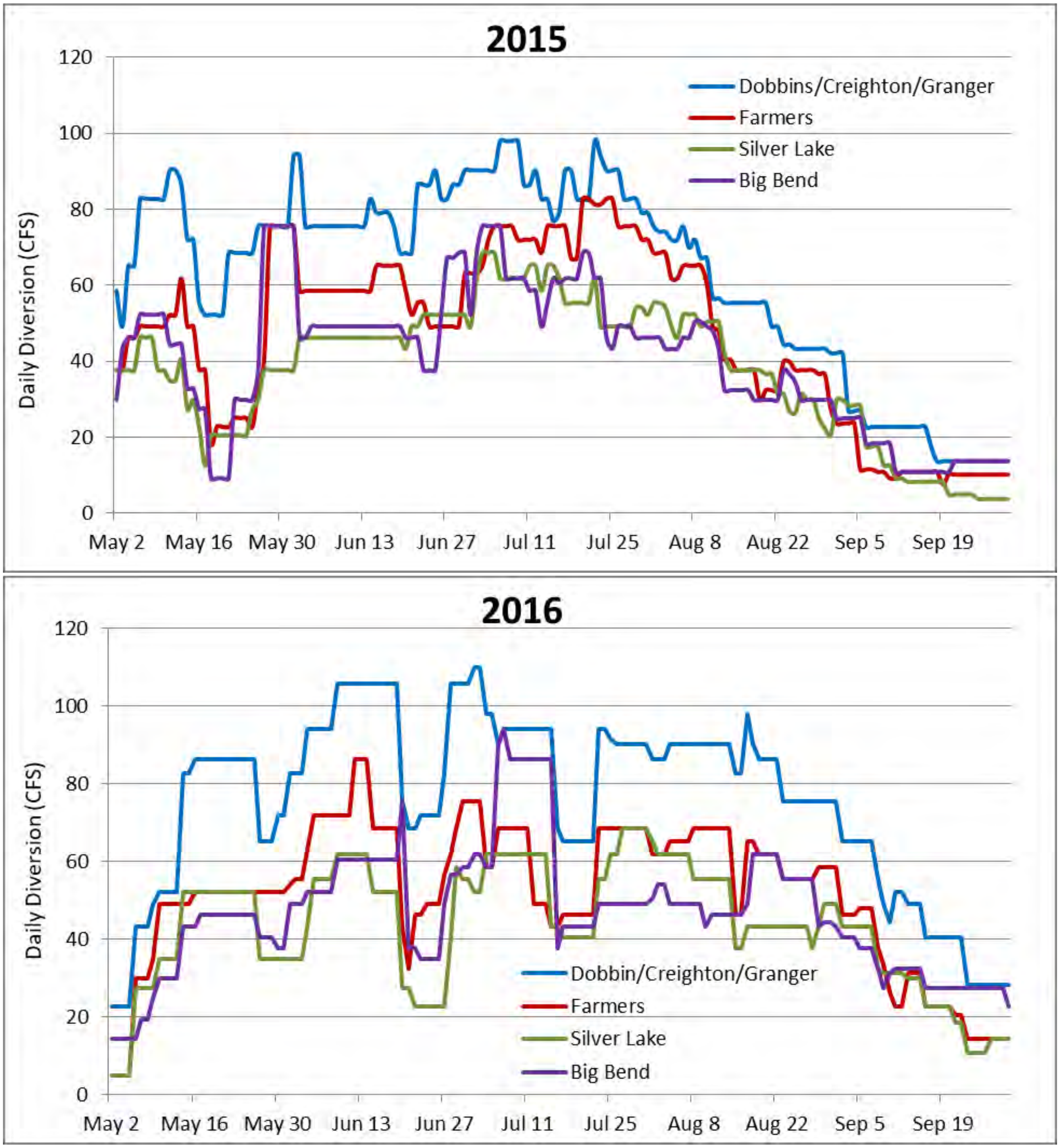


Figure 57. Daily diversion rate for Ditch Companies in 2015 and 2016.

Table 24. Water Use Reports filed by Lower Valley Improvement District with OWRD.

Note: The flow measuring device used by the Lower Valley Improvement District has operated under back-water conditions in the past which likely caused it to over-estimate the flow rate. As such, the values in Table 24 are believe to be incorrect (too high) but are nonetheless presented here to document the water use values that have been recorded.

Year	Unit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2004	AF										0	0	0	-
2005	AF	0	0	0	0	912[1]	1533[1]	2029[1]	3535[1]	22514[1]	0	0	0	10,261[1]
2006	AF	0	0	0	0	1337[1]	1824[1]	2896[1]	1860[1]	2597[1]				10,514[1]
2007	AF										0	0	0	-
2008	AF	0	0	0	0	1485[1]	1586[1]	2590[1]	1253[1]	1208[1]				8,122[1]
2009	AF													
2010	AF													
2011	AF													
2012	AF										0	0	0	-
2013	AF	0	0	0	0	1554[1]	2883[1]	3260[1]	921[1]	890[1]	0	0	0	9,508[1]
2014	AF	0	0	0	0	2070[1]	2831[1]	3188[1]	2047[1]	2124[1]	0	0	0	12,259[1]
2015	AF	0	0	0	0	2467[1]	2403[1]	2215[1]	2999[1]	2174[1]	0	0	0	12,258[1]
2016	AF	0	0	0	0	2500[1]	2560[1]	2340[1]	2955[1]	2300[1]				12,655[1]
Avg [2]	**AF**	**0**	**0**	**0**	**0**	**1,761[1]**	**2,231[1]**	**2,645[1]**	**2,224[1]**	**1,935[1]**	**0**	**0**	**0**	**10,797[1]**
	CFS	**0**	**0**	**0**	**0**	**29.3[1]**	**37.1[1]**	**43.9[1]**	**37.0[1]**	**32.1[1]**	**0**	**0**	**0**	**n/a**

Notes: [1] See note above table, values believed to be higher than actual flow in the canal.
[2] Period used as average is 2004 - 2016.

Table 25. Water Use Reports filed by Wallowa Valley Improvement District with OWRD.

Year	Unit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2004	AF													-
2005	AF													660
2006	AF					1534	2079	2455	1288	772				8,439
2007	AF													617
2008	AF					1841	2376	2762	2455	1188				10,932
2009	AF													876
2010	AF													
2011	AF					1800	2580	3480	3300	2580				14,358
2012	AF					346	935	891	643	519				3,558
2013	AF					490	574	519	386	356				2,523
2014	AF					297	425	574	544	425				2,319
2015	AF					703	8445	809	1116	7388				4,893
2016	AF	0	0	0	0	1231	2421	2039	1394	948	0	0	0	8,034
Avg [1]	**AF**	**0**	**0**	**0**	**0**	**1,231**	**2,421**	**2,039**	**1,394**	**948**	**0**	**0**	**0**	**8,034**
	CFS	**0**	**0**	**0**	**0**	**20.4**	**40.2**	**33.882**	**23.1**	**15.7**	**0**	**0**	**0**	**n/a**

Notes: [1] Period used as average is 2016.

Table 26. Water use data for the Associated Ditch Companies provided by OWRD Water Master.

Year	Ditch	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total (AF)
2015	Dobbins, Creighton, Granger					70.7	79.9	87.9	56.9	20.3				19,007 19,007
	Farmers					43.7	58.0	74.1	46.3	12.1				14,107
	Silver Lake					31.9	47.6	58.1	39.8	11.5				11,367
	Big Bend					41.7	51.0	59.2	37.2	15.4				12,311
	Total					188.1	236.6	279.3	180.3	59.4				56,793
2016	Dobbins, Creighton, Granger					64.5	92.8	88.3	84.8	45.9				22,654
	Farmers					42.5	63.7	60.7	61.4	28.3				15,442
	Silver Lake					37.4	44.9	56.3	50.1	26.9				12,980
	Big Bend					34.8	52.8	61.8	51.5	31.2				13,969
	Total					179.1	254.3	267.1	247.8	132.3				65,045

Table 27. Summary of existing Westside/Poley-Allen system water use (Anderson Perry, 2016)

Month	Maximum Potential Diversion Rate (cfs)	Peak On-Farm Demand (cfs)	Seepage Loss (cfs)	Estimated Diversion Rate (cfs)	Actual On-Farm Use (cfs)
May	45	29.1	5.8	34.9	29.1
June	45	36.4	5.8	42.2	36.4
July	45	47	5.8	46	40.2
August	23.6	39.1	5.8	23.6	17.8
September	23.6	25.7	5.8	23.6	17.8
Total (AF)	**10,967**	**10,672**	**1,746**	**10,251**	**8,505**

Table 28. Summary of average irrigation water diversion per month in the study area.

Entity (values presented are "diversions" and also include return flow and flood control)		May	June	July	August	September	Total
Lower Valley Improvement District[1]	Total (AF)	1,761	2,231	2,645	2,224	1,935	10,797
	Per acre (AF/ac)		See note 1				-
Wallowa Valley Improvement District[2]	Total (AF)	1,231	2,422	2,039	1,394	948	8,034
	Per acre (AF/ac)	0.19	0.37	0.31	0.21	0.15	1.23
Associated Ditch Companies[3]	Total (AF)	10,783	15,304	16,079	14,918	7,962	65,045
	Per acre (AF/ac)	0.50	0.70	0.74	0.69	0.37	2.99
Westside & Poley-Allen[4]	Total (AF)	1,752	2,191	2,420	1,071	1,071	8,505
	Per acre (AF/ac)	0.65	0.81	0.90	0.40	0.40	3.15
Estimate of all irrig. in Wallowa Valley[5]	Total (AF)[5]	30,358[6]	43,086[6]	45,267[6]	41,998[6]	22,416[6]	183,125[6]

Notes:
[1] WVID water use over-estimated (see note on Table 24) so values are not presented here for use per acre.
[2] Based on 6,508 acres per OWRD database.
[3] Based on 21,723 acres per OWRD database for Big Bend (6,395), Farmers (4,782), Silver Lake (4,012+246), Wrenn and Dobbin (3,196), Dobbin (2,024), and Granger (1,068).
[4] Based on 2,700 acres per OWRD database and Nez Perce report.
[5] Based on 61,158 acres per OWRD database for all primary irrigation water rights in Wallowa 8th field HUC.
[6] Uses monthly crop demand calculated for the Associated Ditch Companies.

5.4.3 Crop Water Use

Information in the section above is based on water rights and (to a limited extent) reported water diversions. In this section we use estimates of actual acreage by crop type, along with calculated evapotranspiration (ET) values, to arrive at an independent estimate of actual crop water usage.

Data from the USDA National Agricultural Statistics Service (USDA-NASS, 2016) was used to characterize acreage by crop type within the project area. The USDA -NASS has produced raster, geo-referenced, crop-specific land cover data layers from 2007 to the present. The 2015 layer was the most recent available at the time of this analysis (Figure 58). The 2015 data set has a ground resolution of 30 meters, and was produced using satellite imagery from the Landsat 8 OLI/TIRS sensor and the Disaster Monitoring Constellation (DMC) DEIMOS-1 and UK2 sensors collected during the 2015 growing season. Acreage by crop type and sub-basin are summarized in Table 29

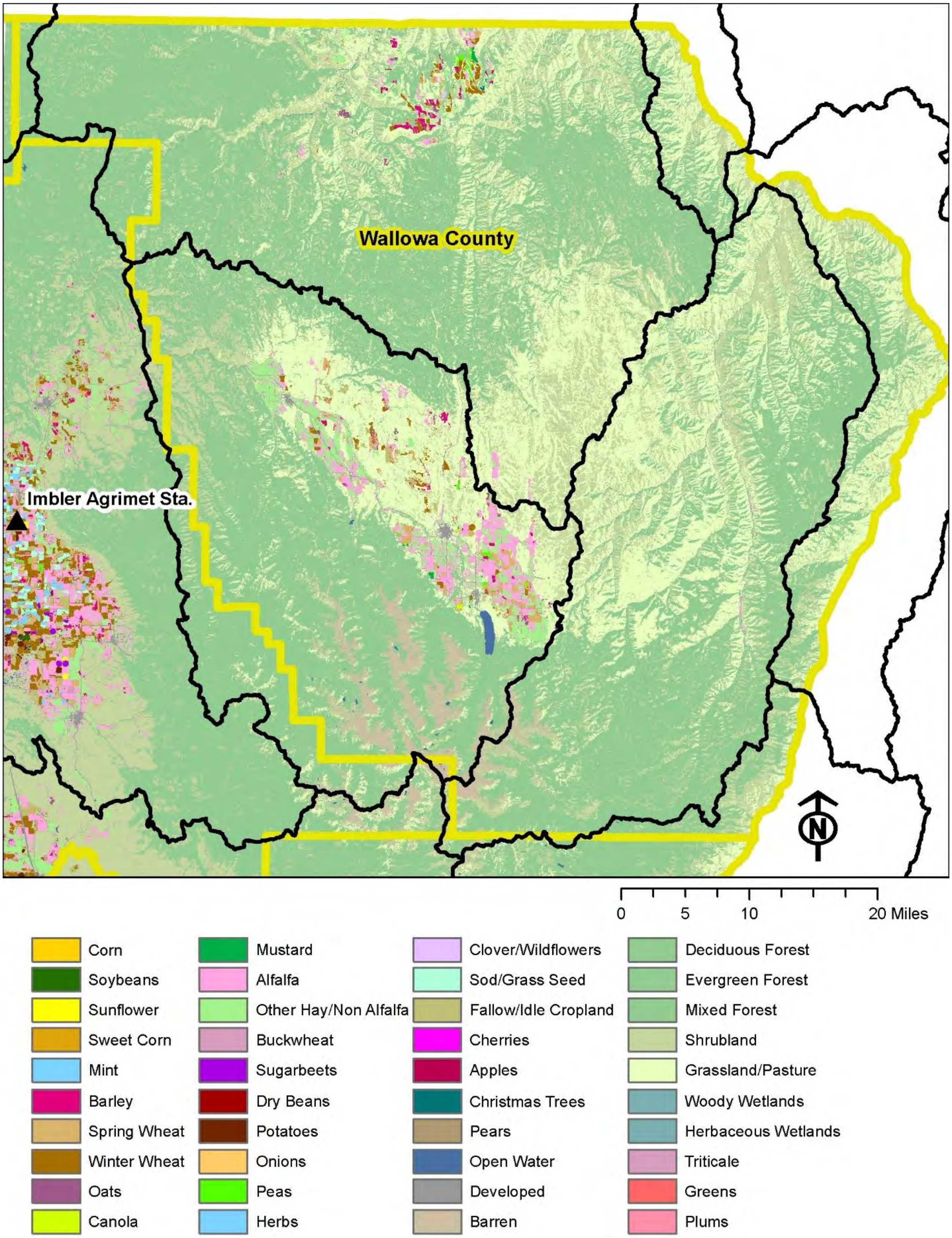


Figure 58. 2015 crop types. Data source: USDA National Agricultural Statistics Service (USDA-NASS, 2016).

Table 29. Acreage by crop type and sub-basin. Data source: USDA National Agricultural Statistics Service (USDA-NASS, 2016).

Crop	Imbler Agrimet crop used	Group	Sub-basin				
			Wallowa	Imnaha	Lower Grande Ronde	Hells Canyon	Lower Snake-Asotin
Alfalfa	Alfalfa (mean)	irrigated	21,543	366	3,020	14	14
Apples	Apples	irrigated	3	-	-	1	-
Barley	Rapeseed	irrigated	1,105	7	1,786	-	-
Canola	Rapeseed	irrigated	183	-	-	-	-
Cherries	Cherries	irrigated	5	-	-	-	-
Clover/Wildflowers	Pasture	irrigated	16	-	201	-	-
Corn	Sweet corn	irrigated	3	-	-	-	-
Fallow/Idle Cropland	Pasture	irrigated	1,644	2	888	1	-
Herbs	Peppermint	irrigated	11	-	-	-	-
Mustard	Peppermint	irrigated	246	2	234	-	-
Oats	Rapeseed	irrigated	902	13	732	1	-
Other Hay/Non Alfalfa	Bluegrass	irrigated	22,966	305	4,458	6	6
Pears	Apples	irrigated	-	-	-	-	-
Peas	Peas	irrigated	484	1	552	-	-
Potatoes	Potatoes	irrigated	-	-	-	-	-
Sod/Grass Seed	Lawn	irrigated	2	-	1	-	-
Sugarbeets	Sugar beets	irrigated	6	-	-	-	-
Sunflower	Rapeseed	irrigated	1	-	-	-	-
Spring Wheat	Spring grain	irrigated	6,233	8	791	-	-
Triticale	Spring grain	irrigated	155	3	2	1	-
Winter Wheat	Winter grain	irrigated	2,630	31	2,302	-	-
Barren	-	non-irrigated	31,439	8,864	3	-	-
Christmas Trees	-	non-irrigated	52	8	110	1	-
Deciduous Forest	-	non-irrigated	-	-	1	7	2
Developed/High Intensity	-	non-irrigated	226	15	56	2	-
Developed/Low Intensity	-	non-irrigated	20	1	2	-	-
Developed/Med Intensity	-	non-irrigated	4,022	1,366	1,358	26	20
Developed/Open Space	-	non-irrigated	1,254	164	332	13	1
Evergreen Forest	-	non-irrigated	322,371	273,526	410,868	36,331	16,107
Grassland/Pasture	-	non-irrigated	106,929	146,234	156,832	39,839	15,724
Herbaceous Wetlands	-	non-irrigated	32	16	13	2	2
Mixed Forest	-	non-irrigated	1	-	2	-	-
Open Water	-	non-irrigated	2,010	14	217	5	-
Shrubland	-	non-irrigated	85,275	113,400	163,587	25,335	8,032
Woody Wetlands	-	non-irrigated	38	385	20	10	12
Out of state areas	-	-	-	-	116,025	-	-

The U.S. Bureau of Reclamation (USBOR) maintains a series of weather stations throughout the Pacific Northwest as part of their Agrimet network. Daily ET values are calculated for common crops in the vicinity of each Agrimet station, and yearly summaries of crop water use are available. Unfortunately, no Agrimet stations are located within the project area, however a station is located in Imbler Oregon, approximately 30 miles west of the town of Lostine in the Wallowa Valley. Elevations at the Imbler Agrimet station (2,750 feet) are slightly lower than the Wallowa Valley (approximately 3,350 in the vicinity of the town of Lostine), but mean annual precipitation is similar (17 inches annually at Imbler; 15 inches near Lostine). Annual water use summaries by crop at Imbler were available from 1994-2015. Minimum, mean, and maximum annual values from the period of record are given in Table 30. Not all crop types within the project area were represented in the Imbler record, however the few that were missing were estimated using the values identified in Table 29 ("Imbler Agrimet crop used" column). Minimum, mean, and maximum depths of water usage from Table 30 were applied to acreages of crops by sub-basin in Table 29 to arrive at a range of estimated crop water usage by sub-basin within the project area (Table 31).

Table 30. Crop water use (inches) estimated at the IMBO Agrimet station.

Crop	Min	Mean	Max
Alfalfa (mean)	30	33.4	38.6
Apples	26.2	30.1	33.1
Bluegrass	12.7	14.7	16.9
Cherries	25.9	31.6	35.2
Dry beans	15.3	18.1	20.9
Field corn	19.2	23.6	26.9
Garlic	22.2	25.5	28.5
Lawn	29	32.5	36.8
Pasture	24	26.7	30.4

Crop	Min	Mean	Max
Peas	11.4	12.8	14.6
Peppermint	19.7	23.4	26.1
Potatoes	19	22.5	27.7
Rapeseed	17.1	20.9	23.3
Spring grain	17.5	21.1	26
Sugar beets	21.5	26.6	31.4
Sweet corn	18.3	20.8	27.9
Winter grain	17.5	20.5	23.1
3rd Year + Poplar	30	34.4	38.8

Table 31. Estimated minimum, mean, and maximum water use by sub-basin and crop type. All values in AF. [note to reviewers: these acreages seem high – please review. Irrigation demand may be ~30k AF less given in-season precipitation]

	Wallowa		
Crop	**min**	**mean**	**max**
Alfalfa	53,858	59,961	69,297
Other Hay/Non-Alfalfa	24,306	28,133	32,344
Spring Wheat	9,090	10,960	13,505
Winter Wheat	3,835	4,493	5,063
Fallow/Idle Cropland	3,288	3,658	4,165
Barley	1,575	1,925	2,146
Oats	1,285	1,571	1,751
Peas	460	516	589
Mustard	404	480	535
Canola	261	319	355
Triticale	226	273	336
Other crops	89	103	118
Total	**98,676**	**112,391**	**130,203**

	Lower Grande Ronde		
Crop	**min**	**mean**	**max**
Alfalfa	7,550	8,406	9,714
Other Hay/Non-Alfalfa	4,718	5,461	6,278
Winter Wheat	3,357	3,933	4,431
Barley	2,545	3,111	3,468
Fallow/Idle Cropland	1,776	1,976	2,250
Spring Wheat	1,154	1,391	1,714
Oats	1,043	1,275	1,421
Peas	524	589	672
Mustard	384	456	509
Clover/Wildflowers	402	447	509
Other crops	5	6	7
Total	**23,459**	**27,050**	**30,974**

	Imnaha		
Crop	**min**	**mean**	**max**
Alfalfa	915	1,019	1,177
Other Hay/Non-Alfalfa	323	374	430
Other crops	98	117	133
Total	**1,336**	**1,509**	**1,740**

	Hells Canyon		
Crop	**min**	**mean**	**max**
Alfalfa	35	39	45
Other Hay/Non-Alfalfa	6	7	8
Other crops	7	8	9
Total	**48**	**55**	**63**

	Lower Snake - Asotin		
Crop	**min**	**mean**	**max**
Alfalfa	35	39	45
Other Hay/Non-Alfalfa	6	7	8
Total	**41**	**46**	**53**

5.5 Instream

The OWRD approves instream water rights (ISWRs) for 1) fish protection, 2) minimizing the effects of pollution, or 3) maintaining recreational uses. Instream water rights set flow levels to stay in a stream reach for a given period of time, have a priority date, and are regulated the same as other water rights. Instream water rights do not guarantee that a certain quantity of water will be present in the stream; under Oregon law, an instream water right cannot affect a use of water with a senior priority date.

5.5.1 Fisheries Overview

The purpose of most instream water rights within the project area are to protect and enhance fisheries and fisheries habitat. This section provides a brief overview of fisheries within the project area; it is focused on the flow-related variables important to fish, and is not intended as a comprehensive assessment of fisheries conditions or trajectories.

Data on Fisheries distribution in the project area are available from ODFW[13]. Distribution by species/run, use type, and sub-basin are shown in Figure 59 and Figure 60, and summarized in Table 32. Note that use type shown has been identified by ODFW as the dominant use, however other uses may be present as well (e.g. rearing with reaches identified as spawning).

[13] https://nrimp.dfw.state.or.us/nrimp/default.aspx?pn=fishdistdata

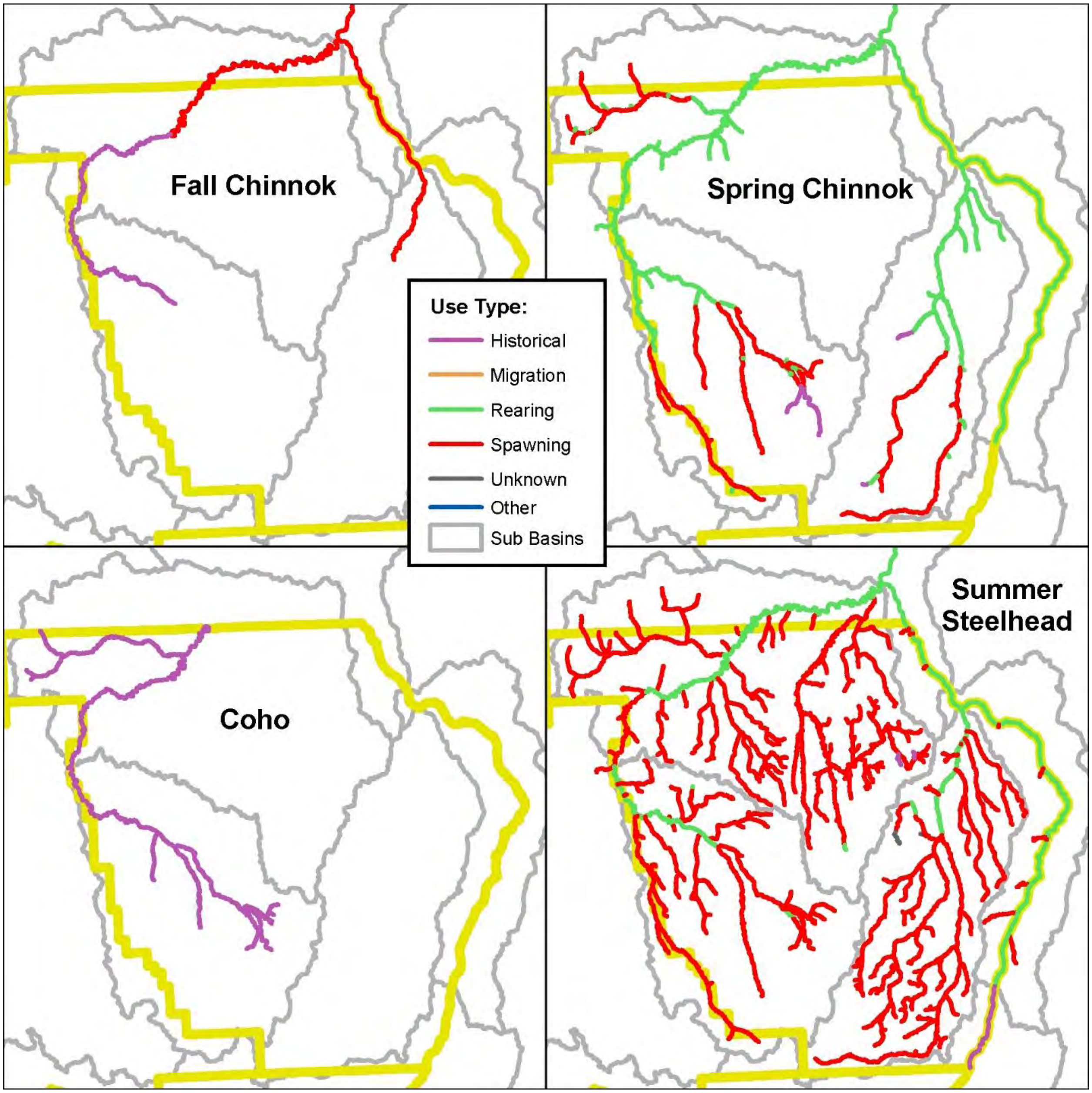


Figure 59. Distribution of Fall Chinook (upper left), Spring chinook (upper right), coho (lower left) and summer steelhead (lower right) by primary use type.

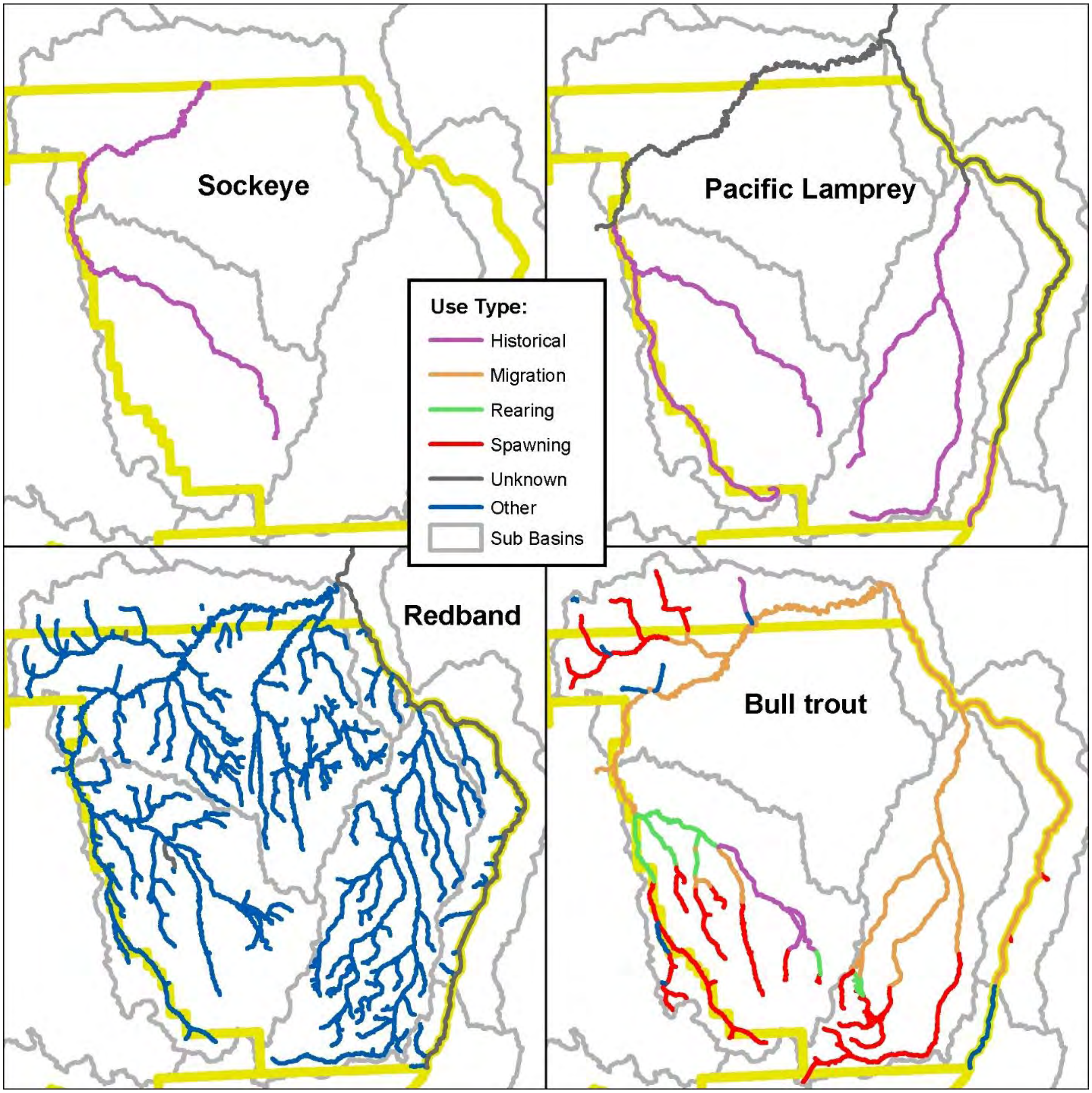


Figure 60. Distribution of sockeye salmon (upper left), Pacific lamprey (upper right), redband trout (lower left) and bull trout (lower right) by primary use type.

Table 32. Fish distribution (miles of stream) by run, use type, and sub-basin.

Use Type	Bull trout	Coho salmon	Fall Chinook	Pacific lamprey	Redband trout	Sockeye salmon	Spring Chinook	Summer Steelhead	White sturgeon
	Lower Grande Ronde								
Historical	5.6	81.2	28.8	0.0		45.1		3.1	
Migration	94.6								
Rearing							108.0	68.0	
Resident (multiple uses)	12.6				569.3				
Spawning	55.0		53.5				40.7	490.1	
Unknown				82.3	1.2				
	Wallowa								
Forage/migrate/overwinter	5.1								
Historical	33.3	96.5	26.0	107.0		57.0	13.4		
Migration	26.0								
Rearing	47.6						57.8	30.1	
Resident (multiple uses)	0.6				278.2				
Spawning	102.5						112.9	241.6	
Unknown					4.7				
	Lower Snake-Asotin								
Migration	19.9								
Rearing							49.4	49.4	
Resident (multiple uses)					20.6				49.4
Spawning			49.4					2.7	
Unknown				49.4	49.3				
	Imnaha								
Historical				103.0			3.2		
Migration	100.0								
Rearing	10.1						83.0	26.4	
Resident (multiple uses)					374.5				
Spawning	88.1		18.3				68.2	335.9	
Unknown				3.8				3.4	
	Brownlee Reservoir								
Forage/migrate/overwinter	13.1								
Historical				13.0				13.2	
Resident (multiple uses)					8.9				13.0
Unknown					13.2				
	Hells Canyon								
Migration	60.0								
Rearing							59.9	60.2	
Resident (multiple uses)					36.7				60.1
Spawning	2.7		3.4					17.9	
Unknown				60.1	60.1				

Fish survival is dependent on the combination of many elements that make up the riverine ecosystem, including function of streamflow's, stream temperatures, and other riverine variables. Different species of salmonids and their life stages are dependent on natural variations in these conditions. To restore salmonid populations to their historic levels in the Wallowa Valley would most likely mean restoring flows to the range of natural variation to meet the habitat requirement of all species at all life stages. With climate change predicting the rain on snow and snowmelt driven system shifting to a rain dominated system restoring the stream flows back to their natural state may not be feasible. This coupled with an over allocation of water rights to the waters in Wallowa

County add a further challenge to restoring stream flows to their natural conditions. In lieu of setting restoration to meet natural flows there were "Target" low summer flows established for the Imnaha River, Wallowa Creek, Hurricane Creek, Lostine River, and Bear Creek in the 2017 Recovery Plan for Northeast Oregon Snake River Spring and Summer Chinook Salmon and Snake River Steelhead Populations (NOAA Fisheries. 2017; Table 33).

Table 33. Target flows. Data source: NOAA Fisheries (2017).

Stream	Target flow (cfs)
Wallowa	70
Lostine	25
Bear Creek	8

Stream	Target flow (cfs)
Hurricane Creek	15
Upper Imnaha tribs	12
Upper Big/Little Sheep	10

An instream flow study was conducted in the Lostine River in 1995 and 1996 to develop habitat-flow relationships for several anadromous and resident fish species (R2 Resource Consultants, Inc. 1998). Naturally low August-October flows in the lower Lostine River are exacerbated by irrigation withdrawals (which may reduce instream flow to as low as 10 cfs), elevated water temperatures associated with these low flows, and by channelization. Results of the study led to recommended minimum instream flows of 25 cfs year around in the portion of the Lostine River from the Westside Ditch to the Cross-Country Canal (Figure 55), between 45 and 60 cfs[14] from the Cross-Country Canal to the confluence of the Wallowa River. These would result in attainment of 50 percent of maximum habitat value for key fish species and life stages). Minimum passage flows of 40 cfs are recommended to allow for spring and early fall chinook salmon through these reaches during the migration periods.

Elevated summertime water temperatures are a result of many factors (loss of riparian vegetation, channel simplification, etc), one of the primary factors being reduced summertime flows. Elevated water temperatures are recognized as a factor to be addressed in efforts to reintroduce anadromous fish species to the stream of Wallowa County (e.g., NOAA Fisheries. 2017; Cramer and Witty, 1998). Isaak et al. (2016) used water temperature data from monitoring sites region-wide to estimate mean August water temperatures in most streams for the baseline period of 1993–2011 (Figure 61, top). Climate change model output were used to model future stream temperatures for periods centered on the years 2040 and 2080. The difference in temperature from baseline was an increase in mean August water temperature of from 0.96 to 1.57^{o} C by 2040 (Figure 61, lower left), and from 1.57 to 2.62 ^{o} C by 2080 (Figure 61, lower right).

[14] 45 cfs from January through March, 60 cfs from April through June, and 45 cfs from July through December

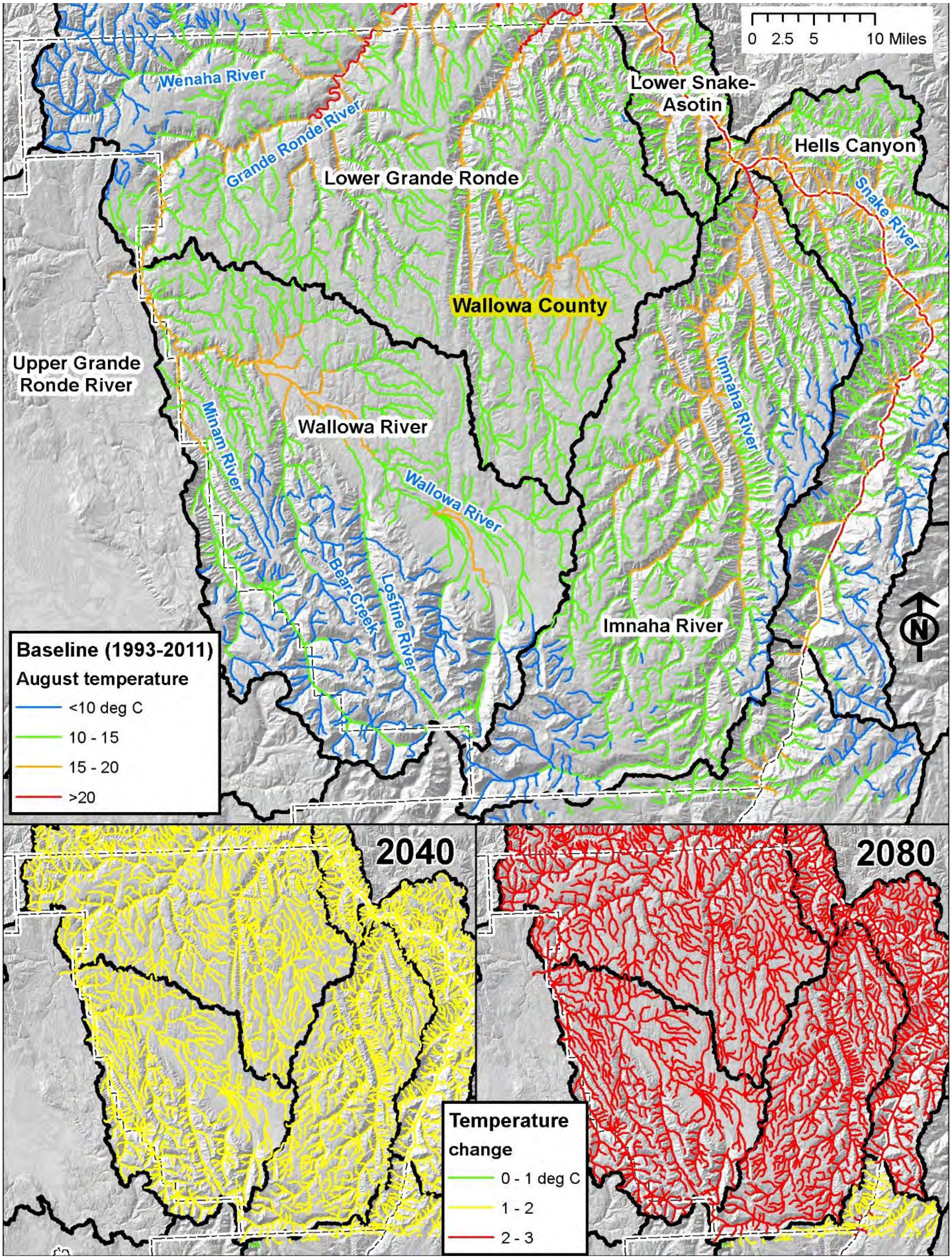


Figure 61. Baseline August stream temperature (top), and projected change in temperature by 2040 (lower left) and 2080 (lower right). Source: Isaak et al. (2016).

5.5.2 Instream Water Rights

Eighteen locations within the project area (Figure 62) have designated instream water rights for "Anadromous and Resident Fish Rearing", "Conservation (Maintenance and Enhancement of Aquatic and Fish Life; Wildlife; Fish and Wildlife Habitat; Other Ecological Values)", and "Flow Augmentation for Fish Enhancement" (Table 34). The oldest ISWR dates back to 1922, and the newest 1991. Five ISWRs are from the 1960's with the remainder in the 1980's and 1990's. The ISWR on Courtney Creek in the Lower Grande Ronde River sub-basin in held by the Oregon Water Trust; all other rights are held by OWRD.

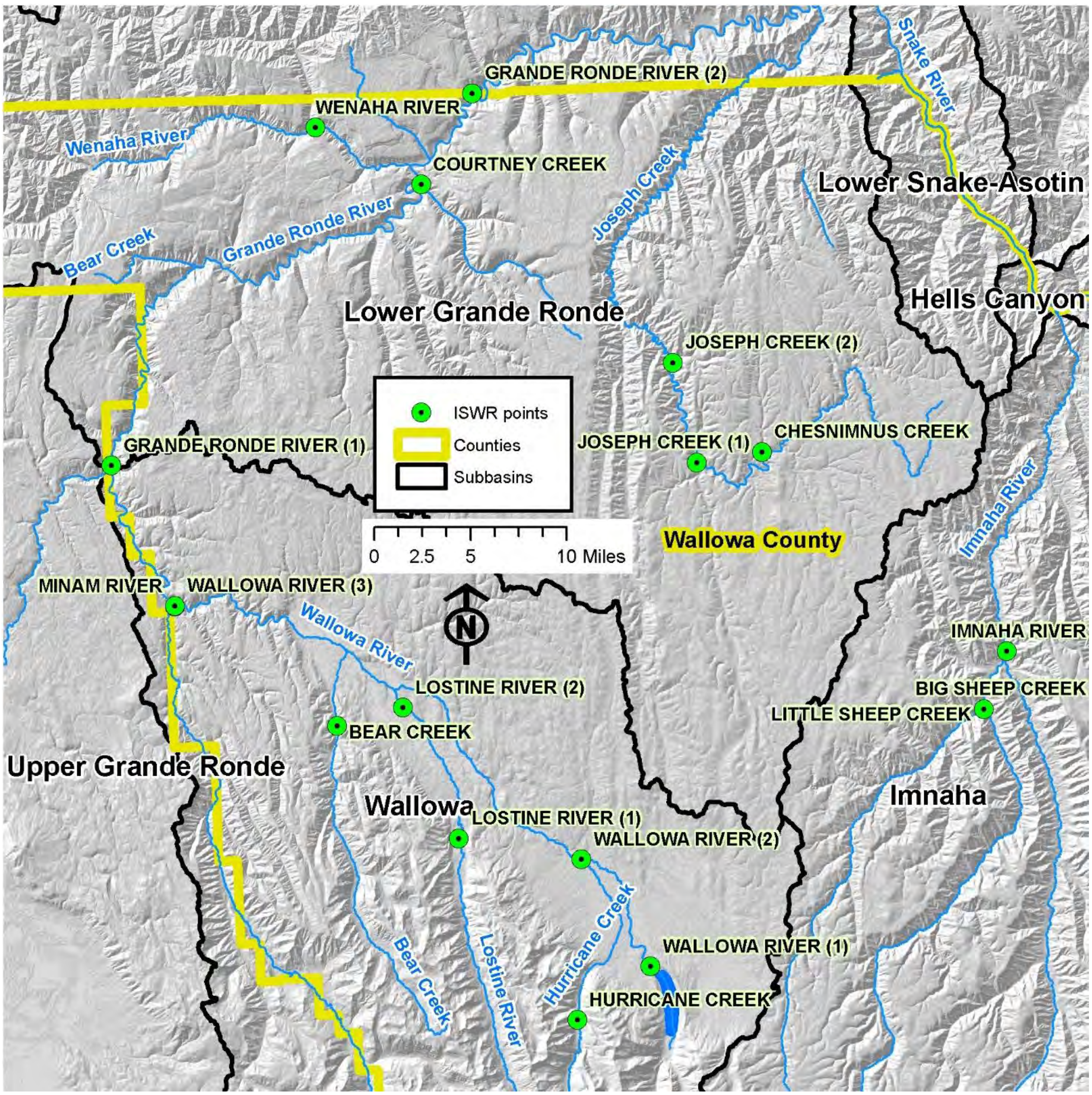


Figure 62. Instream water rights (ISWR) in the project area.

Table 34. Instream water rights (ISWR) in the project area.

Water Right ID	Stream Name	Priority Date	Instream Purpose	Water right Holder
Imnaha Sub-basin				
112177	Little Sheep Creek	11/3/1983	Conservation; Maintenance and Enhancement of Aquatic and Fish Life; Wildlife	OWRD
112173	Big Sheep Creek	11/3/1983	Conservation; Maintenance and Enhancement of Aquatic and Fish Life; Wildlife	OWRD
112176	Imnaha River	5/9/1961	Conservation; Maintenance and Enhancement of Aquatic and Fish Life; Wildlife	OWRD
Wallowa Sub-basin				
125527	Hurricane Creek	9/19/1990	Anadromous and Resident Fish Rearing	OWRD
112178	Lostine River (1)	11/3/1983	Conservation; Maintenance and Enhancement of Aquatic and Fish Life; Wildlife	OWRD
174577	Lostine River (2)	8/11/1922	Conservation; Maintenance and Enhancement of Aquatic and Fish Life; Wildlife; Fish and Wildlife Habitat; Other Ecological Values	OWRD
112172	Bear Creek	11/3/1983	Conservation; Maintenance and Enhancement of Aquatic and Fish Life; Wildlife	OWRD
112179	Minam River	5/9/1961	Conservation; Maintenance and Enhancement of Aquatic and Fish Life; Wildlife	OWRD
125263	Wallowa River (1)	11/22/1991	Anadromous and Resident Fish Rearing	OWRD
125262	Wallowa River (2)	10/22/1991	Anadromous and Resident Fish Rearing	OWRD
125264	Wallowa River (3)	11/22/1991	Anadromous and Resident Fish Rearing	OWRD
Lower Grande Ronde Sub-basin				
125257	Wenaha River	9/24/1990	Anadromous and Resident Fish Rearing	OWRD
129190	Courtney Creek	12/19/1967	Flow Augmentation for Fish Enhancement	Oregon Water Trust
125526	Chesnimnus Creek	8/30/1990	Anadromous and Resident Fish Rearing	OWRD
125525	Joseph Creek (1)	8/30/1990	Anadromous and Resident Fish Rearing	OWRD
125528	Joseph Creek (2)	10/18/1990	Anadromous and Resident Fish Habitat	OWRD
112175	Grande Ronde River (1)	5/9/1961	Conservation; Maintenance and Enhancement of Aquatic and Fish Life; Wildlife	OWRD
112174	Grande Ronde River (2)	5/9/1961	Conservation; Maintenance and Enhancement of Aquatic and Fish Life; Wildlife	OWRD

5.5.3 Imnaha Sub-Basin

There are three ISWRs in the Imnaha River sub-basin (Figure 62, Table 34). The annual distribution of these ISWRs are shown in Figure 63 and Table 35. The oldest ISWR on the Imnaha River mainstem dates to 1961 and specifies a constant rate of 85 cfs. The Big Sheep Creek ISWR ranges from 25 cfs in the winter months to 55 cfs in summer. Little Sheep Creek provides 10 cfs for most of the year and ramps up to 20 cfs in the spring months. Additional waters are available in most months at the 80% exceedance interval within the Imnaha sub-basin (Figure 52 and Figure 53), suggesting that existing water rights will likely be met under future climate conditions, assuming no additional appropriations. The adequacy of existing instream water rights to meet species/life stage needs is not known.

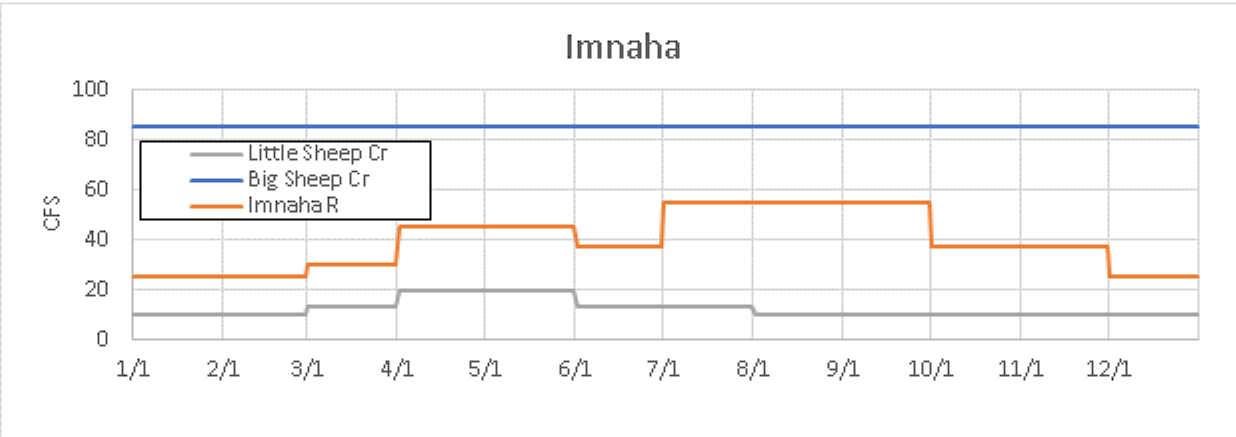


Figure 63. Annual distribution of ISWRs in the Imnaha River sub-basin.

Table 35. ISWRs in the Imnaha River sub-basin. All values cfs.

From	To	Little Sheep Cr	Big Sheep Cr	Imnaha R
1/1/1960	2/29/1960	10	85	25
3/1/1960	3/31/1960	13	85	30
4/1/1960	5/31/1960	20	85	45
6/1/1960	6/30/1960	13	85	37
7/1/1960	7/31/1960	13	85	55
8/1/1960	9/30/1960	10	85	55
10/1/1960	11/30/1960	10	85	37
12/1/1960	12/31/1960	10	85	25

5.5.4 Wallowa Sub-Basin

There are eight ISWRs in the Wallowa sub-basin (Figure 62, Table 34). The annual distribution of these ISWRs are shown in Figure 64 and Table 36. The ISWR with the largest rate is in Bear Creek, varying from 407 to 450 cfs. Two ISWRs occur in the Lostine River, the largest (upstream) right ranges from 170-300 cfs, while the downstream ISWR ranges from 23.3 – 60 cfs. The Wallowa River has three sperate ISWRs; the upstream ranging from 40-70 cfs and the middle location a constant 100 cfs year-around. The lower Wallowa ISWR is only in effect from 5/1 – 9/30, and is for a constant 0.39 cfs. The Hurricane Creek ISWR ranges from 20-40 cfs. Additional waters are unavailable for further appropriation in all parts of the sub-basin in all months (except February in the lower basin) at the 80% exceedance level (Figure 52 and Figure 53). suggesting that existing water rights are unlikely be met under future climate conditions that will likely have a reduced snowmelt component, and reduced summer streamflows; even assuming no additional appropriations. The adequacy of existing instream water rights to meet species/life stage needs is not known.

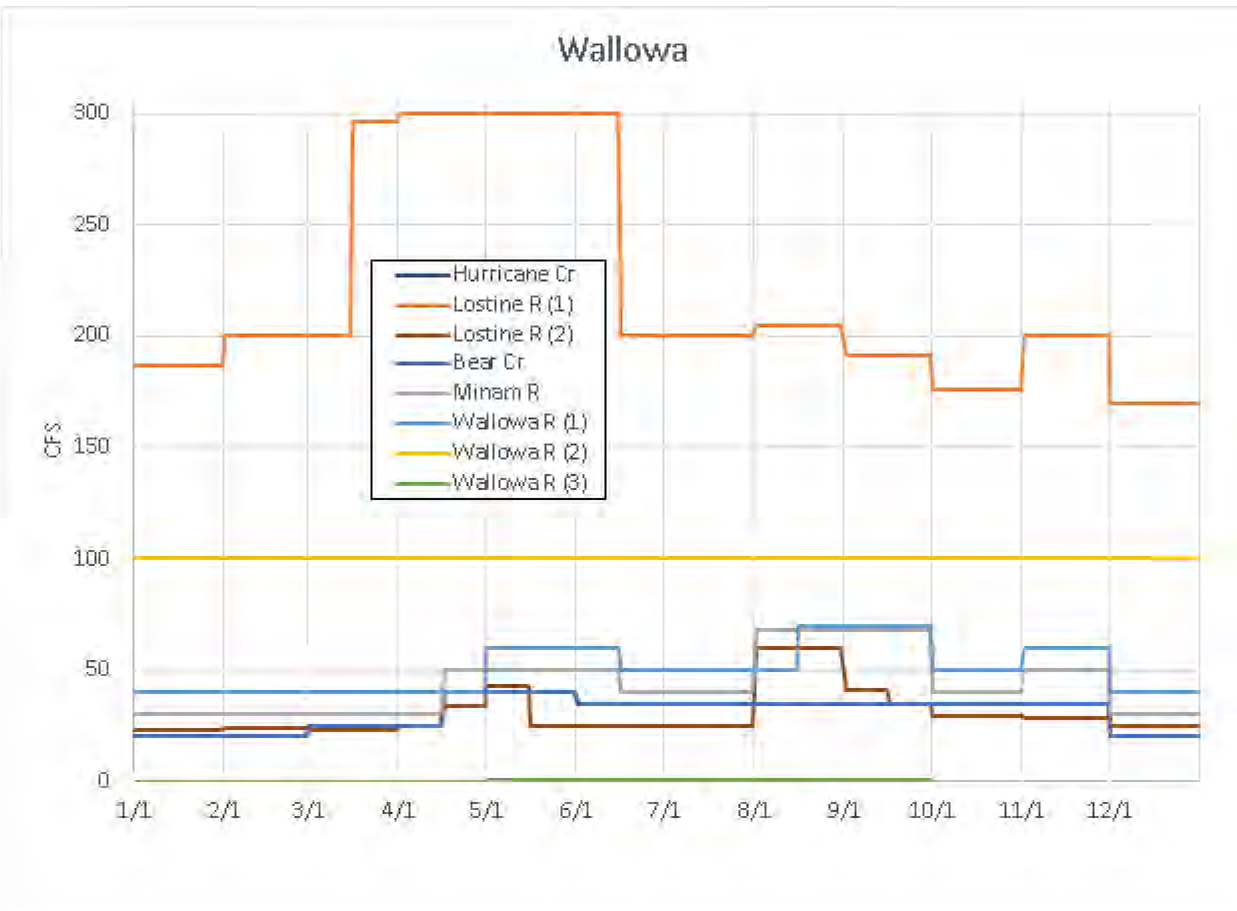


Figure 64. Annual distribution of ISWRs in the Wallowa River sub-basin.

Table 36. ISWRs in the Wallowa River sub-basin. All values cfs.

From	To	Hurricane Cr	Lostine R (1)	Lostine R (2)	Bear Cr	Minam R	Wallowa R (1)	Wallowa R (2)	Wallowa R (3)
1/1/1960	1/31/1960	20	187	23.4	20	30	40	100	0
2/1/1960	2/29/1960	20	200	24.2	20	30	40	100	0
3/1/1960	3/15/1960	25	200	23.3	25	30	40	100	0
3/16/1960	3/31/1960	25	297	23.3	25	30	40	100	0
4/1/1960	4/15/1960	25	300	25	25	30	40	100	0
4/16/1960	4/30/1960	40	300	33.9	40	50	40	100	0
5/1/1960	5/15/1960	40	300	43	40	50	60	100	0.39
5/16/1960	5/31/1960	40	300	25	40	50	60	100	0.39
6/1/1960	6/15/1960	35	300	25	35	50	60	100	0.39
6/16/1960	7/31/1960	35	200	25	35	40	50	100	0.39
8/1/1960	8/15/1960	35	205	60	35	68	50	100	0.39
8/16/1960	8/30/1960	35	205	60	35	68	70	100	0.39
9/1/1960	9/15/1960	35	191	40.8	35	68	70	100	0.39
9/16/1960	9/30/1960	35	191	35	35	68	70	100	0.39
10/1/1960	10/31/1960	35	176	29.5	35	40	50	100	0
11/1/1960	11/30/1960	35	200	28.5	35	50	60	100	0
12/1/1960	12/31/1960	20	170	25	20	30	40	100	0

5.5.5 Lower Grande Ronde Sub-Basin

There are seven ISWRs in the Lower Grande Ronde sub-basin (Figure 62, Table 34). The annual distribution of these ISWRs are shown in Figure 65 and Table 37. The Wenaha River ISWR ranges from 130-220 cfs. Courtney Creek is a constant 0.1 cfs year-around. The three ISWRs in the Joseph Creek watershed are on Chesnimnus Creek (1.14-85 cfs), and two locations on Joseph Creek (site #1: 1.68-120 cfs; site #2: 0.71-60 cfs). The two mainstem Grande Ronde River ISWRs are for 300 and 420 cfs respectively. The upper ISWR includes flows from the upper Grande Ronde River sub-basin, which is outside of this study area.

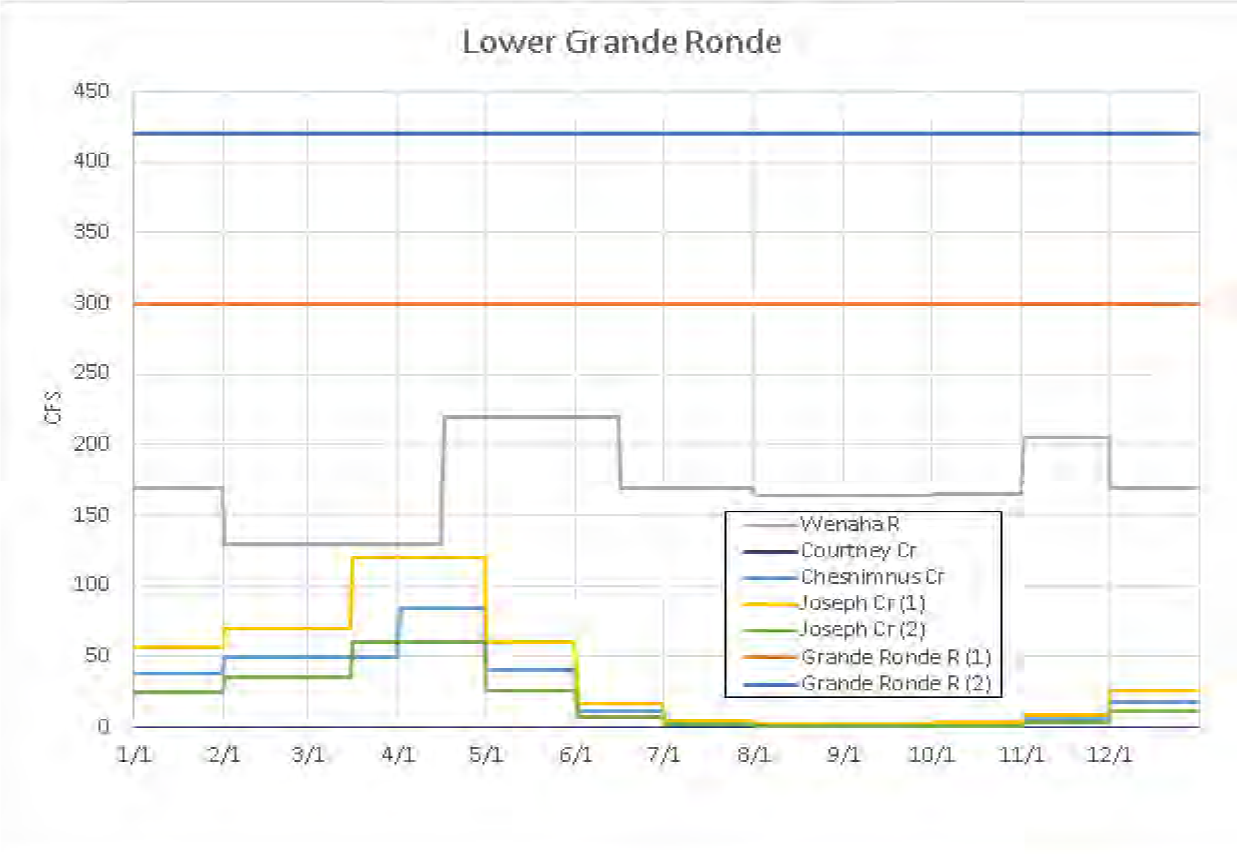


Figure 65. Annual distribution of ISWRs in the Lower Grande Ronde River sub-basin.

Table 37. ISWRs in the Lower Grande Ronde River sub-basin. All values in cfs.

From	To	Wenaha R	Court-ney Cr	Chesn-imnus Cr	Joseph Cr (1)	Joseph Cr (2)	Grande Ronde R (1)	Grande Ronde R (2)
1/1/1960	1/31/1960	170	0.1	37.5	57.2	25.1	300	420
2/1/1960	3/15/1960	130	0.1	50	70	35	300	420
2/15/1960	3/15/1960	130	0.1	50	70	35	300	420
3/16/1960	3/31/1960	130	0.1	50	120	60	300	420
4/1/1960	4/15/1960	130	0.1	85	120	60	300	420
4/16/1960	4/30/1960	220	0.1	85	120	60	300	420
5/1/1960	5/31/1960	220	0.1	40.7	60.4	26.3	300	420
6/1/1960	6/15/1960	220	0.1	11.7	17.3	7.51	300	420
6/16/1960	6/30/1960	170	0.1	11.7	17.3	7.51	300	420
7/1/1960	7/31/1960	170	0.1	3.65	5.45	2.32	300	420
8/1/1960	8/30/1960	164	0.1	1.17	1.75	0.74	300	420
9/1/1960	9/30/1960	164	0.1	1.14	1.68	0.71	300	420
10/1/1960	10/31/1960	165	0.1	2.32	3.38	1.49	300	420
11/1/1960	11/30/1960	205	0.1	5.58	8.2	3.62	300	420
12/1/1960	12/31/1960	170	0.1	17.5	26.4	11.5	300	420

Additional waters are unavailable for further appropriation from the portion of the Lower Grande Ronde sub-basin that drains directly to the Oregon-portion of the Grande Ronde

River in all months except December-February at the 80% exceedance level (Figure 52 and Figure 53), suggesting that existing water rights are unlikely to be met under future climate conditions that will likely have a reduced snowmelt component, and reduced summer streamflows; even assuming no additional appropriations.

The remainder of the Lower Grande Ronde River (primarily Joseph Creek and Cottonwood Creek watersheds) does not flow into the Grande Ronde River within Oregon, and is not subject to the same upstream water demands. These areas have a greater water availability at the 80% exceedance levels, but still have many areas with no further appropriations available (Figure 52 and Figure 53). Existing water rights are unlikely be met under future climate conditions in some portions of the area, particularly in summer months, although snowpack, which is not currently a major contributor to summer flows, is largely unaffected (because it is absent).

The adequacy of existing instream water rights to meet species/life stage needs is not known.

5.6.1 Scenic Waterways

When considering a water right application within or upstream of a scenic waterway, the OWRD is required by law to evaluate if the proposed use will impair the recreational, fish, and wildlife values of the scenic waterway (OWRD, 2013). The OWRD has estimated the streamflow needed to satisfy these values and uses these estimates as part of their Water Availability Reporting System when determining if a new water right in or above a scenic waterway will be authorized. Three scenic waterways exist within the project area. All three are also part of the National Wild and Scenic Rivers System:

- Minam River from Minam Lake to the confluence with the Wallowa River,
- Wallowa River from the confluence with the Minam River (in Minam) to its confluence with the Grande Ronde River (~10 miles),
- Grande Ronde River from the confluence with Wallowa River to the Oregon-Washington border (~43 miles).

Four scenic waterways applications cover these segments (Table 38, Figure 66).

Table 38. Scenic Waterway applications in the project area. Data source: OWRD Water Availability Reporting System.

Sub-basin	Segment	Application	Priority Date
Wallowa	Minam River, tributary to Wallowa River, at mouth	SY 90801 A	12/3/1970
Wallowa	Minam River, tributary to Wallowa River, above little Minam R.	SY 90801 B	12/3/1970
Wallowa	Wallowa River, tributary to Grande Ronde River, at mouth	SY 90802 A	12/8/1988
Lower Grande Ronde	Grande Ronde River, tributary to Snake River, at mouth	SY 90803 A	12/8/1988

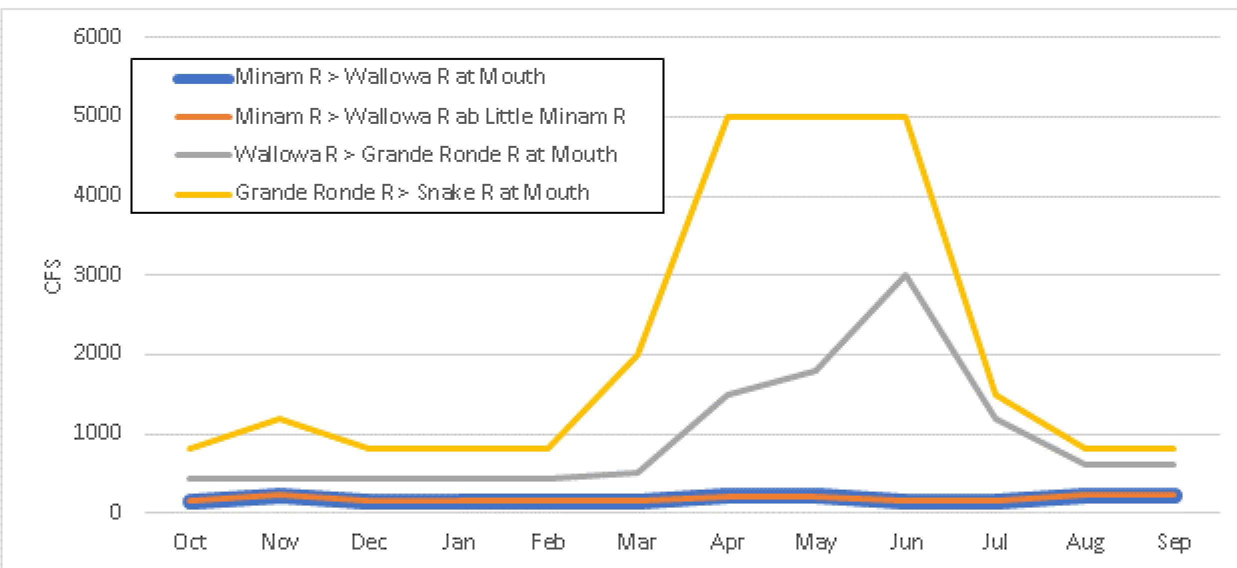


Figure 66. Monthly Scenic Waterway applications in the project area. Data source: OWRD Water Availability Reporting System.

6 Key Findings

1. Although county-average water year precipitation has a high degree of variability, the 10-year moving average has remained between 15-20 inches per year from 1895-present.
2. Climate variability (e.g., El Nino/La Nino, Pacifica Decadal Oscillation) has caused decade-long cool/wet and warm/dry periods and should be considered when interpreting climate trends.
3. The basin has been experiencing a warming trend from 1950-present, with most warming occurring during the summer months (10-year moving average August temperatures shows an approximately 4° F warming from 1955-present).
4. Runoff is snowmelt dominated, with a majority of precipitation in high elevation areas falling as snow and contributing to spring/summer runoff with rapid recession.
5. Annual and summer runoff volumes show a decreasing trend (for all sub-basins except the Imnaha), but the trends are likely driven by the current dry Pacific Decadal Oscillation phase and not actual long-term trend.
6. Instream water rights are met on the Wallowa River at Enterprise all the time. Instream water rights on the Wallowa River at Water Can are met year-around except approximately 20 % of the time in August and September. Instream water rights on the Minam, Bear Creek, and Lostine are typically not met 50 % of the time in the winter, met April through July, and not met in August and September. Instream water rights on the Grande Ronde at Troy are met in all but a handful of days (and likely due to the lag time in regulating off junior users).
7. Summer streamflow is correlated with winter precipitation and snowpack and can be predicted with some accuracy based on regression analysis. However, available climate-runoff modeling results from the CIG are probably the most useful predictor of future streamflow currently available
8. Limited data existing on inflow to Wallowa Lake (period of record is intermittently in the 1920s and 1930, and then continuously 2015 through present), however it appears that typically only 15,000 (acre-feet) AF of active storage is used compared to an average annual inflow 82,000AF/yr.
9. Climate change is expected to increase basin-average air temperatures by 3 to 5° F by 2050, and 4 to10° F by 2080. Annual precipitation is expected to increase by 0-5% for the same period, with a 5-10% decrease in summer.
10. As a result of climate change, winter precipitation will shift from snow to a greater frequency of rain, resulting in a smaller snowpack. Lower elevation areas are expected to lose over 60% of their historical snowpack, while snowpack in upper elevation areas (roughly above 7,000 feet) will remain relatively unchanged. Averaged over the entire Wallowa sub-basin, the 2040s are expected to have 23% less snow than historical snowpack, while the 2080s are expected to have 49% less.

11. Due to increased temperature associated with climate change, natural Wallowa River July-September runoff is expected to decrease by 50% by the 2040s and 67% by the 2080s.
12. Municipal water is supplied by the cities of Joseph, Enterprise, Wallowa, Lostine and the Lake County Service District. Cumulative monthly average water use ranges from a low of 2 cfs in the winter to a high of 5 cfs in the summer (for a total of approximately 2,000 AF/year).
13. There are 681 domestic water rights in the Wallowa sub-basin. No data is available for water use for domestic rights, however, based on municipal use rates it's estimated that cumulative domestic use is on the order of 250 AF/year.
14. Commercial water rights in Wallowa County have a total water right of 35 cfs, though it's likely actual water use is significantly lower than the water rights.
15. 61,158 acres in the Wallowa sub-basin have irrigation water rights, which matches closely with the 2016 USDA estimate of 58,138 irrigated acres.
16. Water diversion data exists for less than 50% of the irrigated area, and no data exists on amount of return flows back to rivers.
17. Based on limited data, it appears the Associated Ditch Company diverts approximately 2.99 AF/acre and the Westside Poly/Allen diverts 3.15 AF/acre.
18. Total basin water diversions are estimated at 183,125 AF/year, compared against average USDA crop demand of 112,391 AF/year, up to 30k AF of which may be being met by in-season precipitation – to be discussed. The difference between the two values includes diversion return flows and water lost during the application process. It should be stressed that both the diversion and crop demand values are based on limited data and should be seen as an initial estimate.
19. The information documented in this report (e.g., water supply, storage, water use, streamflow, instream water rights, climate change) show a relatively 'water rich' basin for most of the year, however, the late summer period shows a deficit of water available with instream flows not met and irrigators needing to reduce diversions. Due to the hydrology of the basin (snowmelt-dominated), climate change is expected to severely exacerbate the shortages that already exist.

7 Recommendations and Funding

Recommendation	Cost estimate
1. Assessment of irrigation water use & water conservation potential that would include: h) Water diversion data for all irrigated acreage i) On-farm delivery data for all irrigated acreage j) Actual crop water use k) Return flow amounts and locations l) Estimate of conveyance efficiency upgrades (cost and water savings) m) Estimate of on-farm efficiency upgrades (cost and water savings) n) Evaluate impacts of piping groundwater recharge and instream flows	$25,000 - $100,000 Depends on existing data and level of analysis
2. Assessment of shallow groundwater storage potential and impacts. Components include: d) Canal leakage and contribution to wetlands/instream flow e) Wetland loss, degradation, restoration - impacts on summer baseflow f) Value of winter use of ditch network to recharge GW and flood amelioration	$25,000 -$50,000
3. Wallowa Lake Storage Assessment: Evaluate if the opportunity exists to more actively use Wallowa Lake storage to meet instream and out-of-stream needs. This includes use of existing storage as well as restoring storage that is not currently used due to dam safety concerns.	$20,000
4. Quantitative monitoring to inform water management decisions and quantify conservation potential: e) return flows f) USBR Agrimet Station for Wallowa Valley g) Stream gage recommendations h) Water temperature monitoring sites	Monitoring plan: $10,000 - $25,000 Implementation varies by type, location, etc.
5. Perform instream habitat study (e.g., Instream Flow Incremental Methodology (IFIM) Study): d) Evaluate adequacy of existing studies e) Work with stakeholders to identify other priority locations f) Implement IFIM at selected sites	$80,000 - $250,000 Depends on # of sites selected
6. Perform watershed studies evaluating rainfall-runoff processes, potential to increase overall runoff volume, and increase groundwater baseflow. For example, watershed studies across the west have shown a strong correlation between stand density and annual runoff volume, while other studies have shown floodplain restoration can increase late summer baseflow.	$25,000-$150,000 Depends on type and scale of study
7. Water temperature study, elements include: d) Assemble, evaluate existing water temperature monitoring data e) Wallowa Lake CE-QUAL2E model to evaluate storage/release configuration impacts on lake and release temperatures, f) Wallowa River and tributary water temperature model development (to evaluate downstream impacts of future storage-flow-temperatures)	$50,000 - $100,000 Depends on downstream extent and data availability
8. Develop water banking system to ameliorate flow impacts in drought years: d) Identify and map croplands, tax parcels, irrigation district, water right etc. e) Use IFIM or other habitat data to quantify benefits of saved water f) Develop outreach program to survey interest and participation of landowners	$50,000-$100,000
9. Develop a Wallowa Valley Water Management Plan that would: e) Use IFIM, water temperature model(s), and other fish/habitat data to quantitatively evaluate benefits/prioritize flow restoration f) Identify optimum Wallowa lake storage, release, outlet configuration g) Develop a basin-wide action plan that prioritizes projects, h) Identify funding sources, partnerships, and other implementation opportunities	$50,000 - $200,000 Depending on completion of previous tasks. #1 required.

Considered but not recommended

Description	Reason for rejecting
Have discussions amongst stakeholders if the ***water available in the Imnaha sub-basin*** **can be used to improve instream flows in the Wallowa sub-basin**, and if it is desirable to pursue that.	Initial stakeholder opinions indicate that this has been considered but rejected due to logistical reasons (high-elevation areas snowbound late into season, long pipeline lengths, administratively withdrawn lands), and concerns over impacts to Imnaha River fisheries
Perform **an *in-depth analysis of projected impacts of climate change*** (specifically decreased late-summer streamflow) on irrigation water supply and ability to meet instream needs.	Current understanding of likely climate change impacts is sufficient to know that future summertime shortages are likely. Funds best spent on other identified recommendations

Potential funding sources

Grant Agency	Grant Name/Type	Due Date
OWRD	Place-Based Planning	No funding available
OWRD	Feasibility Studies	10/17/2018, $2.5M available
OWRD	Water Projects	4/25/2018, $13.8M available
OWEB	Multiple	No date scheduled for 2018
USBR	Water and Energy Efficiency	No date scheduled for 2018
USBR	Water Marketing	No date scheduled for 2018
USBR	Technical Assistance Funding for Tribes	1/19/2018

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Acknowledgments

The authors would like to thank local stakeholders for providing data and review of this report. In particular, David Bates, OWRD Watermaster for the area, provided most of the information found in the irrigation sections of the report. Without data and review from Mr. Bates this report would not be as accurate or complete.

Appendix 1 – Water Rights Information System (WRIS) database

Provided in Microsoft Excel format.

Appendix 2 – Water Use Reports (WUR) database

Provided in Microsoft Excel format.