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Technical Memorandum (TM)

To: Larry Walker Associates

From: Davids Engineering, Inc.

Date: March 16, 2020

Subject: **Estimation of Historical Surface Water Diversions in the Shasta Valley**

Introduction

Davids Engineering (DE) was subcontracted by Larry Walker Associates (LWA) to assist in the development of a Groundwater Sustainability Plan (GSP) as part of implementation of the Sustainable Groundwater Management Act (SGMA) in the Shasta Valley. One task under this effort was to estimate historical surface diversions within the Valley based on available information from the watermaster service, which was established following the 1932 Shasta River Decree to supervise the distribution of water to the land areas included in the Decree. For a long time, the watermaster service was provided by the California Department of Water Resources (DWR); in recent years, it has been provided by the Scott Valley and Shasta Valley Watermaster District (SSWD).

Methodology

The Watermaster Key table[1] was used to identify watermaster service area, diversion number and location, winter and summer diversion rights (given in cubic feet per second, or cfs), and diversion priority; these stem from the 1932 Shasta River Decree. The eight watermaster service areas in the Shasta Valley are Beaughan Creek, Boles Creek, Carrick Creek, Jackson Creek, Little Shasta River, Lower Shasta River, Parks Creek, and Upper Shasta River. For each watermaster service area the total flow volume on record were summed by priority to determine total possible diversions. The Shasta Valley and surface water features corresponding to each watermaster service area are depicted in Figure 1.

[1] The Watermaster Key table is a dataset of decreed water rights that are under the supervision of the Scott Valley and Shasta Valley Watermaster District. It represents only the diversions serving adjudicated lands that are defined in the Orders Creating/Changing Watermaster Service Areas. This dataset does not represent actual diversion volumes and does not guarantee the accuracy of water rights. This dataset contains flow volumes used for developing the annual service fees and billing calculation. A brief presentation describing Service Area Orders can be found on the District's Homepage (sswatermaster.org), select *Responsibility of the Watermaster*. The Watermaster Key table does not include water rights that are outside the Watermaster Service Area or the subject of third-party agreements requiring the bypass of water or otherwise changing the operations and use of a diversion.

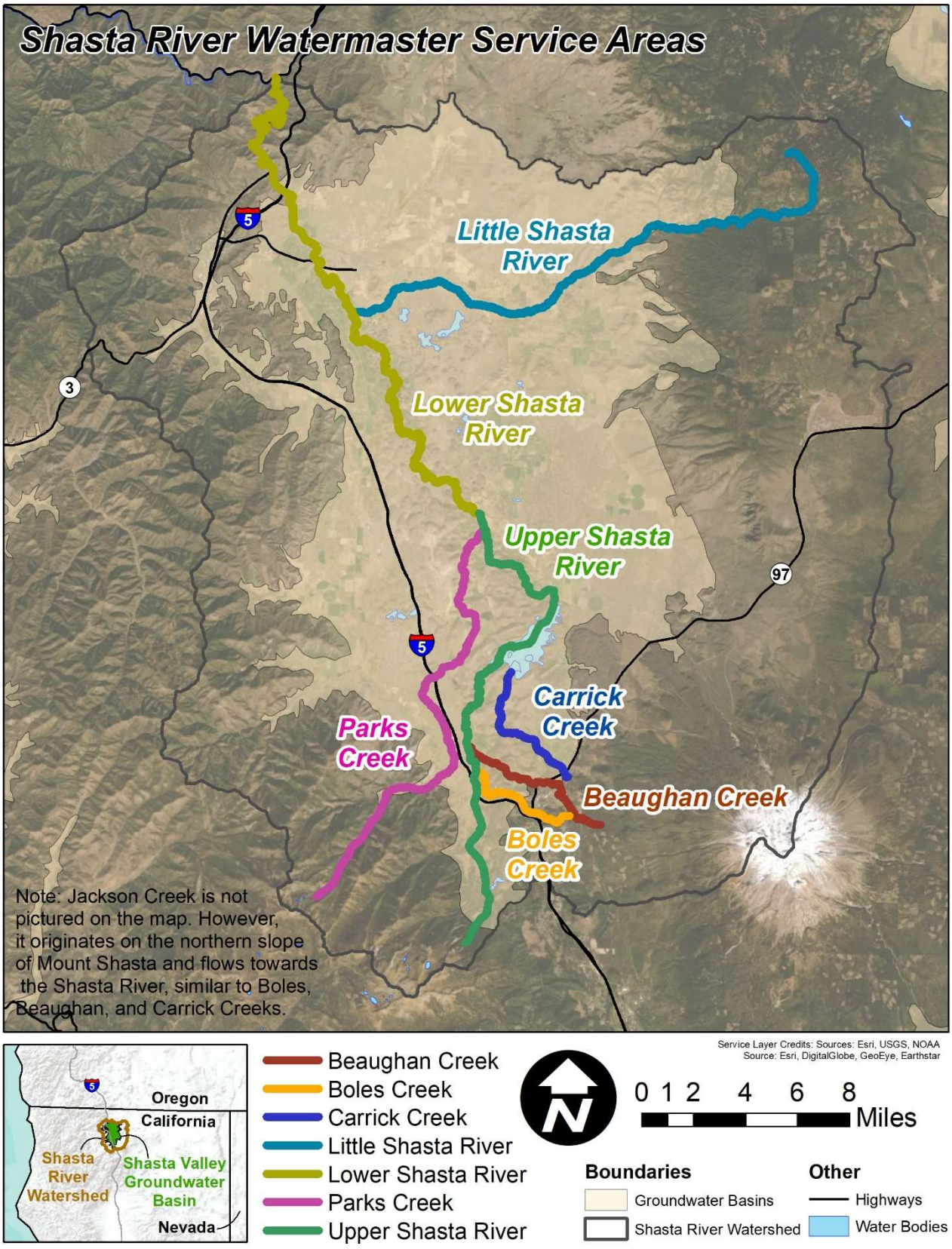

Figure 1. Shasta River Watermaster Service Areas.

Following this, years were selected to characterize Dry, Normal, and Wet conditions in the Shasta Valley. This selection was based on annual average precipitation[2], availability of information from the watermaster service in any given year, and two wet/dry water year indices for nearby areas.

One water year index referenced was the Surface Water Supply Index (SWSI) for the Klamath Basin in southern Oregon. Although the Shasta River watershed is part of the larger Klamath River watershed, the Klamath Basin SWSI is prepared by the state of Oregon and applies to the portions of Klamath Basin within Oregon. The northern portion of the Shasta Valley watershed is roughly 15 miles south of the California-Oregon border. The other water year index referenced was that for the Sacramento Valley, which lies approximately 100 miles to the south of the Shasta Valley.

For each selected year, the Summary of Operations report from the watermaster service was reviewed[3]. The report contains a narrative description of water availability, including a description of the amount of diversions possible throughout the season (typically described by priority, with reductions expressed as a percentage of a specific priority). These narrative descriptions for three of the service areas in the 2000 report are included in Figure 2 as an example. These descriptions were utilized in conjunction with the Watermaster Key table to estimate diversion flow rates on a monthly basis for each of the eight watermaster service areas. These in turn can be summed to determine overall diversions for the Shasta Valley on a monthly timestep for each selected year. The selected years can then be evaluated individually or can be averaged to determine results for Dry, Normal, and Wet Years to estimate diversions in years for which the watermaster reports were not available.

Results and Discussion

In addition to the presentation and discussion of results below, a spreadsheet is included as Attachment A with analysis calculations and results.

Year Selection

Years between 1991 and 2017 were considered for selection to characterize Dry, Normal, and Wet years. Table 1 shows the water year, average annual precipitation, the Klamath Basin SWSI value and category, the Sacramento Valley Water Year Index, whether a report was available from the watermaster service, and whether or not they year was selected as a Dry, Normal, or Wet year. The table is sorted to show average annual precipitation in ascending order.

The years selected to represent Dry years were 1991, 1992, 1994, and 2014; the years selected to represent Normal years were 2000, 2013, and 2016; and the years selected to represent Wet years were 1993, 1996, 1997, 1998, and 1999. The average water year[4] precipitation in the Shasta Valley for the years selected to characterize Dry, Normal, and Wet years was 17.8, 28.8, and 35.7 inches, respectively.

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[2] Annual average precipitation was calculated as the average of the 162 grid cells that represent the overall Shasta River watershed in the Parameter-elevation Regressions on Independent Slopes Model (PRISM) dataset. More information about PRISM is available at: http://www.prism.oregonstate.edu

[3] For years 2011 and prior, this report was produced by DWR and was titled 'Summary of Operations for Watermaster Service in Northern California: 2011 Season'. It included a report for every adjudicated watershed with watermaster service provided by DWR, of which the Shasta Valley was one. It is also not available for most years in the decade between 2001 and 2011. For years 2013 onwards, GEI Consultants, Inc. prepared this report for the SSWD and was titled 'Summary of Watermaster Services for the 2013 Season'. All the reports evaluated, both DWR and SSWD, were very similar in format and content.

[4] A water year represents the period from October 1 to September 30. For example, the 2010 water year corresponds from the period October 1, 2009 to September 30, 2010.

Parks Creek

Flows were above normal with all rights being filled until the middle of June. Flows decreased and third priorities were discontinued by the last week of July. Flows continued to decrease with less than 6 cfs by September.

Upper Shasta River

Upper Shasta River, Dale Creek, and Eddy Creek are on the same order of priorities. The flow was enough to fill all priorities until August 22. Flow decreased to 40 percent of second priorities in August and remained near that level until the end of September. Lower priorities below the Yreka Ditch received return flow and inflow from springs after August 22.

Little Shasta River

There was above-average snowmelt runoff this season on the Little Shasta River. The flows started at 100 percent of all priorities and decreased gradually to 80 percent of fifth priority on July 15. Flows decreased to 70 percent of fifth priority on August 1 and remained that way until the season's end.

Figure 2. Narrative Description Sample from Summary of Operations for Watermaster Service in Northern California: 2000 Season for Parks Creek, Upper Shasta River, and Little Shasta River Service Areas.

2015 was also initially selected to represent Normal years based on annual precipitation records. Preliminary review of this analysis questioned whether the year 2015 (in midst of a period of drought) was suitable for characterization of Normal years. The average annual precipitation record shows that this year experienced more precipitation than Dry years and less than Wet years; however, it does not address the timing of precipitation throughout the water year. In particular, reviewers noted that the 2015 water year had intense storms and greater precipitation early in the year and dry conditions later in the year. Also, the two water indices for this year indicate drier than average conditions. Based on this information, as noted above, the year 2015 was not included in the characterization of Normal years. However, since the analysis has been completed for this year, it is recommended that the efforts requiring diversion estimates for 2015 use the estimated diversions from the 2015 watermaster service records, rather than the Dry, Normal, or Wet year characterization.

The year 2002 could potentially also be reviewed and incorporated into the characterization of Normal years, but it is the only other year in this range for which watermaster service records are available.

The year selection data, analysis, and results are shown in the tab titled 'Precip_WY_Index' in the spreadsheet included as Attachment A.

Table 1. Dry, Normal, and Wet Year Criteria and Selections.

Water Year	Precip-itation (in)	Klamath Basin SWSI Category	Klamath Basin SWSI Value	Sacramento Valley Water Year Index	Watermaster Service Records Available	Selection
2014	15.90	Slightly Dry	-1.64	Critical	Yes	Dry
1994	16.23	Slightly Dry	-1.70	Critical	Yes	Dry
2001	18.16	Slightly Dry	-1.31	Dry	No	
1992	19.55	Moderately Dry	-2.57	Critical	Yes	Dry
1991	19.59	Slightly Dry	-1.88	Critical	Yes	Dry
2009	21.55	Near Average	-0.76	Dry	No	
2012	21.59	Near Average	-0.31	Below Normal	No	
2007	22.46	Near Average	-0.52	Dry	No	
2008	23.64	Near Average	0.04	Critical	No	
2002	24.56	Near Average	-0.78	Dry	Yes	
2013	25.28	Slightly Dry	-1.07	Dry	Yes	Normal
2004	26.48	Slightly Dry	-1.03	Below Normal	No	
2015	26.53	Slightly Dry	-1.35	Critical	Yes	
2010	26.54	Near Average	-0.94	Below Normal	No	
2000	29.88	Near Average	0.83	Above Normal	Yes	Normal
2005	30.92	Slightly Dry	-1.45	Above Normal	No	
2016	31.21	Near Average	-0.54	Below Normal	Yes	Normal
2003	31.63	Slightly Dry	-1.52	Above Normal	No	
2011	31.84	Near Average	0.93	Wet	No	
1999	32.55	Slightly Wet	1.89	Wet	Yes	Wet
1993	34.39	Near Average	0.12	Above Normal	Yes	Wet
1996	36.34	Near Average	0.54	Wet	Yes	Wet
1997	39.34	Slightly Wet	1.15	Wet	Yes	Wet
1995	41.89	Near Average	-0.31	Wet	Yes	
2017	41.96	Near Average	-0.12	Wet	Yes	
2006	42.00	Near Average	0.84	Wet	No	
1998	43.04	Slightly Wet	1.29	Wet	Yes	Wet

Estimated Surface Water Diversions

The total flow volume on record for the Shasta Valley for the summer (or irrigation) season, summed from the Watermaster Key table, was 446 cfs. For each of the years selected, the narrative description for each of the eight service areas was reviewed and used to estimate water diversions on a monthly basis by priority. As an example, if a report said that the flows decreased to 50% of the 5th priority on June 15th for a service area, then all 1st to 4th priority diversions would have an assumed 100% diversion value for the month of June. All 6th or higher priorities would have an assumed 50% diversion value for the month of June (unless prior comments indicated other, earlier diversion flow reductions), and the 5th priority diversion would have an assumed diversion value of 75% (e.g. 100% for the first half of the month, and 50% for the second half). These monthly estimates were then summed for each service area to develop total monthly estimated diversion for each selected year, and the average results for each

year type were determined. The monthly results from March through October can be seen below in Figure 3. As expected, monthly diversions tend to increase from Dry to Normal to Wet years.

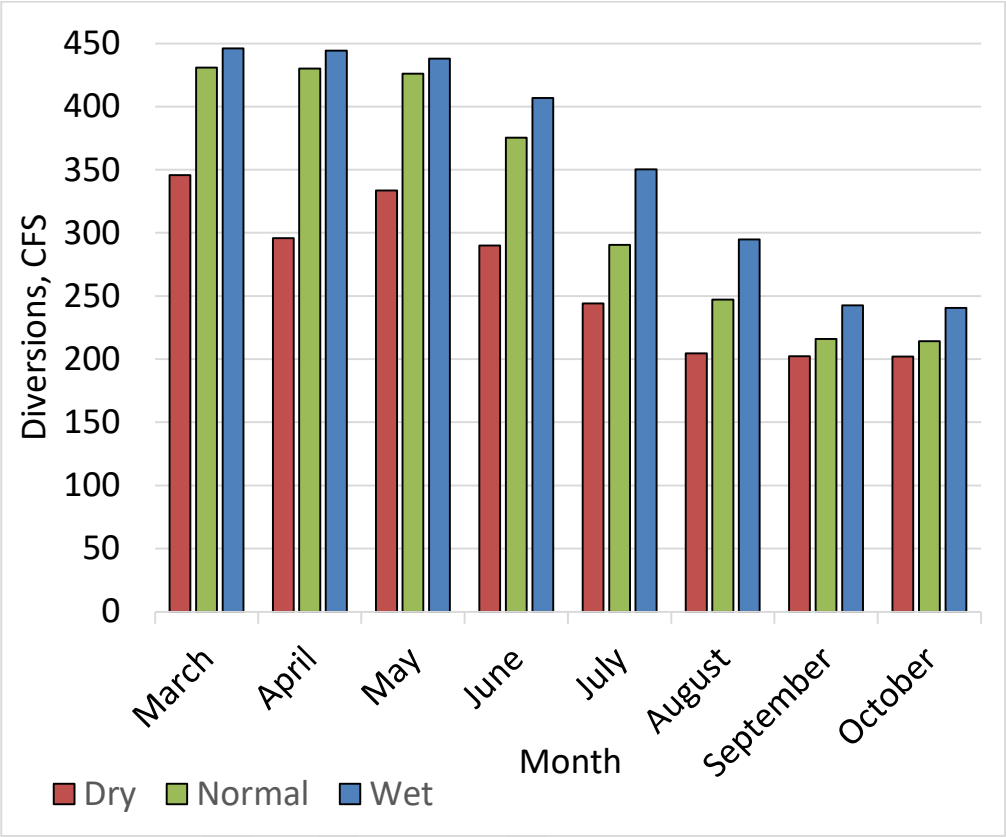

Figure 3. Estimated Average Monthly Surface Water Diversions in Dry, Normal, and Wet Years.

On a monthly pattern, also as expected, diversions tend to decrease as the irrigation season continues, representing decreasing water availability. The exception to this is from April to May during dry years, where an increase in diversions is seen. This could be explained by snowmelt at the end of spring resulting in higher surface water flows and higher diversions during the month of May. Figure 4 shows the average monthly diversions in Dry, Normal, and Wet years, but also includes the monthly diversions in the individually selected years as well. This demonstrates the variability from year to year in estimated monthly diversion volumes.

For the winter period (November through February), the total flow volume on record was calculated using the Watermaster Key table and totaled roughly 83 cfs (19% of the 446 cfs total for the summer period). Due to lesser diversion rates and greater water availability, it was assumed that 100% of winter diversions were possible in all year types[5].

A summary of the data, analysis, and results are included in Attachment A, a Microsoft Excel spreadsheet. It includes estimated monthly diversions for each priority water right in each of the eight service areas, which are then aggregated and summarized for the selected Dry, Normal, and Wet years as described in the spreadsheet.

[5] During review by SSWD Staff, it was noted that not all diversion rights are exercised during the winter period. As a result, this assumption overestimates historical diversions for the winter period.

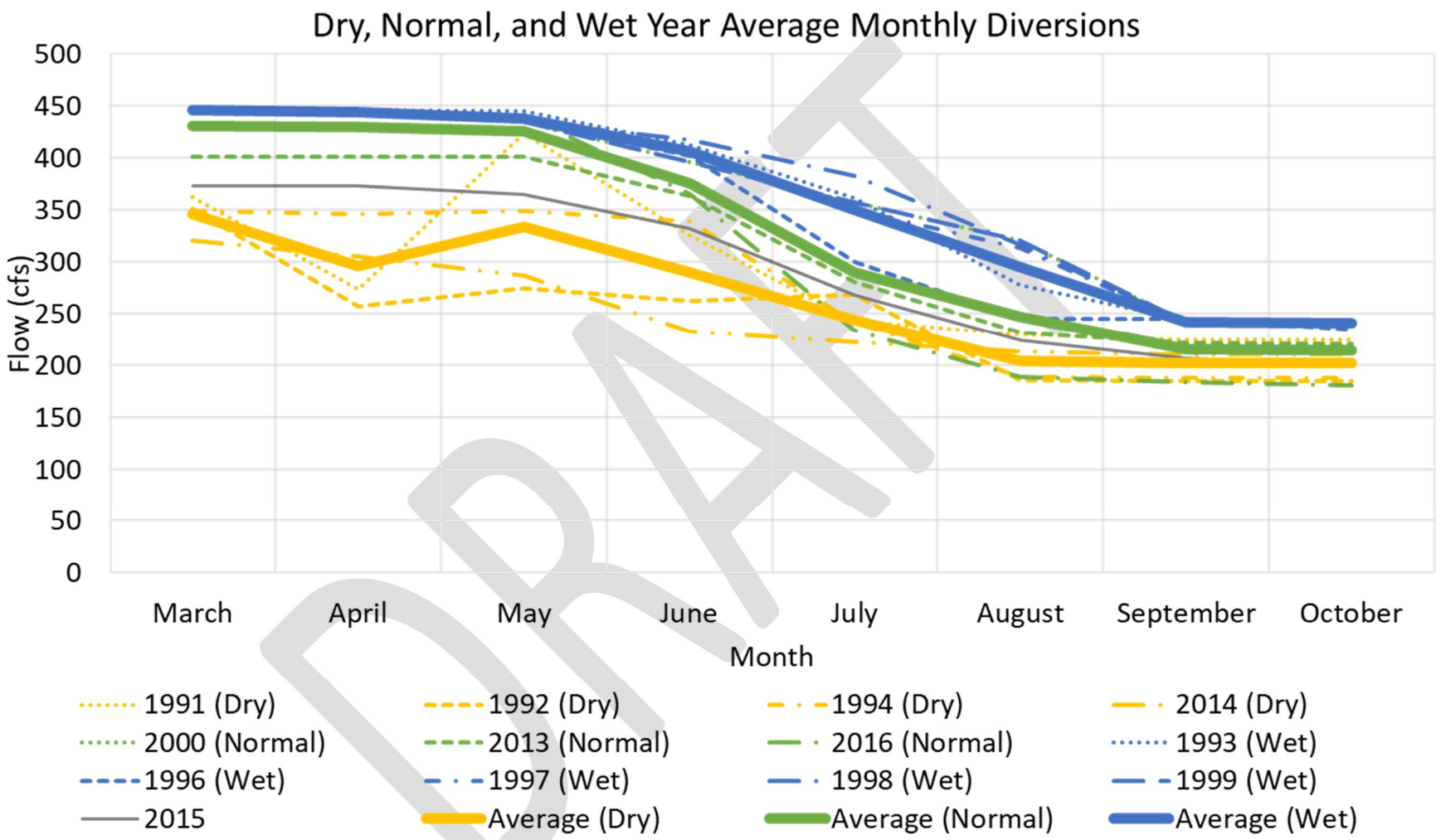

Figure 4. Estimated Monthly Surface Water Diversions in Individually Selected and Average Dry, Normal, and Wet Years.

Comparison to Other Data Sources

Two studies completed in 2009 and 2010 included actual measurements of diversions in the Shasta Valley. One included diversions from the Little Shasta River[6], and the other includes diversions from Parks Creek and the Shasta River (in the Upper Shasta River service area)[7]. Unfortunately, watermaster service records are not available for these years. However, the results from these studies can be compared to the Dry, Normal, and Wet year estimated diversions to evaluate how reasonable the results are[8].

The years 2009 and 2010 years had average annual precipitation of 21.6 and 26.5 inches, respectively. Both of these values are between the average annual precipitation values for the selected dry years (17.8 inches) and the selected Normal years (28.2 inches). Correspondingly, the results for the Musgrave Ditch show diversion volumes from March through October that are greater than estimated diversions during Dry years, but less than estimated diversions during Normal years. Figure 5 below shows the total March through October diversion volumes from these different sources for comparison.

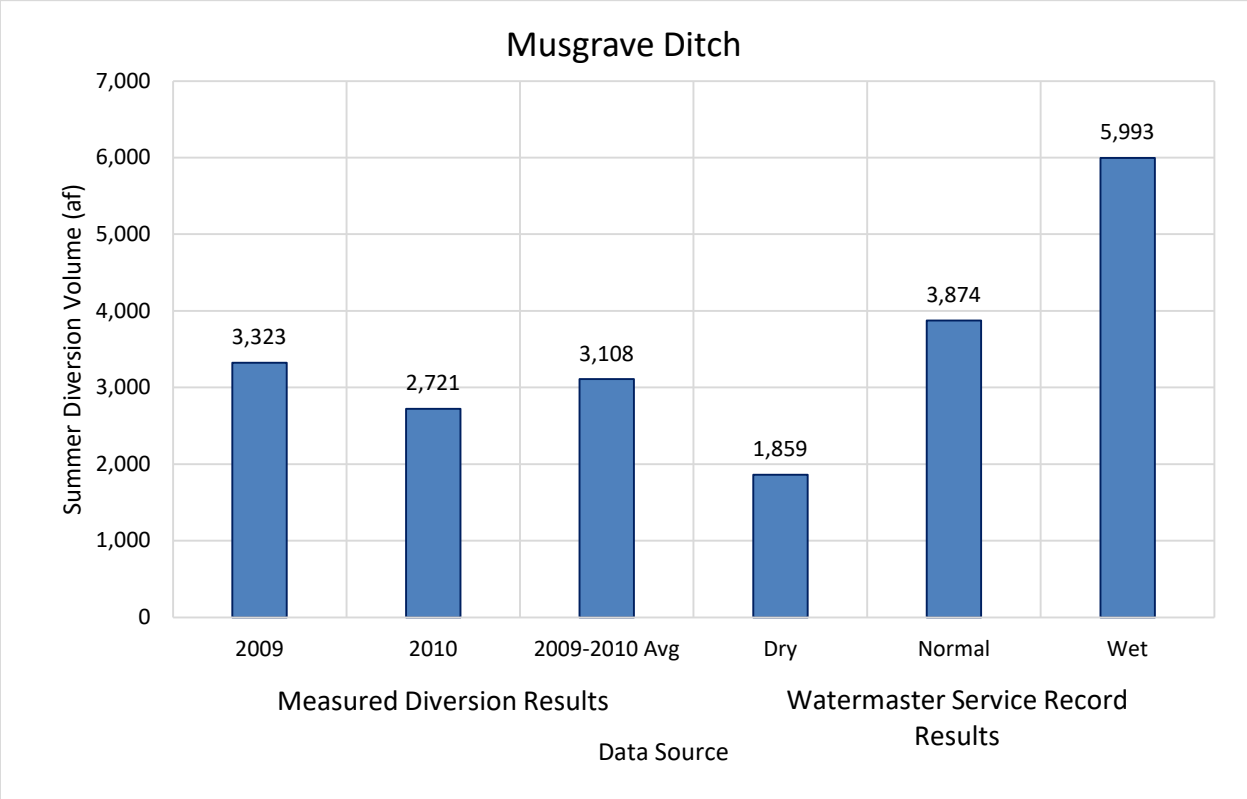

Figure 5. Musgrave Ditch Diversion Volume Comparison.

[6] Little Shasta River Water Efficiency Study: A Cooperative Investigation Undertaken by the California Department of Fish and Game and the Cowley and Hart Ranches, Little Shasta, CA. February 2012

[7] Shasta Springs Ranch Irrigation Efficiency Study: A Cooperative Investigation Undertaken by the California Department of Fish and Game and Emmerson Investments. September 2011.

[8] Additional available measurement data from the SSWD that can be compared to Dry, Normal, and Wet year estimated diversions include documented measurement information from GEI Consultants, Inc. for specific locations and measurement records kept by the SSWD from July 2018 onwards.

Interestingly, although there was more precipitation in 2010 as compared to 2009, there was a smaller volume of measured diversions. This comparison was also completed for Shelly Ditch and Hart-Haight Ditch with similar results: measured diversions in 2009 and 2010 were between estimated diversion in Dry and Normal years, and measured diversion volumes were smaller in 2010 than 2009. This comparison was also done for the Shelly Ditch and Hart-Haight Ditch diversions from the Little Shasta River, yielding similar results for each of those sites.

The comparison was also done for the Evans Spring Ditch, which holds 1st priority diversion rights estimated to be 100% filled in Dry, Normal, and Wet years. However, actual measured diversions show that this number fluctuates from year to year and in both 2009 and 2010 was lower than the estimated diversions for all year types. This may reveal some of the limitations and uncertainty of using watermaster service records to estimate surface water diversions. Figure 6 below shows the Evans Spring Ditch comparison.

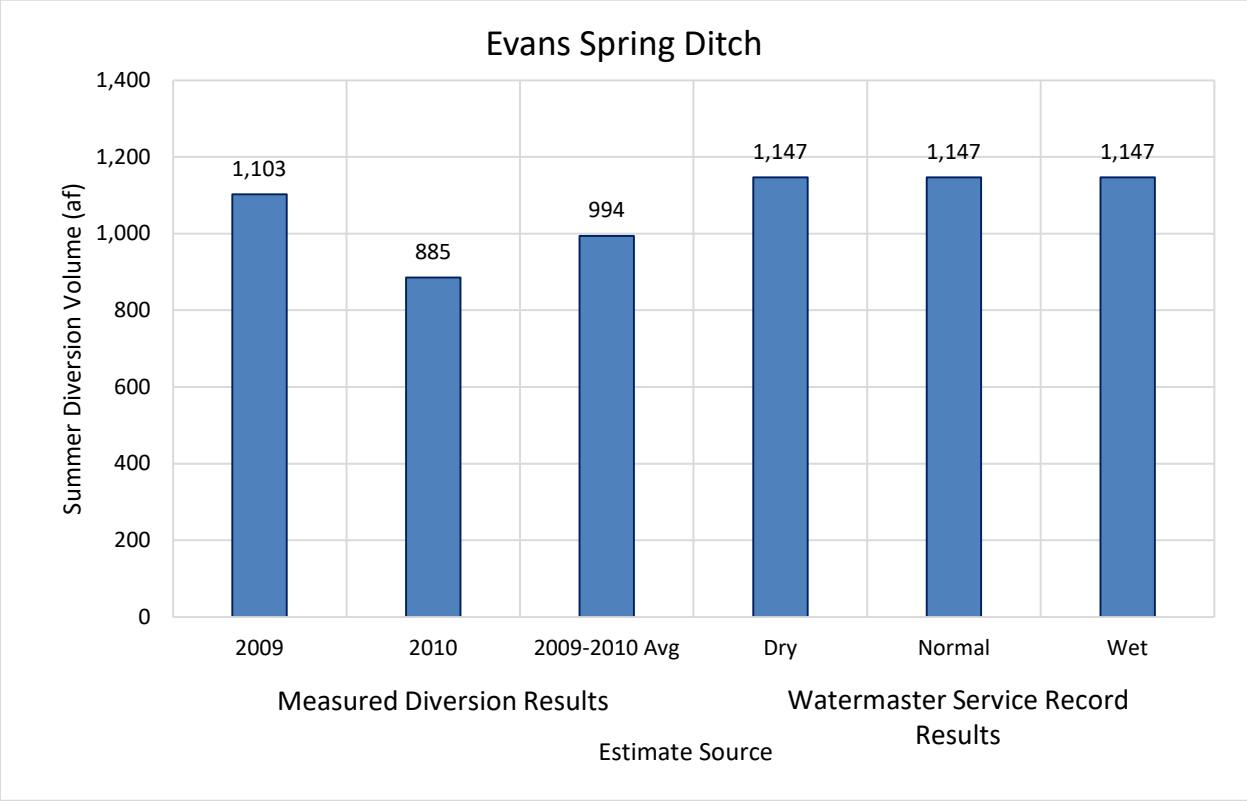

Figure 6. Evans Spring Ditch Diversion Volume Comparison.

In 2010, diversions were measured at five points along lower Parks Creek and the Shasta River below Lake Shastina and upstream of the Parks Creek confluence. A similar comparison was made between measured diversions and estimate diversions during Dry, Normal, and Wet years. At two of the diversion points, the results were the same as those for the Musgrave Ditch, Shelly Ditch, and Hart-Haight Ditch, in which the two datasets aligned relatively well. For the other three diversion points, the measured diversions in 2010 were greater than the estimated diversions in all year types. To illustrate this, Figure 7 below shows the comparison for the HIG Pump diversion.

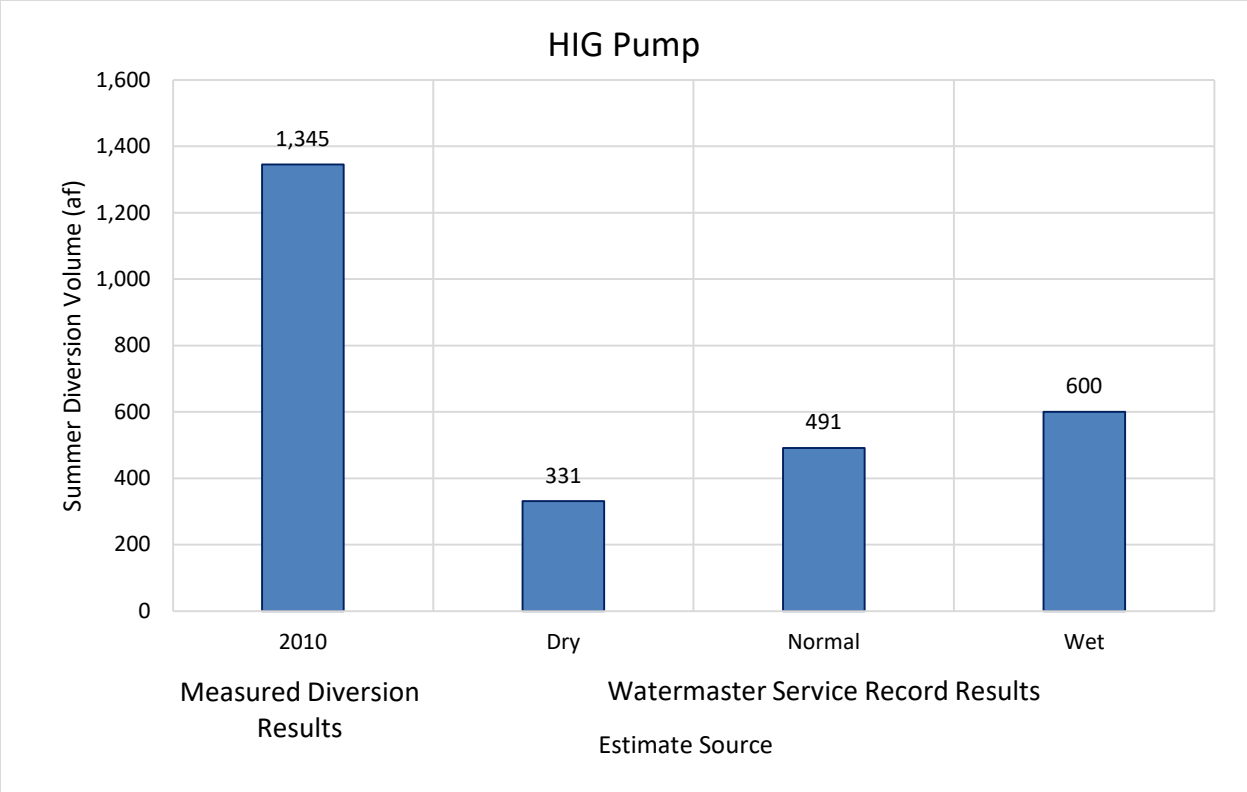

Figure 7. HIG Pump Diversion Volume Comparison.

There are cases in the Shasta Valley where water rights under the Decree and riparian rights use the same diversion location and infrastructure, which is a potential explanation for the greater volume of measured diversions than estimated diversions. Additionally, although this diversion is in the Upper Shasta River service area, it is located below Lake Shastina and Dwinnell Dam. The Upper Shasta River service area tends to have decreasing water availability and decreasing diversions as the irrigation season continues (based on watermaster service records). However, it is theorized that this diversion and other diversions below Lake Shastina are able to be met consistently throughout the year through releases from Dwinnell Dam. The watermaster service records state that releases from Lake Shastina to water users directly downstream of the reservoir are the responsibility of the watermaster.

The three sites with higher measured diversions as compared to estimated diversions may reveal other limitations and uncertainties with using watermaster service records to estimate surface water diversions.

In total, results for nine diversions included in the two studies were compared to the corresponding Dry, Normal, and Wet year estimated diversions. A summary is shown below in Table 2, with the detailed comparison and comments for three of the nine diversions presented previously.

Table 2. Comparison of Measured Diversions to Estimated Diversions.

	Measured Diversion Results (af)			Watermaster Reports (af)		
Location	2009	2010	2009-2010 Avg	Dry	Normal	Wet
Shelly Ditch	888	623	778	581	1,279	2,007
Musgrave Ditch	3,323	2,721	3,108	1,859	3,874	5,993
Hart-Haight Ditch	2,084	2,181	2,203	1,508	3,329	5,012
Evans Spring Ditch	1,103	885	994	1,147	1,147	1,147
HIG Gravity	-	1,133	-	98	146	178
HIG Pump	-	1,345	-	331	491	600
Parks Creek 2	-	354	-	293	549	591
Parks Creek 3&4	-	614	-	346	756	736
Parks Creek 5	-	519	-	94	194	189

Conclusions and Recommendations

These results were presented and discussed with SSWD staff to determine whether the interpretation of the watermaster service records was reasonable, and whether there were better data sources to utilize to estimate historical surface water diversions. SSWD staff shared that flow volumes from the Decree are used for billing purposes for watermaster service but are not always reflective of historical diversion flow rates or the resulting volumes. Actual diversion amounts at a specific diversion point can differ from year to year, even in times of similar water availability. The methodology also does not account for diversions that may be temporarily inactive (e.g. if a field is fallowed in a particular year and surface water is not diverted). SSWD staff anticipated that the methodology used likely overestimated diversions. Through discussion with SSWD staff, it was determined that watermaster service records utilized are the most readily available data source for estimating historical diversions.

For future water accounting efforts or water budgets, more accurate data sources should be identified or developed. In recent years, the SSWD has been collecting more reliable and accurate diversion data that could be used in place of estimated diversions based on the methodology described here. Also, recent legislation in Senate Bill 88 (SB 88) requires surface water diverters statewide to measure and report diversions. This legislation does not apply to adjudicated water rights under the Decree, since the watermaster service already regulates and reports on the timing and quantity of diversions. However, this legislation does apply to riparian water rights (and potentially other water rights) not covered under the Decree and included in the SSWD watermaster service area. There are cases in the Shasta Valley where water rights under the Decree and riparian rights use the same diversion location and infrastructure. SB 88 will provide additional data concerning diversion timing and volume that will be valuable for improving surface water diversion estimates for future water accounting purposes. Additional data collection or coordination with diverters could also be completed to better understand diversion timing and volumes moving forward.

Attachment A: Shasta_Valley_Watermaster_Diversion_Summary.xlsx

Attachment A is a Microsoft Excel spreadsheet used determine and present results of an analysis to estimate historical surface water diversion in the Shasta Valley under the 1932 Shasta River Decree. The datasets used in the analysis were the watermaster key table and watermaster service records (which include narrative descriptions of how much water was available for diversion, and if supplies are limited, approximately when surface diversions were reduced or ended). Based on annual precipitation and water year indices for the Sacramento Valley and Klamath Basin (and Watermaster Report availability), years were selected for evaluation to represent Dry, Normal, and Wet conditions.

The tabs in the spreadsheet are described below:

- Readme – this tab explains the contents of the spreadsheet.
- Summary - this tab presents average irrigation season diversions in cfs and as a percentage of total water rights for the valley as a whole and for the different service areas; it also includes summary figures.
- Aggregated - this tab contains monthly data for the years selected for evaluation of watermaster reports to estimate surface water diversions.
- Precip_WY_Index - this tab presents the data used to select years for evaluation and characterization of Dry, Normal, and Wet years.
- BeaughanCreek_EstDivs – this tab presents estimated monthly diversions for select years for the Beaughan Creek service area.
- BolesCreek_EstDivs – this tab presents estimated monthly diversions for select years for the Boles Creek service area.
- CarrickCreek_EstDivs – this tab presents estimated monthly diversions for select years for the Carrick Creek service area.
- JacksonCreek_EstDivs – this tab presents estimated monthly diversions for select years for the Jackson Creek service area.
- LittleShasta_EstDivs – this tab presents estimated monthly diversions for select years for the Little Shasta River service area.
- LowerShasta_EstDivs – this tab presents estimated monthly diversions for select years for the Lower Shasta River service area.
- ParksCreek_EstDivs – this tab presents estimated monthly diversions for select years for the Parks Creek service area.
- UpperShasta_EstDivs – this tab presents estimated monthly diversions for select years for the Upper Shasta River service area.