TEMPORARY PERMIT FOR DIVERSION AND USE OF WATER

APPLICATION T032564
TEMPORARY PERMIT 21364

Permittee:

Scott Valley Irrigation District
PO Box 216
Fort Jones, CA 96032

Summary Report

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Executive Summary

On January 13, 2016 the Scott Valley Irrigation District (SVID) received a temporary permit to appropriate surface water for groundwater recharge and later instream fish and wildlife habitat enhancement between River Mile (RM) 46.7 and RM 21 in the period January 1 to March 31, 2016. The original application proposed to divert up to 5,400 acre-feet (AF) for groundwater recharge on agricultural fields (about 1,400 acres) adjacent to the SVID ditch. Diversion of surface water for groundwater recharge started on February 4th and ceased on March 31, 2016. Based on streamflow estimates at the point of diversion (POD) at RM 46.7, a total of 680 AF were diverted for groundwater recharge while an almost equal amount (675 AF) was diverted for stockwater use. Surface water was recharged on 5 fields. A total of 8 groundwater wells were instrumented with pressure transducers on the east side of the Scott River to monitor changes in the groundwater surface elevation in response to the artificial recharge activities and natural recharge of precipitation. Based on these measurements a clear response and rise of the groundwater table by 4.5 ft could be detected in the near vicinity of the recharge site in response to the artificial recharge indicating that on-farm recharge resulted in a clear and measurable increase in groundwater storage and possibly additional groundwater contribution to streamflow. Overall the amount of surface water recharged was too small to create a *measurable* increase in streamflow at the Fort Jones stream gauge. However, since October 1, 2015 the Scott Valley also received a total of 23.75 inches of precipitation which had a much larger effect on groundwater storage than the small field-scale recharge events as indicated by the monitoring data. Surface water-groundwater modeling of the past winter indicates that 42 cfs would have to be diverted for 3 months to see a significant enhancement (7.5 cfs) of summer streamflow, which creates a clear target for future replication of these activities. Overall, the study can be considered a successful implementation of artificial recharge on agricultural land for groundwater storage and streamflow enhancement with significant amounts of water recharged and considerable landowner support for adoption of these practices.

In addition to the hydrometric measurements and modeling performed a field trial was set up on a 15-acre, 10-year old alfalfa stand to estimate the effect of different winter irrigation amounts on alfalfa forage crops. Winter off-season irrigation treatments ranged from 1.6 (low), 4.1 (high) to 11.1 ft of water (continuous) per acre in addition to winter precipitation. Overall, the alfalfa yield in the three treatment areas showed no discernible difference in yield in response to the winter irrigation. Interestingly, checks receiving the largest amount of winter water showed a higher yield than the control plots during the 1st and 2nd cutting indicating that winter recharge might lead to increased crop water availability in the deep soil profile offsetting potential irrigation deficits during the growing season. These results suggest that alfalfa is a promising crop for ag-recharge if grown on suitable, well-draining soils.

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1 Diversion and streamflow measurements

The temporary permit for groundwater recharge was issues by the State Water Resources Control Board (SWRCB) to the Scott Valley Irrigation District (SVID) on January 13, 2016. Shortly after the permit was issued SVID volunteer staff started instrumenting groundwater wells and the SVID point of diversion with hydrologic sensors to measure flow rate at the point of diversion and changes in the depth to the groundwater table near fields that woul d receive water for groundwater recharge. Diversion of surface water for groundwater recharge began on February 4, 2016 and ended on March 31, 2016. Recharge was extended until April 22, 2016 on the research field described below.

Based on precipitation data from the Western Regional Climate Center (Fort Jones Ranger Station, COOP ID 043182, Elev. 2730 ft a.s.l.) the Scott Valley received a total of 23.75 inches of precipitation in water year (WY) 2015/16. Of that, 5.07 inches fell between February 1 and March 31, 2016. The total annual average precipitation in WY 2015/16 was slightly above the long-term average of 19.5 inches (1935-2012). In response to the large precipitation events, the flow in the Scott River stayed consistently high (above the 1,000 cfs mark) between January and April in 2016. At no time during this 2-months groundwater recharge period did the streamflow at USGS stream gauge in Fort Jones drop below the USFS minimum flow requirement specified in the Scott River Decree (Fig. 1a).

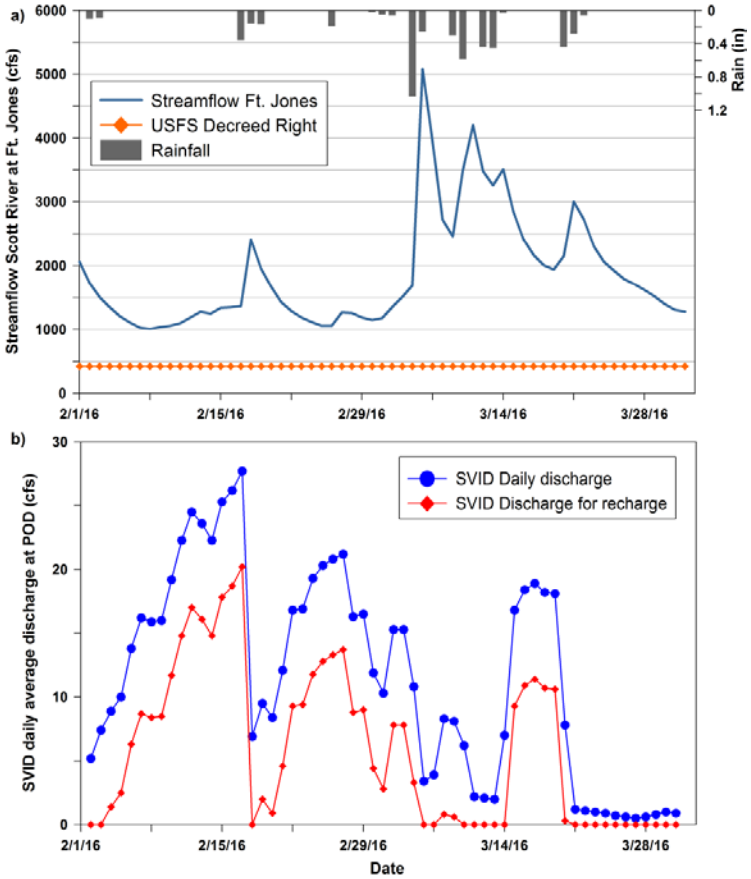

Figure 1: Daily average discharge (cfs) at USGS stream gauge near Fort Jones (USGS 11519500) (a) and at the SVID point of diversion (POD) (b). The orange dotted line in (a) indicates the minimum flow requirement of 426 cfs specified in the Scott River Decree.

The discharge measured at the SVID POD during the diversion period for groundwater recharge is shown in Figure 2. Stage measurements (ft) were converted to volume measurements through a stage-discharge relationship. To establish the stage-discharge relationship eight discharge (cfs) measurements were taken with a flow meter at different flow rates as indicated by the blue dots in Figure 2. Table 1 summarized the dates, time and observed discharge measured with the flow meter at SVID POD.

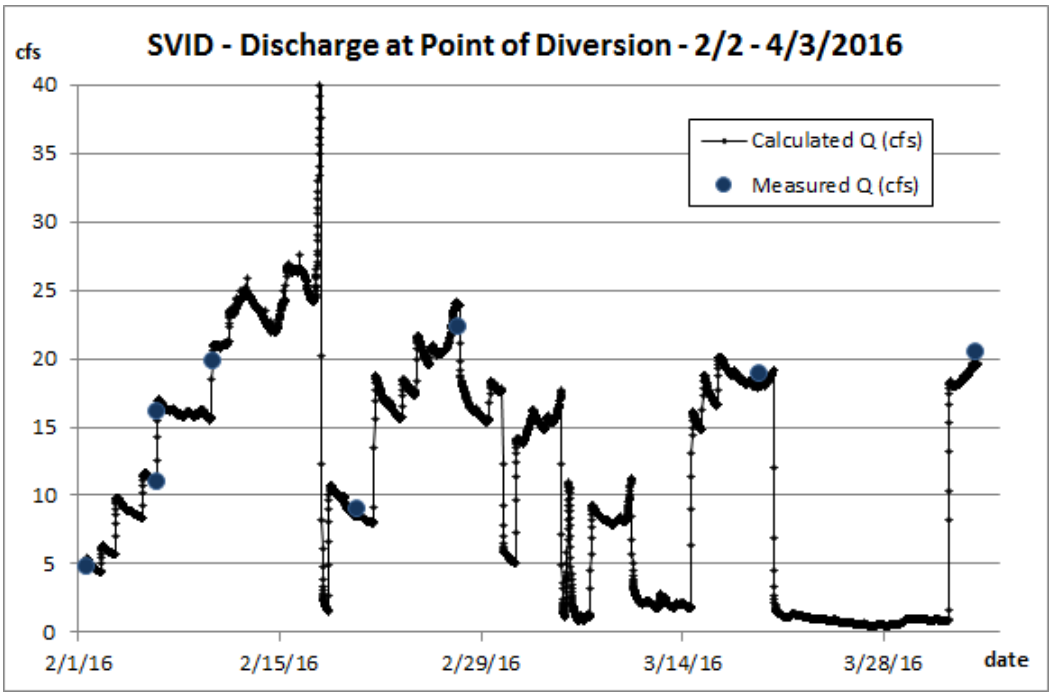

Figure 2: Calculated and measured discharge (cfs) at SVID point of diversion – 2/1 – 4/3/2016.

Table 1: Periodic discharge (cfs) measurements performed at the SVID POD for 2016 Groundwater Recharge.

Date	Time (PST)	Discharge (cfs)
2/1/2016	14:00	4.8
2/6/2016	11:30	11.0
2/6/2016	13:30	16.1
2/10/2016	10:00	19.9
2/20/2016	10:00	9.1
2/27/2016	10:00	22.3
3/19/2016	9:15	18.8
4/3/2016	10:45	20.4

Between February 1 and April 1, 2016 a total of 1355 AF of surface water were diverted at SVID POD from the Scott River. This total includes the amount of water diverted under the existing SVID stockwater right as well as the water diverted for groundwater recharge under this permit

(Figure 3). Surface water demand for livestock approximates about 7.5 cfs. Thus, this amount was subtracted from the observed SVID POD discharge on days when discharge was greater than 7.5 cfs (Table 2). On days when SVID POD discharge was less than 7.5 cfs it was assumed that the SVID discharge was entirely used for livestock. Based on this assumption a total of 680 AF was diverted for groundwater recharge. This number is likely underestimated as water demand for livestock is varying on a day-to-day basis based on temperature and needs.

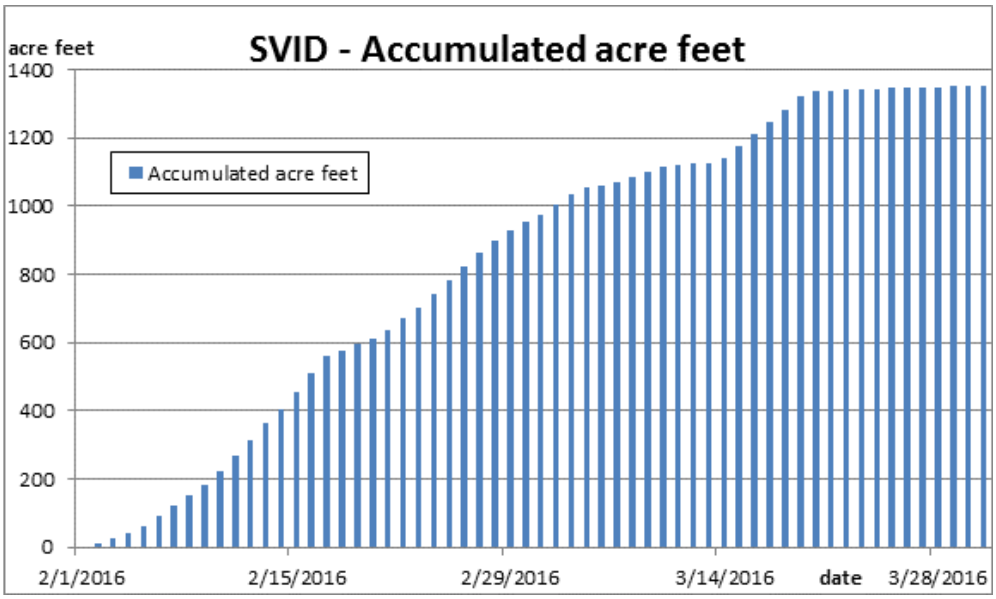

Figure 3: Daily accumulated volume (acre feet) - SVID point of diversion.

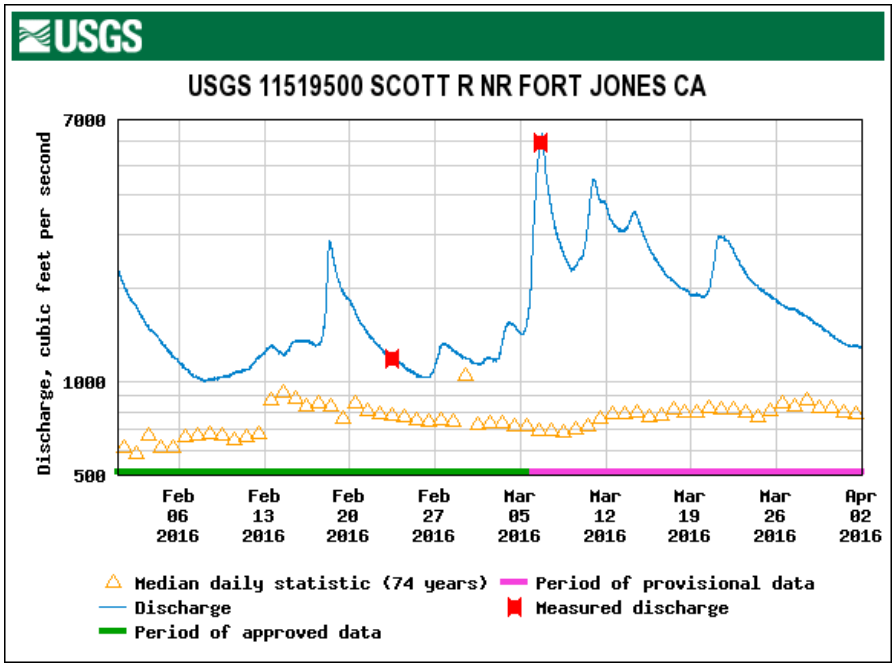

Figure 4: Discharge (cfs) at USGS Station (11519500) Scott River near Fort Jones – Data retrieved at http://waterdata.usgs.gov/ca/nwis/uv/?site_no=11519500&PARAmeter_cd=00065,00060 on 5/18/2016.

Table 2: Daily average discharge (cfs) and daily volume (acre feet) at SVID point of diversion. Daily discharge and daily volume diverted for recharge (column 4 and 5).

	Discharge measured at POD (cfs)	Daily volume diverted at POD (AF)	RECHARGE (cfs) (If Q > 7.5 cfs, flow was used for recharge)	Recharge volume (AF)
2/2/2016	5.2	10.3	0	0.0
2/3/2016	7.4	14.7	0	0.0
2/4/2016	8.9	17.6	1.4	2.8
2/5/2016	10	19.8	2.5	5.0
2/6/2016	13.8	27.3	6.3	12.5
2/7/2016	16.2	32.1	8.7	17.2
2/8/2016	15.9	31.5	8.4	16.6
2/9/2016	16	31.7	8.5	16.8
2/10/2016	19.2	38.0	11.7	23.2
2/11/2016	22.3	44.2	14.8	29.3
2/12/2016	24.5	48.6	17	33.7
2/13/2016	23.6	46.8	16.1	31.9
2/14/2016	22.3	44.2	14.8	29.3
2/15/2016	25.3	50.1	17.8	35.3
2/16/2016	26.2	51.9	18.7	37.1
2/17/2016	27.7	54.9	20.2	40.0
2/18/2016	6.9	13.7	0	0.0
2/19/2016	9.5	18.8	2	4.0
2/20/2016	8.4	16.6	0.9	1.8
2/21/2016	12.1	24.0	4.6	9.1
2/22/2016	16.8	33.3	9.3	18.4
2/23/2016	16.9	33.5	9.4	18.6
2/24/2016	19.3	38.2	11.8	23.4
2/25/2016	20.3	40.2	12.8	25.4
2/26/2016	20.8	41.2	13.3	26.4
2/27/2016	21.2	42.0	13.7	27.1
2/28/2016	16.3	32.3	8.8	17.4
2/29/2016	16.5	32.7	9	17.8
3/1/2016	11.9	23.6	4.4	8.7
3/2/2016	10.3	20.4	2.8	5.5
3/3/2016	15.3	30.3	7.8	15.5
3/4/2016	15.3	30.3	7.8	15.5
3/5/2016	10.8	21.4	3.3	6.5
3/6/2016	3.4	6.7	0	0.0
3/7/2016	3.9	7.7	0	0.0
3/8/2016	8.3	16.4	0.8	1.6
3/9/2016	8.1	16.1	0.6	1.2
3/10/2016	6.2	12.3	0	0.0
3/11/2016	2.2	4.4	0	0.0
3/12/2016	2.1	4.2	0	0.0
3/13/2016	2	4.0	0	0.0
3/14/2016	7	13.9	0	0.0
3/15/2016	16.8	33.3	9.3	18.4
3/16/2016	18.4	36.5	10.9	21.6
3/17/2016	18.9	37.5	11.4	22.6
3/18/2016	18.2	36.1	10.7	21.2
3/19/2016	18.1	35.9	10.6	21.0
3/20/2016	7.8	15.5	0.3	0.6
3/21/2016	1.2	2.4	0	0.0
3/22/2016	1.1	2.2	0	0.0
3/23/2016	1	2.0	0	0.0
3/24/2016	0.9	1.8	0	0.0
3/25/2016	0.7	1.4	0	0.0
3/26/2016	0.6	1.2	0	0.0
3/27/2016	0.5	1.0	0	0.0
3/28/2016	0.6	1.2	0	0.0
3/29/2016	0.8	1.6	0	0.0
3/30/2016	1	2.0	0	0.0
3/31/2016	0.9	1.8	0	0.0
Total Acre Feet		**1355.1**		**680.1**

2 Groundwater recharge and storage

Groundwater and surface water elevations were documented using water level loggers during the period of February – April 2016 in selected locations within the Scott Valley Irrigation District (SVID). Nine sites were monitored of which 8 were groundwater wells (Fig. 5).
Seven of the monitored sites' elevations were documented using a RTK GNSS survey system with a post correction from NGS – OPUS to NAVD 88 computed using GEIOD 12B. Two of the sites elevations were calculated using the previous documented elevation (HR1 & HR2).
Water level loggers (Onset U20 and U20L) were placed in the monitored sites. Manual measurements of depth to water from the surveyed reference point were performed. Calculations of the water surface elevation were performed using the continuous data, manual data and surveyed reference point elevation. Water temperature was documented.

Water was diverted onto 5 fields: JM1, JM2, BL3, HR2, and HA3 (Fig. 5). In addition, a small fraction (0.5 cfs) was turned out from SVID ditch into one of the laterals in Hamlin Gulch. The following table is summarizing the time periods for which water was applied onto each site.

Table 3: List of recharge sites and time periods during which surface water was applied for groundwater recharge.

Site	Time period
JM1	2/4/ – 4/1/2016
JM2	2/4/ – 4/1/2016
BL3	2/23 – 2/28 and 3/9 – 3/16/2016
HR2	3/2 – 4/1/2016
HA3	3/12 – 3/22/2016

Most water surface elevations showed an increase in elevation in response to the large precipitation events in mid-February and early March. In some cases, water surface elevations increased by several feet over the winter and spring season. The large influx of surface water into the Scott Valley groundwater aquifer system was also supported by the groundwater temperature data, which in all cases showed a decrease in temperature in response to the influx of colder surface water.

With exception to the Bryan-Morris ranch, where the groundwater surface elevation response could be monitored directly on site, it was not possible to quantify the rise in groundwater surface elevation related to groundwater recharge vs. natural recharge from precipitation. This is in part due to the fact that most monitoring wells were either located at larger distance or upgradient from the research sites, or the monitoring well was located in an area that received a large influx of surface water from tributaries (gulches) along the east side of the valley. Considering that the winter of 2015/16 had above average precipitation, we conclude that the amount of surface water applied for groundwater recharge was too small to be discernible from

natural recharge. For future work, we hope to increase the amount, spreading area and duration of surface water applications for groundwater recharge to maximize the benefits for instream flows.

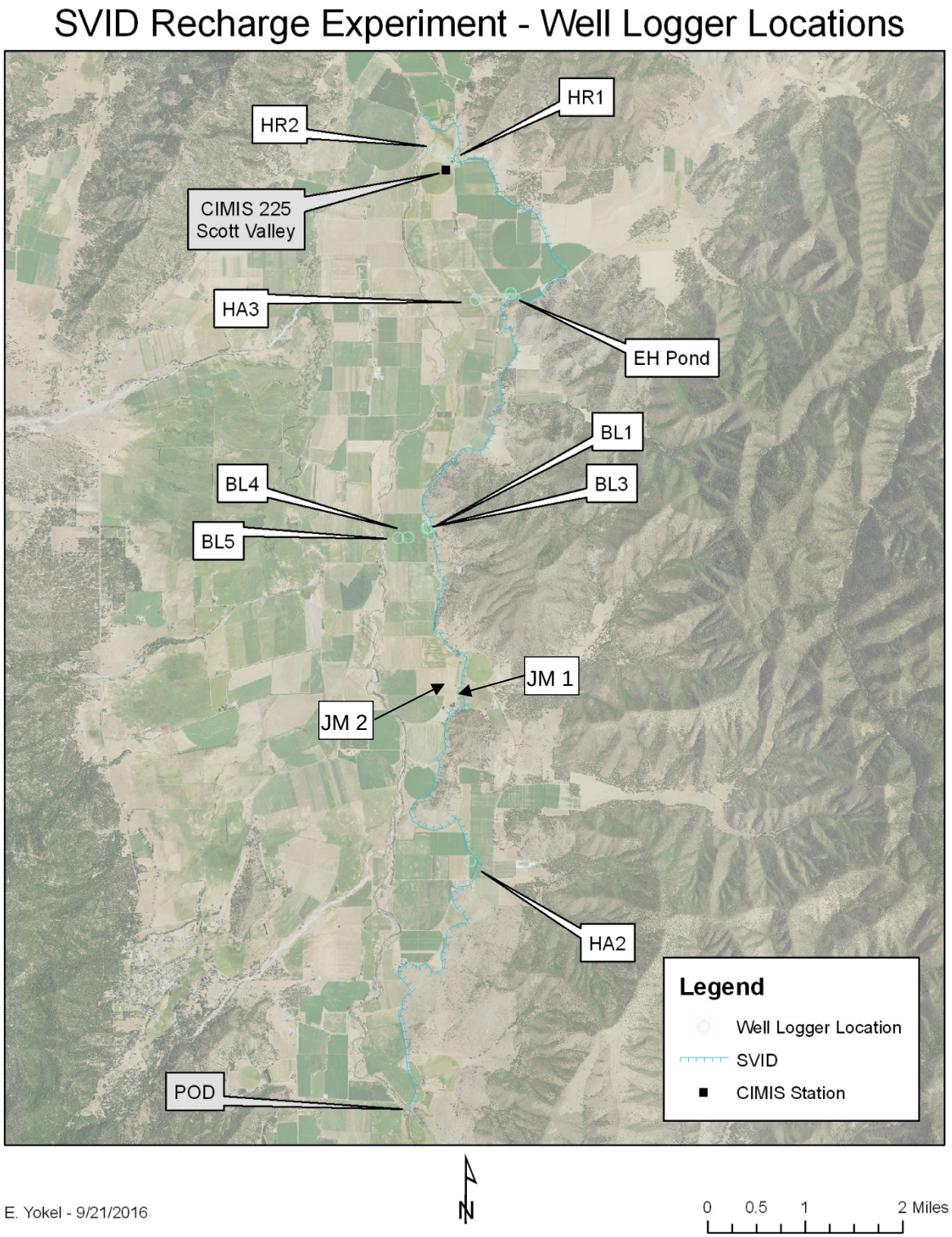

Figure 5: Locations of groundwater and surface water elevation monitoring. POD is the point of diversion, CIMIS 225 is the location of the California Irrigation Management Information System station where meteorological parameters were measured, BL, HA and HR locations are points where water surface elevation was monitored.

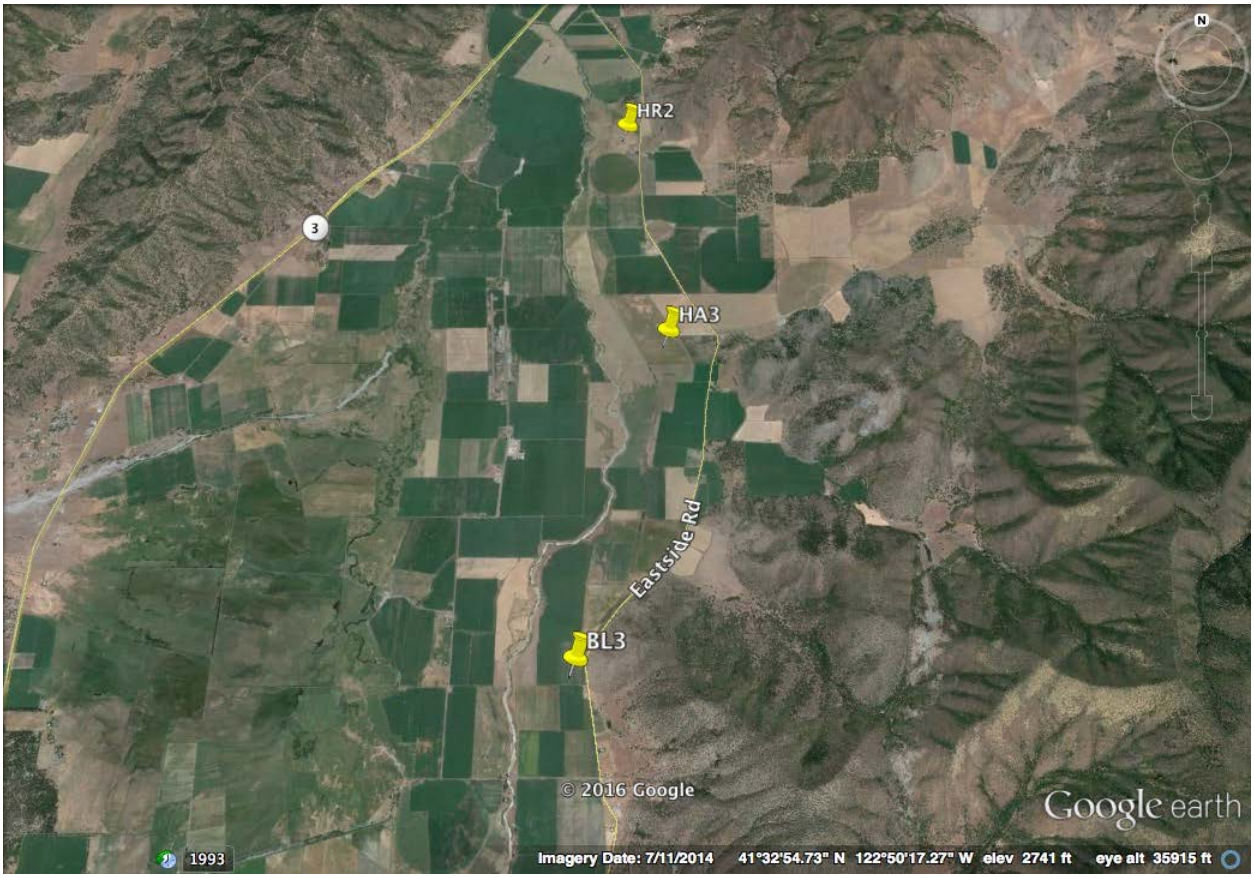

Figure 6: Location of field receiving surface water for groundwater recharge. Note the experimental site instrumented by UC Davis is not shown on this map (see Figure 33).

Table 4: Coordinates of HA2 and SVID Canal water surface elevation.

Site	Feature	Northing (m)	Easting (m)	Elevation (ft)
SVID	**WSE**	**4591484.0**	**514044.5**	**2787.96**

Site	Feature	Northing (m)	Easting (m)	Elevation (ft)
HA2	**GP**	**4591515.6**	**513884.7**	**2784.07**
	RP	**4591515.6**	**513884.5**	**2785.81**

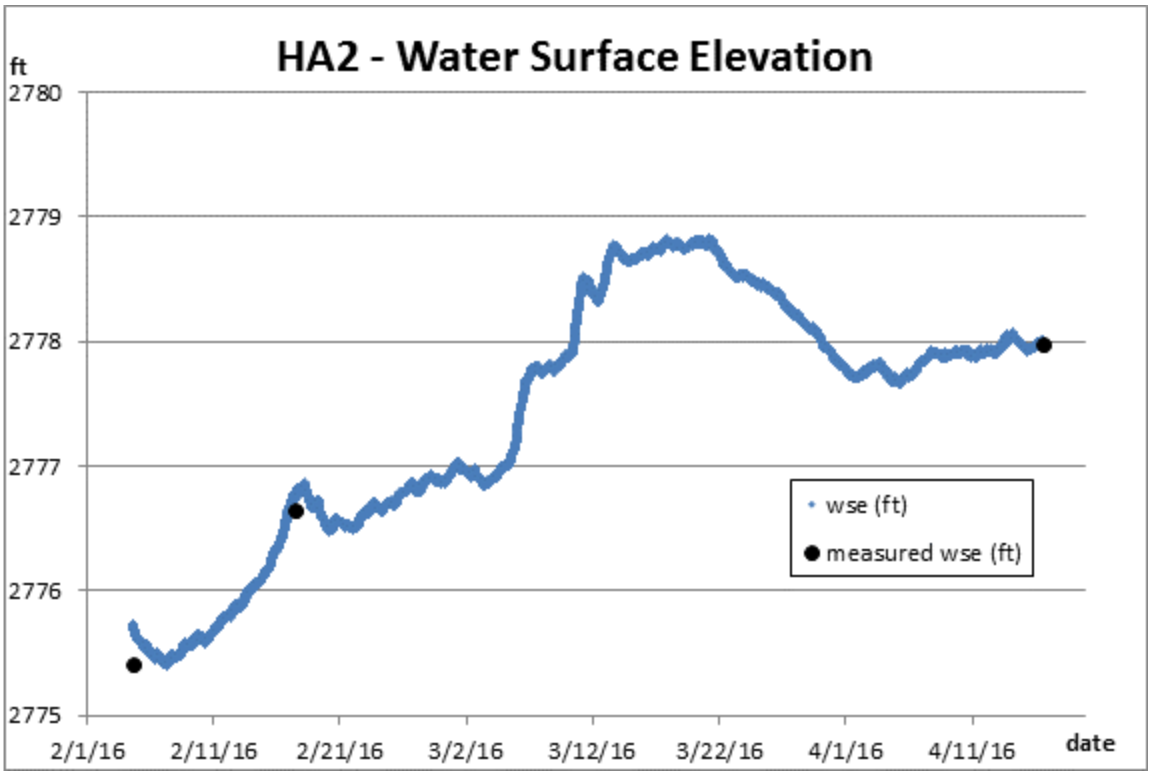

Figure 7: Calculated and measured water surface elevation – HA2.

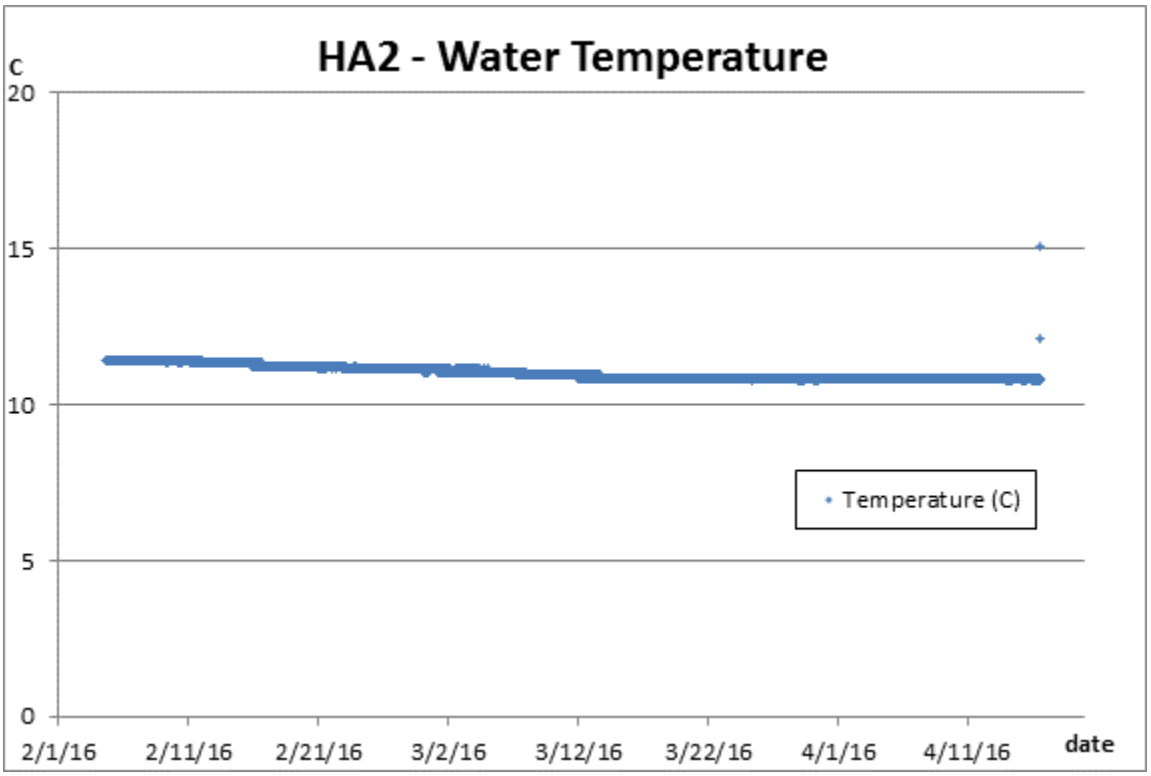

Figure 8: Water temperature – HA2.

Table 5: Coordinates of BL1 – BL5 and SVID Canal & Scott River water surface elevation.

Site	Feature	Northing (m)	Easting (m)	Elevation (ft)
SVID	**WSE**	**4597022.6**	**513282.6**	**2775.70**
Site	Feature	Northing (m)	Easting (m)	Elevation (ft)
BL1	**GP**	**4597012.8**	**513206.0**	**2757.14**
	RP	**4597014.4**	**513206.5**	**2759.72**
Site	Feature	Northing (m)	Easting (m)	Elevation (ft)
BL2	**GP**	**4597008.7**	**513192.8**	**2755.38**
	RP	**4597007.9**	**513192.8**	**2757.13**
Site	Feature	Northing (m)	Easting (m)	Elevation (ft)
BL3	**GP**	**4597002.5**	**513165.5**	**2749.68**
	RP	**4596999.1**	**513163.6**	**2746.23**
Site	Feature	Northing (m)	Easting (m)	Elevation (ft)
BL4	**GP**	**4596843.9**	**512854.6**	**2743.64**
	RP	**4596843.9**	**512854.7**	**2744.12**
Site	Feature	Northing (m)	Easting (m)	Elevation (ft)
BL5	**GP**	**4596841.3**	**512695.5**	**2745.28**
	RP	**4596841.4**	**512695.7**	**2745.59**
Site	Feature	Northing (m)	Easting (m)	Elevation (ft)
Scott R	**WSE**	**4596839.6**	**512475.2**	**2735.28**

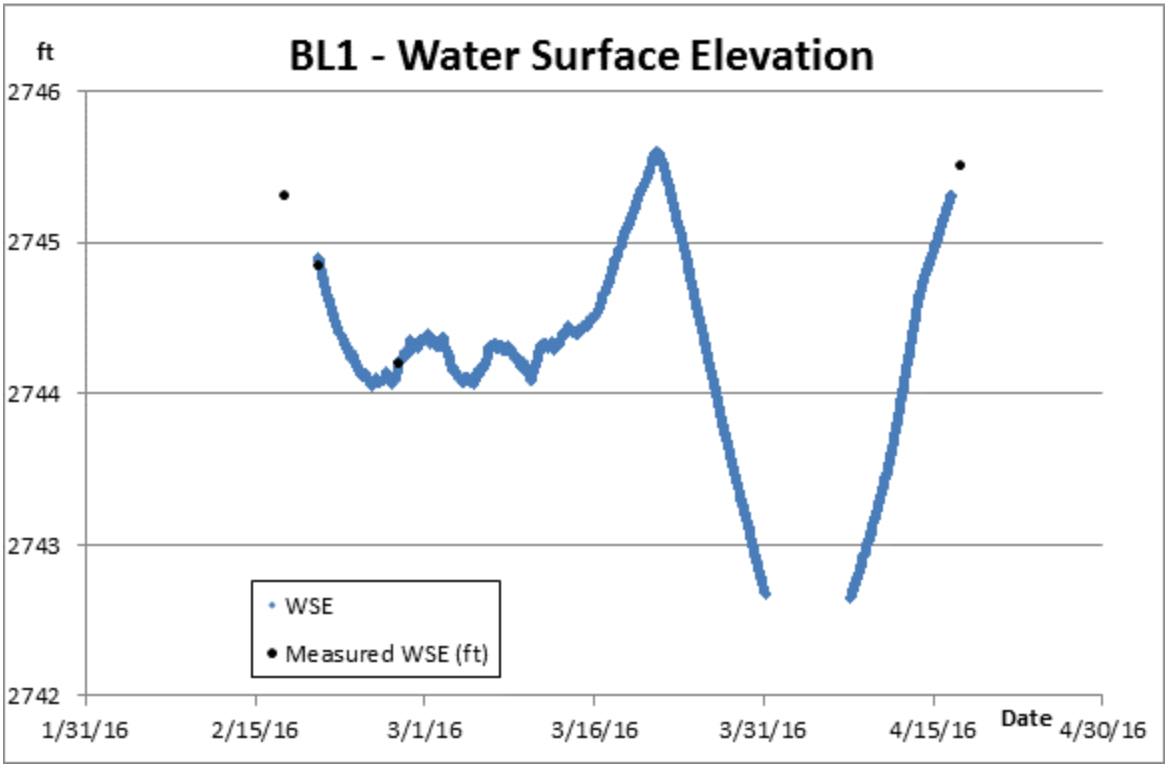

Figure 9: Calculated and measured water surface elevation – BL1.

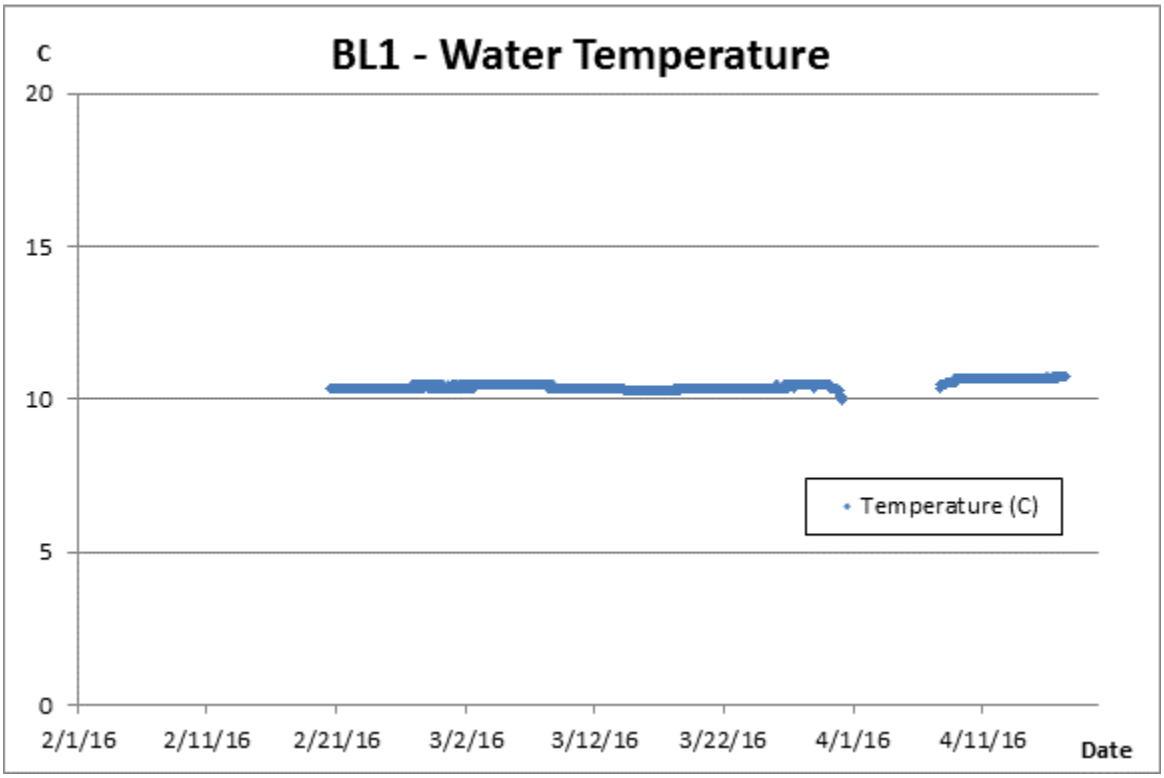

Figure 10: Water temperature – HA2.

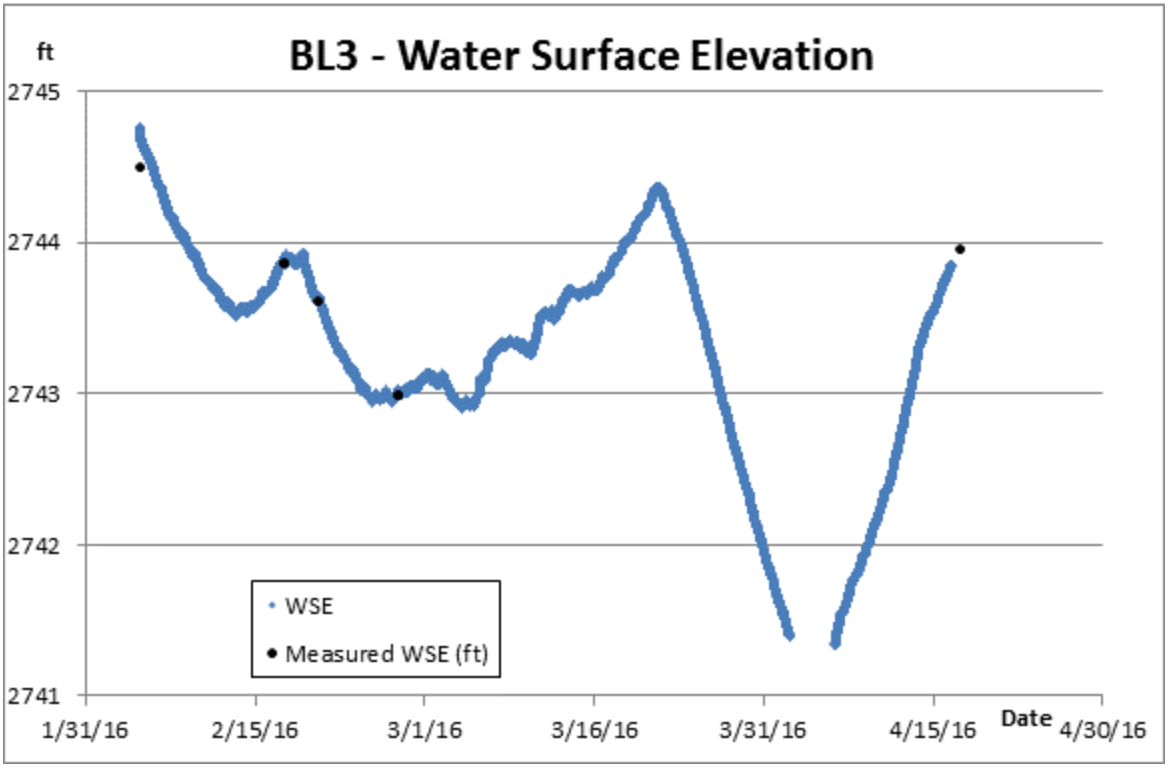

Figure 11: Calculated and measured water surface elevation –BL3.

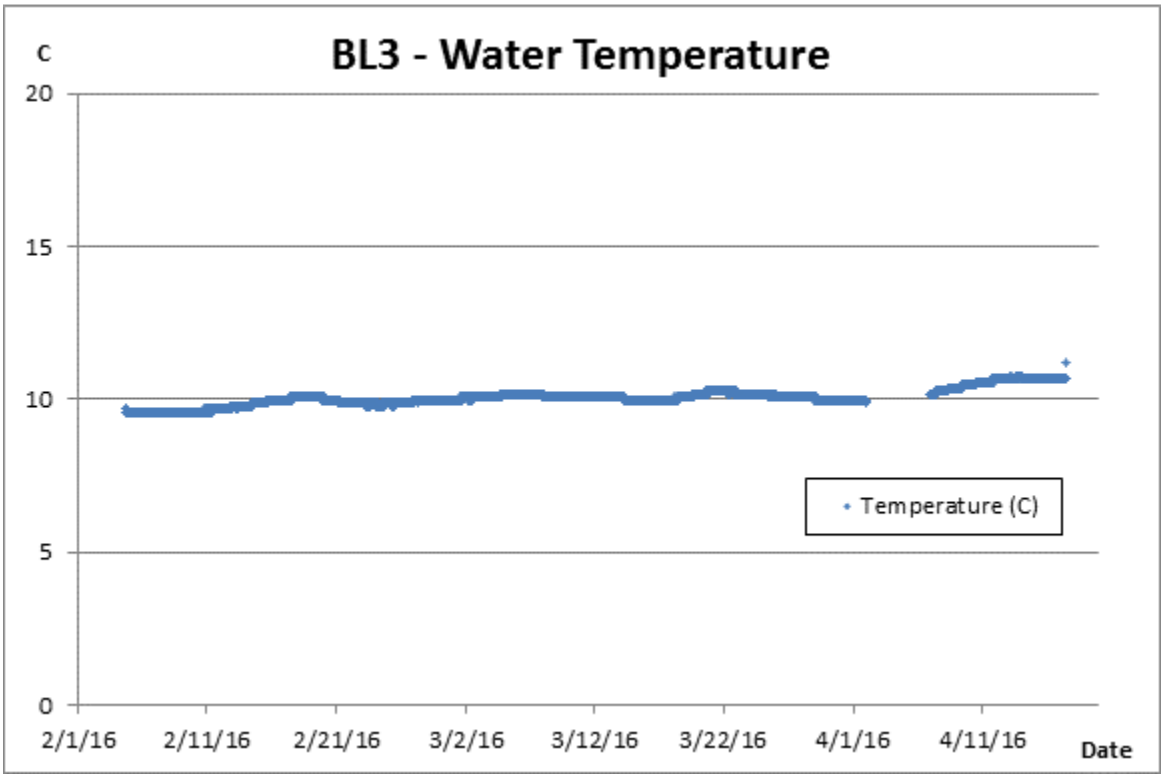

Figure 12: Water temperature – HA2.

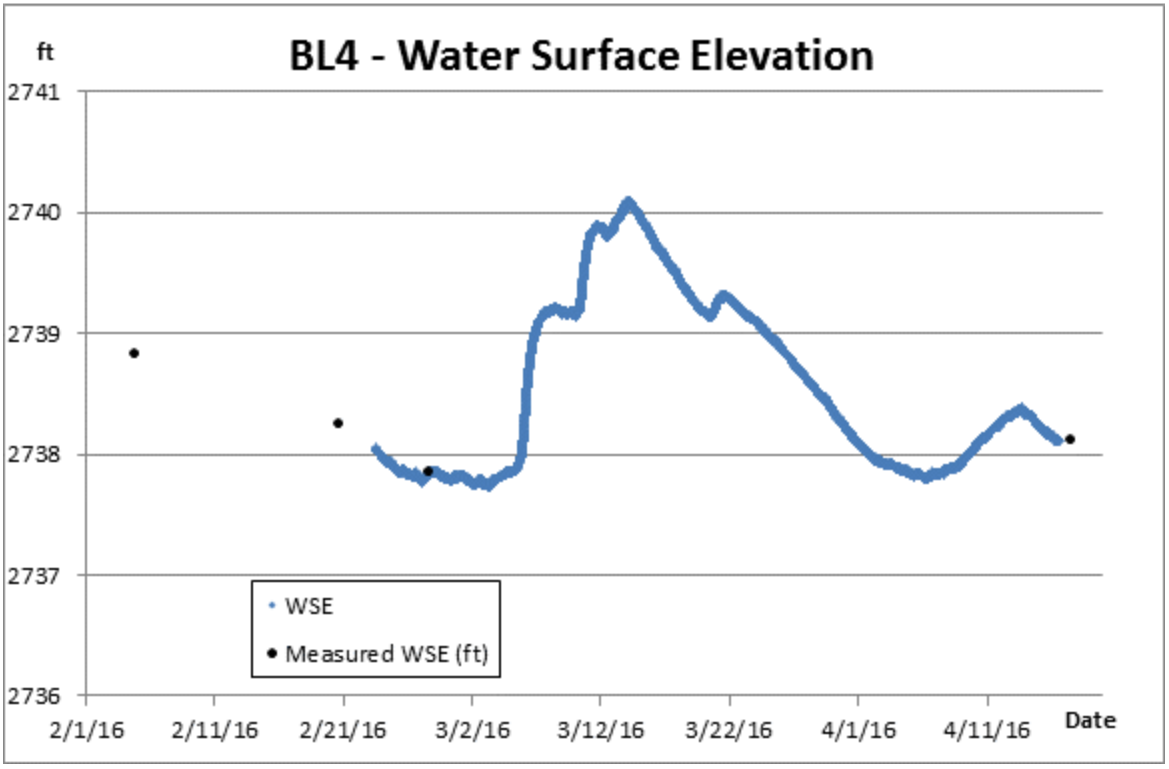

Figure 13: Calculated and measured water surface elevation – BL4.

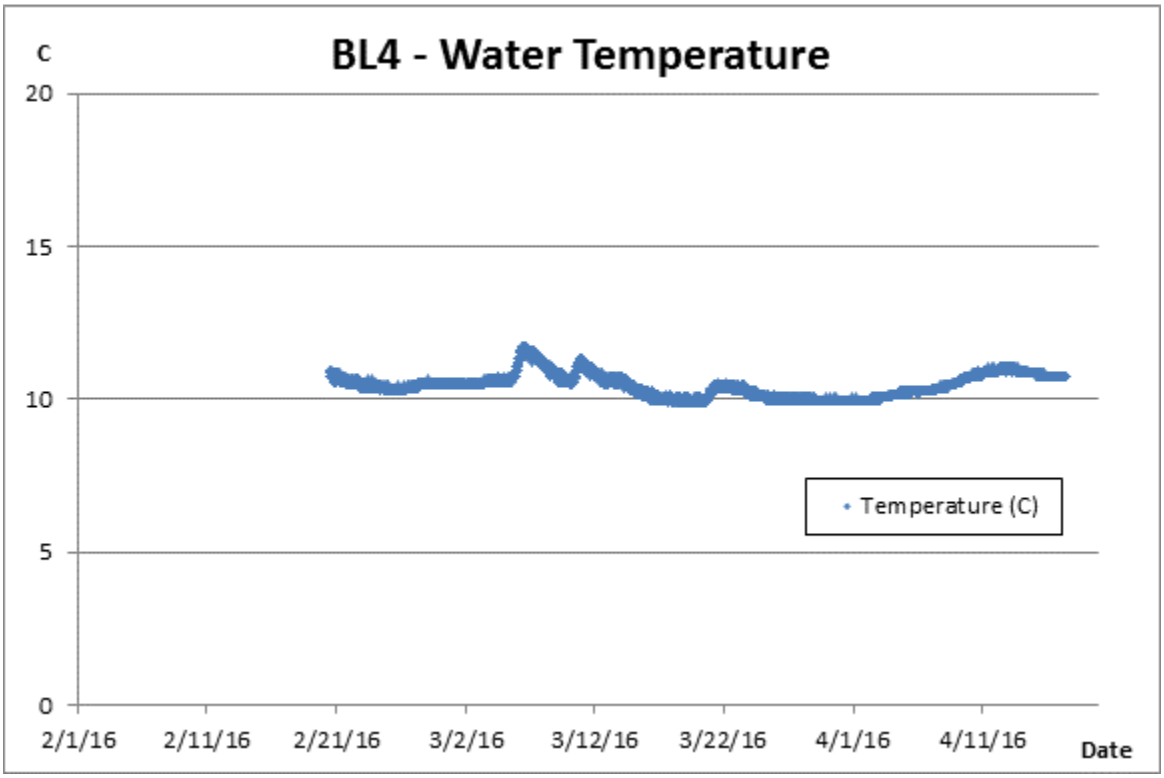

Figure 14: Water temperature – HA2.

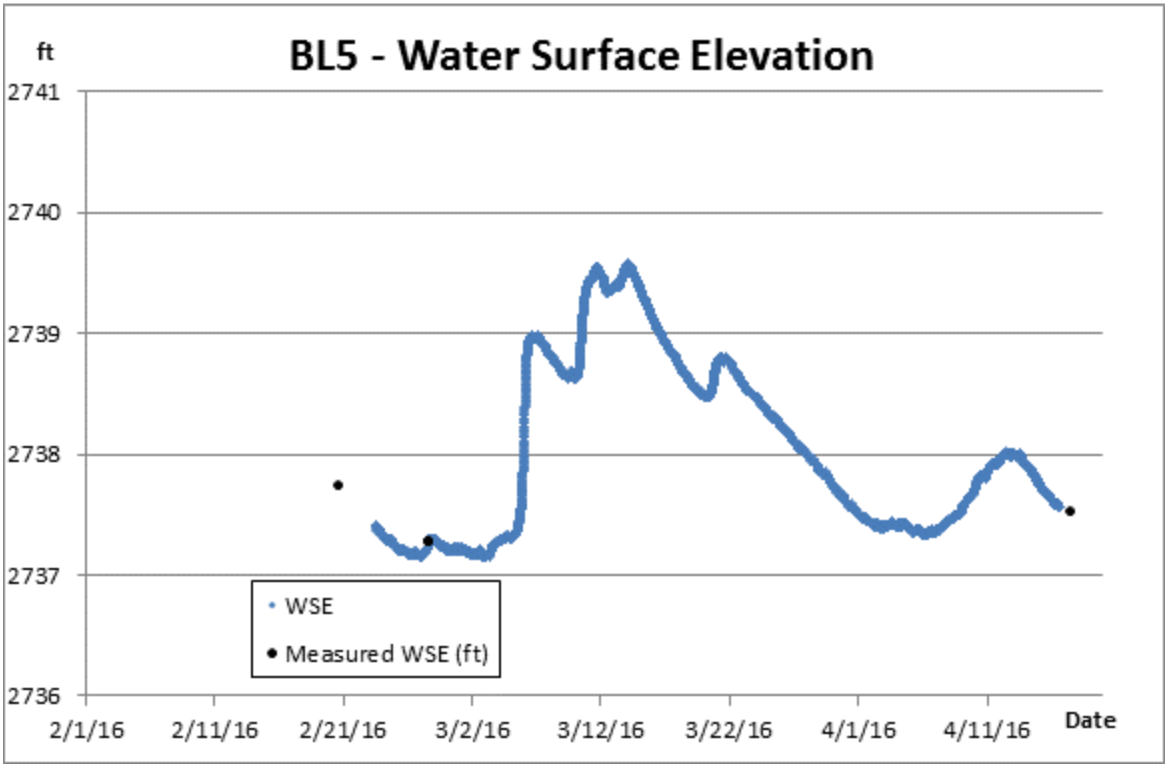

Figure 15: Calculated and measured water surface elevation – BL5.

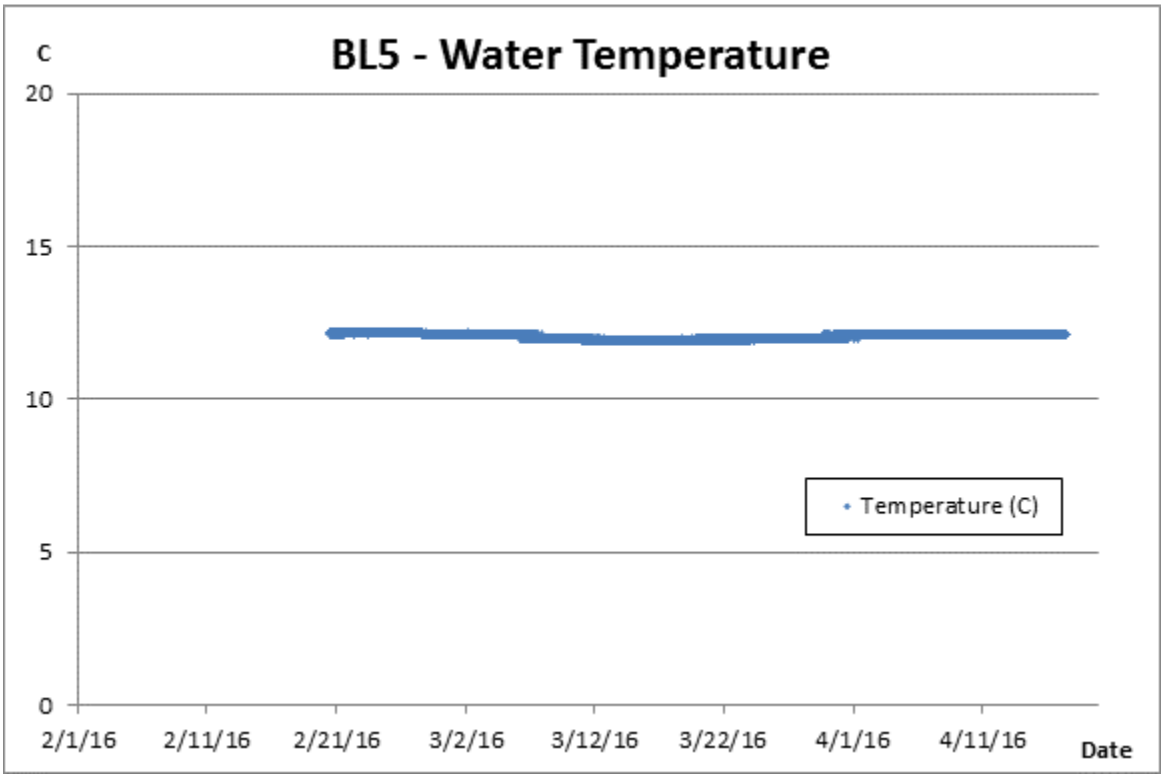

Figure 16: Water temperature – HA2.

Table 6: Coordinates of HA3 and EH Pond.

Site	Feature	Northing (m)	Easting (m)	Elevation (ft)
HA3	GP	4600760.3	513983.4	2732.88
	RP	4600756.0	513983.3	2735.76

Site	Feature	Northing (m)	Easting (m)	Elevation (ft)
EH Pond	GP	4600875.9	514553.4	2746.96
	RP	4600867.1	514555.2	2746.47

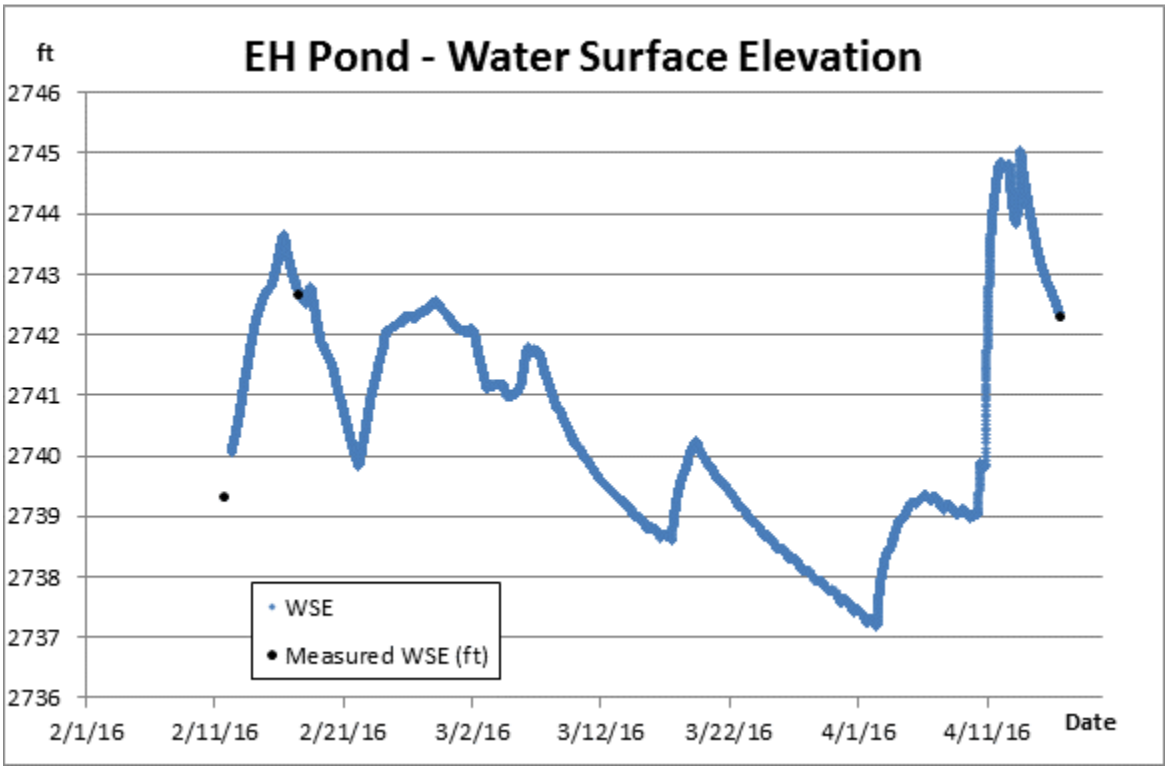

Figure 17: Calculated and measured water surface elevation – EH Pond.

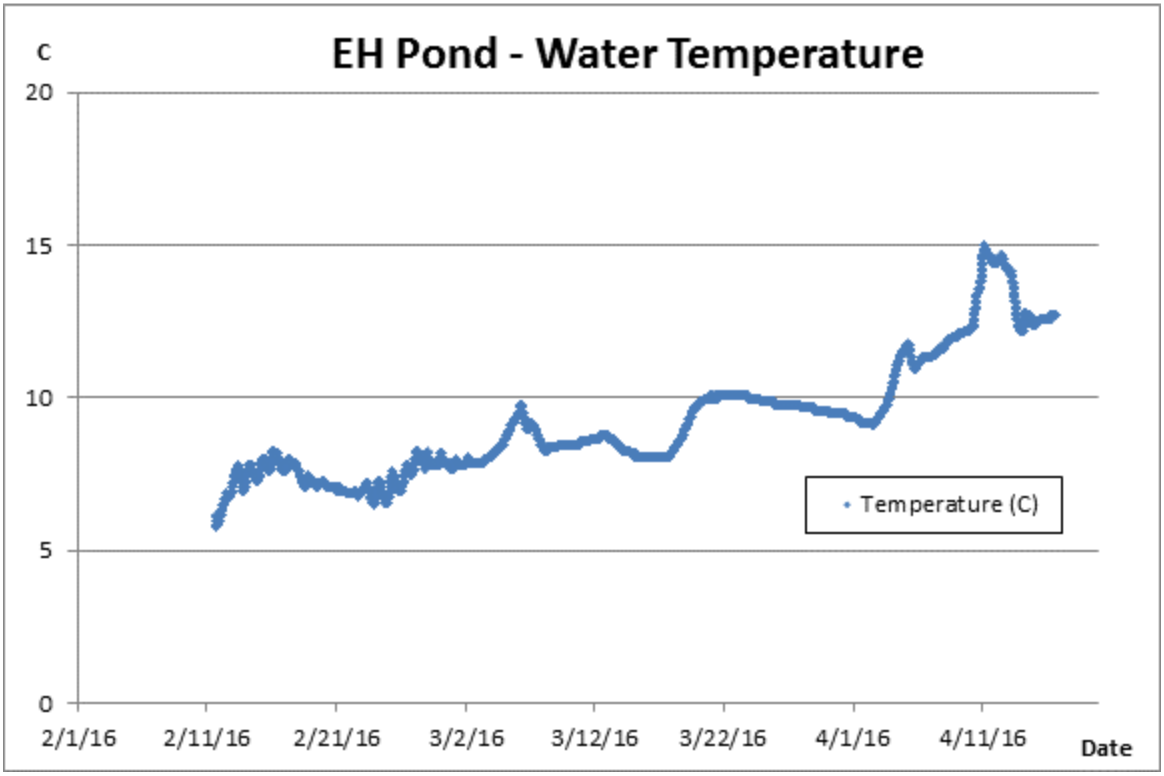

Figure 18: Water temperature – HA2.

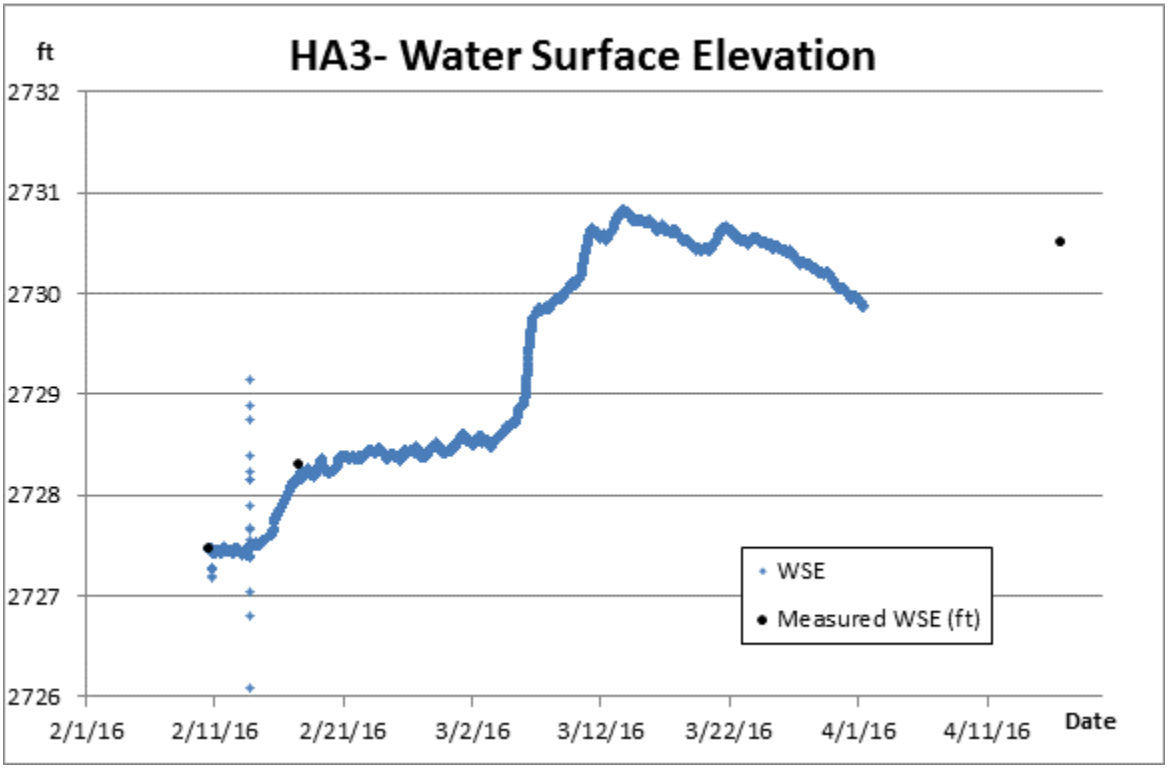

Figure 19: Calculated and measured water surface elevation – HA3.

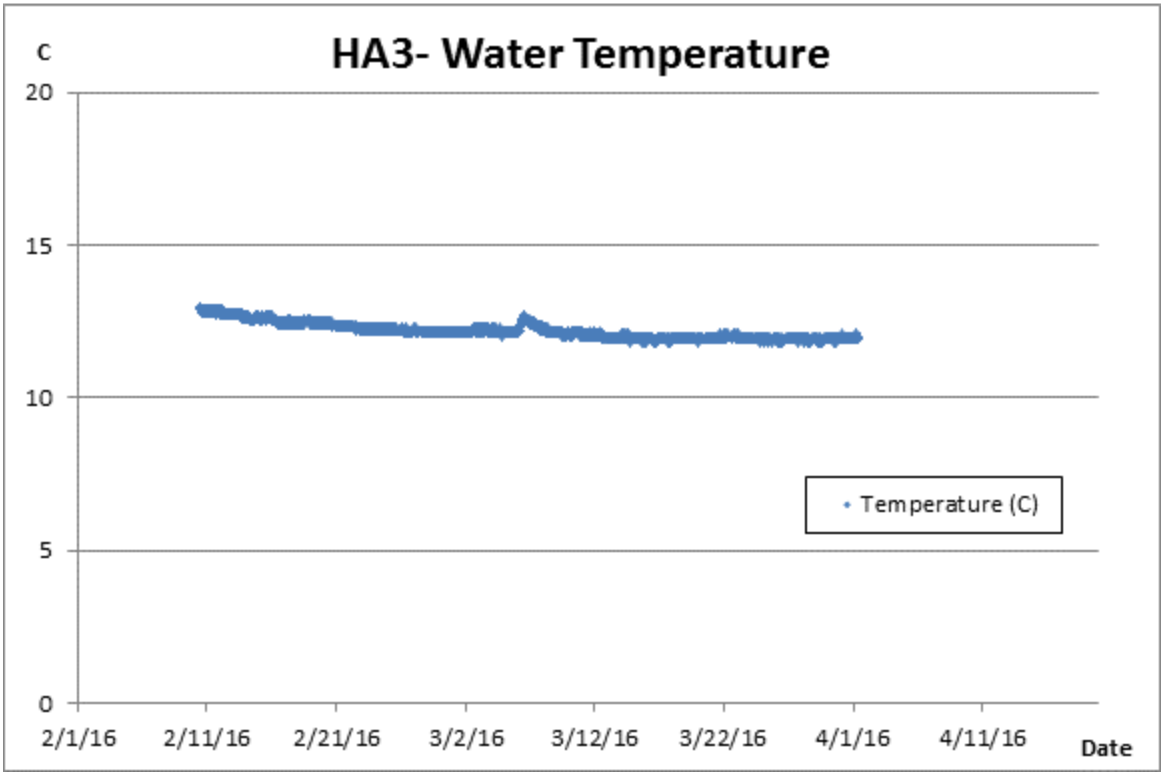

Figure 20: Water temperature – HA2.

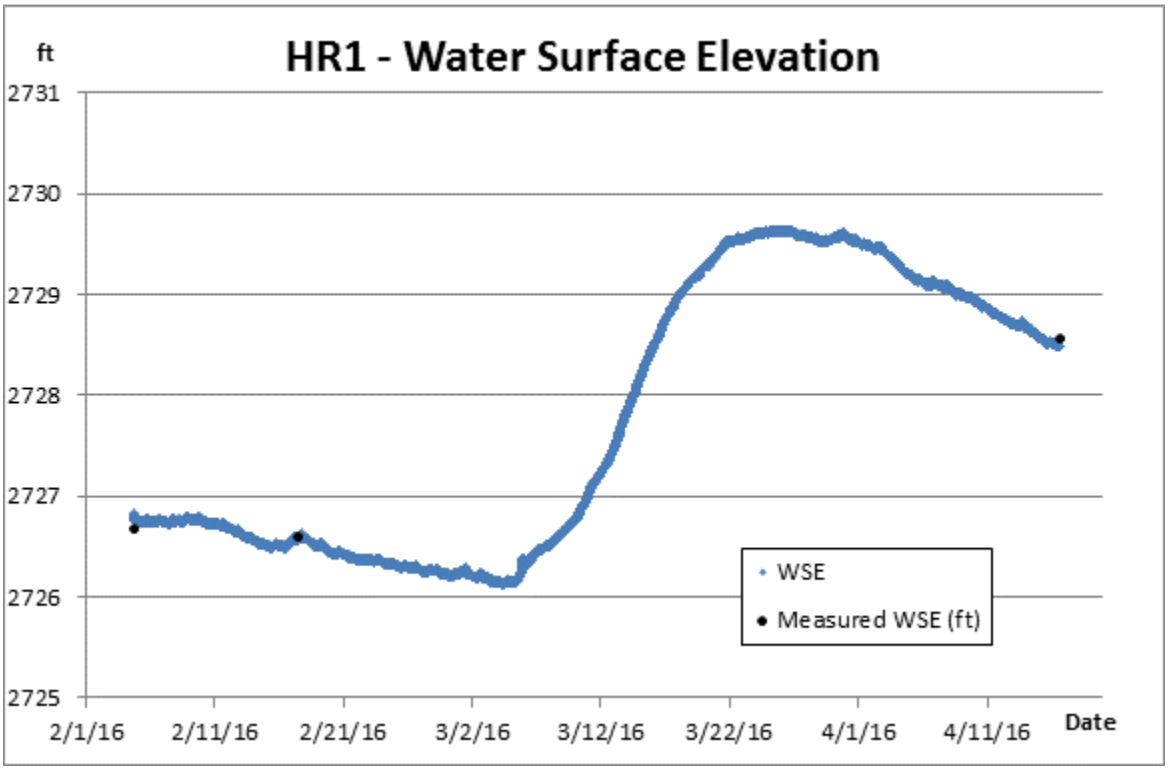

Figure 21: Calculated and measured water surface elevation – HR1.

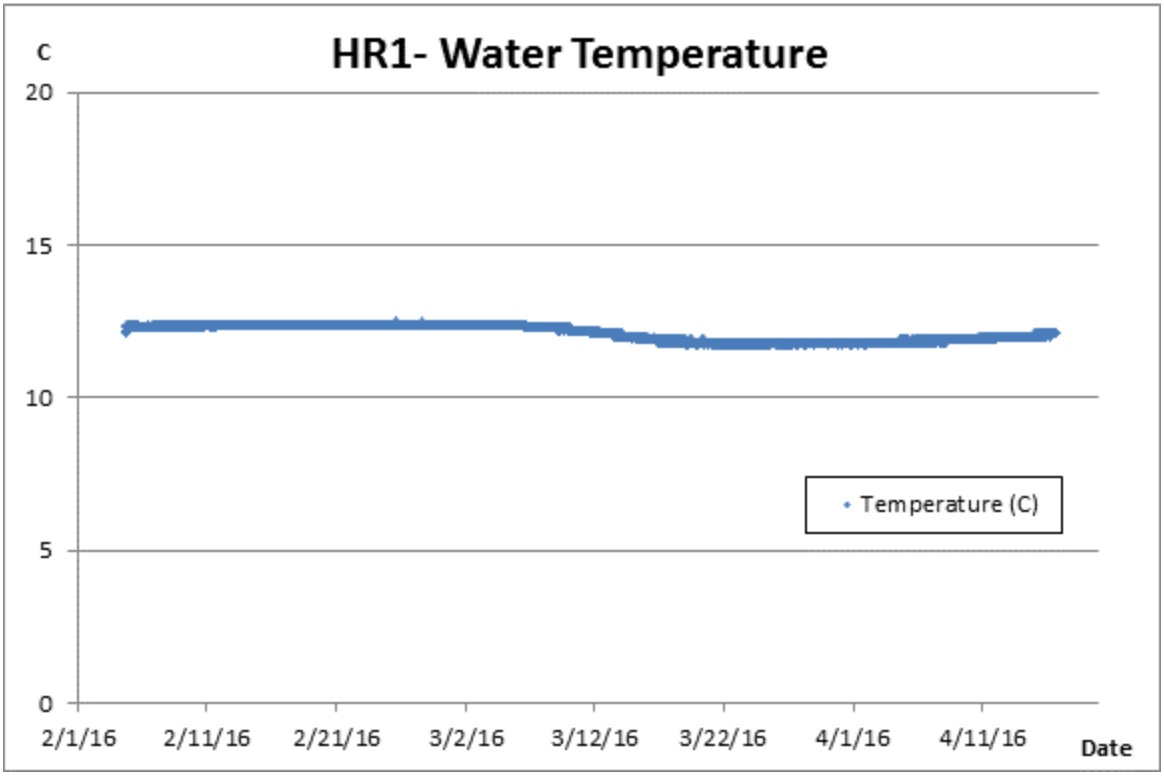

Figure 22: Water temperature – HA2.

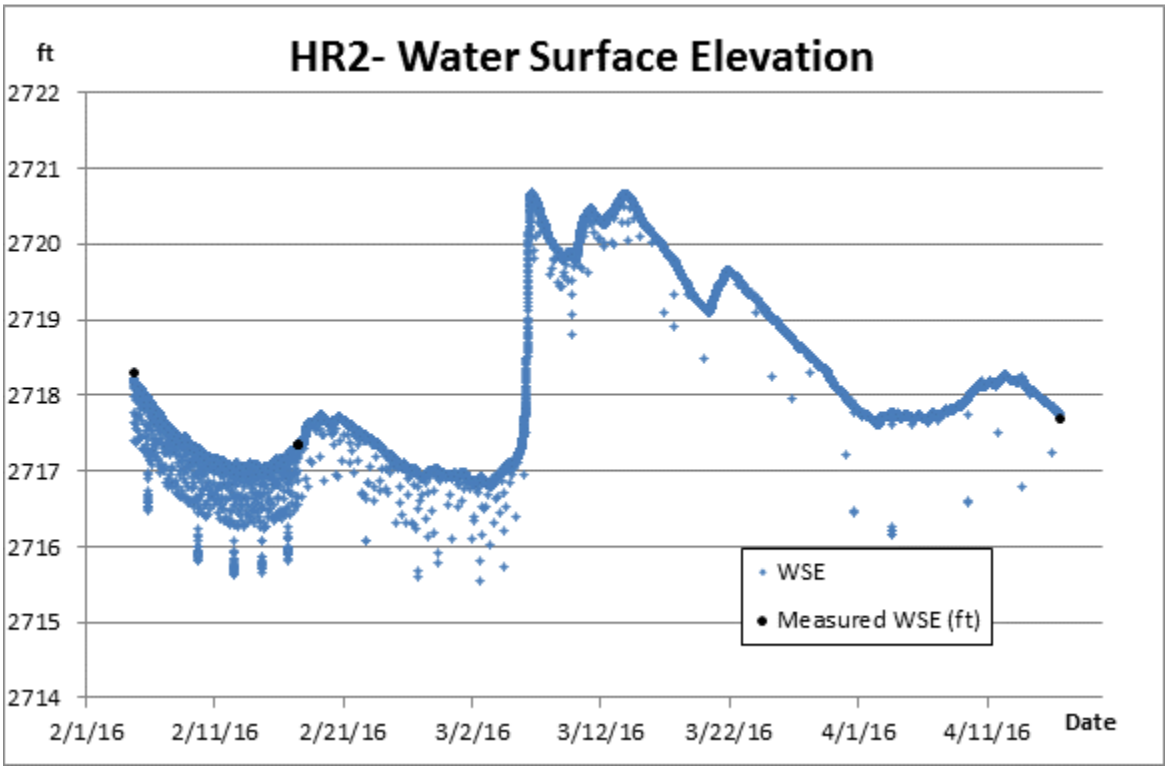

Figure 23: Calculated and measured water surface elevation – HR2.

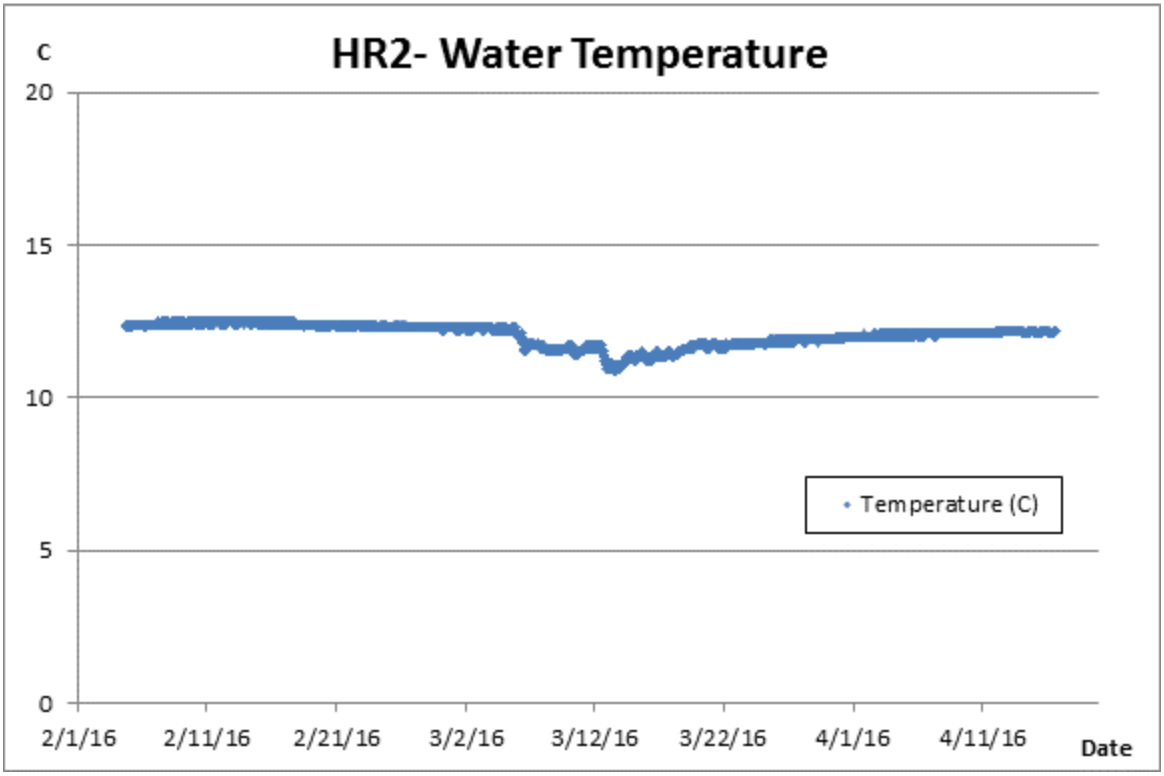

Figure 24: Water temperature – HA2.

3 Streamflow enhancement modeling

The Scott Valley Integrated Hydrologic Model (SVIHM), consisting of a soil-water budget model coupled uni-directionally with a MODFLOW-based groundwater-surface-water model was used to estimate the effect of the on-farm recharge conducted between February and April 2016 on streamflow in the Scott River. For the modeling two different scenarios were compared: 1) recharge scenario in which the total measured amount of surface water (1355 AF) was diverted from the Scott River at the point of diversion and recharged over 55 days, and 2) base scenario in which the model was run without recharge and surface diversions assuming just recharge from precipitation.

The amount of diverted surface water translates to a flow rate of approximately 12 cfs. This amount of water was removed from the Scott River at the SVID POD in the model for the months of February and March. The model year 1998 was used as a proxy for 2016 as the two years had approximately similar streamflow conditions during the early part of the year. Figure 25 is showing the recharge locations and approximate recharge amounts considered in the model. Approximately 70% of the estimated 688 AF of recharge was applied to the green fields and 30% was applied to the pink fields. This corresponded to additional recharge rates of 0.0194 m/day and 0.0098 m/day, respectively, being added to the recharge-from-precipitation rates in the model at these fields. Hydrographs of these locations are shown in figures 26 to 31 show

modeled increases in groundwater levels. Figure 32 shows comparisons of streamflow for the base and recharge scenario.

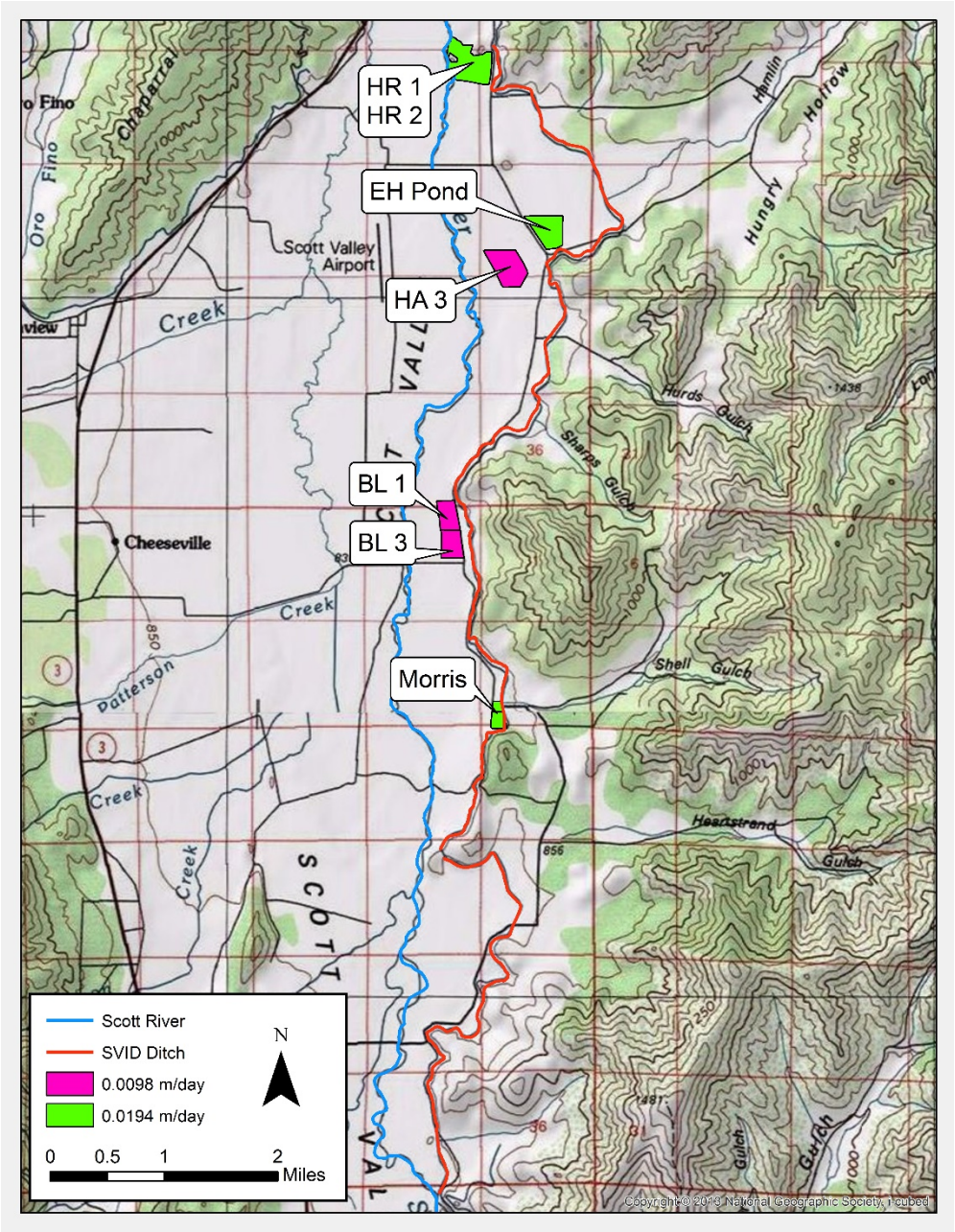

Figure 25: Recharge locations and recharge rates from on-farm flooding assumed in the SVIHM model.

The modeling results indicate that the 688 AF of recharge resulted in a negligible increase in streamflow. There was an approximately 7.5 cfs decrease at the gage during the time of the diversion (February and March), which corresponds to less than 1% of the flow rate observed at the Fort Jones gauge at that time of the year. The results from this simulation agree with previous managed aquifer recharge modeling, which indicated that the greatest streamflow gains are

realized in the months immediately following the recharge (e.g. April, May, June). Howeever, there is very little difference in the simulated streamflow for both scenarios after July. The increase in simulated streamflow shown in December may be due to groundwater levels being slightly higher with the artificial recharge scenario, resulting in greater gradients to the stream when winter storms arrive.

Previously modeled managed aquifer recharge scenarios assuming a diversion of 42 cfs for three months (total of ~7500 acre-ft) showed streamflow gains on the order of about 2.5 cfs in the late summer season. This would correspond to approximately 8-25% increase in late-summer streamflow depending on the year. However, these simulations assumed that all diverted water was recharged to the aquifer. In contrast for the modeling of this years' groundwater recharge activities only about 50% recharge efficiency was assumed for this simulation. The results suggest an order of magnitude increase in recharge would be necessary to impact late-summer streamflow. The previous managed aquifer recharge simulations also indicated that maximum gains in streamflow were not recognized until after several consecutive years of treatment.

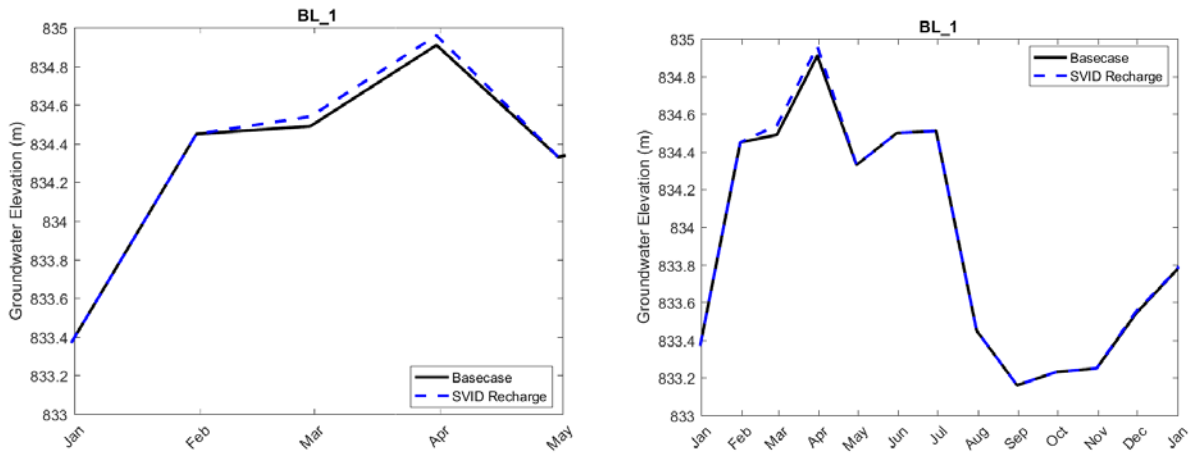

Figure 26: Groundwater elevation at location BL1 for Jan. 1 – May 1, 2016 (left) and the 2016 calendar year for the modelled baseline (black line) vs. recharge scenario (dashed line).

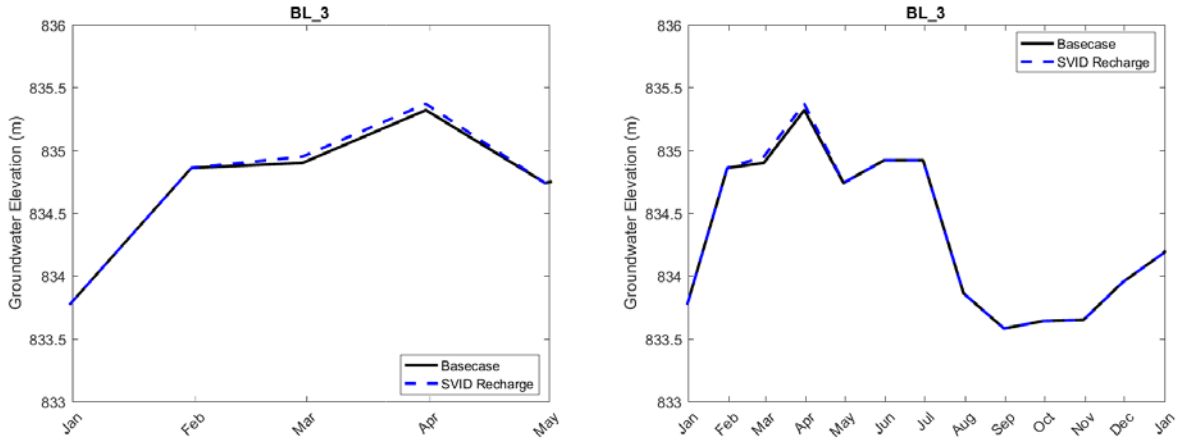

Figure 27: Groundwater elevation at location BL3 for Jan. 1 – May 1, 2016 (left) and the 2016 calendar year for the modelled baseline (black line) vs. recharge scenario (dashed line).

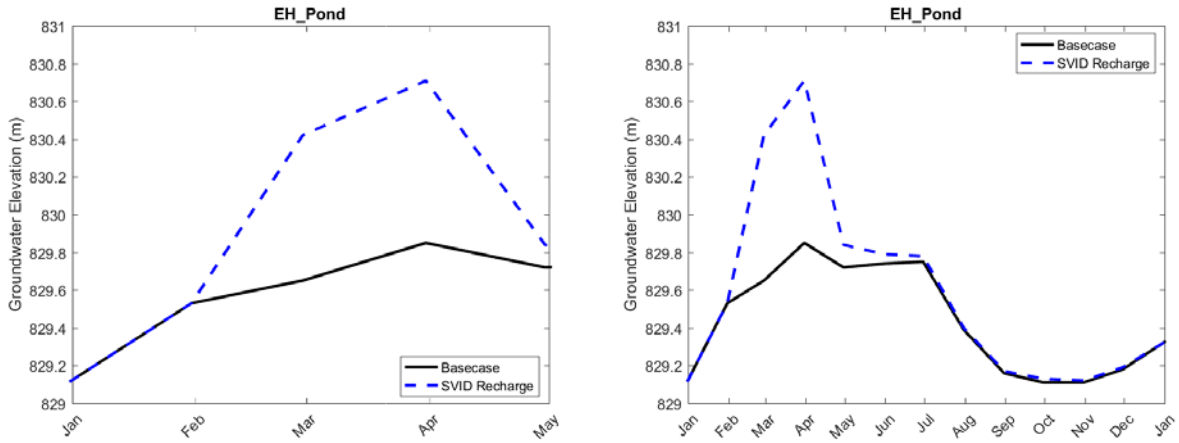

Figure 28: Groundwater elevation at location EH_pond for Jan. 1 – May 1, 2016 (left) and the 2016 calendar year for the modelled baseline (black line) vs. recharge scenario (dashed line).

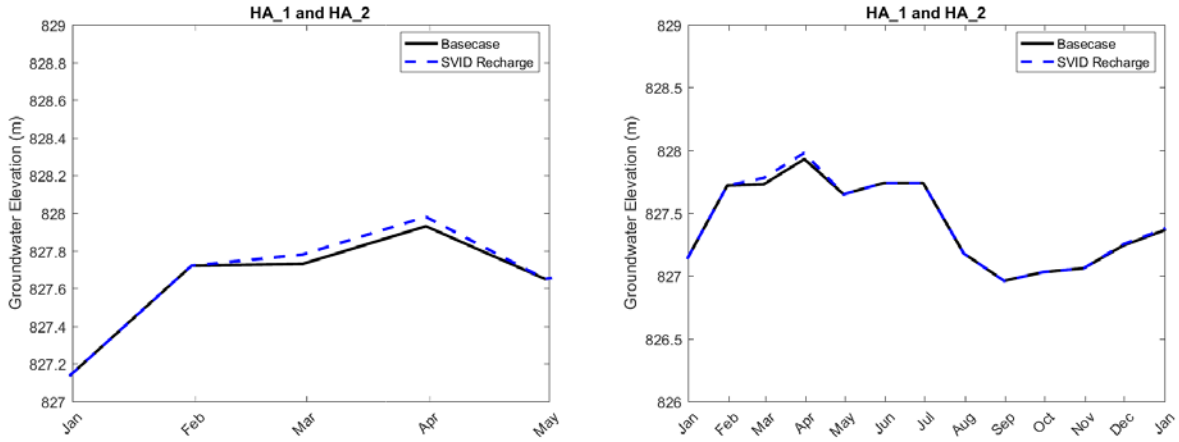

Figure 29: Groundwater elevation at location HA1 and HA2 for Jan. 1 – May 1, 2016 (left) and the 2016 calendar year for the modelled baseline (black line) vs. recharge scenario (dashed line).

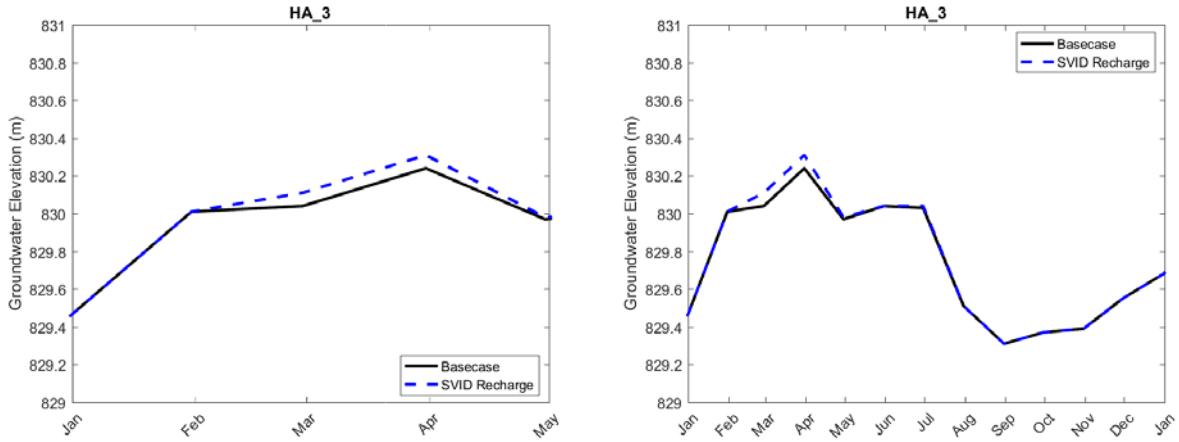

Figure 30: Groundwater elevation at location HA3 for Jan. 1 – May 1, 2016 (left) and the 2016 calendar year for the modelled baseline (black line) vs. recharge scenario (dashed line).

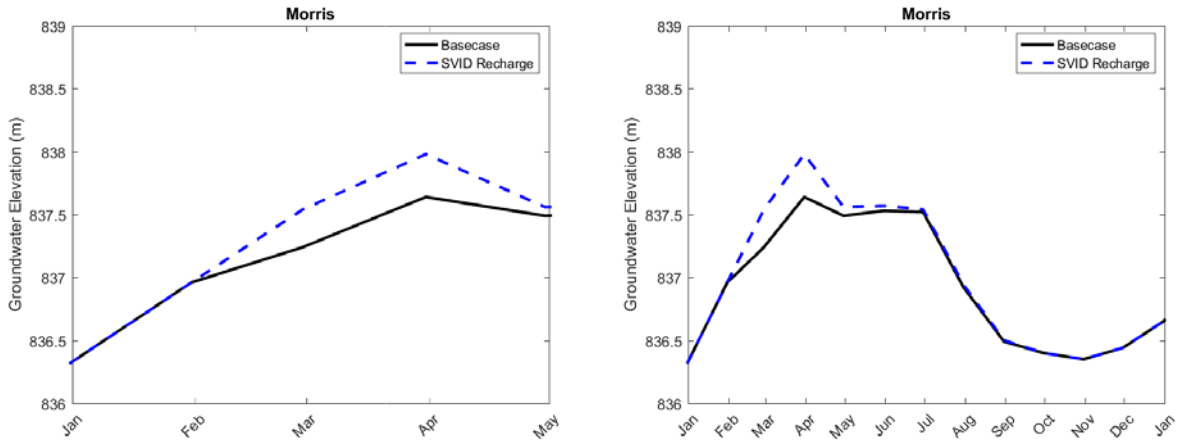

Figure 31: Groundwater elevation at location JM1 for Jan. 1 – May 1, 2016 (left) and the 2016 calendar year for the modelled baseline (black line) vs. recharge scenario (dashed line).

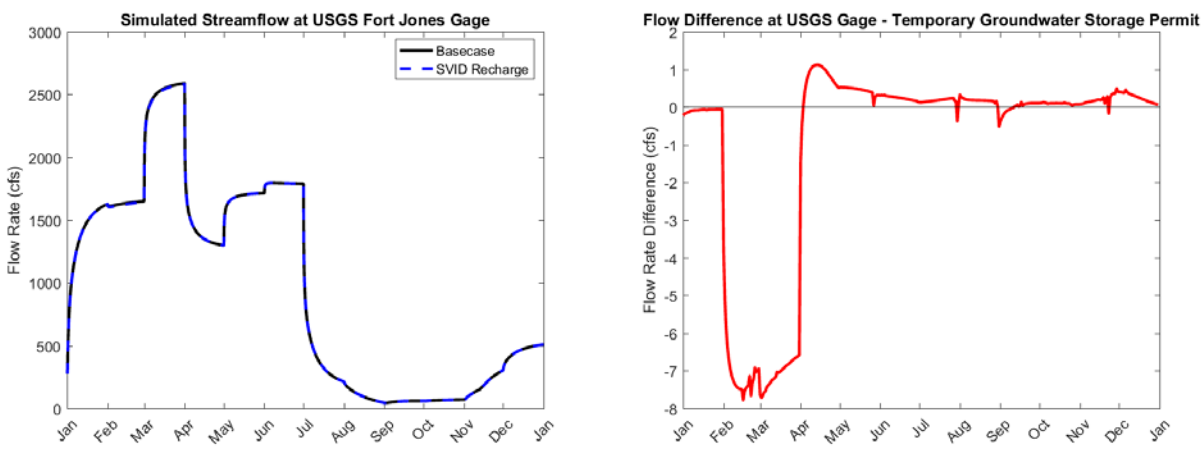

Figure 32: Comparison of simulated streamflow at USGS Fort Jones stream gauge between the base scenario (black line) and the recharge scenario (blue line) (left) and flow difference for the 2016 calendar year (right).

4 Flooding tolerance of alfalfa

4.1 Experimental Setup

To assess the tolerance of alfalfa to winter irrigation and to determine how much water can be recharged on a field planted with alfalfa, an on-farm experiment was conducted on a 15-acre alfalfa field in the Scott Valley (10-year stand in 2016) in the winters of 2014/15 and 2015/16. The field is divided into 11 checks, which were grouped into contiguous areas to test the following four water application rates (see Fig. 33):

(1) ***continuous*** application: every-day application of water except when water was being applied to other treatments (3.13 acres total area, checks 1-3),
(2) ***high*** water application: 3-5 water applications per week (3.97 acres, checks 4-6),
(3) ***low*** water application: 1-3 water applications per week (4.46 acres, checks 7-9),
(4) ***control:*** no winter water application (3.3 acres, checks 10 and 11, received precipitation only).

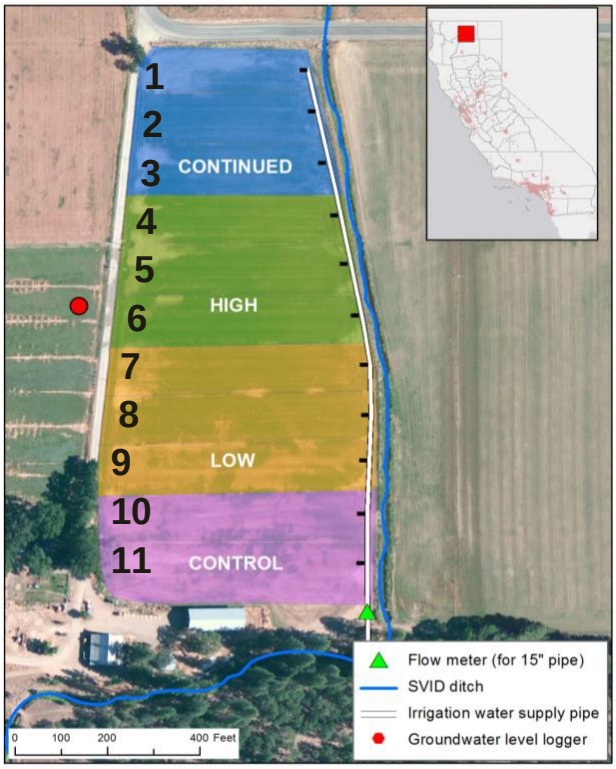

Figure 33: 15-acre field with 10-year alfalfa stand. Three different water application rates were tested: continued, high, low and no water (control) application. Numbers indicate individual checks.

The total amount of applied winter water was measured with a doppler flow meter (Greyline Instruments Inc., green triangle, Fig. 33) and changes in groundwater level was recorded with a pressure transducer deployed in a nearby groundwater well (red dot, Fig. 33). Plant physiological parameters (e.g. total biomass, stem and plant count) were determined in each treatment area before and after the recharge events. In 2015 yield was measured during the first and second cutting on May 27, 2015 and July 15, 2015, respectively. In fall of 2015, the alfalfa field was overseeded with orchardgrass. Plant biomass was harvested on May 24, 2016 (1st cutting) and July 20, 2016 (2nd cutting). In 2015 biomass was collected by hand in several randomly chosen quadrats of 5.5 sq. ft. (0.5 m^2) in size. The cut biomass was dried at 140°F (60°C) and yield (tons/acre) was reported on a dry matter basis. In 2016 yield was estimated based on the total wet biomass harvested using a flail-type forage harvester from an approximately 25 x 3 sq. ft. section from each of the 11 checks. A small subsample was taken from the cut biomass and dried at 50 degrees C for at least 48 hours to determine the dry matter of the forage. Subsamples were also collected by hand clipping areas adjacent to the mowed area to determine the relative proportion of alfalfa, orchardgrass and weed biomass present.

4.2 Results

On the 15-acre field 135 AF and 107 AF of water were applied during the winter/spring season of 2015 and 2016, respectively. Table 7 summarizes the amounts of applied winter water for each check and treatment for both years. The recharged surface water in conjunction with natural

precipitation falling caused a rise in the groundwater table in a nearby well (red marker, Fig. 33) of approximately 6 feet in 2015 and 4.5 ft in 2016 (Fig. 34). The continuous treatment plot received winter water for 31 and 46 days in 2015 and 2016, respectively. Estimated infiltration rates averaged 0.9 ft of water per day.

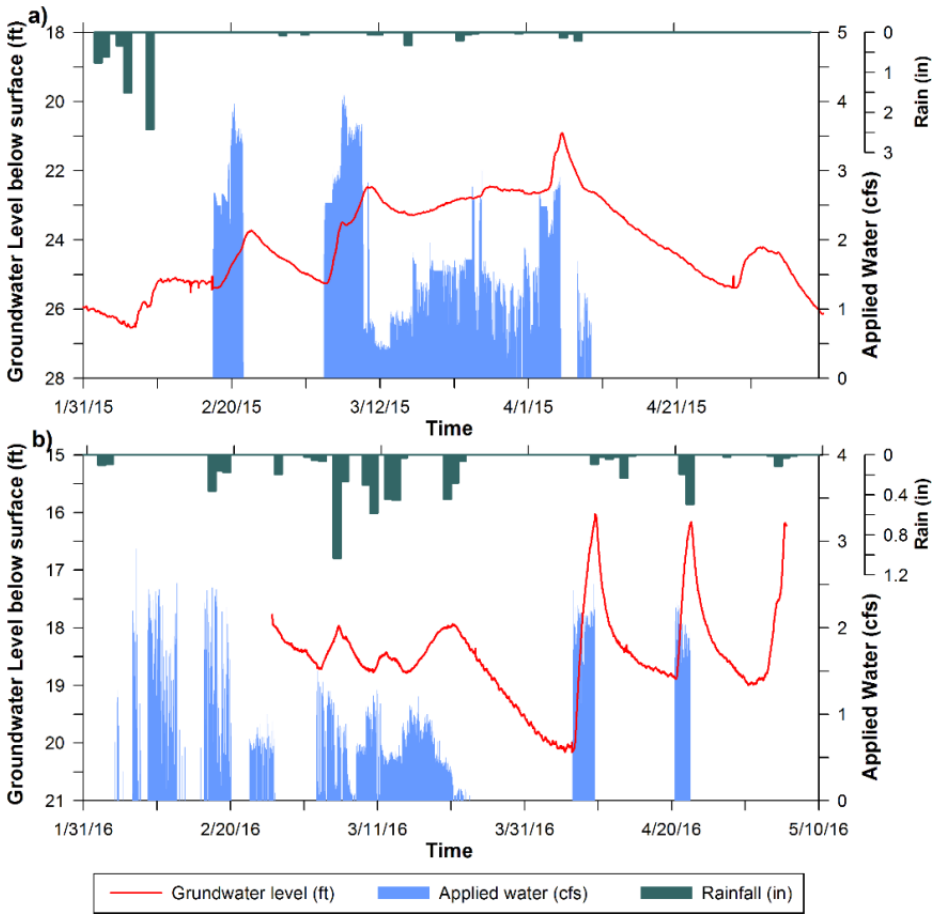

Figure 34: Amount of water diverted for winter recharge (cfs), change in groundwater level below surface (ft) and rainfall (in) measured in winter 2014/15 and 2015/16.

Table 7: Total applied winter water (ft) for groundwater recharge for winters of 2014/15 and 2015/16.

			2014-2015 (02/17-04/09/2015)					**2015-2016** (02/04-03/21/2016)				
				Applied winter water (ft) for recharge					**Applied winter water (ft) for recharge**			
Treat-ment	Check	Check size (acres)	Irrigation Days	Total	February	March	April	Irrigation Days	Total	February	March	April
Contin.	1	0.84	31	32.66	2.72	24.03	5.90	46	13.52	7.09	6.86	0.09
	2	1.1	32	26.49	4.00	17.97	4.51	46	10.32	5.43	5.32	0.09
	3	1.19	32	24.87	4.22	16.48	4.17	46	9.54	5.03	4.94	0.09
High	4	1.18	6	7.20	2.67	3.70	0.83	20	4.45	2.93	1.95	0.09
	5	1.35	6	6.65	2.50	3.48	0.68	20	3.89	2.57	1.75	0.09
	6	1.44	7	8.16	3.27	4.06	0.82	21	3.86	2.64	1.66	0.09
Low	7*	1.41	3	5.20	1.05	1.94	2.21	18	12.96	1.16	1.02	11.31
	8	1.51	3	4.18	0.90	2.56	0.72	11	1.63	1.09	0.97	0.09
	9	1.54	2	3.35	0.89	1.70	0.76	11	1.60	1.07	0.96	0.09
Con trol	10	1.46	0	0.00	0.00	0.00	0.00	0	0.53	0.10	0.34	0.09
	11	1.86	0	0.00	0.00	0.00	0.00	0	0.53	0.10	0.34	0.09

* This check received an additional 11.3 ft of water in two irrigation events in April 2016.

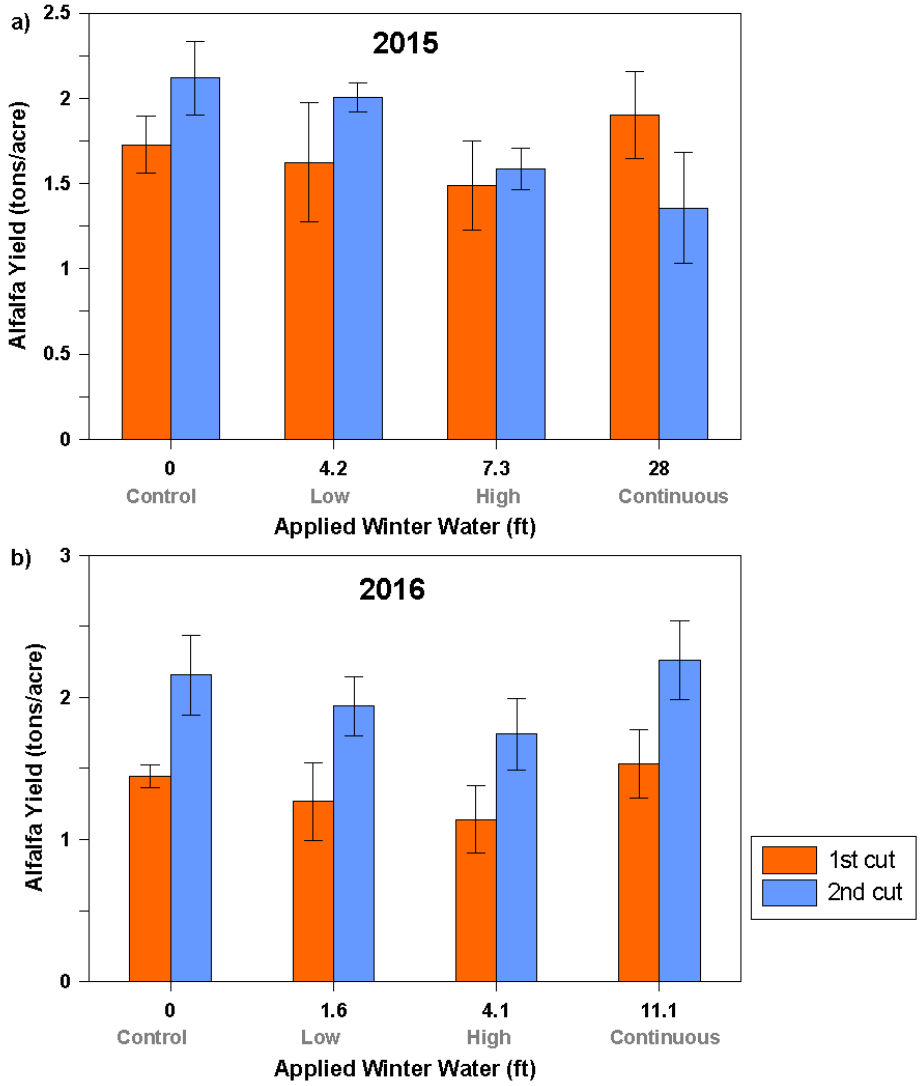

Figure 35: Alfalfa yield for 1st (orange, end of May), 2nd cutting (blue, mid-July), and 3rd cutting (green, end of August) vs. average applied winter water (ft) for 2015 and 2016.

The winter water application of up to 32 ft of water per treatment showed no discernible effect on alfalfa yield except for the 2nd cutting in 2015, which showed a significant decline in alfalfa yield with increasing amount of applied winter water (Fig. 35a). However, despite the significant decline, the yield in the continuous treatment plot was only 0.5 tons/acre lower than the control, indicating that the economic loss for high water application amounts is modest.

In 2016 checks receiving the largest amount of winter water showed a higher yield than the control plots during the 1st and 2nd cutting indicating that winter recharge might lead to increased crop water availability in the deep soil profile offsetting potential irrigation deficits during the growing season.

Part of a second field was flooded on the Bryan-Morris ranch with SVID water between February 4 and March 31, 2016. To estimate the effect of the applied water onto alfalfa yield, biomass was harvested with flail-type forage harvester (see method described in section 4.1). Alfalfa yield data summarized in Table 8 shows the yield data for two areas of the field, one that received additional water during the winter (flooded), the other just rainfall (untreated). In agreement with the experimental plot, there was no discernible difference in the yield between the winter irrigated and non-irrigated areas.

Table 8: Harvest data for second alfalfa field on Bryan-Morris ranch. Forage was harvested on June 1, 2016.

Treated (Flooded)		**Harvest wt (lbs)**	**Plot length (ft)**	**Wet weight (g)**	**Dry weight (g)**	**Dry Matter**	**Yield (tons/acre)**
	1	18.0	21.1	504.7	137.1	0.27	1.7
	2	21.8	22.3	505.1	136.3	0.27	1.9
	3	18.2	19.3	449.5	114.2	0.25	1.7
	4	18.4	19.1	480.0	126.7	0.26	1.8
Average		**19.1**		**484.8**	**128.6**	**0.26**	**1.8**

Untreated		**Harvest wt (lbs)**	**Plot length (ft)**	**Wet wt (g)**	**Dry wt (g)**	**Dry Matter**	**Yield (tons/acre)**
	1	19.5	20.7	435.4	125.1	0.29	2.0
	2	20.8	21.6	402.7	120.0	0.30	2.1
	3	20.9	28.4	438.1	126.4	0.29	1.5
	4	17.7	22.5	484.1	142.7	0.29	1.7
Average		**19.7**		**440.1**	**128.6**	**0.29**	**1.8**

Figure 36: Winter flood irrigation on the second field on Bryan-Morris ranch. Flow from the valve was estimated at 0.3 cfs.

4.3 Major findings – Crop study

- Alfalfa is a promising crop for ag-recharge if grown on suitable, well-draining soils
- Application of 4-28 ft of water in February/March showed no discernible effect on alfalfa yield
- Winter water application for groundwater recharge might increase soil water availability for alfalfa and offset irrigation deficits during the growing season
- In CA about 300,000 acres of alfalfa are grown on soils suitable for recharge – applying 6 ft of water would result in 1.6 MAF of recharge (if 90% passed root zone)

5 References

Foglia, L., Mcnally, A., Hall, C., Ledesma, L., Hines, R., and Harter, T., 2013, Scott Valley Integrated Hydrologic Model : Data Collection, Analysis, and Water Budget. Final Report North Coast Regional Water Board, SWRCB Contract 09-084-110 and 11-189-110, 101 pp.