WATER RESOURCE CLIMATE ADAPTATION PLAN ON ADOBE CREEK FOR THE RECOVERY OF HITCH *LAVINIA EXILICAUDA CHI* IN CLEAR LAKE, LAKE COUNTY, CALIFORNIA

PREPARED FOR: Big Valley Band of Pomo Indians

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DATE: **12/29/2020**

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Introduction and Context

Clear Lake hitch Lavinia exilicauda chi (hitch) are a large minnow endemic to Clear Lake and its tributaries. The hitch, or *chi* as named by the Xa-Ben-Na-Po Band of Pomo people, are a culturally and biologically important species to the indigenous people of Clear Lake. Pomo people have inhabited the Clear Lake area for over 11,800 years (Big Valley Tribe of Pomo Indians, 2020). The hitch migrate each spring from the lake into the tributaries to spawn. European-American immigration in the 19^{th} century and subsequent urban, mining, and agricultural developments in the Clear Lake watershed have degraded water quality, fish passage, and reduced aquatic habitat throughout the lake and tributaries. Clear Lake hitch were designated as threatened species under the California Endangered Species Act in 2014. A status assessment for California native fish ranked the Clear Lake hitch on a scale of "0" (Extinct) to "5" (Low Concern) as a "1.7," with the status value representing:

> *High risk of extinction in the wild; range seriously reduced or greatly restricted in California; population abundance critically low or declining; threats projected to reduce remaining California habitat and populations in the short-term (<10 generations)* (Moyle et al., 2015).

Adobe Creek is a tributary to Clear Lake and provides spawning habitat for the Clear Lake hitch. Clear Lake is the largest natural freshwater lake within California and is located in the Northern California Coast Ranges about 80 miles north of San Francisco (County of Lake, 2010). Adobe Creek flows from upstream in the Coastal Range, just under seven miles to the southwestern boundary of Clear Lake, and provides recharge to the aquifers within the Big Valley subbasin (see Figure 1). In the early 1960s, the Adobe Creek Dam was built on Adobe Creek and the Highland Springs Dam was built on Highland Creek, approximately 0.6 miles upstream of the confluence with Adobe Creek. Sections of Adobe Creek downstream of the Highland Springs Dam were also channelized for flood control purposes. Channelization and gravel mining led to downcutting of the creek bed, lowering the creek elevation by as much as six feet in some areas (County of Lake, 2010). Flood control measures, transportation infrastructure, mining, and agricultural use of Adobe Creek have led to passage barriers and consistently reduced instream flow, which is critical for hitch survival. Climate change impacts including increased drought, higher temperatures, and more variability in precipitation patterns threaten further reduction in instream habitat for hitch.

FIGURE 1: ADOBE CREEK LOCATION

Adobe Creek is one of major streams in the Clear Lake watershed that still provide spawning habitat for the hitch (Center for Biological Diversity, 2012). Adult hitch live in the open water area of Clear Lake and migrate into tributary streams during the reproductive season, where they spawn (Moyle, 2002). Adult migration, spawning, embryo incubation, larval development, and juvenile emigration occur over a relatively short window of time during the wet season (Feyrer, 2019). The spawning migrations usually take place from mid-March through May, and sometimes into June (Moyle, 2002) and can occur earlier depending on the winter storms (see Figure 3). After spawning, hitch eggs sink to the bottom of the channel, where they become lodged in the gravel. The embryos hatch after approximately three to seven days, larvae become free-swimming after another three to four days, and the fry move quickly downstream to the lake (Moyle, 2002).

Although Clear Lake hitch have adapted to spawning during a brief period of suitable stream conditions, water diversions have caused streams to prematurely dry earlier in the spawning season. Combined with increased drought, more variability in storm events, and higher temperatures due to climate change, this trend will likely accelerate and further reduce spawning habitat. As shown in Figure 2, frost protection and irrigation periods for grape and pear crops (UCANR, 2020b; TNGA, 2020) overlap the spawning period further and decrease instream flows available for hitch migration and spawning. Also shown in Figure 2 are two hydrographs from recent wet and dry water year types in the adjacent Kelsey Creek (USGS Gage 11449500) to provide context for when winter storms occur in the watershed (streamflow data is currently unavailable in Adobe Creek). The change in hydrology patterns and migration barriers in Clear Lake tributaries contributed to the extinction of the Clear Lake splittail in the 1970s. The Clear Lake splittail is the hitch's closest relative, and they tended to spawn later than the hitch (Center for Biological Diversity, 2012).

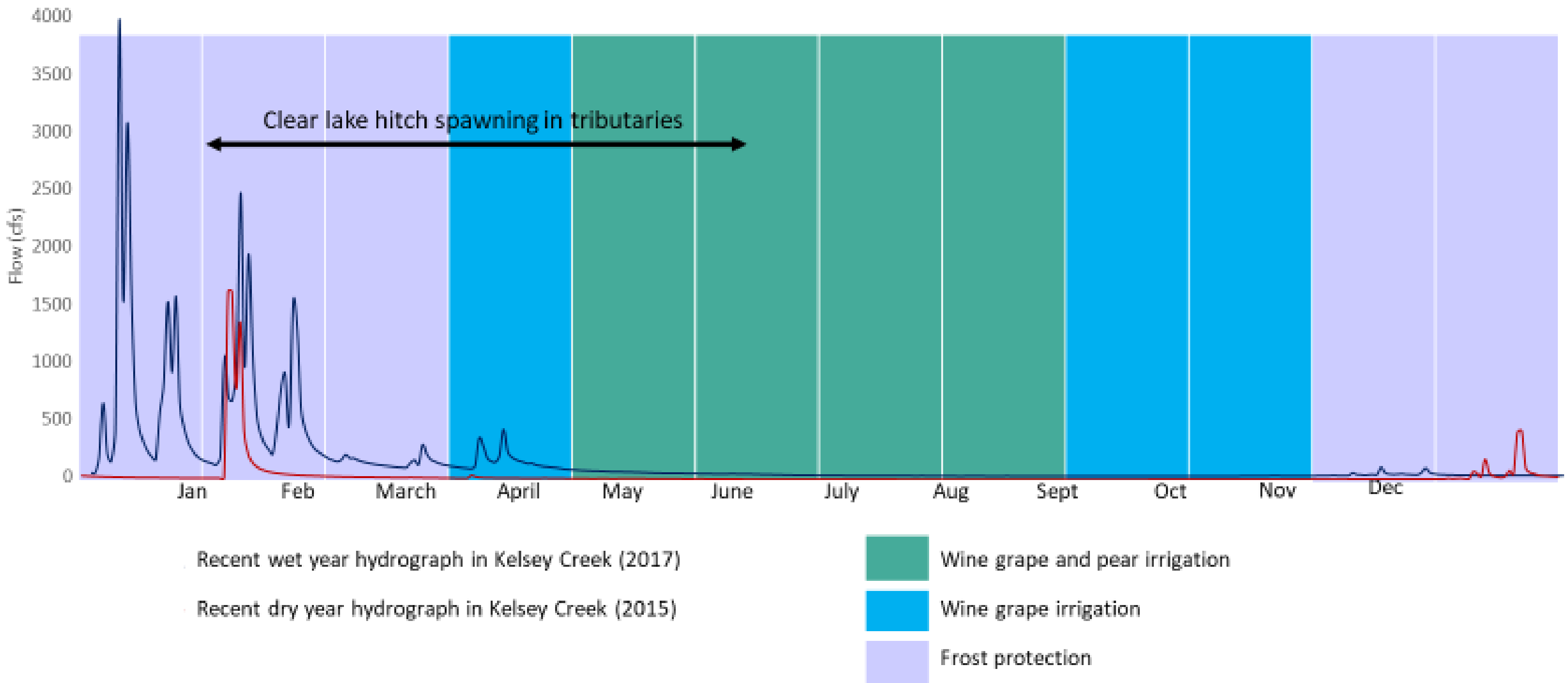


FIGURE 2: HITCH SPAWNING PERIOD, GRAPE AND PEAR CROP WATER DEMAND, AND WET AND DRY YEAR HYDROLOGY FOR NEARBY KELSEY CREEK

Purpose and Scope

This study developed water resources management recommendations in Adobe Creek to improve habitat and enhance on-going recovery efforts for the hitch. To accomplish this, the following tasks were undertaken:

1. Compile groundwater monitoring data, hydrology data, and water use data
2. Infill survey of Adobe Creek
3. Develop rating curve for pressure transducers
4. Build hydraulic model of Adobe Creek
5. Conduct fish habitat modeling
6. Conduct agricultural water demand modeling
7. Develop recommendations for groundwater/surface water management to benefit Hitch lifecycle requirements in the water resource climate adaptation plan for Adobe Creek

The first six tasks culminated in Task 7 as the recommendations for water resource management to benefit the hitch. The recommendations presented, as well as the data and analysis gathered and synthesized in this study provide Big Valley Band of Pomo Indians (the Tribe) with information and insights to share with tribal leaders, Lake County water managers, regulators, and other stakeholders to identify work needed to improve habitat conditions for hitch and support species recovery efforts.

DATA COMPILATION AND ANALYSES

DATA COLLECTED

Data collected included groundwater elevations, hydrology, and hitch counts. Several different sources were used to obtain complete datasets. Each dataset was processed and restructured to be suitable for further analysis. When possible, spatial relationships between the datasets were added. Table 1 details different attributes for each of the datasets collected. FlowWest packaged the cleaned and structured data as an R package (FlowWest, 2020) for further refinement, analysis, and reproducibility in the future.

TABLE 1: DATA AND SOURCES SUMMARY

Data	Type	Source	Period
Groundwater surface elevation	Well records	California Statewide Groundwater Elevation Monitoring (CASGEM)	1950-2019
Highland Creek Historical Flow	Streamflow (mean daily)	USGS (11449010)	1965-1977
Adobe Creek Historical Flow	Streamflow (mean daily)	USGS (11448500)	1970-1977
Kelsey Creek Flow	Streamflow (mean daily)	USGS (11449500)	1970-2019
Hitch data on Adobe Creek	Observations	Chi Council	2005-2018
Topography	Lidar Survey Digital Elevation Model	FEMA, Compass	Winter 2015/2016
Bridge and Culvert Specifications	Field Survey	FlowWest	2019
Adobe Creek Stage and Flow	Pressure Transducers and Flow Meter	FlowWest	2019-2020

The Chi Council is a citizen science resource management and planning group dedicated to the study, protection, and restoration of the Clear Lake Hitch (The Chi Council, 2020). The Chi Council documents hitch observations during spawning season and makes this data publicly available via their webpage. They have been observing hitch and recording counts since 2005 and have made data available through 2018. The monthly average of hitch observations in Adobe Creek from 2005-2018 during spawning seasons are shown in Figure 3.

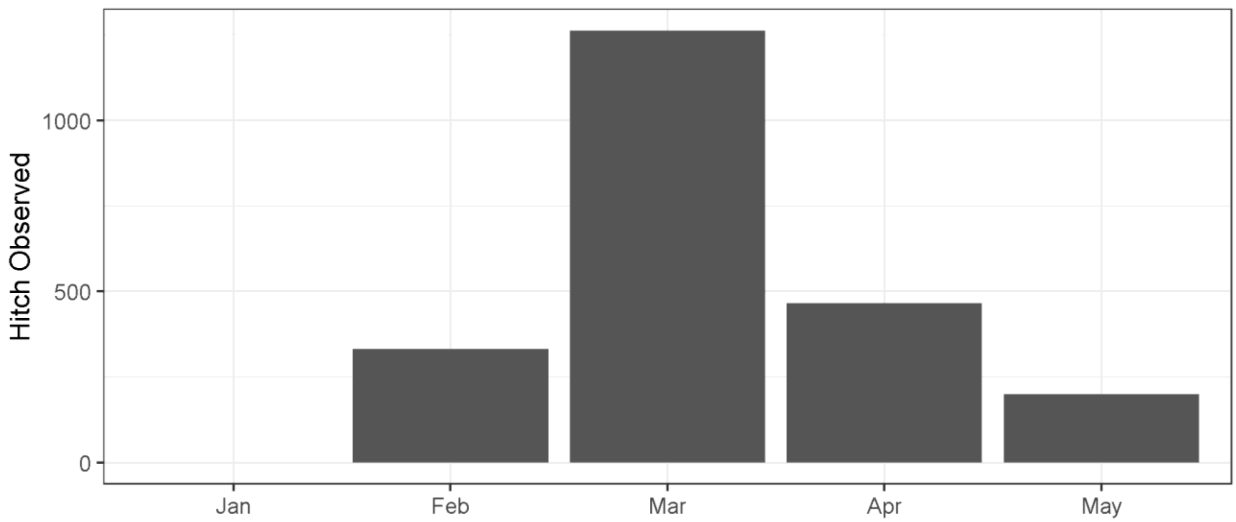


FIGURE 3: AVERAGE HITCH COUNT IN ADOBE CREEK OBSERVED BY MONTH VIA CHI COUNCIL

Streamflow Analysis

Adobe Creek Synthetic Streamflow

To estimate streamflow for Adobe Creek, a required input for the hydraulic modeling, FlowWest implemented a statistical model that used nearby Kelsey Creek flows to estimate Adobe Creek flows. Preliminary analysis and implementation of the model relied on the fact that both the Adobe Creek and Kelsey Creek USGS streamflow gages were in operation from 1970 to 1977. The Adobe Creek gage was discontinued after 1977, while the Kelsey Creek gage is still in operation. Preliminary analysis showed that 95% of flows at Kelsey Creek were below 300 cfs and 97% of flows at Adobe Creek were below 300 cfs. Figure 4 shows all the data for both Adobe Creek and Kelsey Creek gages and the relative abundance of data for flows below 300 cfs.

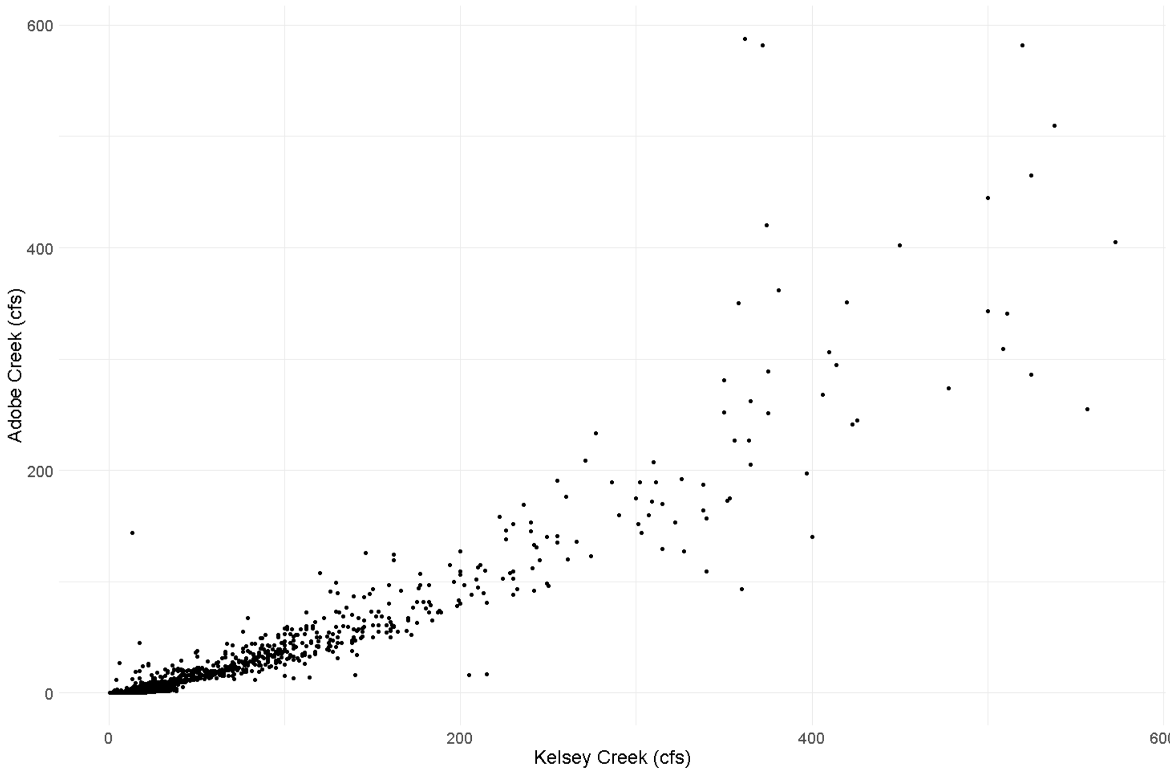


FIGURE 4: COMPARISON OF ADOBE CREEK AND KELSEY FLOWS FOR ENTIRE GAGE PERIODS OF RECORD.

A Generalized Additive Model (GAM) was developed to represent flow relationships between the two creeks. The streamflow data for 1971-1977 for both creeks was used to parameterize the model. The model performed very well with a reported adjusted R-squared value of 0.92, a value that ranges from 0 to 1 to indicate the total variance explained by the model. The 1970 data was then used to quantify how well the model predicted streamflow for Adobe Creek. Using the 1970 flow data as a validation dataset, the model predictions were less than 1 cfs away from actual observed data, as shown in Figure 5. This model was then used to estimate daily streamflow for the years 1978-2019 for the hydraulic model input.

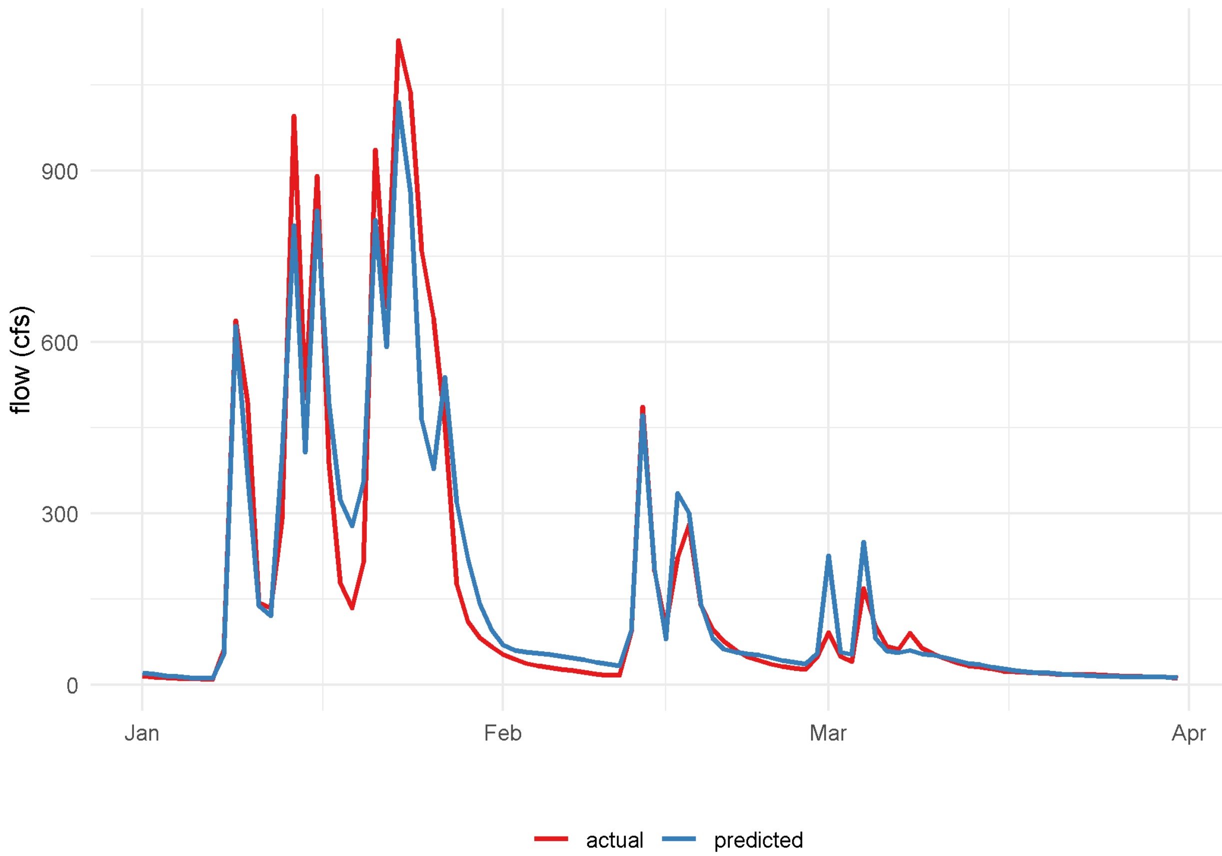


FIGURE 5: PREDICTIVE MODEL RESULTS USING 1970 STREAMFLOW DATA FOR VALIDATION

Hitch Passage Flows

The range of flows that accommodate fish passage have been defined specifically for streams within California (CDFW, 2004). High flows are limiting for fish passage due to flow velocity, whereas low flows are limiting because of water depth. For the hitch, the passage flow criteria for “Native Non-Salmonids” was used and is given as a range between 5% and 90% of the exceedance streamflow (CDFW, 2004; Table IX-5). Alternative minimum flows are also provided in case the calculated 90% exceedance results in a very shallow water depth.

Due to the lack of streamflow data on Adobe Creek downstream of the dams, the streamflow downstream of the confluence with Highland Creek was estimated using the sum of flows at Highland Springs and Adobe Creek dams (USGS gages: 11448500 and 11449010). Fish passage flows were calculated based on this estimated Adobe Creek flow. Due to the resultant low value for the 90% passage flow, the alternative minimum flow of 1 cfs was used. Table 2 shows the calculated passage flows, and Table 3 shows the monthly average flows for February through June from 1970-2019; average flows include predicted flows from the Adobe Creek synthetic streamflow for the years 1978-2019.

TABLE 2: MODELED HITCH PASSAGE FLOWS

	90% (Lower Passage Flow)	5% (Upper Passage Flow)
Flow (cfs)	1	168

TABLE 3: ADOBE CREEK AVERAGE MONTHLY FLOWS (INCLUDING SYNTHETIC STREAMFLOWS FOR YEARS 1978-2019)

	February	March	April	May	June
Flow (cfs)	107	85	34	11	3

GROUNDWATER ANALYSIS

Groundwater basins in the Clear Lake watershed are primarily formed by shallow alluvium and deposits of the Clear Lake Volcanics overlaying Franciscan Formation bedrock (CDM, 2006). Adobe Creek is a primary contributor to groundwater recharge in the Big Valley groundwater basin through infiltration of streamflow to the predominantly unconfined aquifer below the creek floodplain; near Clear Lake the aquifer is confined by a clay layer.

Groundwater data used for this analysis was obtained from the CASGEM database. A total of 17 groundwater wells within a half-mile of Adobe Creek were used, as shown in Figure 6. All these wells are classified as voluntary wells rather than CASGEM wells. Voluntary wells are not required to meet the standards of the CASGEM monitoring program, rather the only requirements for voluntary wells is that their data are entered properly, the groundwater level measurements are collected from wells, and the information submitted is as accurate as possible (T. Lutterman, personal communication, Nov. 6, 2020). Seasonal measurements (Spring and Fall) were recorded at these stations, and the total period of record for these data is 10/28/48 to 3/26/19. Notably, after 2010 there is a significant decrease in groundwater elevation data reported. Typically, there are 2 measurements per year (Spring and Fall) per well, although for some wells more measurements are taken each year. If all 17 wells reported a Spring and Fall measurement, that would be 34 measurements per year. Before 2010, on average there were 26.3 observations per year for this group of wells. After 2010, there is an average of only 3.8 observations per year for the same group. Currently, 13 of the 17 wells have an “active” status, yet only 2 wells have reported groundwater measurements since 2010. Due to the lack of data, an exploratory data analysis was performed. This section presents the results of the exploratory analysis, and a more detailed look at the two wells that reported post-2010 data, with a discussion concerning data abundance.

FIGURE 6: LOCATIONS OF VOLUNTARY CASGEM GROUNDWATER WELLS WITHIN 0.5 MILES OF ADOBE CREEK.

Groundwater Trends within Water Year Type

To explore trends across years, groundwater elevations were grouped into measurements taken in the Fall (September through November) and Spring (March through May) seasons. These two groups were analyzed separately. The focus for this exploration was groundwater elevation change from year to year, and any trends or relationships that would arise from that change—such as trends would give insight into a long-term decrease or increase in groundwater elevation. A change of elevation was calculated as the difference in water surface elevation in consecutive years within season, for example, to calculate the Fall elevation change for a particular well in 1970 the Fall elevation from 1969 was subtracted. This calculation was done for all groundwater wells. Water year types were used to categorize these values. The resulting distribution of annual elevation change for both the Spring and Fall by water year type is shown in Figure 7. Overall, there appears to be a general trend of increased groundwater elevation for wetter years. Critical years, on the other hand, nearly always show a decrease in water surface elevation.

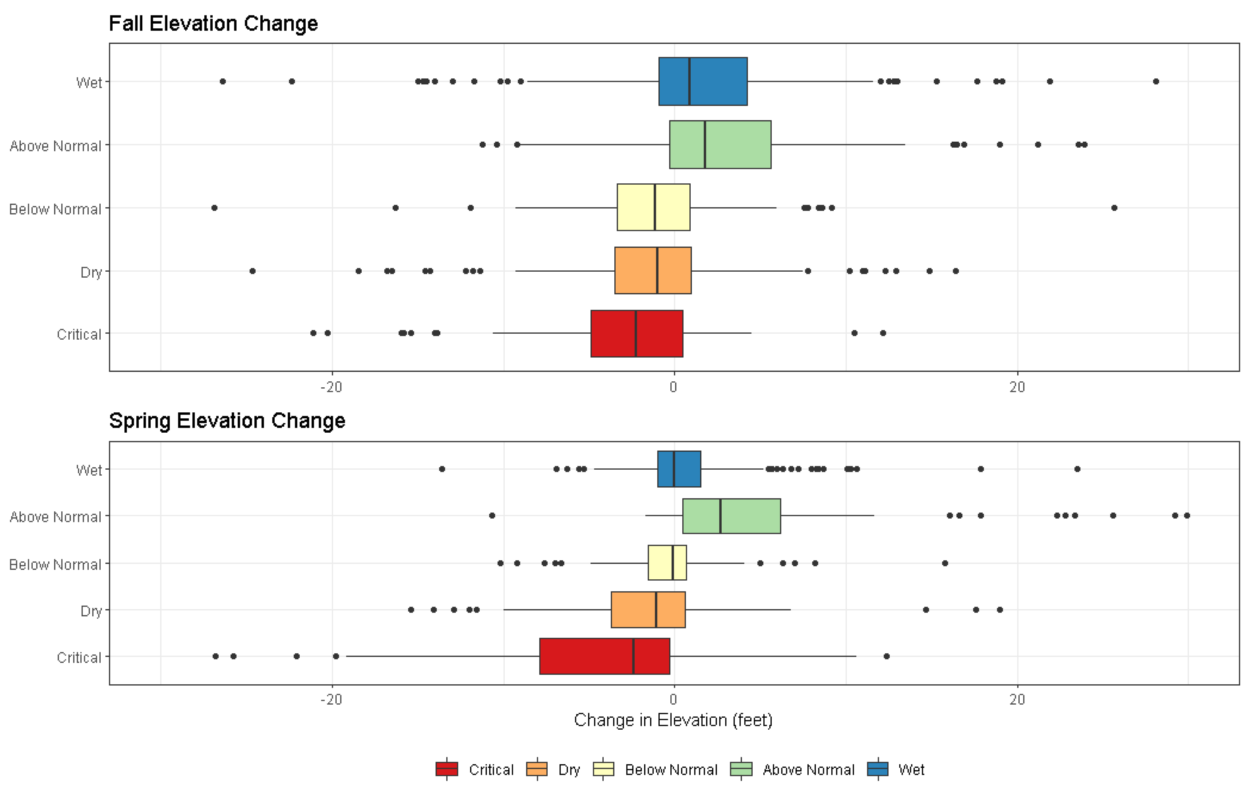


FIGURE 7: GROUNDWATER ELEVATION CHANGE PER SEASON, GROUPED BY WATER YEAR TYPE.

Groundwater Trends since 2010

The two wells with data after 2010 were examined in greater detail. Figure 8 shows these two wells and their proximity to the creek; the CASGEM identification numbers are 389975N1228770W001 and 389930N1228687W001 and they will be referred to as Well 1 and Well 2, respectively. Well 1 is adjacent to the creek, and Well 2 is approximately 0.5 miles from the creek. Figure 9 shows the Fall groundwater elevation measurements for the period of record for Wells 1 and 2, and Table 4 shows the summary statistics for these data. Notably, both wells show significant decreases in groundwater elevation in 2016 and 2017. The means of the Fall groundwater elevations for Wells 1 and 2 are 1329 feet and 1334 feet, respectively. In 2017, Well 1 dropped to 1313 feet, which was the lowest groundwater measurement since 1977. In 2016, Well 2 showed an elevation of 1324 feet. Well 2 has recovered to a higher groundwater elevation (1342 feet) in the most recent 2019 measurement, which is greater than one standard deviation (5.3 feet) away from the mean. The groundwater elevation at Well 1 was below the mean value in 2019 (at 1325 feet), but 4 feet of difference is within one standard deviation for Well 1. It is interesting that in 2017 Well 2 begins to recover groundwater elevation, but the measurement for Well 1 decreased further. The water year type for 2016 was 'below normal' and 2017 was classified as a 'wet.' If there was more well data reported, that could provide additional insights into the significance of the groundwater elevation trends for these two wells. This analysis highlights the importance of the need for additional groundwater monitoring along Adobe Creek, particularly with Well 1 showing an overall groundwater decrease since 2013.

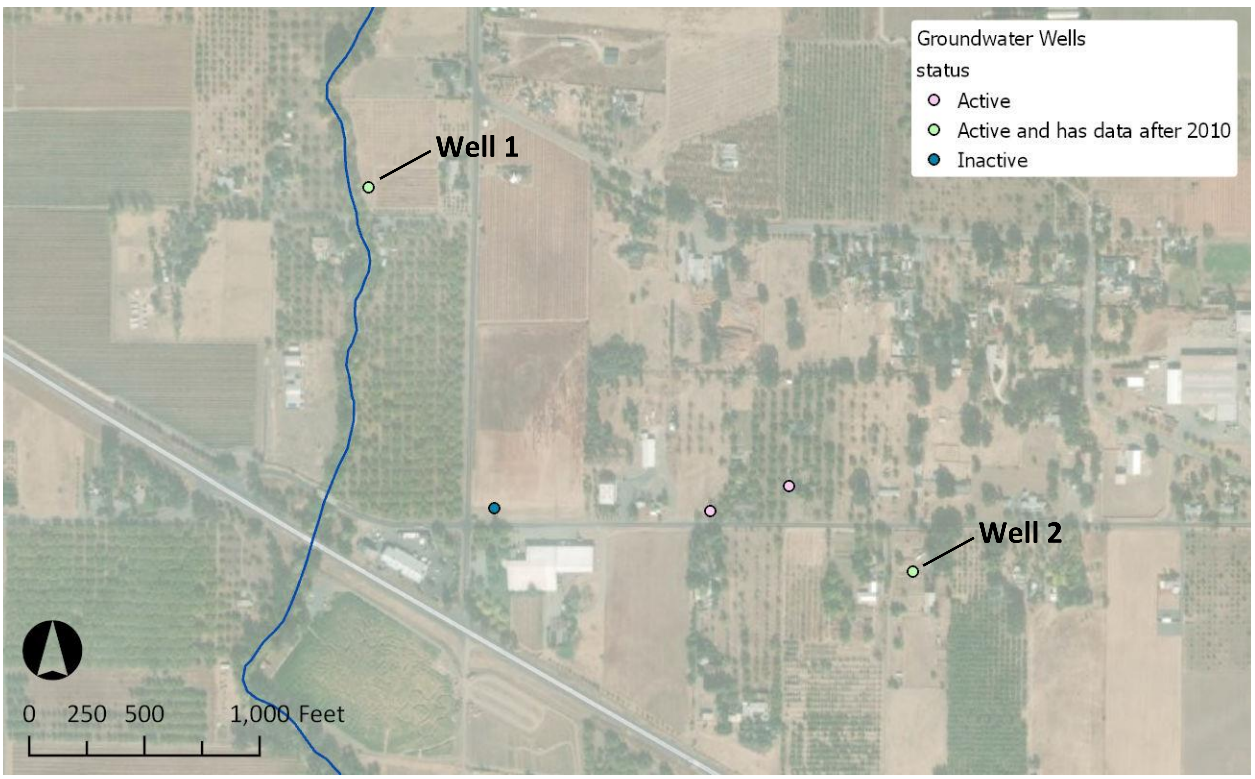


FIGURE 8: LOCATION OF WELLS 1 AND 2

TABLE 4: SUMMARY STATISTICS OF FALL GROUNDWATER MEASUREMENTS FOR WELLS 1 AND 2.

Well	Mean (feet)	Median (feet)	Standard Deviation (feet)
1	1329	1331	6.5
2	1334	1334	5.3

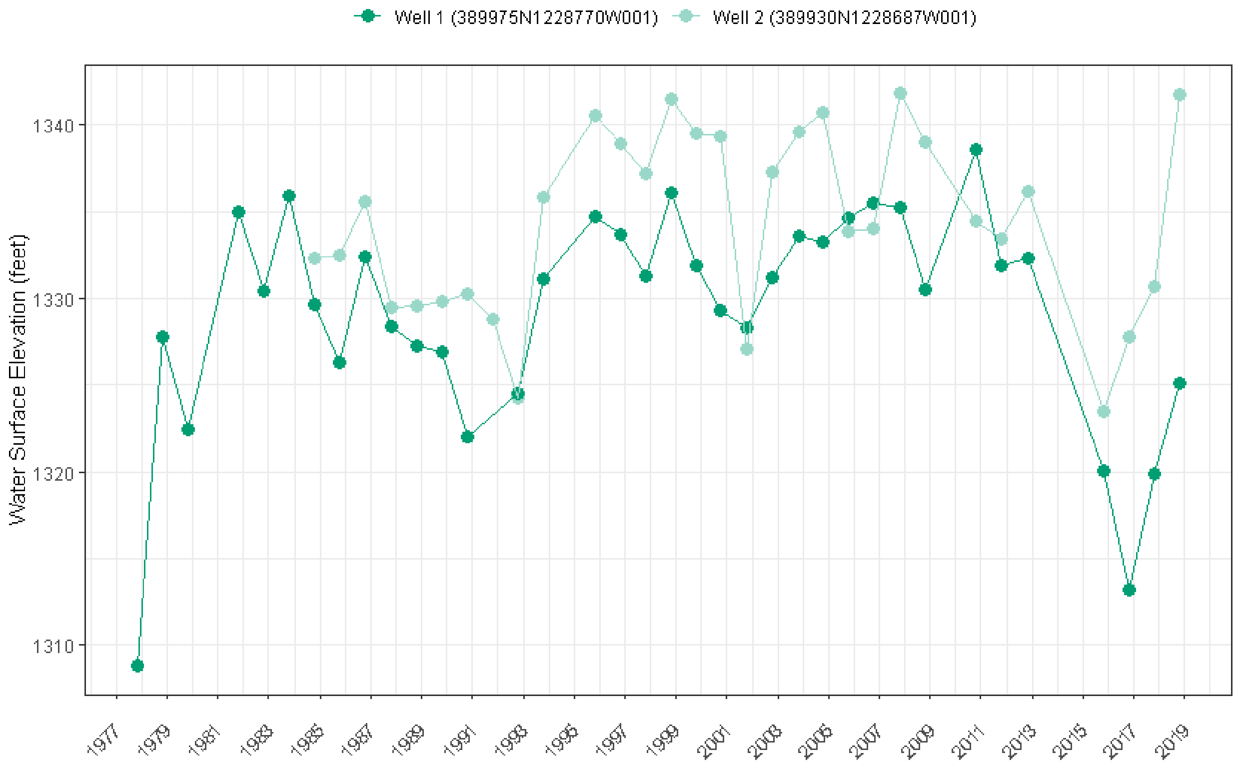


FIGURE 9: FALL GROUNDWATER ELEVATION MEASUREMENTS FOR WELLS 1 AND 2

WATER RESOURCES DATA COLLECTION AND ANALYSIS

INTRODUCTION

This task assessed vulnerability in the Adobe Creek watershed using an analysis of stream stage monitoring stations. The installation of the monitoring network will help develop a baseline to compare and evaluate the success of climate adaptation strategies to support hitch recovery. Three pressure transducers were installed in Adobe Creek to measure stage and temperature at 15-minute intervals. FlowWest started developing streamflow rating curves for three pressure transducers in Adobe Creek, by calculating discharge at the three sites during low flows. The rating curves will continue to be developed with additional funding from the BIA to start in 2020.

MONITORING SITE LOCATIONS

FlowWest installed pressure transducers at three sites in Adobe Creek to record water stage temperature beginning in December 2018; the locations are presented in Figure 10. Although FlowWest only used data collected through the spring 2020 for this report, the pressure transducers will last for up to 10 years, and the Tribe can continue monitoring stage in the creek after this project is completed. Two stage monitoring sites are located at the Argonaut Road and Soda Bay bridges over Adobe Creek, where the channel was accessible via Lake County easements. FlowWest was also given landowner permission to place the upstream pressure transducer 250 ft upstream of the Bell Hill Road crossing. FlowWest recommended this spatial distribution of pressure transducers to collect stage and water temperature data a pool in the upper watershed, stage and water temperature in the middle reach, and stage and temperature in the lower reach. Discharge measurements were collected at the same locations.

FlowWest

Data Sources
Pressure Transducer Locations - FlowWest 2020

FIGURE 10: STAGE AND TEMPERATURE MONITORING SITES ON ADOBE CREEK

Bell Hill Road

FlowWest installed the upstream pressure transducer upstream of the Bell Hill Road crossing of Adobe Creek. The transducer is located along a steep bank adjacent to a bar. The bar creates a shallow pool at this location (Figure 11). The pressure transducer is accessible by walking along the left bank (looking downstream) 260 ft upstream from the Bell Hill Road crossing. The transducer was installed in two-inch PVC pipe that is attached the deepest point in the channel bed with rebar pins and zip ties. The communication wire was encased in armored conduit, secured to the bank, and a locked in a metal box mounted on a T-post.

FIGURE 11: BELL HILL ROAD MONITORING SITE LOCATION

Argonaut Road

The second stage and temperature monitoring site is located at the downstream extent of the Argonaut Road Bridge (Figure 12). The channel was wide and flat at the bridge and the transducer was install at the deepest point in the channel and secured with rebar pins and zip ties. The communication cable was buried in a trench in armored conduit along the channel bed and then attached to the bank with rebar pins and routed to the top of left bank (looking downstream). The communication port was locked inside a metal T-post at the top of bank and adjacent to the downstream face of the bridge deck.

FIGURE 12: PRESSURE TRANSDUCER INSTALLATION AT THE ARGONAUT ROAD BRIDGE

Soda Bay Road

The third temperature and stage monitoring site is located at the Soda Bay Bridge over Adobe Creek (Figure 13). The deepest part of the channel was located near the left bank (looking downstream) at the upstream extent of the bridge. The transducer was installed at the deepest point in the channel and secured with rebar pins and zip ties. The communication cable was buried in a trench in armored conduit up the left bank of the channel and then. The communication port was locked inside a metal T-post at the top of left bank and adjacent to the upstream face of the bridge deck.

FIGURE 13: SODA BAY ROAD PRESSURE TRANSDUCER LOCATION

Monitoring Site Equipment

FlowWest installed non-vented, cabled pressure transducers in the deepest portion of the channel at each site, and attached the communications cable to the contour of the channel bank inside flexible and armored conduit secured with rebar pins into the channel bed and bank. The communication cables are housed in a locked metal box at the top of bank where they will not be inundated by high flows. Pressure transducers with data cables were used to enable data downloading when water is in the channel. FlowWest purchased and tested In-Situ non-vented Rugged TROLL 200 series pressure transducers, which have a stage monitoring accuracy of 1.0-inch error. The non-vented transducers require an additional pressure transducer to record the barometric pressure. Given the small change in elevation between the three sites on Adobe Creek, only one barometric pressure transducer was required. The barometric pressure transducer is locked in the metal box with the communication port at the Soda Bay Road location. Correction of the pressure transducer data with the barometric pressure recorded at the three sites was performed using In-Situ software. FlowWest installed one pressure transducer at each of the sites. Errors or drift of sensor readings will be detected by taking manual water depth readings at the transducer location during data downloading while flow in the channel. FlowWest programmed the pressure transducers to record depth and temperature every 15 minutes to capture peak stage in Adobe Creek during storm events.

Stage and Temperature Monitoring Results

This section summarizes the results of stage and temperature monitoring in Adobe Creek from December 13, 2018 to April 18, 2020. The pressure transducers were left in Adobe Creek and continued monitoring will be conducted by the Tribe. During the initial monitoring period, FlowWest identified trends for both stage and temperature at each pressure transducer location.

Stage

General observations from the review of stage data during the monitoring period and review of USGS gage records for neighboring Kelsey Creek shows that tributaries to Clear Lake including Adobe Creek are flashy systems. During the monitoring period, flow connects Adobe Creek to Clear Lake from late winter through early summer. Table 5 summarizes stage in Adobe Creek and identifies the peak flow stage, and period the channel is wet at each of the pressure transducer locations. There is consistent baseflow in the channel during the wet period and storm events result in peak discharges that rapidly rise and recede in stage. Figure 14 shows the pressure transducer stage data for the Bell Hill Road, Argonaut Road, and Soda Bay Road sites. All three sites track the rapid increase and decrease in stage during and after storm events. Figures 23, 24, and 25 show stage at each site and are discussed in greater detail below.

TABLE 5: PEAK STAGE AND WET PERIOD AT THE GAGE LOCATIONS

Gage Location	Date of Peak Stage	Peak Flow Stage (ft)	Wet Period
Bell Hill Road	2/27/19	8.13	December to June
Argonaut Road	2/27/19	14.6	December to July
Soda Bay Road	2/27/19	9.4	December to June

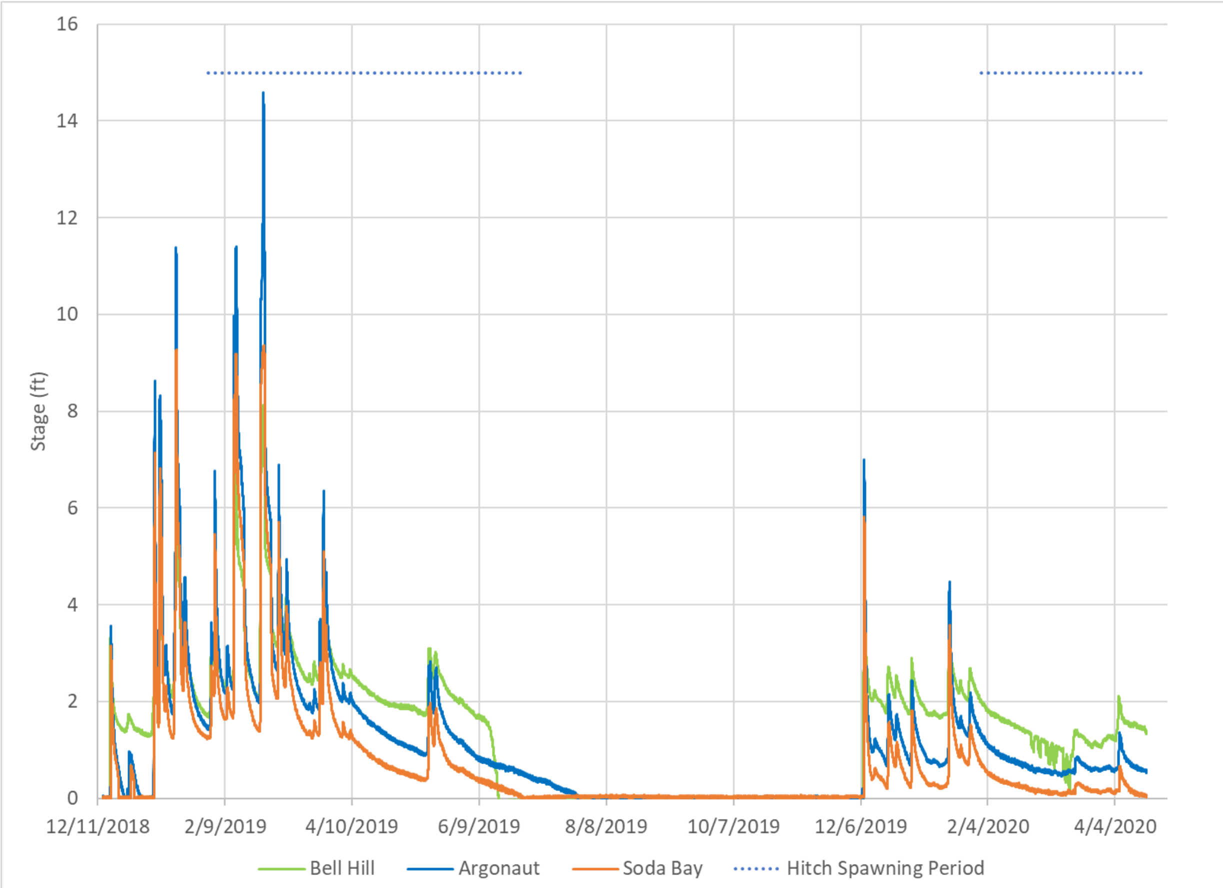


FIGURE 14: STAGE DATA AT MONITORING SITES FOR 12/13/2018 18 TO 4/18/2020

The pressure transducer at the Bill Hill Road site is located along the steep left bank (looking downstream) and the adjacent gravel bar creates a shallow pool between one to two feet (see Figure 15). The pool maintains a minimum depth during the wet period, but the Bell Hill Road site dries the earliest of the three sites in the summer.

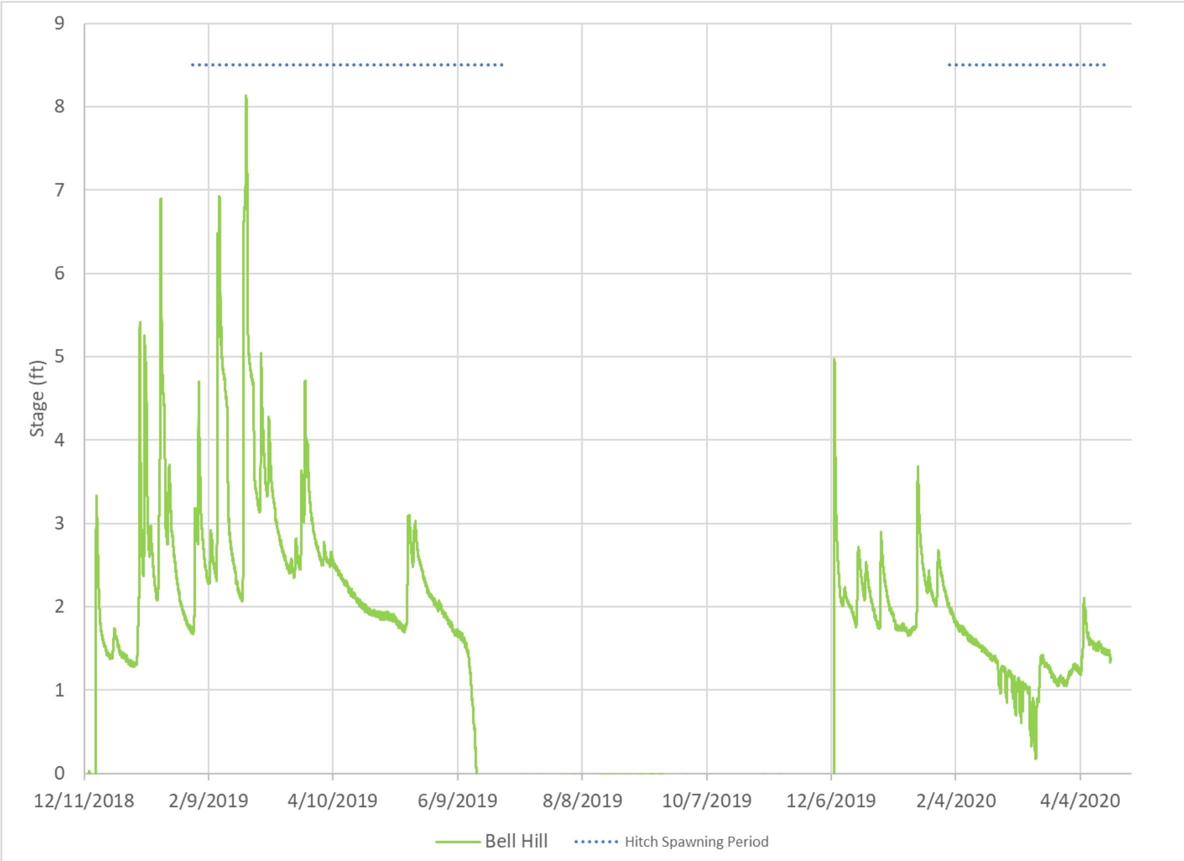


FIGURE 15: BELL HILL ROAD STAGE DATA

The pressure transducer at the Argonaut Road site is the most confined cross section of the three sites and results in the highest peak stages (Figure 16**Error! Reference source not found.**). During a late February, 2019 storm, stage in Adobe Creek at the Argonaut site increased from the winter baseflow of two feet to over 15.5 feet. The winter baseflow takes a series of storm events to establish at the Argonaut and Soda Bay sites. Likely, a few storms are required to saturate the shallow groundwater table.

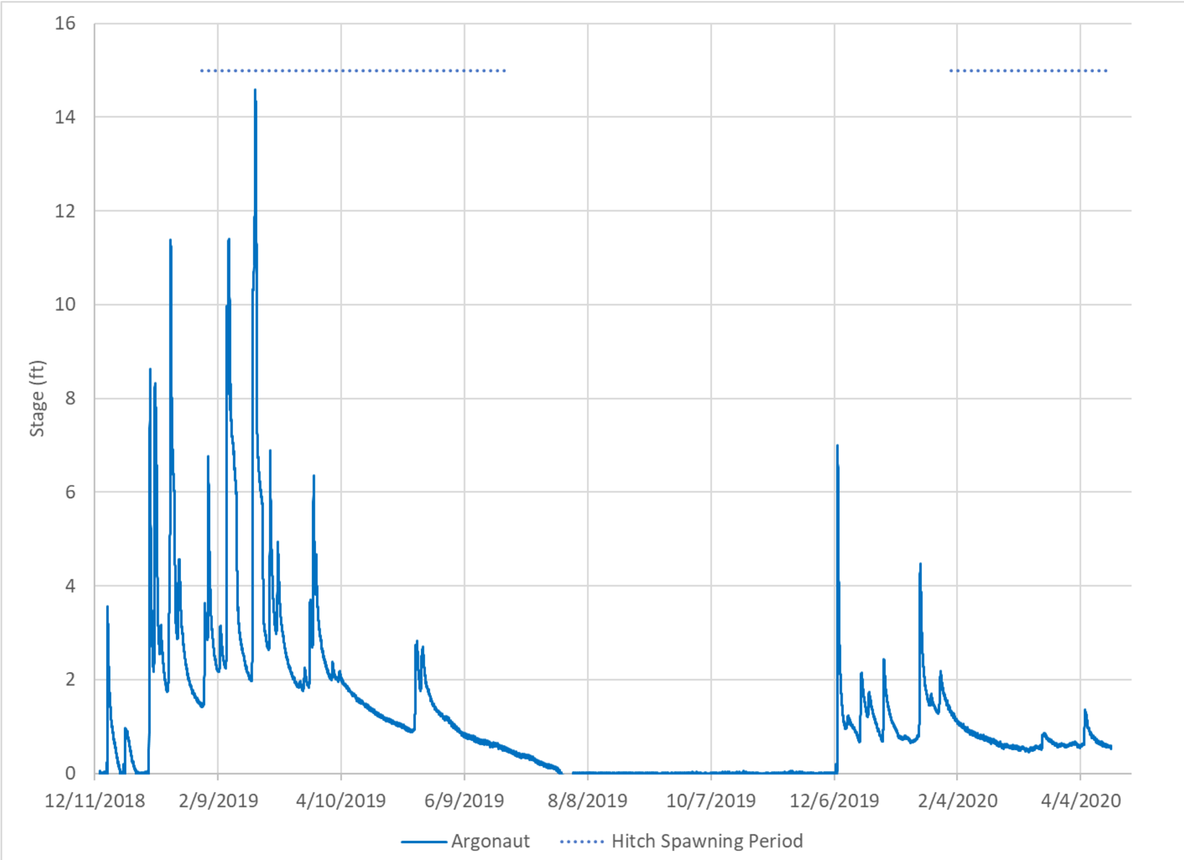


FIGURE 16: ARGONAUT ROAD STAGE DATA

At the Soda Bay Road site, the channel cross section in wider and winter base flow is shallower—approximately one-foot deep (Figure 17). As at the Argonaut Road site, the winter base flow takes a series of storm events to establish at the Argonaut Road and Soda Bay Road sites. Likely, a few storms are required to saturate the shallow groundwater table. The stage data at Soda Bay Road also shows that the peak of a late February, 2019 storm was muted. Possibly, floodplain attenuation decreases stage at high flows between the Argonaut Road and Soda Bay Road sites.

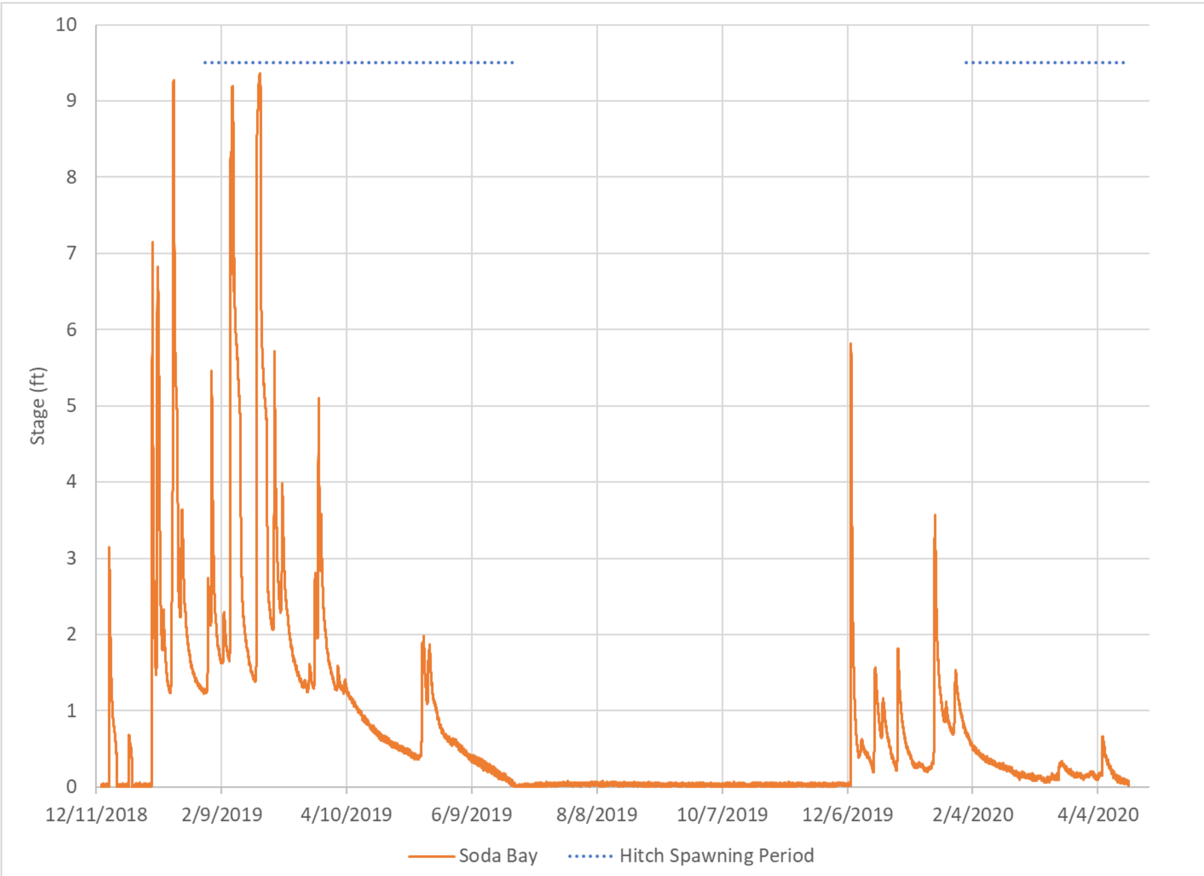


FIGURE 17: SODA BAY ROAD STAGE DATA

Temperature

The pressure transducers installed in Adobe Creek measure temperature along with stage at the three monitoring locations. The transducers record water temperature when submerged and air temperature when the creek is dry. Additionally, a barometric transducer is needed to correct for the changes in barometric pressure for the sealed transducers installed underwater. The barometric transducer is located in a locked metal box that contains the communication cable at the top of bank at the Soda Bay Road site.

At the Bell Hill Road site, the transducer records water temperature when the small pool is inundated and air temperature when the channel is dry (approximately June to December – dashed line shown in Figure 18). The monitoring results for this gage are shown in Figure 18. The pressure transducer is located next to the steep bank and likely receives direct sun for a portion of the day. The channel is wide and vegetation at the Bell Hill Road site is sparse, which also contributes to the warm air temperature recorded at the site when the channel is dry.

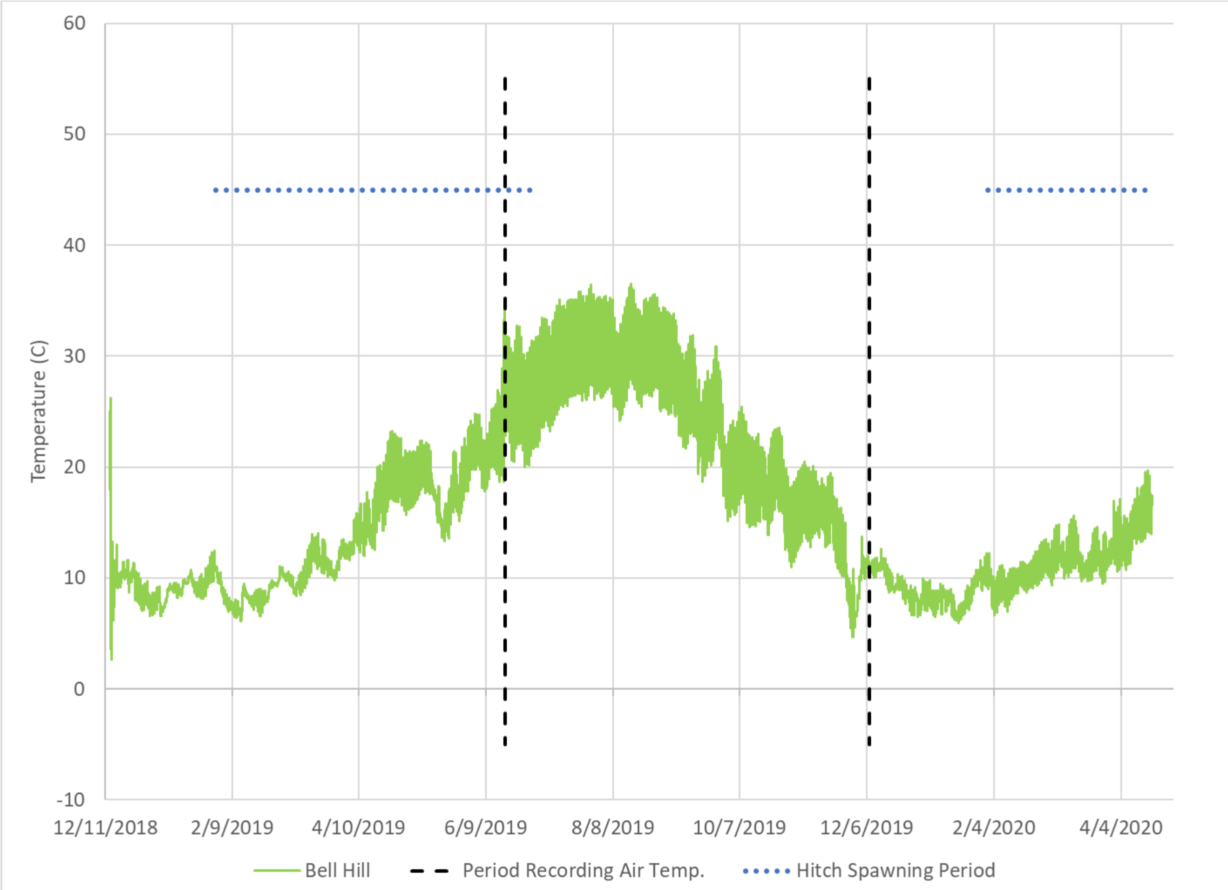


FIGURE 18: WATER AND AIR TEMPERATURE DATA FROM BELL HILL ROAD SITE

At the Argonaut Road site, one pressure transducer was deployed in the channel. The data from this site is shown in Figure 19. The Adobe Creek channel at the Argonaut Road site is incised and covered by mature riparian vegetation, which shades the pressure transducer. The air temperature (delineated by the dashed line in Figure 19) recorded at the Argonaut Road site is lower than the Bell Hill Road site because the transducer does not receive direct sun during the day due to the incised channel and riparian vegetation cover.

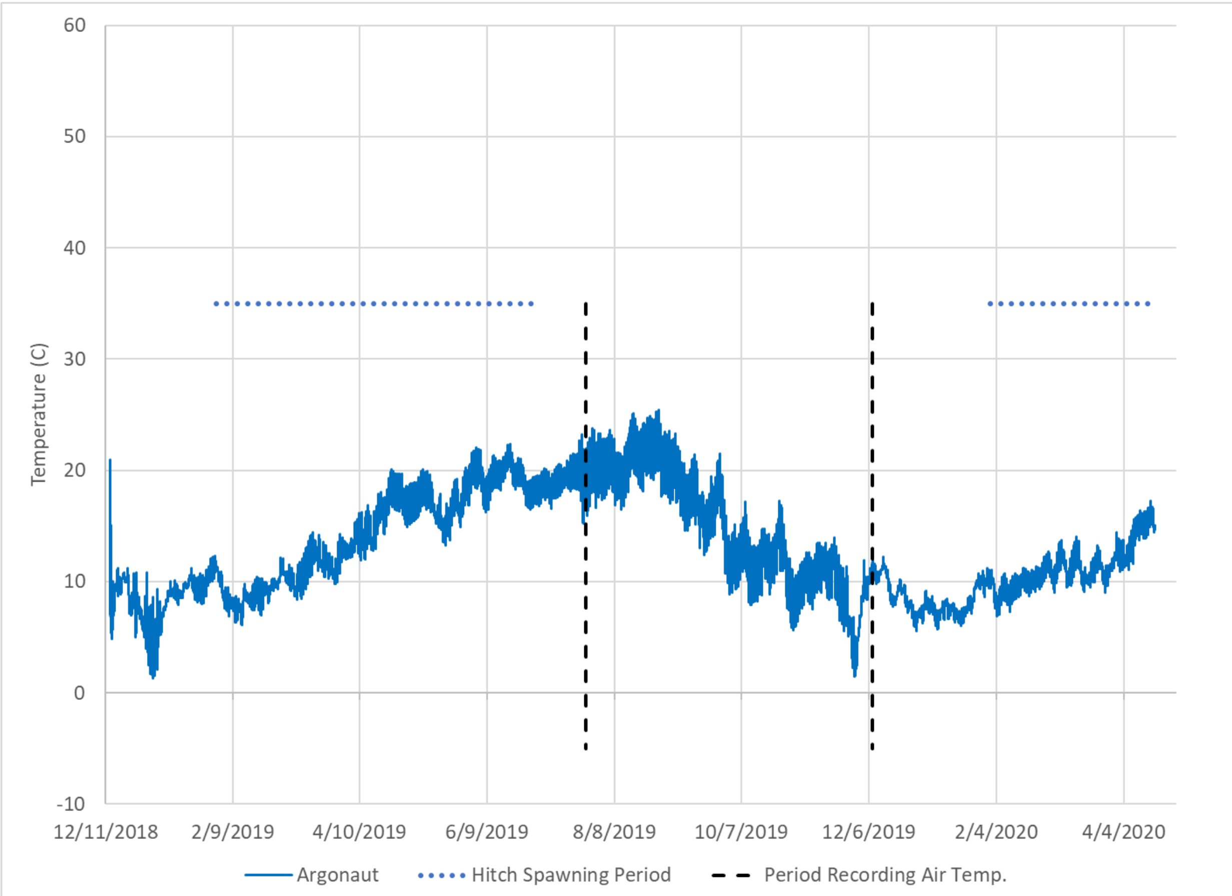


FIGURE 19: WATER AND AIR TEMPERATURE DATA FROM ARGONAUT ROAD SITE

The pressure transducer installed in the Soda Bay Road site is located in a moderately incised reach and the channel is covered by mature riparian vegetation, which shades the pressure transducer. The pressure transducer records water temperature when the channel is inundated and air temperature when the channel is dry (delineated by the dashed line in Figure 20), approximately from June to December. The barometric pressure transducer for the three sites is located in a locked metal box at the top of bank at the Soda Bay Road site. Located at the top of the bank above all high flows, the barometric pressure transducer receives more sunlight than the transducer in the channel and records higher air temperatures. The data for the Soda Bay Road site and the barometric transducer are shown in Figure 20. Comparison of the air temperatures between the instream and barometric transducers at this site highlights the cooling effect of riparian vegetation at the bottom of the channel during the period from the end of June to December (delineated by the dashed line in Figure 20).

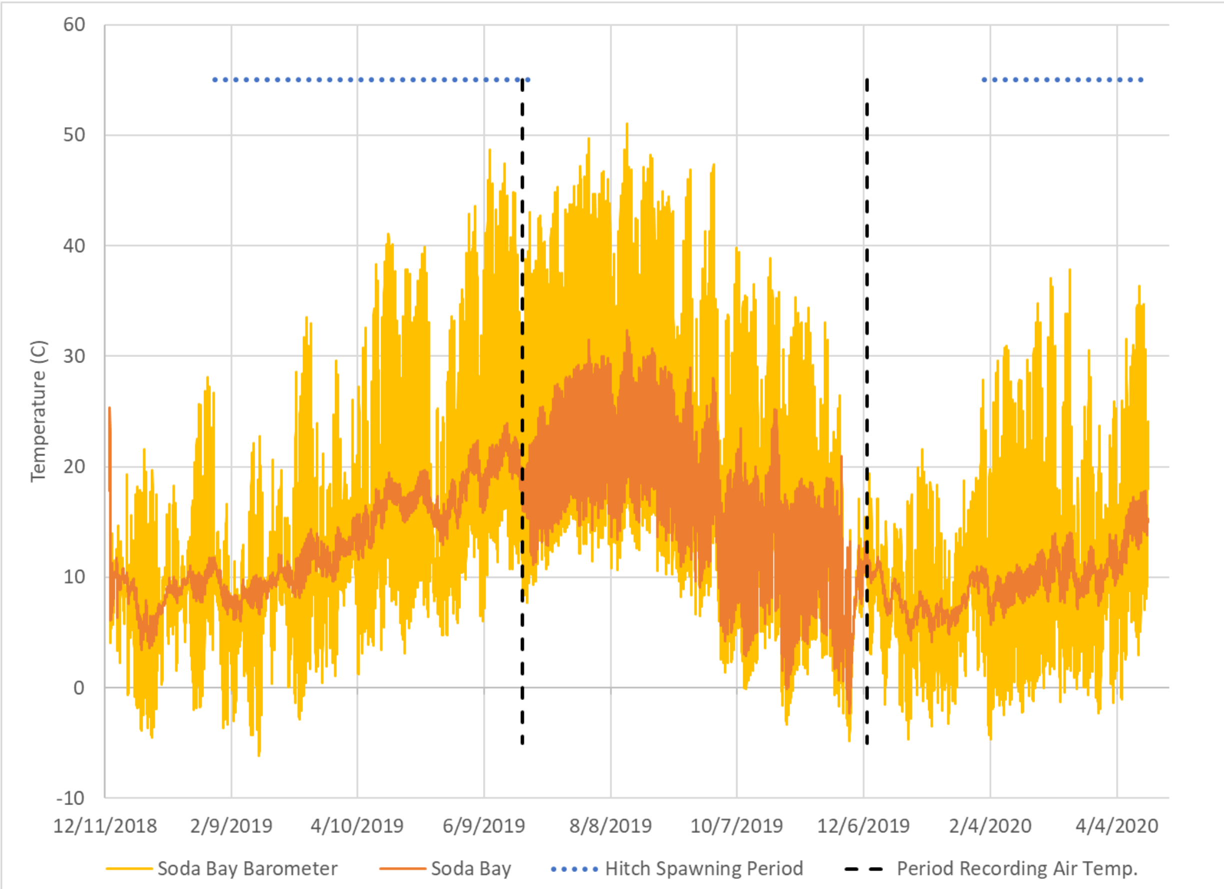


FIGURE 20: WATER AND AIR TEMPERATURE DATA FROM SODAY BAY ROAD INSTREAM TRANSDUCER AND BAROMETRIC TRANSDUCER.

General observations of the temperature data during the monitoring period show that water temperatures in Adobe Creek are similar between the three sites. Water temperature was slightly lower at the Soda Bay Road site during 2020 and warmed upstream (Figure 21). Typically, water temperature in streams increases with the distance downstream. The reversed trend on Adobe Creek in 2020 could show the cooling influence of riparian vegetation along the middle and lower reaches of the channel, and/or cooler shallow groundwater return flow in the middle and lower reaches. Additionally, cooler air temperatures at the Soda Bay Road site could also be the result of the cooling impact of the Clear Lake at lower elevations. Systematic monitoring of groundwater wells adjacent to Adobe Creek in conjunction with surface water monitoring may help explain this trend. Hitch spawn in clean, fine-to-medium gravel, and the preferred range of water temperature for spawning is between 14 - 18 degree Celsius (Murphy 1948; Kimsey and Fisk 1960 cited in Center for Biological Diversity, 2012). Stream temperature at all three sites exceeded the preferred spawning temperature range. Water temperature exceeds the preferred range at the Bell Hill Road site earlier in the spawning period than the Argonaut Road and Soda Bay Road sites. The Bell Hill Road site exceeds the upper limit of the preferred spawning temperature range of 18 degree Celsius on April 22, 2019. Water temperature at the Bell Hill Road site continues to drop below and then exceeds 18 degree Celsius until the channel went dry on June 18, 2019. Water temperature at the Argonaut Road and Soda Bay Road sites both exceed the preferred spawning range on April 22, 2019, but temperatures at these two sites remained cooler than the Bell Hill Road site. The channel at the Argonaut Road site went dry later on July 25, 2019, but the channel at the Soda Bay Road site was dry by June 27, 2019. During spring and summer 2019, flow in the channel controlled the end of the spawning period at both the Argonaut Road and Soda Bay Road sites. Warm water temperature at the Bell Hill Road site has a great impact of spawning suitability because water temperature increases sooner than the other two sites.

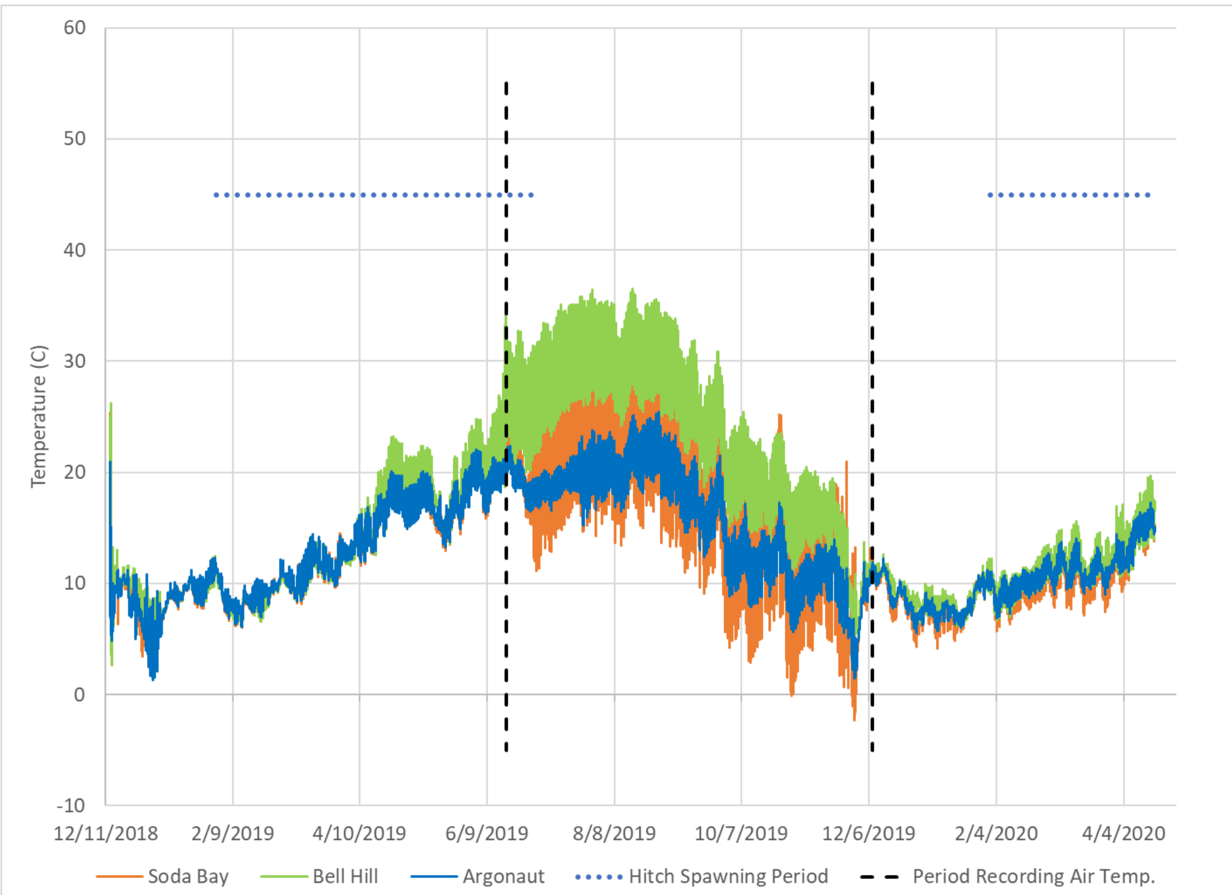


FIGURE 21: COMPARISON OF TEMPERATURE DATA FROM ALL THREE INSTREAM SITES

Discharge Monitoring

To calculate discharge in Adobe Creek, FlowWest conducted velocity measurements on January 21, 2020. Velocity was measured using a Hach FH950 electromagnetic velocity sensor and discharge measurements were collected at the three pressure transducer locations along Adobe Creek (Figure 10). From upstream to downstream, the velocity measurements were conducted at the Bell Hill Road crossing pressure transducer (Figure 22), which is located 260 ft upstream of the of the Bell Hill Road crossing; at the Argonaut Road pressure transducer (Figure 23); and slightly downstream of the Soda Bay Road pressure transducer (Figure 24). Velocity measurement locations are typically located at the pressure transducer so that stage recorded by the pressure transducer can be corelated to the measured velocity and the calculated discharge. Velocity measurements should be collected in a reach with uniform flow across the transect. At the Bell Hill Road and Argonaut Road sites, the velocity measurements were conducted at the pressure transducer. At the Soda Bay Road location vegetation obstructed the left bank and the velocity measurement transect was relocated approximately 30 feet downstream from the pressure transducer.

To calculate discharge from velocities measured along a transect, the transect is divided into verticals at breaks in slope, changes in bed or bank conditions, or different flow conditions. Typically, 10-30 verticals across a transect is sufficient and no individual vertical should contain more than 10% of the channel discharge. A tape is stretch across the channel and the edge of bank station recorded on the data collector. At the next vertical, the station and flow depth is recorded on the data collector and the velocity is measured for the vertical using the flow meter. For depths less than 0.5 ft, velocity was measured at 40% of the depth. For flow depths greater than 0.5 ft, the velocity at each vertical was measured at 20% and 80% of the flow depth. Flow depth was measured using a topset wadding rod. The topset wading rod was also used to determine the velocity measurement elevations at 20% and 80% of flow depth. This process was repeated 20-30 times for each transect and the discharge was calculated at the end of the transect. The transect measurements were repeated. If the difference in calculated discharges was greater than 10% the transect was remeasured.

Table 6 summarizes maximum depth, active channel width, number of verticals, pressure transducer elevation, water surface elevation at the time of the discharge measurement, stage, and calculated discharge for each of the three transects. Of the three sites, the Bell Hill site was the deepest followed by Argonaut and Soda Bay respectively. In terms of width of the active channel, Bell Hill was the widest followed by Soda Bay and Argonaut had the narrowest active channel.

TABLE 6: HYDRAULIC CONDITIONS OBSERVED AT THE THREE LOCATIONS ON ADOBE CREEK DURING A STORM EVENT ON JANUARY 21, 2020

Site	Maximum Depth (ft)	Active Channel Width (ft)	No. of Verticals	Pressure Transducer Elevation[1]	Water Surface Elevation[1]	Stage (ft)	Discharge (cfs)
Bell Hill Road	2.2	47.5	29	1,402.28	1,404.48	2.20	21.3
Argonaut Road	1.5	27.6	24	1,350.31	1,351.78	1.46	20.7
Soda Bay Road	1.0	33.0	23	1,330.23	1,331.23	1.00	19.6

[1] Elevations in NAVD88, feet

FIGURE 22: DISCHARGE MEASUREMENT UPSTREAM OF THE BELL HILL ROAD CROSSING AT THE LOCATION OF THE PRESSURE TRANSDUCER LOOKING ACROSS THE TRANSECT FROM THE LEFT BANK

Flow at the Bell Hill site is concentrated along the steep right bank looking downstream. A gravel bar on the left bank gradually rises from the deeper portion of the channel. At the measured discharge, the velocity of flow was very low across the shallow and wide bar. The verticals and velocity measurements were concentrated in the deeper portion of the channel (Figure 22).

The channel dimensions at the observed flow were similar at the Argonaut (Figure 23) and Soda Bay (Figure 24) sites. The depth and active channel width were similar.

Discharge decreased slightly downstream and the study area is characterized as a slightly losing reach. Typically, as watershed area increases the discharge increases, as more flow is concentrated in the channel. The observed losing nature of the reach suggests that flow in the channel is seeping into the shallow groundwater table. Discharge measurements were made during the winter when irrigation diversions were unlikely and when the shallow groundwater table had recovered. Discharge measurements at the three sites during the spring and summer may show a greater loss of in-channel flows. Loss of in-channel flow during the spawning season could significantly decrease hitch spawning success. During the spawning season, in-channel flows could be decreased by direct diversions from Adobe Creek for agricultural uses and through shallow groundwater recharge through the channel bed. Additional discharge measurements are needed to fully develop the rating curve for each pressure transducer. Systematic groundwater monitoring is needed to develop relationships between surface water and groundwater interaction along Adobe Creek.

FIGURE 23: LOOKING UPSTREAM AT THE DISCHARGE TRANSECT AT THE ARGONAUT ROAD BRIDGE AT THE LOCATION OF THE PRESSURE TRANSDUCER

FIGURE 24: LOOKING UPSTREAM AT THE DISCHARGE MEASUREMENT TRANSECT DOWNSTREAM OF THE PRESSURE TRANSDUCER AT THE SODA BAY ROAD SITE

HYDRAULIC MODELING

A 1-D hydraulic model of Adobe Creek was created using the survey and flow data resources provided in Table 1. The purpose of this model was to evaluate passage conditions for the Clear Lake hitch (Lavinia exilicauda chi).

MODEL DOMAIN AND TOPOGRAPHY

The model domain extends along Adobe Creek from just downstream of the confluence with Highland Creek to upstream of the mouth Clear Lake (Figure 25). Model topography was developed by Compass (2016) and provided to FEMA as a 1-meter resolution Hydro Flattened digital elevation model (DEM). These data were collected in December 2015 and February 2016 in the Adobe Creek watershed. The horizontal datum of the data is the North American Datum of 1983 (NAD83) and the vertical datum is the North American Vertical Datum of 1988 (NAVD88). The projection of the original dataset was transformed from UTM Zone 10 North to State Plane Zone 2, and all units were transformed from meters to U.S. survey feet.

The topographic dataset used in this model excludes some percentage of the channel capacity as lidar is unable to penetrate the water surface and dense vegetation. Many of these areas exist at the downstream end--where Adobe Creek meets Clear Lake. As the lidar data was not accompanied by aerial imagery, it was more difficult to identify other wetted and obstructed areas of the channel. However, the data appear to capture most of the bathymetry and are adequate toward identification of potential passage limitations in Adobe Creek. This dataset could be improved in the future by surveying the Adobe Creek channel using ground-based or aerial survey methods during the dry season.

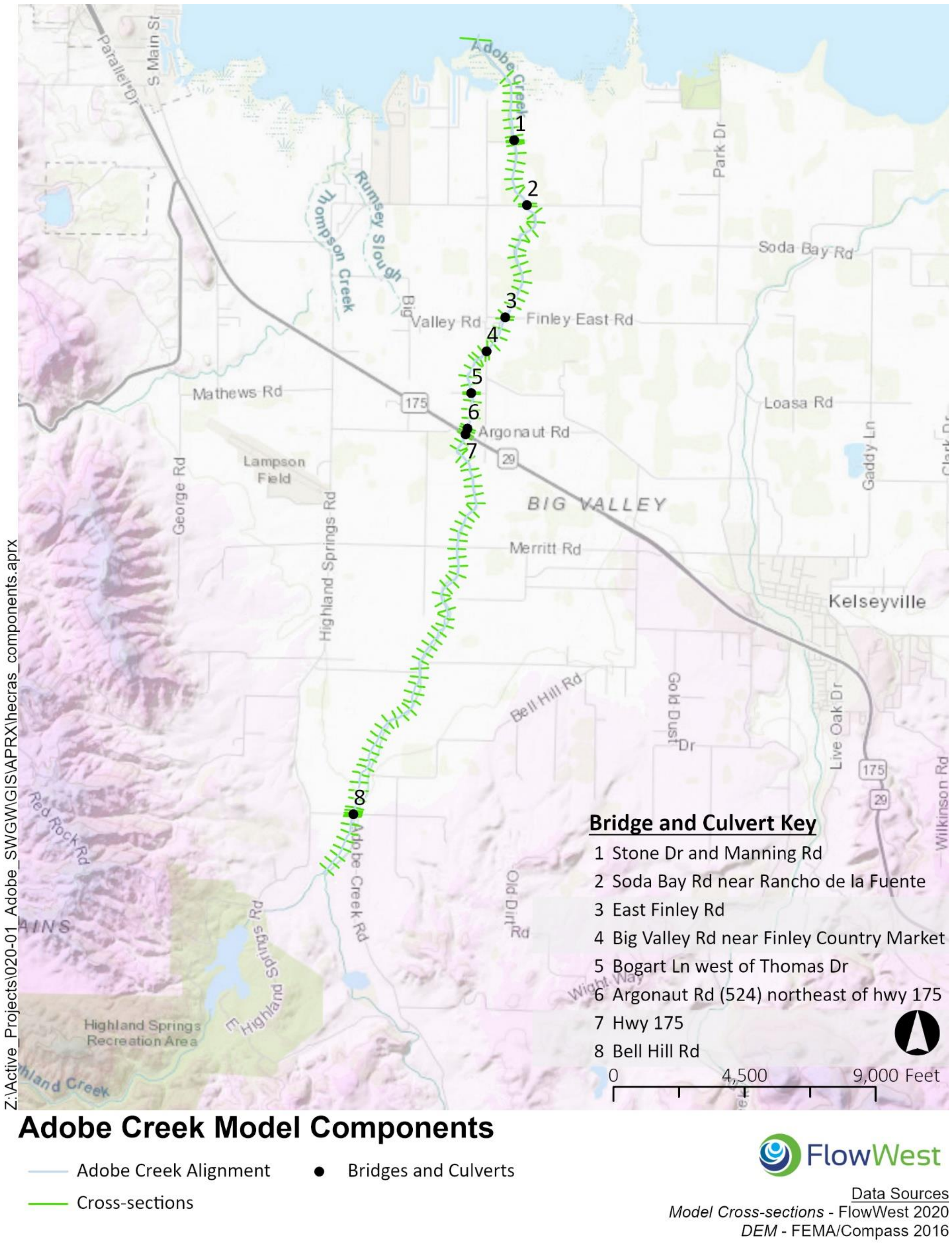


FIGURE 25: ADOBE CREEK MODEL DOMAIN, BRIDGES, AND CULVERTS

Model Boundary Conditions and Flows

The downstream boundary of the model was set as a normal depth boundary with the friction slope matching the longitudinal slope of the terrain between the two downstream cross-sections. The upstream boundary was set to match the hitch passage flows derived from the streamflow analyses described in this report (Table 2). The model was run at each of the flows using a simple steady state flow solution.

Model Structures

A total of 8 hydraulic structures were added to the model (1 culvert and 7 bridges). The configurations of these structures were observed and surveyed by FlowWest in December 2019.

Model Roughness

Manning's roughness coefficients were determined using a combination of ESRI base imagery and observations made during the bridge and culvert survey conducted by FlowWest in December 2019. The coefficients vary from 0.050 in the smoother regions of the channel to 0.065 on some densely vegetated banks.

Modeling Results

This 1-D, steady state hydraulic model was developed to investigate limiting passage conditions for the Clear Lake hitch (Lavinia exilicauda chi) based on minimum depth and maximum velocity criteria provided by Tom Smythe at the Lake County Water Resources Department (Table 7). Feyrer (2019) observed hitch spawning in Kelsey Creek in approximately 0.8 ft of depth during April of 2018.

TABLE 7: HITCH PASSAGE CRITERIA

Criteria	Value
Velocity	< 5 fps
Depth	> 0.5 ft

A combination of CDFW-derived passage flows and synthetic mean monthly flows during known hitch migration times were modeled (Table 2). For each of these flows, depth and velocity suitability were evaluated by comparing the passage criteria to model output for maximum depth (Figure 26) and maximum average velocity (Figure 27) at each cross-section. Depth suitability is also shown mapped along the creek for the February and March mean monthly flows (Figure 28), as well as for April and May mean monthly flows (Figure 29).

According to our analyses, depth is likely a limiting factor throughout most of Adobe Creek at the estimated CDFW 90% passage flow (1 cfs) and likely not limiting at the estimated 5% passage flow (168 cfs, Figure 26). Synthetic mean monthly flow results show depth may start to become limiting in April (at 34 cfs)—originating upstream and continuing to expand downstream as mean flows fall through May (11 cfs), June (3 cfs), and July (0.5 cfs). On average, velocity does not appear to be a limiting factor at any of the modeled flows.

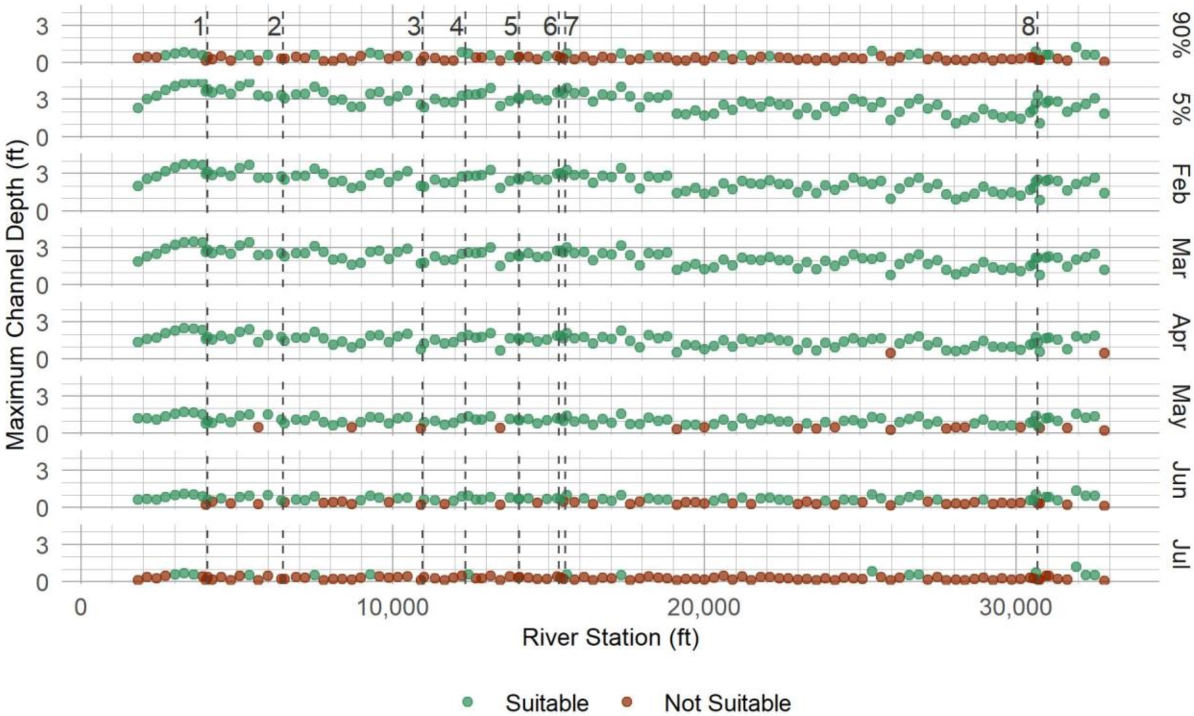


FIGURE 26: HITCH PASSAGE, CHANNEL DEPTH SUITABILITY BY FLOW
Dashed vertical lines indicate culvert and bridge locations (Figure 25).

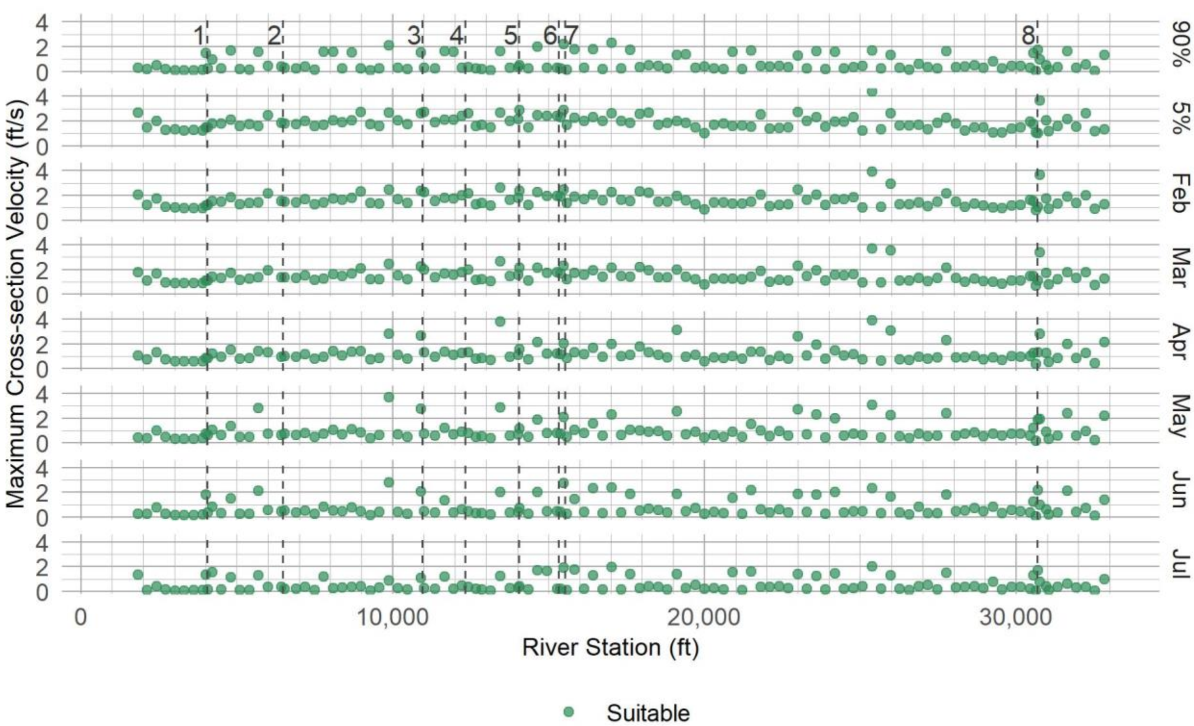


FIGURE 27: HITCH PASSAGE, VELOCITY SUITABILITY BY FLOW
Dashed vertical lines indicate culvert and bridge locations (Figure 25).

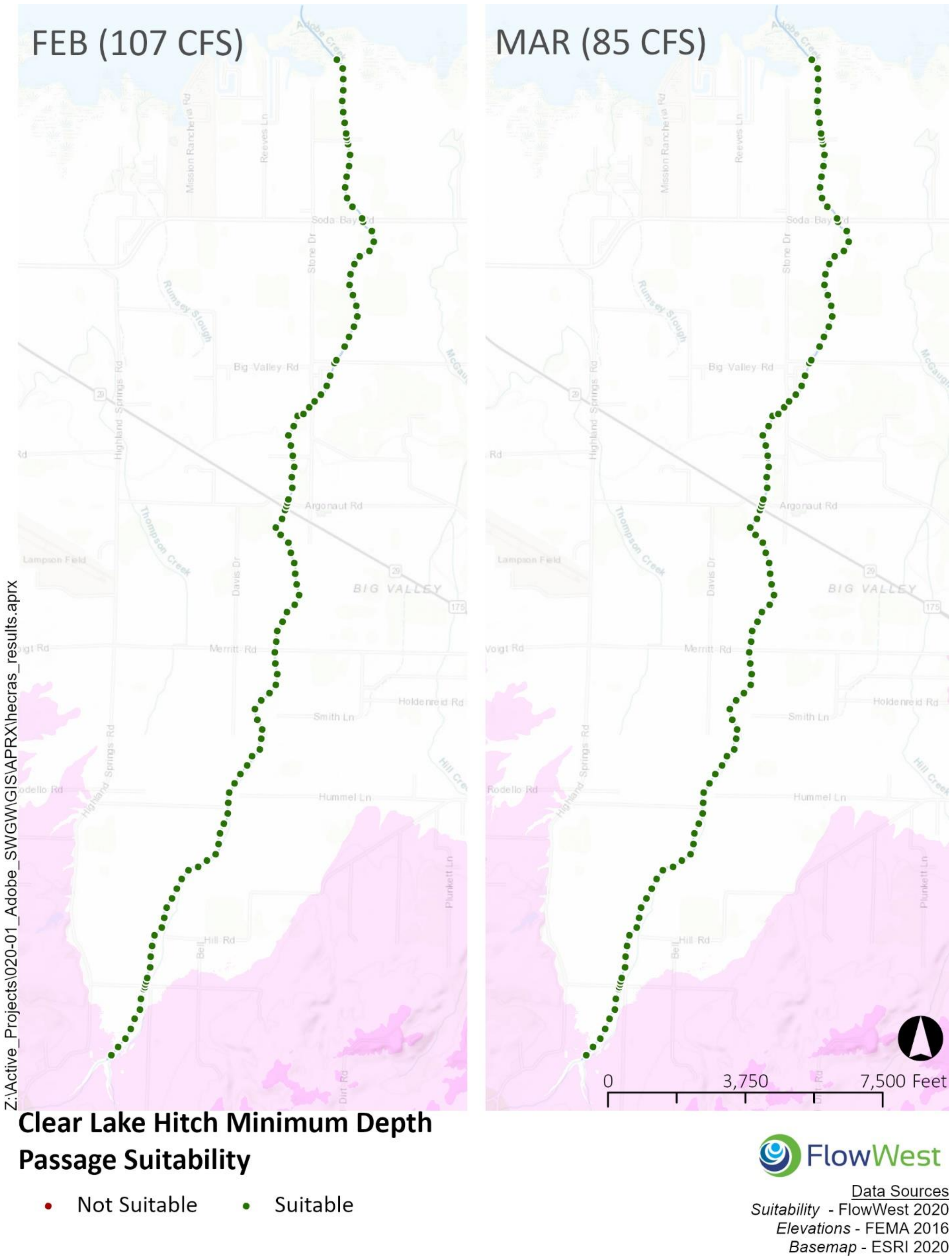
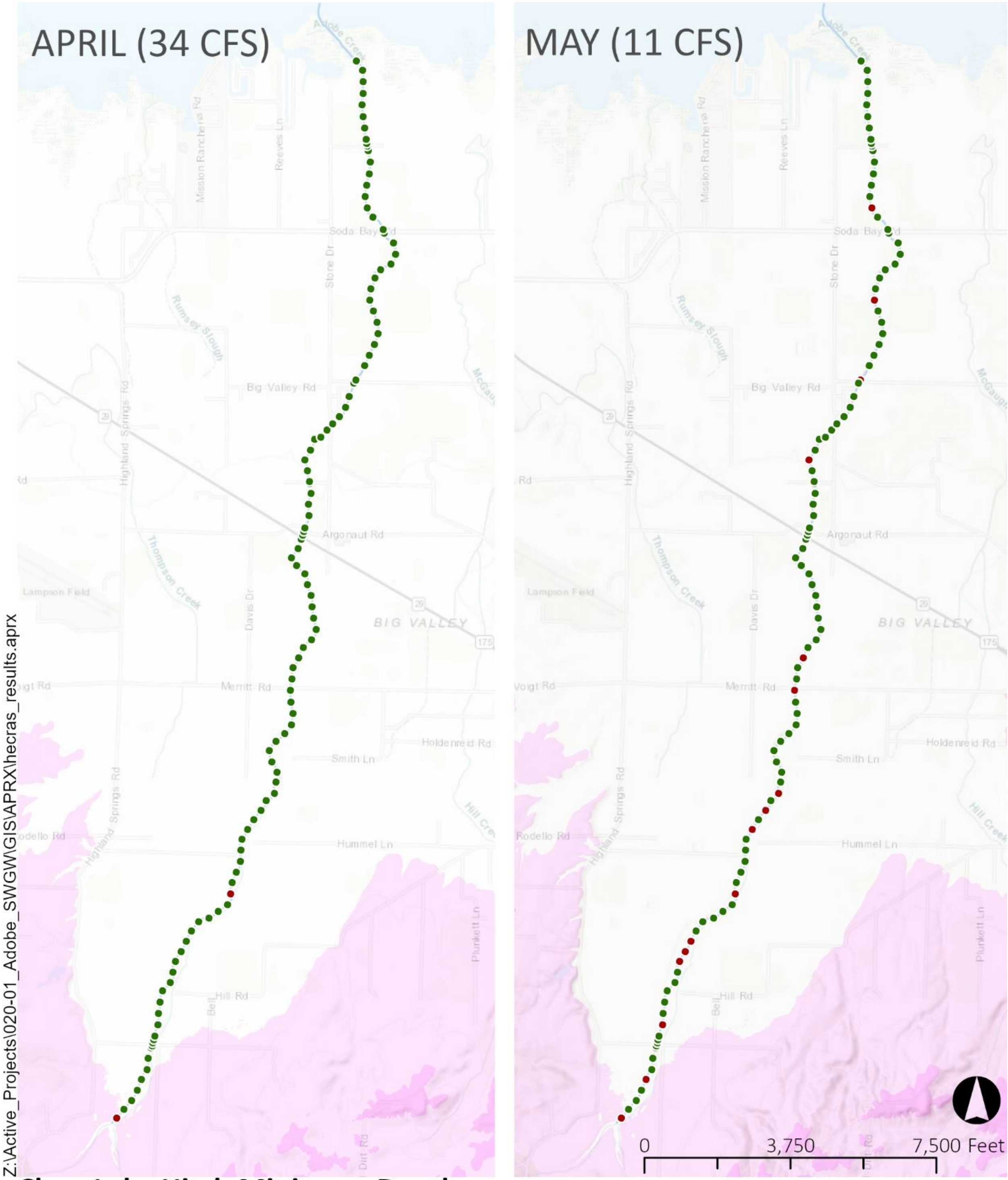


FIGURE 28: CLEAR LAKE HITCH DEPTH SUITABILITY MAP (FEBRUARY AND MARCH)



Clear Lake Hitch Minimum Depth Passage Suitability

• Not Suitable • Suitable

FlowWest

Data Sources
Suitability - FlowWest 2020
Elevations - FEMA 2016
Basemap - ESRI 2020

FIGURE 29: CLEAR LAKE HITCH DEPTH SUITABILITY MAP (APRIL AND MAY)

Model Calibration

Calibration of a hydraulic model involves comparison of model predictions at a defined flow against corresponding field survey data and adjustments to model parameters (e.g., roughness coefficients and downstream boundary) to improve model accuracy. Since Adobe Creek does not currently have a functioning flow gage and rating curves are still in the early stages of development, we were not able to collect data necessary to calibrate this model. However, the model can be calibrated in the future, following rating curve development at the three transducer locations along Adobe Creek.

Model Sensitivity

Sensitivity analysis is the process of investigating how variation in model input parameters effect model results. These analyses can be used to provide insight into model uncertainty and assist with model calibration. Model sensitivity to the downstream boundary friction slope and Manning's roughness coefficients were performed for this model at the flood conveyance flows. Results of these analyses are discussed in the sections that follow.

Downstream Boundary

Sensitivity of the model to the downstream boundary condition was investigated by running the model with a 20% steeper and 20% flatter slope at the downstream boundary. Since the downstream boundary of the model is 1,500 feet downstream of the area of interest, varying this model parameter has a small and localized effect on model results. These differences exist only in the 3 most downstream cross-sections and do not affect overall passage suitability at any flow.

Manning's Roughness

Sensitivity of the model to Manning's roughness was investigated by running the model with a 25% higher and 25% lower roughness coefficient throughout. Varying this parameter changed water surface elevation results by between -0.44 ft to 0.39 feet. Differences of this magnitude will only effect depth passage criteria where model results are closest to the critical depth of 0.5 ft. As shown in Figure 30 and Figure 31, changes in roughness have a small impact on passage suitability at the lower (1 cfs) passage flow but does not affect suitability at the higher (168 cfs) passage flow.

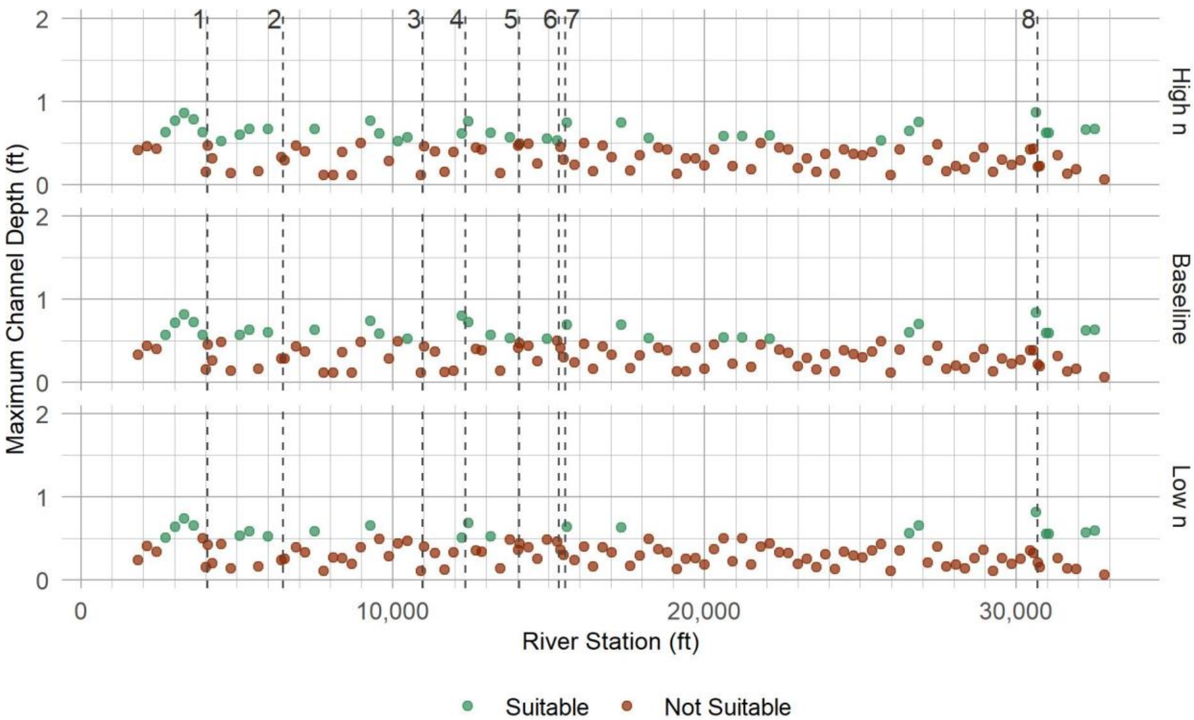


FIGURE 30: MODEL SENSITIVITY TO ROUGHNESS AT LOWER PASSAGE FLOW (1 CFS) – DEPTH SUITABILITY
Dashed vertical lines indicate culvert and bridge locations (Figure 25).

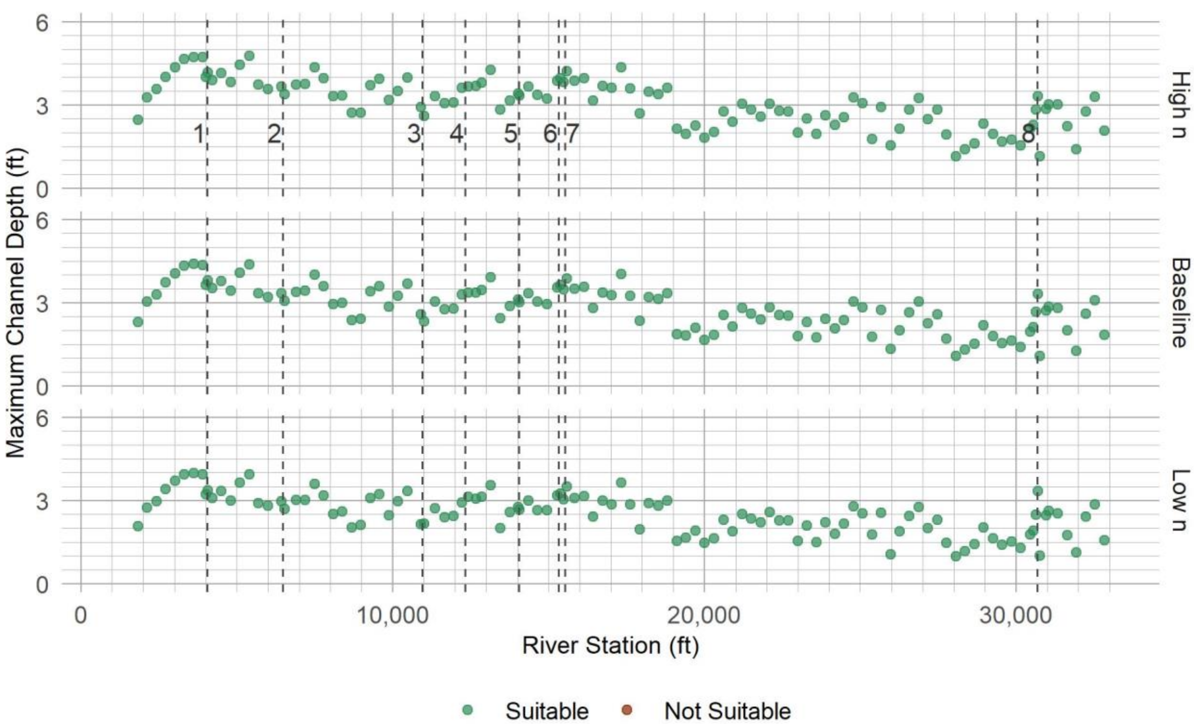


FIGURE 31: MODEL SENSITIVITY TO ROUGHNESS AT UPPER PASSAGE FLOW (168 CFS) – DEPTH SUITABILITY
Dashed vertical lines indicate culvert and bridge locations (Figure 25).

Agricultural Water Demand Modeling

Model Input Data & Methods

The DWR Consumptive Use Program PLUS (CUP+) model was used to estimate the annual applied agricultural water demand for wine grape, walnuts, and pear crops in the Big Valley subbasin for 2014 and 2019. The CUP+ model calculates annual applied water per unique combination of crop and soil type for a given year of climate data. The water demand per crop can vary depending on climatic factors such as solar radiation, temperature, humidity, wind, and precipitation. Results are given as evotranspiration of applied water (ETaw), which is an estimate of the net applied water required to produce a given crop in a year under the defined soil and climatic conditions. Therefore, evapotranspirative applied water demand results can vary annually for the same crop due to differences in precipitation, temperature, etc.

The inputs to CUP+ are climate, crop, and soil data. The Big Valley subbasin (CA DWR, 2016) was used as a spatial boundary for the agricultural water demand analysis (see Figure 32). California Irrigation Management Information System (CIMIS) station 106, Sanel Valley, was used for the daily climate data inputs to the model, which include: solar radiation; maximum, average, and minimum daily temperature, average wind speed, and precipitation. The Sanel Valley station is the nearest available station to the Big Valley subbasin and is located near the town of Hopland, CA, approximately 22 miles west of Kelseyville, CA. The station latitude and longitude are 38.982581 and 123.089280, respectively, and the elevation is 525 feet. Nearly all the crop reference parameters are provided within the CUP+ model, including growing period and crop coefficients per growing period. The maximum rooting depths for pears, wine grapes, and walnuts were referenced from University of California Davis at Division of Agriculture and Natural Resources (UCANR, 2020a).

USDA SSURGO data (Soil Survey Staff, 2020) was used to determine the soil water holding capacity for soils in the Big Valley subbasin. The SSRUGO parameter used is named “Available Water Storage 0-150 cm” and represents the volume of water available to plants within a depth of the first 150 centimeters of soil. These data are provided at the SSURGO “map unit scale” and are shown in the left map of Figure 34. Figure 34 shows the general pattern of soil available water storage throughout the subbasins, with higher values near Clear Lake and following Adobe and Kelsey Creeks. To reduce the number of modeling iterations, representative available water storage values were determined from the distribution of values in the subbasin. Figure 33 shows the histogram of the available water storage values. The histogram indicates a bimodal distribution, with a peak near the mean and median (15.2 cm and 16.4 cm, respectively) and a second peak near the maximum of the distribution (24.75 cm). Based on this distribution, water storage values were broken up into three classes: from 0 to 15, 15 to 20, and 20 to 24.75 cm. To determine a representative value for the three classes, the mean, weighted mean, and mode were calculated per class. These values are shown in Table 8, and the representative available water storage values were selected as: 9 cm, 15 cm, and 23 cm. The representative soil water storage values are shown in Figure 34, alongside the original data for comparison. For each year of climate data and crop type, three model runs were conducted for each representative soil available water storage value.

FIGURE 32: THE BIG VALLEY SUBBASIN WAS USED AS THE SPATIAL BOUNDAY IN THE AGRICULTURAL WATER DEMAND ANALYSIS.

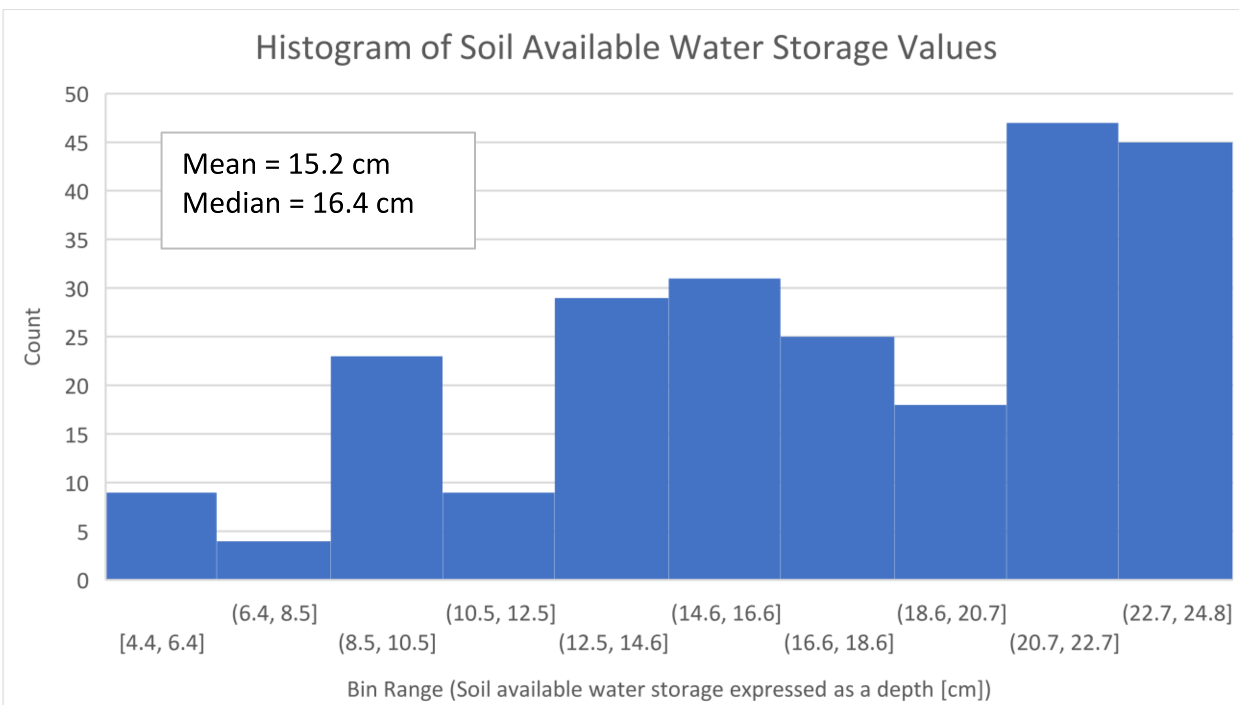


FIGURE 33: HISTOGRAM OF AVAILABLE WATER STORAGE SOIL AVAILABLE WATER STORAGE

TABLE 8: REPRESENTATIVE SOIL AVAILABLE WATER STORAGE VALUES

Class	Mean (cm)	Weighted mean (cm)	Mode (cm)	Median (cm)	Representative value (cm)
0 – 15 cm	9.4	9.8	9	9	9
15 – 20 cm	16.8	16.4	15	16.4	16
20 – 24.75 cm	22.9	22.7	23	22.7	23

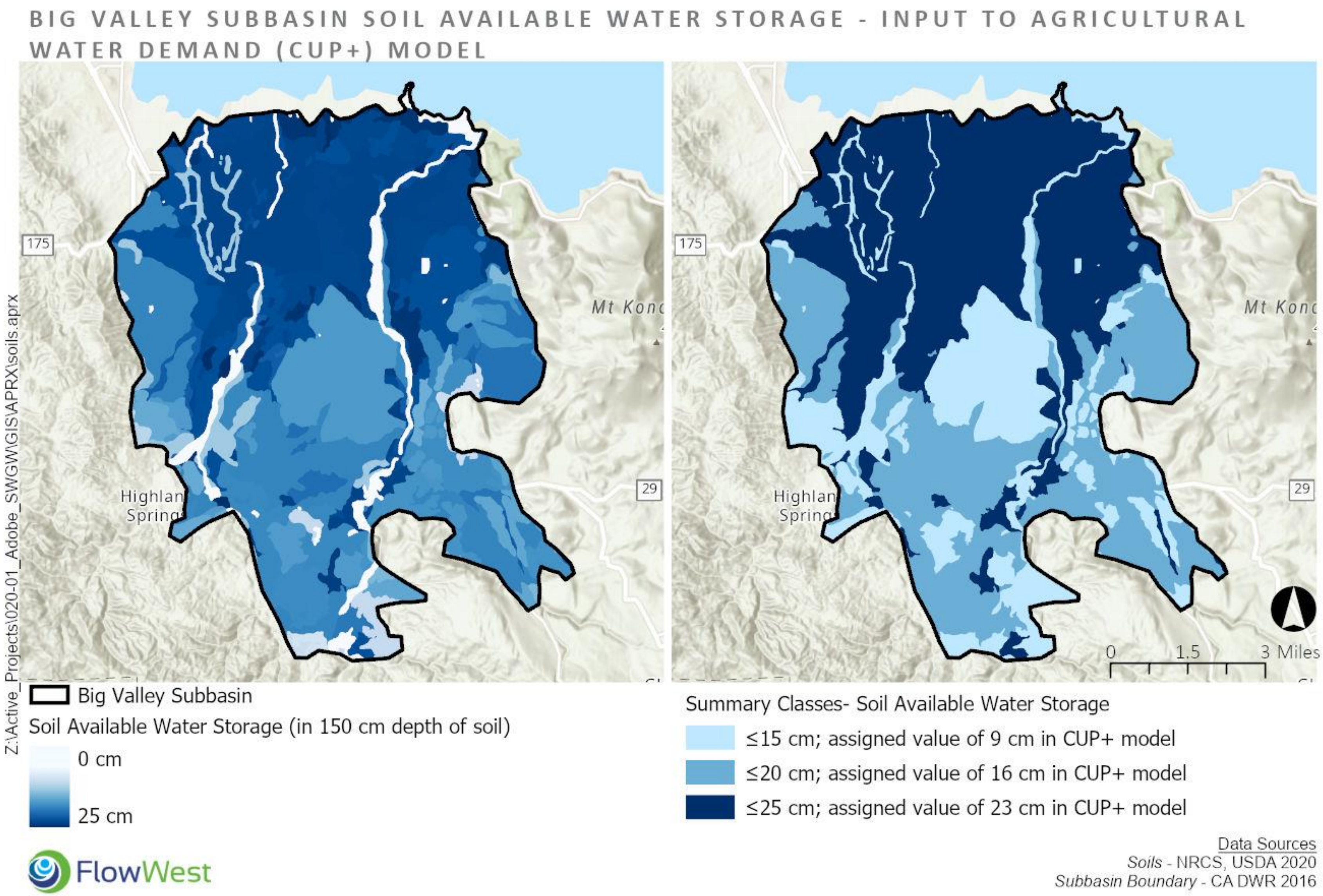


FIGURE 34: SOIL WATER HOLDING CAPACITY (AVAILABLE WATER STORAGE) SUMMARIZED FOR INPUT INTO AGRICULTURAL WATER DEMAND MODEL.

Agricultural Water Demand Model Results

The CUP+ model results are presented in Table 9. The agricultural water demand is estimated as a depth of water—the evapotranspiration of applied water necessary for that crop each year. The modeled water demand results are shown the column titled "Agricultural Water Demand (ETaw) [in]." The average value for each crop per year is also shown, along with the percent change in agricultural water demand 2014 to 2019 based on the average values for the crops. For all crops the CUP+ model results indicate increases in agricultural water demand from 2014 to 2019, 28% for wine grapes, 20% for pears, and 23% for walnuts.

TABLE 9: CUP+ MODEL RESULTS SHOWN FOR ALL THE SCENARIOS. THE MODEL RESULTS ARE EXPRESSED AS AN ANNUAL VALUE, THE DEPTH OF EVAPOTRANSPIRATION OF APPLIED WATER (ETAW) REQUIRED FOR EACH COMBINATION OF CROP, SOIL, AND YEAR OF CLIMATE DATA.

Crop	Year	Soil Available Water Storage [cm]	Agricultural Water Demand (ETaw) [in]	Average ETaw [in]	% increase from 2014 to 2019
Wine Grapes	2014	9	18.2	17.1	28%
		16	16.2		
		23	16.9		
	2019	9	22.1	21.9	
		16	22.4		
		23	21.1		
Pears	2014	9	23.6	24.0	20%
		16	24.4		
		23	23.9		
	2019	9	29.8	28.7	
		16	29.1		
		23	27.2		
Walnuts	2014	9	25.3	24.6	23%
		16	23.5		
		23	25.1		
	2019	9	30.6	30.2	
		16	30.9		
		23	29.1		

The model results shown in Table 9 indicate an increase in irrigation demand from 2014 to 2019 based on the difference in climatic conditions between the two years (assuming the soil parameters remain consistent). To investigate the agricultural water demand results within the context of crop acreages in the Big Valley subbasin between 2014 and 2019, several datasets were referenced:

1. U.S. Department of Agriculture (USDA) CropScape data
2. Lake County Crop Reports
3. USDA National Agricultural Statistics Service California Field Office Grape Acreage Reports

Cropscape is a spatial dataset and was reviewed for crop location and acreage information. The USDA CropScape program provides annual raster datasets of crops at 30-meter resolution. CropScape data is created using Landsat 8 satellite imagery and sensors collected during the growing season of the year reported. The Cropscape program has limited ground-truthing but reported approximately 85%-95% accuracy overall for major crops in California for 2014 and 2019 (USDA, 2020). Upon finding that Cropscape reported 0 acres of pear crops in Lake County for 2014, the Lake County crop reports and USDA grape acreage reports were referenced for comparison of total crop acreages at the County scale. The Lake County 2019 Crop Report is not yet published but estimates for 2019 were provided to the authors by the Agricultural Commissioner (S. Hajik, personal communication, July 22, 2020).

TABLE 10: CROP ACREAGE COMPARISON IN LAKE COUNTY.

Crop	Year	USDA CropScape data	Lake County Crop Reports[2]	USDA's National Agricultural Statistics Service California Field Office Grape Acreage report
Wine Grapes	2014	1,306	8,782	8,782
	2019	6,498	9,800*	10,014
Pears	2014	0	2,073	
	2019	2,053	1,800*	
Walnuts	2014	378	3,932	
	2019	4792	3,550*	

As shown in Table 10, the 2014 Cropscape data significantly under-reports the crop acreages compared with the Lake County Crop Reports. The 2019 Cropscape data aligns more closely with the countywide acreages reported by the Agricultural Commissioner, although the wine grapes and walnuts crop totals are both 34% different and the countywide pear acreage is 14% higher in the Cropscape data than the County Crop Reports. Due to the apparent data limitations, the 2014 Cropscape was not used to visualize agricultural water demand trends in the Big Valley subbasin. The 2019 Cropscape data was used to visualize the water demand, however, with the caveat that the county-level acreage comparison indicates the Cropscape data is likely to be approximately 15-35% off from what is reported in the County Crop reports.

Figure 35 show the 2019 Cropscape data for wine grapes, pears, and walnuts in the Big Valley subbasin. Figure 36 shows the modeled agricultural water demand for 2019 per crop and soil

[2] 2019 crop acreage totals are estimates from Lake County Agricultural Commissioner (S. Hajik, personal communication, July 22, 2020).

type. The highest agricultural water demand values along Adobe Creek track with the walnut crop acreages.

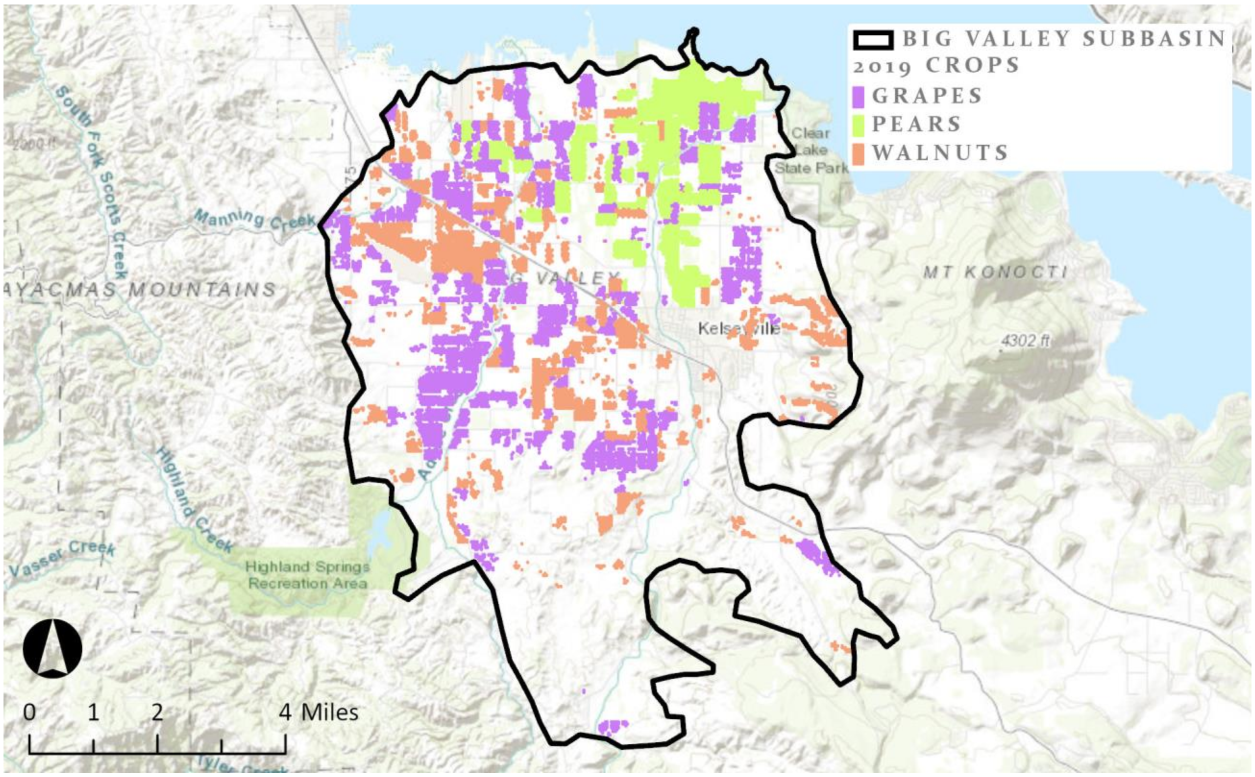


FIGURE 35: USDA CROPSCAPE 2019 LAKE COUNTY DATA

Discussion of Results

The preliminary analysis of agricultural water demand in the Big Valley subbasin shows an increase in the demand from 2014 to 2019 for pears, walnuts, and wine grapes of 20%, 23%, and 28%, respectively. This increase in agricultural water demand is due to the climatic changes between 2014 and 2019. Exploring these findings within the context of crop acreage changes for 2014 and 2019 is constrained by the available spatial data for crops. The Lake County Crop Reports show a 12% increase in wine grape crops in the County from 2014 to 2019, and 13% and 10% decreases in total pear and walnut crops, respectively. From the available data, it is impossible to determine whether the crop changes at the county-scale represent what is happening within the Big Valley subbasin. However, this preliminary analysis indicates that further study on this topic is warranted. The results show increases in the required water for crops based on the climate data for 2014 and 2019. For the Kelsey Creek-Clear Lake HUC-10 boundary, the 30-year projected climate change shows average increases in maximum and minimum temperatures of 3.7 °F and 3.2 °F, respectively (Cal-Adapt, 2020). A 2014 study on climate and wine grape production in Lake County analyzed data from 1954 through 2013 and found changes “due to warmer minimum temperatures include a 33-day reduction in the number of days below freezing (32°F) annually and a 22-day longer growing season length during 1965-2007” (Jones, 2014). The study also found that growing season precipitation for

Lake County has not changed significantly. Therefore, both the climate and agricultural production trends for at least wine grape crops indicate a likely increase in agricultural water demand in the Big Valley subbasin. However, further analysis of this is recommended examine these trends more specifically in the Big Valley subbasin and to quantify likely increases in water demand for agriculture. An improved understanding of the trends for agricultural water demand will aid in planning for and management of adequate instream flows to support the hitch.

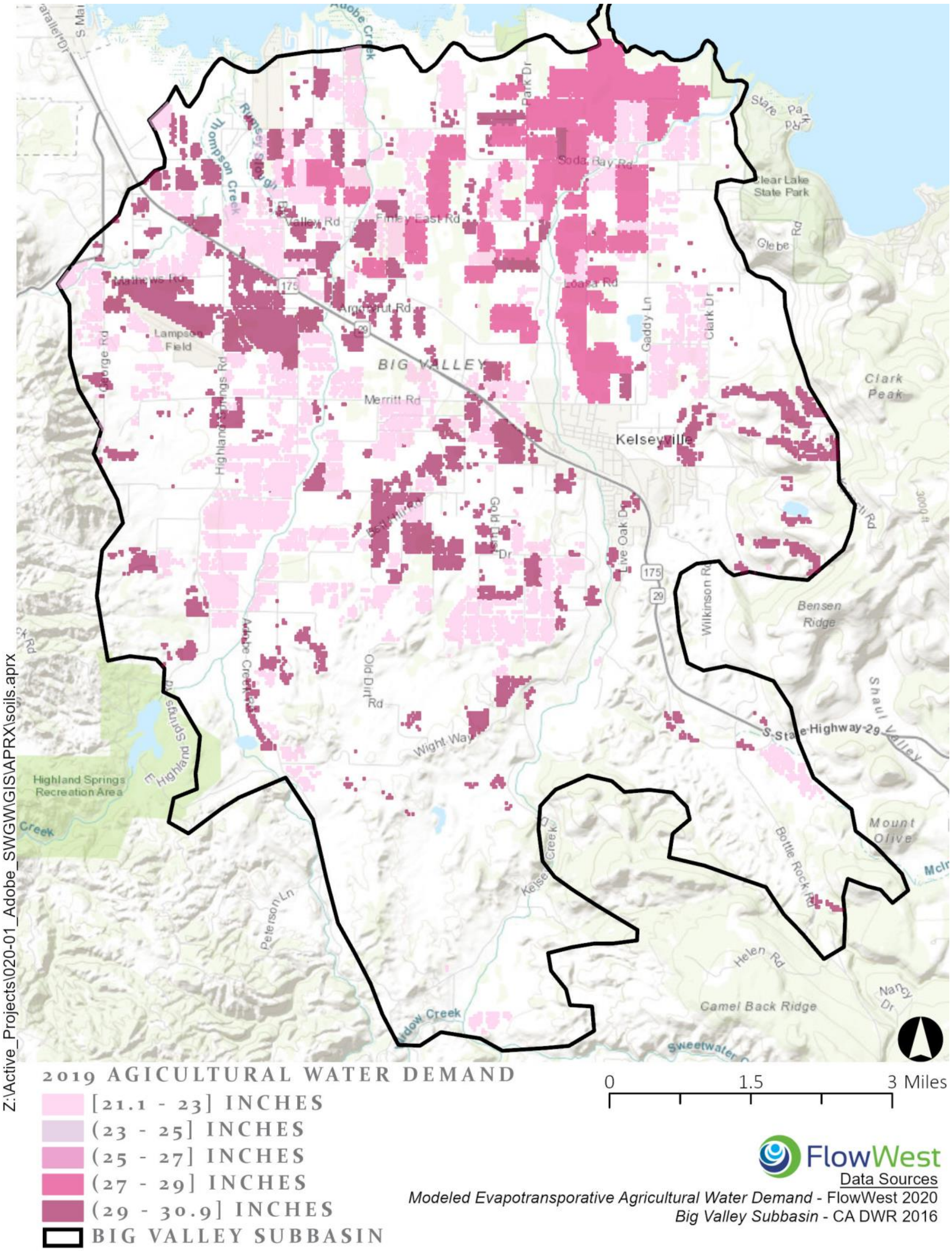


FIGURE 36: MODELED AGRICULTURAL WATER DEMAND FOR 2019 SHOWN PER CROP AND SOIL TYPE.

Recommendations for Groundwater/Surface Water Management to Benefit Hitch Lifecycle Requirements

Expanded data collection and monitoring of water resources and land use data are needed to ensure strategies to support Clear Lake hitch survival in Adobe Creek are effective and sustainable. Recommendations 1-5 are related to data collection and resource monitoring. Recommendations 6 and 7 are actions that FlowWest recommends the Tribe pursue.

1. **Surface water monitoring: High quality, reliable streamflow monitoring is essential for ensuring hitch survival.**
   - Newly installed pressure transducers should be maintained, and the data downloaded and reviewed periodically.
   - Additional pressure transducer streamflow gages should be installed in other tributaries that support hitch runs (e.g. Kelsey Creek and Scotts Creek).
   - The Tribe should conduct outreach to USGS and County to restore USGS gage on Adobe Creek and/or find funding source to restore gage.

2. **Monitor hitch passage and spawning to improve criteria for depth, velocity, and step height. The California Salmonid Stream Habitat Restoration Manual (CDFW, 2004) provides guidance for passage flows, but the manual is not designed for hitch and streamflow data is not recorded on Adobe Creek.**
   - Improved streamflow monitoring as identified in recommendation #1 will support this effort.
   - The Tribe should coordinate with CDFW to gather the necessary additional data to improve the understanding of hitch passage flow and depth criteria. Feyrer (2019) also asserts that additional study is needed to better understand the stream ecology of the hitch, including data on "the conditions which trigger the migration of Clear Lake Hitch into streams, whether the species exhibits philopatry [whether the hitch return to their natal territory to spawn] , and the full range of flow, velocity, temperature, substrate and other habitat features used for holding and spawning."

3. **Groundwater monitoring: Expanded locations and frequency of groundwater elevation data collected would enable tracking impacts of streamflow fluctuations on shallow groundwater table.**
   - Groundwater data in the Adobe Creek watershed is extremely limited. The Tribe should coordinate with the County on SGMA efforts to expand groundwater monitoring locations along Adobe Creek and advocate for at least monthly groundwater elevation measurements.
   - The Tribe should conduct outreach to the CASGEM Voluntary Well owners identified in this study to see if there is the potential to expand monitoring at these well locations.

4. **Adobe Creek channel terrain/bathymetric data: improved in-channel terrain data will help identify and monitor hitch stranding locations.**
    - As part of the post-fire recovery process, lidar is often flown. The Tribe should coordinate with post-fire recovery efforts to advocate for any lidar data collected to include Adobe Creek and for the flight to be conducted when creek is dry if possible.
    - Conduct in-channel topographic survey to update hydraulic model and gain a better understanding of available habitat and potential stranding and passage issues.

5. **Hitch counts: coordinate with Chi Council on Adobe Creek hitch monitoring plan before the next spawning season in February 2021.**
    - Identify when the hitch begin to migrate into Adobe Creek in 2021 spawning season.
    - Develop plan to periodically monitor locations identified as being depth-limited (Figure 28) throughout spawning season.

6. **Land use/crop data in the Big Valley subbasin: improved spatial data of crops along Adobe Creek is needed to better estimate the agricultural water demand and improve water resources planning.**
    - The Tribe should coordinate with the County of Lake / County Agricultural Commissioner office to potentially validate USDA Cropscape data and/or develop other approaches to document crop types and extents in the Big Valley subbasin.
    - If this data were developed, the agricultural demand modeling could be expanded to help estimate changing water demands due to climate change impacts, as well and manage water in the Adobe Creek watershed to support local agricultural and the survival of the hitch.
    - The California Natural Resources Agency also collects spatial data of crops. The most recent dataset available is 2016. When additional data is released by DWR, the agricultural water demand analysis should be updated with the most recent data.

7. **Replace the culverts at Bell Hill Road, which are passage barriers.**
    - Replace the existing low water crossing with a bridge to provide hitch passage and improve sediment continuity.
    - The current low water crossing is not passable for traffic during storm events and deposition of sediment upstream of the structure requires regular maintenance to keep the culverts clear of sediment and debris.

8. **Coordinate with the County to advance the reoperation of Highland Springs Reservoir to enhance streamflow for hitch habitat through the Adobe Creek Conjunctive Use Project, if possible, for the 2021 spawning season.** The Adobe Creek Conjunctive Use Project is planned to designate two hundred acre-feet of water for release in the spring

to supplement natural flows for the hitch, per the Initial Study for the project, which was completed in 2017.

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