SALMON PROTECTION AND WATERSHED NETWORK

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Lagunitas Creek Floodplain Restoration and Riparian Enhancement Project: Post-Construction Monitoring Report

Section 1: Introduction

Background

The Lagunitas Creek Floodplain and Riparian Restoration Project was proposed by the Salmon Protection and Watershed Network (SPAWN) to support improvements to riparian ecosystem function and address limiting factors for Coho salmon *(Oncorhynchus kisutch)* and other listed species in Lagunitas Creek. The focus area of the project is a one-mile stretch of Lagunitas Creek, including the former towns of Tocaloma and Jewell on the Golden Gate National Recreation Area (GGNRA). This reach of Lagunitas Creek has been impacted by historic residential development, encroachment from highways and railways, and watershed changes from a regulated flow regime and upstream dams (Houston 2018).

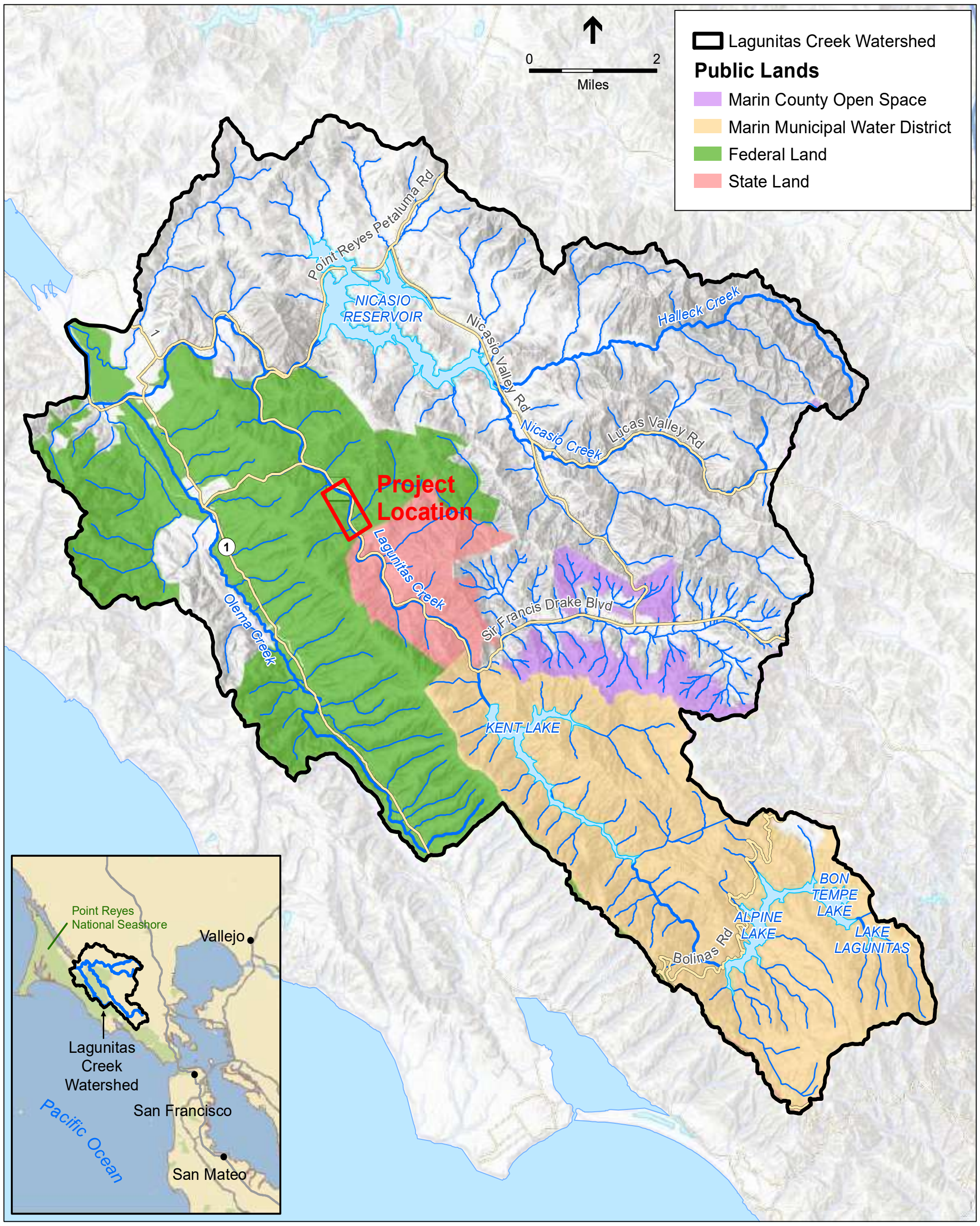
This reach of Lagunitas Creek between Devil's Gulch and Platform Bridge Road has been identified as one of the highest-quality habitats for Coho salmon in Lagunitas Creek (National Marine Fisheries Service 2012) and is known to provide important winter rearing habitat conditions, which are believed to be the limiting factor influencing Coho populations in Lagunitas Creek (Stillwater 2008). Given the high-value habitat and the opportunity to collaborate with the National Park Service, SPAWN conducted a feasibility study to determine opportunities for winter habitat restoration within the corridor, focusing on the locations around the former towns of Tocaloma and Jewell. This study evaluated watershed processes influencing the geomorphic conditions, assessed the biological habitat characteristics, and identified constraints and opportunities for channel and floodplain reconnection. This feasibility study resulted in development of conceptual designs for off-channel floodplain habitat restoration in specific locations. Following the completion of the feasibility study, SPAWN secured funding to prepare final engineering designs, environmental compliance and permitting.

The restoration designs included significant modifications and enhancement of the floodplain in the former developed areas which experienced importation of approximately 40,000 cubic yards of imported fill and 650 linear feet of armored banks and cement retaining walls. This material was imported to elevate structures above the floodplain. The basis of the design was to improve overall geomorphic function, reconnect the incised channel to adjacent floodplains, induce channel bed aggradation, promote large wood recruitment, and improve year-round habitat for Coho, with benefits to other listed species including the CA. freshwater shrimp (*Syncaris pacifica*). Removing the imported fill associated with the developments and selectively creating side-channels and off-channel habitats resulted in the formation of rearing habitat for juvenile salmonids during typical winter base flows while maintaining suitable habitat over a large range of large flows.

To help address limiting factors for Coho survival, including winter rearing habitat for juveniles, and implement actions identified in the Lagunitas Creek sediment TMDL, SPAWN secured funding for implementation of the Lagunitas Creek Floodplain and Riparian Restoration Project. Funders and partners include the State Water Resource Control Board, US EPA, California Department of Fish and Wildlife- Proposition 1 Grant Program, State Coastal Conservancy, The Each Foundation, and the National Park Service. Designs were prepared by Environmental Science Associates (ESA) and Hanford Applied Restoration and Conservation (ARC) was the construction contractor.

Phase I of the project occurred at the Tocaloma reach from August to October 2018. Revegetation and project monitoring occurred after October and this report summarizes the initial findings and results from the first year following the implementation of Phase I.

Figure 1: Regional map showing the project location. This location includes both the Tocaloma and Jewell reaches where Phase I and Phase II occurred.



SOURCE: Marin County

Lagunitas Creek Floodplain and Riparian Restoration Project . 150145

Figure 1
Regional Map

Section 2: Goals and Objectives

Project Goals

The goals of the Lagunitas Floodplain and Riparian Restoration Project are to reconnect Lagunitas Creek with the historic floodplain to 1) create complex off-channel habitats that address limiting factors for Coho survival, 2) increase large wood volumes and expand floodplain areas to meet targets of the Lagunitas sediment TMDL, and 3) improve overall riparian health and create habitats for other listed species.

Project Objectives

Below is a summary of monitoring methods, results, and analysis concerning important areas of focus that act as indicators to gauge the success and impact of the project. These topics include: Floodplain Inundation, Side Channel Activation Patterns, Sediment Metering, Salmonid Habitat Suitability, Large Woody Debris Accumulation, and Riparian Revegetation.

Objective 1: Floodplain Inundation

In 2018, over 13,200 cubic yards of imported fil and concrete debris were removed to clear the fill pad and retaining walls and excavate the floodplain/ side-channel complex. The floodplain excavation aimed to create a multi-stage channel network with channels, benches, and slopes that provide a range of suitable Coho rearing habitat throughout the corridor as flows change.

The objective was to create 4 acres of seasonal floodplain inundation in which off-channel features are activated through a large range of storm events. The first phase of the project at the Tocaloma Site contributed to 4 acres of new floodplain habitat. Phase II at the Jewel site will contribute additional acreage of seasonal floodplain habitat, to be constructed in 2019. Following completion of the restoration in 2018, SPAWN staff and interns have been monitoring the project and collecting data on how the multi-stage design has responded to changes in discharge. To measure the inundation patterns spatially across the site, stream discharge data was collected from USGS Gauge #11460400 in Samuel P Taylor State Park. Photos and videos were taken in designated points throughout the sites that correspond to measurements of flow discharge. The spatial and temporal patterns of floodplain inundation were analyzed using static photos, time-lapse photos, and real-time videos of water moving through the site. Figures 1 and Figure 2 below show the spatial extent of floodplain inundation during two storm events in February and May 2019. The photos below the figures represent the spatial extent of water at the site that correspond to the discharge of the stream gauge. The figures were digitally mapped using a Garmin hand-held GPS unit to help map the area of inundation during the specific runoff events.

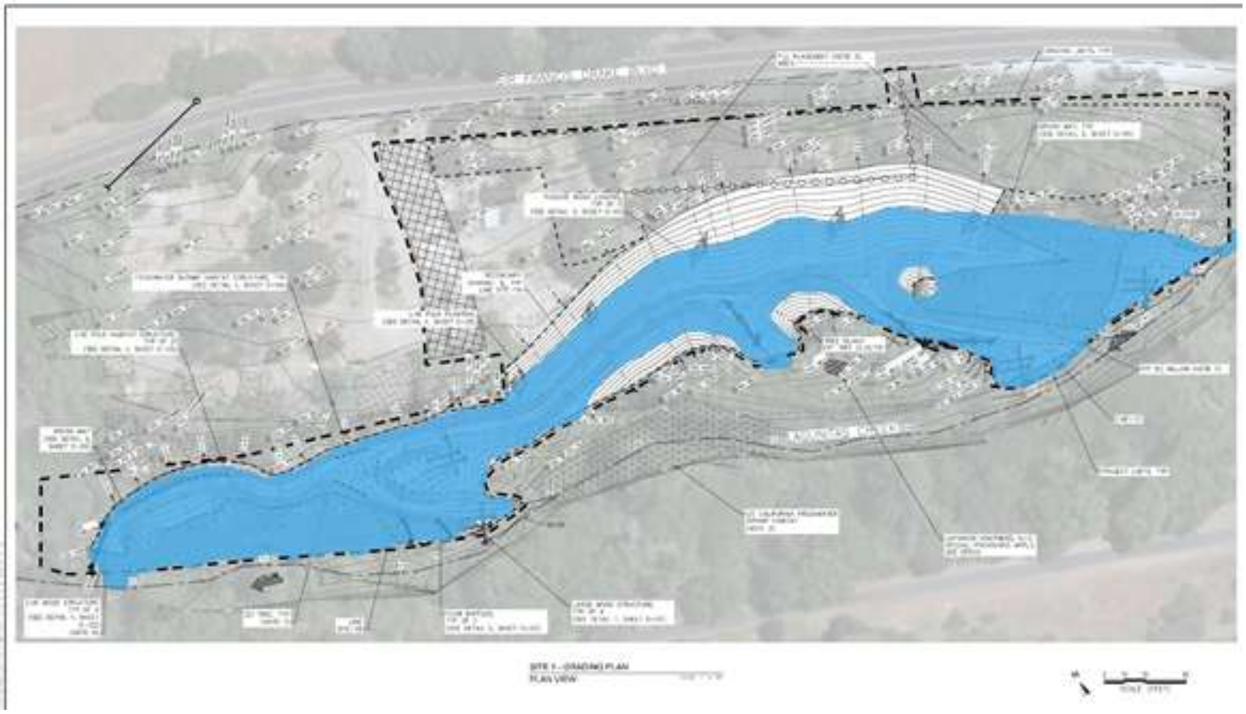
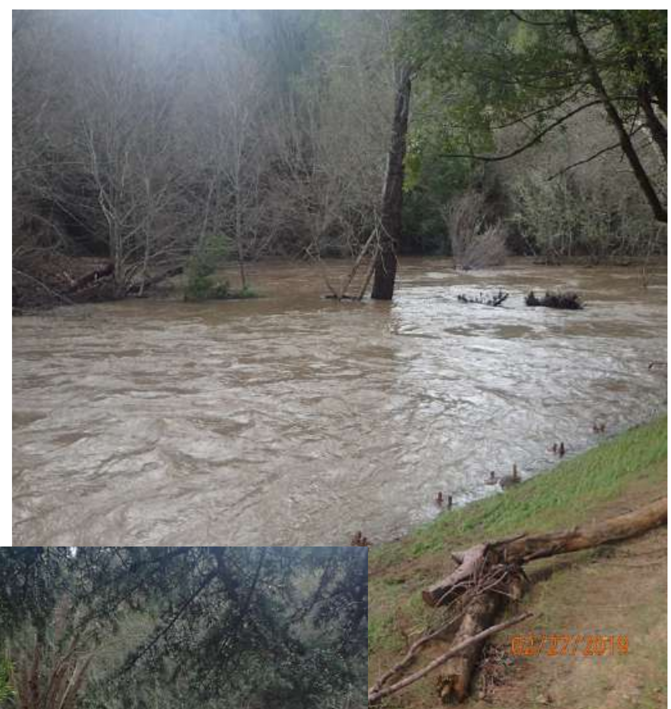


Figure 1. This shows the spatial extent of water inundation on February 27, 2019 at approximately 12:30pm. The discharge measured at the Devils Gulch stream gauge 2 miles upstream at this time was approximately 2,030 cfs.



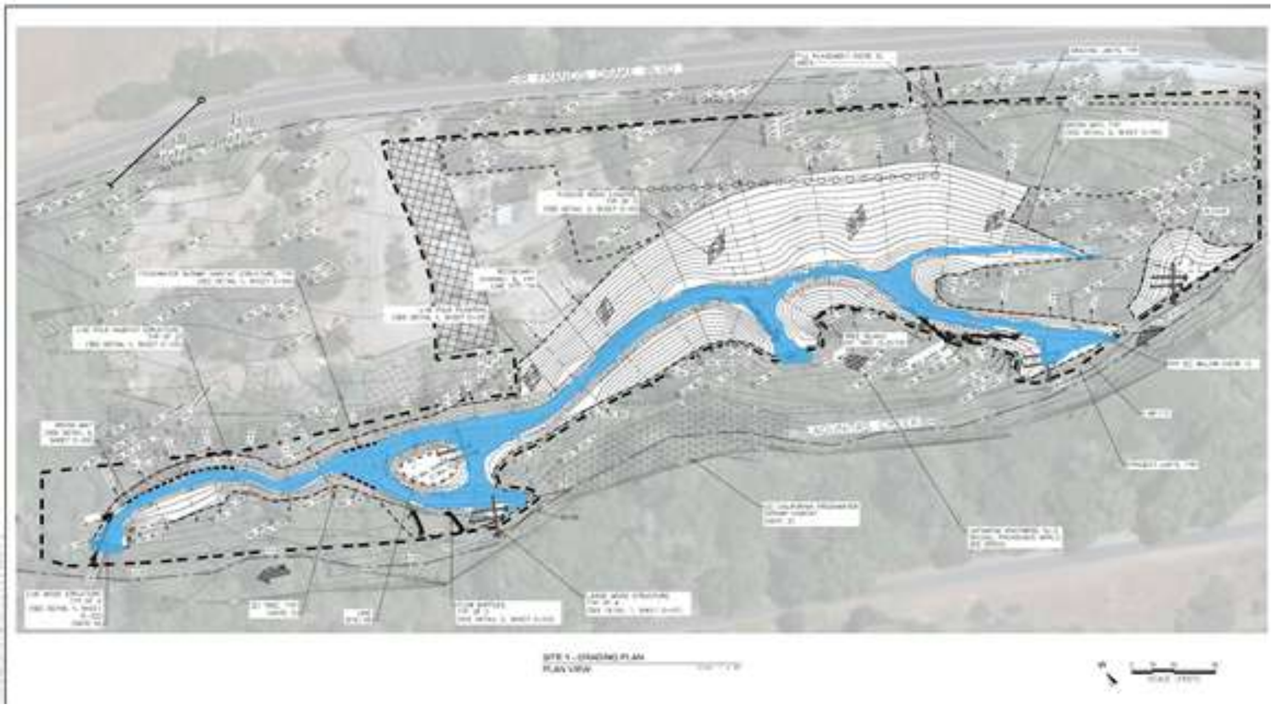


Figure 2. This shows the spatial extent of water inundation on March 01, 2019 at approximately 10:40am. The discharge measured at the Devils Gulch stream gauge 2 miles upstream at this time was approximately 304 cfs.

The spatial inundation patterns of the floodplain restoration using photos and time-lapse video showed that the floodplain restoration provided a multi-stage channel network that became activated with flows over a wide range of discharge. For example, from the photos and time-lapse video, we observed that the high flow seasonal channel shown in the photos above was activated with surface flow by low-range storms (>65cfs). The upstream alcove and high flow channel at the most upstream point of the project site activated with surface flow and becomes inundated at bankful storms (~350 cfs). The floodplain bench perched uphill of the seasonal channel that is activated and inundated with flows (>550 cfs). Lastly, the side channel at the downstream extent of the project area maintained inundation and surface flow year-round with flows (<10cfs). This multi-stage floodplain network experienced changes to the spatial extent of inundation as flows changed. As shown in Figures 1 and 2 above, the wetted area of the floodplain was approximately 3.65 acres with flows at 2,030 cfs, and approximately 0.80 acres with flows at 304 cfs.

Objective 2: Side Channel Activation

Following the removal of imported fill and retaining walls, side channels were constructed at Phase I comprising perennial and seasonal side channels with lateral connections and alcoves. To measure the total length of side channels and off-channel habitats constructed, channels were measured with as-built surveys and with a tape measure. As-built surveys did not survey all of the seasonal and perennial off-channel branches, therefore additional measurements were taken with tape to account for the branches left out in the surveys. In total, approximately 1,165 linear feet of side channels and alcoves were constructed under Phase I. As-built surveys are included in this report as an appendix.

To measure the temporal patterns of side channel activation, maximum daily flow during the 2018-19 winter season was graphed using data from the USGS stream gauge at Devils Gulch (Figure 3). When flows were identified at (>45 cfs), the seasonal side channel was documented to have surface flow. Therefore, Figure 3 below shows the number of days that the season high-flow channel was activated and inundated throughout the 2018-2019 winter season. Days highlighted in red had a maximum flow over 45 cubic feet per second (cfs), which represents the threshold needed to activate side channels and allow water to flow through them. After February 13th, however, the maximum threshold increased to 100 cfs because large storms brought in large gravel deposits that filled in the mouth of the side channel by 1-2 feet. Accounting for this change in the threshold needed for activation, the results of the data show that the seasonal side channel was activated for a total of 84 days from November, 2018 through May, 2019. The greatest duration of flows occurred during February and March when the channel was activated with surface for 48 days during these two months. The longest period of continuous activation was at the end of February/beginning of March when the channel was flowing for 19 consecutive days. In total, from November through May 2018-2019, the seasonal channel was activated with surface flow for a total of 77 days. The perennial side channel also continued to flow through the winter, spring, and through the summer 2019 at a base flow of 8 cfs.

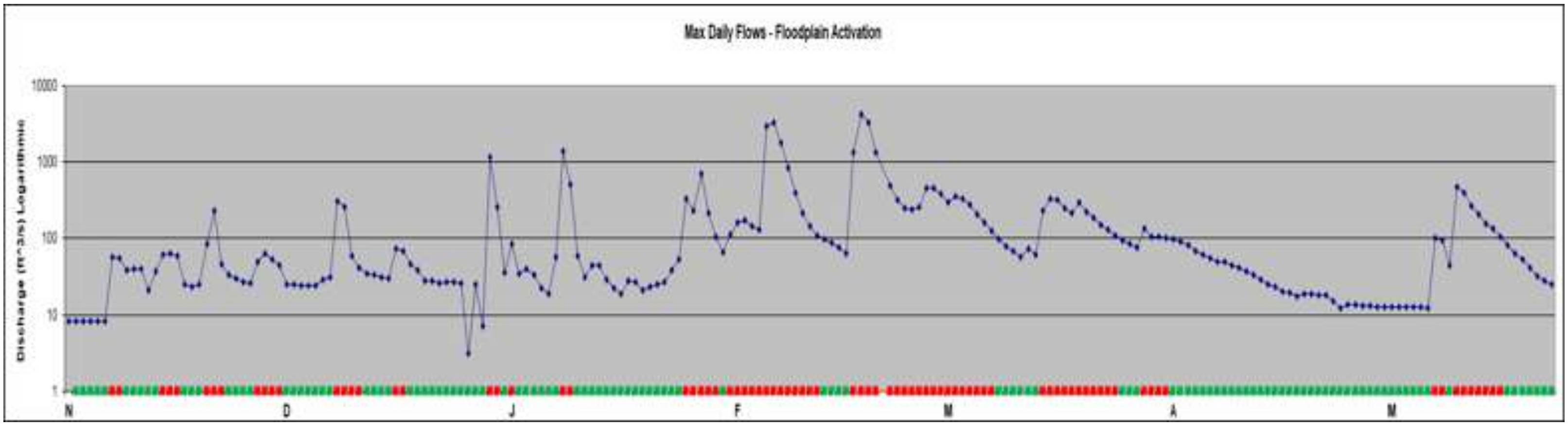


Figure 3. Floodplain activation based on maximum daily flows from Nov 2018 – May 2019. Days highlighted in red represent flows above the threshold (45cfs) needed for activation of the seasonal side channel, and days in green represent flows below the threshold. Note that after February 13, 2019 flows of 100cfs were needed to activate the seasonal channel since 1-2 feet of sediment accumulated at the mouth of the inlet. This is accounted for in the figure.

Data of flood stage was also recorded prior to and following restoration to illustrate differences in water height following the project. Data was taken before (2016-17) and after Phase 1 (2018-19) restoration to monitor the height of the water during storms using a staff gauge (Figure 4). The staff gauge was installed in 2016 and has remained in place without being relocated or disturbed. The gauge was left in place during construction to get an accurate reading pre- and post-construction. During storm events the level of the water was recorded manually using the height it registered on the gauge. We compared stream height to USGS streamflow data using the date and time of the recording, accurate to the nearest 15 minutes. The results show a reduction in flooding by at least 1 foot for any of the recorded storms as a result of the project. This might suggest that through the removal of over 13,200 cubic yards of dirt and debris, and allowing the floodplain to help attenuate the runoff, space was created immediately upstream of the staff gauge to handle water flows where water had not previously been able to spread out. In total, 13,200 cubic yards of debris translates to about 2 million gallons of water that can occupy the space now available on the floodplain. This increase in the cross section of the riparian corridor has allowed flood stage to reduce by approximately 1-2 ft on any given storm following the restoration. Records were taken only on storms >500 cfs due to the placement of the gauge above the baseflow channel.

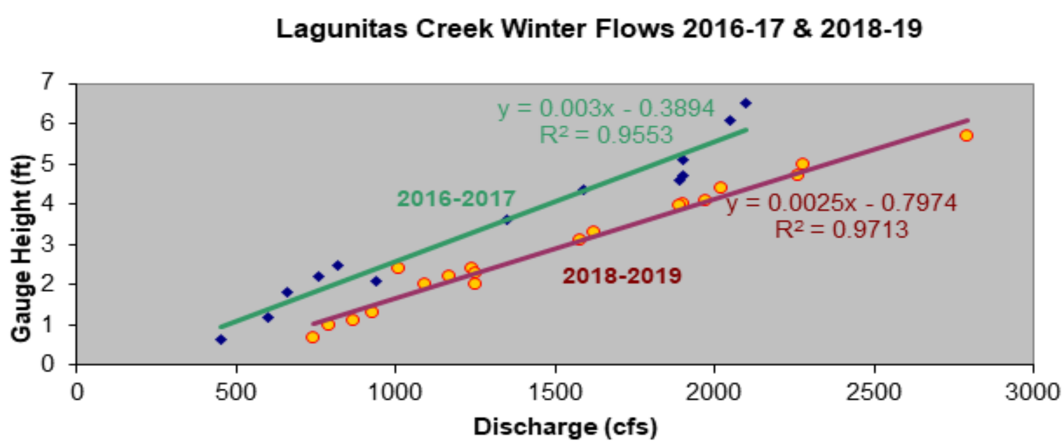


Figure 4. Discharge vs. Water Surface at the project site during the winter of 2016-17 compared to 2018-19.

Objective 3: Sediment Metering

The topography of the floodplain features that add sinuosity to the channels create opportunities for sediments to sort and be metered through the floodplain areas. Elements such as large woody debris jams, channel bends, point bars, alcoves, and undulating topography create locations where slow water can drop fine sediments such as sand and clay, while in-channel faster water can transport larger stones and gravels.

Lagunitas Creek is impaired for fine sediment, primarily sand, and the Tocaloma reach where this project occurs has been identified in the Lagunitas Sediment TMDL as a location where large woody debris installation and floodplain restoration should occur to help attenuate the fine sediments on floodplains and off-channel areas (SFRWQCB 2018). The site experienced flows as high as 4,100 cfs during the winter of 2018-2019 where storms created significant geomorphic changes that included sediment transport and deposition throughout the project area. To monitor these changes, we mapped the spatial extend of sediments as they were deposited throughout the site following the winter flows. Categories of sediments were broken into two size classes: fines (sand and particles <2mm diameter), and gravels (>10mm diameter). The map below demonstrates the result and extent of sediment deposition following the winter flows.

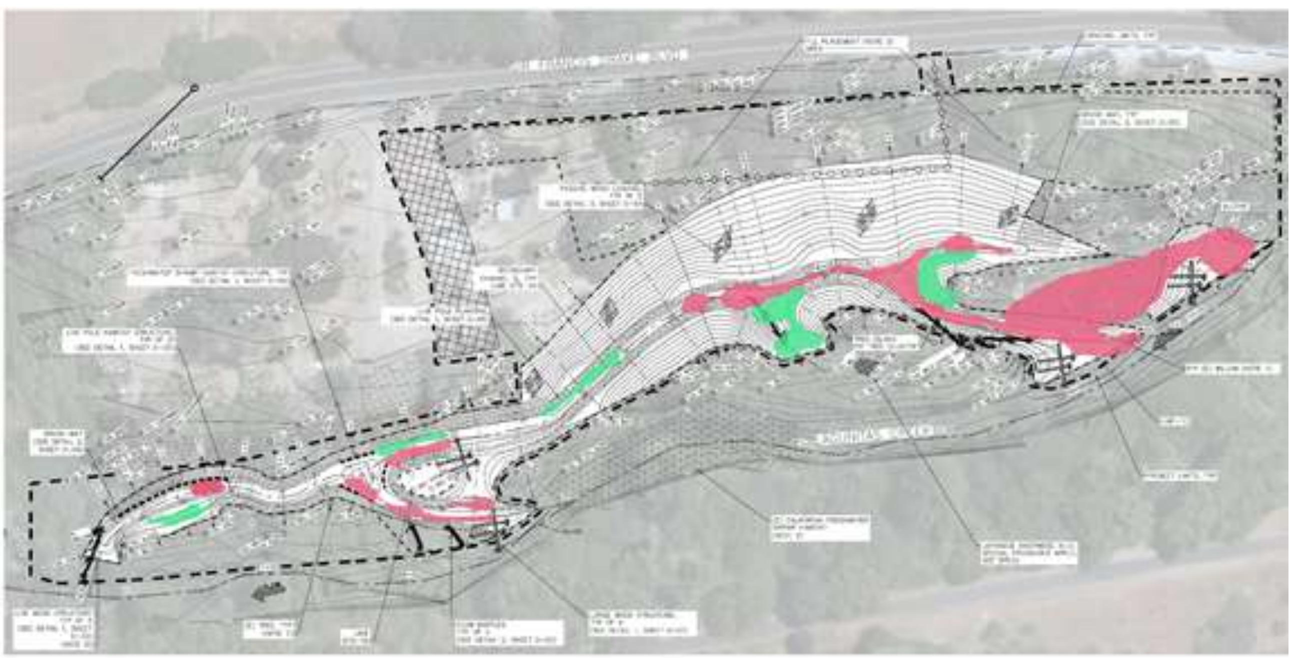


Figure 5. Coarse sediment (>10mm in red) and fine sediment (<2mm in green) deposited in select areas during the winter of 2018-2019, primarily as a result of high flows approaching 4,000 cfs.

Most notably at the upstream extent of the project area, large volumes of coarse bedload deposited in at the alcove feature. This result was anticipated given that prior to the restoration, the channel was incised and more efficient at moving coarse bedload. However, as a result of the slight expansion in the width/depth ratio at the riffle crest, the result was approximately 1-2 feet of bedload deposition in the low flow channel that resulted in a simultaneous rise in water surface, therefore reducing the degree of channel incision locally and upstream of the alcove. Plumes of coarse gravel also were laid down in the seasonal and perennial side channels, directly adjacent to features such as woody debris or undulating topography that captured fine sediments. The difference in spatial distribution of fines and coarse sediments moving through the project area demonstrate the ability for floodplain restoration efforts to allow sediments to sort and meter through the riparian corridor. The photos below demonstrate how sediments were metered and sorted on the floodplain following the winter flows.


Before (November 2018) After (February 2019)

Note the accumulation of gravel at the riffle crest. Water surface raised approximately 3 feet.



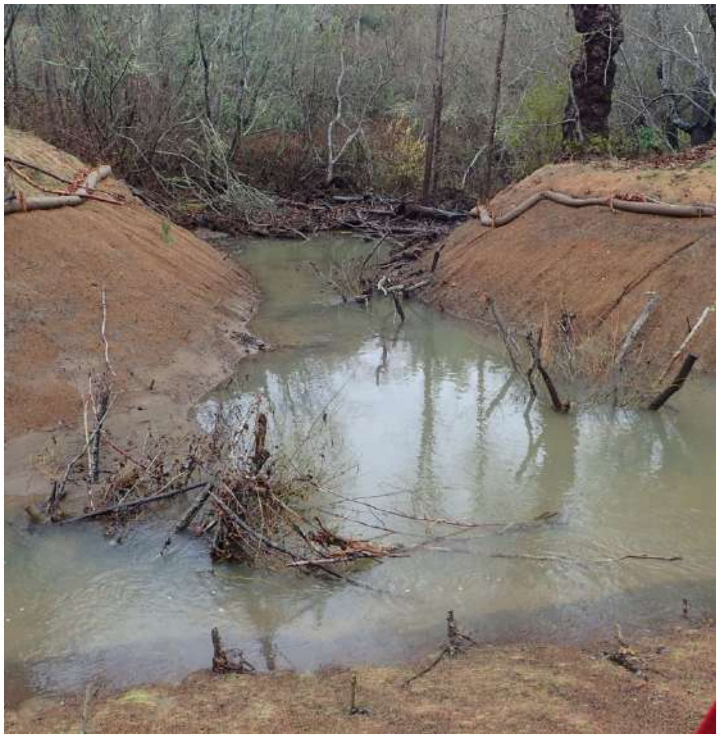
Before (November 2018) After (February 2019) After (March 2019)

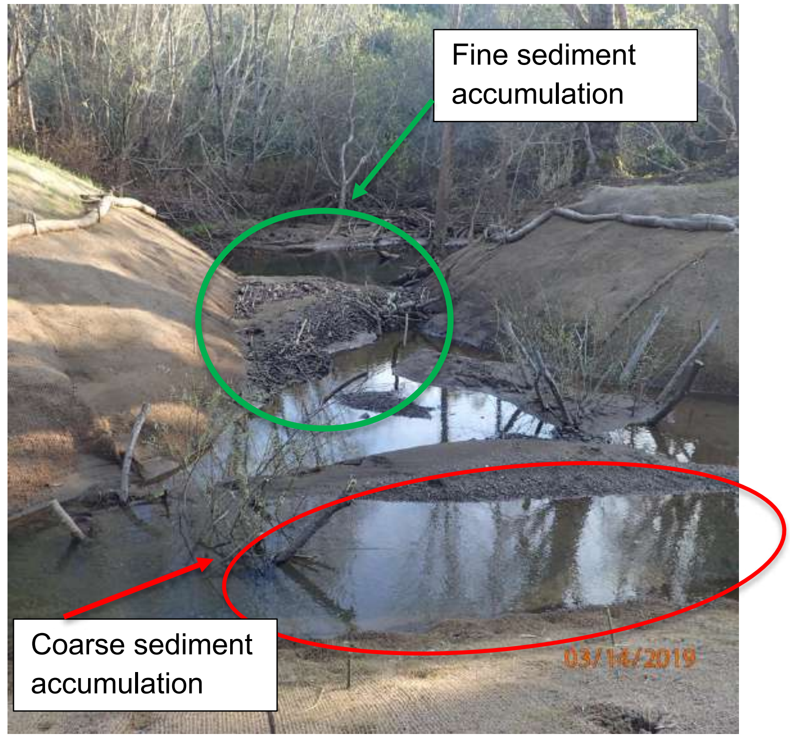
Note the large accumulation of gravel (middle photo) at the inlet of the seasonal channel during the February 2019 storms. Following the February storm events, the gravel that accumulated at this inlet was transported further downstream into the seasonal channel.

Before (November 2018)

After (March 2019)

After (February 2019)

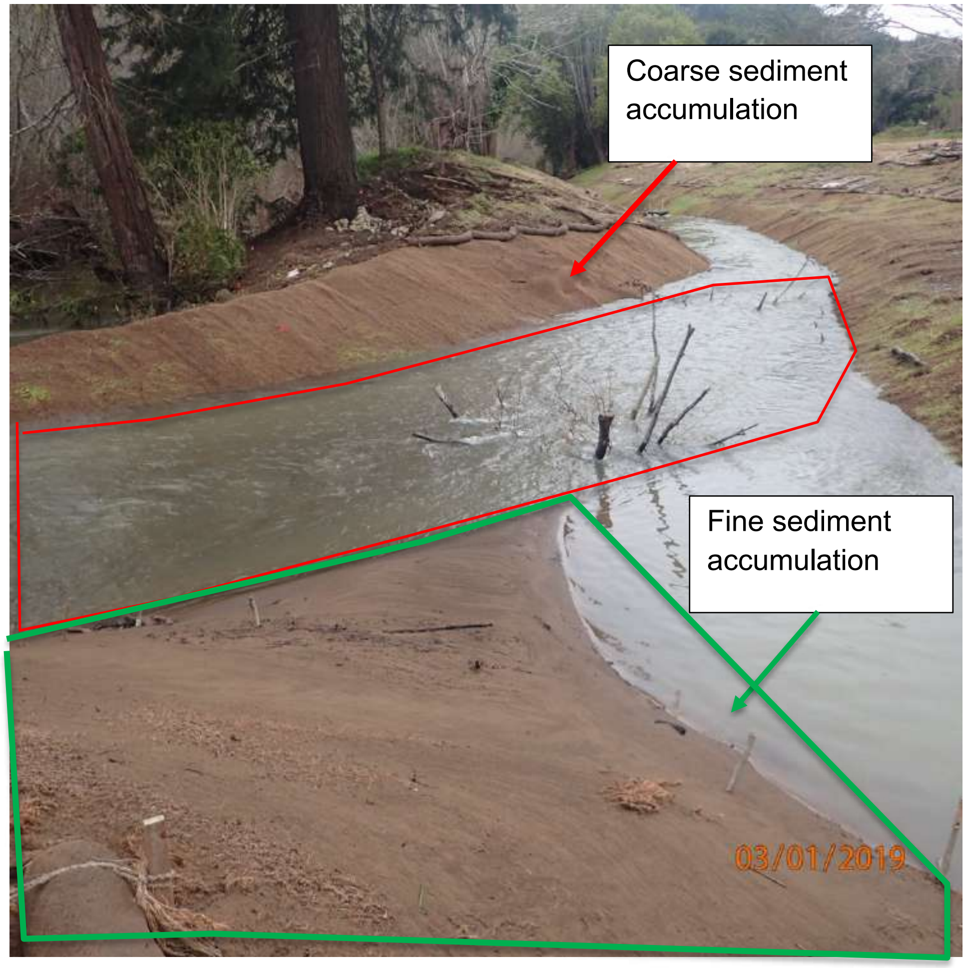




Before (November 2018)

After (March 2019)

Note the significant accumulation of fine sediment in the center of the lateral channel connection. This material is composed primarily of sand and wood.
In the lower portion of the photo on the right is coarse material that accumulated in the channel where sediment transport capacities are higher. This is an example of how sediment is sorting and metering due to undulating topography and small instream wood.



This photo demonstrates the self-sorting capacities of the channel networks. From the left of the photo is the seasonal channel inlet where coarse material has been deposited and transported downstream through the channel. On the right of the photo is a high flow channel that acts primarily as a backwater during flows below bankful (~350 cfs). The accumulation of fine sediment here in this photo is a result of a tree island creating a velocity shadow where slow water and fine sediment accumulate.

Objective 4: Large Woody Debris

The Lagunitas Sediment TMDL implementation plan calls for actions to increase the volume of wood throughout the stream corridor. Specifically, the Lagunitas Sediment TMDL calls for the hardwood-dominated riparian stream corridor, including the Tocaloma reach, to achieve at least $100m^3$ of large woody debris per hectare (SFRWQCB 2015). A primary goal of this project is to add wood to the stream channels to help achieve this target of $100m^3$ per hectare. The TMDL target goal of achieving LWD loading of ≥ 100 m3/ha (in hardwood channel - the channel type of the project area) was evaluated against pre-construction LWD volumes. Below is a calculation of minimum wood loading target for this project:

≥ 100m3/ha. (30ft x 1,200ft) à [30ft (avg. bank-full width) * 1,200ft (length of stream treated)]
= 36,000ft2
(36,000 ft2) = 0.826 Acres
(0.826 Acres) = 0.334 Hectares
≥ 100m3 / 0.334ha = ≥ 33.4m3 TMDL target for 1,200 linear feet of stream channel.

Therefore, the target for LWD loading is ≥33.4m3 TMDL across for 1,200 linear feet of stream channel.

Pre-construction field observations determined that the volume of large woody debris before Phase 1 construction was approximately 14m^3 per hectare. Most of the wood appeared as wracking material and pinned logs along the channel margins.

To help achieve the target of ≥33.4m3 of large wood per hectare, a total of 4 anchored large woody debris structures, totaling 8 anchored logs with root wads were installed into the channels, primarily to force flows into channels and rack up wood debris. Another method to help achieve this goal was passively loading wood and logs on banks and terraces to be recruited into the stream. Approximately 12m^3 were added passively to the graded slopes and terraces and roughly 9m^3 had been recruited into the channels as a result of the high winter flows. Lastly, numerous living woody debris structures, primarily willow, were installed in the side channels that provide additional racking of wood debris.

To measure large woody debris accumulation in the channels following winter flows in 2018-2019, woody debris was identified in the creek as individual pieces, mobile/driftwood, racked logs or debris jams. All wood measured and considered part of the target TMDL goals was found at or below the bankful height. This limited all wood considered for TMDL targets within the main stem, side channels, and off-channel areas of the project. Wood found above this bankful limit and on high-flow banks were not included in achieving this target.

Wood identified within the project area below the bankful mark was measured for length, width, and depth with a tape measure. This included individual logs and racked debris. Large, intact wood jams were measured for average length, depth, and width as a continuous unit. Measurements of the length and average width were taken using a tape measure and a stadia rod was used to measure the average depth. Volume was calculated by multiplying the average width, length and depth of each wood jam, log, and racked debris and converting to m^3. The area of the creek in hectares was calculated by measuring the length and average width of the mainstem and perennial side channel using a tape measure. Finally, m^3 per hectare of wood was calculated by dividing the total wood volume by the total creek area.

<u>Results</u>

The goal was to have at least ≥33.4m3 of large woody debris within the channels at the Phase I site. This goal was surpassed with wood volume below the bankful channel height <u>totaling approximately 40.0 m3 of LWD</u>.

This material consisted of large key pieces, small racking material, log jams and pinned logs along the mainstem and channel margins. The live willow structures in the side channel racked up several key pieces (>6in diameter) but consisted primarily of smaller debris. Three large, intact wood jams were found throughout the project area, the largest wood jam was found where the perennial channel diverges off the mainstem. A noteworthy contribution to the large woody debris in the channel was the recruitment of a mature redwood tree (4 ft diameter) with rootwad that fell into the channel as a result of the project. This tree was not intentionally pulled into the channel during construction but has added significant wood to the system.

The above picture is of the floodplain after the February 27, 2019 storm where the discharge at the Devils Gulch stream gauge 2 miles upstream read approximately 2,030 cfs. Wood that was passively left on the banks were pulled into the creek and racked up further downstream.

Below are photos of example woody debris structures and pieces found within the project area.

Located in the mainstem of Lagunitas Creek within the project area, this large woody debris jam consisted of 4 key members (>9in diameter), but contained a significant about of smaller debris that racked up as a result.

Photos below show pieces of large woody debris that were installed and anchored as a component of the restoration, or racked up and accumulated in the project area during the winter of 2018-2019.

Anchored rootwad, and additional rootwad to left of this one shown was covered in coarse bedload

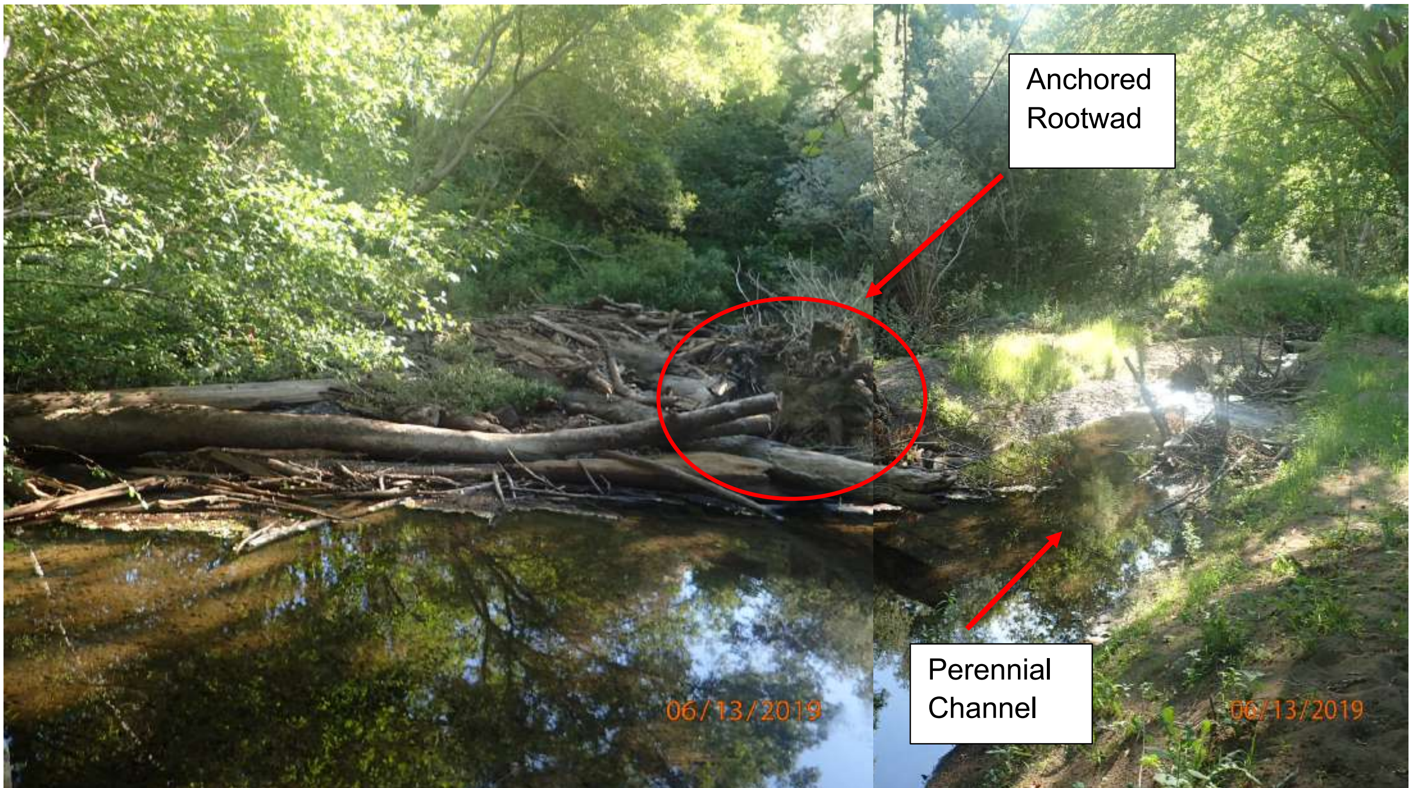
Fallen 4ft diameter redwood into perennial channel

Large woody debris jam formed in mainstem channel.

Example of willow pole structure racking small debris

Large log racked up along channel margin

Wood rack in mainstem at side channel inlet

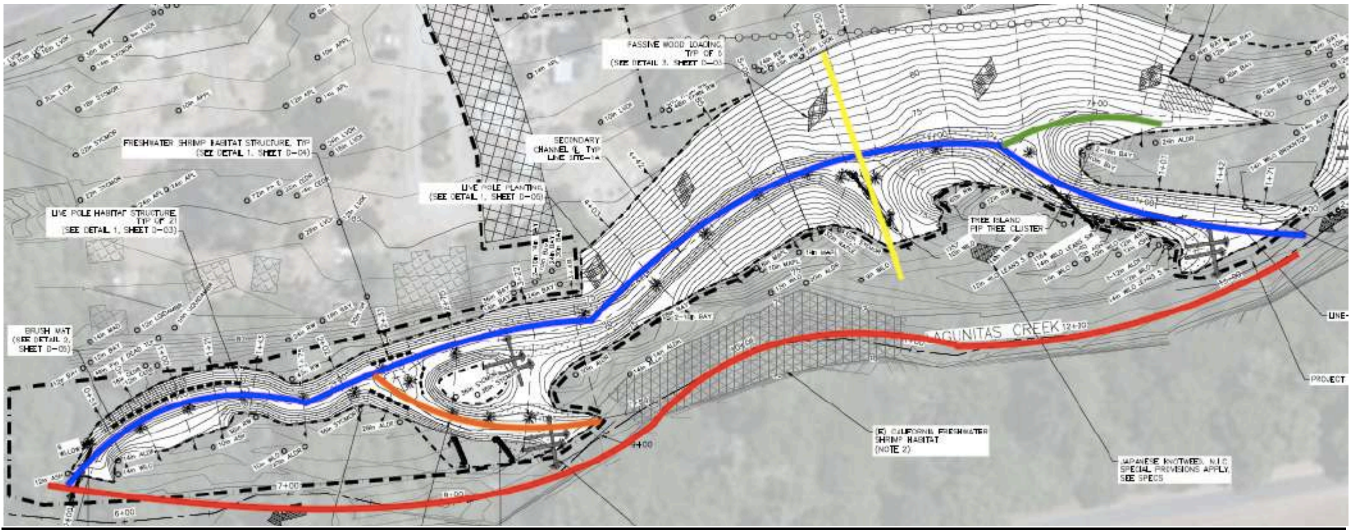


Large woody debris jam located at the connection of the perennial channel with the main stem. Two large anchored logs and rootwads caught large key members and racked the rest of the material.

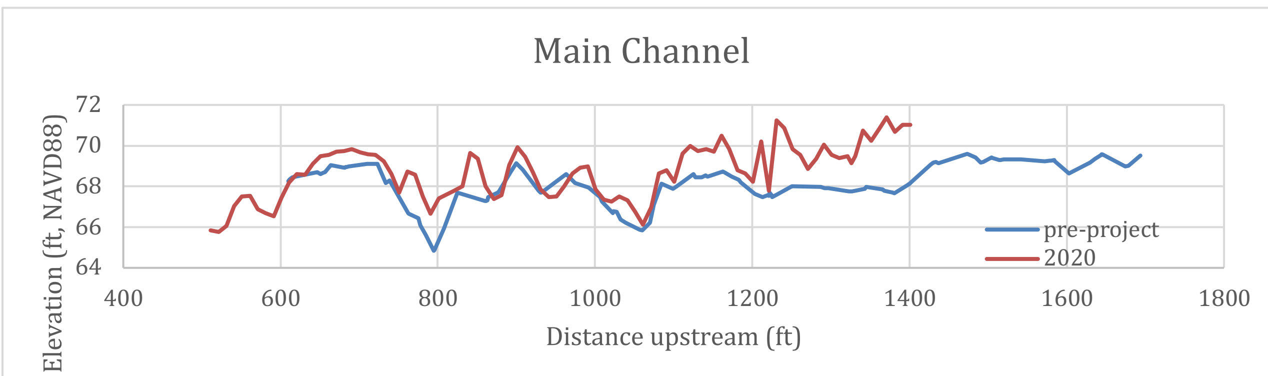
Objective 5: Profile Elevation Survey

A profile elevation survey was completed using an auto-level in March 2020. Since the completion of the project in summer of 2018, the restoration area has experienced two winters (2018-2019, 2019-2020), influenced by Lagunitas creek's flood regime. As covered in this report, floodplain inundation, side channel activation, sediment accumulation, and large woody debris, contributes to a changing elevation within the side channel, and subsequently in the mainstem channel. The below graphs represent the change in elevation of the channels within the project area as a result of the project and accompanying winter flows. These channel profiles were compared as-built channel profiles collected after construction, prior to any winter flows.

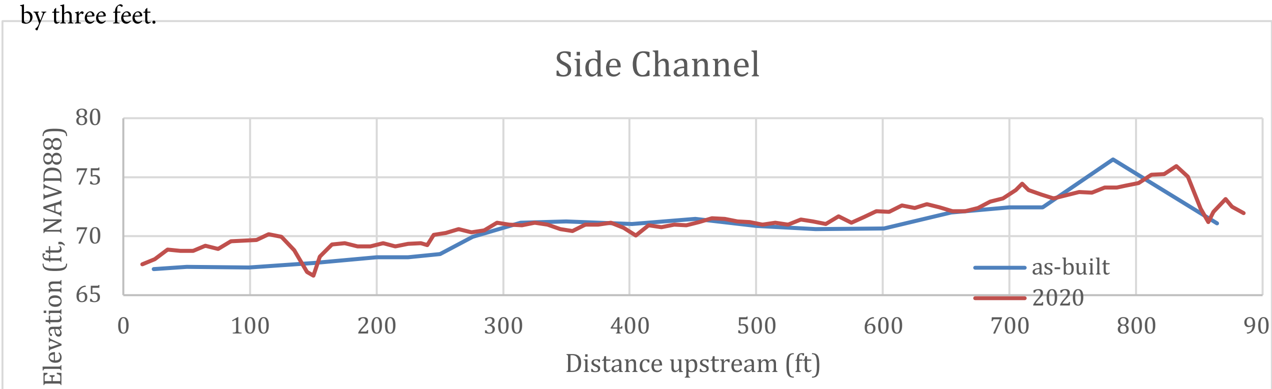
The most obvious result of the profile analysis was observing the rise in the channel bed, and water surface, within the main channel at the most upstream end of the project area between stations 1200 and 1400. The restoration actions from over-widening a small, select location of the main channel resulted in a decrease in sediment transport efficiency and accumulation of coarse bedload. This new channel geometry created a 250 ft long riffle/pool complex where a plane-bed reach existed before. The result has also reduced channel incision at this location by 3 feet, creating a backwater effect propagating upstream, helping to inundate more floodplain habitat upstream. This result shows that by creating small, isolated alcoves within the channel, stream channel incision can be reveresed.



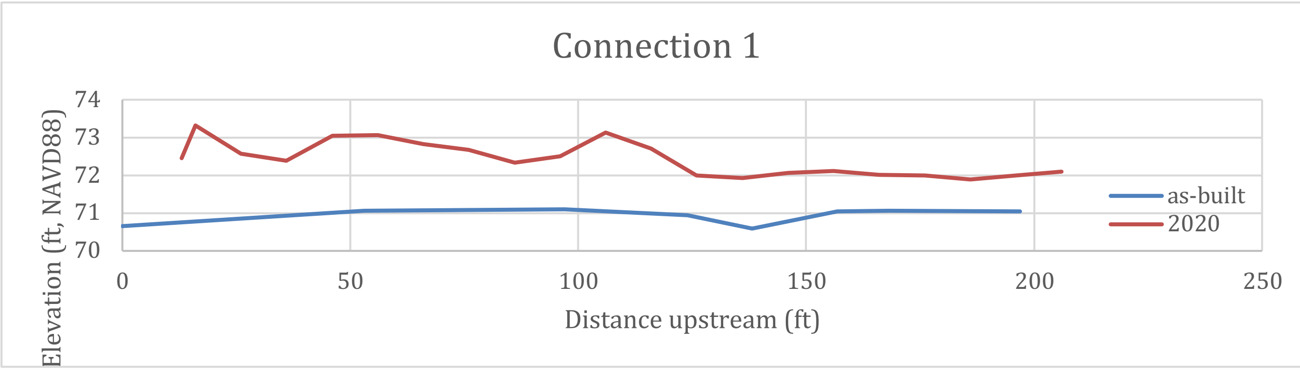
Red: Main channel. *Blue:* Side channel. *Green:* Connection 1. *Orange*: Connection 2. *Yellow*: Cross Section



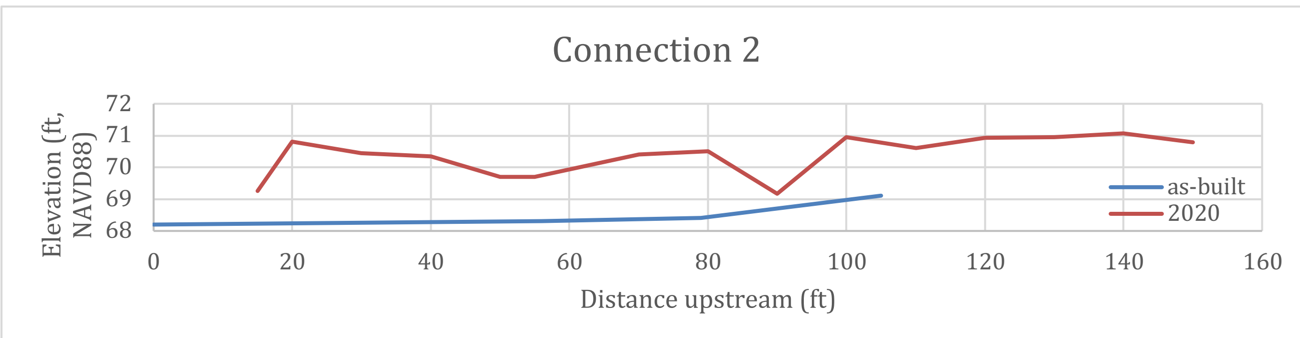
Note the change in channel elevation between stations 1200 and 1400 within the main stem . The resulting difference in channel elevation created a large riffle/pool complex where a placid plane-bed glide existed before. The result also reduced channel incision by three feet.



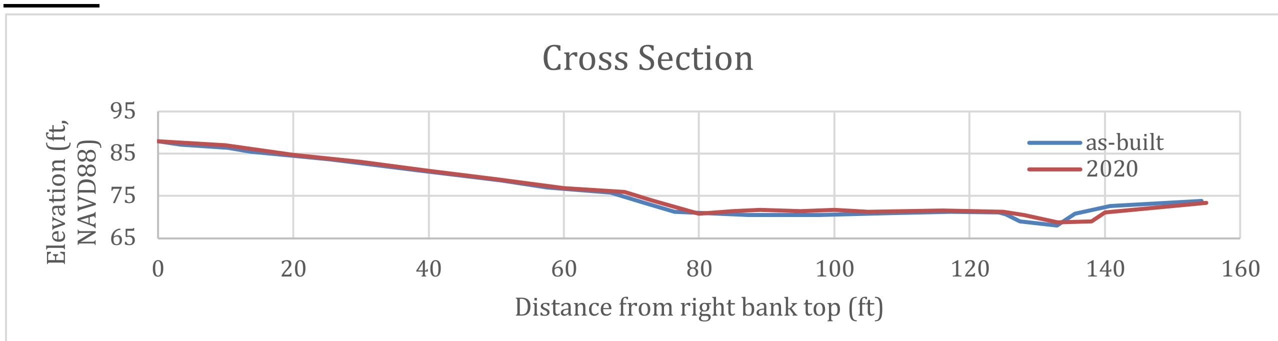
The side channel that was created saw patterns of coarse sediment deposition and erosion, puntuated by large accumulations of sediment and areas of pool scour and erosion. The location between stations 300 and 500 where the featureless channel exists is a result of a slightly steeper section of the channel where transport energy was too high to allow coarse bedload to deposit. Note the large pool at station 150, was created by the scour from a large fallen redwood tree.



The results indicate that roughly 3 feet of course bedload has deposited within the side channel connection. This has resulted in an increase in water surface elevation at the site.



The rise in channel profile and water surface at Connection 2 resulted from a large wood jam that piled up in the mainstem and backed up sediment and water to force flow into the perennial channel (refer to photo on page 17 of large wood jam). This large wood jam accumulated sediment and has led to an increase in water surface elevation, helping force flow into the adjacent side channel.



This section shows the difference in elevation along a floodplain cross-section. Although it seems the pool (the dip ~130 ft), has shifted slightly, there has been little change in the channel elevation as a result of the winter flows.

Objective 6: Salmon Habitat Suitability

In order to assess the effectiveness of the off-channel habitats as suitable habitat for juvenile salmonids, two methods of observation have been implemented. First, throughout the winter and spring during runoff events, the off-channel habitats were sampled for depth and velocity using a stadia rod and a USGS Pygmy meter. This measurement was done to assess the suitability of habitats, as a function of depth and velocity, for rearing juvenile Coho throughout the project area during the winter and spring. Additionally, given that the project included construction of a perennial side channel, measurements were taken during the summer of salmonid habitat use through direct observation.

The following conditions were used as indicators for the suitability of the habitat created in regard to juvenile Coho rearing preferences: Velocities of 0-1 cfs (blue) are considered low flows and is the preferred habitat for juvenile salmonids. Velocities of 1-2 cfs (green) are considered medium and >2 cfs (red) is considered high and is less suitable for juvenile salmonids (Bjorn 1991).

Velocity measurements taken on March 1, March 23, May 20, and June 18, 2019 are mapped (Fig 6-9). Between 10 - 15 measurements were taken each day and the average for the side and main channel calculated.

Results

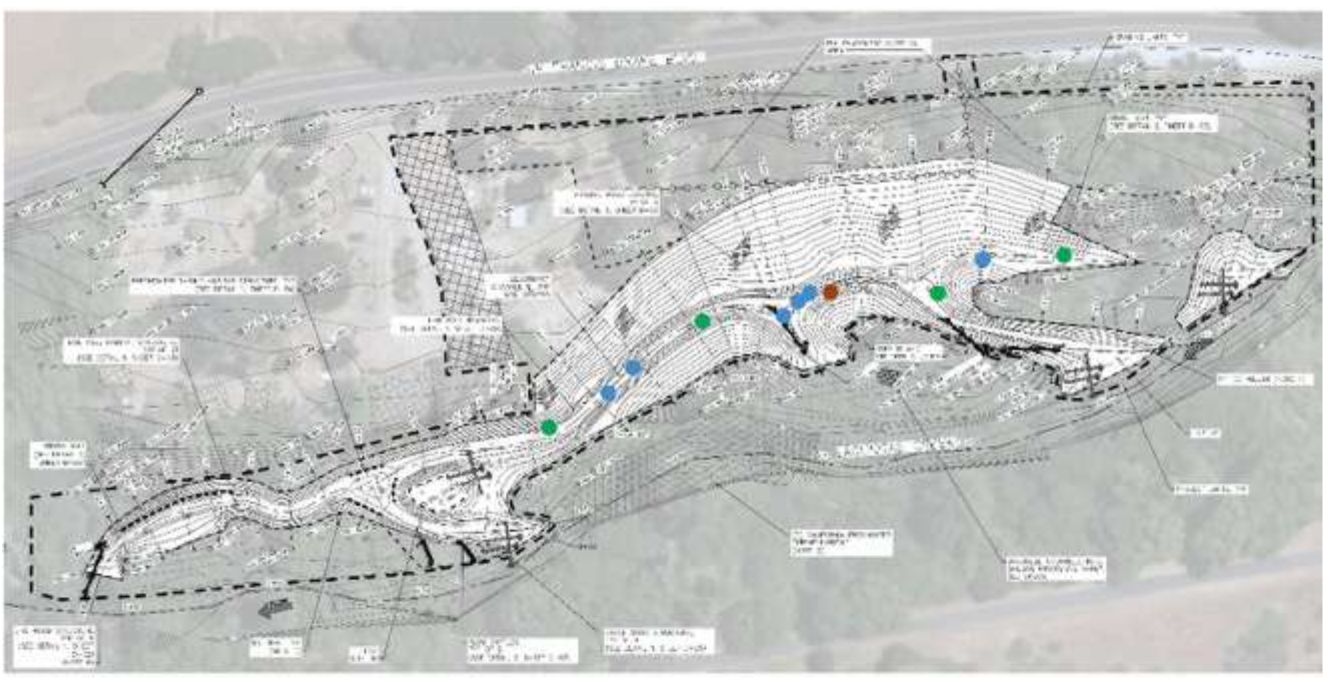


Figure 6: On March 1, 2019 the storm flow maximum was 481 cfs during the time of survey. There was one measured velocity that measured in the high velocity range. Velocities were not measured directly in the downstream perennial side channel given that depth was not wadable.

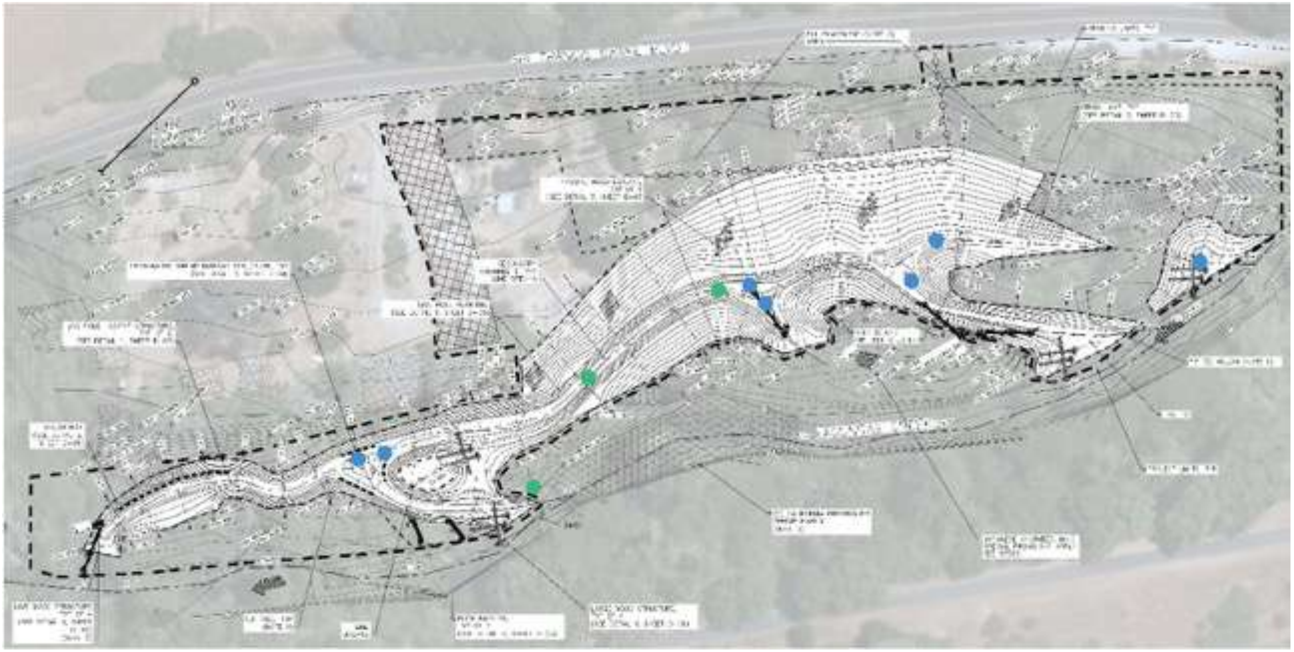


Figure 7: On March 23, 2019 the storm flow maximum was 323 cfs. All measured velocities were either low or medium.

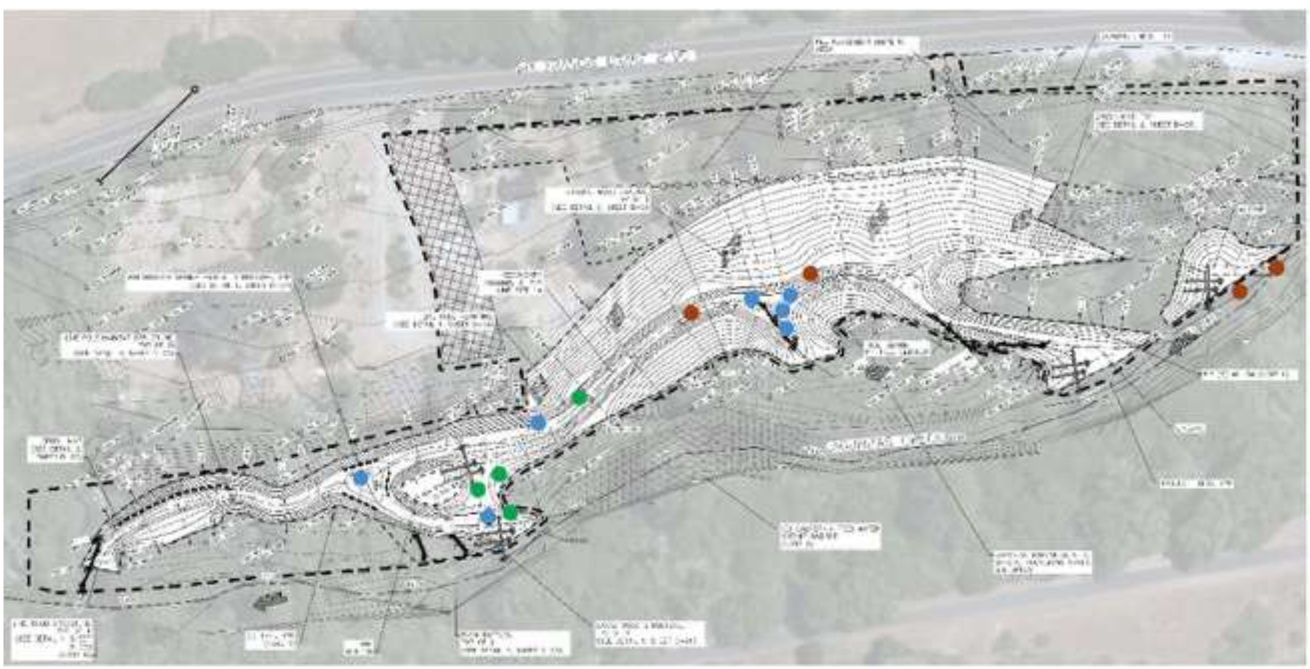


Figure 8: On May 20, 2019 the storm flow maximum was 263 cfs. There were two velocities in the side channel that measured high during this May storm event.

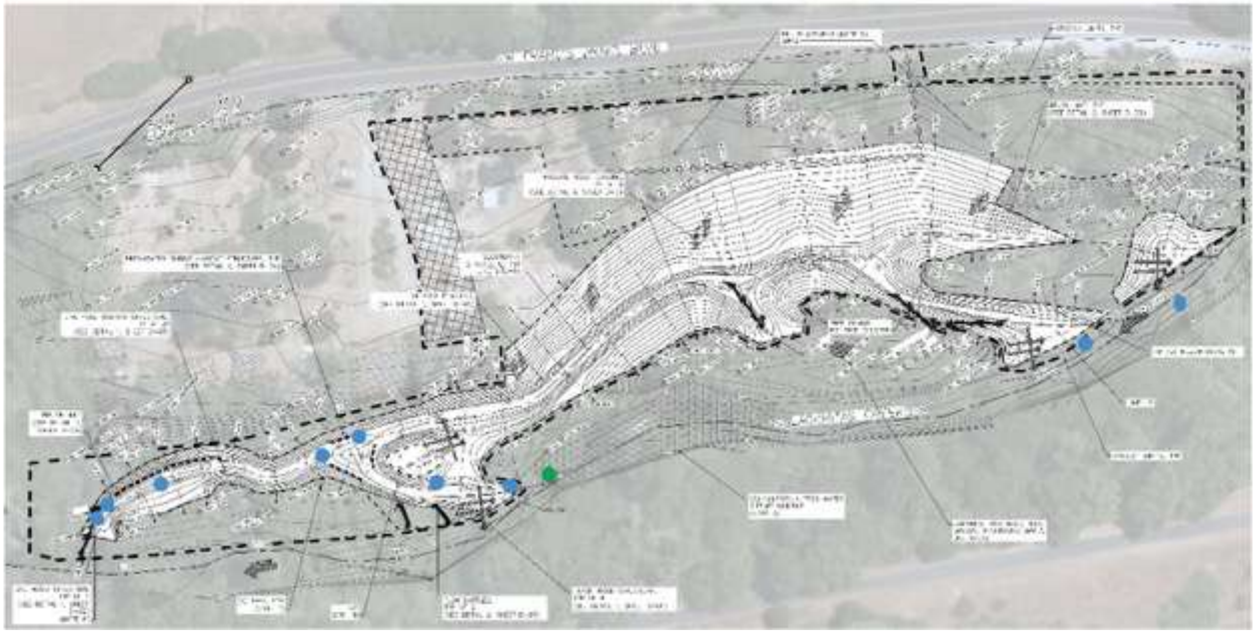


Figure 9: On June 18, 2019 the flow maximum was 8.07 cfs. All but one velocity measurements were in the low range.

Over the range of flows measured (263cfs to 481cfs) in the seasonal side channel, the average velocity was 0.403 cfs. This average velocity of 0.403 cfs is within the preferred range for juvenile Coho and demonstrates that suitable habitat is found during the low-moderate storms. As flows rise, the multi-stage channel becomes activated and the area of wetted channel greatly increases and suitable habitat becomes much more available. A noteworthy observation was that as flows rose from 263 to 481 cfs in the seasonal side channel, velocities in some locations decreased. This may be due to the turbulence observed over roughness features and in-channel wood when waters were lower.

Objective 7: Species Presence/Absence Observations

Direct observation of salmonids in the perennial channel was done during June and July 2019 to assess the presence and relative abundance of juvenile salmonids. Observation was done by walking slowly along the stream bank using binoculars to count fish. Fish were counted in distinct habitat units throughout the length of the perennial side channel. Temperature was taken with a thermometer in degrees Celsius at each section and the average temperature calculated for each day. On average, more Steelhead than Coho were observed in June and July (Figure 10). The average stream temperature was 17.8 °C in June and 17.5 °C in July. The lowest recorded temperature was 15.5 °C on July 1 and the highest temperature recorded was 19 °C on July 17. The highest recorded number of salmonids occurred on June 20 when 55 Steelhead and 28 Coho were observed.

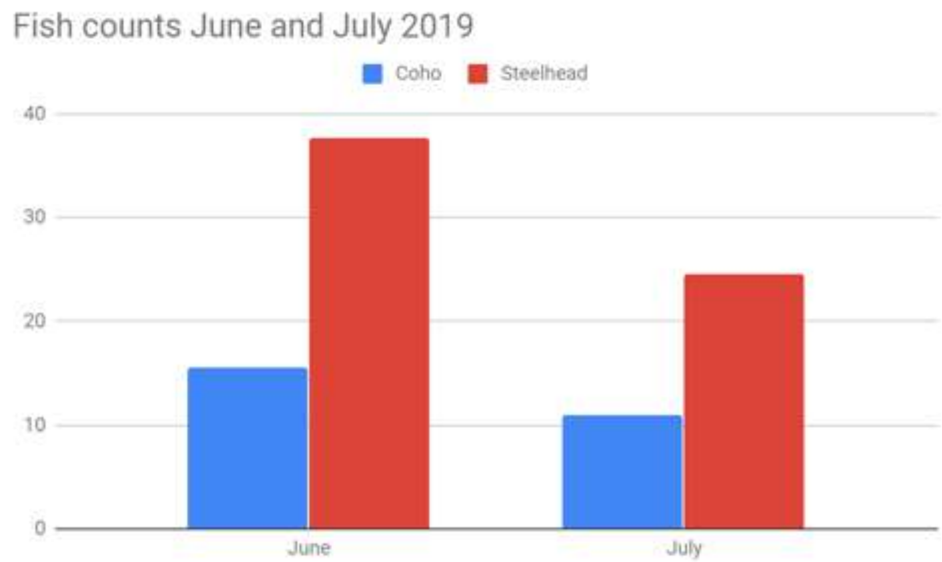


Figure 10: Average fish observations in the perennial channel for June and July, 2019.

Salmonid activity in feeding lanes was predictable and fish were seen consistently in the same areas where insect drift was most common downstream of riffles. Generally, slow-moving water and pools with adequate wood and cover were preferred for Coho. Steelhead were seen in faster moving waters adjacent to riffle, while Coho were more common in the backwater connections with the mainstem and in pools. This is common with juvenile Coho to preferentially use backwater-fed side channels.

Snorkeling is a great surveying technique used to get a visual count on the presence and absence of aquatic species within a system or area. In October 2019, SPAWN staff snorkeled the perennial channel and the length of Lagunitas creek along the Tocoloma project site, 1,165 linear feet. At this point in time, the restoration site had experienced nearly a year's worth of growth, exposure, and natural development since construction finished in October 2018. The main question was if coho salmon and California freshwater shrimp were utilizing the enhanced habitat, constructed channel, and the installed structures. The water temperatures on the October days snorkeled were 12.5- 13°C. In density order of aquatic species present were: Califronia roach, Three-spinned stickleback (*Gasterosteus aculeatus),* Steelhead trout (Oncorhynchus mykiss), coho salmon (Oncorhynchus kisutch), California freshwater shrimp (Syncaris pacifica), Crayfish (Pacifastacus fortis), and California newt (*Taricha torosa*).

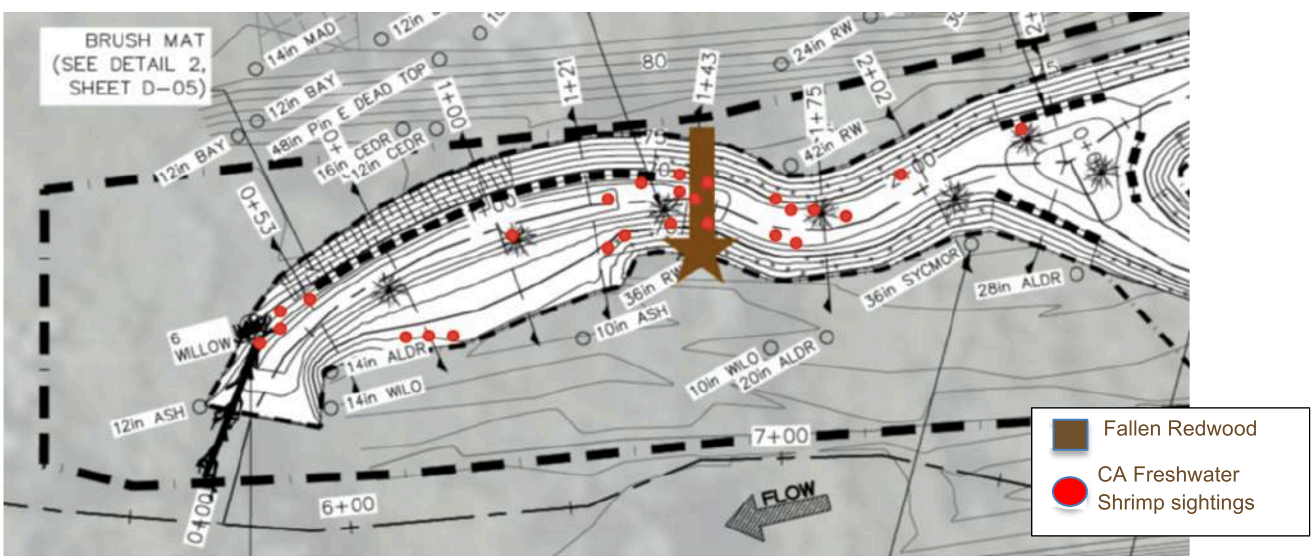
Results:

The **perennial channel,** at the lower extent of the project area, flows all year round. This fluvial feature allows for constant cool water at lower velocities in comparison to the mainstem channel's flow. This channel is to allow juvenile coho salmon and other aquatic species refuge during strong winter storms, otherwise at risk of greater mortality within the mainstem channel. Inverted willow structures, wood introduction, wood racking, and a 4ft diameter redwood tree that fell after a storm early 2019, allowed for scour to occur and create multiple pools at varying depths throughout the channel. Along the banks, additional structures were installed to provide habitat for endangered freshwater shrimp.

Freshwater shrimp are typically found in areas of slow-moving water hidden beneath undercut banks, while hanging off emergent vegetation and fine roots. These log-like structures are made of biodegradable coconut core and held together along the bank with live willow stakes.
The imbedded willow stakes grew throughout the coconut core logs and fine roots were observed beneath the logs, providing ideal habitat for the freshwater shrimp.

Within the deep pool below the fallen redwood tree, submerged branches, emergent vegetation, wood, and gathered debris made this section too complex to snorkel. However, this area was thriving with aquatic life. Any fish utilizing the dense cover within this section were accounted for. Throughout the snorkeled sections, seventy-two (72) total freshwater shrimp were observed. Forty-six (46) of them being adult females and males, and twenty-six (26) juveniles of unknown sex. A majority of the freshwater shrimp were seen along the banks, hanging on emergent vegetation, roots, and over-hanging branches, and in area of slow-moving water. Freshwater shrimp greatly utilized the fallen redwood's branches that dipped into the water column. They were also found surrounding and on the constructed shrimp structures along the banks.
Within the perennial channel, we observed a school of ten (10) coho salmon, while California roach, Three-spined stickleback, steelhead trout, and a California Newt were also present throughout.

Mainstem Lagunitas Creek was snorkeled in order to get a rough population estimate of the various aquatic species in the system along the restoration area. Lagunitas creek is much larger to snorkel. With only a three-person crew, barely spanning the width of the creek, the numbers presented do not accurately represent the population. Presence of species is the main takeaway. Ninety-seven (97) coho salmon were counted and sixteen (16) California freshwater shrimp were observed. The freshwater shrimp documented within the mainstem channel were spotted by chance when habitat looked suitable and the snorkelers took the time to carefully observe the area. In density order, California roach, Three-spined stickleback, steelhead trout, and crayfish were also present.



Above is a map of the perennial channel and the locations CA Freshwater Shrimp were observed when snorkeled in October 2019. Each red dot corresponds to a cluster of Freshwater shrimp presence, but does not represent an individual shrimp. A varying amount of shrimp, at different life stages, were seen at each spot. This map showcases the areas along the site that had the most observations.

Objective 8: Ground Terrestrial Wildlife Data

Cover boards were installed on January 3, 2019 and checked once a week (current data through October 25, 2019). This surveying technique is an easy way to observe what ground species are in the area and utilizing the safety of the cover boards in particular locations. Originally twenty boards were placed along the total length of the Tocoloma restoration site where ground disturbance occurred. Each board is about 100 feet apart along the side channels over the restoration site. Each cover board is roughly 9 square ft plywood boards. Two boards were lost to flooding, but one was eventually recovered. Subsequently, all lower boards along the hillside were secured with 18" pins to prevent floating away during storm events. Four additional boards were installed in March 2019.

Below is the data collected:

Reptiles	Individuals	(Adults/Juvenile)
Fence lizard (*Sceloporus occidentalis*)	10	(7/3)
Chorus frog (Pseudacris)	3	(3/0)
Sharptail snake (*Contia tenuis*)	32	(28/4)
Ringneck snake (*Diadophis punctatus*)	2	(2/0)
Garter snake (Thamnophis)	3	(0/3)
Short-tailed snake (*Lampropeltis extenuata*)	11	(8/3)
Alligator lizard (*Elgaria multicarinata*)	1	(0/1)

Mammals	Individuals	(Adults/Juvenile)
Pocket Gopher (Geomyidae)	2	(1/1)
House Mouse (*Mus musculus*)	58	(32/26)
Unidentified small mammal	4	(4/0)

Amphibians	Individuals	(Adults/Juvenile)
Ensatina salamander (*Ensatina eschscholtzii*)	3	(2/1)
California newt (*Taricha torosa*)	3	(3/0)
California slender salamander (*Batrachoseps attenuatus*)	31	(24/7)
Arboreal salamander (*Aneides lugubris*)	1	(1/0)

Results:

Found below the coverboards were species broken down into 3 classes; reptiles, amphibians, and mammals. There was greater species richness within the reptile class but a greater amount of individual mammal observations. Within the mammal class, the House Mouse (Mus musculus) was most abundant from the Pocket gopher (Geomyidae) and any unidentified small mammals seen. Amongst the amphibians, the California slender salamander (*Batrachoseps attenuatus*) was most abudant to California newt (Taricha torosa), Ensatina salamander (Ensatina eschscholtzii), and the arboreal salamander (Aneides lugubris). Out of all the reptiles seen under the board, Sharptail snakes (Contia tenuis) were the most common to Short-tailed snakes (Lampropeltis extenuata), fence lizards (Sceloporus occidentalist), Chorus frogs (Pseudacris), Garter snakes (Thamnophis), and Ringneck snakes (Diadophis punctatus).

As vegetation begins to mature within the restored areas and more habitat develops, our questions lie in what other species may be attracted and found beneath the coverboards moving forward. The coverboards laid out along the length of the restoration area will continue to be used to monitor changes in species abundance and diversity within the landscape.

Objective 9: Revegetation

Native shrubs, grasses and trees grown at SPAWN's on-site nursery from seeds and cuttings are collected locally and used for restoration of the riparian forest following the initial restoration construction. Following grading and earth moving, prior to installation of erosion control blanket, native seeds were hydro-mulched and hand broadcasted at the site at 50lbs/acre. Two seed mixes made up of perennial and annual grasses, herbs, groundcovers, and wildflowers made up the initial seed bank that has colonized the site and started initial regrowth. Planting of nursery container plants took place during the winter and spring months of 2019. Grasses, shrubs and trees were carefully placed in low-, mid-, and upper-bank according to their preferred habitats.

Following winter 2018-2019, surveys were done to estimate the amount of relative cover of native vegetation, non-native vegetation, and bare ground. Using a 1sq meter PCV frame, transects were placed in random pattern along the channel to measure the vegetation cover on graded slopes. The 1sq meter quadrat was divided into 9 sections, and the relative cover of native vs non-native vegetaiton was estimated for each section to come to an average for the whole quadrat. The names of all species within the quadrat was listed. A total of 22 quadrats were completed and the average percent cover for each category was calculated.

Results

The graded areas along the channels in summer 2018 were measured to have 74% of the ground surfaces covered with vegetation, with about 3 times as much coverage by native plants than non-native plants. Coir erosion control fabric, rock, and wood comprised 19% of the ground surface, and 7% was bare ground.

% Non-Native Vegetation	% Native Vegetation	% Bare ground	% Rock	% Wood	% Ground/Fabric

7.69	66.31	7.2%	0.11	3.05	15.64

Table 1: Average percent cover of non-native and native vegetation, bare ground, wood and rock, and fabric.

All species observed in plots were identified and categorized as either native or non-native. Twenty-two (22) non-native species and eighteen (18) native species were identified (Table 2). Native grasses that appeared most frequently were *Agrostis exarate*, *Elymus glaucus* and *Hordeum brachyantherum* which all appeared in at least 17 of the plots. The non-native species of highest concern include *Brassica rapa*, *Cirsium vulgare*, *Conium maculatum*, *Festuca perennis*, *Holcus lanatus*, *Mentha pulegium*, *Polypogon monspeliensis*, and *Rumex crispus*.

Non-native Species	Common Name	Native Species	Common Name
Brassica rapa	Wild mustard	***Acer macrophyllum***	Big-Leaf Maple
Bromus diandrus	Ripgut Brome	***Agrostis exarata***	Spike Bentgrass
Centaurium tenuiflorum	Jepsom Herbarium	***Alnus rhombifolia***	White alder
Cirsium vulgare	Bull thistle	***Aristolochia californica***	California Pipevine
Conium maculatum	Poison Hemlock	***Baccharis pilularis***	Coyote brush
Cyperus difformis	Nut Sedge	***Elymus glaucus***	Blue Wildrye
Erodium botrys	Broadleaf Filaree	***Eschscholzia californica***	California poppy
Festuca perennis	Italian Rye grass	***Festuca idahoensis***	Blue fescue
Holcus lanatus	Velvet Grass	***Festuca rubra***	Red Fescue
Hypochaeris radicata	Hairy Cat's Ear	***Heracleum maximum***	Cow parsnip
Kickxia Elatine	Sharpleaf cancerwort	***Hordeum brachyantherum***	Meadow Barley
Lysimachia arvensis	Scarlet Pimpernel	***Iris douglasiana***	Doug Iris
Lythrum hyssopifolia	Hyssop Loosestrife	***Juncus patens***	Spreading rush
Mentha pulegium	Pennyroyal	***Navarretia squarrosa***	Skunk Navarretia
Picris echioides	Ox-tongue thistle	***Polygonum punctatum***	Dotted Smartweed
Plantago major	Common Plaintain	***Rubus ursinus***	California Blackberry
Polypogon monspeliensis	Rabbit's Foot grass	***Symphyotrichum chilense***	Aster Chilensis
Prunella vulgaris var. vulgaris	Self-heal	***Trifolium obtusiflorum***	Creek Clover
Pseudognaphalium luteoalbum	Jersey Cudweed		
Rumex crispus	Yellow Dock		
Solanum furcatum	Forked Nightshade		

Torilis arvensis	Hedge Parsley		

Table 2. List of all native and non-native species found in plots.

Surveys of tree survivorship of those seedlings planted in the winter of 2018-2019 revealed that 87% survived through the summer of 2019 **(Table 3).** During the hot, dry summer months tree care is crucial. Trees were set up on drip irrigation, caged to protect against deer, and some were covered in shade cloth to protect from sun exposure. The south-facing floodplain bench is especially exposed to sun, heat and wind because there is not yet any established shade. The soil has high levels of clay which can be tough for plants that prefer drainage. *Acer negundo, Fraxinus latifolia* and *Quercus agrifolia* had 100% survivorship, demonstrating that these species are resilient to tough conditions and clay soil. Trees died included *Alnus rhombifolia , Acer macrophyllum, Aesculus californica* and *Sequoia sempervirens* partly from being inundated with high water for prolonged periods, experienced debris thrashing and damage, and cannot tolerate clay soils. Average tree spacing was found to be 15.8ft.

Botanical Name	**Common Name**	**Number Dead**	**Number Living**	**Notes**
Acer macrophyllum	Big-Leaf Maple	2	16	1 washed away in storm, planted too early; 1 dead
Acer negundo	Box Elder	0	31	
Aesculus californica	California Buckeye	8	53	A lot planted from seed; didn't do as well as mature plants; High sun exposure, low water
Alnus rhombifolia	White Alder	3	6	Washed away in storm; planted too early
Arbutus menziesii	Pacific Madrone	2	0	Old nursery stock; planted in clay-heavy soil not optimal; appropriate planting technique is to give plants very good drainage, disturb roots as little as possible and provide mycorrhizae
Cornus sericea ssp. sericea	Creek Dogwood	5	12	Submerged in water for the winter, planted too early, died in the spring
Fraxinus latifolia	Oregon Ash	0	13	
Quercus agrifolia	Coast Live Oak	0	13	Tough, resilient and adaptable to clay soils and sun; good for upland areas
Sambucus nigra ssp. cerulea	Blue Elderberry	2	2	Eaten by deer; not caged in time
Sequoia sempervirens	Coastal Redwood	1	30	1 planted too early and washed away in storm; Planted 3 in mid-bank clay soil that we had to salvage and transplant back to the nursery; poor drainage; high flow area; they survived
	Total	**23**	**176**	

	%	**13.07**	**86.93**	

Table 3. Tree survivorship for each species of tree and average for the site.

Citations are listed below

References

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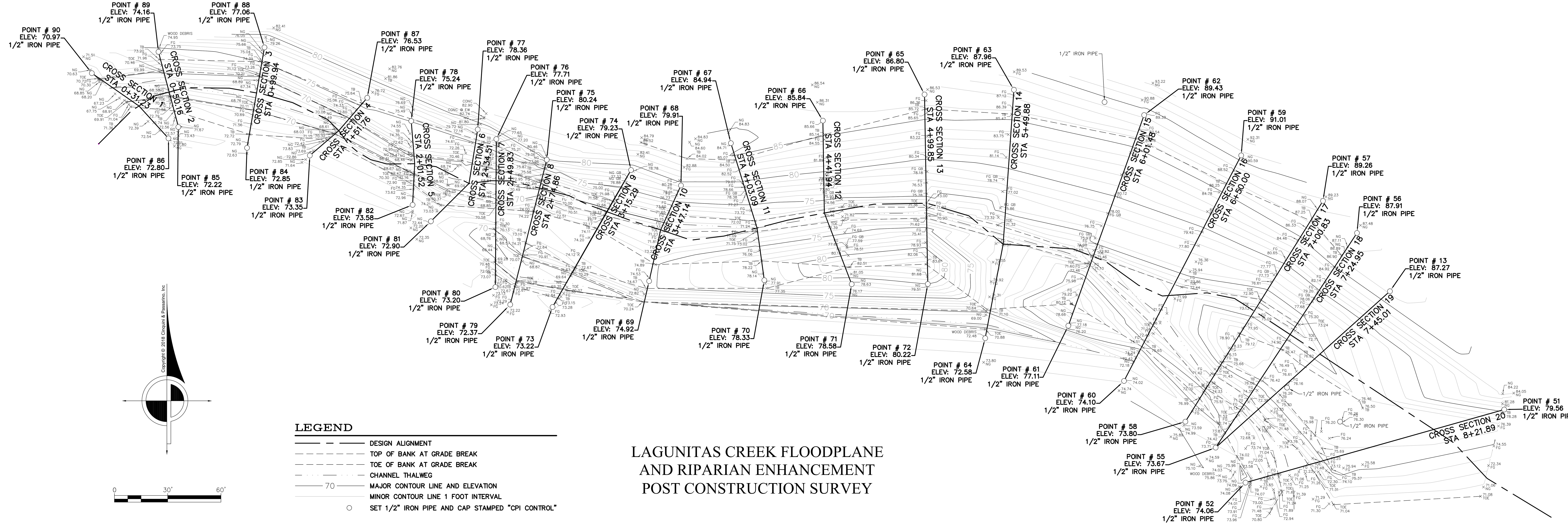
Appendix A – As Built Surveys Phase I



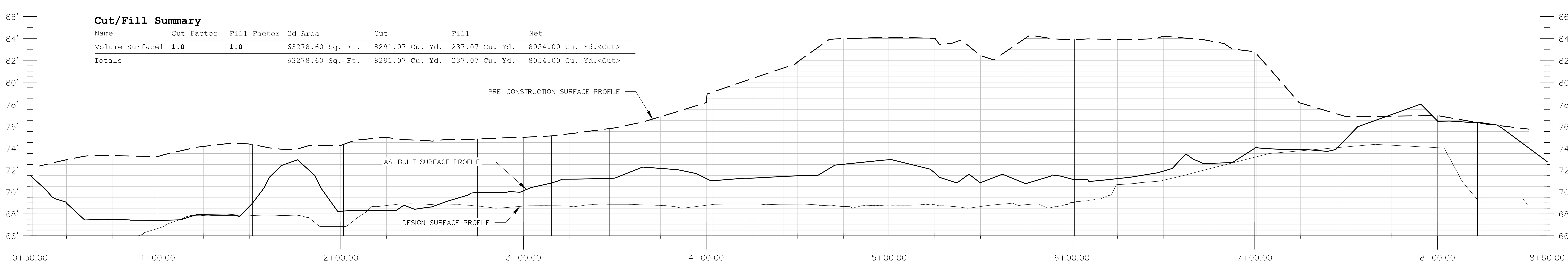
LEGEND

- DESIGN ALIGNMENT
- TOP OF BANK AT GRADE BREAK
- TOE OF BANK AT GRADE BREAK
- CHANNEL THALWEG
- 70 MAJOR CONTOUR LINE AND ELEVATION
- MINOR CONTOUR LINE 1 FOOT INTERVAL
- SET 1/2" IRON PIPE AND CAP STAMPED "CPI CONTROL"

LAGUNITAS CREEK FLOODPLANE AND RIPARIAN ENHANCEMENT POST CONSTRUCTION SURVEY

Cut/Fill Summary

Name	Cut Factor	Fill Factor	2d Area	Cut	Fill	Net
Volume Surface1	**1.0**	**1.0**	63278.60 Sq. Ft.	8291.07 Cu. Yd.	237.07 Cu. Yd.	8054.00 Cu. Yd.<Cut>
Totals			63278.60 Sq. Ft.	8291.07 Cu. Yd.	237.07 Cu. Yd.	8054.00 Cu. Yd.<Cut>



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VERTICAL SCALE: 1"=5'

NOTE

STATIONING SHOWN IS DESIGN STATIONING.

PROFILE VIEW PRE-CONSTRUCTION AS-BUILT DESIGN

SURVEYOR'S STATEMENT

THIS MAP REPRESENTS A FIELD SURVEY MADE BY ME OR UNDER MY DIRECTION ON OCTOBER 24, 2018 AND REPRESENTS THE VISUAL SURFACE CONDITIONS AS OF AFORESAID DATE.

Preliminary

James M. Dickey, P.L.S. 7935 DATE

Job Name:	DRAWN BY: SAJ	CHECKED BY: JMD
LAGUNITAS CREEK FLOODPLANE AND RIPARIAN ENHANCEMENT	SCALE: 1"=30'	
	SHEET: 1 OF 4	JOB NUMBER: 8245-18
Description:	DWG. FILE:	Y:\8245\Cad\8245TOPO-Sections.dwg
POST CONSTRUCTION SURVEY	DATE:	Nov 15, 2018
	TIME:	9:56am

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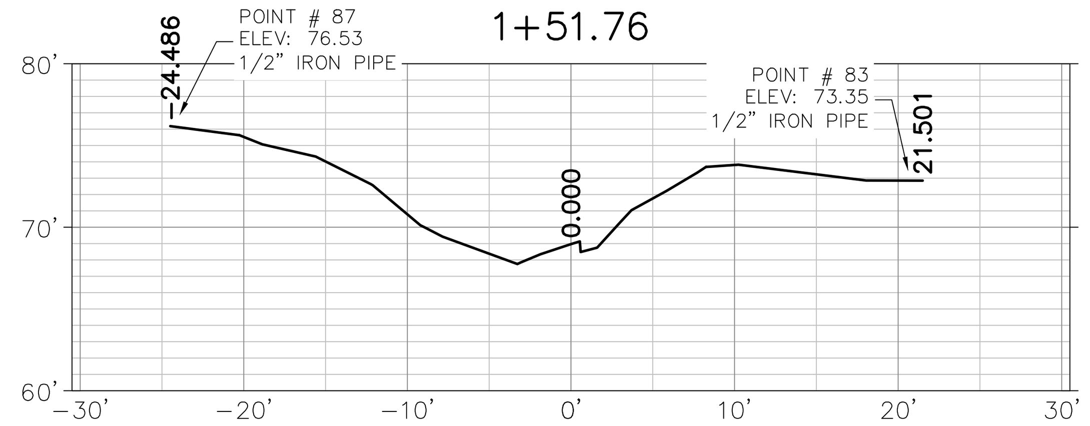

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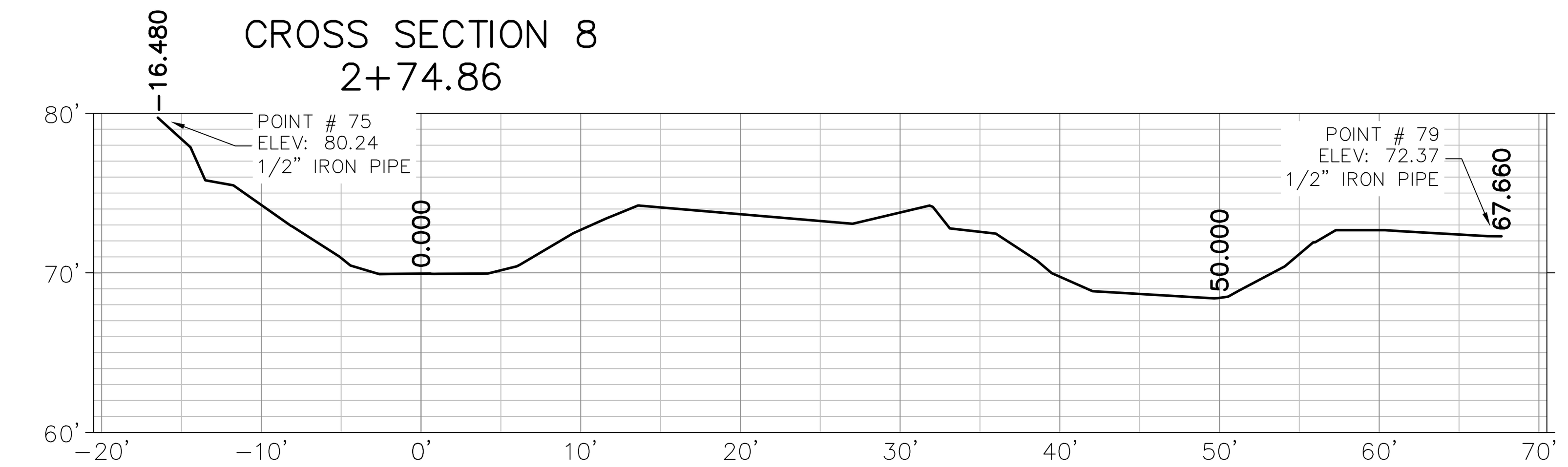

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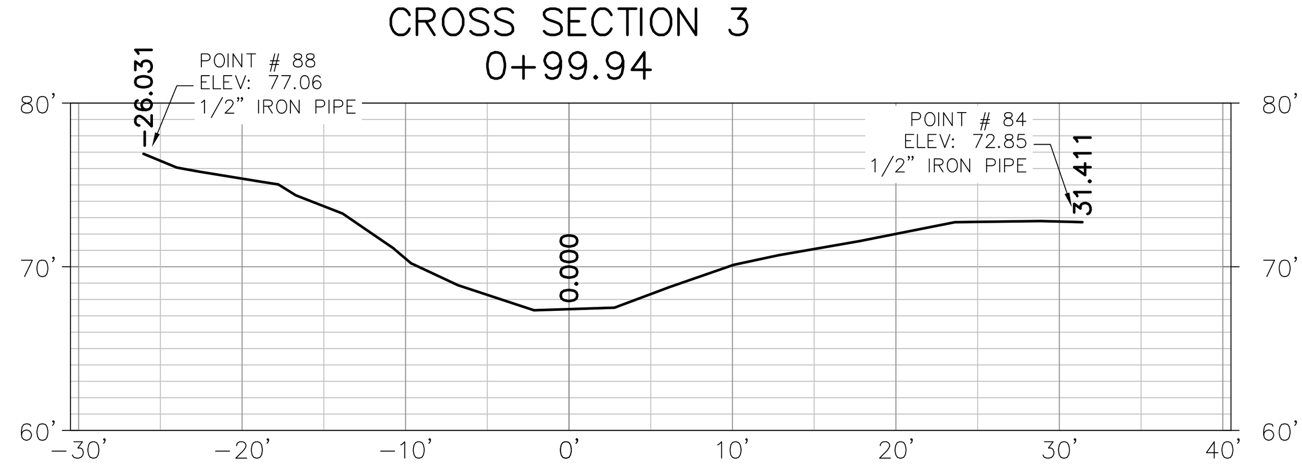

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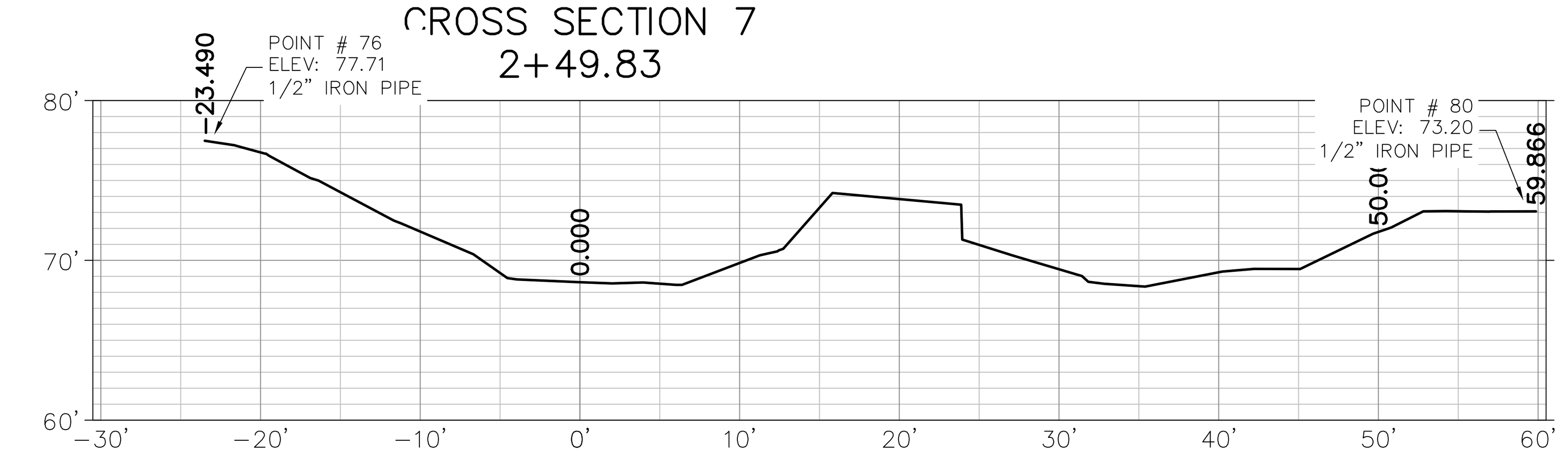

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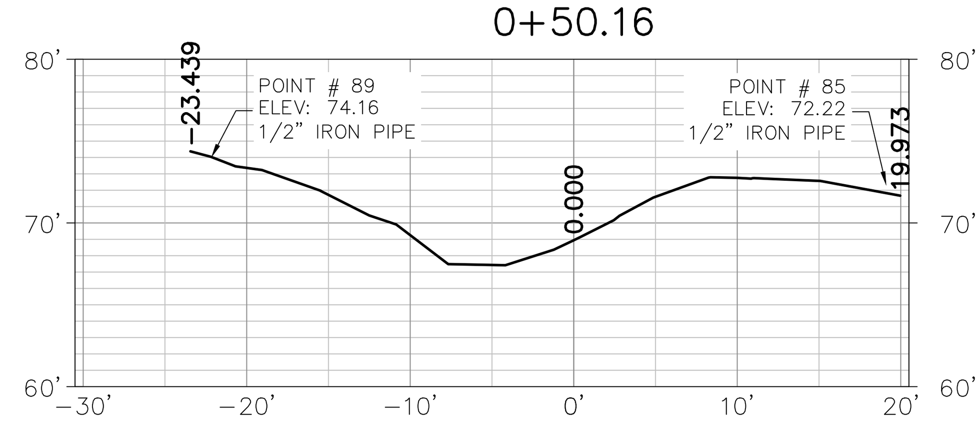

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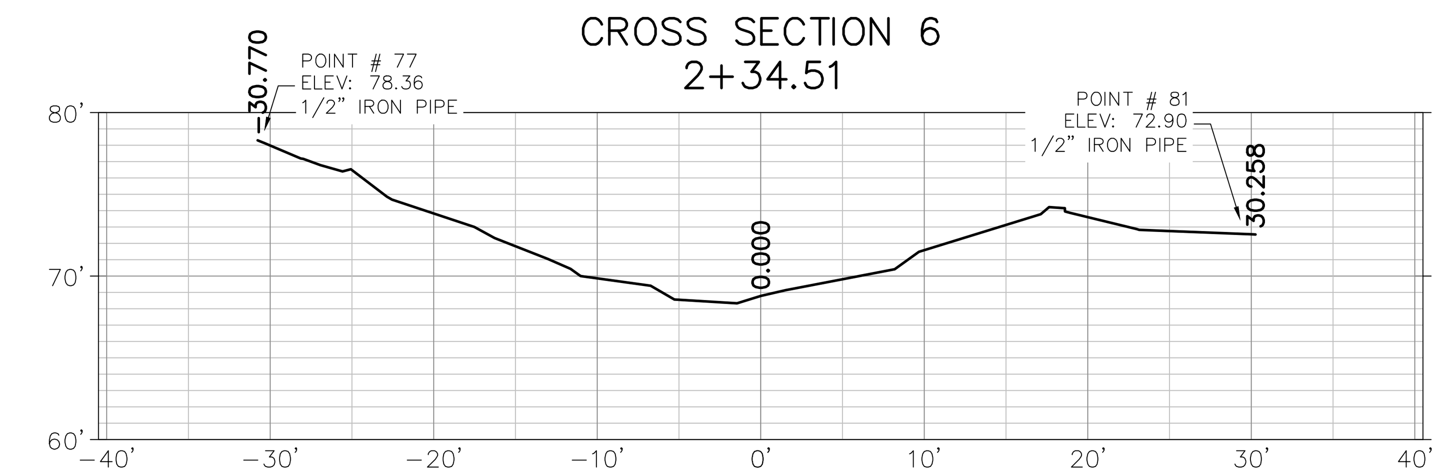

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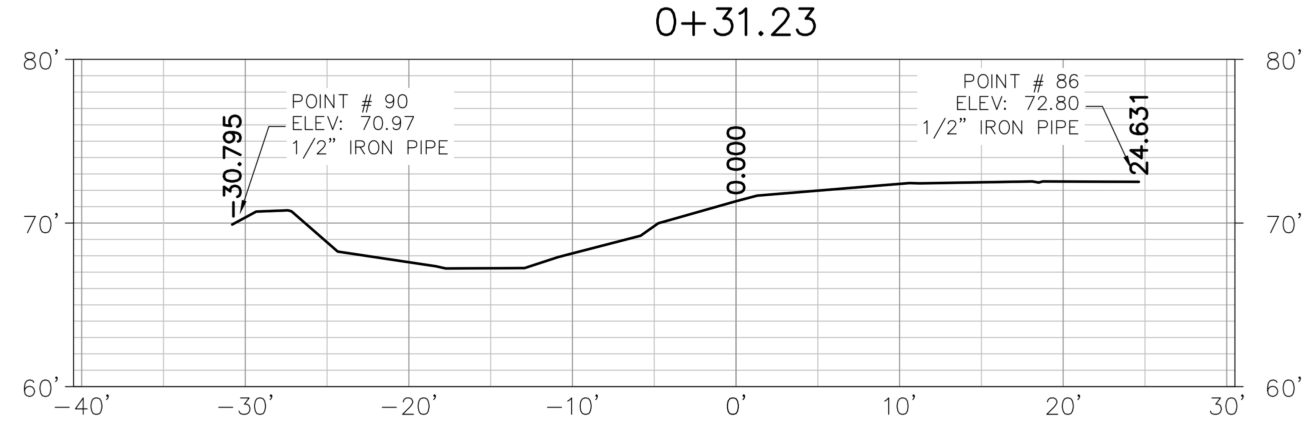

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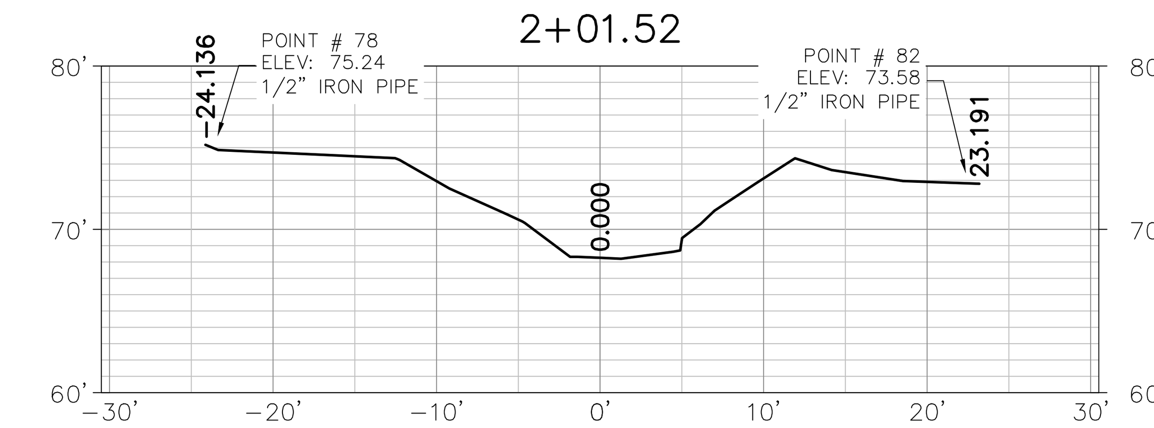

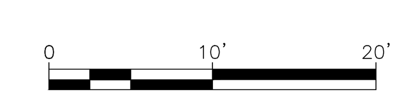

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	DATE:	Nov 15, 2018
	TIME:	9:56am

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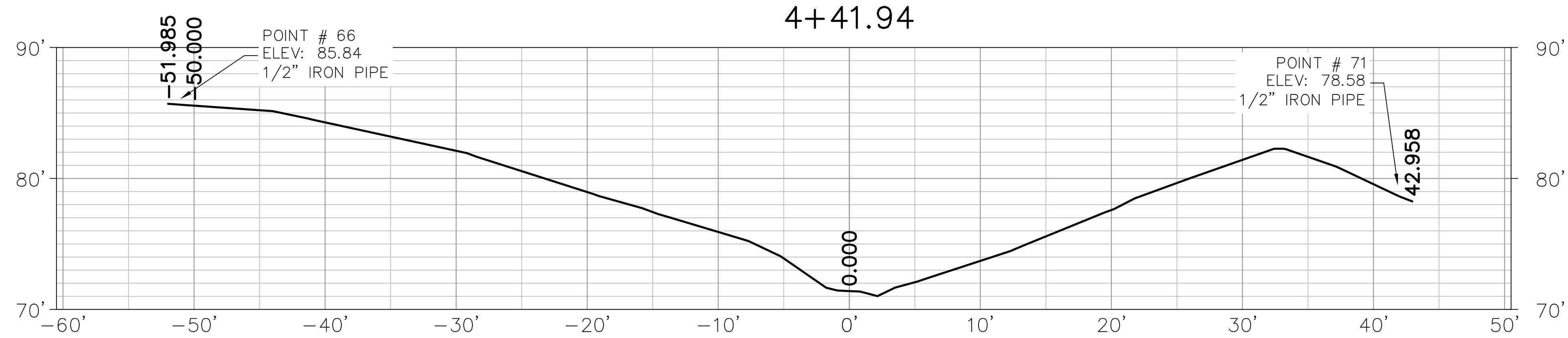

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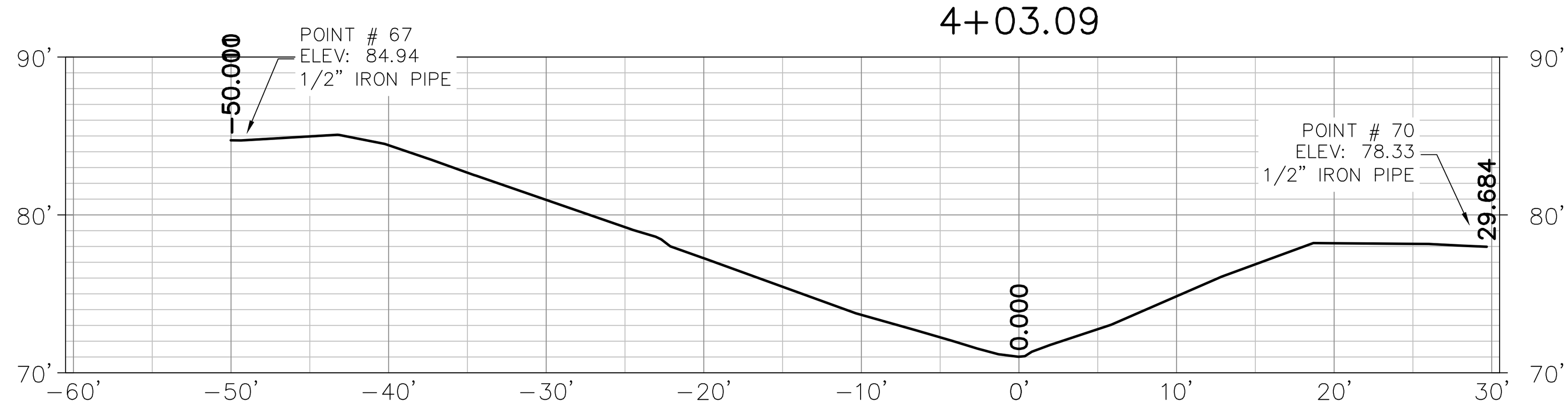

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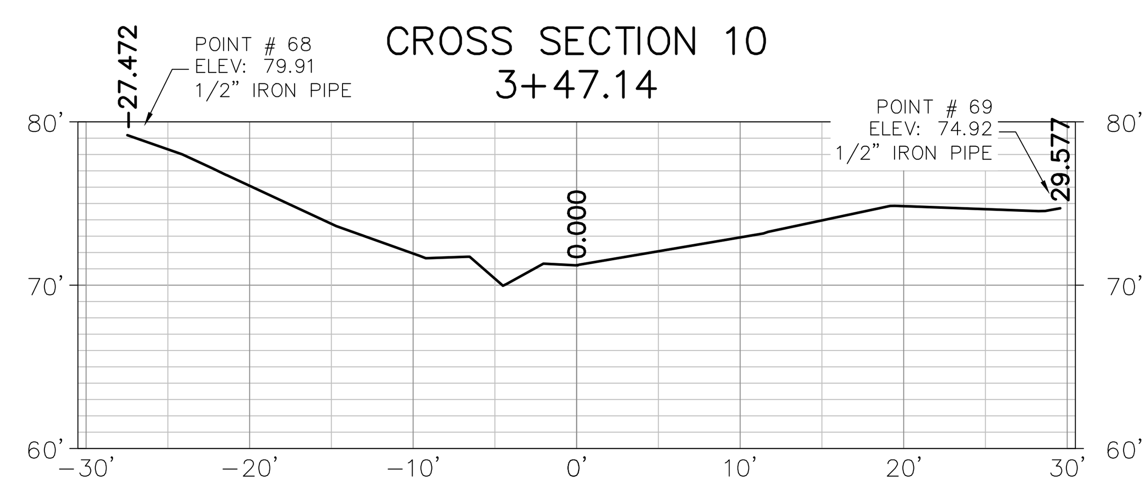

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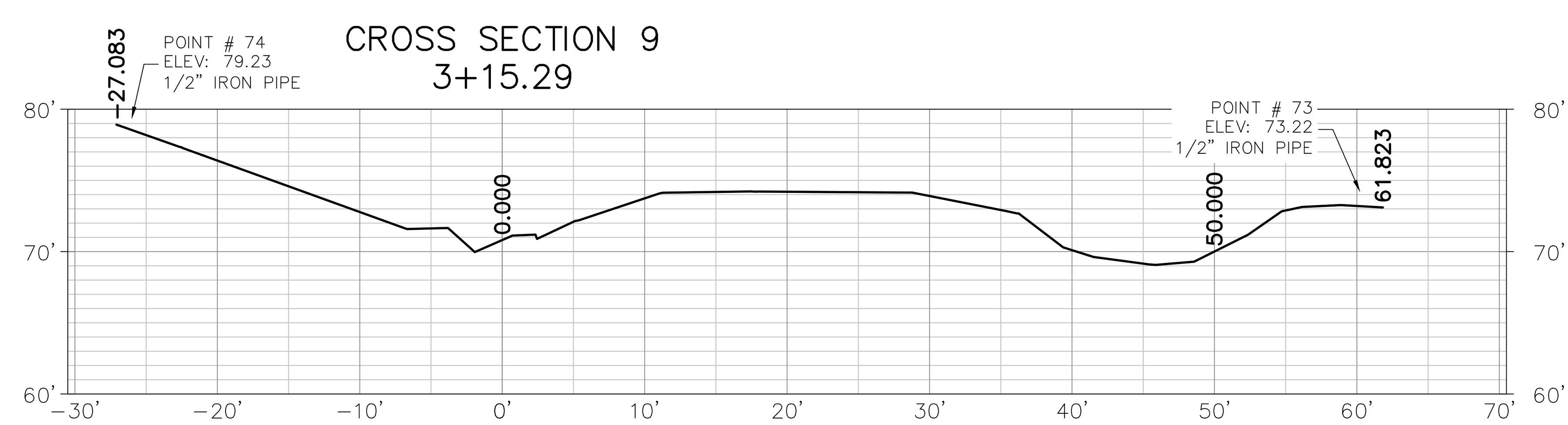

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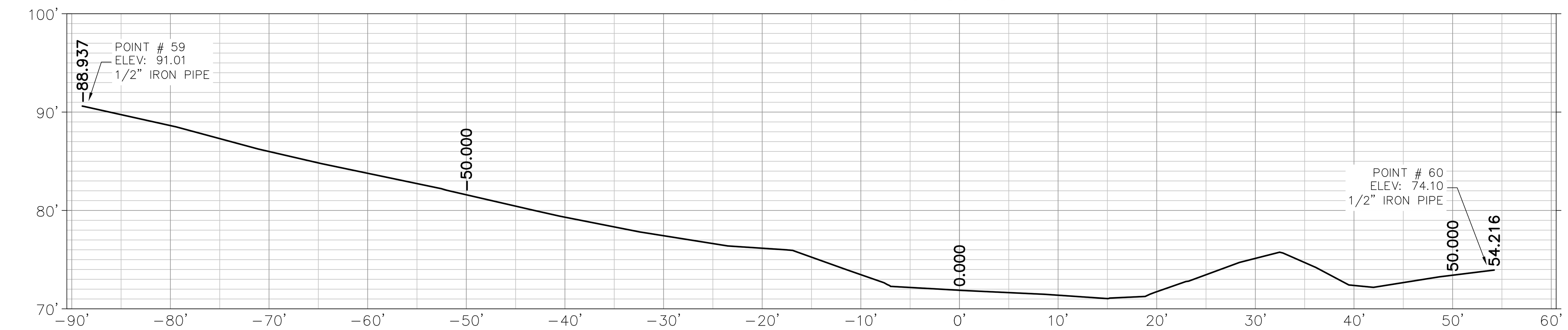

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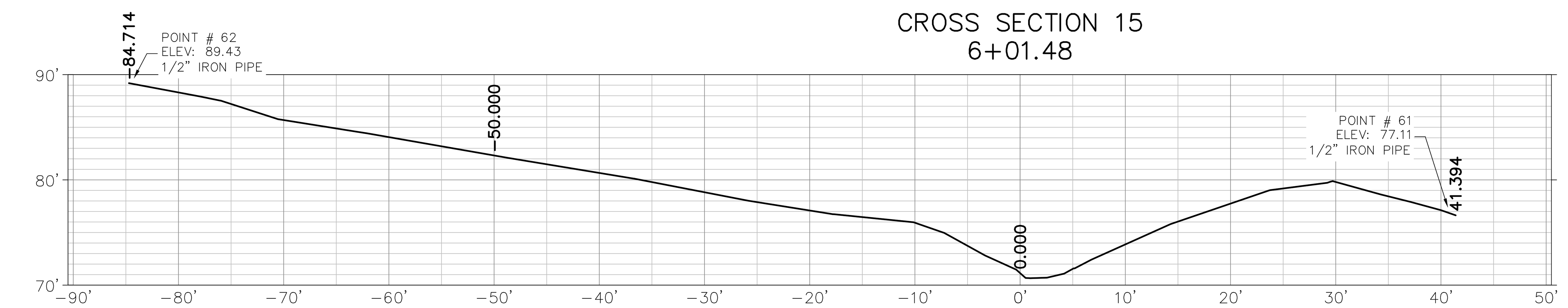

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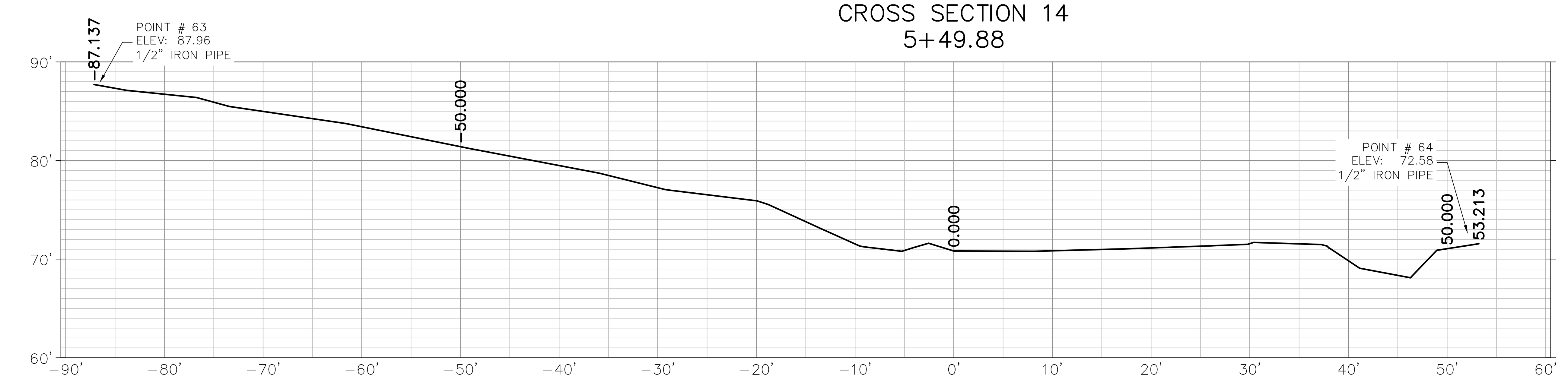

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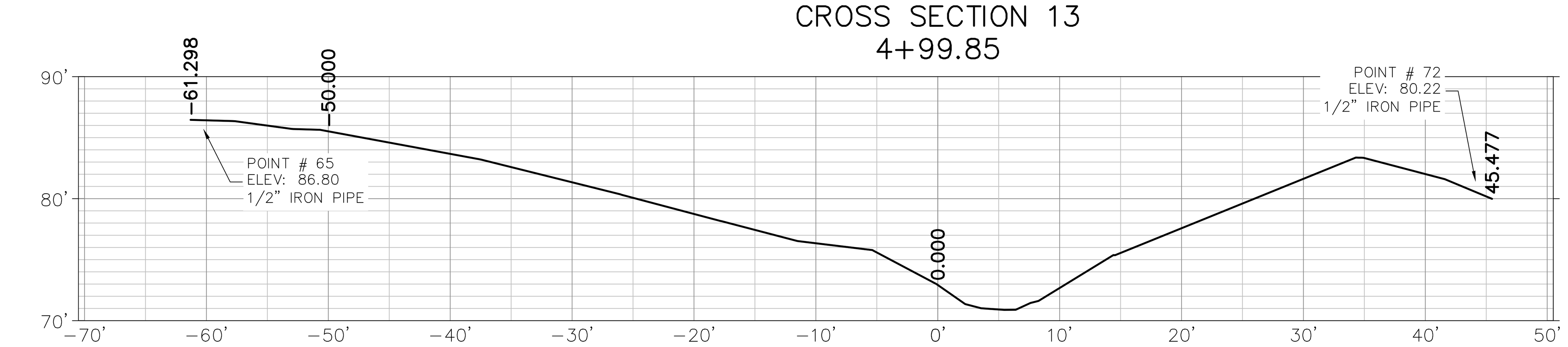

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VERTICAL SCALE: 1"=10'

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	SCALE: 1"=10'	
	SHEET: 3 OF 4	JOB NUMBER: 8245-18
Description: MONUMENTED SECTIONS	DWG. FILE: Y:\8245\Cad\8245TOPO-Sections.dwg	
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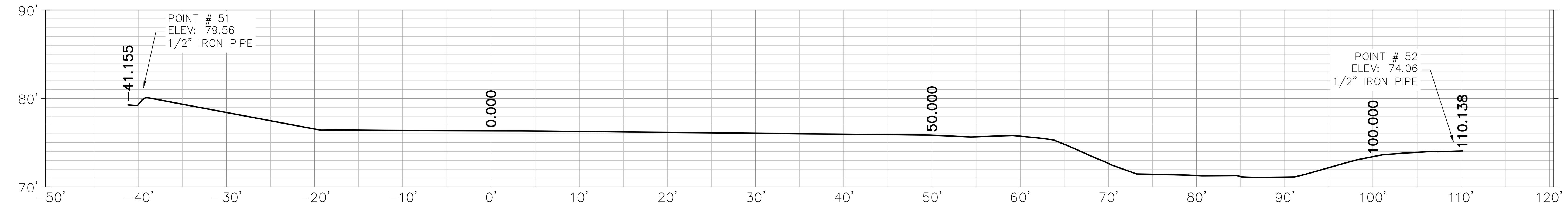
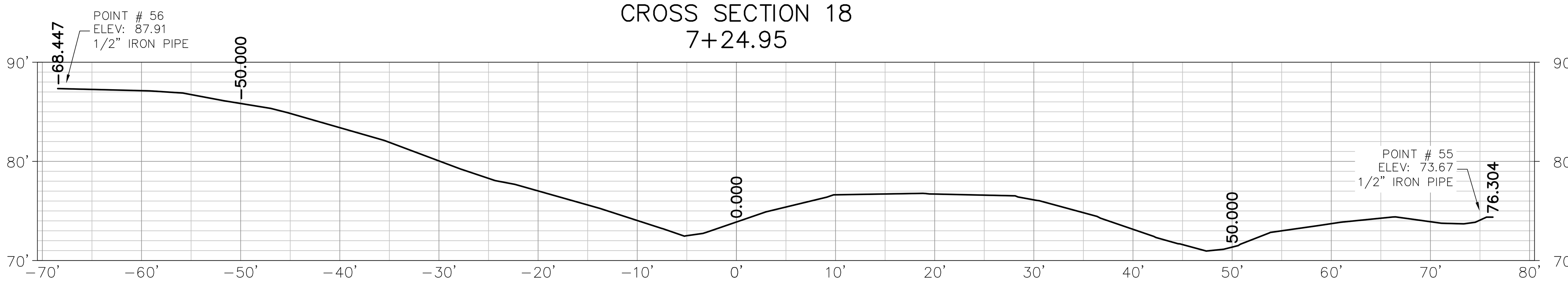
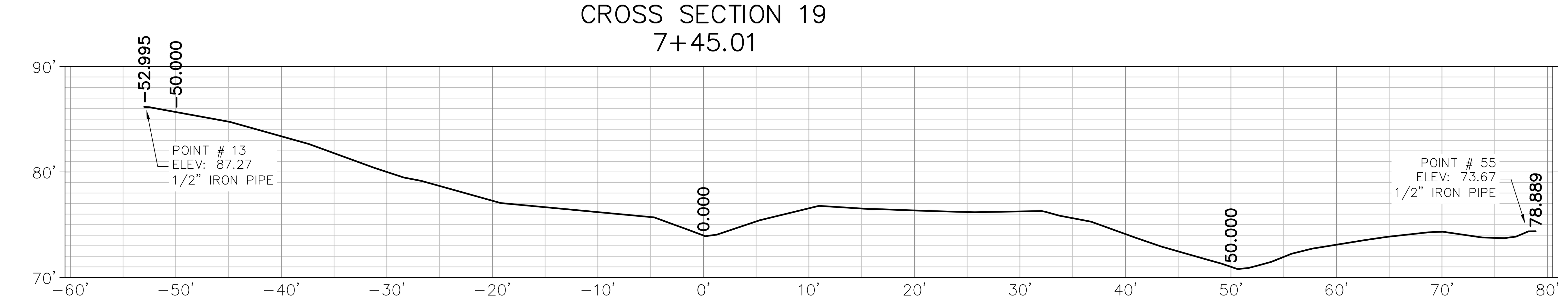
CROSS SECTION 20
8+21.89



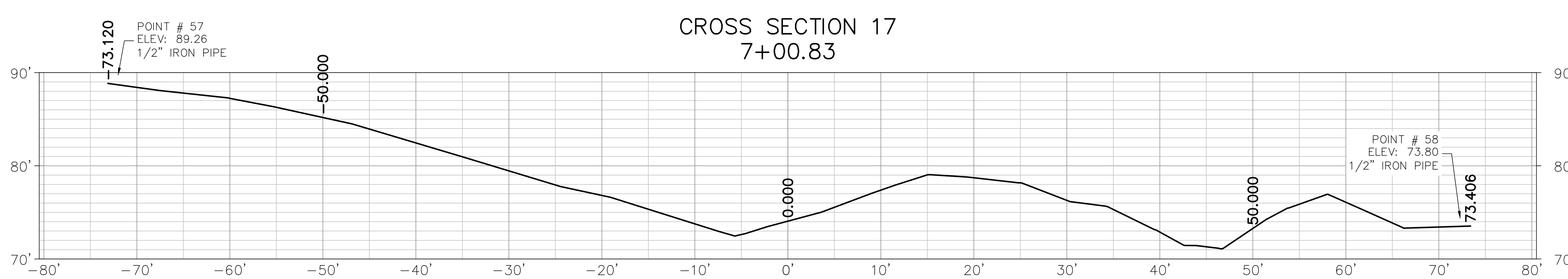
CROSS SECTION 18
7+24.95



CROSS SECTION 19
7+45.01



CROSS SECTION 17
7+00.83



0 10' 20'

HORIZONTAL SCALE: 1"=10'
VERTICAL SCALE: 1"=10'

Job Name: LAGUNITAS CREEK FLOODPLANE AND RIPARIAN ENHANCEMENT	DRAWN BY: SAJ	CHECKED BY: JMD
	SCALE: 1"=10'	
	SHEET: 4 OF 4	JOB NUMBER: 8245-18
Description: MONUMENTED SECTIONS	DWG. FILE: Y:\8245\Cad\8245TOPO-Sections.dwg	
	DATE: Nov 15, 2018	
	TIME: 9:57am	

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BOUNDARY
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CONSTRUCTION
SUBDIVISIONS