RESPONSE OF CHANNEL MORPHOLOGY AND RIPARIAN VEGETATION FOLLOWING RESTORATION AND LAND USE CHANGES, ADOBE CREEK, CALIFORNIA

by

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DEDICATION

I wish to dedicate this paper to my five-month-old son and study buddy, Kit Joseph Ostergaard, and my partner, Sierra Ostergaard. Kit, even though sometimes you were a distraction, especially during the writing process, your presence in my life has been a major motivator to complete this degree. Sierra, without your never-ending support and encouragement, I would never have been able to make it through my project or my classes, you are incredible. I love you both so much and am ecstatic to be able to dedicate this paper to you both.

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I first want to acknowledge Robert Pearce, Ph.D. (retired NRCS DC, Bishop). Without your endless work on the Adobe Creek WRP and the research you performed, my project building on your work would not be possible. I also wish to thank you for your assistance in fieldwork, background information, and editing. Next, I would like to acknowledge the Natural Resources Conservation Service (NRCS) and the landowner for allowing me to use this project for the topic of my professional paper. Thank you to William Kleindl, Ph.D., for instructing me through this paper and project, as well as the time and edits you contributed. Lastly, I could not have completed this project without the support of my family, friends, and colleagues. Thank you for all your support.

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ABSTRACT

The effects of restoration efforts and land-use change on the channel morphology and riparian vegetation of Adobe Creek, California, are examined. The landowners put 667 hectares (1,649 acres) of private land on Adobe Creek into a conservation easement under the Natural Resources Conservation Service's (NRCS) Wetland Reserve Program (WRP). The establishment of Adobe Creek WRP includes physical restoration and land use changes for the stream and surrounding areas previously affected by agricultural practices, such as grazing, an agricultural dam, and irrigation of pastureland. My hypothesis for this project is: With the absence of cattle grazing, reduction in irrigation, and physical restoration of Adobe Creek WRP, stream channel morphology and riparian vegetation will change, specifically with narrowing bankfull widths and increased riparian vegetation. To evaluate changes on Adobe Creek, I used stream cross-sections, satellite imagery, and photo comparisons. I followed the USDA Forest Service methodology (Harrelson et al. 1994) using a laser-level to survey the cross-sections, noting channel morphology. I analyzed satellite images from the creation of the WRP up to 2022 and used available past photos to compare to 2024.

My results indicate that restoration efforts and land use change led to increased woody riparian vegetation and changes in channel morphology. The bankfull widths of three of the four active cross-sections narrowed and decreased in cross-sectional area, with one cross-section showing the opposite effect. All the photo comparisons indicate substantial growth of *Salix* spp. (willow) along the stream channel. The restoration performed on Adobe Creek as part of the Wetland Reserve Program appears to have enhanced the stream and riparian ecosystems. While not conclusive, the result of this study indicates that changes occurred in the channel morphology and riparian vegetation of Adobe Creek following restoration activities, absence of cattle grazing, and reduced irrigation, concurrent with my hypothesis. My findings underscore the importance of tailored restoration strategies and long-term monitoring to sustain healthy stream ecosystems.

INTRODUCTION

Natural waterways and the surrounding environments are highly valued for agricultural and ranch lands in the western United States for providing livestock water, supporting productive riparian areas, and offering irrigation potential. Still, such historic use can cause degradation to these environments. Stream channel morphology is some function of the sediment load and discharge of a stream, both of which have the potential to be altered by agricultural land uses and activities (Petts and Gurnell 2005). The transition area from terrestrial uplands and aquatic environments are riparian habitats found adjacent to waterways such as streams, rivers, lakes, springs, wetlands, and wet meadows (Kattelmann and Embury 1997, Maestas et al. 2023). Much of the western rangelands are characterized as having an arid or semi-arid climate. Within such climates, streams and riparian areas are zones of concentration for the livestock as they provide water, shade, thermal cover, variety, abundance, and quality of forage (Kondolf 1993, Kattelmann and Embury 1997, Belsky et al. 1999). Many negative effects on streams and adjacent ecosystems have been attributed to improper cattle grazing, leading to changes in stream channel morphology and riparian vegetation (Agouridis et al. 2005, O'Callaghan et al. 2019).

Stream riparian areas in the western United States comprise 1-2% of the landscape and are some of the most diverse and productive areas (Kauffman et al. 2022, Krall and Roni 2023). Riparian areas are home to diverse flora and fauna. They are critical to terrestrial and aquatic organisms because of the variability of landforms, soil types, and surface and subsurface water location and availability (Belsky et al. 1999). Riparian ecosystems support microclimates and soil regimes that sustain longer growing periods than other locations (Krall and Roni 2023). Such microclimates and productive forage also attract cattle that avoid hot and dry environments (Belsky et al. 1999).

Riparian areas connect the surface and subsurface flow of water from land to water bodies, affecting the water quality and sediment (Maestas et al. 2023). Riparian areas provide ecological functions to adjacent streams as water storage, moderation of flood intensity, and sinks for nutrients and sediment, maintaining water quality (Clary 1999). The hydrologic function of the riparian ecosystems is a defining factor in the vegetation of riparian areas, and the plants must often survive seasonal flooding and saturated root zones with low-oxygen (Belsky et al. 1999). Some of the ecological characteristics common to riparian plants are fast growth, broad-leaf, winter-deciduous plants that can produce new rooting zones (Kattelmann and Embury 1997). Riparian vegetation and ecosystems provide habitats with abundant water, cover, food, and refuge, as well as migratory corridors, fostering wildlife diversity that is disproportionate to surrounding environments, but cattle are drawn to the areas for many of the same reasons, creating the opportunity to overuse the environment (Maestas et al. 2023).

Riparian areas provide ecological functions to adjacent streams, such as water storage, moderation of flood intensity, and sinks for nutrients and sediment, maintaining water quality (Clary 1999). However, just as riparian areas are affected by adjacent streams and available water, riparian areas affect, alter, and benefit streams. Streams are shaped by the function of transporting water and sediment and the interactions of climate, geology, topography, vegetation, and the effects of human land use.

Some human impacts related to ranching that can change stream channel morphology include grazing, water diversions, channel modification, and dams (Gregory 2006). Livestock pastureland is often located near streams where diversions can be easily made for irrigation water, which can result in sediment, nutrients, and pathogens being transported to surface waters (O'Callaghan et al. 2019). With naturally available water, riparian rangeland has been sought for its low maintenance and cost of providing water for livestock. Livestock grazing and water can affect many factors in stream ecosystems, including destabilizing banks, altering vegetation, increasing sediment and nutrient input, aggrading and widening channels, lowering water tables, and changing the stream hydrology (Krall and Roni 2023). The effects of livestock management, in which unrestricted access to riparian and stream environments is available, have resulted in the need for and interest in restoring these critical environments in western rangelands and different livestock management systems.

The Wetlands Reserve Program (WRP) is a voluntary conservation program that is administrated by the Natural Resources Conservation Service (NRCS) under the U.S. Department of Agriculture and funded through the Farm Bill (USDA NRCS 2004). WRP works on private lands with eligible landowners, providing technical and financial assistance to restore, protect, and enhance wetlands in exchange for retiring land from agriculture. The Wetlands Reserve Program (WRP) is no longer available as other easement programs have replaced it. The National Research Council (1992) defines restoration as "the return of an ecosystem to a close approximation of its condition before disturbance. In restoration, ecological damage to the resource is repaired. Both the structure and the functions of the ecosystem are recreated". After performing a restoration project, or changing grazing management and land use, it is critical to monitor the project area to determine whether the goals of the project are achieved.

Adobe Creek is a small stream in which water flows from the Glass Mountains to Adobe Valley in California near the border with Nevada. The landowners of the historic Adobe Ranch put a portion of their property into an NRCS easement in 2004 and 2005 under the Wetland Reserve Program (WRP), through which a variety of restoration was performed. My study focuses on Adobe Creek and the restoration performed as it relates to changes in the stream channel morphology and riparian vegetation. My hypothesis for this project is: With the absence of cattle grazing, reduction in irrigation, and physical restoration of Adobe Creek WRP, stream channel morphology and riparian vegetation will change, specifically with narrowing bankfull widths and increased riparian vegetation.

LITERATURE REVIEW

The historic ranching activities in the Adobe Creek Watershed, including an agricultural dam, water diversions for irrigation, and livestock grazing, have affected the stream and riparian ecosystem, resulting in a restoration project under the Wetland Reserve Program (WRP). Several literature reviews have been written concerning livestock grazing and the associated effects on stream and riparian ecosystems (Kauffman and Krueger 1984, Belsky et al. 1999, Agouridis et al. 2005, O'Callaghan et al. 2019, Krall and Roni 2023). Within the literature, some effects of livestock grazing have greater correlations than others, and the consistency of the effects varies widely. Additionally, the knowledge base indicates that feral horses, hereafter termed wild horses, have varied effects on stream and riparian ecosystems (Smith 1986, Boyd et al. 2017, Kaweck et al. 2018). The restoration of the Adobe Creek WRP has had several other agriculturally related human alterations that the current body of literature indicates may influence streams and the surrounding ecosystem. During this study, I reviewed a variety of literature. The following is a summation of what may be relevant to the stream and riparian area of Adobe Creek WRP.

Belsky et al. (1999) reviewed the influence of livestock on western streams and riparian ecosystems. They found various effects of livestock on stream morphology, including increased channel depth and width, decreases in water depth and channel stability during flooding, reduced stream bank stability, angle, quality and quantity of undercuts, and fewer meanders. These effects were found over various streams and study areas and may not all occur or have different effects based on the stream and its settings.

Common forms of restoration studied for streams and riparian ecosystems are exclosures, livestock absence, or grazing management implementation (Krall and Roni 2023). Magilligan and McDowell (1997) observed in their streams, with the grazing exclosures in east-central Oregon, a reduction in width/depth ratio and bankfull width, which is defined as the width at the stage of the stream in which any further increase in water level would access the flood plain (Doll et al. 2003). Exclosures in the Russian River Basin, California, resulted in bankfull widths narrowing, cooler temperatures in pools, and greater tree density compared to control reaches (Opperman and Merenlender 2004). The exclosures were for deer; however, livestock had previously heavily grazed the study area, according to the landowner. The authors attribute the riparian vegetation as affecting the changes in channel form, as these changes aligned with the exclosure fence line and restored riparian vegetation (Opperman and Merenlender 2004).

In a Virginia study, bankfull width did not respond to livestock exclusions of varying years compared to the paired control; however, the groundcover vegetation in the livestock exclusion was twice that of grazed reaches (Ranganath et al. 2009). Similarly, a study in the White Mountains on the California-Nevada border (the closest channel morphology to the Adobe Creek study site) found no significant difference in channel morphology with 24-year livestock exclosures but a significant difference in grass and sedge height, an expected result when comparing grazed to ungrazed areas (Kondolf 1993). In a northwestern Nevada creek, bank stability and tree cover increased while the width/depth did not indicate any trend when comparing an excluded headwater stream to an adjacent tributary, with rotational rest grazing over 14 years (Myers and Swanson 1996).

Conversely, Laliberte et al. (2001) findings indicate narrowing for both the grazed and excluded stream reaches in northeastern Oregon using aerial photos and GIS, which they associate with island morphology. They also saw small changes in sinuosity but not a distinct difference between grazed and excluded stream morphology. In an Idaho stream that was previously grazed to a point where a revegetation and rehabilitation project was undertaken, all grazing treatments show narrowing of the stream channel over the study period and an inverse association between narrowing and grazing intensity (Clary 1999). The stream had increases in channel depth, decreased width-to-depth ratios, stream stability rating improvements, and willow cover and height for all treatments. In an Arizona study of five streams with exclosures, tree and shrub species cover generally increased in exclosures; however, the channel morphology was not distinctly correlated to the exclosures, with the width/depth ratio markedly decreasing in less than half of the exclosures (Beard 2004).

Three different restoration techniques for streams in semiarid rangelands improved vegetation production (Silverman et al. 2019). For example, Maggie Creek in Nevada, which had changes in grazing management for restoration, increased in the productive mesic area for the 11-year post-restoration study periods compared to the pre-restoration study period. The authors connect the riparian vegetation at Maggie Creek to likely stabilizing streambanks and reduced channel cross-sectional area (Silverman et al. 2019). In Washington and Oregon, Krall et al. (2021) compare control areas to livestock exclosures at 12 sites. They found a significant reduction in bank erosion and bare ground cover class, although not a significant increase in the other vegetation, cover, and canopy statistics. Overall, livestock exclosures increase vegetation in the absence of livestock grazing and stabilize stream banks with varied responses of channel morphology.

The effects of livestock on stream morphology are well-researched and documented; however, the results of restoration efforts to mitigate the effects of livestock are less clearly defined in the literature, with mixed results (Kauffman and Krueger 1984, Belsky et al. 1999, Agouridis et al. 2005, O'Callaghan et al. 2019, Krall and Roni 2023). With stream restoration for the adverse effects of livestock, many different factors can impact the effectiveness of the treatment, such as the stream type, vegetation, geologic history, and treatment selection. Across the literature reviews that were assessed for my paper, there was a lack of a consistent response to channel morphology. The bankfull or channel width generally decreased or remained the same with restoration effort, whereas depth and width/depth ratio had more of a mixed response, with the most common change to channel depth being to increase and the width/depth ratio to decrease (Agouridis et al. 2005, O'Callaghan et al. 2019, Krall and Roni 2023) (Figure 1). The most consistent channel response seems to be a decrease in stream bank erosion and an increase in bank stability (Agouridis et al. 2005, O'Callaghan et al. 2019, Krall and Roni 2023). In many studies, there was at least some form of positive response in riparian vegetation that occurs with restoration projects (O'Callaghan et al. 2019, Krall and Roni 2023). In the Adobe Creek WRP, cattle grazing is now absent; the remaining use in the WRP is limited sheep grazing for vegetation management and the unmanaged grazing of wild horses and wildlife.

The wild horses at Adobe Creek use the stream and riparian vegetation and have their influences on these ecosystems. Kaweck et al. (2018) conducted a study using game cameras to look at the riparian grazing of wild horses, cattle, and wildlife in riparian areas in Idaho. Their

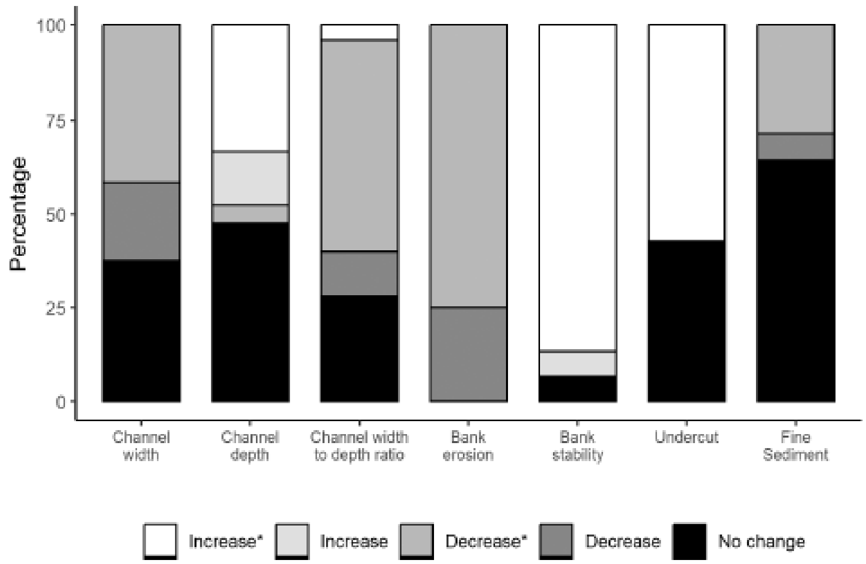


Figure 1. The percentage of published studies that reported an increase, a decrease, or no change in some physical habitat metrics following livestock exclusion and grazing reduction. An asterisk indicates significance. From Krall and Roni (2023).

findings indicate that the best modeling for streambank alteration was wild horses and cattle combined, and this combination was also the best model for vegetation height. Additionally, wild horses alone were more influential on streambank alterations than cattle or wildlife. In contrast, cattle were more strongly related to vegetation height, although on an individual animal basis, wild horses had the greatest effect on herbaceous stubble height (Kaweck et al. 2018). A study by Boyd et al. (2017) examined the wild horses' effect on riparian vegetation in the sagebrush steppe ecosystem in northwestern Nevada, comparing exclosures to grazed areas. They found that herbaceous stubble height was significantly shorter in grazed plots than in the exclosure plots, indicating that wild horses affect the vertical structure of vegetation in riparian areas (Boyd et al. 2017). Smith (1986) suggests that the main diet of wild horses is grasses, although there are a few cases where shrubs were found to be a portion of their diet.

When grazing is not properly managed, grazers such as livestock, wild horses, and big game can negatively affect plant health and vigor, which can create the opportunity for accelerated erosion in riparian areas (Maestas et al. 2023). This is especially difficult in the case of wild horses, as grazing management based on the use of certain areas cannot be enforced in the same way as it would be for cattle to prevent damage in riparian areas. Wild horses often have year-round access to riparian areas, while cattle are removed for part of the year (Kaweck et al. 2018). Scasta et al. (2016) analysis of studies on diet composition in western rangeland indicates that wild horses and cattle both have a diet that is mainly made up of graminoid vegetation species, but throughout the seasons, the percent of wild horses' diet that was browse (including all woody deciduous and coniferous shrub and tree species) did not exceed 10%. Conversely, cattle's diet exceeded 10%, and the percent browse for cattle was either similar to the wild horses, or exceeded it (Scasta et al. 2016). Wild horses utilize stream and riparian areas, and at Adobe Creek, grazing management is not applied in the same manner as would be done with livestock. This creates the opportunity for negative effects on riparian vegetation, thus affecting streams and stream morphology.

The stream restoration performed at Adobe Creek addressed agricultural practices other than livestock or wild horse grazing, namely the agricultural dam and the practice of pasture irrigation, along with the breach of the dam and resulting gully. Dams and the diversion of water, such as for irrigation, cause changes in water availability, substrate, and the frequency and magnitude of floods for the riparian area downstream, which all affect stream channel morphology (Kattelmann and Embury 1997). Over the past 5,000 years, humans have influenced river channels through dam construction and river diversion, altering river channels and natural processes (Gregory 2006).

Flow and sediment transportation are the drivers of stream and river channel form, and dams alter these drivers (Petts and Gurnell 2005). When dams are constructed, sediment from the watershed above the dam is trapped, and the channels below the dam are scoured without the natural sediment input and deposition (Gregory 2006). Additionally, the channel capacity can be reduced downstream, although there is variation in this result possibly related to trapped sediment (Gregory 2006). Dams interfere with the hydrology of streams and rivers, altering all flows over a range of timescales from hours to years (Petts and Gurnell 2005). With the construction of a dam, some common effects on riparian vegetation downstream include the contraction of the riparian area towards the stream channel, stabilization of sediments and constriction of channels as colonization occurs, and decline in channel capacity (Kattelmann and Embury 1997). Dams can have a profound effect on streams and channel morphology by altering the flow, sediment transport, and riparian vegetation.

Dams are often accompanied by the diversion of stream water, which can create alterations to stream channels. Stream flows are greatly reduced when stream water is diverted, especially in drier summer months, such as in the Eastern Sierra Nevada Mountains and Great Basin (Smith et al. 1991). Diversions cause alterations in flow but often remove a substantial portion of the stream's total discharge for extended periods (McKay and King 2006). Caskey et al. (2015) found in a study of unregulated streams in Colorado's Rocky Mountains that downstream of diversions, there was a decrease in bankfull width, depth, and cross-sectional area. Dams and diversions individually alter channel morphology, causing channel incision, decreased cross-sectional area, and narrowing of bankfull channels.

In the Eastern Sierra Nevada and Great Basin, streams and riparian areas have been used for agriculture and irrigation by the American homesteaders and, before that, by Native Americans (Lawton et al. 1976). As homesteaders moved west, water and riparian areas were sought out to allow them to settle and establish agriculture, both crops and livestock (Maestas et al. 2023). The literature indicates varied effects of cattle and wild horse grazing on stream channel morphology and riparian vegetation. Stream diversions and dams also mhave their effects on stream channel morphology and riparian vegetation. The effects on streams are not isolated from riparian vegetation as the stream and riparian vegetation are connected and influence each other by altering riparian vegetation, stream channel morphology, and vice versa. A substantial amount of research has been completed concerning grazing and agriculture's effects on stream and riparian ecosystems, but every stream is slightly different, and various factors are present in every watershed.

Many different human alterations influence Adobe Creek, which led to the conservation easement and the WRP restoration efforts, and thus the question of what changes to channel morphology and riparian vegetation will be affected as indicated by the literature. Though the response to restoration efforts is varied for studies of rangeland streams, the literature supports my hypothesis. With the absence of cattle grazing, reduction in irrigation, and physical restoration of Adobe Creek WRP, stream channel morphology and riparian vegetation will change, specifically with narrowing bankfull widths and increased riparian vegetation.

METHODS

Site Description

Adobe Creek and its tributaries are small perennial streams flowing from the Glass Mountains into Adobe Valley, California, in which the lower reaches are intermittent. The valley is located between the Glass Mountains, Mono Lake, Adobe Hills, and Benton Range in Mono County, California. Adobe Creek (HUC-12 180901010605) enters the northwest side of the arid Adobe Valley. The Adobe Valley is an endorheic basin with an ecosystem that has vegetation that is influenced by the Great Basin Desert to the east, the Sierra Nevada to the west, and the northern Mojave Desert to the south (Winitsky 2020). Adobe Creek passes under California Highway 120, where the stream channel eventually forms small ephemeral lakes that are dependent on water availability.

The historic Adobe Ranch lies along the stream, which has irrigated adjacent pasturelands during the past 150 years, facilitating cattle grazing (Pearce and USDA NRCS 2012b). An irrigation dam was built and then enlarged in 1955. The dam for the Adobe Reservoir failed during the winter of 1969-70 and was eventually determined not to be sufficiently structurally sound to be repaired. The grazing management in the Adobe Creek watershed changed from the past cattle grazing land use. The pasture and range rested from 2004 until 2007, and limited sheep grazing for vegetation management began in 2008, 2010, 2011, 2012, 2015, 2016, and 2017 (Pearce and USDA NRCS 2014). Besides a few private ranch properties, most of the Adobe Creek watershed is public land and holds ecological significance. The U.S. Forest Service allotment above the study area was not grazed from 2000 to 2018 and was grazed by sheep in 2018 and 2022 and by cattle in 2019 and 2020 (Cornachione and USDA USFS 2024).

Project Area Description

The landowners put 667 hectares (1,649 acres) of private land on or adjacent to Adobe Creek into the Natural Resources Conservation Service's (NRCS) Wetland Reserve Program (WRP) (Pearce and USDA NRCS 2014) (Figure 2). Adobe Creek WRP 1 and 2 were contracted in 2004 and 2005 as conservation easements with the NRCS. These WRPs are located at approximately 2,000 meters (6,500 feet to 6,800 feet) of elevation and are on opposite sides of CA-Highway 120. The focus of WRP is the restoration of the stream and surrounding areas previously affected by agricultural practices such as grazing and irrigation of pastureland. The physical restoration performed near the dam and gully from the dam breach includes rock drop structures, fascine, willow mattress, lunker structure, and 153 willow pole plantings that had a 58% survival rate as of 2011 (Pearce and USDA NRCS 2012a). The goals of the restoration efforts were to address wildlife habitat, streambank erosion, and to restore irrigated meadows and grazing lands to native wetland, riparian, and upland habitats (Pearce et al. 2009).

Cross-Sections

In 2006 and 2007, five stream cross-sections were established by Rob Pearce, Ph.D., (retired NRCS DC, Bishop) perpendicular to the stream to monitor the changes in Adobe Creek after the implementation of the WRP restoration projects. The cross-sections are marked with concrete anchors to mark each cross-section's exact beginning and end points. Each cross-section was surveyed three to five times before this study by Rob Pearce, Ph.D., and colleagues. Cross-

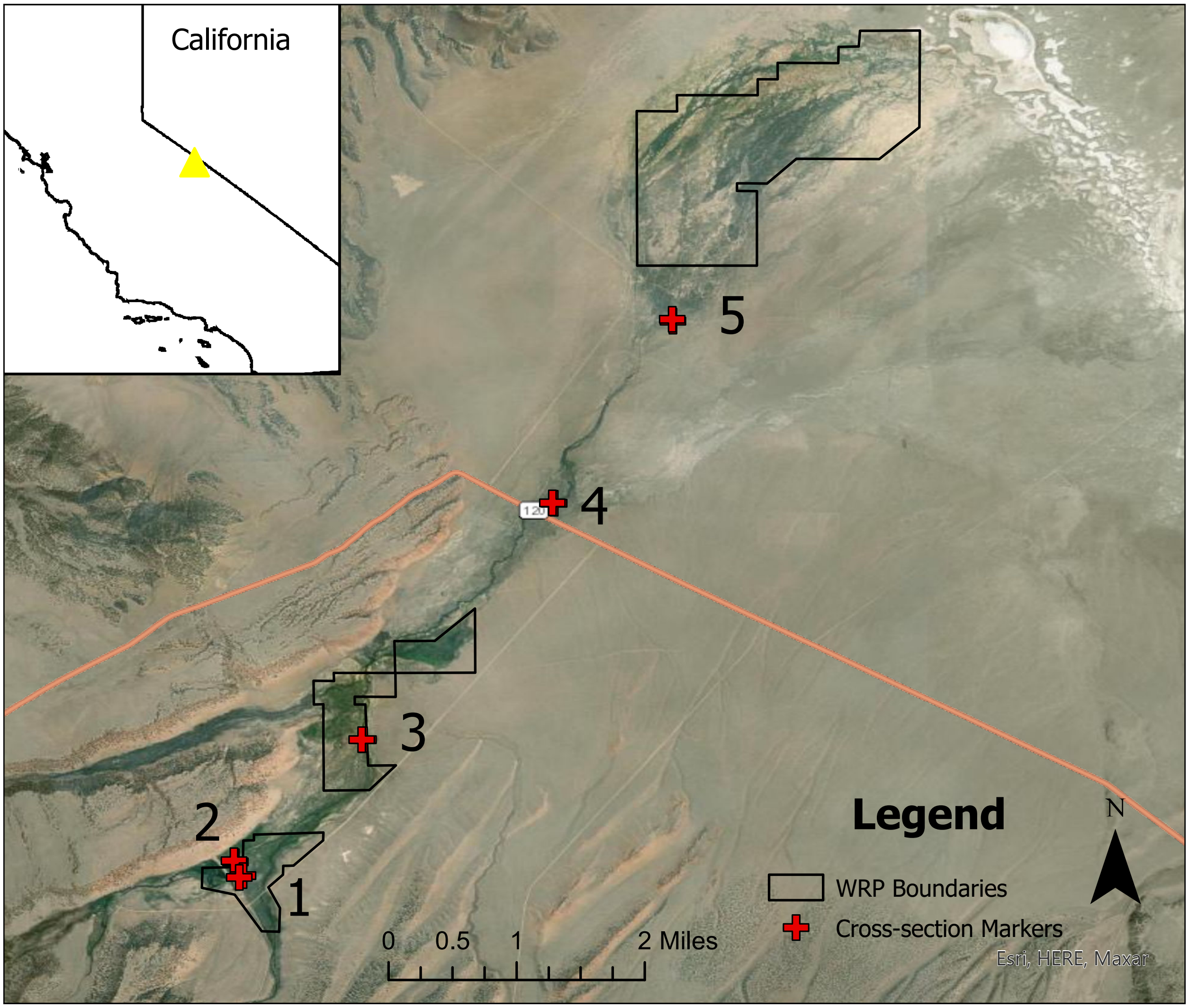


Figure 2. Map of Adobe Creek Wetland Reserve Program (WRP) properties, with permanent markers of the monitoring stream cross-sections and the location in California, USA.

section 5 was not re-surveyed as the stream now flows through a different channel that is not captured by the cross-section.

I located the cross-section markers using a recreational GPS unit (Garmin 64s handheld GPS with an accuracy of 5-10 m) and coordinates from the previous surveys, as well as images taken in the direction of the cross-sections from each marker. While surveying the cross-sections, I followed the USDA Forest Service methodology (Harrelson et al. 1994) using a laser-level (Spectra Precision Laser LL5500). I noted bankfull, thalweg, and the waters wetted edge while surveying the cross-sections. I took elevation readings every foot and more often when appropriate.

Water Surface Slope

Using the laser-level, I measured the elevation at 150 feet of valley length upstream and downstream from the cross-section, measured at the surface of the water. I used the relative elevation readings to determine the stream slope. I took photos from each permanent marker in the direction of the cross-section and took GPS points at each of the permanent markers.

Satellite Imagery

I download National Agricultural Imagery Program (NAIP) satellite imagery from the U.S. Geological Service's Earth Explorer website for 2005, 2009, 2010, 2012, and 2022 (U.S. Geological Survey 2024). Using ArcGIS Pro, I created maps of the Adobe Creek study area with NAIP as background imagery. I added the GPS points for the permanent markers of each cross-section as a layer. From the point where the cross-section is within the stream channel, reference reaches were established 200 feet up and downstream of each cross-section for a total reference reach of 400 feet. The centerline of the stream was mapped within the reference reach for each year of NAIP imagery. For each year, the area of the riparian vegetative zone was mapped, which is essentially where the vegetation appeared to access water in the flood plain.

Analysis

Based on the field observations from the cross-section surveys, I calculated the flood prone area, entrenchment ratio, cross-section area, mean depth, width-to-depth ratio, and water slope. I derived the sinuosity through the data collected from the NAIP satellite imagery. Based on these data, I typed the stream reaches based on the Rosgen Classification system level 1 classification (Rosgen 1994, USDA NRCS 2007). I compared the channel morphology statistics to the years with available statistics. For each cross-section, I graphed the available years of surveys with the left bank marker set at 100 feet of elevation. For cross-section 3, the 2007 data could not be graphed in a way that fit logically within the cross-section. I compared photos from the 2011 cross-sections with photos of the 2024 cross-sections. I also compared photo points from 2006 and 2007 to photos that were taken from similar locations in 2024.

RESULTS

Stream Cross-Sections & Channel Morphology

Three of the four cross-sections in 2024 had bankfull widths between 7.6 and 7.8 feet, while cross-section 1 had a bankfull width of 2.8 feet (Table 1). Cross section 1 had the highest mean depth at 1.80 feet and had the lowest width-to-depth ratio at 1.57. Conversely, cross-section 2 had the lowest mean depth at 0.54 feet and the highest width-to-depth ratio at 14.20. Cross-sections 1 and 2 are the cross-sections closest to the breached agricultural dam and the physical portions of the restoration. These cross-sections have the most similar cross-sectional

Table 1. Channel morphology statistics for the stream cross-sections at Adobe Creek.
* Indicates values that are slightly off due to the limitation of the area surveyed.

		Cross-Section 1				Cross-Section 2		Cross-Section 3		Cross-Section 4	
Calculation	**Unit**	**2006**	**2008**	**2009**	**2024**	**2007**	**2024**	**2007**	**2024**	**2007**	**2024**
Bankfull Width	Ft	13.3	11.8	3.7	2.8	9.4	7.6	14.0	7.7	3.7	7.8
Mean Depth	Ft	0.733	0.341	0.97	1.80	0.98	0.54	1.27	1.72	2.61	1.22
Thalweg Depth	Ft	1.73	1.72	1.44	2.38	1.89	0.95	2.7	3.12	2.2	2.89
Width-to-Depth	Ratio	18.14	29.91	3.81	1.57	9.59	14.20	11.02	4.48	1.42	6.40
Cross-section Area	FT2	9.75	3.49	2.51	5.09	8.82	4.07	17.84	13.24	6.02	9.50
Flood Prone Width	Ft	128.4	83.7	52.5	111*	71.0	17.0	125.0	56.5*	30.5	50*
Entrenchment Ratio	Ratio	9.65	8.21	14.19	39.22*	7.55	8.95	8.92	7.34*	8.20	6.41*
Sinuosity	Ratio	1			1.35	1.16	1.24	1.32	2.05	1.7	1.3
Water Slope	%		-0.38%	-0.43%	-0.42%	-0.61%	-0.87%	-0.001	-0.93%		-0.41%
Rosgen Stream Type		C4	C	E4	E	E4	C?	E	E	E4	E

area at 5.09 and 4.07 square feet, respectively, compared to 13.24 and 9.50 square feet for cross-sections 3 and 4.

The observed trends are the most predominant in comparing the 2024 channel morphology statistics to the available prior year's bankfull width. For cross-sections 2, 3, and 4, there are only data from 2007 and 2024. For cross-sections 2 and 3, there was a decline in bankfull width, while cross-section 4 was the only one to show an increase in bankfull width (Figure 3). Cross-section 1 has channel morphology statistics from 2006, 2008, and 2009 to compare to the 2024 cross-section, and the graph shows a consistent decrease in the bankfull width over time. Three of the four cross-sections showed a decrease in bankfull width, which is

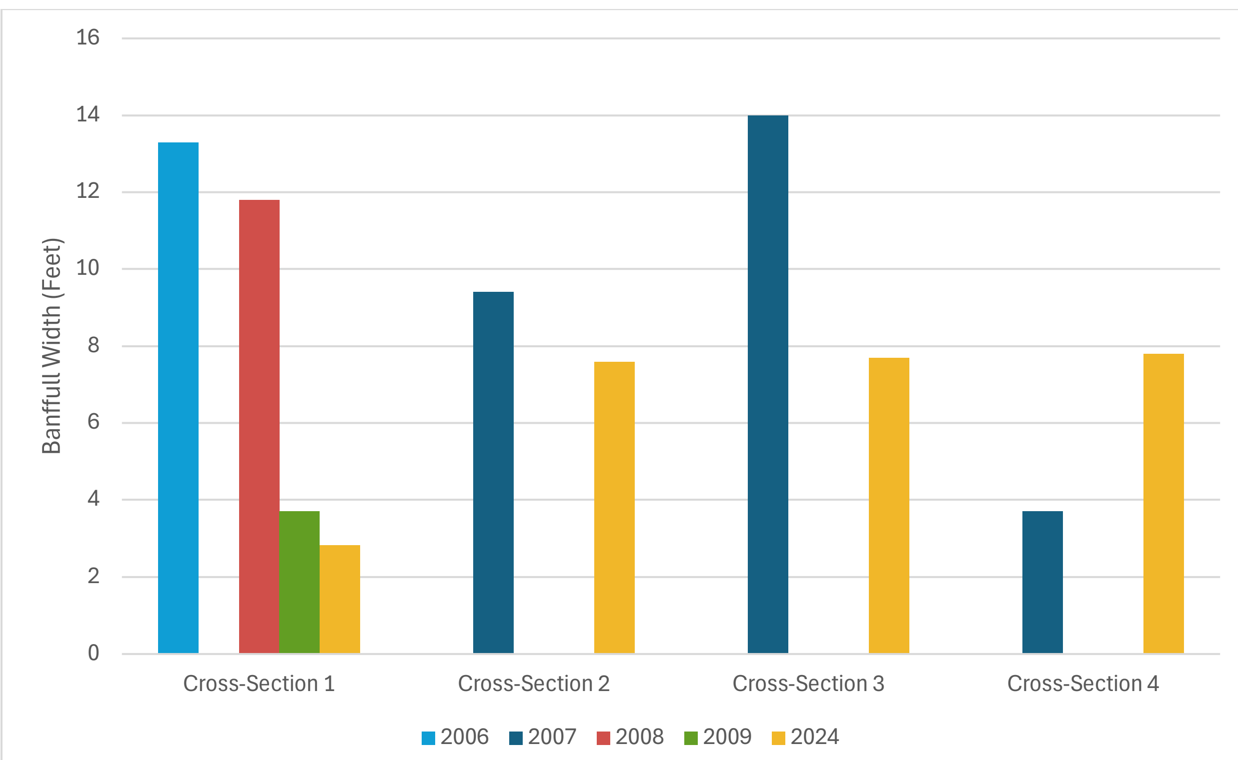


Figure 3. Bankfull width of Adobe Creek at each cross-section by year.

commonly observed in literature reviews for restoration efforts of streams affected by livestock (Agouridis et al. 2005, O'Callaghan et al. 2019, Krall and Roni 2023). The cross-sectional area decreased from 2006 or 2007 to 2024 for cross-sections 1, 2, and 3 however, the cross-sectional area did increase for cross-section 4. Additionally, cross-section 1 decreased by almost half the cross-sectional area from 2006 to 2024. From 2009 to 2024, there was an increase in cross-sectional area (Table 1).

Other channel morphology of Adobe Creek's observed stream reaches, such as mean depth, thalweg depth, entrenchment ratio, and sinuosity, show varied responses between years. The flood prone width for cross-sections 1, 3, and 4 extended past the permanent cross-section marker on one side or the other and was outside the area surveyed. I decided to restrain the flood prone width to the cross-section surveyed, and thus the flood prone width and the entrenchment ratios are altered and are of limited utility.

I determined sinuosity through GIS analysis and NAIP satellite imagery (Table 2). However, the sinuosity in Table 1 for years 2006, 2007, 2008, and 2009 was from previous survey data and was determined using other methods. I decided to present both forms of sinuosity for consistent use of the prior data. The variance in collection methods reduces the utility of comparison. The sinuosity derived from satellite imagery shows little variation year to year, with cross-section 4 showing the greatest variation being 0.2, from 1.50 in 2005 to 1.30 in 2022. This variation is inconsistent over the years surveyed, and this stream reach shows the highest density of shrubbery over the stream, blocking the view from above. Overall, there is a lack of variation in sinuosity from satellite imagery, indicating stability in this aspect of the stream morphology for Adobe Creek.

All cross-sections were classified as type E streams in the prior data, with cross-section 1 moving from type C to type E in 2009. From the cross-sectional survey in 2024, I classified stream reaches 1, 3, and 4 as type E streams, based on the Level 1 Rosgen Classification system (USDA NRCS 2007). The sinuosity for the stream reaches 1 and 4 appear to be slightly outside the parameters of a type E stream, indicating possible classification as a type C stream; however, the width depth ratios are solidly below that of type C streams and are characteristic of type E streams (Rosgen 1994). The stream reach for cross-section 2 is very shallow and thus has a moderate to high width-to-depth ratio, indicating that it is more of a type C stream than a type E as previously classified.

I graphed the cross-section elevation surveys for all available years, with the left bank looking downstream being the northernmost bank, and the permanent marker on the left bank elevation was set to 100 feet for representation (Figures 4 & 5). Each graph demonstrates alteration in the channel or lack thereof because of the precision achieved with permanent cross-section locations. Cross-section 5 last had the cross-section read in 2011 as the stream no longer flows through the cross-section; a historic irrigation ditch is now the main channel of the stream.

The graph for cross-section 1 shows consistent elevations across the years, with the greatest variation in the proximity of the active channel (Figure 5). This is the widest cross-section and requires a turning point on the right bank at approximately 110 feet (performed at 109 feet in 2024). On the left bank in 2006, there appears to be a slight hump in the channel that disappeared in 2008 and 2009. Then, in 2011, the same area appeared to build up with a sharper drop-off into the channel. Over the approximate next 10 years, there is a significant change with both banks of the active channel being built up and the channel deepening. This trend continues

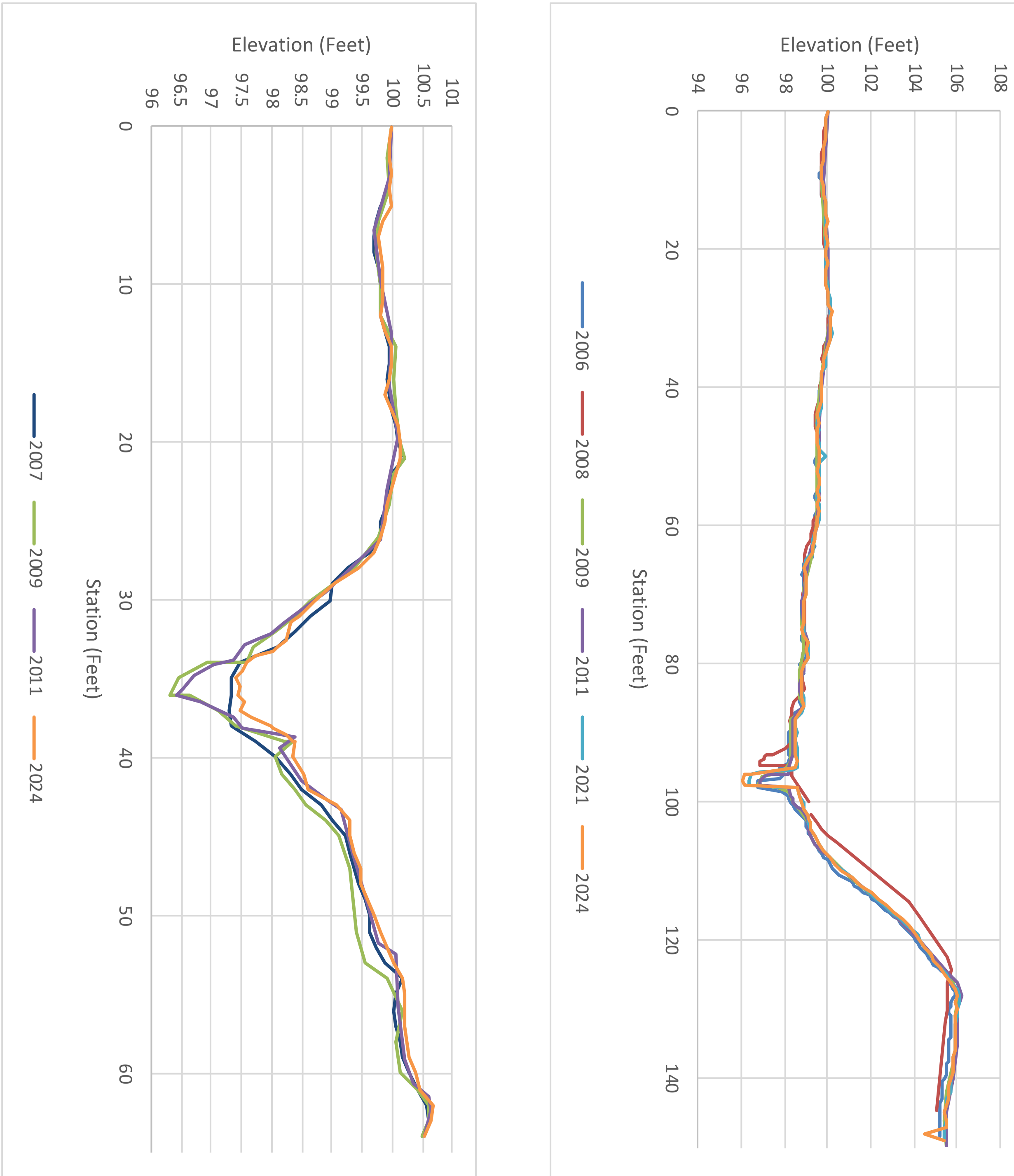
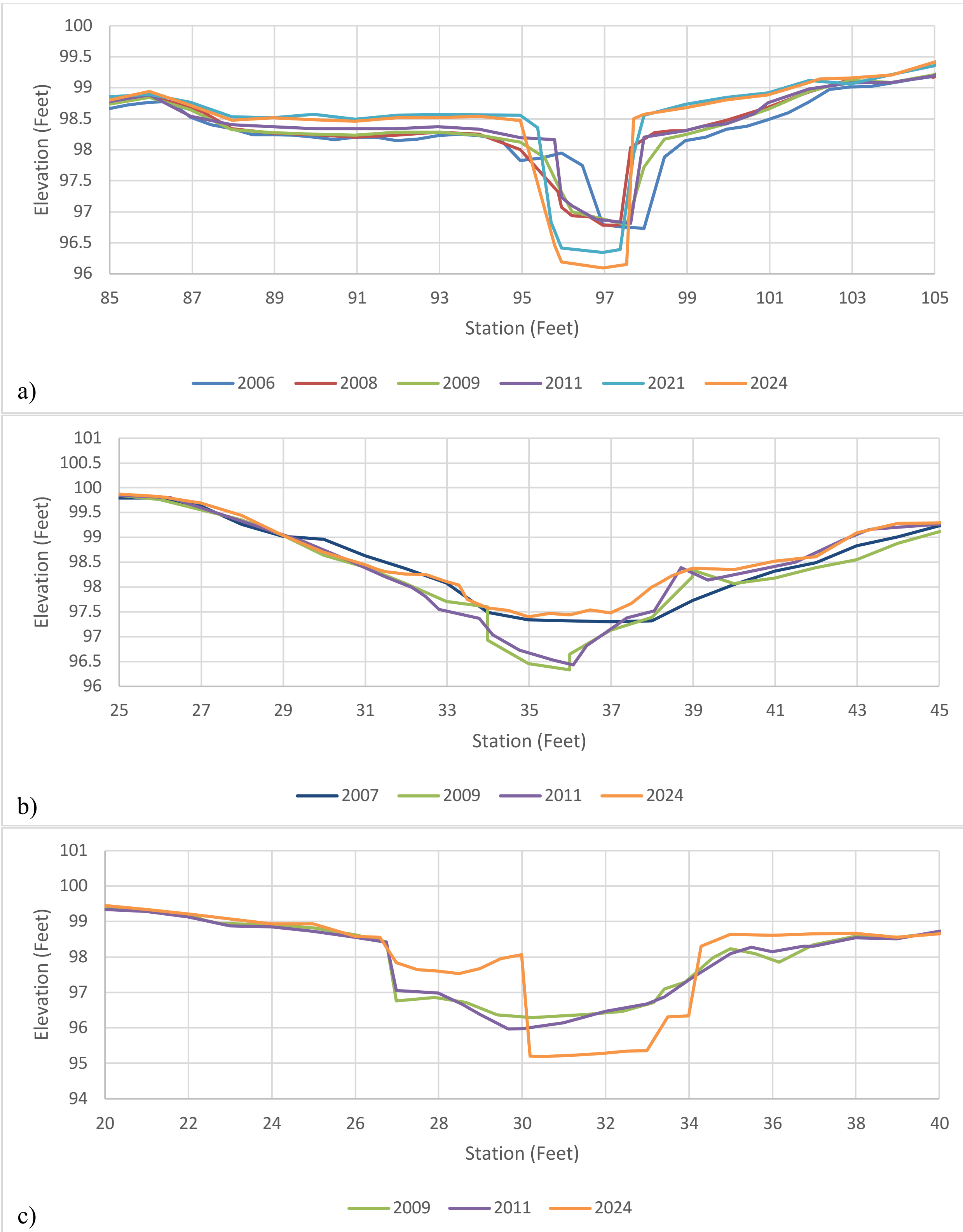


Figure 4. All available years for entire cross-sections 1 (right/top) & 2 (left/bottom) looking downstream with the permanent marker of the left bank set to 100 ft elevation for reference.


100
99.5
99
98.5
98
97.5
97
96.5
96
Elevation (Feet)
85
87
89
91
93
95
97
99
101
103
105
Station (Feet)
2006
2008
2009
2011
2021
2024
a)
101
100.5
100
99.5
99
98.5
98
97.5
97
96.5
96
Elevation (Feet)
25
27
29
31
33
35
37
39
41
43
45
Station (Feet)
2007
2009
2011
2024
b)
101
100
99
98
97
96
95
94
Elevation (Feet)
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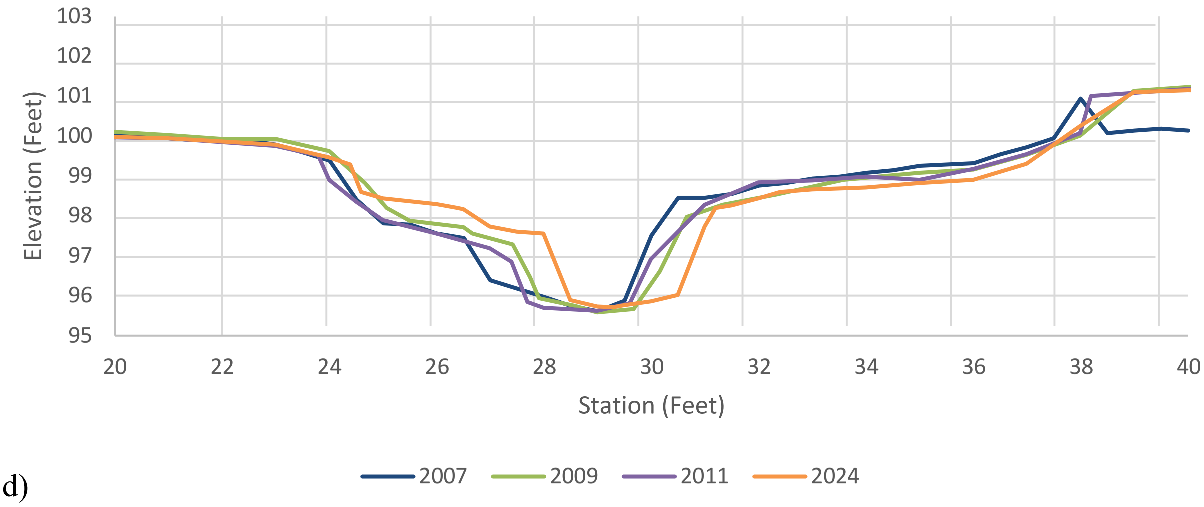
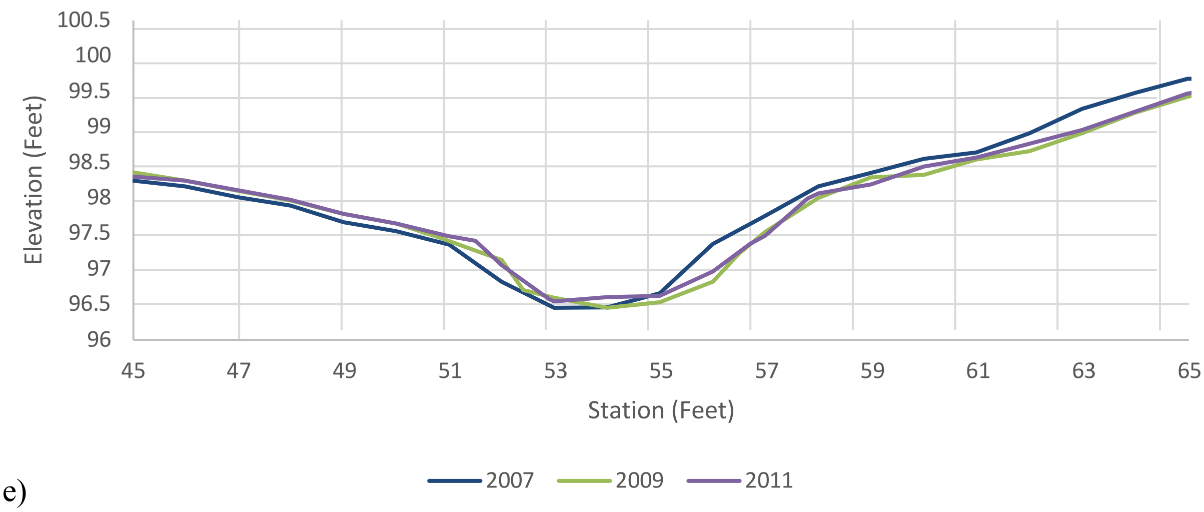
34
36
38
40
Station (Feet)
2009
2011
2024
c)



d)



e)

Figure 5. Sections of 20 ft of all cross-sections, a) cross-section 1, b) cross-section 2, c) cross-section 3, d) cross-section 4, e) cross-section 5, including the active channel looking downstream with the permanent marker of the left bank set to 100 ft elevation for reference.

into 2024 and is even slightly deeper and possibly steeper in the active channel. On either side of this deep active channel, the graph shows that the elevation of the bank areas increased, which indicates that some form of deposition occurred between 2011 and 2021. When I surveyed cross-section 1, the area was flooded with the wetted edge at stations 64.92 and 102.25. Additionally, I observed undercut banks on both banks of cross-section 1.

One of the major changes that can be observed in the graph of cross-section 2 is the increased depth of the channel from 2007 to 2009 when the channel appears to experience deposition between 2011 and 2024 when the thalweg of the channel is at a greater elevation than before 2007. For cross-section 3, the data for 2007 were taken from the starting point on the right side. There are also fewer stations than there are for the other years. Attempts to align the data from 2007 do not appear logical and thus are not displayed on the graph. On the left side of the channel in 2024, there is an increase in elevation, while on the right side of the channel, there appears to be a decrease in elevation or a deepening of the channel (Figure 5). The general shape of the channel for cross-section 4 appears to remain the same throughout the survey years. However, the channel is slowly moving towards the right bank (Figure 5). This was the only cross-section with increased bankfull width based on available data. Cross-section 5 shows very little variation from year to year, indicating that it remained stable throughout the years surveyed, including 2007, 2009, and 2011.

I used satellite imagery from NAIP to map the area of the riparian vegetative zone within the stream's reach. Cross-sections 1 and 5 showed the largest gain in riparian area vegetative zone with a change of 10,439 square feet and 7,278 square feet, respectively (Figure 6). The stream reach of cross-section 1 had a consistent increase from 2005 to 2022, while cross-section 5 showed a consistent increase from 2005 to 2012. Stream reaches 2, 3, and 4 showed a variety of changes in the riparian vegetative area across the years, with stream reach 3 having a net gain of riparian vegetative zone from 2005 to 2022, reach 2 ending approximately the same, and reach 4 having a net loss. The results of the riparian area are mixed, but there is only one reach with a slight net loss of area of the riparian vegetative zone. This would indicate that the riparian vegetation is not contracting towards the channel, which could occur with reduced access to groundwater.

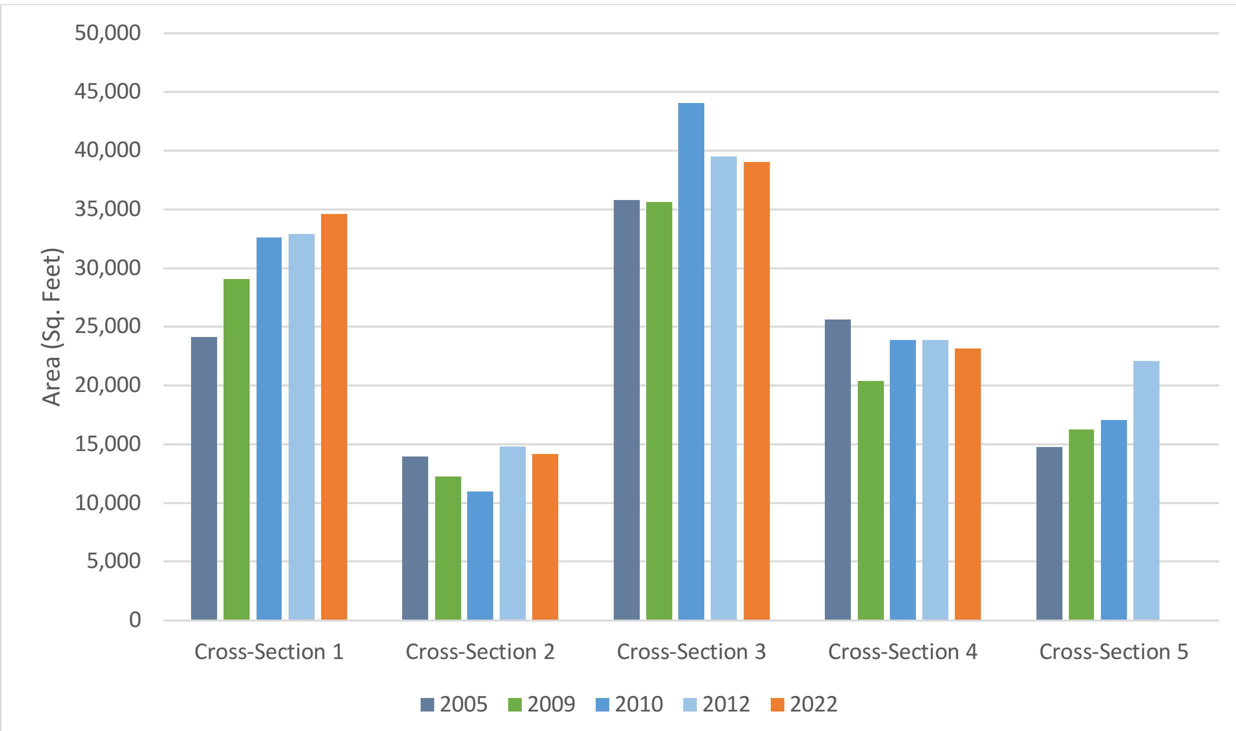


Figure 6. Area of riparian vegetative zone for the stream reaches of Adobe Creek by year and derived from NAIP images.

Photo Comparison

I compared available photos of Adobe Creek and the cross-sections to photos taken in 2024 (Appendix A). There are photos from 2006 and 2007, taken during the restoration, both physical and land use change, which are focused near the site of the stream breaching the dam. The cross-section photos from 2011 occur after physical restoration and grazing management had been implemented for several years. As such, the photos do not represent pre-restoration conditions; however, the evidence of vegetative change is dramatic.

For cross-section 1, two photos for comparison are located on the right bank. The first set does not show the stream or much riparian vegetation at the cross-section; however, the woody riparian vegetation can be seen on the opposite side of the dam in 2024 that could not be seen in 2011, indicating growth in woody riparian vegetation at the dam outlet. The second comparison shows the stream and riparian vegetation, with the most apparent difference being limited, sporadic, and small woody riparian vegetation in 2011 with a grass and herbaceous plant-dominated riparian vegetative zone with a primarily bare ground slope in the foreground. In 2024, the woody riparian vegetation, namely *Salix* spp. (willow), dominates the riparian area in the photo, making it challenging to compare grass and herbaceous plant cover. The bare ground in the lower portion of the photo is still evident, but there is substantially more grass in this area.

Photos from both sides of cross-section 2 align well between 2011 and 2024, with terrestrial shrubs and landmarks lining up. In 2011, there is no evidence of woody riparian vegetation, whereas in 2024, there is evidence of two clumps of willow that are well developed in height and width. For cross-section 3, it would be difficult to determine the alignment of the photos between 2011 and 2024 on either bank without the permanent cross-section markers due to the tremendous growth of the willows, which block all landmarks in the photo background. In 2011, there are large willows up and downstream of the cross-section and smaller willows along the stream, but the opposite bank can be identified. In 2024, the height and bulk of the woody riparian vegetation completely block the opposite bank from either side, evidence of extensive growth. This cross-section does not show an identifiable change in the grass and herbaceous vegetation cover. On the right bank, there appears to be some death of *Chrysothamnus nauseosus* ssp. *consimilis* (rabbitbrush), but this is not conclusive. In 2011, the cross-section 4 photos show well-established willow on both the upstream and downstream portions of the photo, as well as rabbitbrush (also known as *Ericameria nauseosa var. oreophila*) on the left bank, and *Rosa woodsii* (Woods' rose) shown near the left bank marker (Honer 2001, Winitsky 2020). In 2024, the *Salix* spp. shows extensive growth on the upstream side, while the *Chrysothamnus nauseosus ssp. consimilis* has few green stems, and the *Rosa woodsia* has developed well.

The photos near cross-section 1 looking up Taylor Canyon with the Glass Mountains in the background are not from the exact location but cover the same stream reach. The 2006 and 2007 photos show some low woody riparian vegetation, grass, and herbaceous plants dominating the riparian vegetative zone. The 2024 photo shows the same area from a slightly higher elevation. The woody riparian vegetation are well-developed in height and bulk, appearing to be the dominant vegetation in the riparian vegetative zone. The woody riparian vegetation have developed so that if the 2006 and 2007 photos were retaken at the exact points, shrub vegetation would likely be the only thing in the photo.

The 2006, 2007, and 2024 photos depicting the location of a brush mat installed during the restoration project in 2007 are all taken from slightly different locations. There is a curve in the channel, with the right bank being a steep bare ground slope with a slight drop-off above and limited, small riparian vegetation on the left bank. In 2024, the bare ground where the brush mat was installed appears to be covered in approximately chest-high woody riparian vegetation. The left bank also has more shrub coverage. The background shows substantial woody riparian vegetation growth. The channel may have migrated towards the left bank, indicating that the right bank is more stable and that the brush mat and the presence of woody riparian vegetation prevent bank erosion. All the photo comparisons show an increase in woody riparian vegetation.

Many of the observed increases in woody riparian vegetation were substantial. An increase in woody riparian vegetation is consistent with field visits compared to past photos of the area and other prior photo comparisons assembled by Robert Pearce, Ph.D. (retired NRCS DC, Bishop).

Some of the channel morphology statistics demonstrate mixed results in cross-sections 1, 2, and 3, which showed a decrease in bankfull width and cross-sectional area from 2006 or 2007 to 2024. The graphs of cross-sections demonstrate the changes that occurred to each cross-section over time after restoration efforts. Of the five stream reaches surrounding the cross-sections, only one showed a minimal net reduction in the riparian vegetative zone, with three cross-sections showing a net gain of area, two of which were substantial. The photo comparison indicates that there has been a substantial increase in woody riparian vegetation cover for the area where the agricultural dam was breached and for cross-sections 1, 2, and 3. After both physical restoration and alterations in grazing and land management, Adobe Creek appears to have benefited from increases in woody riparian vegetation and changes in channel morphology.

DISCUSSION

My observational study indicates that changes in grazing practices, reduced irrigation, and restoration efforts in Adobe Creek increased woody riparian vegetation and changes to the stream channel morphology. It also indicates changes in channel morphology, with the most substantial changes observed at the cross-section closest to the disturbance created by the bursting of the agricultural dam with associated gully formation and the dam itself. Each cross-section surveyed in 2024 shows changes in channel morphology over time, captured by descriptive statistics or cross-section graphs. Changes in riparian vegetation are indicated by the analysis of satellite imagery and the comparison of photos, which demonstrate that there were areas of substantial increase in woody riparian vegetation on Adobe Creek.

The altered states of streams and riparian areas as a result of the impacts that humans have had on the landscape have often made it difficult to distinguish between their pre-disturbance condition and a path to such conditions (Wohl et al. 2024). For Adobe Creek, the WRP is not centered on returning to pre-disturbance conditions, as the goals for the property and restoration efforts focused on wildlife, fisheries, ranching operations, and wetland and riparian habitats. The long-term general goal for the property related to hydrology states:

> "Expand in-stream habitat by restoring hydrology, ensuring bank stability, promoting and allowing for natural flooding regimes, and establishing native riparian vegetation. Include some wetland creation via structures. Include some deepwater pools and open water stretches." (Pearce and USDA NRCS 2014).

All the cross-section surveys and riparian vegetation observations indicate that this goal is in the process of being achieved.

Stream Cross-Sections & Channel Morphology

The results indicate that three cross-sections show a narrowing of bankfull width, while cross-section 4 is the only reach that suggests an increase in bankfull width. The reviewed literature indicates that with livestock management, combined with stream restoration efforts, narrowing the bankfull width is a typical response, with other articles reporting no change (Agouridis et al. 2005, O'Callaghan et al. 2019, Krall and Roni 2023). Cross section 1 has the most notable change in bankfull width and has the most years of data which shows the consistent narrowing trend. Robert Pearce, Ph.D., states in a field summary in 2011 on the Adobe Creek WRP that there was previously some disagreement on the location of bankfull for this stream reach, he also stated that narrowing was observed at that time (Pearce and USDA NRCS 2012a). The mean depth and thalweg depth also increased, and with such findings, the width-to-depth ratio showed a distinct decrease from 2006 to 2024. These results are similar to those seen by Clary (1999) in Idaho with alterations to grazing management. While there were three to four years of cross-sectional data taken for each stream reach, unfortunately, the bankfull width and other data for channel morphology were not recorded as part of this process. These data would be beneficial, but fortunately, cross-sectional data can be graphed to visually convey changes to each channel over time.

Cross-section 1 is the stream reach that exhibits the most change in channel morphology, with results that compare favorably to the changes observed in the literature (Krall and Roni 2023). The graph of cross-section 1 shows the changes in the channel and floodplain over 6 years of the survey from 2006 to 2024 (Figures 4 & 5). The 2021 and 2024 cross-sections show sediment deposition on each bank, resulting in taller stream banks and a deepening channel with a relatively flat bottom. Based on the graphs and the channel morphology statistics, the banks stabilize while sediment deposition occurs in the floodplain directly adjacent to the streambanks. When I surveyed the cross-section, I observed undercuts of both banks, but these were not captured in the cross-section survey. Notably, the stream was outside of its bankfull width during the survey on May 14, 2024. My observation in the field indicated that there was also no measurable flow in the standing water just outside the bankfull width. The indication based on location and field observations is that the sediment deposition adjacent to the bank results from flood waters.

The graph of cross-section 2 shows an interesting set of channel alterations that were not captured in the two years of channel morphology statistics (Figure 4 & 5). The two years of channel morphology indicate that the stream cross-section narrowed in bankfull width and became shallower. The graph of four years of cross-section data confirms that the cross-section was shallower in 2024 than in 2007 and indicates some channel narrowing, specifically on the right streambank. The descriptive statistics, however, misrepresent the channel form changes captured in the 2009 and 2011 cross-section graphs. In these years, the channel appears to show abundant erosion, indicated by the increased channel depth, which I did not observe in 2024, suggesting the occurrence of erosion and deposition over the observed period. The changes in the channel occurred after stream restoration had been performed. The dramatic difference observed from the graph must be considered for any conclusions drawn from the channel morphology data for cross-section 2. Additionally, while I collected the data for cross-section 2, I observed that the cross-section depth did not appear to be representative of the stream reach. Under the Rosgen

Classification system, the stream reach would change from a type E stream to a type C. Considering my field observations of the reach and cross-sectional history, this change carries limited weight. The other cross-section that shows a change in stream type is cross-section 1, going from type C in 2006 to type E; however, the trend of decreased bankfull width is indicated by more years of data points, increasing the validity of this change.

Cross-section 5 was not surveyed as the stream no longer flows through it with the new channel, a historic irrigation ditch and a legacy of agriculture directly affecting the stream channel. Cross-section 4 had a channel form that remained a similar shape, with observable change being a migration of the active channel toward the right bank. This bank is on the outside edge of a curve in the stream channel, a common area for erosional forces to occur. Cross-section 4 is just downstream of a road crossing in which the stream passes through two culverts under the highway. This is likely a controlling factor on the stream reaches below the road crossing. Cross-section 4 is also the furthest cross-section from the stream restoration. The increase in bankfull width and cross-sectional area could indicate that the stream reach is transitioning. The changes in channel morphology for cross-section 3 are similar to cross-section 1, with the graph of cross-section 3 indicating deposition occurring on the right bank, while the right side of the channel is deepening and appearing to narrow. The cross-sections show channel morphology that changes throughout time, possibly indicative of shifts in the stream and riparian area at Adobe Creek.

The changes in cross-sections and channel morphology from 2006 and 2007 to 2024 are not all consistent, which may indicate multiple forces on Adobe Creek. The effect of livestock grazing was not the only land use altered during restoration. The reservoir initially breached the dam during the winter of 1969-70 with unpermitted embankments, which were built and breached as late as 1996. All this activity would have resulted in disturbance to the stream and channel. Dams alter the sediment load and flow of streams, which, in turn, affect the channel morphology and flow regime. As part of the restoration, a small pond was enlarged and stabilized in the reservoir area, while seven ponds were created on the non-WRP portion of the private land. All of these restoration efforts are in line with the objectives of the project and the WRP, specifically regarding wildlife, waterfowl, and fish habitat (Pearce and USDA NRCS 2014). The pond does, however, slow the flow of incoming water, allowing sediment to settle to the bottom of the pond and disconnecting the sediment flow from the upstream watershed, affecting the stream morphology below the pond and old dam. The diversion of irrigation water can also alter the flow regime, and the absence of such diversion affects the stream channel morphology separately from the effect of the pond (McKay and King 2006).

The channel morphology downstream of diversions can cause a decrease in bankfull width, depth, and cross-sectional area (Caskey et al. 2015). In removing the diversions on Adobe Creek from the dam to cross-section 3, the flow regime below this area is altered as additional water is in the stream that would otherwise have been used for irrigation (McKay and King 2006). Some of the possible effects of stream diversion are opposite of those that are observed with uncontrolled grazing; namely, diversion decreasing bankfull width while uncontrolled grazing can cause it to increase. Additionally, dams and grazing can cause streams to become incised, whereas, with diversion, a decrease in stream depth was observed. The restoration efforts at Adobe Creek altered human land uses on the stream, which has been shown to have opposing effects on stream channel morphology, complicating the channel's response to restoration.

Some channel morphology data I collected in 2024 is of limited utility, specifically those related to flood prone width. For all cross-sections, except cross-section 2, the elevation data I collected did not encompass the flood prone width on at least one side and is thus lower than the actual value. These values are sufficient to indicate that all reference channels are either type E or type C in conjunction with stream and valley forms (Rosgen 1994, USDA NRCS 2007). Large entrenchment ratios such as those seen in this study are indicative of well-developed floodplains (Doll et al. 2003). The sinuosity I found through GIS analysis indicates that there is minimal change in each stream reach and indicates that the stream reaches are all either type E or type C.

Riparian Vegetation

While this is an observational study with no statistical analysis, all the photo comparisons indicate an increase in the woody riparian vegetation across all stream reaches. The height and bulk of *Salix spp.* (willow) increased in all the photo comparisons, specifically those directly adjacent to and in the stream channels. With the removal of grazing pressure from cattle, studies found an increase in vegetation cover (including woody vegetation), as well as bank stability (Kauffman and Krueger 1984). Woody riparian vegetation was particularly connected to improvements in channel form and ecological conditions (Magilligan and McDowell 1997). A literature review found that channels that have vegetated banks are narrower and deeper compared to those that did not have vegetation on the banks, and, additionally, the reviewed studies found that the removal of riparian vegetation increased channel width and decreased depth (Opperman and Merenlender 2004). At Maggie Creek in Nevada, it was found that riparian vegetation likely was the source of streambank stabilization.

The photo comparison shows increased woody riparian vegetation across all photos used. Some of the original photos were taken after restoration activities had been performed. Almost all the original photos show some existing woody riparian vegetation; however, in 2024, all the woody riparian vegetation is well-developed. These findings could be validated quantitatively through the analysis of aerial imagery. I used satellite imagery in this study, and the resolution was insufficient to map vegetation types. A study utilizing high-quality aerial imagery would benefit the understanding of restoration efforts on Adobe Creek. Recently, drone-based lidar has been successfully applied to the survey of channel morphology. This project and stream are candidates for benefiting from such a survey of an arid stream.

A portion of Adobe Valley on the opposite side of the valley from the study area is the Montgomery Pass Wild Horse Territory (MPWHT). The Bureau of Land Management (BLM) and the U.S. Forest Service (USFS) are currently in the NEPA process to remove wild horses that are outside the MPWHT (USDA U.S. Forest Service and Inyo National Forest 2024, Bureau of Land Management 2024). The wild horses that use the Adobe Creek area were verified by my field observation, as well as the presence of horse manure and tracks outside the MPWHT. I observed approximately 30 wild horses in the meadow adjacent to cross-section 3. Wild horses affect riparian vegetation, and the grazing of wild horses cannot be managed as is done with livestock. Wild horses have been shown to graze less on browse as compared to livestock. If the intentions of the BLM and USFS regarding rounding up wild horses outside of the MPWHT are achieved, the utilization of wild horses on Adobe Creek will likely be reduced, affecting the riparian vegetation and stream morphology.

While not conclusive, the result of this study indicates that changes occurred in the channel morphology and riparian vegetation of Adobe Creek following restoration activities, absence of cattle grazing, and reduced irrigation. Concurrent with the hypothesis of this study, the results indicate increased woody riparian vegetation and the narrowing of bankfull width of at least three cross-sections. The use of satellite imagery showed little change and proved rather ineffective in this application. The survey of the cross-sections shows changes in channel morphology, with the graphs being of specific utility. The photo comparisons were of most value in illustrating the changes that have occurred after the implementation of land use change and physical restoration efforts related to the Adobe Creek WRP.

CONCLUSION

The restoration performed on Adobe Creek as part of the Wetland Reserve Program appears to have enhanced the stream and riparian ecosystems. The most obvious indicator of change on Adobe Creek as of 2024 is the amount of woody riparian vegetation on the stream. Many different human impacts are related to the historic use of the area for ranching, including livestock grazing, agricultural dams, and water diversion for pasture irrigation. The restoration efforts of the Adobe Creek WRP include altering land uses, restoring physical land, and managing grazing. All the restoration has the potential to alter riparian vegetation and stream channel morphology, much as the previous land uses did.

In assessing the stream channel and riparian vegetation of Adobe Creek over time, it is challenging to connect observed responses to a specific restoration activity. In the absence of cattle grazing or substantial reduction in grazing, the woody riparian vegetation has increased in coverage, as observed in all photo comparisons. The two cross-sections that showed narrowing of bankfull width had the most substantial increase in willow coverage, based on the photo comparisons.

Channel morphology is often said to take much longer to respond to restoration efforts, especially in comparison to something such as riparian vegetation. To continue monitoring efforts, a more in-depth analysis of the riparian vegetation could be performed both on the ground and through high-quality aerial imagery. Additionally, an expansion of the cross-sectional analysis, including longitudinal surveys, more cross-sections, and pebble count, would improve the understanding of the channel morphology of Adobe Creek. Conversely, the implementation of technology such as drone-based lidar may be the direction of future stream analysis. The restoration efforts appear to have had a positive effect on the stream and riparian ecosystem of Adobe Creek and have achieved many of the goals of the WRP.

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APPENDICES

APPENDIX A

Photo Comparison Adobe Creek

Cross-Section 1

2011 - Cross-Section 1 - Right side of bank, top of slope


2024 - Cross-Section 1 - Right side of bank, top of slope


2011 - Cross-Section 1 - Right side of bank - On slope looking at stream


2024 - Cross-Section 1 - Right side of bank - On slope looking at stream

Cross-Section 2

2011 - Cross-Section 2 - Left side of bank

2024 - Cross-Section 2 - Left side of bank

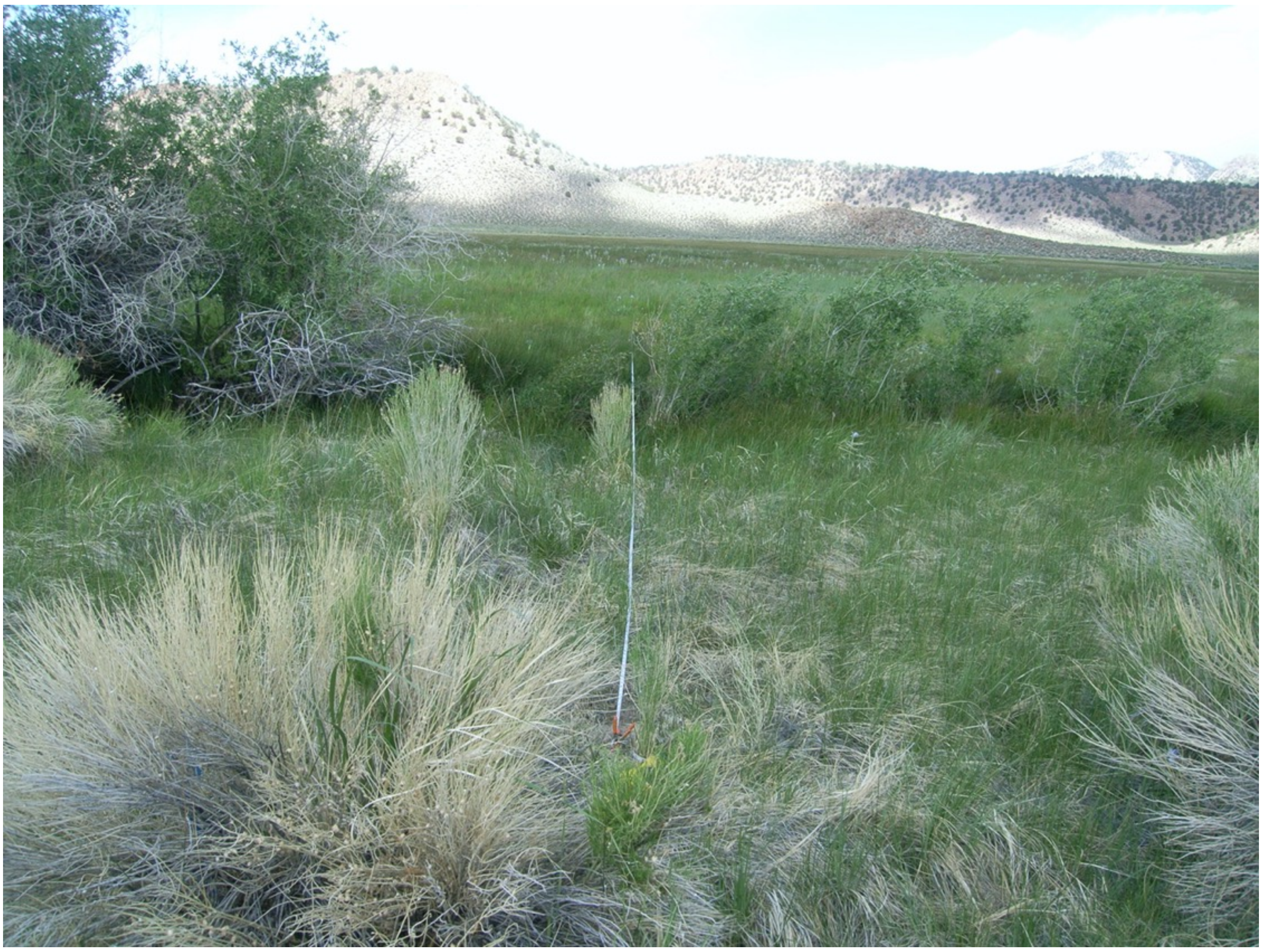

2011 - Cross-Section 2 - Right side of bank


2024 - Cross-Section 2 - Right side of bank

Cross-Section 3

2011 - Cross-Section 3 - Left side of bank

2024 - Cross-Section 3 - Left side of bank


2011 - Cross-Section 3 - Right side of bank


2024 - Cross-Section 3 - Right side of bank

<u>Cross-Section 4</u>

2011 - Cross-Section 4 - Left side of bank

2024 - Cross-Section 4 - Left side of bank

Photo Points

2006 – Slightly upstream from cross section 1 – Right side of bank, looking upstream and at Taylor Canyon with Glass Mountain (covered in cloud) in the background.

2007 - Slightly upstream from cross section 1 – Left side of bank, looking upstream and at Taylor Canyon with Glass Mountain in the background.

2024 – Cross section 1 – Right side of bank, looking upstream and at Glass Mountain.

2006 – Dam cut – Right bank, looking downstream at future Brush mat restoration site – Star indicates same location across photos

2007 – Dam cut – Right bank, looking downstream at future Brush mat restoration site

2024 – Dam cut – Right bank, looking downstream at brush mat restoration site

2024 – Dam cut – Right bank, looking downstream at brush mat restoration site