June 2023

Erosion Reduction and Sediment Capture Assessment

For Stenner and Brizzolara Creeks

Right to left: SLO Coastal RCD staff (Joe Murphy, Hayley Barnes, and Hallie Richard) and Creek Lands Conservation staff (Tim Delany). Photo By Aleksandra Wydzga, Creek Lands Conservation

Creek Lands Conservation

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FOR STENNER AND BRIZZOLARA CREEKS

June 2023

Prepared for:

San Luis Obispo Coastal Resource Conservation District

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TABLE OF CONTENTS

1 INTRODUCTION

The San Luis Resource Conservation District (CSLRCD) received grant funding from the California Department of Conservation Proposition 68 Working Lands and Riparian Corridors Program for the *Stenner Creek Watershed Enhancement Project*. As a result of poorly designed legacy ranch roads and cattle grazing, erosion and sedimentation have degraded refugia Steelhead habitat, impaired water quality, reduced the watershed's resilience and adaptability to climate change, and impacted the sustainability of the ranching operation and public access trails. Specifically, under this grant funding the CSLRCD aims to develop plans to:

- Reduce sedimentation within steelhead habitat,
- Improve water quality,
- Restore and enhance riparian and aquatic habitats, and,
- Identify ecologically friendly solutions to protect and improve the function of public access and ranching infrastructure.

The objectives are being met via a two-phased approach: 1) an erosion assessment of ranch roads, ranch road crossings, and trails and 2) an erosion and sediment capture assessment of the stream channel network. In addition to conducting the assessments to identify sites recommended for repair and enhancement, both approaches also develop recommended treatment concepts for sites and prioritize the sites for repair.

The erosion assessment of ranch roads was completed by Pacific Watershed Associated in 2022 (PWA 2023). This assessment identified ranch road projects that improve road drainage, road drivability, and water quality conditions, as well as reduce erosion, sediment delivery, and future maintenance needs along approximately 4 miles of unpaved California Polytechnic University at San Luis Obispo (Cal Poly) Rangeland roads within the Stenner Creek Watershed.

The second assessment of in-channel erosion sites and sediment capture opportunities is reported herein. Specifically, this assessment investigates approximately 15.5 miles of Stenner and Brizzolara Creeks and identifies projects that reduce erosion and sediment delivery to steelhead habitat, protect and enhance aquatic and riparian habitats, and protect public access and ranching infrastructure. Brizzolara Creek is a major tributary to Stenner Creek (Figure 1) and both creeks are designated as critical habitat for steelhead (NOAA 2005). Furthermore, because Stenner Creek is a tributary to San Luis Obispo (SLO) Creek the reduction of sediment production from the Stenner and Brizzolara subwatersheds will benefit not only steelhead habitat in Stenner and Brizzolara Creeks, but also in mainstem SLO Creek (Figure 1). Furthermore, the projects identified herein could have additional benefits including:

- reducing flood risk in depositional downstream reaches (e.g., lower SLO Creek),
- Slowing or preventing systemic channel incision to ensure high quality channel-floodplain connectivity, and therefore habitats are maintained and dry season base flows for steelhead are protected, and
- slowing or preventing systemic channel incision to maintain a higher groundwater table for adjacent agricultural operations along Cal Poly properties.

To be effective, an in-channel erosion assessment should follow a process of logical steps that embraces a holistic understanding of watershed wide erosional processes and integrates with conceptual models of geomorphology. As such this report begins by presenting relevant Watershed and Geomorphic Processes (Section 2) and is then followed by a description of the Assessment and Prioritization Approach (Section 3), Assessment Results (Section 4), Ecological Implications (Section 5) and finally a Summary and Recommendations (Section 6).

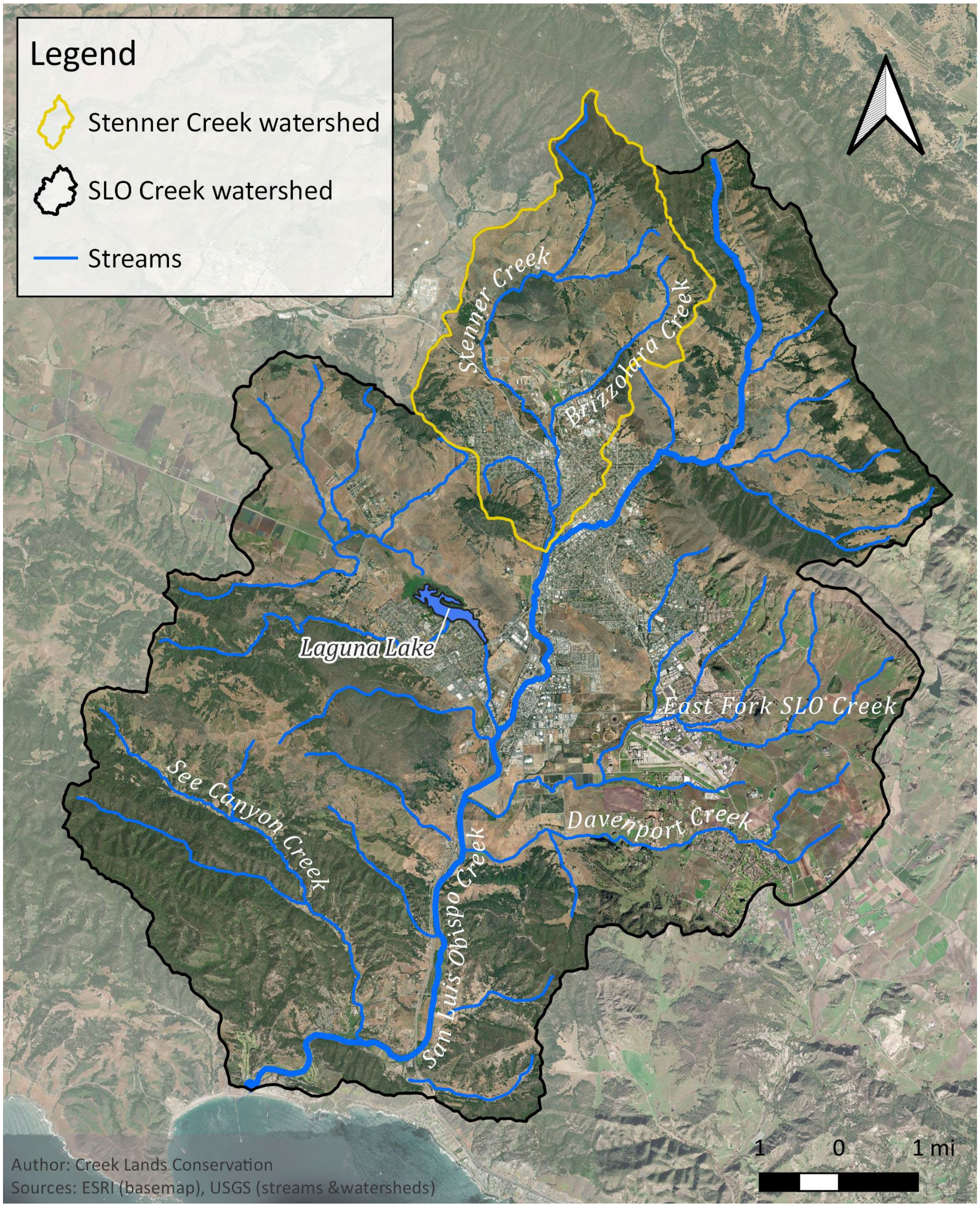


Figure 1: Reduction of sediment production in Stenner Creek Watershed will benefit critical steelhead habitat in Stenner Creek, Brizzolara Creek, and mainstem San Luis Obispo Creek.

2 Watershed and Geomorphic Processes

To provide context for the assessment approach and site prioritization process (Section 3), key watershed processes and a geomorphic evolution model are introduced in this section.

2.1 Watershed Processes

A watershed can be divided into two components: the channel network and the non-channelized landscape which supplies water and sediment to the channel network (Figure 2). The channel network is composed of all inter-connected channels draining the landscape including mainstem channels, tributary channels, ditches, and gullies. The channel network transmits water, sediment, organics, and nutrients to downstream reaches.

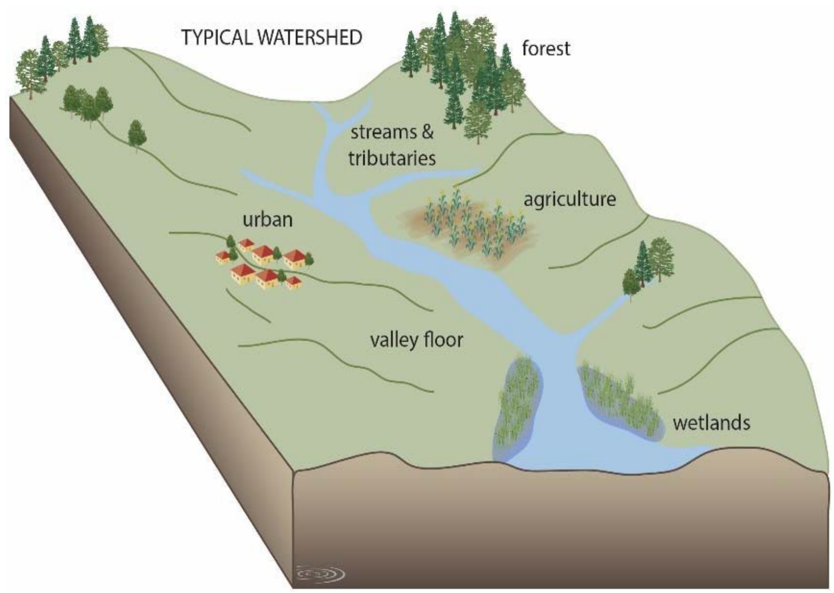


Figure 2: Conceptual watershed diagram showing the channel network (blue) and the non-channelized landscape (green) (Figure from Stillwater Sciences 2017).

One of the most important factors of the non-channelized landscape is the soil's capacity to infiltrate and absorb water into its pores, like a sponge. The infiltration of water into soil is most affected by conditions near the soil surface, such as its texture (e.g., clayey, or sandy), vegetative cover, and the size of its pores. When the conditions on the soil surface favor infiltration, more rainfall is absorbed, and the channel network receives less runoff. The rate at which rainfall accumulates on the watershed's surfaces and runs off without infiltrating is called the rainfall-runoff relationship. The destruction of pore space, loss of vegetation, or alteration of texture can reduce the soil's infiltration capacity. Loss of infiltration on the non-channelized landscape causes more rain runoff to move over the land surface, filling the channel network with water more quickly. This leads to an acceleration of the geomorphic processes described in Section 2.2.

Impacts to the watershed rainfall-runoff relationship in the Stenner and Brizzolara watersheds likely began about 250 years ago with the establishment of the Spanish mission at San Luis Obispo (1772). The California missions marked the beginning of large-scale changes in land use practices including timber harvest, clearing for cattle grazing, and crop cultivation. By clearing the landscape of deep-rooted perennial grasses, shrubs, and trees and replacing those with shallow-rooted annual European grasses, the infiltration capacity of the soil was greatly reduced (Stillwater Sciences 2010). Cattle that crossed and grazed along the streams may have also had a direct impact on the stability of the channel network's banks.

The City of San Luis Obispo experienced much more development in the second half of the 19th century, first with the development of water supplies from San Luis Obispo Creek in the 1880s and then with the extension of the Southern Pacific Railroad through San Luis Obispo in 1894. Extensive grading and modification occurred in the upper Stenner Creek watershed to build the railroad. This work included the creation of multiple culverts along the railroad to pass flow and debris that came down from the headwaters. Many roads also proliferated in the watershed as more people came to live in San Luis Obispo and use the land. This more recent phase of development caused further modification of the rainfall-runoff relationship through the reduction of vegetation cover and increased soil compaction, which would have made the non-channelized landscape more susceptible to raindrop, wind, and rill erosion. As described above, increased runoff from the altered soils can create greater erosion in the channel network. Due to the focus on the channel network, geomorphic processes which affect channel erosion are described in the next section.

2.2 Geomorphic Processes

A list of definitions of key technical terms utilized in this document are provided in the Glossary (Section 7).

Channel shape or form naturally varies over time and over the landscape. However, when the landscape is modified as described in Section 2.1., less water infiltrates into the ground, more surface runoff flows off the surface and reaches the channel, and the size of floods and associated scour potential increases. When scour frequency and magnitude of scour increases, the channel begins to erode vertically (termed incision). An incised channel, no longer connected to its floodplain, tends to confine flows, increase flow velocity, which in turn further increases the frequency and magnitude of erosion and subsequently reduces channel habitat complexity. The channel evolution model, originally developed by Schumm et al. (1984) and modified for channelized streams (Simon and Hupp 1987, Simon 1989), can be used to understand the channel incision and the resultant evolution of the channel (Figure 3). In this sequence, a previously stable channel (Type 1) that undergoes incision (Type 2) will eventually begin to widen (Type 3) and after a period of deposition and stabilization (Stage 4), will finally reach a new quasi-equilibrium (Type 5). Over time, channel incision (Type 2) eventually leads to the mass instability of channel banks of the former floodplain which then makes them a highly effective source of finer sediment (with some coarse sediment) as the channel widens. Fine sediment, rather than coarse sediment, has adverse ecological impacts. Channel erosion may also occur naturally.

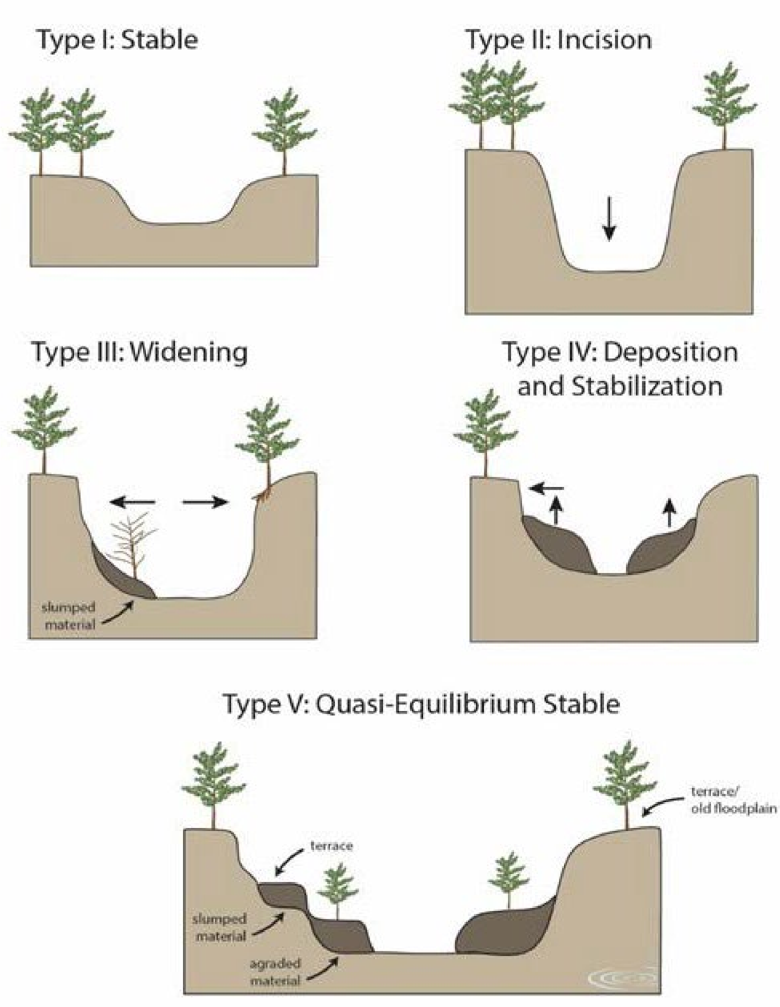


Figure 3: Channel Evolution Model modified from Schumm (1981), Simon and Hupp (1987), and Simon (1989) by Stillwater Sciences (2017).

In an eroding and modified landscape there are several other common erosional features that evolve. While under some circumstances these features could occur naturally, they become numerous and frequent in an actively disturbed and eroding landscape. These features are described below.

Gullies

In general gullies are indicative of an actively eroding landscape. Gullies can form in response to a modification of surface runoff patterns, of the vegetation, or of the surface or soil properties. Gullies also form in response to channel incision and resultant weeping groundwater which can cause unstable soil conditions and thus cause erosion even in the absence of concentrated surface flows. In human modified landscapes a period of gully formation and expansion commonly results in the production of fine sediments as they erode soil-mantled hillslopes. Because gullies are often connected directly to the channel network, a near 100% delivery ratio of sediment can be inferred. However, over time gullies will adjust to the causal modifications and may become stable or semi-stable components of the channel network. Remediating stable or semi-stable gullies will provide limited benefits.

Knickpoints

Knickpoints are steps in the channel profile that can occur if the bed or underlying material has sufficient cohesive sediment (silts and clays). The presence of a knickpoint may be indicative of rapid, active erosion. Knickpoints migrate upstream (Figure 4) creating unstable, incised channels that generate large amounts of fine sediment. Knickpoints are typically unstable features and should generally be prioritized for repair. This is especially true if there is critical infrastructure present upstream or if there are significant ecological resources present on site or downstream that would be negatively impacted by channel incision or downstream sediment deposition. Because knickpoints migrate upstream over time the channel downstream of the site should be evaluated for knickpoints as well. Bedrock knickpoints or knickpoints stabilization by large boulders which are too large to be eroded during flood events are generally stable features and do not require repair. If some features such as complex roots structures or coarse cobbles or boulders have temporarily stabilized the knickpoint, monitoring the knickpoint may be appropriate. When knickpoints occur in ephemeral channels or are near the top (the head) of the channel network the term headcut may be used. These terms can be used interchangeably, and preference for which word is used can depend on the region or professional background of individuals.

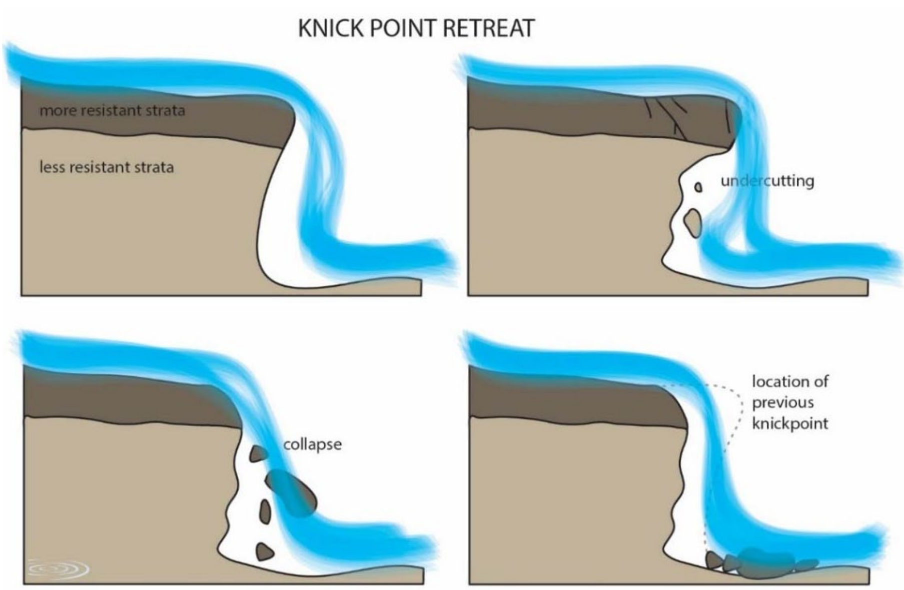


Figure 4: Knickpoints are erodible features in the stream channels that erode headward (Figure from Stillwater Sciences 2017).

Bank Erosion

As creeks vertically incise, banks become unstable. Unstable banks are commonly unvegetated or poorly vegetated and they can erode via a range of processes including dry season ravel, erosional impacts from humans or animals, and/or erosion of the toe during high flows which leads to mass failure and sediment sliding or slumping into the creek.

In additional to watershed wide-scale land-use changes, direct modification of the channel network such as armoring with riprap, gabions, or non-engineered debris, and infrastructure construction such as roads, bridges, culverts, and railroad tracks, have led to significant changes in runoff and erosional processes throughout the channel network. As is common in modified landscapes, geomorphic channel evolution can occur from downstream to upstream as knickpoints form and erode upstream through headward erosion. This leads to an "unzipping" of the channel network that starts in downstream reaches and proceeds to upstream reaches, often taking many decades for the channel network to stabilize in response to the disturbance. While in Stenner and Brizzolara subwatersheds this historic unzipping of the landscape began when the first major human-driven modification of the landscape first occurred, it is overlaid by a series of more current watershed wide and in-channel disturbances. As a result, Stenner and Brizzolara sub-watersheds have both legacy and modern erosional sites. Only those sites which are still actively eroding and that deliver sediment to the channel network are identified in this assessment.

3 Approach

Approximately fifteen and a half miles of Stenner Creek and its tributaries were assessed, including Brizzolara Creek which is the largest tributary to Stenner Creek (Figure 5). Only those portions of the channel network that are located on Cal Poly land and downslope of the railroad were assessed. Landslides that were not connected to and directly delivering sediment to channel network were not included in this assessment. This assessment follows these guiding principles:

1. Channels are naturally dynamic.
2. Channel adjustment and erosion is a natural process.
3. The rate, frequency, or magnitude of erosion can be exacerbated by human activities.
4. To decide ***if*** and ***how*** erosion should be slowed or stopped, the probability of continued erosion is evaluated.
5. To decide ***if*** and ***how*** erosion should be slowed or stopped, both the consequences of allowing the erosion to continue is evaluated and the consequences of trying to slow or stop the erosion is evaluated.

In summary sites that were deemed unlikely to directly contribute sediment to the channel network, sites that would require the disturbance of significant ecological resources (e.g., mature trees) for small erosional benefits, or sites that were beginning to naturally stabilize were not included in this assessment.

To the extent possible this report serves as a template for future erosion assessment and repair work. While certain aspects of future assessment, repair and monitoring can be conducted by professional field crews (e.g., California Conservation Corps, Cal Poly students, or citizen scientists), the identification of erosion sites and the determination of whether and how sites should be repaired needs to be conducted by professionals with adequate geomorphic and engineering experience to make determinations about differences between naturally eroding sites, eroded but mostly stable sites, and sites that will produce sufficient sediment to impact ecological resources or infrastructure to justify effective stabilization repairs. Detailed qualifications of professionals required to conduct this assessment type of work, or subsequent design and implementation work, can be found in a document titled "A Decision-Making Framework for In-Channel Erosion Repair in the Verde Valley, Arizona" (Stillwater Sciences 2017).

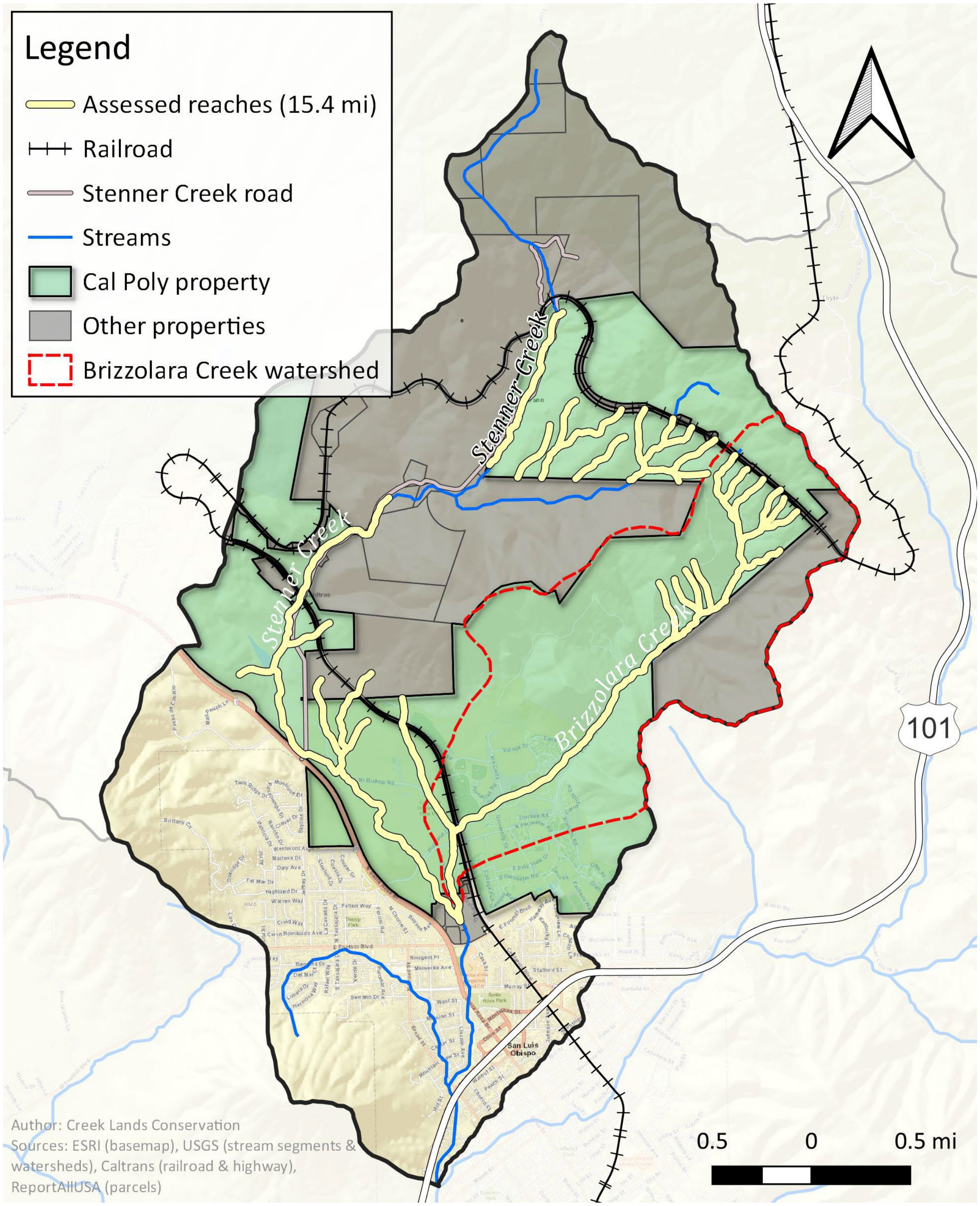


Figure 5: Cal Poly land within Stenner and Brizzolara Creek subwatersheds.

3.1 Assessment Methods

To conduct the assessment, approximately 15.5 miles of channel were surveyed by foot and sites were identified. Data collected included the location, site type, dimensions of each feature, erosion type (chronic/episodic), dominant bed material, dominant bank material, type of bed instability (e.g., localized bed scour, channel incision, head cutting), type of bank instability (e.g., toe scour, active slumping, dry ravel), other type of instability (e.g. heavy cow utilization, sheet or rill erosion), sediment reduction potential (cubic yards (CY)), sediment capture potential (CY), access rating (high/medium/low), potential to protect or enhance on-site or adjacent environmental resources (Y/N), potential to protect on-site or adjacent infrastructure (Y/N), estimated repair cost (major (>$100,000), large ($50,000-$100,000), moderate ($10,000-$50,000), or small (<$10,000)), cost-benefit ratio (cubic yards/cost), anticipated engineering analysis and design effort (high/low/none), and whether work could be implemented by hand-crews. Finally for some sites no repair and instead monitoring was recommended. Sediment reduction potential (CY) volume is estimated to occur on the scale of several decades if not repaired. Costs indicate the general implementation costs and do not include costs for permitting nor engineering analysis and design.

For each site, key results are described in Sections 4.1 and .4.2 and the key data are summarized in a table at the end of each section. A complete summary of data collected (as listed above) at each site is available in a companion excel-based assessment database.

3.2 Prioritization Process

All sites were prioritized for repair as high, medium, or low, based on estimates as follows: 1) the sediment reduction potential (CY); 2) the sediment capture potential (CY), 2) the estimated cost-benefit ratio ($ per CY), 3) potential to protect or enhance on-site or adjacent environmental resources, and the 4) potential to protect on-site or adjacent infrastructure. The sediment reduction/capture potential volumes and costs are approximate and were developed for prioritization purposes (to rate sites relative to one another). These key data are summarized in tables at end of each results section (Sections 4.1 and 4.2).

3.3 Planning Process for Site Design

Three of the high priority sites were selected to advance to full engineering analysis and designs under this grant funding source and are identified as such in the results section (see sites B300, B500, B600 in Section 4.2). Furthermore, for sites identified as needing a lower level of engineering analysis and design effort, conceptual details for recommended repairs were developed and are provided in Appendix B. On the other hand, for sites identified as needing a higher level of engineering analysis and design effort, conceptual designs were not developed based on the assumption that repair treatments will be developed during the next project phase.

4 Results

A total of 38 sites were identified (Figure 6). Sites identified during the PWA road assessment (PWA 2023) are also shown in Figure 6. PWA sites are all associated with road or trail crossings, while CLC results are all associated with the channel network. Results in the Stenner Creek subwatershed are presented in section 4.1 and results for Brizzolara subwatershed are presented in section 4.2.

While the site types identified have some variability, they generally include incising channel (Stage 2), widening channel (Stage 3), knickpoint, eroding ephemeral channel, eroding ditch, gully, unstable bank, slump, and landslide. The term slump is utilizing when a block or mass of sediment is observed to be failing and unstable banks is utilized to describe a wider range of eroding bank conditions (e.g., undermined bank that has not yet failed, unvegetated bank with dry ravel). These terms were introduced in Section 2.2 and a glossary is available in Section 6 for easy reference.

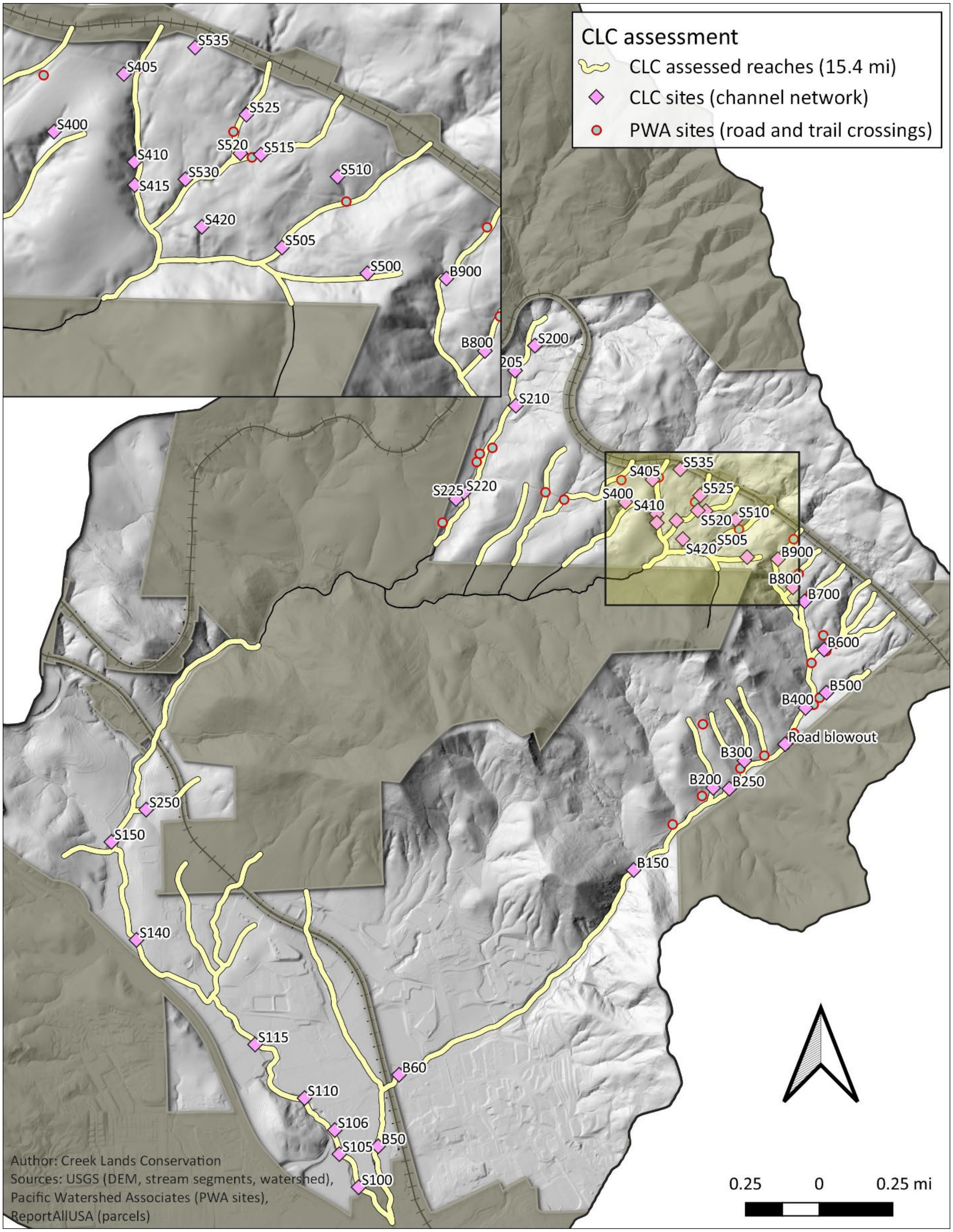


Figure 6: Overview of assessed channels and resulting erosion sites. Grey areas are Cal Poly owned land.

4.1 Stenner Sites

Sites along the Stenner Creek channel network were generally assessed from downstream to upstream, starting at S100. Key assessment results are summarized at the end of this section in Tables 1 and 2. Full assessment results are available in the companion excel-based assessment database.

S100. Widening Channel (Stage 3/4) (Mainstem Stenner)

S100 is a reach of mainstem Stenner Creek that starts at the confluence with Brizzolara Creek and extends to the wetted crossing downstream of Highland Ave (~1,500 feet). This reach is within critical steelhead habitat (NMFS 2005) and contains perennial flow conditions across water year types (Bennett 2015; CLC 2020; CLC 2022). Although multiple waves of incision have impacted this reach, major vertical incision (Stage 2) is no longer predominant, rather, the channel is widening, and deposition is beginning to occur (Stage 3/4). Downstream of Cal Poly land the reach becomes significantly confined by housing infrastructure. Because this channel reach is in later stages of evolution, it presents an opportunity to develop in-channel habitat features that also capture sediment and help manage future channel widening patterns. The sediment reduction and capture potential are estimated to be between 1,000 to 5,000 CY. The anticipated level of future engineering design and analysis effort is high and is likely to include hydraulic modeling (e.g., HEC-RAS). We recommend that this site is combined with adjacent sites (e.g., B50 and S105) when funding for design is sought. Repair and enhancement options include natural channel reconstruction that integrates habitat and sediment capture elements (e.g., log weirs). Concrete structures which act as local grade control structures and are partial fish passage barriers were observed on this reach. Addressing fish passage should also be integrated into future channel repair and restoration. The repair priority is high due to the sediment reduction and capture potential combined with the steelhead habitat enhancement potential.

S105. Unstable bank (Mainstem Stenner)

S105 consists of a large unstable bank on the right side of the creek (looking downstream). This reach is within critical steelhead habitat (NMFS 2005) and contains perennial flow conditions across water year types (Bennett 2015; CLC 2020; CLC 2022). The existing bank slope is estimated to be slightly steeper than 1:1. The bank soil is loose, with dry weather sloughing evident during the site visit. The slope is poorly vegetated but located under a more mature tree canopy. This site is chronically eroding, in both dry and wet weather. An orchard road is present at the top of the bank. The sediment reduction potential from this site is estimated at 500-1,000 CY. The anticipated level of future engineering design and analysis effort is high and is likely to include hydraulic modeling (e.g., HEC-RAS). Repair options for this site include biostablization and revegetation, laying back the slopes to those observed in other parts of this channel (1:2), and in-channel wood features integrated with habitat enhancement and bank protection. Due to the moderate sediment reduction potential, the threat to infrastructure, and the steelhead habitat enhancement potential, the repair priority is medium.

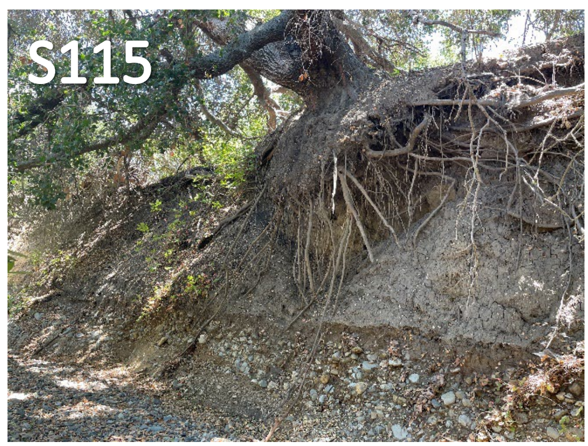
S106. Eroding ditch (Mainstem Stenner)

A small ditch drains an unpaved area next to Highland Drive, and transports sand and silt into Stenner Creek. Erosion associated with the ditch around some utility boxes positioned next to the road was also observed**.** In addition to the ditch shown in the adjacent photo, the channel has caused deeper gulley-type erosion across the left bank (looking downstream) of Stenner Creek where it flows across the bank. Previous manually added woody debris to the gully portion of the ditch (not seen in photo) has slowed but not eliminated left bank erosion. The long-term sediment reduction potential is estimated at less than 100 CY. The overall repair priority is low, but the recommended repair is simple: loose rock check dams (Appendix B: Conceptual Detail B-1) in the ditch adjacent to the road and the addition of larger wood debris in the gulley portion of the ditch as it flows across the left bank of Stenner Creek. The anticipated future engineering design and analysis effort is lower, and all work could be conducted manually by California Conservation Corps (CCC) trained in restoration or equivalent with the supervision of a restoration engineer trained in manual restoration techniques. Recommend monitoring until the fix is implemented to track the degree of on-going erosion and monitoring after the fix to ensure hand-placed repairs are functioning as intended.

S110. Unstable bank (Mainstem Stenner)

The left bank of the Stenner Creek mainstem features a large unstable section, with a slope slightly less steep than 1:1. The loose soil in this area has poor vegetation establishment beneath the tree canopy, leading to some dry weather raveling and increased susceptibility to erosion during wet weather. The unstable bank is adjacent to a field road, though the road appears to have some protection or buffer room from immediate undermining. Stable banks in the surrounding area tend to have slopes approaching 1:2. The potential sediment reduction potential at this site is estimated to be between 100 and 500 CY. This reach is within critical steelhead habitat (NMFS 2005) and is ephemeral across water year types (Bennett 2015; CLC 2020; CLC 2022). Habitat enhancement at this site is possible. The anticipated future level of engineering design and analysis effort is high and may include hydraulic modeling (e.g., HEC-RAS). In-channel wood structures that provide habitat and bank protection structures, revegetation, and other bank stabilization are options at this site. Concrete structures which are likely partial fish passage barriers were observed on this reach. If this site is selected for repair, addressing fish passage should also be addressed. This repair priority is low due to its low sediment reduction potential and high cost-benefit ratio. Because this site has a low priority rating, it is recommended this site is monitored to determine if conditions change.

S115. Unstable bank (Mainstem Stenner)



A 260-foot stretch of the right bank of the Stenner Creek mainstem is unstable. The creek is eroding laterally into the right bank, with present slopes of about 1.25:1. The bank consists of exposed bare soil, which sloughs off in dry weather and is probably very erodible by rain splashes and impinging streamflow. The toe of the bank is eroding away in higher flows and undermining a large oak tree that will likely die or fall into the creek and dislodge a large amount of soil. A dirt road runs close to this feature and may be damaged if the oak tree falls or if the bank's slope erodes back to resemble the surrounding slopes (1:1 or 1:1.5). This reach is within critical steelhead habitat (NMFS 2005) and is ephemeral across water year types (Bennett 2015; CLC 2020; CLC 2022). Habitat enhancement at this site is possible. The anticipated level of future engineering design and analysis effort is high and may include hydraulic modeling (e.g., HEC-RAS). The erosive potential of this site is 500 to 1,000 CY. This site is given a high priority rating due to its higher sediment reduction potential, the threat to infrastructure, and high accessibility rating. Repair and enhancement options include in-channel wood structures in the channel that integrate bank protection and habitat elements, and revegetation are options at this site.

S140. Eroding gully (Mainstem Stenner)
A small headcut has formed on the left bank of Stenner Creek and at the time of the field visit was predominantly vegetated with annual grasses but also featuring some bare patches of soil. We recommend monitoring the area to track the development of the headcut into a potentially larger feature over time. The potential sediment reduction potential at this site is estimated to be less than 100 CY.

S150. Eroding bank (Mainstem Stenner)
This eroding bank is located near a reservoir and road, with a moderately steep slope. The top of the bank is formed by a dirt road that has been built on top of an earthen dam. This site experiences moderate dry weather ravel and has the potential for wet weather erosion. Due to its proximity to the dam and road, it is recommended that the slope be revegetated. Although the total sediment reduction potential is low (<100 CY), road maintenance practices likely contribute on-going additional sediment that would be captured and stabilized by the addition of vegetation. There is no anticipated engineering design and analysis, and all work could be conducted manually by California Conservation Corps (CCC) trained in restoration or equivalent. The site repair priority is medium because the repair - revegetation -is simple. Revegetation should be conducted with local native species, and our local CCC team can both develop a simple planting plan including associated surface and erosion control treatments, propagate plants in their nursery if needed, and install plants. Recommend monitoring until the fix is implemented to track the degree of on-going erosion and monitoring after the fix to ensure revegetation is functioning as intended.

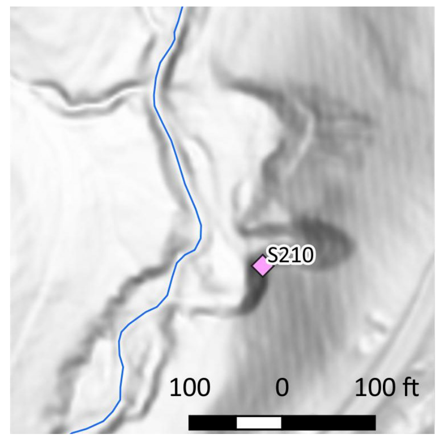
S200. Knickpoint (Mainstem Stenner)
A knickpoint is propagating up a small ephemeral channel that drains along a short path to mainstem Stenner Creek. Photo shows defined headcutting action. There is undermining of the channel at the headward end of the erosion with the banks slumping to a more stable angle in sections where the

knickpoint has already moved through. The knickpoint is poised to erode headward. Starting at 70 feet upslope from the shown headcut, both the channel and hillslopes become steeper. Boulders and weak bedrock are present, but it appears that previous waves of incision have been able to cut through and around them. Small slides on the banks of the channel indicate that the upper areas are still adjusting to previous waves of incision. Sedimental reduction potential is estimated to be between 100 and 500 CY. The anticipated engineering design and analysis is lower, and all work could be conducted manually by California Conservation Corps (CCC) trained in restoration or equivalent. The recommended fix is a headcut repair (Appendix B: Conceptual Detail B-2 or B-3) and revegetation. Revegetation should be conducted with local native species, and our local CCC team can both develop simple planting plans associated surface or erosion treatments, propagate plants in their nursery if needed, install, and monitor plants. Recommend monitoring until the fix is implemented to track the degree of on-going erosion and monitoring after the fix to ensure hand-placed repairs are functioning as intended. The repair priority is medium.

S205. Slump (Mainstem Stenner)

The right bank of Stenner Creek features clayey soil that is slumping into the creek, partially due to cattle movement and creek erosion at the toe of the slope. The initial slump appears to have already eroded away, but this feature continues to evolve and may develop into a gully. We recommend fencing, revegetation and monitoring. Revegetation should be conducted with local native species, and our local CCC team can both develop a simple planting plan including associated surface or erosion control treatments, propagate plants in their nursery if needed, install, and monitor plants. There is no anticipated engineering design and analysis, and all work could be conducted manually by California Conservation Corps (CCC) trained in restoration or equivalent. The potential volume at this site is estimated to be less than 100 CY. This site is assigned a low priority rating.

S210. Landslide (Mainstem Stenner)



A landslide is located on the left bank of Stenner Creek along a bike/walking trail that approaches the "Elevator Trail". A significant slide occurred between 1972 and 2002. Further development of the feature occurred in the winter of 2023. The feature could produce an estimated 1000 to 5000 CY of sediment to Stenner Creek as slopes adjust to a form similar to the surrounding area. Stenner Creek jumps its banks in this location and episodically removes accumulated sediment at the base on the slide, which is deposited on a small inset floodplain. This reach is within critical steelhead habitat (NMFS 2005) and contains perennial flow conditions across water year types (Bennett 2015; CLC 2020; CLC 2022). The anticipated level of engineering design and analysis is high for this site. The repair for this site should consider whether to stabilize the slide and/or how to keep the creek from jumping its banks (channel is poorly defined in this reach) which removes sediment from the toe of the slide, thus reactivating the slide. If an in-channel repair is developed, habitat enhancing features should be integrated to the extent feasible as this perennial reach has a high habitat value. The repair priority is high. To learn more about this site to inform design, annual photo monitoring is recommended.

S220. Widening and Incising Channel (Stage 3) (Mainstem Stenner)

The channel from the Cal Poly Ranch house (where Stenner Creek Road becomes Poly Canyon Rd) to the gate adjacent to the trailhead includes vertically eroding subreaches, widening subreaches, and stable subreaches (~1,700 ft). As a result, the creek has exposed unstable vertical banks in some locations, which in turn undermines large trees and exposing their root systems (see photo). This reach is within critical steelhead habitat (NMFS 2005) and contains perennial flow conditions across water year types (Bennett 2015; CLC 2020; CLC 2022). The sediment reduction and capture potential at this site is estimated to be 1,000 to 5,000 CY. This site is assigned a high priority due to the sediment volume and habitat value for steelhead trout. The mature vegetation limits the use of heavy equipment. A restoration engineer with restoration experience utilizing novel methods (e.g., hand placement, high-lining, adaptive restoration strategies) should evaluate this site. The repair and habitat enhancement priority is high.

S225. Eroding ephemeral channel (Mainstem Stenner)

A small gully (photo, right) has formed where Stenner Creek Road runoff discharges through a ditch relief culvert into Stenner Creek. While further incision is possible, coarse rocks are slowing the process. The sediment reduction potential is estimated to be less than 100 CY. Repair includes loose rock check dams (Appendix B: Conceptual Detail B-1) or addition of loose rock. A different treatment may be required as the channel enters mainstem Stenner Creek. The anticipated priority is low. The anticipated engineering design and analysis is lower. All work could be conducted manually by California Conservation Corps (CCC) trained in restoration or equivalent with the supervision of a restoration engineer trained in manual restoration techniques. As with all handwork, monitoring is recommended post-repair. The repair priority is low.

S250: Eroding ephemeral channel (Mainstem Stenner)

A small but growing ephemeral channel runs through an avocado orchard (see photo), under Stenner Creek Road, and out into the Stenner Creek floodplain. The incision significantly increased in the winter of 2023 compared to the photo at right which was taken in the fall of 2022. The channel banks are steep and will lay back. Using aerial imagery, the gully is approximately 600 feet long, but a closer in-person inspection is warranted. Further incision is also likely. The site is not directly accessible due to a fence along the road. Loose rock check dams are recommended (Appendix B: Conceptual Detail B-1). The anticipated engineering design and analysis is lower. All work could be conducted manually by California Conservation Corps (CCC) trained in restoration or equivalent with the supervision of a restoration engineer trained in manual restoration techniques. Repair priority is high however the site is not located on Cal Poly property.

S400. Incising ephemeral channel (Stage 2) (Tributary 3)

This site features an approximately 1800 ft eroding ephemeral channel with at least six erodible knickpoints, with vertical heights ranging from one to seven feet (see photo). The channel has a history of a series of incision and slumping banks. There is limited and isolated bedrock in slopes which may limit erosion in some locations, but generally, the area has semi-vegetated slopes and significant cow utilization. This site has significant sediment reduction potential from both bed and banks that is estimated to range from 500 to 1,000 CY. A series of loose rock check dams (Appendix B; Conceptual Detail B-1), loose rock or vegetated headcut repairs (Appendix B; Conceptual Details B-2 and B-3), and revegetation are recommended. Revegetation should be conducted with local native species, and our local CCC team can both develop simple planting plan including associated surface or erosion control treatments, propagate plants in their nursery if needed, install and surface treatment or revegetation repair. The anticipated engineering design and analysis is lower. All work could be conducted manually by California Conservation Corps (CCC) trained in restoration or equivalent with the supervision of a restoration engineer trained in manual restoration techniques. The anticipated repair priority is high.

S405. Gully (Tributary 4)

This small gully forms from overland and road runoff, with potential for episodic erosion. This site is recommended for monitoring, especially in relation to road fixes, because altering the road's slope could increase surface runoff and require stabilization efforts. The sediment reduction potential is less than 100 CY.

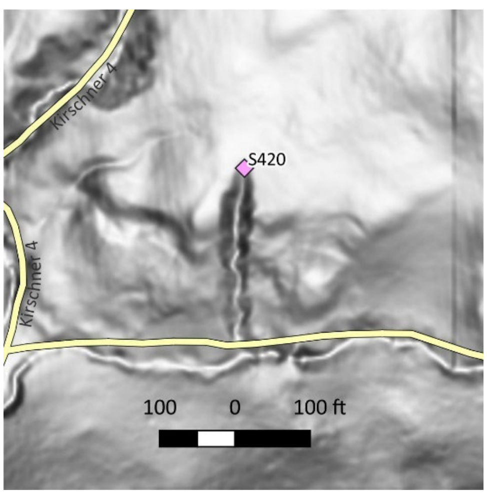
S410. Slump (Tributary 4)

This site features an active slump from channel incision in erosive soils with heavy cattle utilization. The area has highly erosive loose loamy soils, with a large, naturally stabilized (due to boulders and large roots) knickpoint immediately upstream. The vertical incision in the channel at the toe of the slope in the picture appears finished and is now laterally widening. The sediment reduction potential is between 100 and 500 CY. No repair in the channel is recommended due to access limitations but fencing and surface treatment and/or revegetation are suggested on the slope to arrest chronic unraveling and cow trail erosion. Monitoring the toe of the slump is also recommended. Surface treatment and/or revegetation should be conducted with local native species, and our local CCC team can both develop the approach, propagate plants in their nursery if needed, install and monitor the surface treatment/ revegetation repair. Repair priority is high due to the sediment volume, low-cost fix, and the chronic nature of erosion.

S415. Knickpoints (Tributary 4)

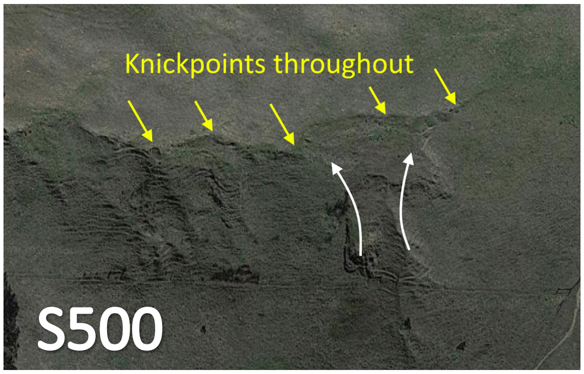
At the time of the first visit (11/2022) the site had a two-foot-high erodible knickpoint in the channel, with the downstream channel exhibiting recent erosion, exposed vertical alluvial banks and slumping. Upstream of the knickpoint, the channel had not eroded. Following the winter storms of 2023, the knickpoint traveled upstream, unraveling the stream channel, and evolving into a series of knickpoints (see photo). The sediment reduction potential from the bed and banks is estimated to be between 100 and 500 CY. When the repair occurs at S410, it is recommended to repair this site by adding boulders utilizing motorized wheelbarrows. Boulder stabilized knickpoints upstream and downstream form a basis of design. The anticipated engineering design and analysis is lower. All work could be conducted manually by California Conservation Corps (CCC) trained in restoration or equivalent with the supervision of a restoration engineer trained in manual restoration techniques. The anticipated priority is medium.

S420. Gully (Mainstem Kirschner Creek)



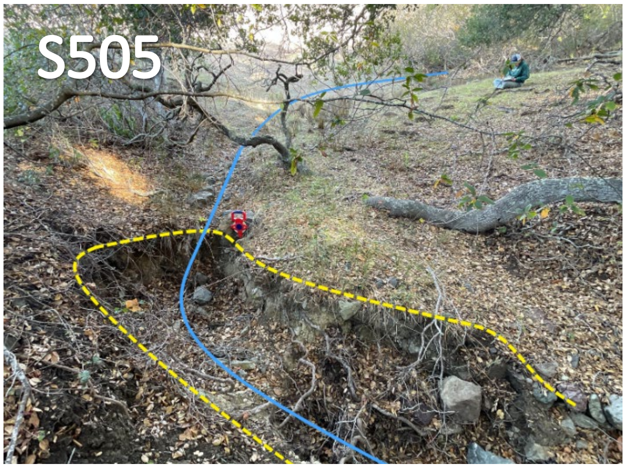
A gully has cut into the left bank of the mainstem of Kirschner Creek, about 200 feet upstream of the confluence of tributary 4 (Figure 5). The gully is 240 feet long and about 40 feet wide on average, with a slope of approximately 27 percent. Historical aerial images from 1937, 1972, and 2005 show that the feature has not expanded significantly over the last 80 years. Recent storms in the beginning of 2023 did not cause a large amount of new erosion in this gully despite being one of the top three wettest years in this watershed since 1870 (Cal Poly 2023), but dry ravel was observed on the sides of the gully in the preceding dry season. Although this feature is relatively stable, long-term monitoring is recommended. This gully is downslope from an area containing ephemeral slope wetlands maintained by groundwater seepage.

S500: Incising Ephemeral Channel (Tributary 6)



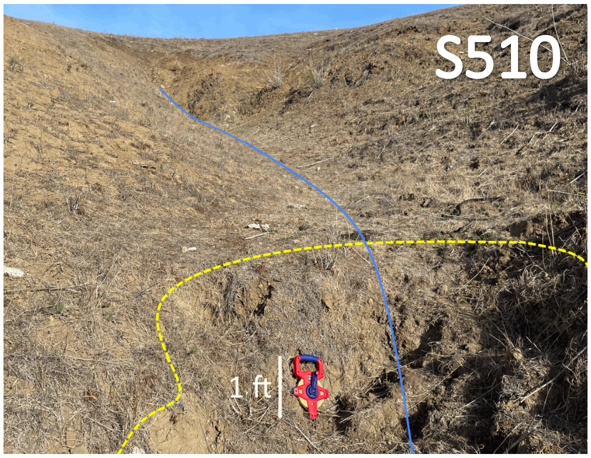
This site is an ephemeral tributary. The channel is actively vertically incising (Stage 2) and beginning to widen in some areas. This an unstable channel that is causing banks to slump and a landslide to form (see photo) delivering sediment directly to the channel. The slumps and landslide will be a chronic sediment source for the foreseeable future. There are approximately five active erodible knickpoints with heights ranging from 1 to 4 feet in height. The site has easy access, and the sediment reduction potential is 1,000 to 5,000 CY. The anticipated level of engineering design and analysis is high for this site due to the presence of the landslide. The repair could include a series of loose rock check dams (Appendix B; Conceptual Detail B-1), loose rock or vegetated headcut repairs (Appendix B; Conceptual Details B-2 and B-3) and building up the bed to stabilize the slumps and slides. The priority for this site is high. Due to the easy access and clear line of this site, this site is ideal for education and developing concept repairs in partnership with Cal Poly Civil Engineering Program.

S505: Knickpoint (Tributary 5)



The site features a vertically incising channel with knickpoints, as well as channel widening. Although access for heavy machinery is limited, the site can be accessed utilizing motorized wheelbarrows. A loose rock headcut repair (Appendix B; Detail B-2) of the three-foot high knickpoint (see photo) is recommended. Further migration of the knickpoint is anticipated to generate between 100 and 500 CY. The anticipated engineering design and analysis is lower. All work could be conducted manually by California Conservation Corps (CCC) trained in restoration or equivalent with the supervision of a restoration engineer trained in manual restoration techniques.

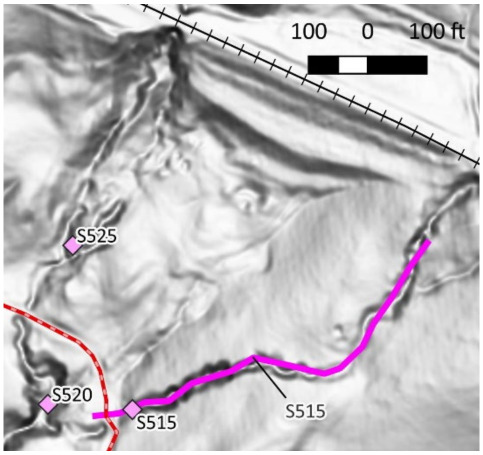
S510: Gully (Tributary 5)



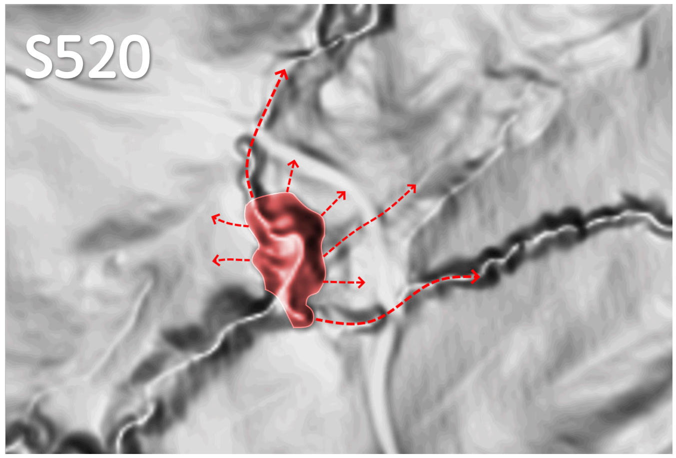
This gully is 150 feet long and extends up from where Peterson Ranch Road crosses tributary 5. It is a well-developed gully, but there is a headcut starting near the road that could propagate up the gully. The sediment would spill onto the road and then into the stream. This site is considered a low priority but has an easy fix. The recommended approach is a loose rock headcut repair (Appendix B; Conceptual Detail B-2). The anticipated engineering design and analysis is lower, and all work could be conducted manually by California Conservation Corps (CCC) trained in restoration or equivalent. Monitoring is suggested to track the site's progress and condition. The area in and around the gully would also benefit from some revegetation to reduce dry ravel erosion.

S515: Incising Ephemeral Channel (Stage 2) (Tributary 4)

This site should be approached on a reach scale, as it consists of several actively incising knickpoints along 700 feet, up to the railroad track. This site begins upstream of site S520, where Peterson Ranch Road crosses over the channel. There are approximately 10 knickpoints ranging from 1 to 10 feet in height. There is sporadic mature vegetation slowing erosion in some areas, but throughout the channel there is active toe scour undercutting the banks and roots, leading to instability and slumping. The estimated sediment reduction potential is between 1,000 and 5,000 CY. Repairs could include grading the banks to create an inset floodplain, check dams, or wood structures in the channel to aggrade the bed. Mobilization to the site would not be very difficult because of its proximity to the road and relatively gentle slopes surrounding the channel. The priority for this site is high because it has a large sediment production potential. This site could benefit from a combination of heavy machinery work with hand work. The anticipated level of engineering design and analysis is high for this site.



S520: Incising and Widening Channel with Large Slumps (Tributary 4)

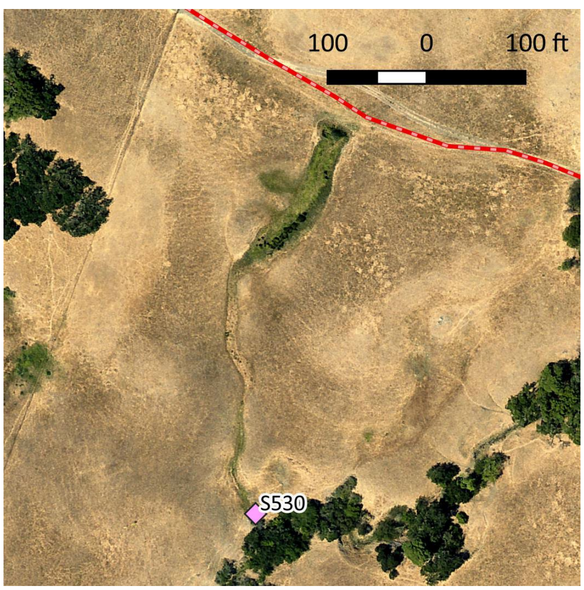


This site is incising and widening, resulting in a bowl-shaped feature. The feature is located on the east fork of tributary 4, where its two branches meet. Incision has been migrating up the east fork of tributary 4 for some time, incising the channel and laying back the bank slopes. The bank slopes in this area are unstable and may expand at the margins toward the road. The road provides easy access to the site, but the steepness and depth of the feature might make in-channel work challenging. A perennial spring along this tributary keeps this site wet year-round. This feature is a high-priority and has a sediment reduction potential from 1,000 to 5,000 CY.

S525: Knickpoint (Tributary 4)

This site is a 6 ft high knickpoint, about 200 feet upstream of S520 and 380 feet below the railroad track. Although this is a large knickpoint, it appears to be hung up on small boulders and weak bedrock in the channel. The banks of the channel are severely undermined but are temporarily held up by weak rock and roots. If the knickpoint were to propagate upstream toward the railroad culvert, a significant amount of sediment could be generated. The channel is surrounded by mature vegetation at the knickpoint, as well as above and below it. A perennial spring is located on this branch of the tributary and satellite imagery of the area shows that some wetland habitat upstream of the railroad culvert exists. Persistent moist conditions may play an indirect role in stabilizing the channel through the establishment of mature trees and root systems. The recommended approach is to monitor the site based on its proximity to the railroad.

S530: Gully Initiation into High Value Wetlands (Tributary 4)



There is a persistent slope wetland adjacent to Peterson Ranch Road that drains into tributary 4. The swale that drains this feature is shallow, wide, and well vegetated with grass. There are two knickpoints where this swale meets the tributary. The knickpoints are also influenced by a cattle trail that crosses the swale, which may contribute to the rate of erosion. Continued knickpoint migration is anticipated to form a gully up the swale and into the wetland, causing the wetland to drain more quickly, erode, or dry out. Stabilizing the knickpoint is important for preserving this wetland. Perennial springs keep this site wet year-round. This site could be repaired with handwork using loose rock and/or vegetated headcut repairs (Appendix B; Conceptual Details B-2 and B-3). Cattle fencing should also be installed around the wetland to deter cows from damaging the wetland or aggravating erosion processes in the swale. The potential sediment reduction at this site is between 100 and 500 CY. The sediment reduction potential and habitat value of the site make this a high repair priority.

<u>S535: Gully (Tributary 4)</u>

The site features a gully that runs up into the railroad track fill. It was already present as early as August 2010. It significantly expanded between April 2015 and June 2017, likely during the winter of 2016-2017. The gully is 300 feet long and ends in a shallow depression that drains toward the west fork of tributary 4. The banks of the gully are nearly vertical and are expected to widen and lay back, which will produce more sediment. This gully seems to have initiated upslope at the railroad tracks and expanded downhill, unlike other gullies and knickpoints observed in the watershed. The solution, besides controlling the runoff patterns on railroad property is the construction of a series of loose rock check dams (Appendix B; Conceptual Detail C-1). The total sediment reduction from reducing gully expansion would range from 100 to 150 CY, and the sediment capture potential behind the check dams could be between 10 to 100 CY.

Table 1. Stenner Creek sites along fish bearing reaches with recommended in-channel work.

Site #	Site Type	Repair/Enhancement	Sediment Reduction and Capture Potential (CY)	Access Rating	Enhance or protect on-site or adjacent environmental resources (Y/N)[1]	Protect on-site or adjacent infrastructure? (Y/N)	Estimated Cost[2]	Cost Benefit Ratio[3]	Anticipated Engineering Effort (H/L/N)	General Repair Priority
S100	Widening Channel (Stage 3/4)	Natural channel reconstruction with habitat and sediment capture structures	1,000-5,000	High	Y	Y	Major (>$100,000)	40	High	High
S105	Unstable Bank	Natural channel reconstruction with habitat and bank protection structures, biostablization, and/or revegetation	500-1,000	Med	Y	Y	Large ($50,000-$100,000)	100	High	Med
S110[m]	Unstable Bank	Wood habitat and bank protection structures, monitor	100-500	Med	Y	Y	Large ($50,000-$100,000)	250	High	Low
S115	Unstable Bank	Wood habitat and bank protection structures	1,000-5,000	High	Y	Y	Large ($50,000-$100,000)	30	High	High
S210[m]	Landslide	Modify stream direction, toe treatment, monitor	1,000-5,000	High	Y	N	Moderate ($10,000-$50,000)	12	High	High
S220	Incising and Widening Channel (Stage 2/3)	Sediment capture and habitat enhancement, bank stabilization	1,000-5,000	Med	Y	N	Major (>$100,000)	40	High	High

1 All sites have environmental benefits in that they will reduce sediment entering steelhead habitat. However, the sites denoted with a ‘Y” here indicate additional environmental benefits at the site location (e.g., in-channel habitat structures, protection of wetlands, etc.)

2 Cost estimate is based on implementation and does not include engineering or permitting. Cost is provided for prioritization purposes only and may not reflect final costs.

3 The Cost benefit ratio is equal to the cost estimate ($) divided by the sediment reduction potential volume (CY). To calculate the cost benefit ratio an average value for the sediment reduction potential (CY) was assumed. For example, for an estimated range of 1,000 to 5,000 C, a mean value of 2,500 CY is utilized in the calculation. Similar assumptions are made for the cost estimate. This calculation is made as an estimate to prioritization purposes only.

m Monitoring recommended until the fix is implemented or until such a time that the site is deemed to be stable and repair unneeded.

Table 2. Stenner Creek sites along non-fish bearing reaches.

Site #	Site Type	Repair/Enhancement	Sediment Reduction and Capture Potential (CY)	Access Rating	Enhance or protect on-site or adjacent environmental resources (Y/N)[1]	Protect on-site or adjacent infrastructure? (Y/N)	Estimated Cost[2]	Cost Benefit Ratio[3]	Anticipated Engineering Effort (H/L/N)	General Repair Priority
S106 [h,m]	Eroding Ditch	Rock check dams or loose rock channel, wood debris	<100	High	N	N	Small (<$10,000)	200	Low	Low
S140 [m]	Eroding Gully	Monitor only	NA	High	N	N	NA	NA	None	NA
S150 [h,m]	Eroding Bank	Revegetate	<100	High	Y	Y	Small (<$10,000)	200	None	Low
S200 [h,m]	Knickpoint	Headcut repair, revegetation	100-500	Med	N	N	Moderate ($10,000-$50,000)	100	Low	Med
S205 [h,m]	Slump	Fencing, revegetation	<100	Med	N	N	Small (<$10,000)	200	None	Low
S225 [h,m]	Eroding Ephemeral Channel	Rock check dams or loose rock channel, wood debris.	<100	High	N	N	Small (<$10,000)	200	Low	Low
S250 [h,m]	Eroding Ephemeral Channel	Loose rock and/or rock check dams	100-500	High	N	N	Small (<$10,000)	40	Low	High
S400 [h,m]	Incising Ephemeral Channel (Stage 2)	Headcut repair, rock check dams, revegetation	1000-5000	High	N	N	Moderate ($10,000-$50,000)	14	Low	High
S405 [m]	Gully	Monitor only	NA	High	N	N	NA	NA	None	NA
S410	Slump	Fencing, revegetation	100-500	High	N	N	Small (<$10,000)	40	Low	High
S415 [h,m]	Knickpoint	Headcut repair, loose rock.	100-500	Med	N	N	Small (<$10,000)	40	Low	High
S420 [m]	Gully	Monitor only	NA	Med	N	N	NA	NA	None	NA

Site #	Site Type	Repair/Enhancement	Sediment Reduction and Capture Potential (CY)	Access Rating	Enhance or protect on-site or adjacent environmental resources (Y/N)[1]	Protect on-site or adjacent infrastructure? (Y/N)	Estimated Cost[2]	Cost Benefit Ratio[3]	Anticipated Engineering Effort (H/L/N)	General Repair Priority
S500 [m]	Incising Ephemeral Channel (Stage 2)	Headcut repairs, check dams, channel reconstruction	1000-5000	High	N	N	Moderate ($10,000-$50,000)	14	High	High
S505 [h,m]	Knickpoint	Headcut repair	100-500	Med	N	N	Small (<$10,000)	40	Low	High
S510 [h,m]	Gully	Headcut repair	100-500	High	N	N	Moderate ($10,000-$50,000)	40	Low	High
S515 [m]	Incising Channel (Stage 2)	Wood and rock structures, grading, headcut repairs	1000-5000	High	Y	N	Large ($50,000-$100,000)	30	High	High
S520 [m]	Incising and Widening Channel (Stage 3)	Rock and log structures to capture sediment and add roughness	1000-5000	High	Y	Y	Major (>$100,000)	40	High	High
S525 [m]	Knickpoint	Monitor only	NA	Med	N	Y	NA	NA	None	NA
S530 [h,m]	Gully	Headcut repair, fencing, cattle trough	100-500	High	Y	Y	Small (<$10,000)	40	Low	High
S535 [h,m]	Gully	Check dams, loose rock	100-500	High	N	Y	Small (<$10,000)	40	Low	High

[1] Or along fish-bearing reaches but with no recommended in-channel work (e.g., bank revegetation or fencing).

[2] All sites have environmental benefits in that they will reduce sediment entering steelhead habitat. However, the sites denoted with a 'Y" here indicate additional environmental benefits at the site location (e.g., in-channel habitat structures, protection of wetlands, etc.)

[3] Cost estimate is based on implementation and does not include engineering or permitting. Cost is provided for prioritization purposes only and may not reflect final costs.

[4] The Cost benefit ratio is equal to the cost estimate ($) divided by the sediment reduction potential volume (CY). To calculate the cost benefit ratio an average value for the sediment reduction potential (CY) was assumed. For example, for an estimated range of 1,000 to 5,000 C, a mean value of 2,500 CY is utilized in the calculation. Similar assumptions are made for the cost estimate. This calculation is made as an estimate to prioritization purposes only.

[h] Site is recommended to be hand-repaired utilizing restoration-trained CCC crews or equivalent. with the supervision of a restoration engineer trained in manual restoration techniques.

[m] Site is recommended for monitoring. All hand repair sites are recommended for monitoring before and after the fix is implemented. Until the fix is implemented to track the degree of on-going erosion and monitoring after the fix to ensure hand-placed repairs are functioning as intended.

4.2 Brizzolara Sites

Sites were generally assessed from downstream to upstream, starting at B50. Key assessment results are summarized at the end of this section in Tables 3 and 4. Full assessment results are available in the companion excel-based assessment database. All rangeland sites (B150 to B900) should be integrated with the riparian fencing and water trough upgrade plan for Brizzolara Creek which is being developed by Cal Poly and the SLO Coastal RCD.

Three of the high priority sites (B300, B500, B600) were selected to advance to full engineering analysis and designs under this grant funding source. These sites were selected because of their position in the watershed (ephemeral, non-fish bearing), their sediment reduction potential (CY), and their capacity to protect on-site or adjacent infrastructure and environmental resources. Furthermore, these sites need to be fixed before upgradient sites are fixed (e.g., B700 to B900). Both B500 and B600 were also prioritized because they are composed of loamy textured soils which have equal or close to equal proportions sand, silt, and clay (e.g., Hydrological Soil Group C) (NRCS 2007). All other things being equal, loamy textured soils will erode more rapidly than more clayey soils (e.g., Hydrological Soil Group D which tends to be composed of at least 40% clay) (see Appendix A for soil maps).

B50: Incising and Widening Channel (Stage 2/3) (Mainstem Brizzolara)

This site is a reach of mainstem Brizzolara Creek that starts at the confluence with Stenner Creek and extends to Highland Ave (~1,500 feet). This reach is within critical steelhead habitat (NMFS 2005) and is hypothesized to contain perennial flow conditions across water year types. Flow mapping by Creek Lands Conservation to determine dry season flow conditions is in progress. This reach is still both vertically incising (Stage 2) and widening (Stage 3). Downstream of Cal Poly land the reach becomes significantly confined by housing infrastructure. This reach presents an opportunity to slow or arrest channel incision, manage channel widening patterns, and develop in-channel habitat features that capture sediment. The sediment reduction and capture potential are estimated at 1,000 to 5,000 CY. The anticipated level of future engineering design and analysis effort is high and is likely to include hydraulic modeling (e.g., HEC-RAS). We recommend that this site is combined with adjacent sites (e.g., S100 and S105) when funding for design is sought. Repair and enhancement options include natural channel reconstruction that integrates habitat and sediment capture elements (e.g., log weirs). The repair priority is high due to the sediment reduction and capture potential combined with the steelhead habitat enhancement potential.

B60: Widening Channel (Stage 3) (Mainstem Brizzolara)

This site is a reach from the California Road Crossing (at the fish ladder) to a bedrock control approximately 350 feet upstream. This reach is within critical steelhead habitat (NMFS 2005) and is hypothesized to be ephemeral. Flow mapping by Creek Lands Conservation to determine dry season flow conditions is in progress. This reach is primarily widening (Stage 3) but the widening is constrained in some locations by existing infrastructure at the top of bank. The sediment reduction and capture potential are estimated at 500 to 1,000 CY. The anticipated level of future engineering design and analysis effort is high and is likely to include hydraulic modeling (e.g., HEC-RAS). The repair priority is medium.

B150: Knickpoint (Mainstem Brizzolara)

This site is upstream of where Poly Canyon Road first crosses mainstem Brizzolara Creek when heading up Poly Canyon. The road crossing at this site was not assessed by PWA (2022) as it was downstream of where the survey began. In the winter of 2023, the road blew out and emergency culverts (see photo placed to provide road access upstream) were installed. We recommend that this site be evaluated by PWA in association with on-going design work in the watershed. The culverts, which presumably are a temporary fix, are undersized for sediment transport and a grade control was not installed upstream. Upstream of the culverts a series of newly formed knickpoints were observed in the spring of 2023. Because this site is the downstream most of all rangeland sites identified by both PWA (2022) and CLC (this report), stabilizing the knickpoints at this site is a very high priority rating to prevent knickpoint retreat upstream which would exacerbate existing upstream erosion and incision. This reach is within critical steelhead habitat (NMFS 2005) and is hypothesized to contain perennial flow conditions across water year types. Flow mapping by Creek Lands Conservation to determine dry season flow conditions is in progress. In addition to any culvert and grade control repairs that may be recommended by PWA in the vicinity of the road crossing, the channel upstream of the road crossing for at least 300 feet should be evaluated for knickpoint stabilization and habitat enhancement potential. Because the knickpoints have the potential to travel upstream and cause a new wave of upstream incision, the sediment reduction potential is estimated as 1,000 to 5,000 CY. The repair priority is high.

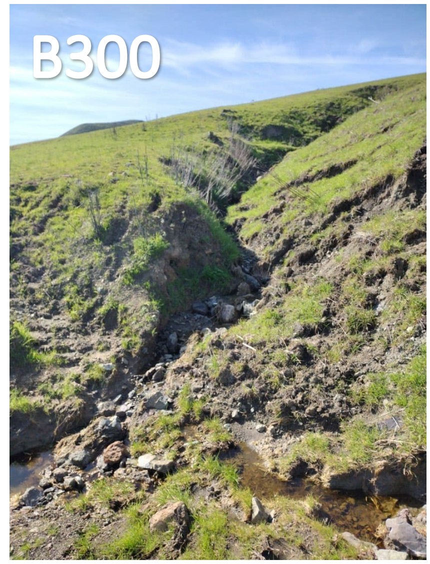
B200: Eroding Ephemeral Channel

This site includes an ephemeral channel with at least three headcuts including "multi-stair head-cut" threatening a road. This site has a modest sediment reduction potential from both bed and banks that is estimated to range from 100 to 500 CY. Loose rock or vegetated headcut repairs (Appendix B; Conceptual Details B-2 and B-3) and revegetation are recommended. Revegetation should be conducted with local native species, and our local CCC team can both develop simple planting plan including associated surface or erosion control treatments, propagate plants in their nursery if needed, install and surface treatment or revegetation repair. The anticipated engineering design and analysis is low, and all work could be conducted manually by California Conservation Corps (CCC) trained in restoration or equivalent. The anticipated repair priority is high.

B250: Incising and Widening Channel (Stage 2/3) (Mainstem Brizzolara)

This site is an incising and widening (Stage 2/3) reach with an unstable bank, a small gully, and the potential for habitat enhancement. This reach is within critical steelhead habitat (NMFS 2005) and could be perennial in some water year types. Flow mapping by Creek Lands Conservation to determine dry season flow conditions is in progress. The sediment reduction and capture potential are estimated at 500 to 1,000 CY. The anticipated level of future engineering design and analysis effort is moderate and will include hydraulic analysis. This reach presents an opportunity to slow or arrest channel incision, manage bank erosion patterns, and develop in-channel habitat features that capture sediment utilizing California Conservation Corps (CCC) trained in restoration or equivalent, with the supervision of a restoration engineer trained in manual restoration techniques. All hand repair sites are recommended for monitoring before and after the fix is implemented. The pre-repair monitoring is to track the erosional process to inform repair and monitoring after the fix to ensure hand-placed repairs are functioning as intended, and to allow for adaptive management of repair elements.

B300: Incising and Widening Ephemeral Channel



This site features approximately 1800 ft of eroding ephemeral channel with at least a dozen erodible knickpoints and slumping banks. The knickpoints range from 0.5 to 3 ft in height. This site has significant a sediment reduction potential from both bed and bed sediments that is estimated to range from 1,000 to 5,000 CY. A series of loose rock check dams (Appendix B; Conceptual Detail B-1), loose rock or vegetated headcut repairs (Appendix B; Conceptual Details B-2 and B-3), and revegetation are recommended. Revegetation should be conducted with local native species, and our local CCC team can both develop simple planting plan including associated surface or erosion control treatments, propagate plants in their nursery if needed, install and surface treatment or revegetation repair. The anticipated engineering design and analysis is low. All work could be conducted manually by California Conservation Corps (CCC) trained in restoration or equivalent with the supervision of a restoration engineer trained in manual restoration techniques. The anticipated repair priority is high. This site is selected as one of three high priority sites to advance to 65% engineering analysis and designs under this grant funding source.

B400: Incising and Widening Channel (Mainstem Brizzolara)

This site is approximately 250 feet of incising and widening mainstem channel (Stage 2/3) with at least four knickpoints and the potential for some limited habitat enhancement. While this reach is within critical steelhead habitat (NMFS 2005), it is likely ephemeral in all water year types and thus considered non-fish bearing. Flow mapping by Creek Lands Conservation to confirm dry season flow conditions is in progress. This site also includes fixing a headcut along a small ephemeral channel that enters at the top of the site along the left bank. The sediment reduction and capture potential are estimated at 500 to 1,000 CY. The anticipated level of future engineering design and analysis effort is lower but will include hydraulic analysis. This reach presents an opportunity to slow or arrest channel incision and develop in-channel habitat features that capture sediment utilizing California Conservation Corps (CCC) trained in restoration or equivalent, with the supervision of a restoration engineer trained in manual restoration techniques. All hand repair sites are recommended for monitoring before and after the fix is implemented. The pre-repair monitoring is to track the erosional process to inform repair and monitoring after the fix to ensure hand-placed repairs are functioning as intended, and to allow for adaptive management of repair elements.

B500: Incising and Widening Ephemeral Channel (Stage 2/3)

This site is approximately 900 feet of ephemeral channel with multiple knickpoints, bank failures, and gullies. The first bank failure (left bank) (photo to the right) formed in response to channel incision and resultant groundwater seepage from the freshly exposed bank. Two more bank failures are located upstream on right bank and another left bank failure further upstream is triggering a shallow landslide. A significant early-stage gully on is also present further upstream on the left bank. This gully extends onto Miossi property at the upslope extent. There are series of knickpoints both upstream and downstream of the road crossing. The knickpoints downstream of the road pose a risk to the road (see photo below). Repairs to the reach should tie into mainstem Brizzolara Creek immediately upstream and downstream of the ephemeral channel location. While the mainstem is within critical steelhead habitat (NMFS 2005), it is likely ephemeral in all water year types and thus considered non-fish bearing. The sediment reduction and capture potential are estimated at between 1,000 and 5,000 CY. The anticipated level of future engineering design and analysis effort is high and could include in-channel check dams, headcut repairs, bank stabilization, beaver dam analogs (BDA's) and loose rock repairs among others. Along sections that have lost mature riparian vegetation, revegetation with local native species is recommended. Our local CCC team can both develop a simple planting plan including associated surface and erosion control treatments, propagate plants in their nursery if needed, and install plants. This site is selected as one of three high priority sites to advance to 65% engineering analysis and designs under this grant funding source. This site could benefit from a combination of heavy machinery work with hand work.

B600: Incising Ephemeral Channel (Stage 2)

This ephemeral channel enters mainstem Brizzolara at the upstream end of critical steelhead habitat (NMFS 2005). This site is approximately 1,100 feet of incising ephemeral channel with approximately a dozen and a half knickpoints, both downstream and upstream of the road crossing. Where the channel enters the mainstem a significant temporarily stabilized knickpoint is now ready to unravel and threatens a high value wetland. This knickpoint, and other ones that are downstream of the road pose a risk to the road. Repairs to the reach should tie into mainstem Brizzolara Creek immediately upstream and downstream of the ephemeral channel location. The sediment reduction potential is estimated at between 1,000 and 5,000 CY. The anticipated level of future engineering design and analysis effort is high and could include in-channel check dams and headcut repairs, among others. Along sections that have lost mature riparian vegetation, revegetation with local native species is recommended. Our local CCC team can both develop a simple planting plan including associated surface and erosion control treatments, propagate plants in their nursery if needed, and install plants. This site is selected as one of three high priority sites to advance to 65% engineering analysis and designs under this grant funding source. This site could benefit from a combination of heavy machinery work with hand work.

B700: Incising Ephemeral Channel (Stage 2)

This site includes portions of an incising ephemeral channel with knickpoints and slumps, both downstream and upstream of the road crossing. Repairs to the reach may need to tie into mainstem Brizzolara Creek immediately upstream and downstream of the ephemeral channel location. The sediment reduction is estimated at between 1,000 and 5,000 CY. Although this ephemeral tributary is actively producing significant amounts of sediment (see photo of active deposition in a flatter subreach of the channel on left), some of the most highly eroding subreaches may be located on railroad right-of-way. The anticipated level of future engineering design and analysis effort is high and could include adding roughness elements to slow erosion and capture sediment, in-channel check dams and headcut repairs, among others. Along sections that have lost mature riparian vegetation, revegetation with local native species is recommended. Our local CCC team can both develop a simple planting plan including associated surface and erosion control treatments, propagate plants in their nursery if needed, and install plants.

B800: Incising Ephemeral Channel (Stage 2)

This site includes portions of an incising ephemeral channel with knickpoints and slumps both downstream and upstream of the road crossing. Repairs to the reach may need to tie into mainstem Brizzolara Creek immediately upstream and downstream of the ephemeral channel location. The sediment reduction is estimated at between 1,000 and 5,000 CY. Some of the most highly eroding subreaches may be located on railroad right-of-way (see gully forming on railroad embankment in photo). The anticipated level of future engineering design and analysis effort is high and could include adding roughness elements to slow erosion and capture sediment, check dams and headcut repairs, among others. Along sections that have lost mature riparian vegetation, revegetation with local native species is recommended. Our local CCC team can both develop a simple planting plan including associated surface and erosion control treatments, propagate plants in their nursery if needed, and install plants.

B900: Incising Ephemeral Channel (Stage 2)

This site is approximately 1,000 feet of massively incising ephemeral channel with knickpoints, unstable banks, and gullies, many downstream of the road crossing. The largest knickpoint is about 8 feet high and 100 feet downstream of the road crossing. This knickpoint poses a significant risk to the road. The sediment reduction potential is estimated at 1,000 and 5,000 CY. The anticipated level of future engineering design and analysis effort is high and could include adding roughness elements to slow erosion and capture sediment, in-channel check dams and headcut repairs, among others. Along sections that have lost mature riparian vegetation, revegetation with local native species is recommended. Our local CCC team can both develop a simple planting plan including associated surface and erosion control treatments, propagate plants in their nursery if needed, and install plants. This site could benefit from a combination of heavy machinery work with hand work.

Table 3. Brizzolara Creek sites along fish bearing reaches with recommended in-channel work.

Site #	Site Type	Repair/Enhancement	Sediment Reduction and Capture Potential (CY)	Access Rating	Enhance or protect on-site or adjacent environmental resources (Y/N)[1]	Protect on-site or adjacent infrastructure? (Y/N)	Estimated Cost[2]	Cost Benefit Ratio[3]	Anticipated Engineering Effort (H/L/N)	General Repair Priority
B50	Incising and Widening Channel (Stage 2/3)	Natural channel reconstruction with habitat and sediment capture structures, bank stabilization repairs	1,000-5,000	Med	Y	Y	Major (>$100,000)	40	High	High
B60	Widening channel (Stage 3)	Natural channel reconstruction with habitat and sediment capture structures, bank stabilization repairs	500-1,000	Med	Y	Y	Large ($50,000-$100,000)	100	High	Med
B150	Knickpoints	Grade control, knickpoint repairs	1,000-5,000	Med	Y	Y	Moderate ($10,000-$50,000)	14	High	High
B250	Incising and Widening Channel (Stage 2/3)	Natural channel reconstruction with habitat structures, bed and bank stabilization repairs, and gully repairs	500-1,000	High	Y	N	Moderate ($10,000-$50,000)	47	High	High

1. All sites have environmental benefits in that they will reduce sediment entering steelhead habitat. However, the sites denoted with a 'Y" here indicate additional environmental benefits at the site location (e.g., in-channel habitat structures, protection of wetlands, etc.)
2. Cost estimate is based on implementation and does not include engineering or permitting. Cost is provided for prioritization purposes only and may not reflect final costs.
3. The Cost benefit ratio is equal to the cost estimate ($) divided by the sediment reduction potential volume (CY). To calculate the cost benefit ratio an average value for the sediment reduction potential (CY) was assumed. For example, for an estimated range of 1,000 to 5,000 C, a mean value of 2,500 CY is utilized in the calculation. Similar assumptions are made for the cost estimate. This calculation is made as an estimate to prioritization purposes only.

Table 4. Brizzolara Creek sites along non-fish bearing reaches.

Site #	Site Type	Repair/Enhancement	Sediment Reduction and Capture Potential (CY)	Access Rating	Enhance or protect on-site or adjacent environmental resources (Y/N)[1]	Protect on-site or adjacent infrastructure? (Y/N)	Estimated Cost[2]	Cost Benefit Ratio[3]	Anticipated Engineering Effort (H/L/N)	General Repair Priority
B200 h,m	Incising Channel (Stage 2)	Eroding ephemeral channel	100-500	High	N	Y	Small (<$10,000)	40	Low	High
B300 *h,m*	***Incising and widening channel (Stage 2/3)***	***Headcut repair, rock check dams, reveg***	***1,000-5,000***	***High***	***N***	***Y***	***Moderate ($10,000-$50,000)***	***14***	***Low***	***High***
B400[4] *h,m*	Incising channel (Stage 2)	Knickpoint repairs, habitat enhancement	500-1,000	Med	Y	Y	Moderate ($10,000-$50,000)	47	Low	High
B500	***Incising channel (Stage 2)***	***Headcut repairs, check dams, BDA, loose rock, grading, & reveg***	***1,000-5,000***	***Med***	***N***	***Y***	***Large ($50,000-$100,000)***	***30***	***High***	***High***
B600	***Incising channel (Stage 2)***	***Knickpoint repairs, habitat enhancement***	***1,000-5,000***	***Med***	***Y***	***Y***	***Large ($50,000-$100,000)***	***30***	***High***	***High***
B700	Incising channel (Stage 2)	Rock and log structures to capture sediment and add roughness, knickpoint repair, rock check dams	1,000-5,000	Med	N	Y	Large -$50,000-$100,000	30	High	High
B800	Incising channel (Stage 2)	Rock and log structures to capture sediment and add roughness, knickpoint repair, rock check dams	1,000-5,000	Med	N	Y	Large -$50,000-$100,000	30	High	High
B900	Incising channel (Stage 2)	Rock and log structures to capture sediment and add roughness, knickpoint repair, rock check dams	1,000-5,000	Med	N	Y	Large -$50,000-$100,000	15	High	High

1 All sites have environmental benefits in that they will reduce sediment entering steelhead habitat. However, the sites denoted with a 'Y" here indicate additional environmental benefits at the site location (e.g., in-channel habitat structures, protection of wetlands, etc.)

2 Cost estimate is based on implementation and does not include engineering or permitting. Cost is provided for prioritization purposes only and may not reflect final costs.

3 The Cost benefit ratio is equal to the cost estimate ($) divided by the sediment reduction potential volume (CY). To calculate the cost benefit ratio an average value for the sediment reduction potential (CY) was assumed. For example, for an estimated range of 1,000 to 5,000 C, a mean value of 2,500 CY is utilized in the calculation. Similar assumptions are made for the cost estimate. This calculation is made as an estimate to prioritization purposes only.

[4] ***Bold and italicized sites are progressing to 65% design under this grant funding.***

[h] Site is recommended to be hand-repaired utilizing restoration-trained CCC crews or equivalent. with the supervision of a restoration engineer trained in manual restoration techniques.

[m] Site is recommended for monitoring. All hand repair sites are recommended for monitoring before and after the fix is implemented. Until the fix is implemented to track the degree of on-going erosion and monitoring after the fix to ensure hand-placed repairs are functioning as intended.

5 Summary and Recommendations

Summary

1) Thirty-eight sites were identified (Tables 1-4).
2) Three high priority sites (B300, B500, and B600), which include rapidly eroding sites were selected to advance 65% engineering plans under this grant. All three sites are incising ephemeral channels with active knickpoints, slumps, and gullies (Table 4).
3) Of the remaining thirty-five sites, ten sites are in fish bearing reaches that will require a higher level of engineering analysis and design but will provide direct benefits to steelhead habitat, twenty-one sites were in non-fish bearing reaches, and four sites were recommended for monitoring only at this time.
4) Of the twenty-one sites in non-fish bearing reaches, approximately three-fourths of the sites could be implemented primarily manually by California Conservation Corps (CCC) trained in restoration or equivalent.
5) If all sites were repaired approximately 40,000 CY is estimated for sediment reduction over several decades. If we assume this reduction was to occur over three decades, that reduction would be approximately 13,000 CY per decade.

Recommendations

1) Conduct additional assessments on private properties (e.g., Kirschner, Miossi), public properties (e.g., City of SLO) and on Cal Poly land upslope of railroad tracks.
2) Identify demonstration landscape treatment practices and repairs such as but not limited to key line plowing, amunas (Inca infiltration channels) (Fritz 2019), or infiltration micro-basins (Addis, H.K. et al, 2015) to improve rangeland infiltration in an area where soils have been compacted by cattle.
3) Develop 65% designs for sites which are in fish bearing reaches in combination with improving fish passage conditions (e.g., Lower Stenner and Lower Brizzolara Creeks) (Tables 1 and 3). These sites will require a higher level of engineering design and analysis effort and may require hydraulic modeling (e.g., HEC-RAS)
4) Develop 65% designs for sites which are in non-fish bearing reaches (e.g., ephemeral rangeland sites) integrating CCC crews to develop designs that support hand installed solutions (Tables 2 and 4).
5) Develop monitoring program in partnership with Cal Poly.

6 Glossary

Channel network: All mainstem and tributary channels in a watershed. The channel network may also include gullies if they are present.

Cohesive Sediment: Sediment containing a significant proportion of silts or clays, the electromagnetic properties of which cause the sediment to bind together.

Coarse sediments: Typically refers to sediments that are coarser than 2 mm (gravels, cobbles, or boulders).

Deposition: The process of sediments and other materials accumulating. In the context of this memo, deposition typically refers to the emplacement of mobile sediment out of the water column.

Frequency: How often a process occurs over a given duration.

Fine sediments: Typically refers to sediments that are 2 mm or finer in diameter (sand, silt, clay).

Grade control structure: A physical structure that is resistant to erosion, spans the channel width, and prevents the channel bed from incising. A grade control structure can be made of cement, rocks, or wood. Bedrock can act as a natural grade control.

Gully: A gully is a term to describe a new channel on the landscape that has formed in response to changing variables such as changes in surface runoff patterns, vegetation, or surface/soil properties. Gullies commonly look like ditches or small valleys. Gullies erode upstream, much like Knickpoints (see knickpoint erosion definition and model on the next page). The top of the gully is called the head or headcut. Gullies can erode headward via several mechanisms including surface flow runoff and groundwater seepage.

Impinging flow: A jet or flow of fluid that strikes a surface, such as when streamflow runs into the bank of a creek at a sharp turn.

Incision: The process of erosion that lowers the elevation of the bottom of a channel (opposite of aggradation). Channel incision typically occurs in response to a lowering of the base level, increasing erosive power in the channel (e.g., changes in magnitude and frequency of erosive flows) or reducing the amount of sediment transported by the channel.

Incised channel: The resultant channel left behind by erosion that is disconnected hydrologically from its floodplain. Incised channels commonly have steep, vertical or near vertical banks. In a non-incised channel, floods spill out onto the adjoining floodplain relatively frequently (every 1-3 years for alluvial channels), whereas, in an incised channel, the flood flows spill onto the floodplain less frequently and a greater proportion of the flows are confined within the channel.

Knickpoint: That part of a river or channel bed where there is a sharp change in channel slope. If water is flowing over a knickpoint, it may look like a waterfall. If no water is present it will look like a vertical step in the channel bed. Sometimes referred to as headcuts.

Knickpoint erosion or retreat: The process of a vertical step in the channel bed eroding. Knickpoints often erode upstream over time (See Figure 4).

Magnitude: The size or extent of a feature or process.

Riparian vegetation: Vegetation growing on or near the banks of a stream or other body of water in soils that exhibit some wetness characteristics during some portion of the growing season.

Scour: The erosion of the channel bed or banks.

Sediment transport: The movement of sediment.

Slope wetland: A type of wetland ecosystem characterized by its occurrence on hillsides or slopes, where water is typically supplied by subsurface flow or seepage rather than direct precipitation or surface runoff.

Tributary: A stream that joins or flows into a larger main channel.

7 References

Addis, H.K, Adunga, B., Gebretsadik, M. and Ayalew, B. Gully Morphology and Rehabilitation Measures in Different Agroecological Environmnets of Northwestn Ethiopia. Applied and Environmental Soil Science. Volume 2015, Article ID 789479, 8 pages. http://dx.doi.org/10.1155/2015/789479

Bennett, S. 2015. Baseflow Data Compilation and GIS Analysis in San Luis Obispo Creek Watershed. Prepared by Shane Bennett in collaboration with Cal Poly San Luis Obispo and Central Coast Salmon Enhancement. December 11th, 2015.

National Oceanic and Atmospheric Administration National Marine Fisheries Service (NMFS). 2005. Endangered and Threatened Species; Designation of Critical Habitat for Seven Evolutionarily Significant Units of Pacific Salmon and Steelhead in California; Final Rule. Federal Register, Vol. 70(170). Pp. 52487-52627.

Cal Poly. 2023. Annual Precipitation Report. Irrigation Training & Research Center, California Polytechnic State University, San Luis Obispo. http://www.itrc.org/databases/precip/

Fritts, Rachel. 2019. https://eos.org/articles/pre-inca-canal-system-uses-hillsides-as-sponges-to-store-water

PWA. 2023. Stenner Creek Erosion Control and Sediment Reduction Plan, California Polytechnic State University, San Luis Obispo County, California. Report #231039902. Prepared by Pacific Watershed Associates, Petaluma, California, for Coastal San Luis Resource Conservation District, Morro Bay, California. April 2023.

Creek Lands Conservation. 2020. Stenner Creek Flow Map, August 2020. Unpublished data.

Creek Lands Conservation. 2022. Stenner Creek Flow Map, December 2022. Unpublished data.

Natural Resource Conservation Service, 2007. Hydrologic Soil Groups. Part 630 Hydrology, National Engineering Handbook. Chapter 7. United States Department of Agriculture issued May 2007. p. 14.

Stillwater Sciences. 2010. Santa Rosa Creek Watershed Management Plan: watershed geomorphology assessment. Final Technical Report. Prepared by Stillwater Sciences, Berkeley, California for Greenspace – The Cambria Land Trust, Cambria, California.

Stillwater Sciences. 2017. A Decision-making Framework for In-channel Erosion Repair in the Verde Valley, Arizona. Prepared by Stillwater Sciences, Berkeley, California for Friends of Verde River Greenway, Cottonwood, Arizona.

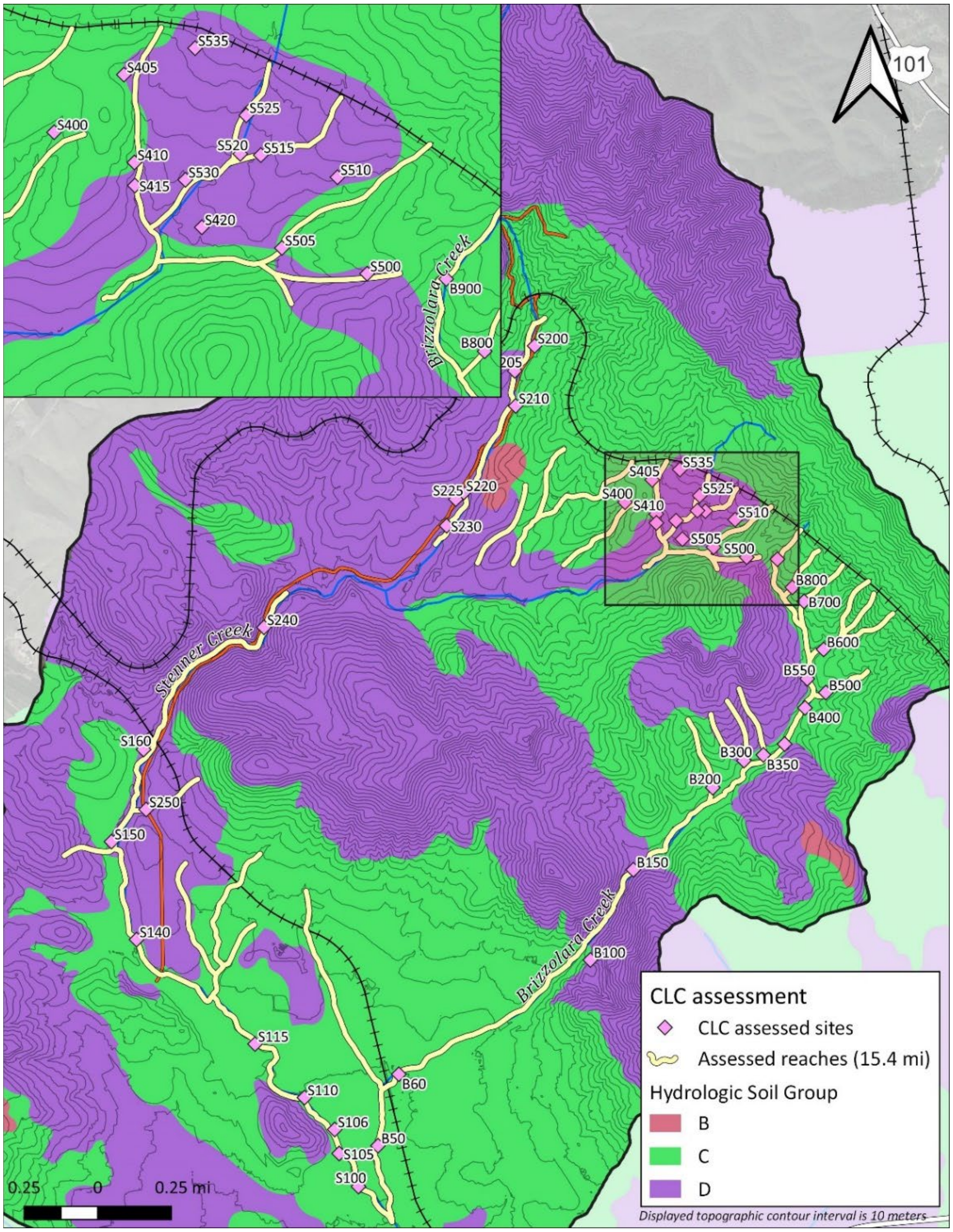
Schumm, S. A., Harvey, M. D., & Watson, C. C. (1984). Incised channels: Morphology, dynamics, and control. Water Resources Publications, LLC.

Schumm, S. A. 1981. Evolution and Response of the Fluvial System, Sedimentologic Implications. In Recent and Ancient Nonmarine Depositional Environments: Models for Exploration (Vol. 31, p. 0). SEPM Society for Sedimentary Geology. https://doi.org/10.2110/pec.81.31.0019

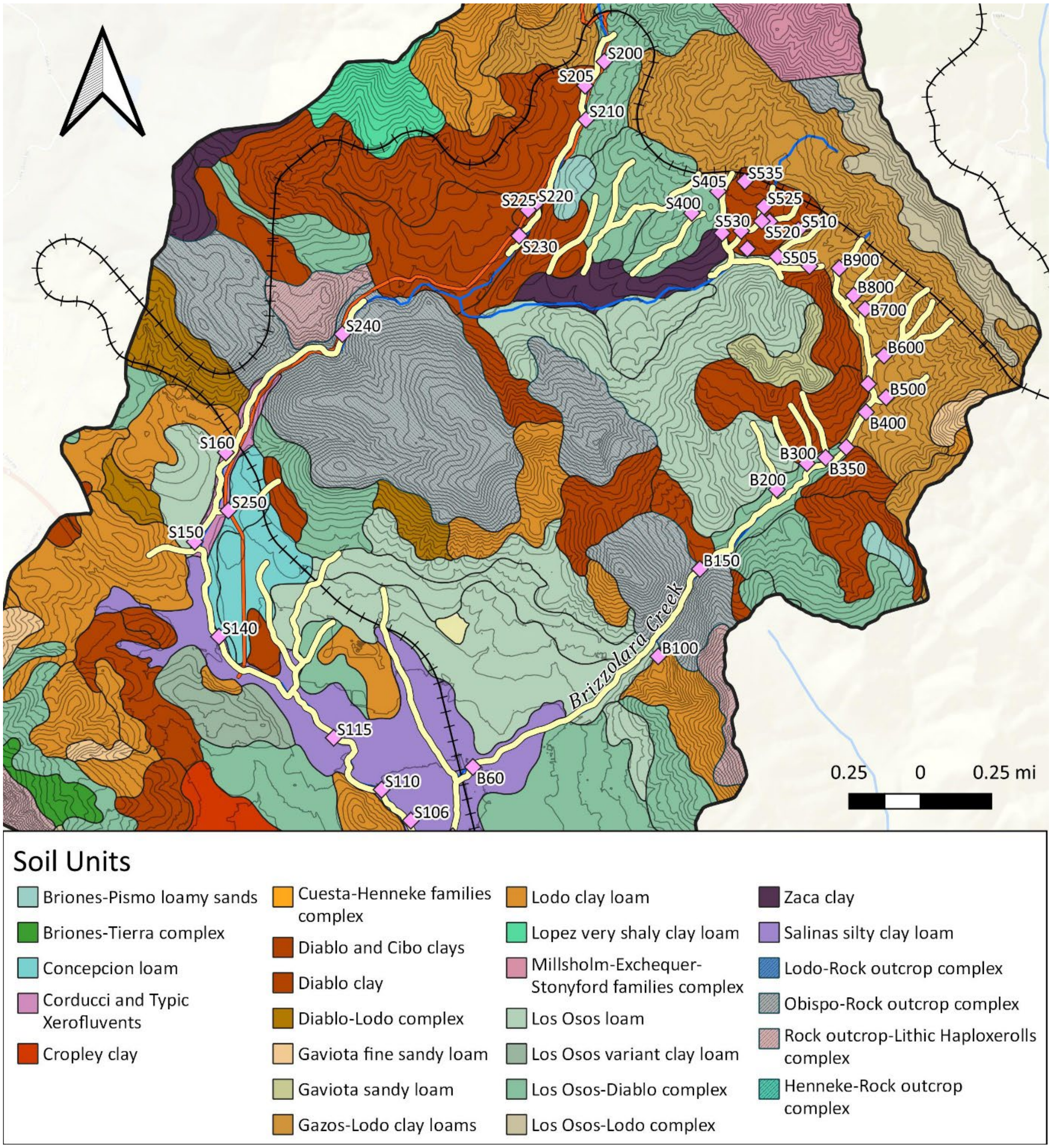
Simon, A., & Hupp, C. R. 1987. CHANNEL EVOLUTION IN MODIFIED ALLUVIAL STREAMS. Transportation Research Record, 1151, 16–24. USGS Publications Warehouse.

Simon, A. 1989. A model of channel response in disturbed alluvial channels. Earth Surface Processes and Landforms, 14(1), 11–26.

Appendix A: Soils Map

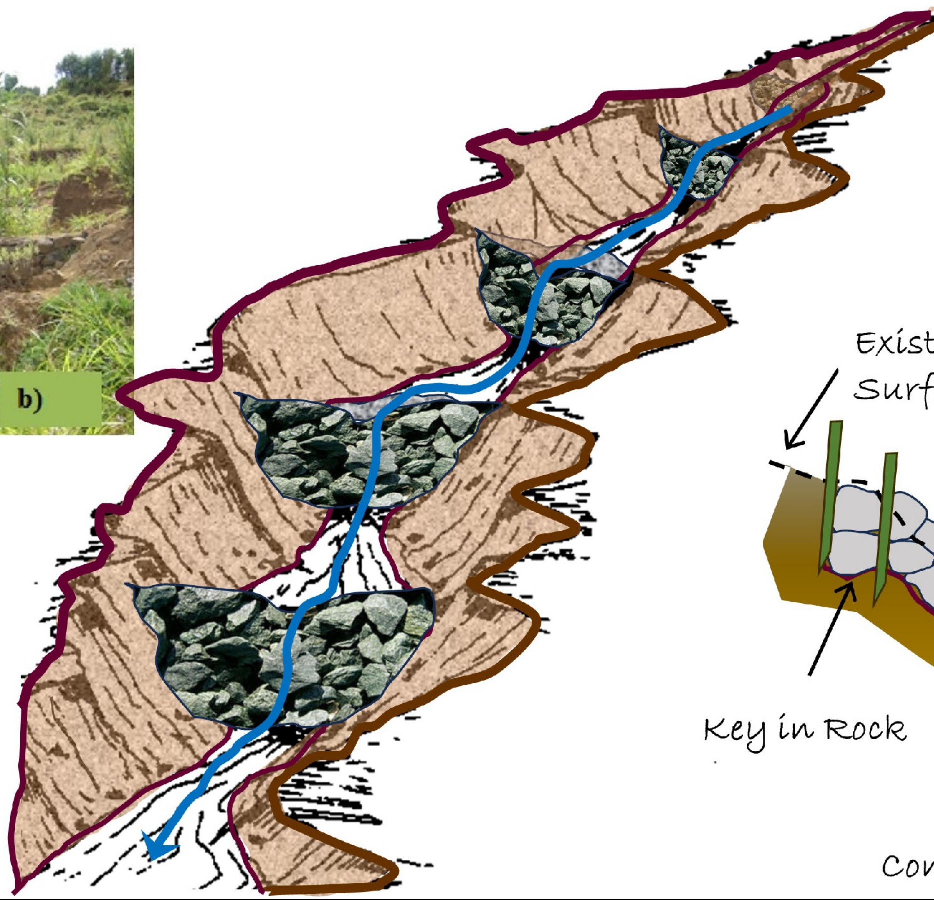


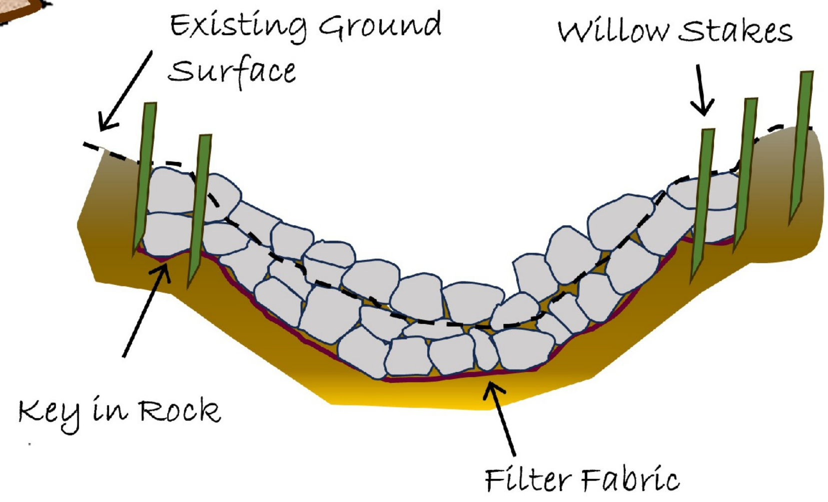
Assessed reaches, assessed sites, and engineering Hydrological Soil Group Types (NRCS 2007).



Assessed reaches, assessed sites, and soil types.

Appendix B: Conceptual Repair Details





Conceptual Cross-Section

Conceptual Details B-1: Rock Check Dams

Conceptual details – not for construction. For small drainages only. Can be constructed using a variety of packed vs. loose rock approaches. Must be designed to prevent water from flowing around edge of check dam by keying into native soils, utilizing soil cement and/ or concentrating water in the center of the dam check. Photo of a packed check dam from Addis et al (2015).

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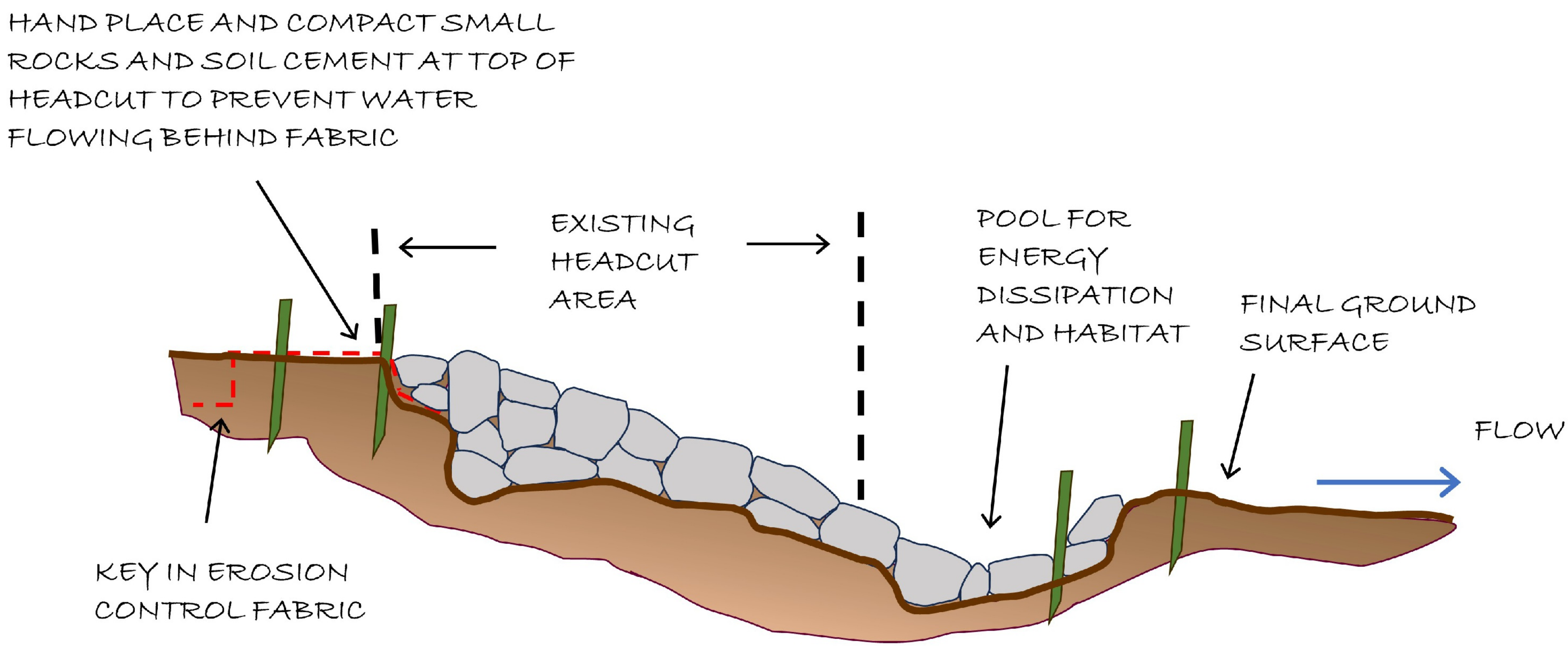

Conceptual Detail B-2: Loose Rock Headcut Repair

Conceptual detail – not for construction. For small drainages only. Willows or other vegetation can be integrated as site conditions allow.

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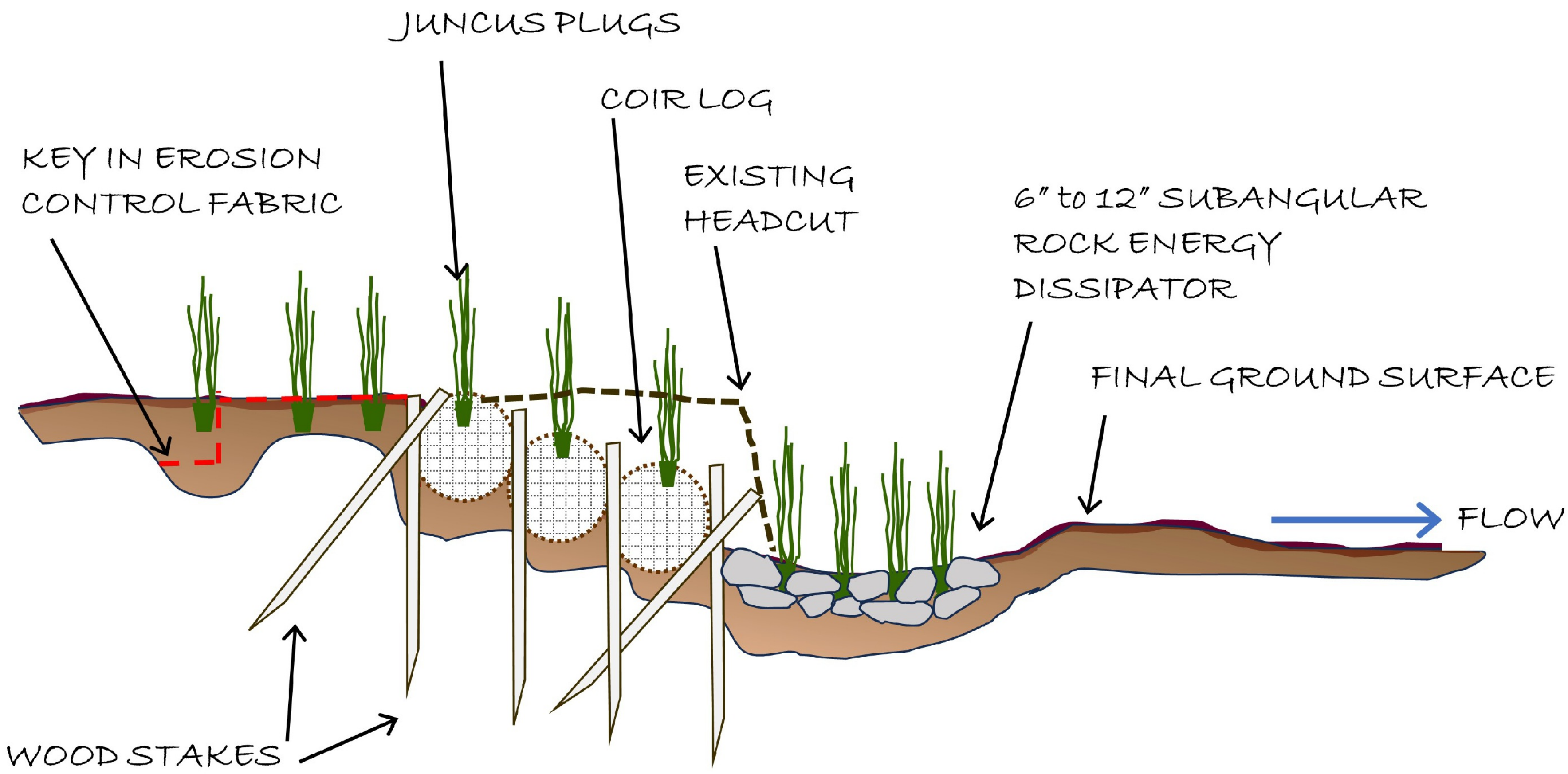

Conceptual Detail B-3: Vegetated Headcut Repair

Conceptual detail – not for construction. For small drainages only. Vegetated headcut repairs can be designed with a range of plants including but not limited to juncus, willow, or coyote brush. Similarly, it can be designed with coir logs, rocks, or earth reinforced fill lifts.

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