Euer Valley Meadow

Baseline Stream Condition Inventory Summer 2020

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On Behalf of the Truckee River Watershed Council

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Introduction

Euer Valley is located on the South Fork of Prosser Creek, a tributary to the Lower Truckee River with its headwaters near Frog Lake (Elevation ~7608 ft, 2319 m). It is heavily influenced by extensive volcanic activity and several large glacial periods that cut from the high Sierran rock and formed valleys thick with glacial alluvium that eventually became wet meadows. The Indigenous inhabitants of the area, the Washoe Tribe (Wašiw), were historically a semi-nomadic tribe that wintered in lower elevations at the eastern edge of the Sierra Nevada and migrated up in elevation in the spring as spawning runs began for numerous fish including Lahontan Cutthroat Trout (*Oncorhynchus clarkia henshawi*) and Cui-ui *(Chasmistes cujus*), a large, long lived sucker endemic to Pyramid Lake and the lower Truckee River (Moyle 2002, Washoe 2009.). They used the Euer Valley area primarily in the summer time as receding snow eased access to the higher elevations and plants and animals thrived in the brief Sierran summer. Euer Valley would have been rich in large and small game animals, abundant, lush culturally important wet meadow vegetation species including many edible plants (bulbs, berries, corms) and others used for basketry and other applications (Washoe 2009.). Traditional ecological management practices such as cultural fire, and management and curation of culturally important plants for food, basketry and other uses supported the verdant wild landscape (Whyte 2013). As the fall temperatures dropped, the tribes descended to the eastern Sierra Valleys for the Pinyon Pine harvest and other seasonal hunting opportunities to stock up on food for the long winter. Fur trappers first recorded contact with the Wašiw people in 1826. In 1844, John C. Freemont and his surveying party encountered the tribe without hostilities but soon after, settler violence against tribal members began. As California's Gold Rush drew a frenzy of 300,000 fortune seekers (approximately half coming overland across the country by wagon train), the Wašiw territory was quickly overrun by white settlers followed by the completion of the transcontinental railroad in 1869 (Washoe 2009.). In the latter half of the 19th century, both slopes of the Sierra endured furious period of mining, logging, ranching, farming, and development (Richards 2004). The feverish pace of timber harvest during the Tahoe Comstock era with accompanied logging railroads, splash dams and river channel created untold impacts on the landscape. Contiguously, thousands of head of livestock were grazed on the summer pastures of the Sierra Nevada, adding more impacts to already stressed ecosystems and altering the landscape further.

Extensive logging took place in Euer Valley in the late 1860s and in 1868, the Euer Family began acquiring land and ran a dairy cow operation which later branched out to include beef cattle, as well as summer cabins and horse camps (Dickson 2008). The family continued to ranch in Euer Valley until the early 2000s when the Tahoe Donner Association began acquiring land from the Euer family to allow ecological conservation and recreation access (Dickson 2008).

Wet meadow habitats represent a tiny proportion of ecosystem types in the Sierra Nevada (0.01%) but they are disproportionately important supporting more species of wildlife than any other habitat type in the Sierra Nevada (Kauffman and Krueger 1984, Kattleman and Embury 1996).The stream and meadow floodplain still sustain many ecological benefits and support numerous wildlife and plant species, however, settler land uses from the mid-1800s to the 20th century had a profound impact on the form and function of the ecosystem. Railroad logging created major shifts in hydrologic function by earth moving to create railroad beds cut off historic flow paths while clearcutting practices drastically altered the vegetation cover and structure of the hillslopes and increased erosion. Dairy and beef cattle ranching created direct impacts to the meadow and stream by trampling and fracturing of stream banks, consumption of riparian and wetland vegetation, soil compaction, and stream bank erosion that led to channel incision and widening that remains to this day. The historic floodplain is disconnected from what is now a single-thread channel with some inset floodplain development, and rarely reaches flows where the stream can access its floodplain, recharging groundwater, attenuating flooding, providing high flow refugia to fish and other historical species, and activating the entire valley bottom (Purdy et al. 2012, Viers et al. 2013, Pope et al. 2015). Historical conditions at the site likely had a shallow, multi-thread, anastomosing channel with frequent floodplain inundation, and channel habitat and flow complexity. This corresponds to the Stage 0 concept in the Cluer and Thorne Stream Evolution Model and is the likely historical condition of the majority of Sierran riparian meadows (Weixelman et al. 2011, Cluer and Thorne 2013). A common practice for livestock ranchers was to straighten and divert stream channels to encourage drainage of overly wet meadows and convert vegetation from hydric species dominated (i.e., sedges and rushes) to a greater proportion of grasses and forbs which are more palatable and nutritious for livestock (Kauffman and Krueger 1984, Beesley 1996). This resulted in decreased sinuosity, channelization of multi-thread systems, and encouraged stream incision and erosion. Stream channels could also capture livestock trails and those would become the channel losing much of the natural sinuosity and increasing stream power. There are numerous relic channels on the surface of the floodplain that indicate a much shallower stream bed, multiple threads, and major shifts in the location of the channel over time. Euer Valley is a long, narrow meadow with limited area for lateral stream movement in most of the valley but the stream channel is certainly more incised and concentrated than it was historically. Ongoing erosion affects portions of the stream channel and the overall bed elevation is deeply incised exposing preserved wood from ancient forests that may date back 10,000+ years (personal communication Brian Hastings, Balance Hydrologics)

Currently, there is extensive evidence of beaver activity throughout the stream channel and floodplain. If they were historically present at this site, beaver dams and woody debris jams would have supported and created Stage 0 habitats. There is increasing evidence throughout the Sierra Nevada that beavers were historically present, counter to the hypotheses put forth in the early 20th century that they were native only to the Central Valley and Great Basin but not the higher elevations in the Sierra. That thinking has been revised and novel physical evidence as well as ethnographic and historical evidence indicates beavers were ubiquitous throughout the range (James and Lanman 2012, Lanman et al. 2012). Though this notion is still hotly debated in some circles, the fact remains that there are extensive indications of long-term beaver activity in present-day Euer Valley and that their activities could help regenerate historic processes and conditions and help provide climate change resilience.

Methods

We used a modified version of the USDA Forest Service Stream Inventory Protocol to assess stream condition and overall function of the riparian zone (USFS 2010). This protocol centers on quantifying the instream habitat types that reflect the condition of the stream and drive the ecological conditions that support biodiversity and maintain biotic community structure. We surveyed 7 reaches within the meadow in order to get an overview of the range of ecological conditions present in the system, identify areas that present opportunities for restoration as well as help assess threats, stressors, and areas of imminent vulnerability. Each reach is surveyed from downstream to upstream. Each instream habitat unit is identified and categorized in a hierarchical naming convention according to the USFS protocol. These are known as channel units. At the primary level, the channel unit is identified as a fast or slow (pool) unit. At the secondary level, fast water units are subdivided into turbulent and non-turbulent flow and slow water units (pools) are divided into dam pools and scour pools. At the tertiary level, the units are further subdivided by gradient or water depth for fast water units and by the driver that formed the pool for slow water units such as beaver dam pool or plunge pool (Table 1).

Table 1. Hierarchy of Channel Unit Codes and habitat type descriptions

First Level (& code)	Second Level (& code)	Third Level (& code)	Channel Unit Code	Channel Unit Description
Fast Water (F)	Turbulent (T)	Cascade (CC)	FTCC	A riffle with stream gradient greater than 10%
		Rapid (RP)	FTRP	A riffle with stream gradient greater than 3% but less than 10%
		Riffle, Low Gradient (RF)	FTRF	A riffle with stream gradient less than 3%
	Non-Turbulent (N)	Run (RN)	FNRN	Unit has a homogenous streambed, no residual depth, laminar flow, and nearly no gradient... a glide
		Sheet (SH)	FNSH	A unit that has hardpan clay or bedrock as its streambed, very shallow flow, noticeable gradient
Slow Water (S)	Dam (D)	Beaver (BV)	SDBV	A dam pool upstream of a beaver dam, generally raises the surface-water elevation and water table. Typically captures sediments and raises stream bed elevation over time. Depositional
		Debris (DD)	SDDD	A dam pool upstream of a woody debris jam. The dam slows water velocity and backs water upstream. Typically, sediments accumulate upstream of debris dam raising the streambed over time. Depositional
		Landslide (LS)	SDLS	A pool upstream of a landslide (typically soil and rock) that creates a dam that slows water velocity and backs water upstream. Typically, sediments accumulate in the dam pool raising the streambed over time. Depositional
	Scour (S)	Convergence (CV)	SSCV	A pool scoured at a channel convergence by the addition of a tributary's stream flow
		Lateral Scour (LS)	SSLS	A pool scoured against a streambank (typically the outside stream bend), the bank forces a change in the direction of streamflow causing scour at the lateral edge
		Mid-Channel (MC)	SSMC	A mid-channel pool scoured underneath woody debris, between boulders or stream banks (where

				deepest point in the channel is center), or downstream of one or more boulders that have redirected water around them or partially dammed the stream creating a scour depression on the downstream side
		Plunge (PL)	SSPL	A plunge pool is created by a drop in elevation from upstream to downstream as water is directed by one of the following conditions: • A woody debris jam, log, or beaver dam • A waterfall or boulders • A transverse bar of substrate • A human-built dam or culvert A change in jump height is necessary to differentiate from other scour pool types
		Trench (TR)	SSTR	A narrow scour pool through bedrock or hardpan clay parallel to the stream bank. The trench is the deepest part of the pool and instream habitats at the stream margins are generally shallow

At each channel unit, we perform the following measurements and surveys:

- Identify, name and number each channel unit
- GPS waypoint at the bottom and top of each unit
- Unit length
- Length and average height of unstable banks (left and right side)
- Wetted width
- Wetted cross-sectional depths (at 25%, 50%, 75% channel width)
- Bankfull width and cross-sectional depths
- Bankfull elevation above water surface
- Length of Undercut banks (left and right side)
- Flood prone width
- Historic floodplain elevation above current bankfull
- Historic floodplain width (i.e., from left to right side across channel)
- Photographs of every unit depicting channel, stream banks, and riparian vegetation
- Percent substrate particle size composition (bedrock, boulder, cobble, gravel, sand)
- Woody debris count
- Percent shade cover at upstream end of each unit (solar pathfinder)
- Fish Presence
- Beaver sign (Dams, breached dams, remnants, chew marks, geomorphic features)
- Dominant Vegetation Seral Stage (left and right side)
- Percent understory vegetation cover (bare soil, grasses and forbs, and sedges and rushes)
- Percent overstory vegetation cover (woody shrubs, sagebrush, hardwoods, and conifers by type)

Results

Figure 1. Overview of Euer Valley with survey reaches EV1 to EV7

We conducted Stream Condition Inventory surveys on 7 reaches in September and October of 2020 excluding a segment of private property mid-valley. The survey reaches contained 200 discrete channel habitat units. Reaches ranged from 321 m in length to 1188 m in length and breaks occurred at natural features. Overall, each of the reaches was very low gradient, all much less than 1% slope. Median stream flow measurements averaged 0.47 cfs, very low baseflow.

We encountered extensive past evidence of beaver activity throughout all of the reaches including dam remnants, partial dams, geomorphic evidence of past dam presence including sediment accumulations, bank morphology, and old, valley spanning dams with rows of willows sprouting from the dam, and chew marks on old willows. Some contemporary activity was observed with a few zones where fresh chew sticks were in the water and 2 channel-spanning and currently maintained dams were found in EV2, but the physical evidence suggests past numbers of beavers were significantly greater than the present population. We encountered remnant dams or other past evidence of beavers in every channel unit we surveyed and most units had multiple dam remnants. We gathered wood remnants from several dam remnants throughout the valley to be kept for carbon dating if funding becomes available.

The long, narrow character of the valley with steep hillslopes on both sides supports the conditions for significant groundwater inputs into the meadow soils and throughout the channel, small seeps and springs line the stream margin indicating ground water inputs as well as some areas of mound peatlands and discharge slope peatlands (Weixelman et al. 2011). The incised channel creates a low point where water flows into the channel rather than being retained in the soil and increases the pace of groundwater drainage from the meadow (Loheide and Gorelick 2007, Hammersmark et al. 2008, Hunsaker et al. 2015).

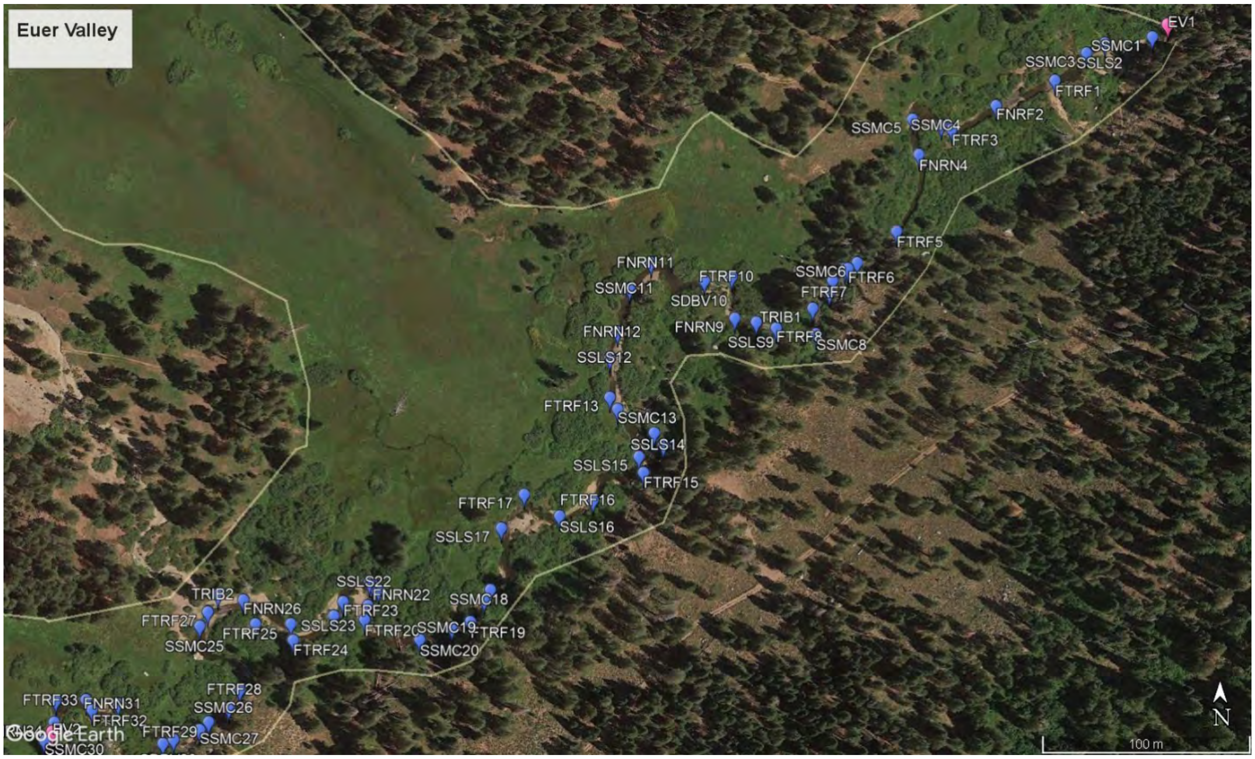

Figure 2. Reach EV1 with Channel Units

Reach EV1 had a total channel length of 1195.6 m including side channels and 1188.5 m excluding side channels. It contained 27 scour pools, 2 dam pools, 25 riffles, 9 runs, 2 side channels, and 2 tributaries. It was 43.2% fast water units by length and 56.8% slow water units by length. Fast water units averaged 15.1 m in length and slow water units averaged 23.3 m in length. Wetted widths averaged 2.82 m in fast water units and 5.03 m in slow water units and bankfull widths averaged 5.66 m in fast water units and 7.07 m in slow water units. Bankfull depths averaged 0.34 m in fast water units with an average maximum depth of 0.6 m and averaged 0.73 m depth in slow water units with an average maximum depth of 1.13 m. The stream channel was incised an average of 0.8 m below the surface of the historic floodplain and the historic floodplain terrace averaged 11.1 m across the channel demonstrating significant channel incision and widening to create a narrow inset floodplain that is generally isolated from the floodplain and only connects during extremely high flow events though there are some high flow channels that become inundated at lower flood flows. Bank instability occurs in 17.5% of the reach with and average instability height of 0.7 m but with some areas as high as 3 m where the stream channel cuts into the adjacent moraine. The loss of bed elevation in the channel results in drier than historic conditions on the surface of the meadow and loss of floodplain function and connectivity. We found 11 pieces of large wood in the channel in this reach, mostly the result of the channel cutting into the lateral moraine on river right and recruiting large trees. This provides excellent structure and habitat for aquatic species as well as creating hydraulic diversity in the flow and encouraging deposition of fine sediment. Substrate composition in the stream channel averaged 15.7% sand/silt/clay in fast water units and 29.8% in slow water units. Gravel averaged 58.6% in fast water units and 44.7% in slow water units. Cobble averaged 21.9% in fast water units and 18.2% in slow water units. Boulders averaged 3.9% in fast water units and 7.3% in slow water units and were typically only encountered in areas where the stream cuts close to the moraine. Total shade averaged 10.8% with 2.5% coming from riparian vegetation and the remainder from conifers and hillsides. Understory vegetation cover averaged 49% grasses and forbs, 32.9% sedges and rushes, and 18.2% bare, unvegetated ground. Overstory vegetation cover averaged 10% for conifer species, 47.6% riparian deciduous species (willow dominated) and 2.2% sagebrush.

The north lobe located on the left bank of EV1 is a broad side-meadow with evidence of significant groundwater inputs including seeps and multi-thread channels. This area can provide an important reference for historic floodplain conditions.

Figure 3. Reach EV2. Note the glacial boulder deposits and remnant channels on the historic floodplain. Current beaver activity was observed in this reach with 2 channel-spanning dams being maintained on the mainstem as well as smaller dams on side channel SIDEF3 just upstream of the bridge crossing. This section of the meadow is constricted by old glacial deposits.

Reach EV2 had a total channel length of 537.9 m and 498.9 excluding side channels. It contained 12 scour pools, 2 dam pools, 3 riffles, 1 run, and 1 side channel. It consisted of 8.8% fast water habitats by length and 91.2% slow water habitats by length. Fast water unit lengths averaged 11 m and slow water units averaged 32.5 m in length. Wetted widths averaged 2.83 m in fast water units and 4.74 m in slow water units while bankfull widths averaged 5.58 m in fast water units and 5.22 m in slow water units. Average bankfull depths were 0.3 m in fast water units and 1 m in slow water units. Average maximum depth in fast water units was 0.52 m and 1.39 m in slow water units. Stream channel incision is demonstrated by the difference between the historical floodplain lip and current bankfull elevation. The average height of the historic floodplain above current bankfull indicators averaged 0.55 m and the average with across the channel to the historic floodplain terrace was 7.9 m indicating this portion of the channel has experienced less channel incision and widening than EV1. Bank stability was also improved in this reach over EV1 with 7.4% unstable banks with active erosion at an average height above bankfull of 0.95 in fast water units and 1.05 in slow water units. This improvement in bank stability is largely due to the dense beaver activity in this reach with geomorphic features such as bank shape and stability and sediment aggradation behind active and remnant dams that helped stabilize and aggrade the channel. Substrate composition in EV2 averaged 26.4% sand/silt/clay in slow water units and 20.0% in fast water units. Gravel averaged 59.9% cover in slow water units and 70.8% in fast water units. Cobble averaged 9.9% cover in slow water units and 9.3% in slow water units. Boulders averaged 3.9% cover in slow water units and 0% cover in fast water units. We encountered one piece of large woody material. Total shade in the reach averaged 5.0% with 0.3% derived from riparian vegetation sources and the remainder from conifers or topographic features.

Understory vegetation consisted of 48.5% grasses and forbs, 41.2% sedges and rushes, and 10.3% bare ground. This indicates mesic meadow conditions with sedges primarily at the stream margins and wetter zones and a mix of grasses on forbs on the drier meadow floodplain surface. Overstory vegetation consisted of 9.1% conifer cover, 28.7% riparian shrubs and trees (willow dominated), and 2.9% sagebrush, mostly on the moraine on the right bank.

The bridge crossing in EV2 shows some immediate erosion on the downstream side, which commonly indicates an undersized span as well as some channel widening just downstream where horses commonly cross the creek. Heavy recreational use by horses and mountain bikes can impact the stream channel at crossing points creating an unvegetated section of bare soil that may encourage channel widening and erosion.

Figure 4. Reach EV3 upstream of the private property with historic outbuildings and corrals leftover from earlier livestock operations. The stream channel is highly altered and incised in this reach.

Reach EV3 is located upstream of the private property in the central meadow zone near a cluster of old outbuildings on the river left side of the stream. The reach length was 387.5 m including side channels and 381.4 m excluding side channels. It consisted of 16 scour pools, 6 riffles, 1 tributary, and 1 artificial structure. It was 20.7% fast water units by length and 79.3 slow water units by length. Slow water habitats averaged 18.9 m in length and fast water units averaged 11.3 m in length. Bankfull widths averaged 4.9 m in slow water units and 4.44 m in fast water units. Wetted width averaged 4.3 m in slow water units and 1.47 m in fast water units, leaving lots of exposed gravel bars in fast water units. Bankfull depths averaged 0.85 m in slow water units and 0.25 m in fast water units. Average maximum bankfull depth was 0.54 m in fast water and 1.16 m in slow water units. This reach was more incised than EV1 and EV2 with an average height of the historic floodplain above current bankfull indicator at 0.95 with a maximum of 1.35 m. The width between the historic floodplain terraces across the channel averaged 11.2 m with a maximum width of 17 m indicated both channel incision and channel widening. Unstable banks with active erosion occurred in 16% of the reach with an average height of 0.84 m above bankfull in in slow water units and 1.23 m above bankfull in fast water units.

Substrate composition averaged 31.3% sand/silt/clay in slow water units and 21.7% in fast water units. Gravel cover averaged 68.0% in slow water units and 77.9% in fast water units. Cobble averaged 0.3% in slow water units and 0.1% in fast water units. Boulders averaged 0.8% in slow water units and 03% in fast water units. There was no bedrock in any of the reaches, which is unsurprising given the depositional nature of meadow formation.

Stream shade averaged 1.7% with 1.3% from riparian vegetation and the remainder from conifers or topographic features. There was no large woody material in this reach. This part of the channel deviated from the lateral moraine on the right side of the valley and therefore, less conifer cover occurred along the channel in this reach and provided less opportunity for large wood recruitment.

Understory vegetation cover averaged 36.7% grasses and forbs, 45.1% sedges and rushes, and 18.3% unvegetated bare ground. The higher prevalence of sedges and rushes in this reach combined with deeper channel incision point to the possibility of increased groundwater activity near the meadow surface in this reach. The narrowness of the valley here might play a role in water table depth relationships. Overstory vegetation averaged 0.5% conifer cover, 25.4% riparian deciduous shrubs and trees (primarily willow). There was no sagebrush present in the riparian zone within this reach.

While we observed copious amounts of remnants of historic beaver activity throughout the reach, with fresh chew sticks indicating contemporary beaver activity but no channel spanning or currently maintained dams. Evidence of beaver influence on the channel were near ubiquitous with near constant remnants, sediment wedges behind remnants creating shallow habitats, and old eroded cutbanks that had been largely repaired by beaver dams raising water tables and slowing flow to encourage deposition of fine sediments which in turn encourage growth of sedges and other aquatic species that are very important for holding soil together and helping provide organic material. We observed *Glyceria* grass mats in the stream channel growing on the shallow sediments left behind by breached beaver dams in multiple units on this reach. This type of feature provides excellent cover for juvenile fishes and habitat for many aquatic macroinvertebrates.

Near the historic outbuildings, the artificial unit was a series of culverts placed in the stream to enable winter stream crossing by ski trail snow grooming machines. These culverts appear to concentrate flow at the channel margins in higher flow conditions and contribute to stream bank and channel erosion. However, this location has likely had a higher concentration of impacts from livestock and human activities than many other locations on the channel between corrals and outbuilding and snow machine crossing in winter. Though the floodplain is narrow in this reach (Valley width averaged 113 m), there are still a number of remnant channels on the floodplain surface indicating a likely past morphology of more complex, multi-thread channels.

Figure 5. Reach EV4. While this is one of the narrowest portions of the valley, remnant channels and willow sprouted from historic beaver dams are still visible.

Reach EV4 was 321 m long including side channels and 285 m long excluding side channels. It consisted of 23.1% fast water units (riffles and runs) and 76.9% slow water units (pools) by length and contained 14 scour pools, 4 riffles, 2 runs, and 1 side channel. Bankfull widths averaged 5.66 m in slow water units and 4.29 m in fast water units. With low flows at the time of surveys, wetted widths showed greater disparity with an average width of 5.13 m in slow water units but just 1.47 m under water and much of the active stream channel exposed. Bankfull depths averaged 0.8 m in slow water units and 0.28 m in fast water units with an average maximum depth of 1.05 m in slow water units and 0.45 m in fast water units.

The difference between the historic floodplain surface and the current bankfull indicator (a measure of stream incision) averaged 1.12 m in this reach with a maximum height of 1.30 m and the width across the channel between the floodplain terraces (a measure of stream channel widening) averaged 10.8 (approximately double the current bankfull width average). Bank instability was a little higher in EV4 than in the previous reaches encompassing 19.4% of the stream banks. Height of unstable banks was higher than average due to the stream channel cutting into the historic moraine on the right bank with an average height of 1.79 m in slow water units and 2.87 m in fast water units with a maximum height of 9 m. This amount of bank instability in an area where the channel cuts into a moraine or toe slope is a natural part of stream channel evolution and provides a source of sediment for the stream as well as helps recruit large wood. This is only minimally a function of stream incision and should not be regarded as the same issue as channel incision on the floodplain surface.

Substrate composition in this reach averaged 36.4% sand/silt/clay in slow water units and 23.3 % in fast water units. Gravels averaged 61.9% cover in slow water units and 76% cover in fast water units. Cobble averaged 1.7% cover in slow water units and 0.7% in fast water units. Boulders accounted for 0.7% of the substrate in slow water units and 0% in fast water units. The marked shift in average substrate size from EV1 which had much cobble and boulders than the upstream reaches may be a function of tributary contributions to sediment such as from Crabtree Creek. The long, low gradient nature of Euer Valley makes it difficult to transport larger diameter sediments (low stream competence). The prevalence of larger sediments at the lower end of the valley suggests a different source for the material.

Large woody material was much more present in this reach due to the stream cutting into the moraine allowing it to recruit larger trees into the channel. We observed 4 pieces of large wood in this reach as well as numerous woody debris piles that did not qualify as "large wood" per the protocol definition (>35 ft and 6" diameter at small end), but nonetheless contribute to instream habitat and provide velocity refugia and hydraulic diversity which drives in-channel habitat diversity and sediment sorting.

Stream shade in this reach averaged 3.9T with just 0.5% derived from riparian sources and the remainder stemming from conifer cover and topographic features. Understory riparian zone vegetation (within 10 m of the bankfull margin) averaged 35.7% grasses and forbs, 35.2% sedges and rushes (primarily along the bankfull margin), and 29.0% bare unvegetated surfaces. The large amount of bare soil was primarily a factor of the stream channel cutting into the moraine on the right bank leaving steep, unvegetated eroding banks. Overstory composition consisted of 5% conifer cover, 33% riparian deciduous species (willow mainly with some alders), and no sagebrush encroachment into the meadow.

Near-ubiquitous evidence of past beaver activity occurs throughout this reach with well developed undercut banks in some areas and numerous scour pools formed by water cutting through beaver dam remnants forming a constriction that drives scour or riffles formed by sediments accumulated behind formerly present beaver dams.

The channel has had a few significant adjustments in fairly recent history in this reach and there are areas where multiple remnant channels occur adjacent to current mainstem. We also observed what appears to be ancient trees buried in the exposed lake sediment layers (glacial varves) from the time period that Euer Valley was a glacial lake rather than a meadow that the channel has incised down to reveal. These were hypothesized to possibly be 10,000 or more years old by Brian Hastings of Balance Hydrologics but would require carbon dating for definitive answers. These also were exposed in EV1 and EV2.

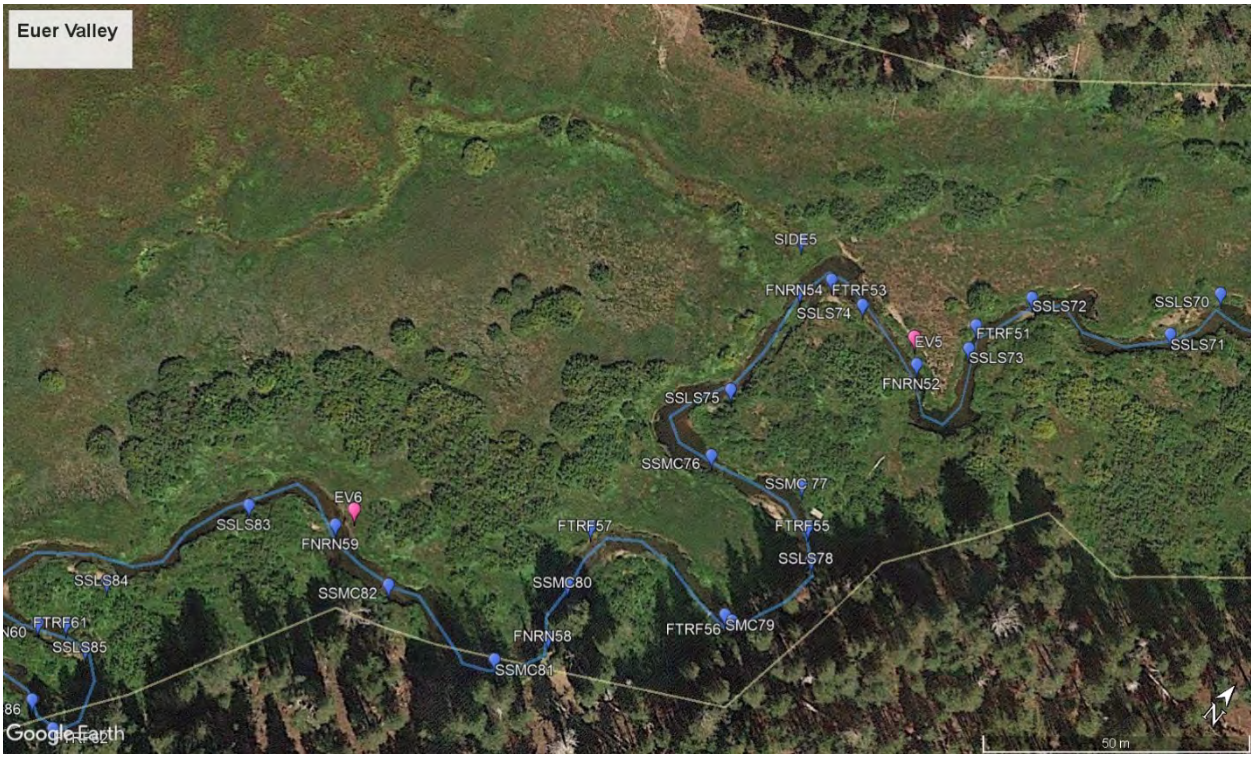

Figure 6. Reach EV5 is characterized by dense willows and a sinuous stream channel.

Reach EV5 was 696.2 m in length including side channels and 236.2 m excluding side channels. A very large side channel enters the current main channel on river left and was likely a dominant channel for the stream historically and fills with water during runoff and periods of saturation on the floodplain. The reach consisted of 29% fast water (riffle and run) habitats by length and 71% slow water habitats (pools) by length with 8 scour pools, 4 riffles, 3 runs, and 1 side channel. The average length of slow water habitats was 18.6 m and the average length of fast water habitats was 9.8 m. The bankfull width of the stream channel averaged 5.22 m in slow water units and 5.21 m in fast water units. The wetted width averaged 4.48 m in slow water units and 2.5 m in fast water units leaving much of the stream bed substrate exposed in fast water habitats. The height of bankfull above the surface of the water at the time of our surveys averaged. 0.25 m. Bankfull depths averaged 0.74 m in slow water units and 0.34 m in fast water units (making average water depth in fast water units ~0.9 m). This was fairly consistent across all reaches, but EV2 averaged slightly deeper due to the presence of very deep beaver dam pools. Maximum bankfull depths averaged 1.18 m in slow water units and 0.53 m in fast water units and typically occurred in fast water units at stream margins in small pockets of scour, often around the base of beaver dam remnants.

Stream channel incision, measured as the difference between the current bankfull indicator (the average 2 year return interval flood scour line) and the historical floodplain lip that is now well above bankfull due to unchecked past erosion event, averaged 0.83 m of channel incision. And channel widening (the distance across the channel to the historical floodplain on both banks) averaged 9.1 m. Bank stabilty in this reach was the worst of the 7 reaches surveyed in Euer Valley at 22.8% by length. The average height of unstable banks above current bankfull indicator was 0.75 m in slow water units and 0.76 m in fast water units with a maximum height of 1.05 m.

Substrate cover averaged 27.8% sand/silt/clay in slow water units and 17.9% in fast water units. Gravels averaged 67.2% in slow water units and 74% in fast water units. Cobbles averaged 4.3% in slow water units and 2.4% in fast water units. Bolders averaged 0.7% in slow water units and 2.9% in fast water units. No bedrock occurred anywhere in Euer Valley but layers of somewhat erosion-resistent clay (glacial varves) near the bottom of the channel were common in all reaches.

No large wood (>35 ft, wider than 6") per Forest Service definition occurred in EV5 but debris jams and piles from willow branches, roots, and accumulated woody detritus in the stream ocurred regularly throughout the reach and create aquatic macroinvertebrate and fish habitat as well as velocity refuge and hydraulic diversity that provides a portion of instream habitat diversiy and is a driver of sediment sorting. Stream shade averaged 3.1% in the reach with 0.2% coming from riparian vegetation and the remainder from conifer cover or topographic features.

Understory vegetation cover averaged 45% grasses and forbs, 36% sedges and rushes, and 19% bare ground with no vegetation. The overstory consisted of 2.7% conifer cover, 11% riparian deciduous species (willow dominant) and 0.3% sagebrush largely on the moraine side of the channel in drier upland zones. The dominance of grasses and forbs over sedges and rushes (which were densest at the channel margin) indicates less ground water mediation than in EV3, despite similar levels of stream incision. The role of hillslope aquifers that feed groundwater in the valley bottoms in Euer Valley and its sister valley on the north fork of Prosser Creek, Carpenter Valley, is critical in maintaining meadow vegetation in better condition than would be expected in streams with the level of incision observed at both sites. This groundwater mediation effect has prevented the conversion of much of the floodplain into sagebrush steppe and annual grasses, a common occurance in Sierran meadows that do not have the same levels of groundwater influence.

Figure 7. Reach EV6. The valley bottom is wider in this section but the stream channel is pinned tight to the moraine along the right meadow margin. This may have been intentionally diverted or channelized as livestock grazing impacts compounded. Historic channels are still present on the floodplain and likely still convey water in peak flows. Willows sprouted from a historic beaver dam are obvious adjacent to SSMC91.

Reach EV6 was 552.2 m long with no side channels. It consisted of 12% fast water habitats by length and 88% slow water habitats by length. The average length for slow water units was 30.4 m and the average length for fast water units was 9.4m EV6 contained 16 scour pools, 5 riffles, and 2 runs. The average bankfull width was 5.21 in slow water units and 5.13 in fast water units. The average wetted width was 4.7 m in slow water units and 2.79 m in fast water units leaving much of the substrate exposed in fast water units. The average bankfull depth was 0.78 m in slow water units and 0.29 m in fast water units with an average of 0.25 m bankfull height above the surface of the water. Wetted depth was very shallow in fast water units. Average maximum depth was 1.11 m for slow water units and 0.47 m for fast water units (typically a small scour pocket at a beaver dam remnant or debris pile/jam, or under wood or willow branches.

Stream incision (measured by the difference between the historical floodplain surface and the current bankfull elevation) averaged 0.7 m below historic levels with a maximum measurement of 1 m. Stream channel widening (measured by the distance across the channel between the historical floodplain terraces averaged 9 m with a maximum width of 13.6 m. This indicates slightly less channel widening and incision than in most of the other reaches with the exception of EV2 and nearly identical to EV5. Bank stability was better in this reach than all other reaches besides EV2 as well with 10.4% of the channel showing continued unstable banks and vulnerability to erosion. The average height of instability above the bankfull indicator was 0.73 m in slow water units and 0.54 m in fast water units.

For much of the reach, the channel is pinned tight to the moraine on the right side of the stream channel. This may be a natural channel migration, but it is also possible (as was common practice by many livestock ranchers in the Sierran meadows) that the stream was diverted in order to reduce the soil saturation and encourage more mesic grasses to grow (preferred forage for livestock) instead of hydric sedges and rushes that dominate wet meadows and are less nutritious. Another possibility is that the stream captured a livestock trail and diverted itself. The very long side channel that began in EV5 reconnects to the current mainstem near SSLS94. This zone is likely where the channel was diverted from the central thread in the meadow.

Stream channel substate composition was similar to the other nearby units dominated by gravel and sand, which makes it valuable spawning habitat for fishes and good habitat for aquatic macroinvertebrates. Sand/Silt/Clay accounted for 31.9% cover in slow water units and 20% in fast water units. Gravel averaged 64% in slow water units and 78.4% in fast water units. Cobble was very limited and covered just 3.1% in slow water habitats and 1.6% in fast water habitats. Boulders accounted for just 0.6% in slow water units and did not occur in any of the fast water units. Bedrock was absent throughout the meadow due to the depositional nature of the ecosystem. Gravels tended to be small and medium size in this part of the system and are highly mobile. There are certainly some very interesting sediment/hydrologic dynamics occurring at this site as beaver dams slow water velocity (reducing stream competency) and encourage sediment deposition and aggradation of the channel upstream of the dam. Depending on when and where the beaver dam eventually breaches, the sediments stored behind it may be suddenly released in a dynamic downstream burst that alters the channel morphology and bed elevation below. Lateral breaches or “flanking” tend to increase sinuosity and may create bank erosion. Center breaches that are fairly narrow tend to concentrate flows and form a mid-channel scour pool through the sediments exporting them to the pool tail crest downstream. Channel spanning breaches often leave behind much of the sediment and the side of the former beaver dam, typically with a dam pool on the upstream side and a scour pool on the downstream side, rapidly transforms into a shallow riffle or bar. Beaver dam-sediment dynamics are a profound driver of stream geomorphology and ecological function in this system and deserve more study Sierra-wide.

We found only one piece of large wood (>35’ long, wider than 6” diameter at narrow end) in this reach, but numerous rootwads and debris piles that act on the channel morphology and provide important habitat for fish and macroinvertebrates. Undercut banks occurred in most slow water units on the cutbank side and around beaver dam remnants as well as in the clay layers of the glacial varve. Stream shade averaged 10.8% with 0.4% coming from riparian vegetation and the remainder from conifer cover and topographic features which provide more shade to the channel in the areas where the stream is pinned to the forested moraine at the valley margin.

Understory vegetation cover in the riparian zone (within 10 m of the bankfull indicator on both sides of the channel) averaged 46.3% grasses and forbs, 41.2% sedges and rushes, and 12.5% unvegetated bare soil. This blend of vegetation indicates a mesic meadow with generally good vegetation cover and minimal non-vegetated surfaces. Overstory vegetation averaged 9.2% conifer cover, 27.2% riparian deciduous species (willow dominated), and 2.6% sagebrush (generally only on the moraine side of the channel above the floodplain zone.

Figure 8. Reach EV7 is the uppermost survey reach. Note the discharge slope peatland/fen habitat on the hillslope at the bottom of the image and areas of shallow groundwater table on the floodplain on the left stream bank.

Reach EV7 was the final reach in our surveys and ended at the Coyote ski hut at the culvert crossing for snow machines. On the river right bank near the upstream end of the reach a discharge slope peatland type section of the meadow occurred and met the riparian channel (Weixelman et al. 2011). It was 541 m long with no side channels. It consisted of 17.2% fast water habitats by length and 82.7% slow water habitats by length. It contained 17 scour pools, 5 riffles, 4 runs, and 2 tributaries. Bankfull width averaged 5.22 m in slow water units and 4.72 m in fast water units. Wetted width averaged 4.35 m in slow water units and 2.8 m in fast water units, generally leaving a dry exposed gravel bar. Bankfull depth averaged 0.80 m in slow water units and 0.33 m in fast water units with an average maximum depth of 1.17 m in slow water units and 0.53 m in fast water units.

Stream incision (measured as the difference between the height of the historic floodplain and current bankfull elevation) averaged 0.9 m in EV7. Stream channel widening (the distance across the channel between the historic floodplain terraces) averaged 10.4 m indicating channel widening and inset floodplain development. This reach as well as the others are a mix of Cluer and Thorne (2014) Stream Evolution Model stages 3S (Arrested degradation), stage 5 (Aggradation and Widening), and stage 6 (Quasi-equilibrium). Bank instability in EV7 totaled 193.7 m (17.8% of the reach) with an averaged unstable bank height of 0.57 m and a maximum height of 0.94.

In channel substrate cover averages tracked with nearby reaches averaging 31.5% sand/silt/clay content in slow water units and 21.1% in fast water units. Gravels (dominant throughout) averaged 63.6% in slow water units and 78.9% in fast water units. Cobbles were rare in this section of the stream with 0.75% in slow water units and 0% in fast water units. Boulder cover averaged 4.1% in slow water units and 0% in fast water units. There was no bedrock. See EV6 for a discussion of sediment dynamics and beaver dams.

There were no pieces of large wood (per Forest Service definition) in the reach but many rootwads and debris piles creating scour, velocity breaks, and microhabitats for fishes and aquatic macroinvertebrates. Stream shade averaged 3.6% total with just 0.8% from riparian vegetation and the remainder from conifer cover and topographic features.

Riparian vegetation (within 10 m from both sides of the channel above bankfull) tracked fairly closely to EV6. Understory vegetation averaged 40.6% grasses and forbs, 46.4% sedges and rushes, and 13.1% non-vegetated bare substrate. The increase in sedge and rush cover likely stems from the increase in groundwater inputs and depth to groundwater on the right bank where the discharge slop peatland occurs as well as a shallow groundwater table on the floodplain on the river left side of the channel. Overstory vegetation averaged 5.2% conifers, 15% riparian deciduous (willow dominated), and no sagebrush encroachment.

The channel is actively widening at the upstream end of the reach where several culverts laid in the channel in order to provide winter crossing for snow grooming machinery and skiers and scour is being created by the hard surfaces at the channel margins. Multiple recreation trails go through the meadow in this area and there is parallel trail development in low lying areas where saturated soils drive recreationists to make new trails in order to avoid wet areas.

Overall, Euer Valley retains a large amount of functional and diverse habitats but is impaired by past land-management that is not self-repairing even with the stressors having been largely removed.

Table 2. Essential metrics for survey reaches including slope, sinuosity, lengths, and habitat types

Metric	EV1	EV2	EV3	EV4	EV5	EV6	EV7
Ave. water temp (C)	13.04	8.89	10.05	8.42	4.31	3.98	4.93
Reach slope (%)	0.01	0.002	0.004	0.005	0.009	0.006	0.003
Sinuosity	1.6	1.4	1.65	1.3	2.02	1.6	1.45
Total Reach Length (m)	1,195.6	537.9	387.5	321.0	696.2	552.2	541.4
Total Reach Length (m, excluding side channels)	1,188.5	498.9	381.4	285.0	236.2	552.2	541.4
Avg. Unit Length - Slow Water Units (m)	23.3	32.5	18.9	15.7	18.6	30.4	26.4

Avg. Unit Length - Fast Water Units (m)	15.1	11.0	11.3	11.0	9.8	9.4	10.4
% Fast Water	43.2	8.8	20.7	23.1	29.0	12.0	17.2
% Slow Water	56.8	91.2	79.3	76.9	71.0	88.0	82.8
% Scour Pools	50.3	73.1	79.3	76.9	55.4	88.0	82.8
% Dam Pools	6.5	18.1	0.0	0.0	0.0	0.0	0
% Riffle Units	26.4	5.2	19.9	12.4	9.7	5.6	6.1
% Run Units	16.9	3.6	0.0	10.7	19.3	6.3	11.1
Count Scour Pools	27	12	16	14	8	16	17
Count Dam Pools	2	2	0	0	0	0	0
Count Riffles	25	3	6	4	4	5	5
Count Runs	9	1	0	2	3	2	4
Count Artificial	0	0	1	0	0	0	0
Count Side Channels	2	1	0	1	1	0	0
Count Tributaries	2	0	1	0	0	0	2
Count Dry	0	0	0	0	0	0	0

Table 3. Channel geomorphological measurements including bankfull width and depth profiles, wetted width and depth profiles, bank stability metrics, floodplain connectivity and incision depth and width.

Metric	**EV1**	**EV2**	**EV3**	**EV4**	**EV5**	**EV6**	**EV7**
Avg. Bankfull Width (m)	6.22	5.30	4.83	5.12	5.18	5.18	4.84
Avg. Bankfull Width Slow (m)	7.07	5.22	4.99	5.66	5.22	5.21	5.23

Max. Bankfull Width Slow (m)	17.70	6.80	7.20	8.35	7.55	7.90	7.7
Min. Bankfull Width Slow (m)	2.55	3.30	2.50	3.50	2.50	3.25	3.2
Avg. Bankfull Width Fast (m)	5.66	5.58	4.44	4.29	5.21	5.13	4.73
Max. Bankfull Width Fast (m)	10.40	6.70	6.20	6.10	8.70	6.95	6.6
Min. Bankfull Width Fast (m)	2.70	4.90	3.15	2.30	3.25	3.80	2.6
Avg. Wetted Width (m)	3.79	4.11	3.55	4.35	3.62	4.12	3.67
Avg. Wetted Width Slow (m)	5.03	4.74	4.30	5.13	4.48	4.70	4.36
Avg. Wetted Width Fast (m)	2.82	2.83	1.47	2.54	2.50	2.79	2.79
Avg. Bankfull Depth (m)	0.52	0.85	0.67	0.65	0.57	0.63	0.64
Avg. Bankfull Depth Slow (m)	0.73	1.00	0.85	0.80	0.74	0.78	0.80
Avg. Max. Bankfull Depth Slow (m)	1.13	1.39	1.16	1.05	0.99	1.11	1.17
Max. Bankfull Depth Slow (m)	1.75	1.95	1.50	1.65	1.18	1.50	2.2
Avg. Bankfull Depth Fast (m)	0.34	0.30	0.25	0.28	0.34	0.29	0.33

Avg. Max. Bankfull Depth Fast (m)	0.60	0.52	0.54	0.45	0.53	0.47	0.53
Max. Bankfull Depth Fast (m)	1.10	0.71	0.64	0.57	0.89	0.64	0.73
Avg. Height Historic Floodplain above bankfull (m)	0.80	0.55	0.95	1.12	0.83	0.70	0.90
Max. Height Historic Floodplain above bankfull (m)	8.76	0.79	1.35	1.30	1.09	1.00	1.35
Avg. Width Historic Floodplain Terrace across Channel (m)	11.1	7.9	11.2	10.8	9.1	9.0	10.41
Max. Width Historic Floodplain Terrace across Channel (m)	24.90	13.40	17.00	15.70	13.10	13.60	18.9
Length Unstable Banks (m)	415.8	73.5	122.3	110.8	107.5	114.5	193.7
% Unstable Banks (% of Total Length)	17.5	7.4	16.0	19.4	22.8	10.4	17.89
Avg. Unstable Bank Height above Bankfull (m)	0.7	1.0	0.9	2.0	0.8	0.7	0.57
Avg. Unstable Bank Height above Bankfull Slow (m)	0.61	1.05	0.84	1.79	0.75	0.73	0.60

Max. Unstable Bank Height above Bankfull Slow (m)	1.50	3.00	1.50	9.00	1.05	2.00	0.9
Avg. Unstable Bank Height above Bankfull Fast (m)	0.82	0.95	1.23	2.87	0.76	0.54	0.52
Max. Unstable Bank Height above Bankfull Fast (m)	3.00	2.00	1.40	7.00	0.88	0.65	0.94
Surface Area Unstable Banks (Slow; sq m)	0.20	0.15	0.27	0.80	0.27	0.16	0.24
Surface Area Unstable Banks (Fast; sq m)	0.33	0.19	0.41	1.41	0.24	0.14	0.15

Table 4. Substrate percent cover of sands/fines, gravels, cobbles, boulders, and bedrock.

Metric	EV1	EV2	EV3	EV4	EV5	EV6	EV7
% Sand/Silt/Clay (Slow Water Units)	29.8	26.4	31.3	36.4	27.8	31.9	31.6
% Gravel (Slow Water Units)	44.7	59.9	68.0	61.9	67.2	64.4	63.6
% Cobble (Slow Water Units)	18.2	9.9	0.3	1.7	4.3	3.1	0.75
% Boulder (Slow Water Units)	7.3	3.9	0.8	0.0	0.7	0.6	4.06

% Bedrock (Slow Water Units)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
% Sand/Silt/Clay (Fast Water Units)	15.7	20.0	21.7	23.3	17.9	20.0	21.1
% Gravel (Fast Water Units)	58.6	70.8	77.9	76.0	74.0	78.4	78.9
% Cobble (Fast Water Units)	21.9	9.3	0.1	0.7	2.4	1.6	0.0
% Boulder (Fast Water Units)	3.9	0.0	0.3	0.0	2.9	0.0	0.0
% Bedrock (Fast Water Units)	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 5. Large Woody Material, Stream Shade, and Understory and Overstory vegetation cover.

Metric	EV1	EV2	EV3	EV4	EV5	EV6	EV7
Count Large Woody Material	11	1	0	4	0	1	0
% Riparian Shade	2.5	0.3	1.3	0.5	0.2	0.4	0.8
% Total Shade	10.8	5.0	1.7	3.9	3.1	10.8	3.6
% Understory Grass/Forb	49.0	48.5	36.7	35.7	45.0	46.3	40.6

% Understory Sedge/Rush	32.9	41.2	45.1	35.2	36.0	41.2	46.4
% Understory No Veg/Bare Ground	18.2	10.3	18.3	29.0	19.0	12.5	13.1
% Overstory Conifer	10.0	9.1	0.5	5.0	2.7	9.2	5.2
% Overstory Riparian Deciduous (Willows, Alder, Aspen)	47.6	28.7	25.4	33.0	11.0	27.2	15.0
% Overstory Sagebrush	2.2	2.9	0.0	0.0	0.3	2.6	0

Discussion and Conclusion

Nearly two centuries of intensive post-settlement land uses including railroads, logging, road building, livestock grazing, and recreation have altered the landscape in numerous profound ways in Euer Valley. Most significantly, the stream channel has shifted from a multi-thread complex of dynamically meta-stable channels with a full suite of diverse habitats, instream structure, water velocities, and channel depths connected across a broad, valley spanning floodplain to a single, incised channel that is much more homogenous (mostly pool habitat with a few short riffles and runs) and a loss of floodplain connectivity that is fundamental to meadow ecosystems.

To the casual observer, Euer Valley is a beautiful valley with a healthy meadow and stream surrounded by conifer forests edged by glacial moraines. While this is true, the alterations to the ecosystem began in the mid-1800s and we have no visual record of its pre-settlement conditions. However, many clues exist showing us what previous conditions were on the site including a network of smaller relic channels on the historic floodplain, the evidence of many generations of beavers driving geomorphology and ecosystem function, sediment layers in the stream channel tell the history of the depositional landscape going back to glacial periods when Euer Valley was a glacial lake. The conditions and processes that create meadow ecosystems have been fundamentally altered by post-settlement economic endeavors and are no longer functioning in the same way. Stream channelization and incision has altered more than just the stream channel. Critical floodplain processes are no longer adequately functioning in the system including ground water recharge, flood attenuation, habitat diversity, seasonal wetlands, high flow velocity refugia, thermal mediation, and many other important ecosystem services (Beechie et al. 2010, Cluer and Thorne 2013). Other changes include loss of native fish populations (Lahontan Cutthroat Trout *Oncorhynchus clarkia henshawi),* loss of native amphibians such as Sierra Yellow Legged Frog

(*Rana sierrae*), and numerous other species of wildlife whose numbers have dwindled leaving less biotic richness in the system.

Wheaton et al. (2019) argue that "structural starvation of wood and beaver dams in riverscapes is one of the most common impairments affecting riverscape health." Riverscapes lacking structure (debris jams, large wood, or other obstructions to flow drain too quickly and efficiently which impairs depositional processes and overall creates a simpler, more homogenous habitat (Wheaton et al. 2019). Conversely, an appropriate amount of structure supports structurally forced hydraulic diversity which in turn leads to more complicated geomorphic processes resulting in "far more diverse habitat, resilience, and a rich suite of ecosystem services (Pollock et al. 2014)." Cluer and Thorne (2013) describe depositional zones as one of the most ubiquitously altered riverscape types globally and that their near universal alteration from complex, anastomosing, multi-thread channels to more manageable single-thread channels has resulted in far-reaching impacts to the ecosystem services these habitats support. The current channel configuration in Euer Valley falls in the Stream Evolution Model stages 3S, 5, and 6, which Cluer and Thorne (2013) demonstrate provides the least amount of habitat and ecosystem benefits.

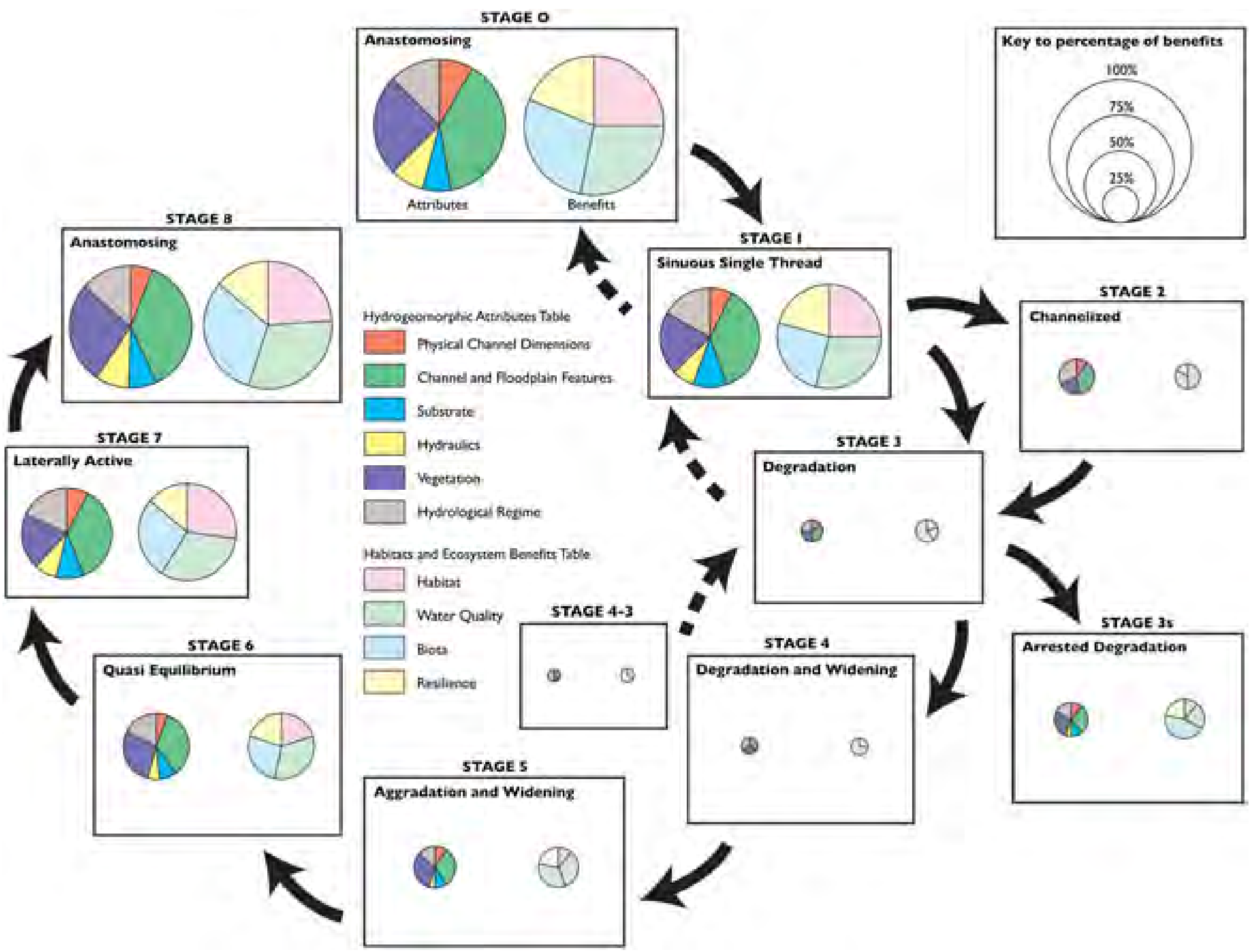

Figure 9. From Cluer and Thorne 2013. Habitat and ecosystem benefits provided in each stage of the Revised Channel Evolution Model. Each stage is represented by two pie charts whose diameters signify the relative percentage of maximum. For each stage, the pie chart on the left summarizes the richness and diversity of the hydromorphic attributes, whereas the pie chart on the right summarizes the associated habitat and ecosystem benefits

As the science of ecological restoration in meadows progresses, we see many projects that seek to restore the river to a former condition that may be a) an inaccurate assessment of what true former conditions were, or b) not realistic given the alteration of prevailing hydrologic, sediment, and climatic regimes. Rather than idealizing a particular morphological end goal, our efforts are likely to be more ecologically lucrative if we focus on reinitiating the processes that facilitated the evolution of the landscape. In the case of riparian wet meadows, that may be best accomplished through encouraging depositional processes through structural diversity, reconnecting the historical floodplain and increasing its extent and connectivity to support attributes such as sediment storage, groundwater recharge, carbon sequestration, nutrient processing, and biocomplexity (Kondolf 1998, Palmer et al. 2005, Beechie et al. 2010, Cluer and Thorne 2013, Hunsaker et al. 2015).

While there is still lack of definitive proof of the historic presence of beavers in Euer Valley, it is clear that they have played a major role in the current geomorphology of the stream channel. Despite the vast numbers of dam remnants and the habitat configurations that have been supported by dam building, there appears to be relatively little current beaver activity at the site and we observed only a few active, channel spanning dams during our surveys. The structure and hydraulic diversity engendered by beaver dams and large wood appear to be a critical component for maximizing ecosystem services and habitat attributes, and are a viable means of improving floodplain and channel function and process in riparian meadows (Pollock et al. 2003, Pollock et al. 2014, Pope et al. 2018).

Euer Valley in its current condition has a great deal of aesthetic, recreational, and ecological value, but its setting and relative wildness provide the potential to dramatically enhance its ecosystem and habitat attributes through restoring process and structure in the system. This may not ultimately be the management goal for the Tahoe Donner Association, or it may be that the current configuration is desirable for various management and social reasons but there is enormous potential to recover the site to a highly functioning, complex, anastomosing, multi-thread, connected floodplain wet meadow if that were desired.

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Figure 10. Aerial image of Euer Valley shows a sinuous single thread channel with a developing inset floodplain. It has limited connectivity to the historic floodplain but a relatively high groundwater table mediating soil water content and preserving mesic meadow vegetation structure.

Figure 11. EV1. Beaver Dam Remnants on channel margin where a valley spanning beaver dam once was. The dam is now fully breached across the channel but aggraded sediments remain forming a gravel bar and a row of mature willows has sprouted from the dam remnants on the floodplain.

Figure 12. A close up of beaver dam remnants at the channel margin.

Figure 13. Remnants of the glacial history at Euer Valley provide structure and stability for vegetation to get a foothold as well as providing excellent cover and velocity refuge for fishes at higher flows

Figure 14. The channel cuts into the moraine on the right bank. Conifers shade the stream and provide potential for large wood recruitment in the future.

Figure 15. Large wood falling into the channel provides essential structure, hydraulic diversity, and scour and deposition.

Figure 16. Exposed sediments at the pool crest at the site of a former beaver dam. The effects of the beaver dam remain in the sediment wedge across the channel and the emergent marsh vegetation that formed from the deposition of fine sediments behind the dam. The persistent habitat features created by beaver dams are visible throughout Euer Valley.

Figure 17. Bank Erosion and incision with the stream disconnected from the historical floodplain.

Figure 18. An area of complex habitat formed upstream of a now-breached beaver dam with lush sedges and emergent vegetation, side channels and backwater habitats, and well-developed undercut banks.

Figure 19. An old, partially breached beaver dam with well-developed meadow vegetation and sod forming on top of it.

Figure 20. The channel cutting into the toe slope confines the stream on the right bank but provides opportunities for wood and sediment recruitment.

Figure 21. A small beaver dam on a side channel aggrades sediment and raises the water table. Fine sediment deposition encourages obligate and facultative wetland plant recruitment.

Figure 22. Beaver dam remnants across the channel with major deposition upstream. Emergent marsh habitat develops behind persistent dams and remain after the dam washes out.

Figure 23. Channel incision disconnects the stream from its floodplain and drives erosion. In this section, multiple beaver dam remnants against the cutbank show the density of beaver activity in Euer Valley.

Figure 24. Barely visible old cutbank scars are covered by low angle banks formed by beaver dams.

Figure 25. The culvert crossing for snow machines near the old barns in EV3 with multiple beaver dam remnants at the channel margins.

Figure 26. The culverts are filling with sediment and have created some widening at the stream margins

Figure 27. Inset floodplain development within the channel but incision has completely disconnected the stream and its floodplain losing critical floodplain processes. Note multiple beaver dam remnants in the foregroiund.

Figure 28. Relic channel visible on the historic floodplain surface with inset floodplain development in the active channel zone with ubiquitous beaver dam remnants front and center.

Figure 29. SIDE5 In EV5 may have once been the dominant channel through the meadow but became disconnected due to an avulsion event. This may have been a natural process or it may have been an intentional management decision in order to drain and dry out the wet meadow.

Figure 30. Incised but stable and possibly aggrading channel with bank vegetation developed by former beaver dam located where Helen is standing in the foreground.

Figure 31. Tall, eroding cutbanks where the stream channel meets the lateral moraine at the margin of the valley provides a recruitment opportunity for large wood and sediment. Note, beaver dam remnant under wood.

Figure 32. Active erosion and lateral channel migration. Note the depth of channel incision.

Figure 33. A gravel bar formed at the location of an old beaver dam with long established emergent marsh and relic channel in the background.

Figure 34. One of few channel-spanning beaver dams currently in the system. Note the pillow-shaped banks developing upstream. These will persist after the beaver dam is breached and provide bank stability and undercut bank habitat.

Figure 35. Riffle formation over old beaver dam remnants.

Figure 36. The stream is deeply incised and disconnected from the floodplain but fairly stable. This represents Stream Evolution Model Stage 6 (Quasi-equilibrium) per Cluer and Thorne (2013)

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